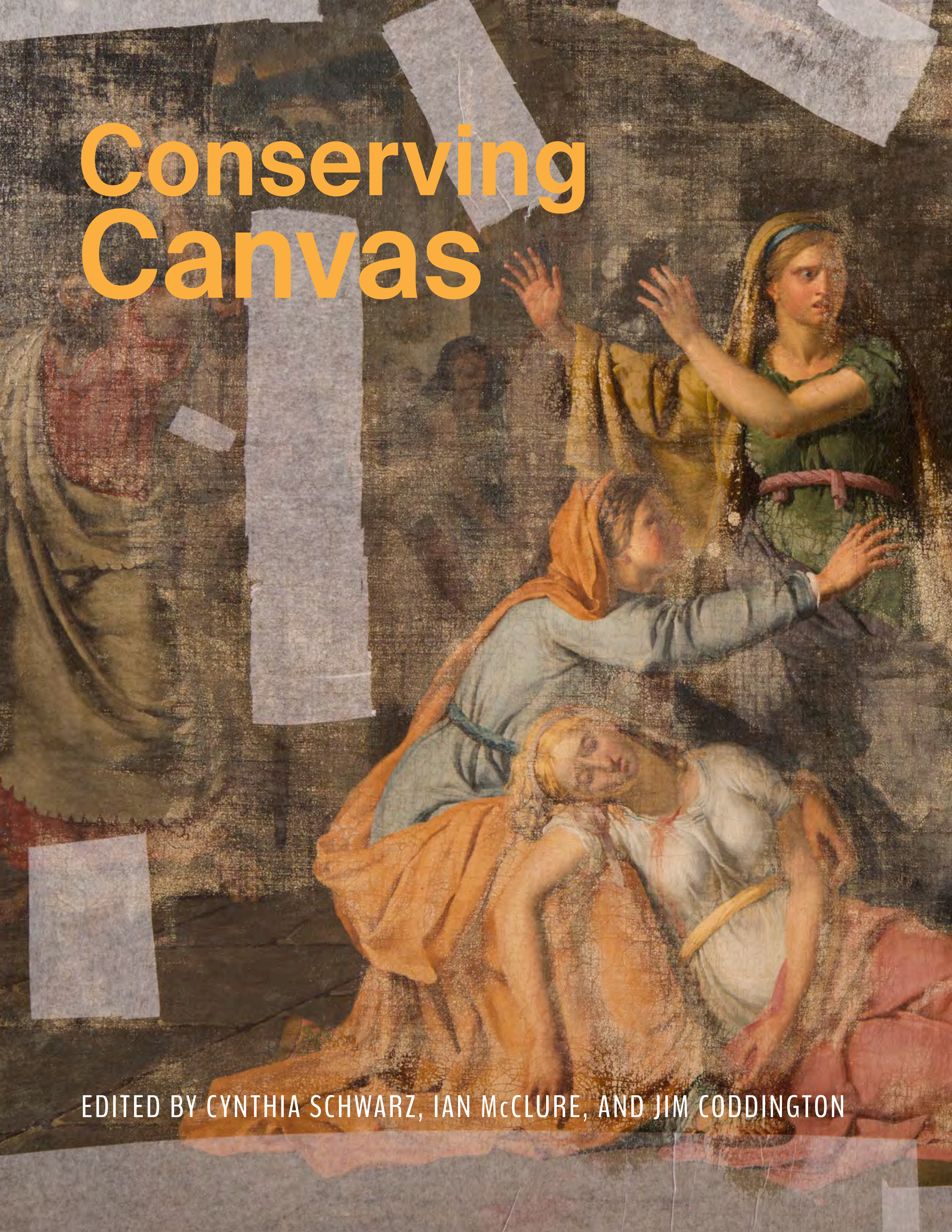

Conserving Canvas

EDITED BY CYNTHIA SCHWARZ, IAN McCLURE, AND JIM CODDINGTON

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GETTY CONSERVATION INSTITUTE, LOS ANGELES

Paintings conservator Debra Daly Hartin (1953–2022) died just two weeks after making final edits to her paper in these proceedings. Three years earlier, Debbie pushed herself to prepare her presentation and deliver it in person at the 2019 Yale symposium. For her, it was the opportunity to wrap up her life's work on linings, knowing there might not be another chance.

Conservation research institutes around the world have long advocated the symbiosis between practitioner and scientist, a feat not easy to accomplish. Debbie made it work, with humility about what she did not know, tenacity about what she did know, and grace during all deliberations. Debbie was truly passionate about understanding linings, building practice through structured research, and passing paintings into their best possible futures. This book is dedicated to her memory.

Stefan Michalski and Barbara A. Ramsay

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Foreword

We are delighted to present the proceedings of the October 2019 international symposium Conserving Canvas. Like the Getty Foundation initiative carrying the same name, the symposium focused on the structural care and conservation of paintings on fabric supports. Organized by the Institute for the Preservation of Cultural Heritage at Yale University, with support from the Yale University Art Gallery and Yale Center for British Art, this momentous event gathered no less than 370 conservators and conservation scientists from around the globe to discuss what was once a heated topic in the field. We are referring to the method of wax-resin lining that previously dominated in the field and was heavily criticized and largely abandoned after the legendary 1974 conference held at the National Maritime Museum in Greenwich, England. At that conference, conservators ushered in an era of new approaches, alternative procedures, and novel synthetic materials. The conference at Yale in 2019 was the first major international gathering on the subject since 1974, allowing specialists to look back on more than forty-five years of practice and take stock of the current state of the field. Thanks to the symposium organizers, professionals from India to Argentina and from Scotland to South Africa met and exchanged ideas, setting new standards for international inclusion in the field. We extend special recognition and thanks to the organizers and advisers who worked hard to make this experience so valuable for so many: Ian McClure, Elizabeth Williams, Cynthia Schwarz, Mikkel Scharff, Christina Young, Alan Phenix, and Jim Coddington.

The care and conservation of paintings on canvas is an ongoing concern for museums around the world. Ever since the 1974 Greenwich conference, many conservators have shied away from structural repairs perceived as too invasive. In many cases this led to unintended consequences, with new generations of conservators possessing little to no practical experience with structural treatments. To address this knowledge gap, in 2018 the Getty Foundation launched the Conserving Canvas grant initiative, which to date has supported twenty-six projects involving conservators and other specialists from more than three dozen countries. The initiative is meant to ensure that conservators remain fully informed about how to preserve these important works of art through support for training activities, scientific research, and information sharing. The Yale conference was a crucial launching pad for this work.

As you will read in this volume, presenters at the Conserving Canvas symposium addressed historical approaches to the treatment of canvas paintings; highlighted current methods, materials, and research; and pointed to the growing challenges associated with the structural conservation of modern and contemporary works. While the record indicates that the atmosphere at the Greenwich conference was quite contentious, the Yale conference could not have been more collegial. Productive dialogue and discussion proved how far the field has come in the last four decades, and the energy and enthusiasm generated among participants was positively electric. Over four days the presenters shared diverse views and approaches, which prompted frank and in-depth conversations. The forty papers and twenty-three posters included in these proceedings reflect that quality and diversity.

The Getty Conservation Institute (GCI) is pleased to sponsor this publication as part of its ongoing service to the international conservation community. Information dissemination is a core activity of the GCI, and the conference papers recorded in this volume are both a touchstone of where the field is today and a vision of where it may be heading next. As such, it forms a valuable reference work for conservators everywhere who are responsible for canvas painting collections.

We are grateful to the volume editors, Cynthia Schwarz, Ian McClure, and Jim Coddington, for their tireless efforts in preparing the manuscript. In Getty Publications, Kara Kirk, Karen Levine, Nola Butler, Greg Albers, and Clare Davis provided invaluable assistance. We thank the book team in Publications—Greg Albers, Rachel Barth, Danielle Brink, Erin Dunigan, and Molly McGeehan—for helping to prepare and shape the final publication. Finally, we are grateful to Leslie Tilley and Dianne Woo for providing careful, thorough editing. This publication and the Conserving Campus symposium represent a renewed openness in the field to a variety of structural interventions, and we thank all our contributors for engaging in productive debates that keep the field moving forward.

Joan Weinstein
Director, Getty Foundation

Timothy P. Whalen
John E. and Louise Bryson Director, Getty Conservation Institute

Introduction

Ian McClure
Jim Coddington
Cynthia Schwarz

The symposium held at Yale University in October 2019 grew out of the Getty Foundation's Conserving Canvas initiative, which, through a combination of practical workshops, publications and research support, and expert meetings, aims to evaluate and foster the structural treatment of paintings on canvas (fig. 0.1). The symposium was planned with the 1974 Greenwich Conference on Comparative Lining Techniques,[1] the last international conference to be held on this subject, very much in mind. At that event, conservators from institutions and in private practice demonstrated a wide range of techniques, both innovative and traditional, and in doing so raised some fundamental questions that are still central to our thinking and decision-making process in planning structural treatments. In the forty-five years since, however, the options for lining and alternatives to lining have expanded. The new options are drawn from a variety of sources: advances in the materials industry, with the production of synthetic adhesives and textiles and the introduction of nanotechnology; new research into the mechanical behavior of laminate structures; and the resourcefulness of conservators who take an innovative approach to their work. Concerns at the forefront of the field in 2019 also included environmental sustainability and a heightened awareness of the benefits of a global perspective on painting conservation.

Figure 0.1 Presenters delivered papers over the course of four days. Seated, from left: Dale Kronkright, Brad Epley, Desirae Dijkema, Mary Piper Hough, Stefan Michalski, Mary Gridley, and Yujin Kim. Image: Mikkel Scharff

The timeliness of the Conserving Canvas initiative and the conference is clear. In the planning stages, it was thought the sessions would be held on Yale's West Campus, where the conservation studios and the Institute for the Preservation of Cultural Heritage are located. High demand quickly dictated a move to the more spacious auditorium at the Yale Art Gallery. The auditorium was filled to capacity with over 370 attendees from more than twenty-five countries, likely the largest gathering of painting conservators ever convened (fig. 0.2). The amount of interest in the topic was also mirrored in the international response, as reflected in the number of papers presented by conservators from more than twenty countries.

Figure 0.2 The Yale Art Gallery auditorium was filled with hundreds of attendees from around the world. Image: Mikkel Scharff

The impact of the postprints of the 1974 conference was even greater than that of the conference itself, as they not only presented to a much wider audience the different approaches introduced there but also questioned previously held assumptions. While the conference provided the opportunity for conservators to compare lining techniques, with a focus on practical workshops, the necessity of lining as a preservation measure was ultimately called into question. For many, the most perceptive and significant paper was the opening presentation by Westby Percival-Prescott, "The Lining Cycle," in which he demonstrated how artists' techniques of a certain period affected the response of those paintings to particular lining practices of the time, usually evident many years later when those paintings were deemed to require lining.[2] Percival-Prescott's paper, after reviewing different lining techniques, called for research into methods that might prevent the necessity of lining (see Stoner in this publication). In effect, a call for historical research and a minimalist approach was made.

With this context in mind, the call for papers for this symposium, made in September 2018, announced, "The symposium will address historical approaches to and theories of the structural conservation of canvas paintings; current methods, materials and research, both practical and scientific; and the challenges facing the structural conservation of modern and contemporary works." This reflected, in the view of the Advisory Committee,[3] developments and concerns in the structural treatment of works on canvas today. The response to the call for papers was much larger than expected, and the proposals submitted guided the committee to choose the sections laid out in these postprints.

While Percival-Prescott's paper was unique in providing a historical review in 1974, at the 2019 symposium historical research played a very significant role. The recent research into contemporary documentary sources, discussed in contributions by Angela Cerasuolo, Matteo Rossi-Doria, and Ana Calvo et al., attest to considered practices dating back to the eighteenth century and earlier. In many cases, written sources can be linked to surviving treatments, often demonstrating the unexpected longevity of linings carried out with natural materials. A strong case is made for the use of natural materials—both for their low toxicity and their performance over time. On the other hand, assumptions about the stabilizing hydrophobic attributes of wax-resin treatments were called into question by new research, as can be seen, for example, in the work by Emilie Froment. A divide on seeking flexibility (as in mist-lining) or rigidity (as demonstrated in Lynne Harrison's paper) in a lining or lining system emerged, which also represented the trends of research on lining procedures and the mechanical behavior of the composite structure of paintings since the Greenwich conference. The fact that many of the practical and philosophical divides in structural practices still fall along geographic lines speaks to the sustained, deep roots in historical treatment practices.

Another theme that emerged at the Yale conference was an emphasis on the history and treatment of collections as a whole, as well as forward-looking preventive care of collections. Here, too, the role of past and ongoing research was evident, although perhaps not always carried over into practice. Increased levels of documentation also allow for the examination and analysis of more data, mostly focused on collections and their treatment histories. The greater attention to documentation has enabled reviews of institutional practice—which, when the data are extensive enough, reveals trends, as evidenced in the contributions by Nicola Costaras and Lauren Bradley and Josh Summer. A series of case studies covered the treatment of works large and small and highlighted the significant attention paid to local interventions, which demonstrate conservation's continuing ability to adopt and adapt existing techniques and equipment from other fields, such as textile conservation, imaging technology, and mechanical engineering. Papers included research using samples of significant natural aging and showed the ongoing embrace of new materials—both from other fields and those specifically developed for conservation. The audience was introduced to Hannah Flock et al.'s "Winnie" for the application of glue in tear mends, for example, as well as the adhesive meshes developed by Mona Konietzny et al.

Threaded through all of these topics was the ongoing question of definitions, of finding a common vocabulary to describe—with as much precision and accuracy as possible—what conservators see and do. This is especially critical in order to exchange philosophies, methodologies, and techniques with an international community that has grown out of a variety of historical traditions and practice in vastly different climates. To that end, we have included a glossary based on the one published in the 1974 preprints. Terms no longer in use have been deleted and terms that have become current have been added. It is our hope that this revised glossary reflects developments since 1974 while also attempting to define terms that can be used universally. Finally, around the margins but clearly moving to a central position is the question of sustainability in all its various forms. Indeed, here is a term in need of definition and common understanding.

One part of the conference that is not available to the reader of these proceedings is the day devoted to practical demonstrations—“sandbox sessions”—that provided the opportunity for experiential learning (fig. 0.3). Expert contributors led sessions on historical reconstructions, innovative tools and equipment, hands-on mechanical demonstrations, and localized tear mending. It is the continued refinement of established practice, as well as development of new, more effective practices, that these sessions represent, and to which we believe these proceedings will be an ongoing contribution.

Figure 0.3 Conference participants took part in “sandbox sessions” led by experts giving practical demonstrations. Here, author Helena Loermans leads a workshop on reconstructing historical fabric weave patterns. Image: Mikkel Scharff

None of this would have been possible without the support of a large network of our generous, capable colleagues. First, thanks are owed to the rest of the symposium Advisory Committee: Alan Phenix, Mikkel Scharff, Antoine Wilmering, and Christina Young. At Getty, thanks also to Joan Weinstein and Allison Reilly. At Yale, thanks go to Stephanie Wiles; Henry J. Heinz II, director of the Yale University Art Gallery; and Courtney Martin, director of the Yale Center for British Art, for their support, contribution of space and resources, and hospitality shown to the participants. The conference would not have been possible without the ongoing efforts of Laurie Batza, Beth Bolen, and Elizabeth Williams at the Yale Institute for the Preservation of Cultural Heritage. Also, thanks to the Yale Conferences and Events staff, especially Shannon LeGault, who arranged two meals a day and warm welcomes for our 370 participants. The Avangrid Foundation provided critical funding support for presenters and attendees from Spain, and our special thanks go to Nicole Licata Grant. The program books were designed by Stephanie Bedoya with the assistance of Yale University Art Gallery designer Chris Sleboda, who also designed the tote bags for the participants. Advertising support from Willard Conservation Products, Everett Fine Art, and Getty Publications made the program books possible. At the Yale University Art Gallery, thanks are owed to Molleen Theodore, Liz Harnett, Mark Paturzo, and Roksana Filipowska. Many Yale University conservators, conservation fellows, and interns contributed to the success of the symposium, from hosting guests and providing directions to assisting in sandbox sessions and hanging posters, and too many other supportive roles to mention. Our deep thanks for this to Irma Passeri, Kelsey Wingel, Mark Aronson, Jessica David, Anne Gunnison, Olav Bjornerud, and Beth Godcher. We are also deeply grateful to Rachel Barth, Leslie Tilley, and Dianne Woo for their support, dedication, and patience as they edited and proofed sixty-three papers. We hope that this publication will be of great value to the international conservation community for years to come.

NOTES

1. The postprints were published as Villers 2003b.
2. Many of these effects changed the appearance of the paintings. These changes to the structure, topography, and other attributes of the painting have been described in various ways in the conservation literature. Most importantly, though, a consensus emerged that these changes compromised the aesthetic integrity of the painting, bringing aesthetic discussions of the surfaces of paintings to the fore as well as discussion of technical matters.
3. The Advisory Committee consisted of Jim Coddington, Ian McClure, Alan Phenix, Mikkel Scharff, Cynthia Schwarz, Antoine Wilmering, and Christina Young.

I

History, Principles, and Theory

1

Understanding Structure, Changing Practice

Stephen Hackney, Head of Conservation Science (retired), Tate, London

In the latter part of the twentieth century, conservators questioned the practice of lining paintings on canvas. This inspired fundamental scientific studies of the structure, material, and aging of paintings. The implications of mechanical and chemical aging can now be better predicted. This knowledge has provided conservators with a wide variety of alternative treatments, and it supports the concept of collections care.

STRUCTURAL CONSERVATION

By addressing the structure of a painting, we are forced to consider not only the image intended by the artist but also the artwork's physical nature and history. A stretched canvas is a subtle and delicate construction devised for both stability and lightness, but if the structure is damaged or failing, this creates risks for both the appearance and purpose of a painting.

As any artifact ages and deteriorates, it eventually reaches a point when its appearance and functions are judged to be no longer acceptable. Some of these changes demand action in order to preserve the artifact's use and prevent further decay. Some changes are not reversible—for instance, cracks, which indicate fragility and may cause a disturbing interference with an image. Yet, in a painting, cracks are also viewed as a sign of authenticity.

Structural conservation of a canvas painting can be a more profound intervention than cleaning or varnish removal, and each intervention presents fundamental aesthetic challenges for the paint surface and ethical doubts for the concept of reversibility. A structural treatment may be applied to an entire painting, perhaps in a single, rapid operation. Like other aspects of conservation, such a treatment requires considerable judgment and skill, and success is often determined by the treatment's invisibility.

Fifty years ago, a traditional lining method was considered a normal component of any conservation treatment. The lining used was defined by the choice of adhesive, and these materials had a surprisingly wide range of properties, from water based to water repellent. The goal of lining was to turn a fragile canvas painting into one that was much more resilient, but the means and the outcome were not well defined. The dangers in lining were recognized, however, and it was normally carried out by skilled and experienced professionals. But attempts were also made to automate and deskill the process by using hot tables and vacuum pressure.

For the student, there was little published information except for some early discussions on reservations about glue lining, the justification for introducing wax-resin adhesives, and designs for hot tables (Ruhemann 1953; Straub and Rees Jones 1955). From this background, Westby Percival-Prescott conceived the Conference on Comparative Lining Techniques, held in Greenwich (London) in 1974. This ambitious project brought together experts from various backgrounds, but it succeeded in uncovering much confusion of purpose and also a genuine desire to improve the situation (Percival-Prescott 2003b). Traditional methods were described by practitioners, and several research projects investigating alternative adhesives and lining methods were presented. A wide variety of conservation aims emerged, from restoring the original appearance of a painting to accepting its existing condition (Mehra 2003). For the first time, the advantages and disadvantages of all materials and methods were openly debated, including wax-lining methods (Berger and Zeliger 2003; Cummings and Hedley 2003).

During a period when lining was widely, uncritically accepted, most practitioners had honed their skills in a narrow lining specialty based on one specific adhesive and had a limited range of experience. The establishment of conservation training courses with academic aspirations has now largely replaced the former apprenticeship training, which passed on the strengths and skills of existing practices but had no mechanism to compare or improve on them. Formal training has provided an impetus for conservation science, and the study of conservation methods has influenced the materials and practice of conservators and even some artists.

SCIENTIFIC RESEARCH

After Greenwich, it was clear that an understanding of the structure and mechanisms of stretched canvas paintings was needed. This has since been achieved by a number of researchers, beginning with Marion Mecklenburg and his systematic studies that provided measurements of painting materials under tension and different RH conditions, identifying the high tension in glue films and grounds at low humidity. Measurements of breaking strains of oil paint films led to an explanation of the observed cracking of canvas paintings (fig. 1.1).

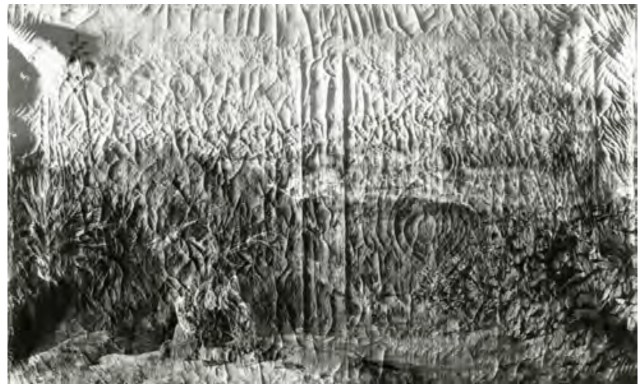


Figure 1.1 Edward Lear, *View of Reggio and the Straits of Messina*, 1852. Oil on canvas, 51.4 × 81.2 cm (20 1/4 × 32 in.). Typical raised crack pattern, impact cracks, and canvas corner undulation in raking light. Image: Tate

The response of paintings to moisture had been a particular concern since the nineteenth century. Mecklenburg's plot of tension against RH for all the materials on a stretched and primed canvas was a major advance (Mecklenburg 1982; Mecklenburg and Tumosa 1991a). Gerry Hedley explained the mechanism of canvas shrinking when exposed to water or RH approaching 100%. He also saw the effect of initial weave crimp transfer from warp to weft (Hedley 1993; Hedley and Odlyha 1993). The differing influence of pigments on the drying (curing) of linseed oil explained why the application of moisture and pressure is not enough to flatten most mature lead white paints. Temperature response of paintings was also investigated (Michalski 1991). Cracking of otherwise flexible acrylic paintings at extremely low temperatures was at first surprising. The concept of glass transition temperature (Tg) clarified why familiar flexible materials became brittle at these low temperatures.

Long-term mechanical behavior, such as relaxation and creep, has also been measured, providing useful predictions of future behavior. It took sixteen years to collect the data presented at the Canadian Conservation Institute, which show the relaxation (loss of tension) of stretched canvas paintings and linings over that period of time, plotted on a logarithmic time axis (fig. 1.2). Such data are critical when deciding on the best choice of adhesive and lining material.

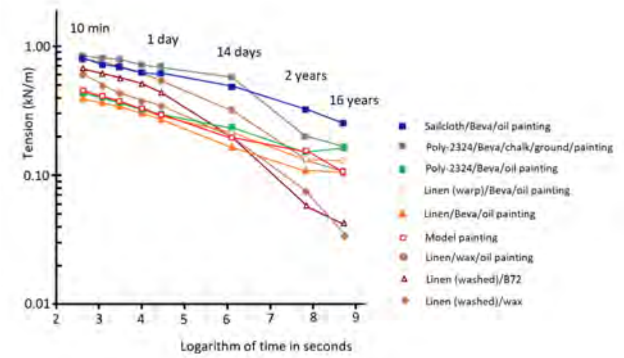


Figure 1.2 Long-term relaxation for several canvases and linings plotted logarithmically against time (Daly Hartin et al. 2011). Image: Stephen Hackney

The use of biaxial stretching, first proposed by Berger (Berger and Russell 2000), and electronic speckle pattern interferometry (ESPI) for strain measurement (fig. 1.3) enabled Young and Hibberd to look in further detail at conservation issues and lining practices, such as the strain associated with stretcher attachments (Young and Hibberd 1999; Young and Hibberd 2000). The complex structure of stretched canvas is now understood in sufficient detail to consider computer modeling of the mechanical properties of both paintings and linings. It also offers the opportunity to study in more detail the effects of minimal treatments on more contemporary paintings (Hagan et al. 2007; Hagan et al. 2011b). Temporary solutions and physical protection may prove to be our best options, but many have not yet been fully assessed objectively.

CONSERVATION PRACTICE

Transferring research results into conservation practice on historical objects involves special problems. Understanding materials in a pristine state is not enough to predict the behavior of deteriorated old paintings (Ackroyd 2002; Hackney 2004b; Phenix 1995; Reeve 1984; Scharff 2012). Since an assessment of physical condition and appropriate treatment requires such knowledge, measuring slow processes such as "natural" aging is increasingly necessary in order to make reliable long-term decisions.

Progress in devising and applying new conservation treatments is made difficult because at some stage practical experience can be gained only by working directly on unique and valuable original aged material (fig. 1.4). It might be argued that this amounts to carrying out scientific experiments lacking a control. As a consequence, we can choose our treatment method but cannot be sure it was the best of several possible options.

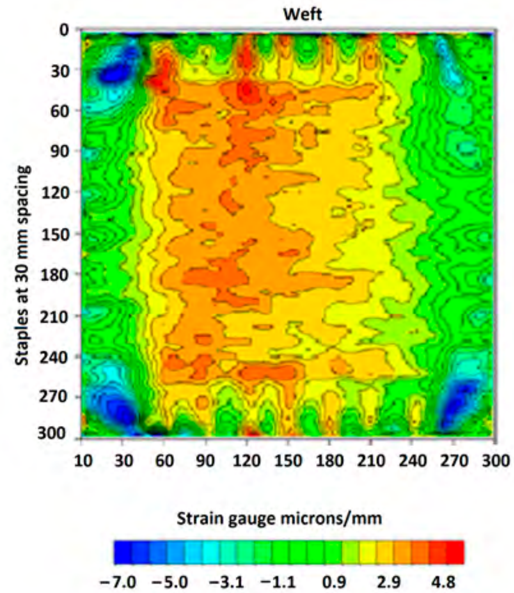


Figure 1.3 Strain variations near the canvas edges associated with the use of tacks for attachment to the stretcher (Young and Hibberd 1999). Image: Stephen Hackney

Figure 1.4 Julius Caesar Ibbetson, *Smugglers on the Irish Coast*, 1808. Oil paint on canvas, 54.6 × 85.1 cm (21 1/2 × 32 in.). Glue-lined oil painting, possibly including megilp chosen by the artist for its fluidity (Ibbetson 1803). The raking light reveals flattened impasto and weave emphasis from glue lining. Image: Tate

In the United Kingdom, original nineteenth-century loose linings have provided a limited source of acceptable experimental material, but such material has still not been replicated reliably in all its aspects by artificial aging methods.

For the conservator concerned with historical paintings, it is important to be aware of artists' changing methods, materials, and intentions. There is much detail, accumulated from the examination of examples of painting practice, to inform the conservator of the likely behavior of a specific painting to be treated. For the period from the latter part of the nineteenth century until the present, artists were less bound by academy controls; their aims became more adventurous, and their materials and methods expanded. As paintings from this period increasingly demand attention and treatment, the conservator is presented with a variety of interesting new problems and conflicts, many of which have already contributed to modified conservation practice for works on canvas, currently leading to a more preventive approach. The demands of much recently created art provide a challenge that requires radical solutions, and they are pointing to new directions in conservation of both contemporary and traditional art (Heiber 2003).

Some developments of lining processes using new materials, such as sailcloth fabric (Hedley and Villers 1982) and Beva 371 adhesive (Berger 1975), have so far survived the test of time. Exploring the properties and stability of possible alternative conservation structural materials is a major undertaking, made more difficult by the risk that material manufacturers may discontinue their supply. Economics also conspire to deter time-consuming structural treatments. As a consequence, for many contemporary paintings, restoration often challenges existing experience and costs much more than preventing damage (fig. 1.5).

Figure 1.5 A painting made from three stretchers interwoven by strips of canvas, which presents a structural conservation challenge. Stephen Buckley, *Nice*, 1972. Acrylic on canvas, 81 × 90.2 × 5.1 cm (32 × 35 1/2 × 2 in.). Tate, London. Image: © Stephen Buckley / Photo: Tate

COLLECTIONS CARE

Given the many unavoidable problems encountered in conservation treatments, protecting canvases from physical and chemical deterioration is now considered a priority in many museums. For the conservator, it has always been difficult to predict the range of conditions to which a painting has been and could be exposed. The environment that a specific painting is likely to encounter remains uncertain, even within museums. Increasingly, we ask what are the true risks for paintings on canvas, and how should we decide when intervention is necessary?

Improvements in the environment of modern museums (controlled and filtered air-conditioning, UV filtration); careful handling and operating procedures; and protection during transport and handling have all contributed to more reliable conditions. Defining exact relative humidity/temperature (RH/T) conditions is virtually impossible, but the absence of identifiable damage that can be directly attributed to current museum conditions is a positive indicator. However, more recently, an open-ended commitment to long-term protection by air-conditioning has been challenged as expensive and unsustainable in energy terms.

In the past, the risks of travel were unpredictable and thought to be large. Conservators were therefore obliged to reinforce a painting's structure to the best of their ability. With increasing loan and exhibition programs and major blockbuster exhibitions, this has become an international problem. The transport environment has now been examined in terms of shock, vibration, moisture content, and temperature along with their consequences for paintings in transit. Criteria for behavior and designs for packing cases to minimize exposure to risks have become established. An interesting observation from the Art in Transit research group was that, by using reliable methods and tight procedures, transport risks could be reduced below those of handling within a museum (Mecklenburg 1991).

By introducing consistent procedures for the physical protection of works of art, it is easier to avoid much accidental damage and unnecessary early deterioration. Successful collections care procedures have together made the idea that lining is a requirement much less persuasive and forced us to be more precise about its purpose.

CHEMICAL AGING PROCESSES

For the long-term survival of paintings, the less dramatic yet equally important chemical degradation of canvas, size, ground, and paint needs to be considered. However, the exact condition of aged canvases and their continuing rate of decay cannot be known in sufficient detail and are not readily captured in most risk analysis, which is currently concerned with shorter term, mainly physical activity.

The slow reactions of oxidation and hydrolysis that take place in degrading cellulose and oil paint are the main reasons that painting materials become fragile. What were originally stable structures no longer perform their design function, and physical damage often follows. Air pollution and light contribute to this deterioration, involving chemical interactions between canvas and its immediate environment. They play a subtle, perhaps unstoppable role in aging.

Between 1900 and 1960, air pollution was at its worst in many countries. Most museums were not air-conditioned, and until about 1990 concentrations of particulates and the strong acidic gas sulfur dioxide remained unacceptably high. In the last hundred years or so, exposed canvas has adsorbed sulfur dioxide from air pollution; the sulfur dioxide then reacts with the cellulose in the canvas. The products are not volatile and remain in the canvas, facilitating hydrolysis reactions. All acidity, whether from external and internal pollution or simply from oxidation, cause measurable weakening and embrittlement of the canvas (fig. 1.6).

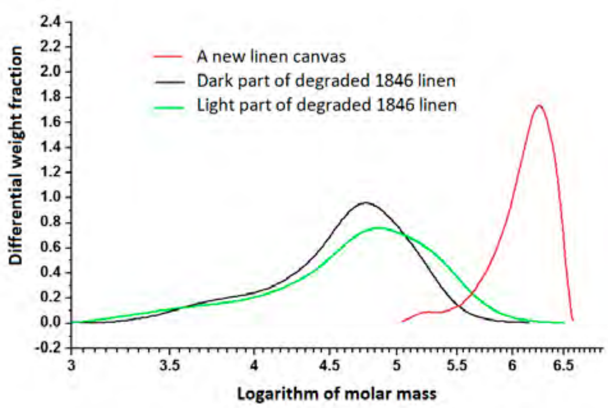


Figure 1.6 Plot of molar mass distribution. A new canvas on the right with a range of very high molecular weights compared with two samples of a J. M. W. Turner loose-lining canvas (painting dated 1846). The peaks (modes) for the Turner canvas are at much less molar mass and there is a greater spread of molar masses than for the new canvas, indicating that the long cellulose molecules have been cleaved at many points. Also, the darker exposed parts are more degraded than the lighter parts behind the stretcher. Canvas samples analyzed at BOKU Vienna during the EU MEMORI project (Jeong et al. 2013). Image: Myung-Joon Jeong, Manuel Becker, Antje Potthast, Susana López-Aparicio, and Stephen Hackney

Efflorescence can occur on the surface of oil paintings, especially unvarnished ones, and on glazed works it is sometimes transferred onto the glass. This deposit has been analyzed as fatty acids (Williams 1989), which must have been released from the oil paint. The hydrolysis of oils is well known, and migration of its reaction products within dried oil paint films explains efflorescence.

There has been a major advance in understanding the degradation of oil paint and how it changes the paint's optical performance and our perception of a painted image (Boon, van der Weerd, and Keune 2002; Keune 2005). We are all familiar with the increase in transparency of oil paintings and grounds. The impregnation and lining of paintings with thin grounds can also cause increases in transparency, especially when wax resin has been used (Bomford and Staniforth 1981). We now know that old paint films form an ionomeric structure that continues to deteriorate by hydrolysis and oxidation. Saponification reactions of free acids with alkaline or basic metals present in finer pigments, such as calcium, magnesium, lead, and zinc, can dissolve pigments into the paint. Removal of these light-dispersing fine pigments causes the paint to increase in transparency.

I recently conducted experiments involving mixing acid-base titration indicators into various fresh white oil paints and then painting them out. In a few minutes, the pH 4, 4.1, and 4.7 indicators began to change color, but the pH 3.3 and 3.7 indicators remained unchanged for months. For comparison, samples were removed and exposed to ammonia vapor to return them to their initial color (for a short time). Similar control samples in artists acrylic paint did not change color at all. This demonstrates that oil paint becomes acidic within a short period of time (Hackney 2020).

The acidic nature of dried oil paint is the reason why artists do not paint directly on canvas but instead protect it with a coat of glue size. The application of an oil ground or paint on top of this water-soluble size layer produces many of the structural and mechanical problems that we have to deal with. A hot glue size will engulf the canvas, but when applied cold it can accumulate on the canvas surface (Morgan et al. 2012). If and when a glue size cracks, its barrier properties are reduced and volatile breakdown products (VOCs) may reach the canvas.

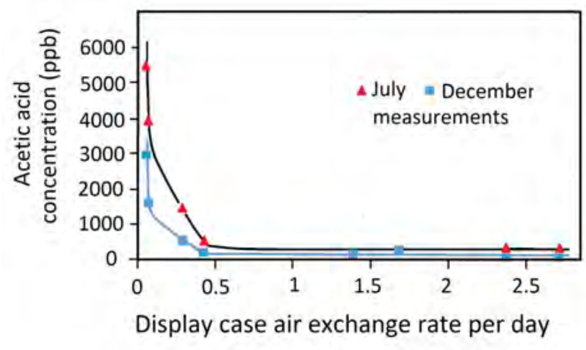
Similarly, if we add a consolidating or lining adhesive that can become acidic on oxidation, the canvas will be exposed to more rapid deterioration. These arguments suggest more research is needed into both conservation adhesives and ways of achieving adequate deacidification of canvas (Hackney, Townsend, and Wyplosz 1996; Ryder 1986).

Enclosure on display or in storage to reduce moisture exchange and deposition of external pollution, such as nitrogen dioxide and particulates, is an important conservation measure (McClure 2012) and a more sustainable alternative to air-conditioning, but measurements within enclosures demonstrate that we have to be careful in its use (fig. 1.7).

The concentration in air is not in itself a measure of reaction rate, but it shows that more molecules are available to react. Below 0.5 AER (air exchange rate), the rate of off-gassing of acetic acid, both from the packaging and (some) from the object, exceeds the combined leakage rate and rate of deposition or reaction, the latter being slow processes. When reactive molecules collide, only a small proportion reacts, but in these circumstances trapped pollution molecules can collide many times and will eventually react. The introduction of sacrificial adsorbers or reactants might therefore be useful, provided they are placed close to the object.

CONCLUSION

There is still plenty of work to be done, but at last we know that we can build on a growing body of knowledge. We still need to turn this knowledge resource into genuine expertise and practical conservation experience. We also need to embed in our minds the concept of preventing deterioration, which will be appreciated by future practitioners who will still be addressing the same ethical issues. The Conserving Canvas symposium provided a useful forum to take stock of recent progress and to assess its contribution to the development of an agreed way forward.



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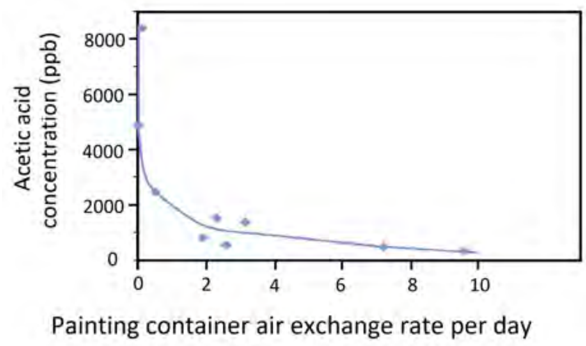

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Figure 1.7 Two separate studies showing that below 0.5–1.0 air exchanges per day, the air concentration of internally generated volatile pollution soars. (a) Large-volume display cases (Thickett et al. 2007). (b) Various narrow painting frames and cases (Grøntoft et al. 2011). See Hackney 2016. Image: Stephen Hackney

2

Applied Mechanics and the Structural Treatment of Paintings on Canvas

Eric Hagan, Senior Conservation Scientist, Canadian Conservation Institute

Paintings on canvas are composite structures with mechanical properties that are difficult to characterize due to many complicated issues: the wide range of artists materials and techniques, which vary by region and time; the changing properties of materials with age and environmental exposure; and the addition of conservation treatments. Paintings are also composed of viscoelastic materials, which means that properties such as stiffness and extensibility are time and temperature dependent. This large matrix of variables makes it impossible to characterize the behavior of all paintings in the same way that an engineer might describe a distinct structure under a narrow window of conditions and boundary constraints. Valuable information is instead derived from materials testing of representative samples, development of simplified models, and expert knowledge from past successes and failures. As a result of the complexity, heuristics is often applied in conservation treatments. This paper provides a generalized overview of the mechanical behavior of paintings in tension and describes trends that help to refine the heuristics approach. The discussion is presented in the context of a viscoelastic (time-dependent) material model rather than elastic-plastic in order to highlight key concepts.

INTRODUCTION

Those studying the mechanical behavior of artists paints and painting structures will likely begin with the general elastic-plastic stress-strain relationships often discussed in introductory engineering texts. A classic diagram will label elastic modulus, yield point, ultimate tensile strength, and failure strain from a simple tensile test. The concepts then become incredibly complex when delving deeper into the response of polymeric materials under varying conditions. This is particularly true for artists paints when considering the influence of temperature, rate of deformation, moisture content, additives to the polymer matrix, and many other factors. To accurately characterize the small-strain behavior of paint films over a wide range of conditions, it often necessary to consider a linear viscoelastic material model (Ferry 1980). Describing the large-strain response may require adding hyperelasticity (Treloar 1975) for an extension to a nonlinear viscoelastic material (Christensen 1982). An example of this approach was developed for acrylic (latex) artists paints containing titanium dioxide (Hagan et al. 2009), which provided parameters for finite element analysis in software such as Abaqus. Calibrating such a model—even for one material—is no easy task. It involves many tests and numerical iteration to solve the best fit parameters to experimental data, and simplifying assumptions still remain.

When pigment particles are included in the polymer matrix of a paint film, the material becomes a particle-filled composite with a viscoelastic matrix. Stiffness enhancement as a function of particle volume concentration is described in many micromechanics models; however, most give little consideration to geometry effects. The Mori-Tanaka theory is particularly useful since it considers the influence of particle shape and orientation in addition to volume fraction (Tandon and Weng 1986). Clements and Mas extended this theory from an elastic to linear viscoelastic matrix for small-strain modeling (Clements and Mas 2001). The effects of particle shape and concentration were highlighted for artists acrylic paints using kaolin, calcium carbonate (aragonite), and titanium dioxide as an inorganic phase in a recent study (Hagan et al. 2011a). From this research, it is easy to imagine that the properties of a paint layer may be different along a brushstroke relative to the transverse direction, due to the alignment of pigment particles with an aspect ratio not equal to 1. The composite structure of a painting on canvas adds further complexity given the layering of different materials and boundary conditions at the stretcher. Common treatment approaches, such as linings, add further variables.

It is impractical to think that we can precisely understand the mechanical behavior of paintings with so many influencing factors, which additionally include chemical effects of the aging process, the physical aging of polymers (Struik 1980), load cycling, fracture, and delamination (Tantideeravit et al. 2013). While researchers work to better understand and model these materials for risk analysis, it is important to use the best information available in a heuristic approach to resolving practical problems of the moment. Waller and Michalski emphasized the value of heuristics in preventative conservation:

> A fully rational approach would require that all possibly relevant information be obtained and used in arriving at a decision or evaluation. The cost of—and time required for—a fully rational decision is infinite. Instead, a conservator evaluates, using heuristics (simple rules of thumb or intuition), whether there is an advantage in seeking more information before deciding whether a particular issue, such as a risk to a collection, is significant or not. (Waller and Michalski 2004, 6)

In "Toward a Definition of the Engineering Method," Koen defines *heuristics* as "anything that provides a plausible aid or direction in the solution of a problem but is in the final analysis unjustified, incapable of justification and fallible. It is anything that is used to guide, discover and reveal a possible, but not necessarily, correct way to solve a problem" (Koen 1988, 308). An important comparison is given to the different approaches of the scientific and engineering methods. Koen also states that "the engineering method is the use of engineering heuristics to cause the best change in a poorly understood situation within the available resources" (Koen 1988, 308). There is clearly a similarity between the work of a heritage conservation professional and an engineer, with respect to problem-solving under challenging circumstances with many unknowns.

A pertinent example of the engineering method is found in the renowned body of research by Mecklenburg related to the mechanics of artists materials and the effects of the museum environment. In the proceedings of the 1991 Art in Transit meeting, Mecklenburg and Tumosa present findings that highlight the tensile properties of artists paints as a function of strain rate (Mecklenburg and Tumosa 1991a). In contrast, subsequent research gives descriptions of material behavior that use an elastic-plastic (time-independent) model (Mecklenburg 2005). Strain rate is fixed to a constant value in mechanical tests to generate timely and practical information on the effects of the museum environment without the burden of viscoelastic theory.

The aim of this paper is to revisit some key concepts in the time-dependent mechanical behavior of paintings, as a supplement to fundamental knowledge of mechanics. The concepts relate to many of the treatment methods used in practice where material behavior is altered by changing different parameters. Detailed theory and test results are presented elsewhere; therefore, the focus is on generalized trends for clarity. A brief review of lining effects on stiffness and stress relaxation of painting is also provided to complement a more in-depth discussion regarding the Canadian Conservation Institute (CCI) Lining Project (Daly Hartin et al. 2011).

MECHANICAL RESPONSE OF PAINTINGS IN TENSION

Stress-Strain Curves

A stress-strain curve is derived from a simple tensile test, and it is often used to characterize the mechanical properties of painting materials. Force and displacement measurements are converted to stress and strain in order to remove the effects of sample geometry. The initial slope of a stress-strain curve in uniaxial tension is a measure of stiffness called the modulus of elasticity, E, or Young's modulus. Experiments in shear mode define the shear modulus, while hydrostatic pressure gives the bulk modulus. For a viscoelastic material, these elastic moduli are time dependent, and the stress-strain relationship is nonlinear due to polymer relaxation during the test. Figure 2.1 shows stress-strain curves from a series of tensile tests performed on free films of an artists oil paint. The results highlight that the modulus decreases with higher temperature and reduced rate of deformation, while the failure strain increases. Despite this trend, there is no simple relationship between stiffness and failure strain for materials in general. A material may be stiff and brittle or compliant and brittle.

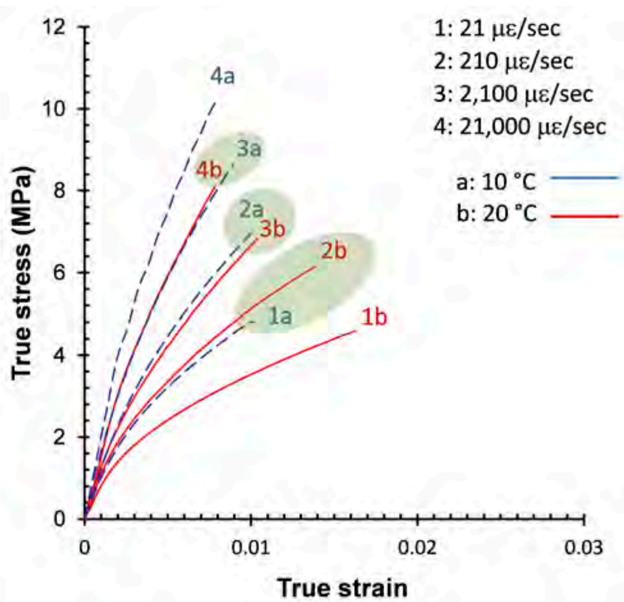

Figure 2.1 Stress-strain curves for a titanium white artists oil paint at different strain rates and temperatures in uniaxial tension. Image: © Government of Canada, Canadian Conservation Institute

Figure 2.2 illustrates the results of a tensile test with the time dimension added. The first graph (fig. 2.2a) shows the strain history as millistrain versus time, and indicates that the strain rate, *R*, is constant during the constant speed test due to the low failure strain. At higher strains, the strain rate would measurably decrease during a constant speed test due to the changing length of the sample. The second graph (fig. 2.2b) gives stress versus time, and the third (fig. 2.2c) presents a stress-strain curve. The latter shows a secant modulus, E_s (at strain ε = 0.005), and the strain at failure ε_f. Secant modulus can be a useful measure of stiffness due to nonlinearity caused by relaxation during the tensile test.

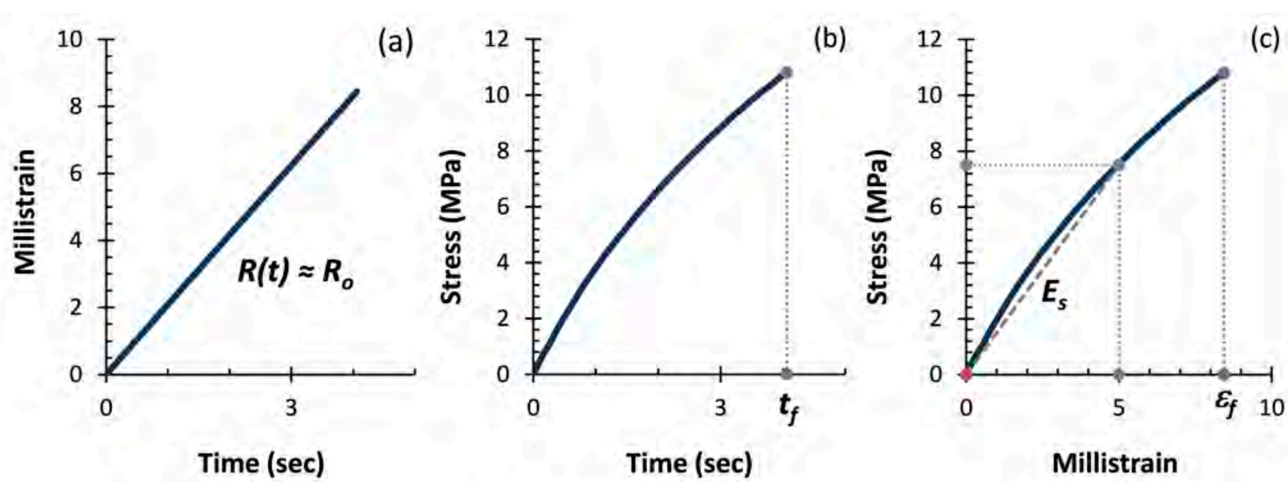

Figure 2.2 Tensile test data for a nine-year-old sample of Winsor & Newton Foundation White at 20°C, 50% RH, and a rate of 2100 με/sec. Image: © Government of Canada, Canadian Conservation Institute

Stress Relaxation

A relaxation test is another useful experiment for studying time-dependent material properties, and it is particularly relevant to canvas-supported paintings. Figure 2.3 illustrates the different parameters in a stress-relaxation test performed on a Winsor and Newton Foundation White film. The first graph (fig. 2.3a) shows the strain history as an initial loading ramp, followed by constant strain during measurement of stress relaxation. The second (fig. 2.3b) shows the loading ramp on a stress-strain curve, and a vertical drop in stress during the constant strain segment. Figure 2.3c gives the stress relaxation process on a plot of stress versus time, where it appears that stress is approaching equilibration after a sharp initial drop. The final plot (fig. 2.3d) shows the same data on a log-log scale and highlights that the sample is still relaxing. The results also show similar findings for a repeat test that was performed on the same sample after a twenty-four-hour recovery period. During cyclic load testing on viscoelastic materials, it is important to consider strain history and its effects on repeated measurements.

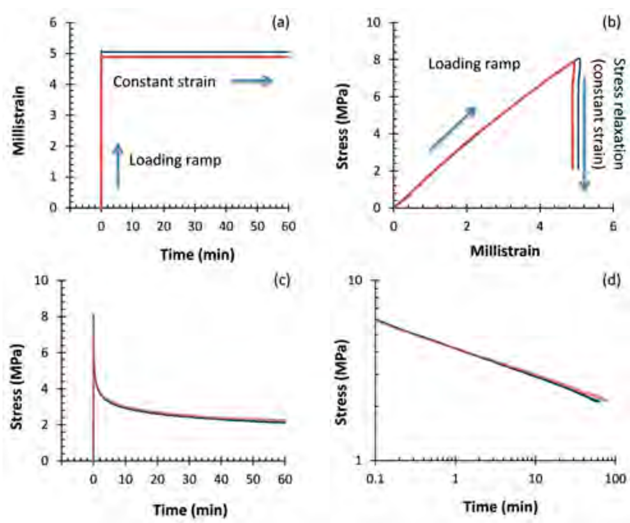

Figure 2.3 Stress-relaxation test performed on a nine-year-old sample of Winsor & Newton Foundation White: (a) strain history, (b) stress-strain curve, (c) stress relaxation on a linear scale, (d) stress relaxation on a logarithmic scale. The red lines show a repeat test on the same sample after unloading and a twenty-four-hour recovery period. Image: © Government of Canada, Canadian Conservation Institute

The stress-relaxation test method outlined in figure 2.4 is the approach used in the CCI Lining Project to investigate the effects of different lining treatments for paintings on canvas (Michalski and Daly Hartin 1996). From recent work, figure 2.4 shows a plot of tension (kN/m) versus time after a fixed strain was applied to each sample (Daly Hartin et al. 2011). The initial sharp spike is caused by the rapid initial strain (see figs. 2.3b, 2.3c), which is followed by a quick decay in tension due to stress relaxation. The model painting with a linen lining shows no difference from the model painting (unlined) over the measurement time scale. The sailcloth lining causes a uniform vertical shift in tension due to the stiffness of the fabric, which is constant over the sixty-hour period. An advantage of the sailcloth lining is that its stiffness allows for a stable increase in tension, with less strain imposed on the painting. In fact, the strain could be reduced to roughly half and still maintain a similar tension to the model painting in the experimental time scale. The wax-resin lining also shows a strong vertical shift due to the wax stiffness; however, it also exhibits relaxation characteristics.

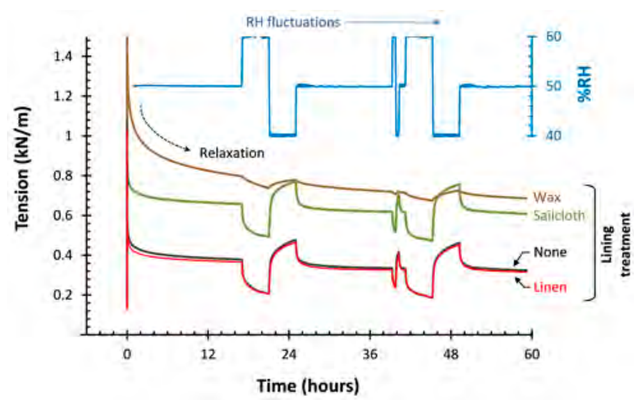

Figure 2.4 Stress relaxation at 1 millistrain for a prepared model oil painting with different lining treatments. Image: © Government of Canada, Canadian Conservation Institute

The addition of RH fluctuations in figure 2.4 highlights some further trends in the lined painting response. Sailcloth and linen have no effect on the response of the painting, since the linings do not constrain the paint layers in the direction of applied tension—that is, painting and lining are free to shift across one another. In contrast, the wax-lining impregnates the canvas and constrains the paint layers from shrinking or swelling due to contact with the supporting layers of the painting. The paint layers still respond to RH fluctuations; however, the wax adds surface constraint that prevents movement and a subsequent change in tension measured at the ends of the sample. A more in-depth discussion of the CCI Lining Project is provided by Daly Hartin and colleagues (Daly Hartin et al. 2011); therefore, the following discussion provides more general information regarding the viscoelastic behavior of painting materials.

Time-Temperature Superposition

Over a wide range of test conditions, it is impractical to summarize tensile data from a viscoelastic material with stress-strain curves. It is also not feasible to measure the full relaxation behavior from glassy to rubbery—a process occurring over many decades—at one temperature, due to equipment limitations and time constraints. In figure 2.1, it is clear that a relationship exists between strain rate and temperature, since increasing the rate by an order of magnitude is equivalent to decreasing temperature by 10°C. This implies that time-temperature superposition (TTS) is a potential tool for efficiently summarizing data (Williams, Landel, and Ferry 1955). To illustrate this method, figure 2.5a shows a simplified summary of modulus values at three temperatures and four strain rates within a practical test window. This test window is bounded by equipment limitations and practical time available for data collection. Figure 2.5b shows the result of fixing data at a chosen reference temperature, T_{ref} = 20°C, and figure 2.5c shows horizontally shifting data at the other temperatures to line up as a single master curve. The result shows a shift from glassy to rubbery behavior over a broader scale than the experiments allowed in direct measurement. Tabulated results of the horizontal shift factor versus temperature allow one to create a master curve at any T_{ref} of interest within data limits. Defining T_{ref} at the glass transition temperature, T_g, would also allow comparison with theoretical functions, and possible extrapolation to temperatures beyond the test conditions. There are many reasons why the simple TTS method may not work for certain materials; however, it is a powerful tool when it does.

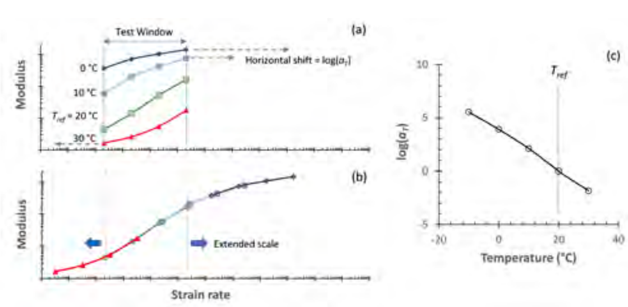

Figure 2.5 Illustration of time-temperature superposition applied to tensile test data. (a) Secant modulus measured at four strain rates and four temperatures. (b) Data at each temperature shifted along the time axis to form a master curve at T_{ref} = 20°C. (c) Experimental shift factor values recorded versus temperature. Image: © Government of Canada, Canadian Conservation Institute

It is helpful to consider practical situations where the viscoelastic properties are of importance. As a simple example, figure 2.6a shows a schematic of a broken and curled flake of paint that is deformed back into the plane of the painting. The radius of curvature (*r*) and film thickness (*h*) is labeled simply to highlight that it is possible to estimate the strain rate from a few parameters and define the time scale of the applied deformation. Rolling or unrolling a canvas painting is another similar and geometrically simple example. In figure 2.6b, the stiffness reduction caused by decreasing the rate of deformation is shown as the path from point A to point B along the master curve. In contrast, path A→C indicates the effect of keeping the same strain rate but using higher temperature to shift the master curve horizontally. The higher temperature accelerates the polymer relaxation and leads to a lower stiffness at a given strain rate. The horizontal shift may also be caused by a plasticizing effect, such as an increase in moisture content (Maksimov, Mochalov, and Urzhumtsev 1972). Path A→D shows a final example from the combined effect of decreasing the rate of deformation while also increasing temperature. Care should, of course, be taken when increasing temperature and moisture content, since extremes may cause unwanted effects beyond the simple relaxation process described here.

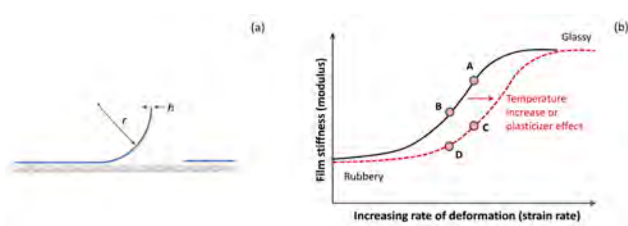

Figure 2.6 Deforming a curled flake of paint back into the plane of the painting. (a) Illustration of the curled paint layer of thickness, *h*, and radius, *r*. (b) Effect of temperature and rate of deformation on film stiffness. A→B: slower rate of deformation, same temperature; A→C: elevated temperature, same rate of deformation; A→D: slower rate of deformation and elevated temperature. Image: © Government of Canada, Canadian Conservation Institute

The concepts discussed in this section are often studied using a technique called dynamic mechanical analysis (DMA) (Nielsen and Landel 1994). This can rapidly give modulus data as a function of temperature and frequency using a single sample and show transition regions. Experiments involving tensile tests are typically used when the large-strain response, or failure properties, are of interest.

Ultimate Properties

The purpose of using tensile test data in studies of artists paints is due to the interest in characterizing their large-strain response, particularly the failure criteria as a function of time and temperature. The related research work of Thor Smith in the 1960s is of interest since it shows the application of TTS to the ultimate properties of plastics and elastomers. Smith clearly summarizes an important finding in one of his many papers on this topic:

> The ultimate tensile properties (the stress at break σ_b, and the corresponding extension ratio λ_b) vary markedly with the temperature and with the stress-time or strain-time history prior to rupture. Considerable evidence indicates that data obtained at different temperatures can often be superposed to give master curves which show the variation of σ_b and λ_b over many decades of time at a fixed temperature. Further, the temperature shift factor is the same—or nearly the same—as that used to superpose viscoelastic data representing small-deformation behavior. In other words, the same molecular parameters which influence chain mobility, thus the time and temperature dependence of linear viscoelastic response, also have a controlling effect on the time and temperature dependence of the ultimate tensile properties. (Smith 1965, 275)

Recent studies on artists paints have highlighted the application of this approach for generating master curves of failure strains from tensile data. Figure 2.7a shows a generalized illustration of a failure envelope created using a similar approach to that shown for modulus data (see fig. 2.5). The path to point A results in failure before reaching the target strain at the defined strain rate. Reducing the strain rate avoids failure for the path to point B, which is outside of the failure envelope. Figure 2.7b shows the path to point C outside of the failure envelope due to a horizontal shift of the master curve from a temperature increase or possibly a plasticizing effect (e.g., increased moisture content). Combining higher temperature and reduced strain rate locates point D even farther from the failure line.

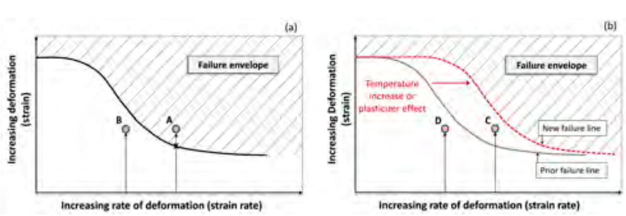

Figure 2.7 Deforming a curled flake of paint back into the plane of the painting. (a) Effect of reducing strain rate on failure criteria. (b) Effect of reducing strain rate and elevating temperature on failure criteria. Compare to figure 2.6. Image: © Government of Canada, Canadian Conservation Institute

This concept of a failure strain master curve is also shown in figure 2.8 using tensile data from two artists paint films at T_{ref} = 20°C (Hagan 2017). The acrylic paint film (fig. 2.8a) shows a considerably larger combination of strains and strain rates that avoid failure compared to the oil paint (fig. 2.8b). This illustrates why cracking of acrylic latex paints is much less common than in traditional oils over a wide range of conditions.

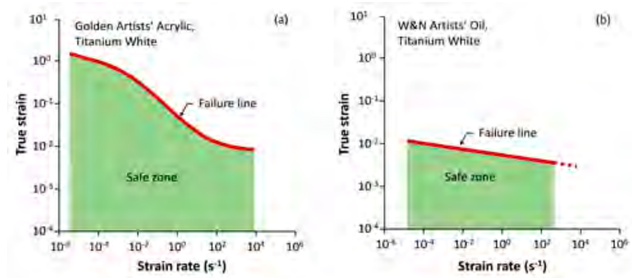

Figure 2.8 Failure strain master curves for two titanium white artists paint films at T_{ref} = 20°C. (a) Golden acrylic. (b) Winsor & Newton oil. Image: © Government of Canada, Canadian Conservation Institute

CONCLUSIONS

An overview of the viscoelastic properties of artists painting materials was provided to highlight important trends in their mechanical behavior. Example tensile test and stress relaxation data were presented for paint films and lined painting samples, respectively. These data showed a time and temperature dependence on measured stiffness and failure strains. For lined painting samples, stress-relaxation data indicated clear differences in the response of different treatment methods. The sailcloth lining showed value in maintaining consistent tension over time, potentially reducing the amount of strain on the painting for a given tension.

The concepts were further developed through a discussion of the time-temperature superposition principle and the creation of master curves of stiffness and failure strains. This technique can effectively summarize properties over a broad time scale and may be referenced at a temperature of interest. The master curves were used to illustrate how stiffness and failure strains are manipulated by changing the rate of deformation, temperature, or moisture content. In practice, it is not possible to know the shape of these curves for the wide variety of materials found in paintings; however, an understanding of the trends in material behavior is important when applying heuristics to treatment methods.

3

To Treat or Not to Treat, That Is the Question: Structural Treatment of Canvas Paintings from a Danish Perspective

Mikkel Scharff, Associate Professor, Institute of Conservation, The Royal Danish Academy

This paper discusses the situation in Denmark before the Greenwich conference on lining of canvas paintings and how the subsequent period of fifteen to twenty years was filled with curiosity, eagerness to try out new ways and ideas, testing of methods and materials, contemplating failures, building of new and glorious equipment—and a longing for better understanding of treatments and the structural behavior of paintings. In the 1990s, the focus gradually changed. Interventions became more limited, techniques and materials changed, and development of new treatment methods and materials was deemphasized, while better understanding of the structural behavior of canvas painting and its consequences came to the forefront through increased scientific study of the subject.

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INTRODUCTION

The paintings conservation community in Denmark in the mid-twentieth century, as in many other countries, was composed of, on one hand, individual practitioners working privately for smaller collections and museums and for historic buildings, and on the other, a few conservators working at larger institutions, primarily museums, in permanent positions.

Paintings conservators considered themselves craftspersons. Most had a background in the house painting craft[1] or were trained artists from the Royal Danish Academy of Fine Arts School of Painting. Training as paintings conservators usually followed an apprenticeship in a conservation studio or work in historic buildings.

House painting or artistic training constituted the background for the approach to treatments, choice of materials, and recipes for treatment. This produced a somewhat conservative approach based on generations of experience, but it was sometimes open to new approaches or novel materials. For example, newly available commercial materials were adopted, and after World War II internships with and visits by a generation of young conservators to conservation studios across Europe provided inspiration. In this way, for example in the 1950s, the idea of simple material analysis and photographic documentation gradually found its way to Denmark from Belgium’s Royal Institute for Cultural Heritage (KIK-IRPA) (Coremans 1953).

Conservators, in general, mainly undertook treatments without making note of methods and materials, although some books and journals about methods and materials did exist. Danish conservators could draw on a tradition of apprenticeship going back to the early nineteenth century (Scharff 1998, 2000), including some treatment descriptions written in Danish (Greve 1855). Recipe books for house painters or artists were also available, as well as books on gilding and varnishing. Danish paintings conservators in the mid-twentieth century knew about and practiced the main trends and techniques of structural treatments from the nineteenth century onward, including glue-based, glue-paste, and wax-resin treatments, though the latter were not practiced very much until the 1960s, when they were in regular use at the Statens Museum for Kunst (Royal Danish Museum of Fine Arts) (Andersen et al. 2014). Structural treatments were divided between primary treatments (first linings) and secondary retreatments (relinings), and (much less frequently) more radical treatments such as transfers or marouflage.

STATE OF THE ART IN THE 1970S—CONSIDERATIONS, CHOICES, CONSEQUENCES

When summing up his overview of structural treatments and choice of methods and materials in his influential "Lining Cycle" introduction to the 1974 Greenwich conference, Westby Percival-Prescott stated that "the purpose of this conference is to see that our choice is a wise one" (Percival-Prescott 2003b).

This aim could well stand as the general effect of the Greenwich conference on the established paintings conservation field in the 1970s and onward and describes the impact on young conservators making their way into the field. A number of publications have dealt with the conference and its major influence, and they often discuss historical developments preceding and following the conference, for example, the introduction to the 2003 postprint publication (Villers 2003a), most recently Hackney's overview book *On Canvas* (Hackney 2020), and elsewhere (Bomford 2017; Burnstock 2017; Hackney 2012). Given this background, this paper focuses on information preceding the Greenwich conference that is relevant to developments in Denmark during the 1970s in particular—a decade with a number of defining events in paintings conservation that have had a lasting impact for the future.

The experiences and events of the 1960s formed the immediate background. A new generation of postwar conservators with new experience and ideas gained from abroad was in a position to carry out various structural reforms in their institutions—and to review the approach to treatments followed in most paintings conservation studios in Denmark.

For a while in the 1960s, wax-resin treatments were seen as a major improvement and were widely used in combination with the innovative equipment: the new vacuum hot table (Andersen et al. 2014). Another milestone occurred when the river Arno inundated a major part of the medieval city of Florence and its artwork. Subsequently, conservators from abroad, including eighteen paintings conservators from the Nordic countries, participated in the immediate rescue and undertook conservation and restoration treatments (Plahter 1999). The disaster itself—and the observation that treatment approaches between conservators differed vastly—caused many in the assembled conservation community to reconsider materials, methods, and approaches and to realize that for the future of conservation it would be essential to obtain a more consistent entry to the profession.

Formal educational programs could be one of the means, but few existed at that time in Europe and the Americas. In Denmark, a government commission was formed in 1965. In 1969, it produced a report aimed at establishing new legislation on the protection of heritage in Denmark.[2] The report considered a revision of the conservation strategy and improved conservation facilities in Danish museums, as well as plans to establish an educational program that would supply the museums and the private market with qualified conservation staff. Concurrently, UNESCO was preparing the World Heritage Convention,[3] which was widely adopted in 1972 (including by Denmark) with a broad impact.

The Danish conservation community held seminars, lectures, and courses on various subjects while awaiting the inauguration of the School of Conservation, including the development of new equipment and approaches and the testing of alternative materials or methods. These were presented and discussed at the Nordisk Konservator Forbund (NKF), at the IIC Nordic Group, and at international forums including IIC and ICOM congresses, and especially at the ICOM Committee for the Care of Paintings—later to become part of the ICOM Committee for Conservation. The proposal by Percival-Prescott at ICOM-CC in Venice in 1975 to halt lining treatments pending a full review (Percival-Prescott 1975) was discussed as well, but it did not have a lasting effect in Denmark. It did, however, encourage consideration and testing of alternative and perhaps less intrusive treatment methods.

In 1973, Steen Bjarnhof, head of the Statens Museum for Kunst conservation studio, answered a questionnaire distributed by Stephen Rees Jones, head of the technology department of the Courtauld Institute of Art, University of London, in advance of the Greenwich and ICOM-CC conferences. His answers[4] revealed the conservation studio's use of traditional materials and methods and noted the deficiencies of wax-resin linings: canvases becoming slack after wax-resin lining, and hygroscopicity even in wax-resin linings. Bjarnhof also reported on experiments with EVA dispersion using "laminations"[5] and further information about the experiments and developments, such as those described by Hacke in the 1960s (Hacke 1963–64) and Bøgh and Ketnath's experiments with EVA as adhesive (Bøgh, Ketnath, and Thorvildsen 1975; Ketnath and Bøgh 1975). In 1974, Bjarnhof and other Danish paintings conservators attended the Greenwich conference.

REAL CHANGES—THE SCHOOL OF CONSERVATION IS ESTABLISHED

At the time of the Greenwich conference, the Royal Danish Academy of Fine Arts School of Conservation had been functioning for about a year. The founding of the educational program in 1973 resulted in a major planned change to the field of paintings conservation in Denmark—not at first, perhaps, but gradually over the following years.

I entered the paintings conservation program as part of the third admission of undergraduate students in conservation, in late August 1977. There had been many challenges in setting up a training program during the first four years, but the class of 1977 found a three-year educational program with quite a structured curriculum. We attended lectures, undertook a lot of practical work and exercises, and practiced extensive documentation, including photographic and X-ray techniques. Microscopy was the main analytical technique available to study a painting, its surfaces, and layered structure. The thorough process of documenting observations, reflections, descriptions, and errors was considered a major leap forward in the professionalization of the field and underscored the importance of compiling empirical knowledge for future use. Coursework was based on established treatment techniques, but we were also introduced to new techniques and materials as directed by teachers.

The available literature was limited. Descriptions of established techniques were provided by copies of the small Greenwich offprints, including the useful *Handbook of Terms* (see Percival-Prescott and Lewis 2003). Hacke and others presented new developments, discussing the outcomes of the Greenwich conference and the innovations of Mehra and Berger. Hacke had experimented with suction-table techniques (termed *low-pressure techniques*) since the 1960s (Hacke 1963–64, 1976, 1978), and in 1979 the School of Conservation received its first custom-built low-pressure table, which he had designed. Hacke held a seminar in September of that year for the students on suction-table techniques, in which we tried out the equipment and discussed "requirements" or options for treatments. These requirements were similar to those proposed by Mehra (see Andersen in this volume) and consisted of a set of principles, requirements, options, and methods guided by a philosophy that had formed over the previous years and constituted the basis for the equipment's design as well as the techniques employed. The seminar caused quite a stir, as the new equipment, the new techniques, and the whole approach offered interesting alternatives to the techniques we had tried during the previous years of coursework—and had, we understood, been intensively discussed at Greenwich.

We had also begun to follow conservators who were beginning to publish post-Greenwich information on canvas painting behavior and its response during treatment. Everything taken together, to be honest, made us feel somewhat lost at times. We were trying to understand the real impact of the more established techniques as well as understand how the new techniques worked. It was obvious that more information or knowledge was needed, but we tried to follow the publications and the views expressed, though they at times conflicted somewhat with the views of our teachers and tutors. There was a clear trend toward less intervention or even no intervention, raising the question of whether to treat or not to treat a given painting. And if treatment was preferable, how were we to approach it?

CASE STUDY—BACHELOR'S THESIS WORK, 1979–80

The Thesis Proposal

To illustrate the introduction of the new techniques for the conservation community in Denmark, I have retrieved my bachelor thesis report, which was based on thesis work done over six months in 1979 and 1980 (Scharff 1980). It may serve as an example of the knowledge and understanding used at the time for making decisions—from a student's point of view. The thesis subject was a small seventeenth-century painting in rather deteriorated condition that had been lined with glue paste. Structurally, the lining no longer served a function, the paint layers were cupped all over the surface, and the varnish had become opaque. Having established and documented the condition and the problems, the student was to propose a treatment: either an established method using well-known materials, where arguments were less necessary, as it was the normal choice; or one of the new, somewhat experimental (not well established) methods, which would need to be supported by arguments in its favor and references to publications and the recommendations they made. To seriously propose not to treat was not yet an option for a student thesis. My suggestion, to try a new approach, was accepted, and I began a quest for the literature and arguments.

In addition to a few 1950s publications on the subject of the then-new hot tables and vacuum hot tables (e.g., Ruhemann 1953),[6] select publications from the 1960s provided critical views on the new lining techniques and specific issues of vacuum hot table treatment practice (Brachert 1965; Linard 1965; Straub 1965). Alternative solutions to the drawbacks of established or newer lining techniques were published (Berger 1965, 1966; Etchinson 1969; Hacke 1963–64; Wales 1968). Some publications took a different approach that was new to me: attempting to define some of the deterioration mechanisms (e.g., Keck 1969) and indirectly pointing toward a different or better practice in treatment.

The more recent part of the literature review, through the 1970s, was easier, as most of the literature (not least the Greenwich conference papers) was relatively accessible and had been recently discussed in the student group. Alternative structural treatments appeared in publications from international organizations such as IIC and ICOM-CC and in national organizations like the NKF and the American Institute for Conservation; a few authors presented ongoing work throughout the decade in journals or at conferences. While some publications were based on a more scientific approach, most were still based on assumptions, a few experiments, practical experience, and tacit knowledge, making it somewhat difficult for students to evaluate the decision-making, as they lacked experience and had few examples of a more stringent approach.

Examination of the thesis painting, the literature review, and my considerations resulted in a treatment proposal that was primarily based on treatment philosophy and techniques related to Mehra and Hacke—their publications as well as the lectures and workshops with Hacke.

The alternative "low-pressure table" equipment to be used, the "lamination" adhesives and technique, and the underlying philosophy rested on a new approach that Mehra and Hacke shared to a considerable degree but not entirely. There were significant differences between the two, and it is interesting to compare Mehra's statements (treatment options) from 1972 (see Andersen in this publication) and his subsequent publications in the 1970s with Hacke's statements published during the same decade (Hacke 1976, 1978), and compiled in 1979 (fig. 3.1; table 3.1). The second column of table 3.1 presents a set of options for proper lining treatment that came out of a seminar Hacke held at the School of Conservation in September 1979. The list was compiled by the students based on the seminar and Hacke's previous publications (Hacke 1976, 1978).

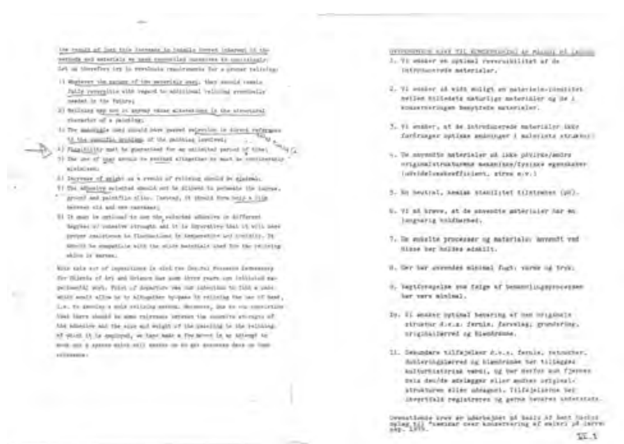

Figure 3.1 The original statements (treatment options) from V. Mehra and B. Hacke, used in the thesis arguments for treatment principles and choices. Image: © Mikkel Scharff, Institute of Conservation, The Royal Danish Academy

Table 3.1
Mehra and Hacke treatment prescriptions (“Requirements for a proper relining”)

	Mehra 1972*	**Hacke 1979**†
1	Whatever the nature of the materials used, they should remain fully reversible with regard to additional relining eventually needed in the future.	Optimal reversibility of the materials introduced (or added)
2	Relining may not in any way cause alterations in the structural character of a painting.	As far as possible a material identity between the natural materials in the original painting and the materials used in the conservation (process).
3	The materials used should have passed selection in direct reference to the specific problems of the paintings involved.	Introduced materials should not cause optical changes in the painting structure.
4	Flexibility must be guaranteed for an unlimited period of time.	Materials used should not affect/change the mechanical/physical characteristics of the original materials (expansion coefficient, stress, etc.).
5	The use of heat should be avoided altogether or must be considerably minimized.	A neutral chemical stability is to be endeavored.
6	Increase of weight as a result of relining should be minimal.	Materials used should have long-term durability.
7	The adhesive selected should not be allowed to penetrate the canvas, ground, or paint-film alike. Instead, it should form only a film between old and new canvases.	Individual processes (and materials used for these individual processes) should be kept separate.
8	It must be optional to use the selected adhesive in different degrees of cohesive strength, and it is imperative that it will have proper resistance to fluctuations in temperature and humidity. It should be compatible with the other materials used for the relining which it serves.	Water/humidity, raised heat, and pressure should be kept at a minimum.
9		Increase of weight as a result of the conservation treatment should be minimal.
10		Optimal preservation of the original structure is aimed for, such as varnish, paint layers, ground, original canvas, and stretcher / strainer.
11		The cultural history of secondary additions should be recognized, including additional varnish, retouches, lining canvas, and stretcher. Such materials or items should only be removed or replaced in case they deteriorate or change the original structure or the appearance. If need be removed, they ought to be registered and preferably kept elsewhere.

Sources:

* Scharff 1980, 1: 23.

† Compiled by students based on Hacke 1976, Hacke 1978, and the 1979 seminar given by Hacke. (Translated from Danish by the author.)

Table 3.2
Scharff treatment principles

1.	Optimal reversibility.
2.	—
3.	No optical changes in the painting structure.
4.	Mechanical/physical characteristics of painting structure unchanged by materials.
5.	Chemically neutral stability of materials.
6.	Long-term durability of materials.
7.	Individual processes should be kept separate.
8.	Minimal use of humidity, heat, and pressure.
9.	—
10.	Preservation of original structure.
11.	Acknowledge the cultural history of all constituents.

Source: Scharff 1980, 1:23.

In the thesis, both Mehra and Hacke are referred to, but only the Hacke-inspired (unpublished) statement is listed as an appendix to the thesis. In table 3.1, the Mehra and the Hacke statements are shown side by side with their original numbering. They appear mostly to agree, although some statements appear in different order and some do not appear in both lists. The main difference is probably regarding the use of heat or raised humidity or liquid water in the treatments, along with a difference of opinion as to the consequences. In the main thesis text, I summed up my opinion regarding each of the statements, listing which option I chose to follow in a condition list (table 3.2). My condition list was introduced with acknowledgments of the ideal nature of the list and the fact that it would probably not be possible to fulfill all of the options. Likewise, I expected that as the treatment progressed the selection of treatment methods and materials most likely would involve compromises compared with the ideal situation.

A closer look at the treatment options for the thesis work reveals that item 1 (reversibility) was qualified as "optimal" rather than "full" as Mehra has it. At the student seminar, the unrealistic option of full reversibility was discussed, while attempting optimal reversibility was accepted to include a possible failure situation.

Item 2 ("material identity") was deselected as a treatment condition to avoid material identity between the natural glue materials in the painting and an aqueous animal glue commonly used as a treatment constituent in consolidation. The use of aqueous glue would counter the demands of items 4 and 8. It is further noted in the thesis that item 9 (minimal increase of weight) was also deselected as it was assumed to be of minor significance on the small painting that was the designated thesis subject.

Mehra's conditions 4, flexibility, and 5, to fully avoid heat, were not included. Nor was Mehra's term *compatible* (item 8) used in the arguments for or against the selected materials. In all, where the Mehra and Hacke prescriptions differed, the treatment proposal had a greater affinity with the Hacke statements, for example, by keeping heat as low as possible but not fully ruling it out. A prominent principle listed by Hacke (item 7 in table 3.1) was that each treatment step be kept discrete, and Mehra promotes the principle as well in his Venice ICOM publication (Mehra 1975a).

The treatment proposal could be seen as trying alternate means to counter the more traditional treatment solutions and their inherent problems, not least by including the new treatment options employing a low-pressure/suction table. In this way, the proposal followed up on the many discussions that came out of the Greenwich conference and subsequent experiments, discussions, and publications that followed over the next five to six years.

Thesis Outcome—Results of the Planned Treatment

As expected, the actual treatment as described in the thesis did not turn out fully as planned. The final treatment ended up as a selection of compromises to some extent, where some of the ideal demands had to be partly diluted, deselected, or dismissed.

For instance, the application of facing paper with an acrylic solution that had been proposed did not work as planned. At the suggestion of the tutors, it was replaced with a thin layer of wax-resin paste applied at a temperature of no higher than 45°C. In the end, however (according to the thesis documentation), a temperature of 65°C had to be used to ensure the adhesion of the facing paper—thus compromising the idea of keeping the temperature as low as possible.

Subsequent removal of the previous glue-paste lining went well (figs. 3.2, 3.3) and so did the flattening procedure. A humidification chamber setup on the low-pressure table was used, with a tabletop temperature of 35°C and pressure at 50 millibars (mbar). To avoid liquid water in the structure, consolidation was done with an acrylic solution, and after solvent evaporation the consolidant was "activated" by heating the painting on the low-pressure table at 100 mbar and 42°C. The linen lining canvas was coated with a layer of thickened acrylic dispersion, and after a drying period the dry acrylic layer on the lining canvas and the consolidated painting were activated at 100 mbar and 42°C. After cooling, the proper lamination was obtained, basically following directions in Hacke and Ketnath (Hacke 1976; Ketnath 1976).

Figure 3.2 The author (right) working on the thesis painting at the top of the new suction table, spring 1980. Image: © Mikkel Scharff, Institute of Conservation, The Royal Danish Academy

Figure 3.3 The new suction table, acquired in 1979. Image: © Mikkel Scharff, Institute of Conservation, The Royal Danish Academy

A final, unplanned step in the structural treatment was added at the suggestion of the tutor to remedy a certain canvas structure enhancement and moating—most likely stemming from the previous glue-paste lining. The prescription was a final treatment of the painting, facedown on a vacuum hot table at 500 mbar and 42°C. The resulting painting surface after this treatment did not exhibit any canvas structure at all, and the painting was ready for the restoration part of the thesis project. However, neither the facedown treatment nor the 500 mbar pressure was fully in line with the ideas of the planned treatment. Nevertheless, the restoration went well, and in the summer of 1980 I obtained my bachelor's degree in conservation and went on to the master's program.

CONSEQUENCES—EVALUATION OF A TREATMENT AND ITS CONSEQUENCES

In general, it is interesting to note how much the new treatment concepts and material choices influenced the treatment design of the thesis work for me and my fellow students, and how little actual knowledge about the impact of the treatment and the choice of materials to use was available to us at the time. Most choices were based on the then-current "demands" or "recommendations," but they were also partly based on the critique of bygone treatments and materials as discussed in publications during the 1970s and especially after the Greenwich conference in 1974. The Greenwich offprints were also mostly based on assumptions, common sense, and empirical and tacit knowledge.

It was also interesting to see how treatment inadequacies or shortcomings in the conglomerate of new techniques and materials were addressed by reverting to better-known techniques and materials during the thesis treatments—eventually once again reverting to empirical and tacit knowledge. However, this was to gradually change over the ensuing ten to twenty years. At the time of the first thesis, to treat or not to treat was perhaps not yet a mature question to pose, but it would turn out to be an issue of increasing debate in the next couple of decades.

FURTHER DEVELOPMENTS—THE 1980S AND ONWARD

In the 1980s, after the relatively new suction table was added as new equipment at the School of Conservation and other conservation studios in Denmark, conservators across the country began to further develop the equipment, as it seemed a useful tool for the treatment of many canvas paintings. The first suction table at the school was rather small, so an all-aluminum suction frame was developed based on the design of larger wooden frames at the National Museum of Denmark and the Museum of Fine Arts. It was constructed to fit the surface of the larger vacuum hot table and could utilize its heat capacity if need be. This made it possible to treat larger paintings with suction-table techniques.

Construction of minisuction equipment was the result of one student thesis during these years (Mitka 1985). A different student thesis included the construction of a large suction table (Petéus 1984), and another large, experimental table was built by Mitka at the School of Conservation. All these tables had built-in heating capacity, and the latter included conditioned air which flowed in from below or via a chamber above the painting during treatment on the suction table. Built-in sensors enabled the user to follow and record temperature and humidity on paper tape.

Similar new—and even larger—low-pressure tables were designed and built ad hoc for special projects in situ in manor houses or for general use in the Danish conservation studios. Comparable activities took place in many countries, with either in-house designed equipment or commercial suction tables (Reeve 1984). The interest in the techniques and equipment (see Coddington in this publication) and the results of the construction and use of suction tables were reported and discussed at conferences such as ICOM-CC, including the 1984 ICOM-CC conference in Copenhagen.

In the following six years, summer programs on the subject were organized at the School of Conservation (in collaboration with ICCROM) to introduce and discuss suction-table techniques and principles and making it possible for numerous participants over the years to try out selected techniques (fig. 3.4). Discussions were lively (figs. 3.5, 3.6) and included technical and ethical debates on the specific aspects of the techniques and the use of new materials. Such topics included nap-bond acrylic dispersion-adhesives, EVA-based adhesives (e.g., Beva 371), fiberglass cloth, limited interventions, temperature, humidity, strip-linings, loose-linings, and much more. In tune with the prevailing discussions in paintings conservation in general, the idea of how much treatment was really necessary—and if so, what kind—was discussed as well, and Percival-Prescott’s 1974 concept of the lining cycle and whether to treat or not to treat was a regular part of conversations.

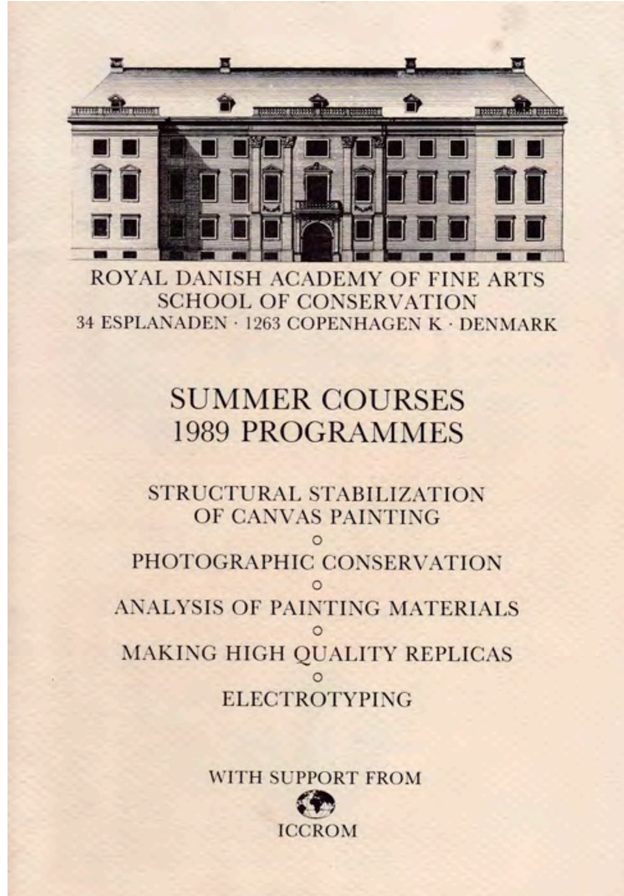

Figure 3.4 Cover of a summer school presentation from 1989. Image: © Mikkel Scharff, Institute of Conservation, The Royal Danish Academy

In parallel with the summer schools, a set of visual teaching aids was being produced in collaboration with the Getty Conservation Institute. The aim was to produce step-by-step images of the recently developed lining techniques, along with a detailed description of each step, as a didactic tool for teachers in canvas paintings conservation. The aids were used at each summer program and in regular courses at School of Conservation before being finalized in 1990 (Scharff 1995).

The production of the aids turned out to be a real challenge, since the treatment steps needed to be explained and, if possible, supported by recent knowledge. As the understanding of canvas paintings’ reactions to treatments was very limited at the beginning of the 1980s—and only gradually became supported by publications during the second half of the decade and beyond—it was not always possible to present a well-supported argument for some of the treatment steps or material choices. However, the process for developing the aids was designed to let any teacher using a given

Figure 3.5 Lecturers and participants in an exercise treatment at a summer workshop, 1988. Image: © Mikkel Scharff, Institute of Conservation, The Royal Danish Academy

Figure 3.6 Lecturers and participants discussing the outcome of the treatment of two of the exercises in the painting workshop, 1988. Image: © Mikkel Scharff, Institute of Conservation, The Royal Danish Academy

treatment add new and relevant information as it became available, as well as to discuss the logic of the approaches with the students or to dismiss some treatment steps as obsolete. In this way, the treatment rationale and background for the treatments could be updated.

While some parts of these teaching aids appear outdated today, thirty years later other parts remain useful, and the whole set serves as both a legacy and documentation of a major evolution in the philosophy and practical approach to canvas paintings conservation in the two decades following the Greenwich conference.

Teaching in paintings conservation programs has changed in many respects since the 1980s and 1990s. Less emphasis is now placed on learning a complete set of treatment techniques in favor of a greater concentration on principles and a better understanding of the materials and structures that a painting is composed of, with the aim of better understanding deterioration mechanisms and the properties and impact of treatments and associated materials. Experimental work plays an increasing role, as it further enhances the understanding of the concepts. Hopefully, it will have an impact on whether the future profession concentrates mainly on hands-on treatments or develops a more general approach to entire collections.

The development of a better scientific understanding of the behavior of canvas painting structures themselves, as well as treatment techniques and materials, took place in parallel with the practical experiments and experiences among a limited number of researchers and conservators. Results were published and discussed at conferences, not least at the ICOM-CC working group on structural treatment of canvas paintings that was active at the second half of the 1980s and into the 1990s, as presented in more recent accounts (Hackney 2020). In particular, publications from Hedley, Mecklenburg, and Michalski provided new insights; Hedley regularly published on the behavior of canvas paintings with a special interest in studying the interaction with humidity (Hedley 1993). Mecklenburg and Michalski provided new and valuable insights in painting structure behavior, for example at the Art in Transit conference and its subsequent publication (Mecklenburg 1991; Michalski 1991). Such advances originated from or gradually fed into the educational programs in Denmark and abroad, in collaboration with the steadily growing group of practitioners with strong interests in canvas behavior. Without continued research supporting and advancing the field, it would have been impossible to gain a proper understanding of the structure of a painting, its mechanics, and the impact of environment and treatments.

The interest in and experiments with new equipment, methods, and materials in the 1980s that resulted from recognizing the need for changes in canvas conservation gradually faded away as a different approach to canvas painting treatments evolved and became accepted. The new approach placed more focus on preventive means, perhaps following principles of more limited interventions, and coincided with the growing popularity of EVA-based adhesives and adhesive sheets and several proposed nap-bond application techniques (although still using a relatively high temperature of 65°C).

Thus, gradually, as treatment methods evolved, a better understanding of the impact of structural treatments emerged, and as interest in preventive conservation grew, an increasing number of practitioners became more reluctant to carry out the number of treatments that had been customary in the past. Little by little, practitioners began leaning toward the more limited interventions that many have identified collectively using the term *minimalism* (see, e.g., Ackroyd and Villers 2003). The increasing impact of preventive conservation and risk management/assessment (Antomarchi et al. 2005) in decision-making may also influence the approach to the preservation of canvas paintings in the future.

While further development of treatment methods and materials seems largely to have been on hold over the past twenty years, research into canvas paintings' material structure and mechanics has increased: How is the structure affected by the environment during exhibition or storage? What is the impact of conservation treatments—past and present? A growing number of conservators and scientists are working together in national and international research groups, taking advantage of the steadily growing availability of analytical equipment and methods, including the use of computer modeling to predict behavior. A steady increase in publications in the field also provides everyone in conservation studios and conservation students in educational institutions with an ever-expanding trove of relevant information. Hopefully, in the future, all of this will lead to a better understanding of material behavior and deterioration phenomena, and we will be able, ultimately, to predict the future response of canvas paintings under given conditions and develop better means to preserve them—either by active treatment procedures or by preventive measures—and thus maintain our cultural heritage for future generations.

Today, we may have passed the point where there were only two options: to treat or not to treat at all. Perhaps the question now should be whether to line or not to line. Luckily, the advances in the field in practice, as well as research since the Greenwich conference, have given us a sounder basis for selecting better options to preserve canvas paintings. Nonetheless, there is still much to learn, and we hope that it will be conducted in the spirit of the Greenwich conference, which laid the groundwork for nearly fifty years of progress in canvas paintings conservation.

NOTES

1. Training as house painters in Denmark up to the 1970s included learning a variety of techniques, such as decorative paint finishes, faux marbling, and graining.
2. Danish Ministry of Culture, *Betænkning om organisation af konserveringsvirksomheden ved museer, arkiver og biblioteker samt om oprettelse af en konservatorskole*, Parliamentary Report 525, 1969.
3. UNESCO, Convention Concerning the Protection of the World Cultural and Natural Heritage, 1972. https://whc.unesco.org/en/conventiontext/.
4. A copy exists in the museum archives.
5. The term *lamination* used in Denmark at the time was later referred to in some publications as "nap bond."
6. Ruhemann suggested the design to Stephen Rees Jones, who constructed the table.

4

Lining at the National Maritime Museum and at the Courtauld Institute of Art: Past and Present

Camille Polkownik, Paintings Conservator, Hamilton Kerr Institute, University of Cambridge
Clare Richardson, Senior Lecturer, Courtauld Institute of Art
Maureen Cross, Senior Lecturer, Courtauld Institute of Art
Sarah Maisey, Senior Remedial Conservator for Paintings, National Trust

Since the 1970s, the Courtauld Institute of Art (CIA) and Royal Museums Greenwich (RMG) (formerly the National Maritime Museum [NMM]) have been at the forefront of developments in lining methods, including research and practice using new adhesives including PVA, Beva 371, and synthetic wax resin. RMG worked closely with Stephen Rees Jones and Gerry Hedley from the Technology Department of the Courtauld to adopt their innovative methods, including lining using a vacuum hot table and vacuum envelopes, working together to develop the way paintings would be lined in the future. The present study reexamines archival materials related to the Greenwich Lining Conference and subsequent practical treatments undertaken at the CIA and RMG in the 1970s and 1980s. The authors explore the impact of the conference on contemporary practice, and a small group of case study paintings is presented to evaluate the success and longevity of these treatments after forty to fifty years on display in museums or in storage.

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INTRODUCTION

From the 1970s onward, the National Maritime Museum (NMM), now Royal Museums Greenwich (RMG), and Courtauld Institute of Art (CIA) were at the forefront of UK developments in lining methods and the use of modern adhesives. NMM conservator Westby Percival-Prescott worked closely with Professor Stephen Rees Jones and Gerry Hedley at the Courtauld to adopt their innovative methods, including the use of a vacuum hot table and vacuum envelope for lining (Percival-Prescott 2003a).

As part of the Getty Foundation's Conserving Canvas initiative, CIA and RMG collaborated once again to explore lining methods and our common history of lining. The first part of this collaborative project invited an expert panel of liners from the United Kingdom and Europe to review the condition of seventeen paintings from the two collections that had received structural treatment in the late twentieth century (see the appendix at the end of this paper).[1] We were interested in assessing the longevity of the modern lining methods used in order to inform collections care for the future. Alongside this work, and to establish the structural conservation history of both institutions from the 1970s onward, a survey of all treatment reports was undertaken, and each institution's conservators were interviewed.

Of the seventeen paintings (see appendix) examined by our experts, the majority remained in excellent structural condition, as might be expected, as the treatments were between twenty and fifty years old. Reviewing the treatment documentation alongside the paintings highlighted the change in attitude toward structural conservation in the ensuing decades.

NATIONAL MARITIME MUSEUM

The NMM collection contains approximately four thousand paintings. In 1960, Percival-Prescott joined the NMM and founded the conservation department in the Royal Observatory building (Bomford 2005). He was joined by Ronald Chittenden, who focused solely on structural conservation, and paintings conservator Gillian Lewis. Thanks to Percival-Prescott's intense interest in painting materials and his passionate views on ethical methods of conservation, his department built and developed an international reputation (Bomford 2005). When asked by Dr. Basil Greenhill, then director of the NMM, for a research area that could culminate in a large conference, Percival-Prescott put forward the idea of the structural conservation of canvas paintings, with a particular focus on lining. This was the origin of the Comparative Lining Techniques conference, held in Greenwich, April 23–25, 1974 (Percival-Prescott 2003a). The conference had an extraordinary impact on the conservation profession, and Percival-Prescott's keynote speech, "The Lining Cycle," articulated the trend for minimalism in structural treatment that still prevails today (Percival-Prescott 2003b).

From 1970 to 1974, Percival-Prescott, Lewis, and Chittenden traveled throughout Europe, the East Coast of the United States, and Russia to learn more about lining, meeting experts and filming them at work. Upon return to the UK studios, they experimented with the new techniques, adhesives, and fabrics discovered abroad, and extensive (unpublished) peel tests were undertaken in the engineering research department of the Royal Naval College, a few of which still remain in the Percival-Prescott archive at the Hamilton Kerr Institute.[2]

Trends and Patterns: Treatments

To understand the trends and patterns in the use of adhesives and fabrics at the NMM, treatment reports from 1963 to 2000 were reviewed and the information collated. Out of the 2,023 reports consulted, 447 included structural treatment of some sort (approximately 22% of all paintings treated).

The impact of the 1974 conference was evident in the treatment data, but other factors influenced the types of structural work undertaken. Chittenden's retirement as a dedicated liner in the early 1980s meant that his workload was absorbed into the work of other paintings conservators in the studio: Caroline Hampton and Sally Wakelin, who both joined in 1974, and Elizabeth Hamilton-Eddy, who joined in 1978. The move to the Feather's Place conservation studios in 2000 resulted in the loss of the hot vacuum table due to lack of space, and major structural treatments such as lining were sent out to private studios.[3]

When reviewing the treatment reports from 1965 to 2000, the impact of these various factors was evident: the number of linings diminishes, whereas strip-linings appear in 1974 and quickly become a regular occurrence (fig. 4.1). Similarly, a change in thinking was noticeable, for example, in the introduction of other minimal or preventative treatments, such as loose-lining and local reinforcing (corners and edges, and tear mending).

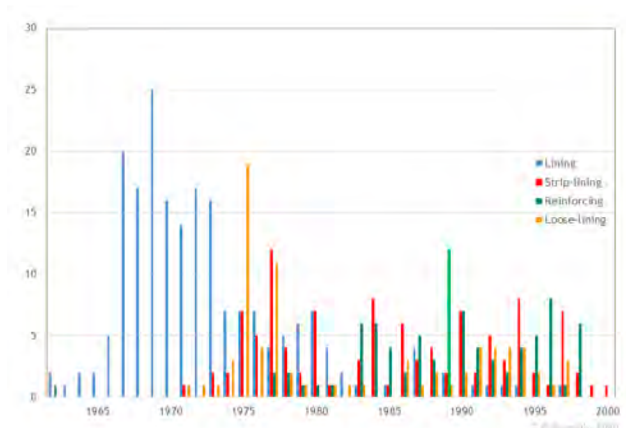


Figure 4.1 Trends in lining, strip-lining, loose-lining, and local reinforcing at the National Maritime Museum, 1963–2000. Image: Camille Polkownik

Trends and Patterns: Materials

In terms of adhesives used for lining and strip-lining, the NMM shows a preference for a small number of adhesives and techniques, which were refined into streamlined processes (fig. 4.2). Initially, wax-resin lining is the only method used. Linen was used almost exclusively,[4] and reports mention combinations of AW2 or dammar resin with wax and elemi gum, or later, MS2 resin combined with wax, colophony, and elemi.[5] These linings were almost all done on the hot table using the prestretching technique and the vacuum envelope developed in-house (Chittenden, Lewis, and Percival-Prescott 2003). Chittenden's reports were usually very brief, such as “lined in the usual way” or “lined with satisfactory results.”[6]

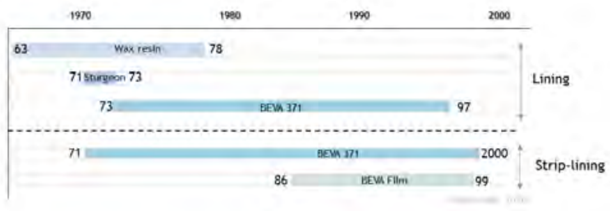


Figure 4.2 Summary of adhesives used for lining and strip-lining at the National Maritime Museum, 1963–2000. Image: Camille Polkownik

From 1971 to 1973, five sturgeon-glue linings were performed. These are rather rare in the United Kingdom and drew upon the team’s training from “masterly restorer Brianzev” in Russia (Percival-Prescott 2003a, viii). Reports for the 1971 treatment of George Knight’s *Cleopatra’s Needle Being Brought to England, 1877*, ca. 1877 (BHC0641), revealed that “sturgeon bladder adhesive” was selected because the work was “painted upon a white ground and of materials which would have yellowed and darkened had wax been used.”[7] These linings were performed only prior to the conference and were quickly abandoned; studio notes and treatment reports convey the impression that the technique was difficult to master.[8]

Beva 371 was used for both strip-lining and lining, combined with a variety of fabrics (see figs. 4.2, 4.3). Initially, the preference was for TenCate, a polyvinyl alcohol fabric from the Netherlands, but this was gradually superseded by polyester sailcloth beginning in 1982, most likely introduced to the NMM by the Courtauld. Linen was used on one occasion with Beva 371 for lining but more frequently for strip-lining. Other materials were used more sporadically in conjunction with Beva 371, including woven polypropylene and glass fiber. These fabrics seem to have been used experimentally around the time of the lining conference and were not incorporated into usual practice. Glass fiber, introduced by Pierre Boissonnas (A. Boissonnas 1961), was used over a prolonged period (1973–81), in combination with wax resin, Beva, or Beva with added wax, to help produce transparent linings.[9]

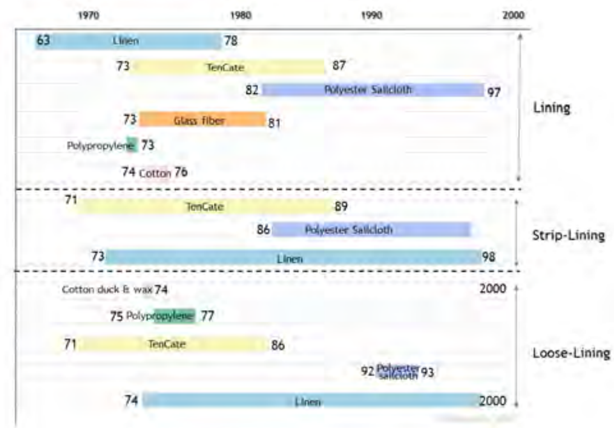


Figure 4.3 Summary of fabrics used for lining, strip-lining, and loose-lining at the National Maritime Museum, 1963–2000. Image: Camille Polkownik

As surface deformations could not be addressed during a wax-resin or Beva lining, they had to be treated beforehand. The NMM developed the prestretching technique, first published at the 1974 conference, to introduce tension and address cupping and deformation out of plane (Chittenden, Lewis, and Percival-Prescott 2003). This technique was used routinely in the 1970s and 1980s.

Loose-lining starts in the early 1970s, and sixteen paintings were loose-lined in 1975 using either TenCate or Fabrene, possibly in preparation for an exhibition. TenCate was used until 1986, after which it was replaced with polyester sailcloth. One painting was loose-lined with wax-impregnated cotton duck in 1974, possibly as an experiment around the time of the conference. Linen was used regularly for loose-lining, perhaps prioritizing aesthetics over mechanical properties for this purpose (see fig. 4.3).

Case Studies

Many of the paintings selected for assessment by the expert panel were paintings lined using wax resin in the 1960s and 1970s, as well as some that were lined or strip-lined with Beva 371 more recently. Among the paintings selected for examination were several of the seemingly experimental treatments undertaken immediately prior to the lining conference, which reflected the Greenwich team’s interest in learning new techniques. Fabrics included linen of various weights, cotton duck, and black polypropylene fabric. As discussed below, two very large paintings were also among those selected: one by Philippe-Jacques de Loutherbourg and another by Carl Saltzmann, treated in 1973 and 1992, respectively (fig. 4.4).

Figure 4.4 Meeting in July 2019 at the Prince Philip Maritime Collections Centre, Kidbrooke. Participants and experts examine Carl Saltzmann's *German Fleet Manoeuvres on High Seas*, which was relined in 1992 using Beva 371 on polyester sailcloth. Image: Royal Museums Greenwich

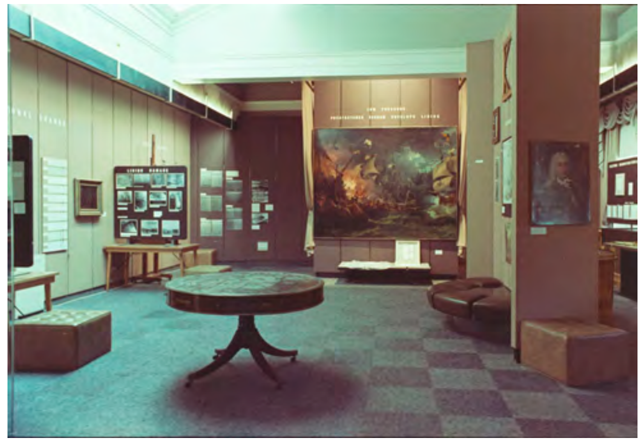


Figure 4.5 View of the Lining Exhibition Gallery at the 1974 Comparative Lining Techniques conference. At the back, Philippe-Jacques de Loutherbourg's *Defeat of the Spanish Armada, 8 August 1588* (1796) is exhibited as an example of the low-pressure, prestretched, vacuum-envelope lining developed by the NMM conservation studio. Image: Royal Museums Greenwich

An early example of the typical NMM method of wax-resin lining can be seen in the treatment of Matteo Perez d'Aleccio's *The Siege of Malta: Siege and Bombardment of St Michael, 28 June 1565,* 1656 (BHC0255). The painting was relined in 1967, and the treatment was deemed successful at the time. However, in 1989 the canvas was found to be sagging near the bottom edge, which necessitated removal from the stretcher and restretching. The painting was of a reasonably large size (137.2 × 193 cm) and was exhibited in the time between the two treatments in a fluctuating environment, so these issues were not felt to be particularly surprising.

Due to failure of the previous lining along the top edge, de Loutherbourg's *Defeat of the Spanish Armada, 8 August 1588* (BHC0264) was relined in 1973. The work was included in the exhibition accompanying the 1974 conference as an example of a contemporary lining (fig. 4.5). A wax-resin relining followed the standard NMM litho paper prestretching (Chittenden, Lewis, and Percival-Prescott 2003). However, complications arose in the process. Records indicate that the large size of the painting (214.6 x 278.1 cm) necessitated relining on the hot table in two parts. After some technical difficulties in heating the table to the necessary temperature, it was found that the lined half displayed cockling due to differential thermal expansion. The expert panel cited cockling as a common phenomenon when paintings were lined in sections and explained that this could often be magnified over a large scale. Despite the documented difficulties, our experts agreed that the lining appeared to be performing well, and in the long term these issues did not appear to have a detrimental effect.

Throughout the study, several examples of experimental lining fabrics were examined. Rowland John Robb Langmaid's *HMS* Dido, Ajax *and* Orion *in Action Off Crete, 21 May 1941* (BHC0678) was lined in 1973 using Beva 371 and a black polypropylene fabric (fig. 4.6). Although well adhered, the lining textile is now displaying signs of embrittlement and degradation, with splitting on the turnover edges. Another unusual choice was the wax-resin double lining on cotton duck with a Melinex film stuck to the reverse, which was used in the 1974 relining of Dominic Serres's *Destruction of the American Fleet at Penobscot Bay, 14 August 1779*, late eighteenth century (BHC0425). Robert Luny's *The East Indiaman* York *and Other Vessels,* 1788 (BHC3735), was lined in 1974 onto "post office bagging," a fairly coarse linen that had been collected as a sample during the research travels prior to the conference.[10]

As indicated by the conservation records, the post-1974 conference years saw a general move away from wax-resin linings on linen and toward Beva 371 linings on synthetic fabrics. The relining of Saltzmann's *German Fleet Manoeuvres on High Seas* (BHC0648) in 1992, using Beva 371 on polyester sailcloth, exemplifies this trend. Prior to relining, the painting had suffered from a poor mix of glue paste, which exhibited hard lumps, and the inexplicable inclusion of egg and eggshell. As with the de Loutherbourg, the painting's vast size necessitated lining in two halves, which again resulted in substantial undulations. Once it was off the hot table it was noted that the lining was not well adhered in places, and a hand lining with local pressing was employed to address the problem. Despite the initial issues, the lining was very successful, and today it is performing well, with little evidence of the

Figure 4.6 Rowland John Robb Langmaid (British, 1897–1956), *HMS* Dido, Ajax *and* Orion *in Action Off Crete, 21 May 1941*, mid-20th century. Oil on canvas, 35.5 × 69.8 cm (14 × 27 1/2 in.). Front (top) and reverse in normal light, current state (2020). The painting was lined in 1973 using Beva 371 and a black polypropylene fabric. Image: Royal Museums Greenwich, BHC0678

undulations present before the 1992 treatment and only very slight slackness.

Indeed, those reviewing these paintings in 2019 felt that the vast majority were in good condition and the linings and strip-linings were performing well. Aside from some experimentation around the time of the lining conference, the team at the NMM tended to employ tried-and-tested methods and materials that they had developed gradually over the years. This consistent approach surely contributed to their calm ability to overcome obstacles when they arose, as demonstrated in the de Loutherbourg and Saltzmann treatments.

COURTAULD INSTITUTE OF ART

The Courtauld collection was established by key bequests of old master paintings and Impressionist works in the 1930s. When the Department of Conservation and Technology was created in 1931, the collection's paintings were first treated by the experienced tutors and by the students under their supervision. In 1998, Stephen Gritt was appointed as the first Courtauld Gallery conservator, and the majority of this workload shifted away from the Department.[11] The students primarily worked on paintings from other museums, societies, and private collections that dated from the fourteenth century to modern periods, with treatments ranging from surface cleaning to full lining/relining.[12]

From the 1950s, the department was involved in lining research (Straub and Rees Jones 1955). At the 1974 Greenwich conference, students Gerry Hedley, Stephen Hackney, and Alan Cummings presented their research work (Hedley, Hackney, and Cummings 2003). Vishwa Mehra was invited to the department on at least two occasions (1978 and 1981) to give workshops demonstrating his cold-lining technique.[13] From 1982 until his untimely death in 1990, Hedley was a lecturer focusing on, among other things, the mechanical properties of synthetic canvases as lining supports (Hedley and Villers 1982). The environment was thus favorable for experimentation and development of techniques and materials (e.g., Phenix and Hedley 1984).[14]

Trends and Patterns: Treatments

Two strands emerge in the Courtauld reports: the paintings from the Courtauld Gallery collection and the paintings from external collections. Out of the 1,023 reports consulted from 1968 to 1996, 124 included structural treatment of some description (approximately 12%). Only eighteen reports from before 1980 were found, so the pre-1980 areas on the graphs shown in figures here should be interpreted with caution due to the unknown quantity of missing reports. Pre-1980 practices were gathered through interviews with conservators studying or working at the Courtauld during this period.

The vacuum-envelope table developed by Hedley, Hackney, and Cummings was used from the 1970s until the early 1980s (Hedley, Hackney, and Cummings 2003, 83). In 1984, a commercially built lining table, based on the design created in the department in the 1950s, came in as a long-term loan; this was used until 1994. Subsequently a multipurpose suction table with air-flow capability and a conventional hot-plate top was acquired from Willard Conservation Ltd.[15] Occasionally, hand linings were also undertaken.[16]

Trends and Patterns: Adhesives and Fabrics

CIA has a long history of using wax-resin. Waxes used were beeswax, bleached beeswax, or microcrystalline wax, combined with natural dammar or synthetic resins such as Ketone N or AW2. These mixtures were used exclusively for lining until the early 1970s, when Beva 371 and polymer dispersion adhesives were introduced. The very last wax-resin lining was performed in 1990 (fig. 4.7).

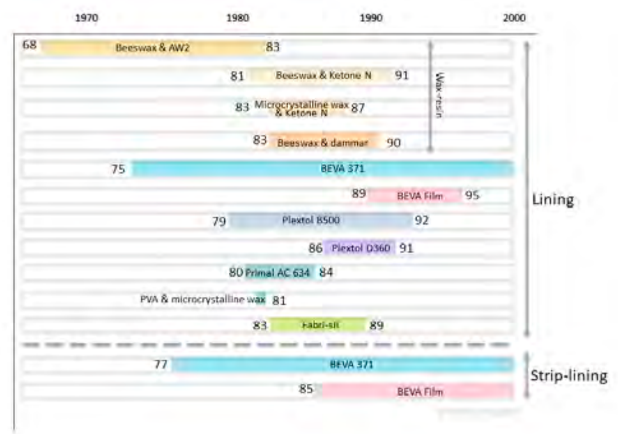


Figure 4.7 Summary of adhesives used for lining and strip-lining at the Courtauld Institute of Art, 1975–2000. Image: Camille Polkownik

Beva was taken up shortly after the 1974 conference. Cummings and Hedley had a long conversation with Gustav Berger during the conference, and that discussion was key to the adoption of Beva 371 at the Courtauld.[17] PRIMAL AC-634 was introduced to the conservation world by Mehra in 1972 and began to be used at CIA soon after (Mehra 1972). It was used for cold-linings until 1984, when research conducted in the department showed its poor aging properties (Howells et al. 1984). Plextol B500, also introduced by Mehra, was used for cold-linings until 1992.

Fabri-Sil, a Teflon-impregnated glass fiber with a silicon pressure adhesive, was introduced to CIA in the 1980s and studied by Alan Phenix as his student research project (Phenix and Hedley 1984, 84.2.39). This product, developed by Robert Fieux, was used seven times at CIA from 1983 to 1989 (Fieux 1977). It was abandoned due to the weakness of the bond even after solvent reactivation, and its high cost.[18]

In terms of lining fabrics, CIA experimented with different fabrics, almost entirely synthetics, before settling on polyester sailcloth, a fabric Hedley had thoroughly researched and tested (fig. 4.8) (Hedley and Villers 1982, 154). Other polyester fabrics included Vylene and Permawear 122. In many treatment reports, lining fabrics were referred to as "polyester" or "polyester fabric," and it is not possible to know precisely which fabrics were used.

Glass fiber was used from 1975 until 1981, most likely for experimentation after the 1974 conference (P. Boissonnas 2003). There were also a few examples of marouflage onto aluminum honeycomb. Polypropylene was used from 1979 and abandoned by 1981. Lascaux P110, a textile with a

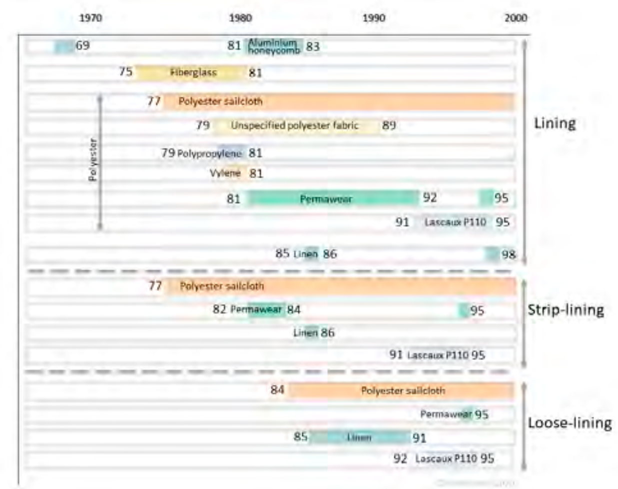


Figure 4.8 Summary of lining fabrics used at the Courtauld Institute of Art, 1975–2000. Image: Camille Polkownik

similar appearance to linen but made of polyester, was used from 1991 until 1995.

As at NMM, the adhesives used for strip-lining are Beva gel and film. The fabrics used for strip-linings are mostly synthetics, apart from one example in 1986 using linen. Synthetics used include Permawear 122, polyester sailcloth, and Lascaux P110.

In terms of loose-lining fabrics, there is more variety than at NMM. While polyester sailcloth was adopted in 1984 and remains in use, other fabrics were also tested. Linen was used from 1985 until 1991 and could be combined with a lining onto synthetic fabric for a more sympathetic appearance from the reverse. Lascaux P110 took over linen from 1992 to 1995.

Case Studies

Reviewing the Courtauld paintings with the expert panel, it was striking to see the widespread and enthusiastic adoption of modern lining fabrics and adhesives for the treatment of these works. The documentation of treatments, written in the context of a research and teaching institution, often gives a full insight into the decision-making processes and selection of materials.

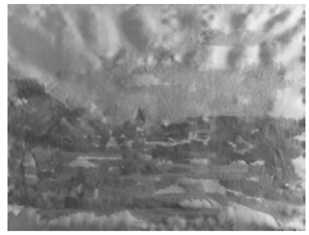
As already mentioned, very few paper records remain for the earliest treatments. For example, the 1969 marouflage of Lucien Pissarro's *Le Brusq*, 1923 (P.1932.SC.322), onto aluminum was recorded only by the materials and date inscribed on the rigid support: "April 1969, 90% beeswax, 10% AW2 resin." Similarly, the wax-resin lining of a fire-damaged painting attributed to Giovanni Francesco

Barbieri, or Guercino,[19] in 1976 is only recorded in a treatment database.[20] This lining appears to have been carried out using cotton duck in a manner similar to that of the near-contemporaneous lining of the Serres *Penobscot Bay* painting at the NMM.

While the marouflage appeared to be an extreme intervention, our expert panel remarked that this had been a popular "preventative" measure in the 1960s. Chief among the problems associated with marouflage was weave emphasis resulting from the unyielding nature of the secondary support, an unfortunate outcome in the treatment of the Pissarro. The painting appears structurally sound with no apparent justification for the marouflage. The work seemed to be an example of lining for preventative measures.

In the 1980s, several Impressionist paintings, accessioned from the Princes Gate bequest, were treated before they went on display in the Courtauld Gallery for the first time (Brown 1981). All then nearly a century old, these unlined canvases were suffering from planar distortion and embrittlement. Some paintings had large areas of unpainted ground and delicate impasto, which posed lining challenges. Each painting was treated with a different solution, which highlighted the speed of evolution of thinking in lining practice at the time, as well as the intellectual flexibility of the conservators.

Paul Cezanne's *Turning Road (Route Tournante)*, ca. 1905 (P.1978.PG.61), was treated in 1980 using a low-pressure, cold-lining technique learned from Mehra in 1978. The adhesive, Primal AC-634 thickened with Natrosol, was applied through a mesh screen. One particular concern was the danger of staining and potentially darkening the ground with the adhesive. The report describes painstaking spectrophotometry readings taken before and after treatment. The lining fabric was polyester, Permawear 122, and the report contains correspondence with the manufacturer. The deformations out of plane (fig. 4.9a) were treated prior to lining by misting with water and drying on the cold-lining table at minimal pressure (8.5 cm water), repeated three times with local weighting. The treatment was deemed a success and was subsequently chosen to illustrate a book in Hedley's memory (Hedley 1993). Although it was incorrectly described as a Plextol lining, the success of the flattening moisture treatment and the lining in retaining the improved surface is commented on in the picture caption. Our expert panel agreed the lining was extremely successful in terms of correcting overall distortion while keeping a very light, unlined feel (fig. 4.9b). Only one area of lifting of the lining on the turnover edge was identified, but this was not felt to be an indicator of more widespread failure concerns.



a

b

Figure 4.9 Paul Cezanne (French, 1839–1906), *Turning Road (Route Tournante)*, ca. 1905. Oil on canvas, 73 x 92 cm (28 3/4 x 36 1/4 in.). The Samuel Courtauld Trust, The Courtauld Gallery, London, P.1978.PG.61. (a) Raking light picture taken before treatment in 1980. (b) Current state of the painting photographed in normal light. Image: The Courtauld, London (Samuel Courtauld Trust) / Photo: © The Courtauld

Edouard Manet's *Au Bal—Marguerite de Conflans en Toilette de Bal,* 1870–80 (P.1978.PG.233), was treated the following year, in 1981, to address the buckling of the canvas recorded in raking-light photographs before treatment. Caroline Villers's recommendation seemed to follow the successful precedent set by the treatment of the Cezanne painting: to carry out a cold-lining at low pressure. A change of plan is described with Villers's typical understatement: "Although the tacking margin had not seemed to exhibit exceptional sensitivity to moisture . . . the canvas was found to be extremely responsive."[21] They switched to using Beva 371 with sailcloth at 60°C–65°C and using 12 "Hg vacuum-envelope pressure. The envelope system was designed to avoid textural changes, and the conservators also removed large slubs and residues from the reverse prior to lining. However, when reviewing the treatment with the aid of archive raking-light images, it did seem that there had been some increased weave emphasis. Despite this, the treatment was published by Hedley as an exemplar treatment the following year (Hedley and Villers 1982, 157). It was interesting to reflect on this treatment with the expert group. It seemed to particularly highlight the change in attitudes toward lining over the thirty-eight years since this painting was treated. The consensus now would be to accept the deformations out of plane and to try to avoid lining for as long as possible.

Edgar Degas's *Lady with a Parasol*, ca. 1870–72 (P.1978.PG.87), was treated almost immediately after the Manet. The painting was first strip-lined using Permawear 122 and Beva 371, but during restretching the original canvas fractured along the turnover edge. At this point, close to the exhibition opening, it was decided to mend the tear locally and return to the painting after the show. The painting returned for treatment in 1983 in preparation for considerable travel as part of a loan to Japan and Australia, and the decision was taken to line the painting (fig. 4.10). Hedley, leading the treatment, selected Fabri-Sil, but adapted the process to incorporate solvent activation, which was concurrently investigated by Phenix in his research project (Phenix and Hedley 1984). Using solvent activation, the peel strength of Fabri-Sil increased to approximately match a "strong wax-resin" formulation. Despite the treatment being among the early Fabri-Sil linings, our inspection of the painting found that the experimental method performed well: the impasto looks crisp and sharp, and the ground layer appears unchanged by the adhesive, with the lining remaining well adhered throughout.

Figure 4.10 Lining of Edgar Degas, *Lady with a Parasol*, with Fabri-Sil on the vacuum table. Courtauld Institute of Art conservators Caroline Villers (left) and Gerry Hedley (right), and student Alan Phenix (right, partial view). Image: The Courtauld, London (Samuel Courtauld Trust) / Photo: © The Courtauld

CONCLUSION

Reflecting on past practice at both institutions, the impact that the sharing of knowledge had in the years surrounding the Greenwich lining conference was apparent. Both institutions were enthusiastic about adopting new methods, adhesives, and fabrics, underpinned by comparison with existing methods to ensure that new techniques were at least as good as old. Most treatments appear to have aged well thus far, although some adhesives and fabrics have unknown aging characteristics in the longer term.

The variety of adhesives used by the NMM conservators was clustered around a specific period: a few years before and after the 1974 conference. As organizers, the conservators wanted to explore all avenues of new materials and methods. The experimentation led to the elimination of unsuitable methods and materials, such as sturgeon-glue linings and black polypropylene as lining support, and the refinement and adoption of methods and materials that fit their collection and work ethos. The Courtauld showed how research conducted within the department informed choices of adhesives and fabrics.

The rationale behind structural treatments was explored through interviews with conservators and by reading the archival documentation. Reviewing treatments with our expert panel highlighted how much attitudes have changed over time and the lasting influence of minimalism that was ushered in by the Greenwich conference. Nowadays, the inclination is to resist intervention until the point of complete failure. The conclusion drawn from the 2019 examination was to prolong the life of existing linings by shoring up failures at turnover edges, reactivating old glues, or feeding in adhesive for localized delamination. Future research will explore this topic further by revisiting paintings identified as in need of lining—but not treated in the 1970s due to time or budget constraints—to assess their condition now.

ACKNOWLEDGMENTS

The authors would like to thank the following persons and institutions. The Getty Foundation for funding this project. The expert panel: Simon Bobak and Tom Bobak (Bobak Conservation Studio, London), Elizabeth Hamilton-Eddy (conservator emeritus at Royal Museums Greenwich), Trevor Cumine (private practice, London), and Tannar Ruuben (Metropolia University, Helsinki). The meeting participants: Rachel Turnbull and Alice Tate-Harte (English Heritage), Katey Twitchett-Young and Anna Cooper (Tate), Alice Aurand (freelancer in Paris), Katya Belaia (National Trust), and Aisling Macken and Tom Barrow (RMG). The conservators interviewed for this project, in particular Gillian Lewis, Alan Cummings, and Alan Phenix. The conservation volunteers at RMG for their assistance collating the NMM data.

APPENDIX

Table 4.1 lists the seventeen paintings from the CIA and RMG collections that were examined by an expert panel for this study.

Table 4.1
Paintings examined by expert panel in July 2019

Painting	Accession number	Collection	Treatment date	Treatment
Le Brusq, Lucien Pissarro, 1923	P.1932.SC.322	The Courtauld Gallery, Samuel Courtauld Bequest	1969	Marouflaged onto aluminium using wax resin (90% beeswax, 10% AW2 resin)
Samson Sharing Honey, after Guercino, 17th century	Not accessioned	Department of Conservation and Technology	1976	Lined with wax resin onto cotton(?)
Turning Road (Route Tournante), Paul Cezanne, ca. 1905	P.1978.PG.61	The Courtauld Gallery, Princes Gate Bequest	1980	Lined with Primal AC-634 + 2% Natrosol onto Permawear 122
Au Bal—Marguerite de Conflans en Toilette de Bal, Edouard Manet, 1870–80	P.1978.PG.233	The Courtauld Gallery, Princes Gate Bequest	1981	Lined with Beva 371 onto polyester sailcloth
Lady with a Parasol (Femme à l'ombrelle), Edgar Germain Hilaire Degas, ca. 1870–72	P.1978.PG.87	The Courtauld Gallery, Princes Gate Bequest	1981	Strip-lined with Beva 371 and Permawear 122
			1983	Lined with Fabri-Sil
Still Life with Peaches and Pears, Othon Friesz, 1920	P.1935.RF.140	The Courtauld Gallery, Roger Fry Bequest	After 1985	Strip-lined with Beva 371
The Virgin and Child with St. Elizabeth and St. John the Baptist, Giovanni Battista Salvi (Il Sassoferrato), ca. 1660	P.1947.LF.389	The Courtauld Gallery, Lee of Fareham Bequest	Early 1990s	Strip-lined with Beva film and sailcloth
The Siege of Malta: Siege and Bombardment of St Michael, 28 June 1565, Matteo Perez d'Aleccio, ca. 1656	BHC0255	Royal Museums Greenwich, National Maritime Museum Collection	1967	Lined with wax resin onto linen
			1989	Corners reinforced and restretched
Cleopatra's Needle Being Brought to England, 1877, George Knight, ca. 1877	BHC0641	Royal Museums Greenwich, National Maritime Museum Collection	1971	Lined with sturgeon glue onto linen
Defeat of the Spanish Armada, 8 August 1588, Philippe-Jacques de Loutherbourg, 1796	BHC0264	Royal Museums Greenwich, National Maritime Museum Collection	1973	Lined with wax resin onto coarse linen
HMS Dido, Ajax *and* Orion *in Action off Crete, 21 May 1941*, Rowland Langmaid, mid-20th century	BHC0678	Royal Museums Greenwich, National Maritime Museum Collection	1973	Lined with Beva 371 onto black polypropylene
Destruction of the American Fleet at Penobscot Bay, 14 August 1779, Dominic Serres, late 18th century	BHC0425	Royal Museums Greenwich, National Maritime Museum Collection	1974	Lined with wax resin onto cotton duck and Melinex
The East Indiaman York *and Other Vessels*, Thomas Luny, 1788	BHC3735	Royal Museums Greenwich, National Maritime Museum Collection	1974	Lined with wax resin onto post office bagging

Painting	Accession number	Collection	Treatment date	Treatment
The East Indiaman Asia, William John Huggins, 1836	BHC3209	Royal Museums Greenwich, National Maritime Museum Collection	1979	Strip-lined with Beva 371 onto TenCate
Indiaman in the Thames, William Adolphus Knell, ca. 1864	BHC1228	Royal Museums Greenwich, National Maritime Museum Collection	1979	Lined with wax resin onto linen
Section through a First-Rate, after Thomas Phillips, 19th century	BHC0872	Royal Museums Greenwich, National Maritime Museum Collection	1986	Strip-lined with Beva film and sailcloth
German Fleet Manoeuvres on High Seas, Carl Saltzmann, early 20th century	BHC0648	Royal Museums Greenwich, National Maritime Museum Collection	1992	Lined with Beva 371 onto sailcloth

Table: Camille Polkownik, Clare Richardson, Maureen Cross, and Sarah Maisey

NOTES

1. Meeting held July 15–16, 2019, at the CIA and RMG stores in London.
2. Gillian Lewis, interview conducted by Camille Polkownik, October 4, 2019, Westby Percival-Prescott Archive, Hamilton Kerr Institute, University of Cambridge, Whittlesford.
3. Elizabeth Hamilton-Eddy and Caroline Hampton, interview conducted by Camille Polkownik, September 19, 2019.
4. Lewis, interview.
5. Treatment report for BHC0636, 1967, mentions AW2/beeswax/elemi gum; treatment report for BHC0444, 1967–75, mentions AW2/wax; treatment report for BHC3019, 1968–69, mentions dammar/wax; treatment report for BHC3329, 1969–74, mentions MS2/wax; treatment report for BHC3318, 1971, mentions colophony/wax; treatment report for BHC3283, 1978, mentions MS2/wax/colophony/elemi.
6. As seen in treatments for BHC3530 in 1972 and BHC2989 in 1971, respectively.
7. Treatment report for BHC0641.
8. Treatment report for BHC1674, Eduardo de Martino, *HMS* Edinburgh *on Anti-Torpedo Exercise*, 1887.
9. Lewis, interview. The recipe was found in treatment reports for BHC2515, BHC0301, BHC1818, BHC0294, BHC2685, and BHC0274.
10. Samples were slotted in a display book and are part of the archives of RMG's paintings conservation studio.
11. Board of Studies Meeting minutes, November 10, 1998. Conservation and Technology Department Archive, Courtauld Institute of Art, London.
12. University of London: Courtauld Institute of Art, 1998. *1997/98 Annual Report*, 18–19.
13. David Wallace to D. Franklin, June 21, 1978, Information and Correspondence of Early Years of Diploma in the Conservation of Easel Painting Course, Conservation and Technology Department Archive, Courtauld Institute of Art, London.
14. Dr. Christina Young joined the department as a lecturer in 2000. Her contributions to lining practice at the Courtauld have been widely published and are outside the scope of this paper.
15. Robert Bruce Gardner to Jocelin Weldon (Weldon U.K. Charitable Trust), May 15, 1995, General Correspondence, Conservation and Technology Department Archive, Courtauld Institute of Art, London.
16. Thanks to interviews with students at the time, we now know that hand linings were performed, as the lining table was broken and out of action.
17. Alan Cummings, interview conducted by Camille Polkownik, October 11, 2019.
18. Alan Phenix, interview conducted by Camille Polkownik, October 2, 2019.
19. This painting does not have an inventory number as it has not been accessioned.
20. FileMaker Pro database, Conservation and Technology Department, Courtauld Institute of Art, London.
21. Treatment report for Edouard Manet, *Au Bal—Marguerite de Conflans en Toilette de Bal* (P.1978.PG.233).

5

The Lining of Paintings on Canvas in Naples

Angela Cerasuolo, Head of Restoration Department, Museo e Real Bosco di Capodimonte, Naples

The paper outlines the contribution of the Neapolitan tradition to the structural conservation of paintings on canvas. It is possible to trace the existence in the eighteenth century of diversified practices, which included the use of temporary stretchers for lining. It also defines the mesticatori-foderatori *(fillers-liners), professionals who specialized in the preparation of new canvases for painting and the lining of old ones. A profound knowledge of the materials of painting during the nineteenth century in the Museo Borbonico advised extreme caution in interventions on glue-tempera paintings by Parmigianino and Bertoja, which were not lined but equipped with additional canvases. The use of transfer has been practiced since the eighteenth century in Naples but has been consciously avoided in the nineteenth century in the museum and only put into practice at the beginning of the twentieth century, with questionable results. In the second half of the twentieth century, an improvement to traditional lining techniques was found by Antonio De Mata, who developed an effective procedure for the preventive consolidation and lining of paintings on canvas that reduced the risks of humidity. With due caution, this method continues to be effective in many cases.*

◆ ◆ ◆

INTRODUCTION

The intention of this paper is to outline the important contributions made by the Neapolitan tradition of structural conservation of paintings on canvas, the history of which remains little known. Knowledge of this tradition has increased over the past twenty years thanks to studies that have brought to light many documents presented during two conferences held in the Capodimonte Museum in 1999 and 2007 (Catalano and Prisco 2003; D'Alconzo 2007. These studies made it possible to compare elements from the examination of the paintings themselves, elucidating the contents of the documents and allowing an understanding of the methods employed.

A number of interesting elements were thus brought to light, such as the distinction—as early as the eighteenth century—between the "artistic" operations of cleaning and retouching and those of lining/consolidation, which were entrusted to the "liner" rather than to the "restorer." The studies highlighted the existence in the eighteenth century of diverse practices in the museums, often limited to cautious interventions, together with an awareness of the specificity of the materials involved. Traditionally, animal glue and flour paste were almost exclusively the materials employed to consolidate the paint layers and line the canvases throughout the period under consideration.

These studies also identified the presence of certain "professionals" who specialized in the preparation of new canvases for painting and in the lining of old ones. The history of the Chiariello, a family of *mesticatori-foderatori* (fillers-liners) from the eighteenth to the twentieth century, is of particular interest.

TELAIOLI AND *FODERATORI*: FIRST EVIDENCE OF LINING PRACTICES

The history of the profession of *foderatore* (liner) in Naples sits at the intersection of craft, art, and profession, and it is here where the definition of the discipline of conservation-restoration unfolds.

In 1960, Raffaello Causa, the renowned art historian who in the 1970s and 1980s would direct the *soprintendenza* for the Historical and Artistic Heritage of Naples, and who at that time headed the restoration laboratory of the Capodimonte Museum, highlighted this aspect by observing how in our city the conservation of paintings on canvas had been guaranteed by means of "an indisputable skill—and we would like to say a reckless ease—with which the lining of the canvases was performed here in Naples, an operation widely practiced by local restorers" (Causa 1960, 10).

In fact, it is possible since at least the eighteenth century to trace the evidence and documents relating to the practice of *rintelaggio* or *foderatura*: the consolidation of deteriorated textile supports carried out by gluing these onto a new canvas. We also find that such activities were performed early on by a particular figure, the *telaiolo,*[1] or manufacturer of canvases for painting, who would also repair damaged canvases if required.

One of these craftsmen was Giuseppe Maria Ranzenò, known as il Filosofo (the Philosopher), who as early as 1726 was paid for "*due tele imprimate*" (two primed canvases) (Pavone 1994, 140). In 1740, he supplied some cases of canvas to the Reale Arazzeria, established by Charles of Bourbon, which produced many splendid tapestries for the royal residences (Siniscalco 1979, 278). The Arazzeria was based in Via San Carlo alle Mortelle, together with the Pietre Dure laboratory, in the same location where the Art Academy would soon be born.

Other testimonies regarding the activity of the Arazzeria between 1761 and 1768 clarify the specificity of Ranzenò's profession. This information is found in a collection of documents published in 1979 as part of a campaign of wide-ranging research aimed at reconstructing the various and multifaceted artistic activities of the eighteenth century, thanks to a group of historians whose scholarship would come together to give rise to the great *Civiltà del Settecento a Napoli* exhibition in Naples (December 1979–October 1980) (Catalano and Prisco 2003; N. Spinosa 1979).

In the Reale Arazzeria, several painters, including Girolamo Storace, Giuseppe Bonito, and Orlando Filippini, were engaged to create oil paintings that served as a guide to tapestry weaving (fig. 5.1). Ranzenò supplied them with prepared canvases on which to make their models, and for this reason in the documents he is called "*mesticatore*" (Siniscalco 1979, 282), from *mestica*, the mixture with which the canvases were prepared for painting. But we also find him at work in other activities closely related to those of the painters active for the Arazzeria, which he assisted with all aspects relating to the preparation of the supports.

a

b

Figure 5.1 (a) Pietro Duranti (Italian, 1710–1791, *Allegoria dell'Aurora*, ca. 1768. Tapestry. (b) Giuseppe Bonito (Italian, 1707–1789), *Allegoria dell'Aurora* (model for tapestry), ca. 1768. Oil on canvas, 220 × 139 cm (86 3/5 × 54 3/4 in.). Images: (a) Napoli, Palazzo Reale; (b) Caserta, Palazzo Reale

A payment note dated 1763 describes the variety of these supplies. It refers to a "canvas for painting made by Giuseppe Maria Ranzenò called the Philosopher, ordered by the Court Painter D. Giuseppe Bonito to make the frieze of the tapestry by the painter Filippini," and the canvas is described as "with its good stretcher with the crossbar, prepared with priming the color of lead white" (A. Spinosa 1979, 382).

A real restoration is then described of two old *modelli* for the frieze. Orlando Filippini was in charge of painting the patterns for the floral friezes that adorned the tapestries, the main "stories" of which were then entrusted to Bonito. Indeed, in 1768, the same Ranzenò would still declare he had supplied Filippini with the canvases on which to paint "the flowers for the friezes" (A. Spinosa 1979, 383). Evidently, sometimes these oil paintings that served as *modelli* for the friezes were reused, and this explains the restoration of the "old *modello* for the frieze" mentioned in the note of 1762: "It has been lined with a single piece of fine canvas and it has been filled in many areas having first flattened it on a larger stretcher; then it was attached to its own stretcher that was in the Arazzeria" (A. Spinosa 1979, 382).

The lining procedure is described here with details rarely found in the sources. The document indicates the type of canvas used: "*fina*" (fine, or thin) and "a single piece" (that is, without seams). It describes the use of a stretcher that we would now call temporary: larger than the original one, prepared specifically for the lining procedure. And it tells us that the lined painting was then placed back on its original stretcher.

We also learn that Ranzenò filled the gaps with "*stucco*" (filler), and we therefore learn that this phase of the restoration was carried out by the liner himself. In fact, the *stucco* used at the time for these reparations was of a nature closely related to the *mestica*—a mixture of oil and pigments with which new canvases were prepared for painting (applied over a layer of animal glue plus other ingredients such as flour, starch, and sugar). And as mentioned, Ranzenò is described precisely as a *mesticatore.* The profession of one who prepares canvases for painting was evidently already well defined at the time and closely linked to that of the supplier of canvases and stretchers—and finally to that of a liner and repairer of canvases. The profession is what we would call restorer, but it was at the time—and for a long time after—reserved for the operations considered more "noble": the "restoration" was the pictorial one, of the painting surface, and the specific task of the artist. It was not yet autonomous.

Paradoxically, however—precisely because it belonged to a subordinate profession that lacked pretensions to artistry—the type of restoration that we would call conservative, related to the mending and lining of the canvas, already appears in the mid-eighteenth century with characteristics and methods that have been perpetuated (with necessary adjustments), up to the present day.

THE EIGHTEENTH-CENTURY RESTORATIONS FOR THE ROYAL MUSEUM

In 1758 and 1759, Ranzenò was engaged in the restoration of the paintings from the Royal Collection housed in the Palace of Capodimonte, where he directed two *stiratori* (ironers), Nicola di Mauro and Pasquale Senzapaura, who in this case worked exclusively on the repairing and relining of canvases (Filangieri di Candida 1902, 225).

In these years, Father Giovanni Maria della Torre was the custodian of the Farnese Collection in the palace, and in charge of setting up the gallery. In a letter in which he gives an account of the work on the paintings, he describes the intervention of the ironers as follows: "The *accomodamento* [repair] of them consists in tensioning again, repairing, and changing the canvases, and working on them. All this is carried out by *manuali* [skilled workers]."[2]

There is a further subdivision of the work. "The other part of the *accomodamento* consists of filling the holes of which there are many, making good the flaking [...] with the utmost diligence and skill by means of the *stucco a colore* [colored filler]."[3] This operation is assigned to Andrea Liano, an artist of limited prestige who dedicated himself to the diligent repair of paint losses, recovering the unity of the paintings; as a result, they are deemed "so perfect that they do not require anything further."[4] Although it is difficult to identify with certainty restorations of this historical moment and situation, we can very frequently identify paintings that contain traces of restorations dating back to the eighteenth century in which the losses are filled with a material composed of oil and earth pigments, completely similar to the preparation applied on the canvases at the time. We can imagine that this phase, carried out with care, effectively recovered the material—and even chromatic continuity, to a certain extent—of the painting.

In contrast to the assessment of the *accomodamento*, the artistic restoration, entrusted to the court painter Clemente Ruta, is questioned by della Torre, who reports the critical opinion of the connoisseurs (*Intendenti*): "I therefore do not see what else is desirable for these same paintings, and consequently I do not see any need for the painter D. Clemente Ruta to bring them to the Royal Palace of Naples, if not to give them a brushstroke or two, or some varnish, which in the opinion of all the *Intendenti* is to alter the old paintings."[5]

A distinct intermediate activity was therefore taking shape—if not conservation, exactly, perhaps adjusting or repairing—a field of action somewhere between lining and artistic restoration in which both Ranzenò and his collaborator Senzapaura—the latter also called the Philosopher in his turn—were involved. Between 1762 and 1775, the two were engaged in the restoration of the copper paintings by Domenichino, Ribera, and Stanzione in the Cappella del Tesoro of San Gennaro in Naples Cathedral. The restoration of the paintings on copper would have included a cleaning but also probably consolidation of the flaking layers of paint, a consistently recurring conservation problem throughout the history of the numerous interventions on the seven great altarpieces (Cerasuolo 2010, 113).

A few years later we see the emergence of the *telaiolo* Pasquale Chiariello, the first exponent of a family of restorers whose names we meet over a very broad span of time, from the late eighteenth to the second half of the twentieth century. In 1796, the latter supplied prepared canvases to the painter Tischbein: "Six *tele impresse* were delivered by the *telajolo* Pasquale Chiariello to the Director of the Royal Academy of Painting, D. Guglielmo Tischbein, to paint figures on them" (Cerasuolo 2007, 29). From that date until almost to our own times, the activity of the Chiariello family as manufacturers of canvases and as liners unfolds seamlessly. From 1826 to 1828, we find repeated references to the "*foderatori Raffaele e Antonio Chiariello*" engaged in work for the preparation of the Real Museo Borbonico (Catalano 2007).

In the 1820s, in preparation for the opening of the museum in the rooms of the Palazzo degli Studi (the current Museo Archeologico Nazionale di Napoli), an intense campaign of restorations was undertaken, for which many important documents have survived, such as notes drawn up in order to estimate the necessary expenses (D'Alconzo 2003). For the "canvas paintings of the Neapolitan School," a summary table lists the paintings (thirty-two works, including ones by Jusepe de Ribera, Luca Giordano, Salvator Rosa, and Aniello Falcone) and links them over three columns to the list of operations envisaged: "*Foderatura e tutt'altro occorre al completo*" (Lining and anything else is needed in full), "*Spianatura a colla e rassetto in telaro*" (Glue leveling and rearrangement on the stretcher), and "*Telari a zeppe*" (Stretchers with wedges)[6] (Cerasuolo 2008, 28).

The operations described in the first two columns are obviously alternatives. In fact, in less serious cases, in place of the lining, only the *spianatura* operation would be performed. From other documents we can better understand what this "flattening" consisted of: the consolidation of the paint layers carried out by applying animal glue—the "strong glue" traditionally used for this purpose and also used for the lining—on the reverse of the canvas, without removing the painting from the stretcher, and then ironing it in this way.

The application on a new stretcher, "*a zeppe*"—that is, with triangular wedges that allow the canvas to be put back under tension—is almost systematically proposed for lined paintings but could occasionally also be carried out for those subjected to "flattening" only[7] (Cerasuolo 2008, 28).

For example, an expense report for the treatment of Ribera's *Drunken Silenus*, describes the operation as follows: "flattening from the front of the painting, glue on the back, stretched onto the new frame and fully adjusted."[8]

It is interesting to observe that diversified practices are adopted but always implemented with materials compatible with those originally used, and at the same time to note that harmful practices were not employed, even though they were widespread in other contemporary contexts, especially in northern Europe. Such practices include the application of *beveroni* (Conti 2007, 106), oily substances of various natures applied to the reverse of canvases in order to consolidate and revive their colors—which, however, over time caused irreversible darkening of the tones and contraction of the pictorial layers.

For the Real Museo of Naples also, we see that both the lining and the operations relating to the carpentry of the paintings on panel were practiced by professional figures distinct from the "restorers" who were entrusted with the operations deemed more noble, namely, cleaning and pictorial restoration. The work of these operators was often assessed separately, although sometimes the payment was made through the party who took care of the "artistic" part of the intervention (Cerasuolo 2008, 28).

A FAMILY TRADITION: THE CHIARIELLO

In the middle of the nineteenth century, we meet Francesco Chiariello, who was working for the Real Museo. He was an important person who proudly claimed the rights of the profession of *telaiolo*. Chiariello became very popular among Neapolitan artists of the time, acquiring a singular reputation and importance—so much so that he is remembered by various writers as an authoritative adviser. In the memoirs of the life of the painter Bernardo Celentano, written by his brother Luigi, for example, we find many references to him. Bernardo buys his canvases from Chiariello—indeed, in a letter from Rome he considers the possibility of having a large canvas sent from Naples, and we learn the address of his shop, in Via Fosse del Grano, in the neighborhood called Museo. An unusual episode then shows the ease with which Chiariello offers himself to help the novice artist Bernardo in solving a problem of perspective, involving for this purpose a very young Domenico Morelli (Cerasuolo 2007, 32–33).

A lively description by Vittorio Imbriani also allows us to identify the portrait of Francesco Chiariello—called by the diminutive Ciccio—in a gentleman depicted by Giovanni Ponticelli in the historical painting *The Convalescent Cavalier Bajardo*, presented in 1867 at the exhibition *Quinta Promotrice Napoletana* (fig. 5.2). Imbriani produced a booklet to accompany the exhibition (which is later cited by the eminent historian and philosopher Benedetto Croce), and it includes a description of the *telaiolo*: "Ciccio Chiariello, the medal-winning *telaiuolo* who supplies canvas to all the painters of Naples, richly disguised as an Italian gentleman of the times, is observing the scene" (Cerasuolo 2007, 25–26).

Figure 5.2 Giovanni Ponticelli (Italian, 1829–1880), *Il cavalier Bajardo convalescente*, 1867. Oil on canvas, 77 × 103 cm (30 1/3 × 40 1/2 in.). Image: Napoli, Collezione d'arte della Città Metropolitana di Napoli

The *telaiolo* referred to in the description clearly highlights the characteristics that make his figure singular, in some way unique, in the nineteenth-century Neapolitan artistic scene: he provides canvas "to all the painters of Naples," and he is so highly thought of as to be honored with awards.

Francesco Chiariello had in fact received a silver medal as a prize in the Solenne Mostra Industriale of 1853, the last of the major biannual exhibitions dedicated to the products of the National Industry of the Bourbon Kingdom. These exhibitions, held by the Reale Istituto d'Incoraggiamento, were aimed at encouraging entrepreneurs' initiative and supporting the manufacturing activities that had once been promoted and financed by the royal court.

The exhibition of 1853 divided the exhibits into five categories: Chiariello exhibited his "*tele buone da dipingere*" (good canvases for painting) in the class collectively described as "different objects" and was awarded the Silver Medal "for the improvement of canvases for painting," as we read in the relative *Disamina*, a report of the examination made by the commission of the Reale Istituto. After an interesting excursus on the various types of canvas congenial to the different inclinations of the artists, the "*artiere Chiariello*" is praised for his ability to prepare canvases of various fabrics and preparations "corresponding to the wishes of our painters" (Reale Istituto d'Incoraggiamento 1855, 231–32; see also Cerasuolo 2007, 30–32).

In this context, the social elevation of the "craftsman Chiariello" suggests a new awareness of the dignity of the artisan craft and the value of entrepreneurial skills, and speaks to the personal esteem and friendship of the artists to whom he supplied the "good canvases"—a guarantee of the durability of their works.

Francesco was evidently proud of these medals, so much so that in a plea presented to the king to claim his rights as "manufacturer of canvas for painting, and liner of paintings,"[9] he cited the entire text praising him that lay behind his award from the Reale Istituto. In his plea, he asked to be named "Foderatore del Real Museo Borbonico" and claimed as his right—"acquired with great labor"—the exercise of the profession of liner. He also complained that "often restorers"—clearly those who dealt with "artistic" restoration—"allow themselves, to the detriment of art, to put onto canvas paintings that should by rights have been handed to the petitioner." In addition to the services already offered to the Real Museo, he cited as a credential the "large silver medal" won in the public exhibition.

Francesco Chiariello's familiarity and friendship with Neapolitan artists—foremost among these Domenico Morelli and Giuseppe Palizzi—would be testified to, at a much later date, by the certificates his son Pasquale obtained in order to promote the elevation in his social status. This enterprising son, in fact, succeeded in obtaining a further prestigious award from King Vittorio Emanuele III in 1901: the concession to "display the Royal Crest on the sign of his studio," which together with the medals won in public exhibitions would prominently feature on his letterhead (fig. 5.3).

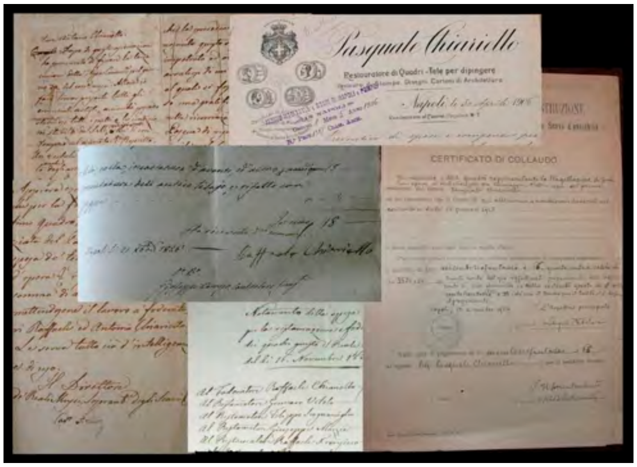


Figure 5.3 Documents concerning the activity of members of the Chiariello family. At upper right, notice the letterhead of Pasquale Chiariello with the medals and royal crest. Image: Archivio Storico del Museo Nazionale di Napoli; Archivio Storico del Museo di Capodimonte

Permission to display the royal crest was gained thanks to an impressive list of accolades by the best-known artists and scholars of the time. Reference letters were signed between 1896 and 1900 by Domenico Morelli, Filippo Palizzi, Giulio De Petra, Vittorio Spinazzola, and Vincenzo Caprile; a group of professors from the Royal Institute of Fine Arts signed a collective document that reads, "for a long time . . . the paintings in need of lining or restorations are entrusted exclusively to him either at the Real Istituto di Belle Arti or by the Museo Nazionale, the Museo di San Martino, and the Pinacoteca Reale of Naples."[10]

These letters also refer to Pasquale's father, and it is emphasized that the son, in the excellence of the results, "even surpassed Francesco Chiariello himself, who was his father and teacher, and was the first in this genre." They further highlight that "Chiariello always successfully maintained the name of his father as the first preparer of canvases for painting," and on the quality of these canvases they add interesting observations: "These canvases of special and varied preparations have the characteristics of excellent fabrics, the right amount of material and aging, so that they are not subject to cracking, and the painting that the artist executes on it does not alter with time, as is often seen with poorly prepared and improperly aged canvases."[11]

The emphasis is therefore placed on a direct relationship between the guarantee of durability ensured by the excellence of the products prepared by Chiariello and his ability to restore this durability to damaged old paintings.

KNOWLEDGE OF MATERIALS AND CAREFUL INTERVENTIONS

To great expertise in the practice of lining, Neapolitan liners added a profound knowledge of the materials of painting, which during the nineteenth century advised extreme caution in interventions. We have found evidence—both material and documentary—of interesting interventions in the case of two glue-tempera paintings: Parmigianino's *Holy Family* and Bertoja's *Virgin and Child* (figs. 5.4, 5.5), respectively (Cardinali et al. 2002). Both interventions are notable in their sensitive attention to the behavior of the materials involved. In these two beautiful canvases, the rare qualities provided by the medium have been preserved thanks to the care taken, which ensured their good conservation, and which is still effective today.

Figure 5.4 Parmigianino (Italian, 1503–1540), *Sacra famiglia*, ca. 1528. Tempera on canvas, 159 × 131 cm (62 3/5 × 51 3/5 in.). Image: Courtesy of MIC – Museo e Real Bosco di Capodimonte

Figure 5.5 Jacopo Bertoja (Italian, 1544–1574), *Madonna col Bambino*, ca. 1565. Tempera on canvas, 100 × 76 cm (39 2/5 × 30 in.). Image: Courtesy of MIC – Museo e Real Bosco di Capodimonte

A document signed by the restorer Pasquale Chiariello and dated September 6, 1899, lists the "lining works" he carried out in the National Museum of Naples. In the same list, it is specified that the paintings defined as *guazzi* (glue-tempera paintings) "were only put behind glass and 'conditioned' in order to avoid further damage."[12]

The examination of the paintings revealed that the canvases of the Bertoja and of the Parmigianino were not lined but equipped with an additional canvas: both have been "conditioned" in a similar way: using a densely woven fabric, not glued, but only stretched on the reverse for protective purposes, and fixed to the edges with nails that also tension the original canvas (fig. 5.6).

Figure 5.6 Detail of reverse of Bertoja's *Madonna col Bambino*. Notice the not-glued new canvas beneath the original one, as well as the nails that fix both. Image: Courtesy of MIC – Museo e Real Bosco di Capodimonte

The edges of the canvases were fixed with strips of wood nailed along the perimeter to the stretcher and then wrapped with a glued paper. The stretchers, from different and unspecified periods—that of the Parmigianino is older and could be original—are of the fixed type.

Glue-tempera makes colors look soft and light and is easily spoiled by the application of varnish or oily materials. In fact, glue, although relatively strong as a binder, does not form a continuous, even film on the surface, which therefore is quite porous. As a result, the colors once dried appear lighter and less saturated than when wet (Cerasuolo 2017, 220–30; Cerasuolo 2019).

A conscious and attentive protective intervention driven by the same care was taken with the two *Tüchlein* by Bruegel, which were placed under glass as a preventive measure, rejecting the choice of more invasive interventions so as not to distort the optical qualities of the medium (Cerasuolo 2017, 220–30; Cerasuolo 2019).

The documents testify to a remarkable awareness of the conservation problems posed by these works, which resulted in efforts of a purely conservative nature, thus avoiding the risks entailed by intrusive interventions. In 1846, Camillo Guerra, a professor of painting, wrote to the director of the museum reporting on the poor condition of the two Bruegels. In an 1847 document in reference to one of the two paintings, he wrote that "as it is painted in glue-tempera it is more easily subject to deterioration." On May 13, 1853, the Commissione dei Restauri (the commission of artists who supervised restorations at the museum) took the decision "to put behind glass the two tempera paintings by Pieter Bruegel, which are kept in the Dutch school" (Cerasuolo 2019).

THE TRANSFER: ANCIENT TESTIMONIES AND DANGEROUS PRACTICES

Another important aspect of the caution shown by the museum administration concerns the practice of transfer, which was consciously avoided in the nineteenth century in the Museo Borbonico thanks to the awareness of its dangers. We find a clear testimony of this in a document dated 1810: Michele Arditi strongly opposed Paolino Girgenti, who wanted to transfer the *Strage degli Innocenti*, by Andrea Vaccaro, in order to eliminate the imperfection caused by the seam joining the two pieces of canvas (D'Alconzo and Prisco 2005, 84).

The practice of transfer was carried out very early in Naples, since at least the eighteenth century. In 1742, Bernardo De Dominici recounted the skill of two Neapolitan artists, Nicolò di Simone and Alessandro Majello, who specialized in the transfer of flaking paintings on panel onto canvas supports (De Dominici [1742–43] 2003–14, 796, 994, cited in Conti 2007, 140).

The restoration of a painting by Fedele Fischetti, *Noli me tangere*, from the Church of Santa Caterina da Siena (fig. 5.7a), in 1998,[13] enabled us to examine a material example of a partial transfer procedure, probably carried out by the artist himself during the execution of the painting, which can be traced back to 1766–67. There are documents that refer to Fischetti's activity as a restorer (Nappi 1984, 320), but in this case it was possible to verify the procedure carried out long ago directly on a painting.

Observation in raking light before restoration showed a clear difference in the surface of the lower part of the painting, which was smoother and more adherent to the canvas, while in the upper part, lifting of the poorly adhering paint layers was visible.

The painting appeared to have been lined a long time ago, and the adhesion of the lining canvas was no longer effective. But when the restorer proceeded to remove the lining canvas, she realized that in reality only the lower part retained the original canvas, while in the upper part the pictorial layers were glued directly to the canvas applied during the old restoration.

Evidently—probably following an accident—the painter needed to restore his own painting, which was adhering poorly to the canvas. He then removed the canvas from the affected part and glued to it a new canvas of a very similar weave to the original, while throughout the lower

a b

Figure 5.7 (a) Fedele Fischetti (Italian, 1732–1792), *Noli me tangere*. Oil on canvas, 355 × 182 cm (139 3/4 × 71 5/8 in.), from the Church of Santa Caterina da Siena, Napoli (1766–67). (b) Diagram showing the boundary line between the lower part, which retains the original canvas, and the upper part, which has undergone the partial transfer (in black) and the areas affected by old “integrations” (in green). Image: (a) Ministero dell’Interno, Fondo Edifici di Culto (F.E.C.); (b) Museo di Capodimonte, Centro Documentazione Restauro

part he continued gluing over the earlier canvas where it had not been necessary to remove it.

The fact that the intervention was carried out by the artist himself is deduced from the nature of the canvas and from the fact that the gaps in the upper part are filled with an oily mixture quite similar to the original, applied from the back—underneath the lining canvas—and the color applied on the front over these fillings is similar to the original in the handling of the brushstrokes and color scheme, but slightly obscured in these areas. Figure 5.7b shows the areas affected by these “integrations.”

The practice of transfer—often claimed by restorers to be a secret capable of saving deteriorated paintings—causes more problems than it solves, as is now well understood. Although in the nineteenth century it was banned during restoration at the Real Museo Borbonico, it was unfortunately no longer avoided in the early twentieth century. In the years leading up to the 1960s, the transfer of easel paintings was considered a way of giving paintings greater durability (much like the *strappo* technique used with frescoes), so much so that it was also approved by rigorous ministerial circulars, and indeed it was practiced repeatedly, with questionable results. If the operation could have been carried out without very serious consequences for Neapolitan seventeenth-century paintings, which are characterized by remarkably thick and compact preparatory layers (although even there it actually impoverished the paint layer and its texture), in other cases the consequences of these interventions were truly deleterious. This was the case with Titian’s *Paolo III col camauro.* Titian famously painted directly onto lightly prepared canvas, and *Paolo III* was seriously damaged by the transfer carried out by Stanislao Troiano in 1932 (Cerasuolo 2013, 197).

In the first half of the twentieth century, Pasquale Chiariello and his sons Umberto and Raffaele also carried out many transfers (not always with positive results), while they successfully continued the activities of the family business and extending them to all “restoration” operations—perpetuating the traditional practice of flour-paste lining (Cerasuolo 2007, 41).

THE TWENTIETH CENTURY: THE EXPERIENCE OF ANTONIO DE MATA

Finally, in the second half of the twentieth century, improvements to traditional lining techniques with *colla pasta* (glue paste) were developed by Antonio De Mata (Cerasuolo 2008, 40–42).[14] De Mata personally took care of the lining and the cleaning and restoration. In his vision, structural conservation was not a subordinate phase but together with the other phases of conservation/restoration contributed to the aesthetic recovery of the materiality of a work. He developed a temporary stretcher with adjustable tie-rods that allowed a canvas’s tension to be controlled by loosening and tightening as necessary. He also devised a procedure for the preventive consolidation of paintings on canvas. After freeing the surface from dust and foreign matter, animal glue was gradually applied on the back, in several stages if necessary, keeping the canvas fixed at the edges. This procedure, which was completed by ironing the painting from the back, reduced the risks of humidity and allowed the improvement of the surface of the paint film without damaging its material qualities.

The procedure is particularly suitable for solving the conservation problems of Neapolitan paintings on canvas of the seventeenth and eighteenth centuries, with their thick, rigid preparation layers. Indeed, the animal glues and flour—materials that have always been used for preparing canvases before applying the oil ground and the oil-bound paint layers (Cerasuolo 2017, 240–41; Véliz 1982, 50–51)—are highly compatible with the original ones, and are able to effectively consolidate old master paintings on canvas.

Comparing the condition of many paintings in the Capodimonte Museum that have been lined in the last fifty years—as well as documented and continuously monitored—makes it possible to evaluate the positive outcome of these linings over time. In many cases, this method continues to be effective, and some restorers who learned directly from De Mata and continued his practice can still teach us much about the behavior of materials and intervention techniques. To preserve a testimony, a meeting was organized in January 2014: an interview with the restorers of that generation, recording their memories and observations, in order to capture a tradition that has been too often left unrecorded.[15] The recovery of these procedures, insofar as they can be effective and safe, will hopefully be a task and a legacy of the new generations.

NOTES

1. The term *telaiolo* is found in contemporary documents with different spellings but the same meaning: *telaiuolo*, *telajolo*.
2. The letter is kept in the "Quaderni di Giovanni Fraccia": a transcription made in the 1880s by the scholar Giovanni Fraccia of documents already present in a bundle of the Naples State Archive was destroyed during World War II. The 'notebooks' containing these transcriptions are now kept in the archives of the National Archaeological Museum of Naples. Archivio Storico del Museo Archeologico Nazionale di Napoli (ASMANN), II inv., 40, II, "Quaderni di Giovanni Fraccia," 1759, 68; cited by Denunzio 2002, 264, 270n16. See also Cerasuolo 2007, 28–29.
3. ASMANN, "Quaderni di Giovanni Fraccia," 1759, 68.
4. ASMANN, 1759, 68.
5. ASMANN, 1759, 68.
6. ASMANN, B7, f. 13; June 1822, signed by *Ispettore* Finati and *Controloro* Campo.
7. ASMANN, B7, f. 13; June 1822.
8. ASMANN, B7, f. 13; May 2, 1822.
9. Archivio Storico di Napoli (ASN), Ministero della Pubblica Istruzione, Fs. 343, 1858.
10. ASMANN, XXI B5, f. 11; 1896–1900.
11. ASMANN, XXI B5, f. 11.
12. ASMANN, XXI B5, f. 11.
13. The intervention was carried out by Giulia Zorzetti, whom I thank for information.
14. See https://www.archiviostoricorestauratori.it/esplora.html?permalink=%2Frestauratori%2Fdetail%3Furl%3Dhttps%3A%2F%2Fwww.archiviostoricorestauratori.it%2Fapi%2Frestauratori%2F735.json.
15. My thanks to Bruno Arciprete, Luigi Coletta, Marisa Cristiano, Bruno Tatafiore, and Francesco Virnicchi, who agreed to participate in the meeting, and to Simonetta Funel, who shot the video documentation. The recording of the interview is kept in the Archivio Storico Nazionale dei Restauratori Italiani of the Associazione Giovanni Secco Suardo.

6

Structural Conservation of Canvases in Russia from the 1960s to the Present: Evolution of Methods and Approaches

Anastasia Yurovetskaya, Research Fellow, Department of Scientific Conservation of Oil Paintings, State Research Institute for Restoration (GOSNIIR), Moscow

The Russian school of oil paintings conservation has come a long way since the 1960s—from applying only traditional structural treatment techniques with water-based adhesives to accepting modern approaches and synthetic polymer materials. This article is devoted to the milestones achieved during this process. Transformation of traditional lining methods is discussed, including changes in procedure and formulations. The paper also covers the development of less-invasive conservation techniques (such as tear mending, sizing, and hydrophobization) and putting them into practice.

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INTRODUCTION

The tradition of Russian conservation officially started in 1743, when the German artist Lucas Conrad Pfandzelt came to Saint Petersburg to care for the royal painting gallery. During the first decades of its existence, conservators established main principles that were retained for about two centuries. One of these was sticking to a complex structural treatment that would always include such serious interventions as transferring paintings from their original supports and, of course, lining (Alyoshin 1989, 55).

For a very long time after the October Socialist Revolution of 1917, conservation in Russia developed in isolation from the rest of the world. With the beginning of the thaw period in Soviet culture (from the mid-1950s to the mid-1960s), the sphere of heritage preservation experienced significant evolution, and the restoration community started to wander away from techniques developed in the nineteenth century. In 1957, with the founding of the All-Union Central Research Laboratory for Conservation and Restoration of Museum Valuables,[1] conservation science in Russia gained momentum; however, it was not until the 1960s that conservators of easel paintings were able to access professional literature and scientific events from abroad to learn about methods used in current practice by their foreign colleagues.

These developments coincided with advances in the chemical industry—all of which set the stage for big changes in the conservation field in Russia. Analyzing professional scientific journals published in GOSNIIR in the 1960s,[2] we can see a deep interest in chemical research into objects. The use of new synthetic materials for consolidation, the study of biocide agents, and the use of new conservation equipment such as vacuum hot tables were discussed. During this period, worldwide experience was collected and evaluated. Some journal issues were devoted solely to reviewing specialized essays for museum conservation professionals.[3]

From the 1960s to the 1980s, Soviet conservators reviewed, created, and adapted structural conservation techniques, some of which were considered to be a quantum leap in our country. At that time, the most successful branch was on the track of choosing noninvasive methods (as they were understood then). Despite some new approaches introduced to the professional community during the Greenwich Conference on Comparative Lining Techniques (Villers 2003b), Soviet conservators would not turn away from natural materials and traditional methods. But the drive to make treatments less invasive and more reversible triggered a significant number of research projects. Such operations as tear mending, consolidation of the flaking paint layer, and improvement of deformations were reconceived in order to avoid dipping canvases in collagen adhesives and to delay lining for as long as possible.

TRANSFORMATIONS OF TRADITIONAL LINING TECHNIQUE

From the beginning of the 1960s until the mid-1980s, attention was particularly given to the traditional lining technique. A lot of experiments were undertaken to work out best recipes (Lelekova 1966, 107–8) or to pick plasticizers. Historically, natural honey was used for this purpose, but its effects and properties in lining compounds were always questioned. In 1960, research on different lining adhesives was published in which specialists from State Central Arts and Conservation Studios[4] discussed shrinkage of sturgeon-glue films, both pure and with different added plasticizers. As a result of their experiments, the authors proposed using polyvinyl alcohol with glycerin, as these materials guarantee a more predictable effect, whereas the plasticizing properties of honey were considered insignificant and very much dependent on the amount of sucrose in its composition (Trostyanskaya, Tomashevich, and Sorokina 1960, 181–82).

However, the results of this research were not widely applied in practice. New instructions and publications would still recommend that conservators use compounds for lining made up of different proportions of sturgeon glue and honey. For example, Margarita Alekseyeva and Zinaida Tcherkasova in an article on aqueous lining solutions mention all the known drawbacks of sturgeon glue–honey compounds but still include the recipes in their guidelines (Alekseyeva and Tcherkasova 1968, 19–21). The authors offer two practical methods of performing the process of lining canvases. The first is based on a recipe with a 1:1 ratio of honey to dry sturgeon glue, by weight. It suggests that the lining canvas be glued three times: the first two with a 4%–8% solution and the third with an 8%–10% solution. All three layers of glue should be dried in sequence. The original canvas is covered with a 3%–6% water solution of sturgeon glue with honey. After it dries, a second layer of 8%–10% solution is applied. As this second layer becomes tacky, the two canvases are joined, evenly pressed together, and ironed using warm and cold irons alternately until the condensed moisture stops being released.

The second method is based on a recipe with 2:1 ratio of dry sturgeon glue to honey, again by weight. The lining canvas is prepared with two layers of warm 6%–8% solution of sturgeon glue and honey. The original canvas of the painting is infused with the same compound from one to five times, with each layer being allowed to dry between coats. Before the lining procedure, both canvases would be infused with a 12%–17% solution prepared in a proportion of 2–3:1 of dry sturgeon glue and honey, respectively. As the layers on both canvases become tacky, they are joined evenly and left to dry in a vertical position for three to six hours. After that, the canvases are ironed using warm and cold irons alternately until the condensed moisture stops being released (Alekseyeva and Tcherkasova 1968, 22).

Several years later these methods and their variations were included by Ivan Gorin and Zinaida Tcherkasova in a chapter of a text for art colleges teaching conservation; it remained the most popular guide to practical restoration for at least twenty years (Gorin and Tcherkasova 1977, 126). Interestingly, it also has chapters on structural treatments with wax-resin adhesives that were already falling out of practice by that time.

In 1974, Larissa Yashkina made a presentation at the Greenwich conference, basing her speech on a variation of the first method described above, though she offered slightly different formulations of the lining compounds and gave more technical details about the procedure (Yashkina 2003). It was a more common method at that time and considered to be more reliable.

Further investigations on sturgeon-glue lining compounds were conducted in the 1970s and 1980s. In 1975, Roza Yabrova presented a paper discussing some new materials for plasticizing sturgeon glue (Yabrova 1975). Her comparative research showed that such additives as polyethylene glycol (trade name PEG 600), carbamide, and sorbitol could replace natural honey without all its problems and drawbacks. But traditions seem to be extremely strong among the Russian conservators, as none of these materials were adopted in standard practice, so later research continued to focus on sturgeon-honey solutions—as well as concentrating on solving the problem of collagen glues being prone to biodeterioration (Nazarova 1984; Nazarova and Potapov 1984; Rebrikova 2013).

Nowadays traditional lining technique is still one of the most common methods of consolidation of original canvas supports of the paintings. But during the past ten years, there has been a significant change in the whole procedure. First of all, sturgeon has become an endangered species in Russia—since 2013 it has been protected by a federal law that limits sturgeon fishing and processing. The State Research Institute for Restoration has studied rabbit-skin glue as an alternative to sturgeon glue and came to the conclusion that if used in less-concentrated solutions, rabbit-skin glue can be successfully applied to consolidate paint and ground layers and also used for lining.[5]

Moreover, there is now a trend toward reducing the amount of additives in the lining compounds. As the storage and exhibit conditions in Russian museums have generally become more stable—with balanced temperature and humidity—there is no need to add biocides and plasticizers during each treatment. Case studies demonstrate good results for paintings that were treated with collagen glue solutions without honey (Alyoshkina 2015; Voronina 2019; Yurovetskaya 2016).

TREATMENTS TO POSTPONE LINING

In the 1970s and 1980s, leading studios and institutions evolved new methods of preserving linen canvases that are still widely used in conservation practice in Russia. One of the most vivid examples is a tear-mending technique developed at GOSNIIR in the 1970s that is still widely used by conservators throughout the country (Surovov and Yashkina 1979). It suggests that tears and cuts of the textile painting supports are treated with 5% solution of polyvinyl butyral (PVB) in ethanol or isopropanol. Saturated threads are interwoven and after drying are fixed using a hot spatula. This adhesive has been widely used in conservation practice in Russia since the 1950s (Rumyantsev 1953), especially for treating murals, ceramics, and fabric painting supports. Its glass transition temperature (Tg) is approximately 60°C–70°C. "PVB films are resistant to light and heat-sealable at temperatures above 120°C … PVB films are noted for their biostable and abrasion resistance properties as well as for good colorfastness against UV light, low static generation, and low water absorbtion" (Sannikova 2018, 106). In 2008, the tear-mending technique was slightly extended by adjusting the method for strip-lining two-sided paintings to avoid overlaps of new margins over the paint layer (Yashkina and Churakova 2013). The working procedure has also slightly changed. Following a general trend holding that less is more, conservators tend to use less adhesive for the process: instead of saturating canvas around the tears, they just apply it to the direct spots.

A method of stabilizing canvases by starch sizing was introduced by conservators of the State Tretyakov Gallery and came into common practice as a procedure for conserving canvas (Yushkevich 1995). The technique was first developed in the 1970s but was not published until the mid-1990s, being constantly improved in the interim by its author, Galina Yushkevich (Yushkevich 1995).

Before performing the operation, the picture must be stretched on paper margins; the painting layer should be fully covered by the facing. These precautions guarantee that the canvas of the painting is kept from shrinking during treatment, which involves heat and moisture. Afterward, the painting is put facedown on a flannel or woven felt to protect the impasto. Sizing is performed by applying a 10% starch paste on the reverse of the picture and spreading it evenly. After the paste dries a little, it is delicately removed with a palette knife. The small amount of remaining starch is pressed with a warm iron. This causes the residue of the paste to be absorbed into the structure of the picture, which helps reduce canvas deformations and makes the support less responsive to changes in temperature and humidity.

This method is effective for treatment of canvas undulations, so it was adopted by many conservators and is still widely used in many studios. However, during the past few years this method has been reevaluated. Saturating canvas with starch ultimately makes the linen fibers more brittle and prone to microbiological damage. Nowadays cellulose ethers are mostly substituted for the starch; this also functions to better adsorb dust and glue residues from the canvas (Churakova, Karasyova, and Yurovetskaya 2018, 56), but such total saturation of fabric support is still debatable.

In the late 1980s, another interesting technique used to stabilize canvas supports was introduced by GOSNIIR: hydrophobization of textile supports with solutions of organosilicons in isopropanol or refined gasoline (Malachevskaya and Yashkina 1986). Two coats of a 5% solution of polymethylhydrosiloxane are applied sixty minutes apart by brushing or spraying onto the reverse side of the picture. This coats the textile fibers and reduces the canvas's response to changes in temperature and humidity. The process of polymerization is usually finished after eight to ten days of exposure, when the solvent evaporates. The properties of organosilicons (such as polymethylhydrosiloxane) still allow for later protein glue treatments, including sturgeon-glue linings (Fedoseeva 1999, 68–69).

Evaluating methods of hydrophobization of canvases with solutions of organosilicons seems to be a more complicated task for now. All tests performed with the samples showed very good results. According to publications on the project, treated canvases quickly repel surface moisture, do not get wet, are not prone to shrinkage and deformation, and withstand sharp increases in humidity (Nazarova, Malachevskaya, and Yashkina 1990). Furthermore, the air and vapor permeability of canvases did not change (Malachevskaya and Yashkina 2013). However, when this treatment was applied to the paintings, it turned out that on some artworks the consolidation operations with water-based solutions were not as effective as they were on the untreated paintings with organosilicon objects. Moreover, the process of degradation of polymethylhydrosiloxane is still to be investigated.

ACCEPTING GLOBAL TRENDS AND MATERIALS

We did not have an industry dedicated to conservation products in the former Soviet Union, nor do we currently have one in Russia. None of the polymers that have been studied, tested, and applied were produced specifically for conservation purposes; all of them were created for the production sector and then adapted to conservation needs. In the 1990s, not only the political but also the economic life of our country underwent serious changes after the collapse of the Soviet Union. Many manufacturers either closed or changed production technology, afterward offering new materials to the market. At the same time, importation of European and American conservation materials started to grow, so people working in the conservation and restoration sphere suddenly had a broad selection of totally new polymers to get acquainted with. Consequently, the beginning of the new period in Russian history started with much experimentation, comparative work, and research in the conservation field. Specialists returned to the international conservation community, attending conferences and scientific seminars and learning more about the work of their foreign colleagues. At this time numerous tests were also carried out, including those on materials for structural conservation of canvases.

GOSNIIR conducted comparative research on three acrylic dispersions: Lascaux 498 HV (Lascaux Colours & Restauro) was compared to two adhesives originally produced in Russia for coated paper and textile manufacturing. The first has the trade name ABV-1B and is a copolymer of butyl acrylate, methacrylic acid, and vinyl acetate. The second has the trade name AK-243 and is a copolymer of ethyl acrylate, methacrylic acid, vinyl acetate, and acrylonitrile. Both have a working concentration of up to 50% (Fedoseeva et al. 2016, 98–99). All three dispersions meet the general requirements for a strip-lining adhesive: they do not penetrate deeply into the threads of the canvas, they do not cause shrinkage of the canvas, they have a high adhesive capacity, and they form a film with elasticity that persists over time.

Results of the comparative analysis showed that the AK-243 and ABV-1B dispersions are superior to the Lascaux adhesive on a number of indicators; in particular, they penetrate less into the threads of the canvas and do not cause shrinkage (Fedoseeva, Malachevskaya, and Yashkina 1997). Nevertheless, today the most popular adhesives for strip-lining are Beva products (Beva 371 Film or Beva D-8 Dispersion) and Lascaux 498 HV (Romanova 2019). This is despite the fact that both AK-243 and ABV-1B are still produced in Russia: manufacturers sell them only in industrial-scale volumes and retailers are not interested in organizing packaging the products in smaller sizes, thus conservators have problems obtaining them.

Following international trends, in the 1990s the Russian conservation community started to familiarize itself with synthetic materials for lining and to compare them with traditional techniques (Fedoseeva 1998). There was also the intent to develop or adapt Russian synthetic polymers for the lining process.[6] In the end, an understanding that the most common sturgeon-glue lining has obvious drawbacks and is not suitable for all artworks led to adopting a method for treating oil paintings that has been well known for lining textiles since the 1970s, when it was introduced at the Pranas Gudynas Centre for Restoration in Lithuania.

The method employs an acrylic adhesive with the trade name A-45-K, which is a copolymer of vinyl acetate, butyl acrylate, and acrylic acid in ethyl acetate (Emelyanov 2005). In a form of either a dispersion or acetone solution, it can be brushed or sprayed on a lining cloth and later activated by temperature (Semechkina 1993, 125). Its properties are in many ways similar to Plextol and Lascaux adhesives, but choosing a local manufacturer was preferred in the 1990s, not only to support the country's economy but also because this particular material was well known and tested. A-45-K has not become very popular for standard lining procedures for canvases, but it showed good results in a few specific case studies.

One example is the lining support of the eighteenth-century painting *Conclusions of Field Marshall General Count B. H. Minikh on the Seizure of Ochakov* (fig. 6.1) (Iurovetskaia et al. 2019). Silk was used as a support (fig. 6.2), and the image layer combined oil, gold paint, and ink. Adhesive A-45-K dissolved in acetone was sprayed on the surface of the lining cloth (fig. 6.3) and after matching with the original support was activated locally by heat (fig. 6.4). Effective application of A-45-K for this art piece still has not led to widespread adoption of this technique among professional conservators because, since 2006, when this method was first introduced for lining the Mikhail Vrubel painting *Gwydon* on a sackcloth support, it has become increasingly complicated to acquire the material from the manufacturers.

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b

Figure 6.1 Unknown artist, *Conclusions of Field Marshall General Count B. H. Minikh to the Seizure of Ochakov*, 1737. Mixed techniques on silk, 172 x 143 cm (67 3/4 x 56 1/3 in.). (a) After removing old facings. (b) Detail. Image: © State Historical Museum, Moscow

Figure 6.2 Back side of the painting in fig. 6.1 after removing old facings; silk support in raking light. Image: © State Historical Museum, Moscow

Figure 6.3 Fragment of lining textile sprayed with adhesive A-45-K. Image: The State Research Institute for Restoration, Moscow

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Figure 6.4 *Conclusions of Field Marshall Minikh*. (a) After structural treatment. (b) Detail. Image: © State Historical Museum, Moscow

Nowadays restoration professionals in Russia often face difficulty accessing materials adapted for conservation purposes in our country and thus turn to reliable professional materials by internationally known suppliers. In this way, the conservation field in Russia is experiencing globalization, with all its challenges and opportunities, and mostly sticking to materials and techniques that are used worldwide. This certainly makes our work more comfortable, but it also eliminates distinctions between different conservation schools with their unique methods and approaches.

NOTES

1. Later reorganized into the All-Union Research Institute for Restoration, now called the State Research Institute for Restoration (GOSNIIR).
2. The online library of GOSNIIR includes periodicals from 1960 to the present: http://www.gosniir.ru/library/artistic-heritage.aspx.
3. *Reports of All-Union Central Research Laboratory for Conservation and Restoration of Museum Valuables*, issues 12, 15, and 22–23 (1964–70). http://www.gosniir.ru/library/artistic-heritage.aspx.
4. Later reorganized into the All-Russian Scientific Restoration Center, now called the Grabar Conservation Center.
5. "Studying the Properties of Rabbit Skin Glue," archival fonds of GOSNIIR, no. 1, inventory 37, 2013, p. 51.
6. "Developing Method of Lining Easel Oil Paintings Using Russian Synthetic Materials," archival fonds of GOSNIIR, no. 1, inventory 13, folder 105, 1992.

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Sustainable Trajectories for Terminologies, Methods, and Materials in the Structural Treatment of Paintings on Fabric Supports

Matthew Cushman, Conservator of Paintings and Affiliated Assistant Professor, Winterthur Museum, Garden & Library, and the University of Delaware

Emphasizing international inclusivity and valuing regional and traditional practices, this paper offers recommendations for sustainable practice. The development of a multilingual, collaborative lexicon is favored over a standard terminology in English. Frameworks are proposed for practical research, dissemination of treatment information, and preparing for future challenges of material availability.

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INTRODUCTION

In his essay "Three Days That Changed Conservation," David Bomford reflected upon the circumstances surrounding the 1974 Conference on Comparative Lining Techniques and its status as an important inflection point in the history of paintings conservation: "It was the beginning of a new precision, a new refinement, and it heralded a new technical intelligence in targeting conservation treatments . . . Greenwich was when conservation came of age" (Bomford 2017, 1). What followed was a proliferation of approaches to treatment, coincident adoption of new materials, and a need for supportive fundamental and practical research.

The past forty-five years have seen technical refinements of traditional methods, changes in the ways that conservators communicate the nuances of structural treatment, engineering of new purpose-built equipment for lining and alternatives to lining, development of new approaches to lining, changes in material formulations, adoption of sophisticated research instrumentation, and increased international exchange of information. While the advances have been numerous, the challenges ahead are equally numerous and increasingly formidable. This paper attempts to anticipate some of these significant challenges and to provide a framework for sustainable collaborative efforts to address future difficulties.

THE CURRENT STATE OF TERMINOLOGY

One of the efforts of the Greenwich conference proceedings was the production of a handbook of terms used in the lining of paintings—an attempt to define about three hundred terms so that conservators from different countries and different lining traditions and philosophies could communicate effectively. This handbook was reproduced for subsequent conferences and seminars, and it is included as a glossary in the volume republished nearly twenty years ago (Villers 2003b). Despite the handbook's status as a key resource in the training of paintings conservators, and despite international efforts to standardize terminology in the realm of conservation of cultural heritage,[1] Cecil Krarup Andersen found in 2012 that the frequency of deviations from terminology established in the Greenwich handbook increased with the passage of time in English-language publications included in AATA, the Getty Conservation Institute's online database (Andersen 2012).

The reasons behind these deviations are many. Given the adoption of English as a lingua franca in conservation literature, Andersen and others have noted the persistence of English cognates in different lining traditions, resulting in a collection of terms having essentially the same meaning: lining, relining, doubling, and redoubling, for example. Additionally, the introduction of new materials and innovative approaches to treatment have given rise to adjustments to classical terminology and the creation of new terms and variants. Further confusion can result from techniques falling under umbrella terms while being fundamentally different procedures. For example, the thread-by-thread tear-mending techniques, first described by Winfried Heiber (Heiber 2003) and adapted by Petra Demuth and others, have influenced the development of various bridging and reweaving techniques for the stabilization and reestablishment of tension in torn supports. Of the two, reweaving may be more consistent with Heiber's approach, yet both approaches may be described as thread-by-thread tear mending or a modified Heiber technique.

One might suggest that our terminology has sprawled due to the lack of an explicit, unified imperative for international consistency. Inconsistent terminology may be cause for alarm; however, this "problem" is a natural consequence of parallel research and practical innovation that leverages the material traditions of varied regional practice. The expansion of our shared lexicon and authors' apparent agency to redefine accepted terminology suggests that the international community has engaged in rapid adoption of new techniques and materials to such a degree that flexibility has been valued over rigid language structures. To stifle experimental creativity by imposing specific linguistic constraints could strip some of the nuance from technical descriptions of practical applications—particularly if those communications originate outside of English-speaking traditions. If the trajectory of modern structural treatment is founded upon flexible decision-making trees—an intentional move away from prescriptive treatment—then it is imperative that paintings conservators aim to embrace and understand the breadth of traditions and techniques that exist internationally.

INTERNATIONAL COLLABORATION AS SUSTAINABLE PRACTICE

In the current global environment, with its mounting uncertainties due to climate change, political unrest, and public health crises, and given the limited resources allocated to the conservation of cultural heritage, conservators must seek out opportunities to create efficient practices. Shared knowledge, sustained longitudinal research, and the ability to anticipate future material challenges will have increased value in the decades ahead. Our best shot for rising to these demands is through international collaboration.

A Living, Multilingual Terminology

Of course, conservators must be able to communicate the technical aspects of their work with precision and clarity, and we must be willing to make nuanced adjustments to our terminology with the accumulation of scientific, philosophical, and practical information—shifting away from idealistic "reversibility" in favor of the practical "retreatability," and gaining a more granular understanding of increased transparency of oil paint films (van Loon 2008) due to deterioration processes and through structural intervention (Froment 2019), for example. Although the adoption of English as the operating language imposes some structure for a shared terminology, doing so also inhibits the participation and investment of experts globally, and we risk the erosion of nuance with each translation. If conservators embrace international collaboration as a benchmark of sustainable practice,[2] we will increase the probability of discovering new insights and relationships between differing international (and intergenerational) practices.

An updated terminology for the structural treatment of paintings on fabric supports—and indeed for topics within the specialty of paintings conservation and across disciplines—could be produced in the following manner:

1. Designate an international working group dedicated to the project.
2. Within each participating country and language, accumulate terminology and definitions as used natively.
3. Generate thesaurus entries to describe parallel terminology across languages.
4. Translate terminology and definitions for those terms that have no apparent equivalent from language to language.
5. Identify key literature to be translated across languages.
6. Perform iterative editing and expansion of the resulting living document.

This initiative would be a significant undertaking building upon and necessarily superseding efforts such as the Greenwich conference handbook of terms and the LMCR project spearheaded by the Associazione Giovanni Secco Suardo;[3] however, the benefits and potential efficiencies should be apparent to the reader, and the greater understanding and respect for traditions and innovations outside of the English language would help to build a more inclusive international community.

While parallels to medical fields might suggest that conservators should adopt a standardized lexicon, so much of the variation in our work is influenced by geography—the materials and techniques employed by the artist, the environmental conditions to which the painting has been subjected, and historical regional restoration practices—that a monolithic definition of best practice is neither reasonable nor sustainable. Rather, adopting a multilingual, multiregional approach to terminology would ensure that our common knowledge does not suffer an erosion of empirical nuance.

Ensuring a Sustained Pipeline of Applicable Research

Our terminology is only as good as our ability to fully understand the material demands of a treatment, and our ability to execute effective treatments depends on accurate heuristics and decision-making as well as appropriate use of purpose-built equipment. Each of these parameters is developed and delineated through fundamental and practical research. Our understanding of material properties and environmental response, the development of technologies and equipment in support of treatment refinements, and the evaluation of treatment procedures all require collaboration between conservators and scientists. Scientists ensure that research methodologies are sound, and that the interpretation of data holds scientific merit, and conservators ultimately decide how applicable the scientific research is to their daily practice, wherein conservators sort materials and techniques qualitatively (e.g., “weak” versus “strong” and “sympathetic” versus “invasive”) for specific use cases.

A sustainable research pipeline for aspects of structural treatment might include the following:

- Distribution of research questions among multiple groups to accomplish as much as possible in an expedient manner
- Embedding of early and midcareer conservators and scientists into research groups to carry on projects when principal investigators retire or are otherwise unable to continue their work
- For materials research, aiming to describe the use limits of the material beyond ideal museum conditions
- Ensuring that research is not limited to high-tech or high-cost instrumentation, incorporating low-tech materials and qualitative, experiential observation whenever reasonable

In all cases, diversifying our pool of researchers, supporting the work of nonscientists in scientific studies, and ensuring long-term continuation of research projects will require more diverse streams of funding and coordination across projects.

Expanding Publication of “Ordinary” Treatments

Research only gets us so far toward understanding structural treatment. Ultimately, hands-on experimentation, practical treatment, and object-level study are supported by fundamental and practical research. A conservator’s ability to recalibrate their heuristic understanding of treatment options relies upon an accumulation of data: experiential, anecdotal, and peer reviewed. Unfortunately for everyday practice, the conservation treatment literature is overwhelmingly geared toward the extraordinary: iconic paintings, material curiosities, and technical challenges. It can be difficult for a conservator to know when a project or observation is appropriate for or worthy of publication. Thoughts that this treatment is not interesting enough for publication or this painting is not important enough for publication are counterproductive in the long term, resulting in collective blind spots in the conservation literature.

A more sustainable and collaborative approach to this problem would be to encourage the publication of seemingly routine data about methods of manufacture and treatment procedures, either making room within established scholarly spaces or supporting new publication venues devoted to communications of "routine" treatments. This is an uncomfortable thought, however, for some practitioners and institutions, especially in the realm of conservation of modern and contemporary materials, wherein confidentiality is often key to the conservator-client (and conservator-client-dealer-foundation) relationship. We cannot expect colleagues to jeopardize their working relationships, but we should not feel satisfied by a discourse illustrated with redacted images and presentation slides with do-not-tweet warnings.

A reasonable compromise that would provide some degree of confidentiality while enabling the aggregation of treatment data would be to encourage periodic publication of treatments within an institution or private practice over the course of five to ten years. These summaries would overcome the misconception that individual treatments may not be worthy of publication, while tracking adoption and use of techniques and materials. Moreover, such publications would provide opportunities to discuss successes and shortcomings of treatments both ordinary and extraordinary. Lastly, this initiative would generate opportunities for conservators to think critically about their work and how their philosophies evolve over time. In sum, a critical mass of such publications would provide enough information to allow the field to better describe use boundaries between different structural treatment options in different exhibition and storage environments. Of course, this proposal hinges upon the support of existing editorial boards and/or the foundation of one or more new journals.

Increasing Practitioners' Command of Diverse Treatment Methodologies

An outgrowth of the production of a new international terminology and broader publication of practical treatment information (and indeed, of the Conserving Canvas initiative) should be the increase of conservators' capacity for understanding and commanding multiple approaches for structural treatment. The past few decades have seen a proliferation of new cleaning technologies aimed at greater specificity, efficacy (Ormsby et al. 2010), control (Tauber et al. 2018), and increased safety to the practitioner.[4] Yet the same demand for specificity in structural treatment is seemingly lacking; a paintings conservator might be expected to utilize only a few structural treatment procedures each for humidification, consolidation, tear mending, and lining. One goal of modern structural treatment should be to work toward the understanding of and proficiency in multiple techniques to service different needs and to achieve differing effects.

The ways in which we describe treatment parameters can be expanded by considering varied approaches. For instance, a more nuanced understanding of treatment possibilities allows us to better define one's intent with a treatment: whether or not adhesive methods are required, and if they are, where within the structure of the painting one aims to localize the adhesive bond, and what is intended for the method of retreatability. From there, the choice of materials and the ability to control the conditions imposed upon the painting during treatment determines (in part) the success at realizing the intent of the treatment.

An individual conservator, a training program, and a museum might have their own proficiencies when it comes to structural treatment; by relying upon one another, we are able to fill in knowledge gaps and develop formal and informal advisory groups to guide individual treatments and long-term practical advancement. An ancillary benefit of gaining proficiencies across several different types of structural treatment is an increased ability to adapt when working in nonideal conditions or when material formulations change.

Material Sustainability and Probable Impacts on Structural Treatment

In recent years, sustainability has transformed from a buzzword to an urgent concern. Increased focus has been placed upon material sourcing, with specific attention paid to materials refined from petroleum and other nonrenewable resources. Other key factors in material sustainability are environmental impact (how a material influences the stability of various biomes) and human health and safety (how chronic and acute exposures affect organ function and how materials metabolize and bioaccumulate within the body). One consequence of pursuing sustainable materials and practices is the greening of our chemistry, either by choice or through governmental regulations.

Of the various regulatory frameworks worldwide, the European Union's Regulation, Evaluation, Authorization and Restriction of Chemicals (REACH) is a good predictor of materials to which conservators might lose access in the near future.[5] Under REACH is a list of substances of very high concern (SVHC): a register of chemicals that are deemed problematic and have been proposed for restricted use or other regulations. Suppliers and manufacturers can receive authorizations to formulate substances containing restricted materials; however, if a manufacturer were to find a substitute chemical that performs similarly while being unrestricted, there is a strong likelihood that the formulation of the substance will change. For the purposes of structural treatment, conservators need to be aware of the current formulations of our common materials and the chemical similarities between components of conservation materials and those on the SVHC list.

Although the number of changes to paintings conservation practice resulting from governmental regulations should be low, there are examples of anticipated changes that are of significant concern. Phthalates feature in general on the SVHC list,[6] mostly because of the risk of oral exposure due to the presence of phthalate plasticizers in children's toys and in plastic bottles. The most common occurrence of phthalates in paintings conservation is in the formulation of Beva 371 and Beva 371b, both of which include Cellolyn 21, a phthalate ester of rosin acids.[7] Replacing Cellolyn 21 in the formulation of Beva products will likely change the tacking, setting, and melting temperatures of the adhesive.[8] Phenol ethoxylates, a class of nonionic surfactants, are under increasing scrutiny.[9] Nonylphenol ethoxylates, for example, are restricted materials under REACH, but they have been used in the past in formulations of acrylic dispersions. It is likely that the surfactant components of acrylic dispersions will undergo a series of substitutions, possibly resulting in different working properties and changes to the pH of acrylic dispersion formulations. Lastly, some of our common solvents have been deemed problematic, including many aromatic solvents. Any restrictions placed upon these solvents could have implications for reversibility of certain treatments and for the feasibility of some adhesive formulations.

In addition to material substitutions due to governmental regulations, conservation materials extracted from threatened or endangered species may not be available in the future. Examples of these species include many types of sturgeon, from which protein glues can be extracted, and some algae species responsible for the production of agar-agar and agarose. Conservators need to be aware of the possibility of formulation changes. Not only do we have a moral obligation to comply with regulations, but we also have an ethical obligation to anticipate material changes and the impact such changes may have on retreatability of current treatments. Luckily, being prepared for changes in the name of sustainability can be accomplished by attempting to address all of the challenges highlighted above.

CONCLUSION

Our ever-evolving understanding of the structural treatment of paintings on fabric supports is built upon nuance and experience expressed first in native tongues and shared across cultures thereafter. If conservators and scientists can work together to communicate effectively and efficiently, to explore the limits of our current techniques, to respect the expertise inherent in regional traditions, and to encourage fundamental and practical research within our international conservation framework, we will have followed sustainable and adaptable trajectories for progress. These collaborative efforts will be most effective if we avoid impulses toward secrecy and proprietarianism, embrace communications detailing treatments and studies, both routine and extraordinary—whether they be successes or failures—and plan ahead for conditions where problematic or scarce materials need to be replaced. Thus, multilingual and multiregional inclusiveness will provide the field with a plurality of best practices to adopt, adapt, and evolve into the future.

NOTES

1. For example, European Committee for Standardization CEN/TC 346/WG 1, General methodologies and terminology: https://standards.cen.eu.
2. International partnerships are among the United Nations' seventeen Sustainable Development Goals: https://www.un.org/sustainabledevelopment/sustainable-development-goals/.
3. The Multilingual Technical Scientific Glossary in Conservation and Restoration was a multiphase project (2001–7) focused on the production of a common thesaurus in English, German, French, Italian, and Spanish. See http://www.associazionegiovanniseccosuardo.it/?q=en/node/163.
4. For several examples, see Angelova et al. 2017.
5. https://echa.europa.eu/regulations/reach/understanding-reach.
6. At the time of this writing, eighteen different phthalate esters are included on the SVHC list.
7. See http://cameo.mfa.org/wiki/Cellolyn.
8. At the Conserving Canvas symposium, Michael Swicklik, senior conservator of paintings at the National Gallery of Art, in Washington, DC, related an anecdote from his time working with Gustav Berger wherein Berger explained how Beva 371 did not function as intended without the addition of Cellolyn 21.
9. At the time of this writing, twenty-seven different phenol ethoxylates are included on the SVHC list.

II

Present Practice

8

The Relining of Van Dyck's *Equestrian Portrait of Charles I*

Paul Ackroyd, Conservator, National Gallery, London

The previous conservation treatments of Anthony van Dyck's Equestrian Portrait of Charles I *present a history of lining. Having been lined with a glue-paste adhesive twice in the late nineteenth century, the painting was relined with a wax-resin adhesive in 1952, and in the recent treatment was relined with Lascaux 375, an equivalent heat-seal adhesive to Beva 371. This article describes the recent treatment, starting with the removal of the wax-resin lining, and includes the repairs to the original canvas and the relining, which was carried out in two separate stages on a heated low-pressure table while the painting was held in a vacuum envelope.*

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INTRODUCTION

The *Equestrian Portrait of Charles I* by Anthony van Dyck (NG 1172), painted around 1637–38 and monumental in scale (368 × 292.5 cm), imposingly depicts the king as the divinely chosen ruler of Great Britain, celebrating the union between England and Scotland following the accession of Charles's father, James I, to the throne in 1603 (fig. 8.1). Van Dyck's choice of an equestrian portrait not only demonstrates the king's horsemanship but is also deliberately reminiscent of equestrian statues in ancient Rome that were intended as assertions of temporal power. It was painted toward the end of a period of relative prosperity in England and set in a tranquil English landscape, shortly before the country was plunged into a bloody civil war in which Charles lost the throne—and his head, when he was executed on January 30, 1649. The depiction of this poignant moment in English history has ensured its popularity with visitors to the National Gallery and its importance within the collection. Only rarely has it been taken off display, and it normally hangs in room 31, where it creates an imposing impression and forms a vista to draw the public into the gallery as they enter through the Central Hall.

Van Dyck painted the portrait on a twill weave canvas with a black ticking pattern, which has a central horizontal join (fig. 8.2); it bears Charles I's original cipher at the center of the reverse. This type of canvas, commonly used for domestic upholstery, was probably chosen for its strength and toughness and because it could be obtained in large widths, making it an attractive choice of material for large paintings. The canvas was prepared with a red-brown ground followed by a thick, oil-based gray priming.

The decision to fully retreat the picture in 2018 was based on the fact that the lining canvas was detaching from the original and the previously applied varnish and retouchings had discolored significantly. All lining activity at the National Gallery since the late 1970s has entailed the relining of paintings—that is, the replacement of an old and degraded lining with a new one. On the occasions when previously unlined pictures have required structural attention, less-invasive forms of treatment than lining have

Figure 8.1 Anthony van Dyck (Flemish, 1599–1641), *Equestrian Portrait of Charles I*, 1637–38. Oil on canvas, 368 × 292.5 cm (144 7/8 × 155 1/8 in.). Before treatment. Image: National Gallery, London

Figure 8.2 Van Dyck's *Equestrian Portrait of Charles I*. Detail of the canvas reverse showing the black ticking pattern. The wax-resin adhesive is being removed in this photograph. Image: National Gallery, London

been selected. In the case of the Van Dyck, the recent relining was a nonimpregnating, nap-bond treatment carried out with an equivalent of Beva 371, Lascaux Heat-Seal Adhesive 375, using a vacuum-envelope technique.

EARLY HISTORY AND OWNERSHIP

The painting's checkered early history has affected its condition. In 1650, shortly after Charles I's execution, Cromwell sold the painting to Sir Balthazar Gerbier, who resold it to Gisbert van Ceulen in Antwerp, from where it was sold yet again to Duke Maximilian II Emanuel, elector of Bavaria and governor of the Spanish Netherlands (Martin 1972, 44). In 1698, the painting was looted from Munich by Emperor Joseph I, who gifted the picture to the first Duke of Marlborough in 1706. From then, it remained in the United Kingdom at Blenheim Palace until the National Gallery acquired it in 1885 for the sum of £17,500. Throughout all these changes in ownership, the painting would have been rolled up and transported by horse and cart or by ship. The raised, horizontal craquelure in the picture is indicative of the painting having been rolled, as are the large number of splits and losses at the sides (fig. 8.3). A series of vertical losses at the right edge also suggest that the rolled canvas was tied too tightly, crushing the paint in these areas.

Figure 8.3 Van Dyck's *Equestrian Portrait of Charles I*. Detail of the canvas reverse showing the splits at the sides during their repair with inserts of new primed canvas. Image: National Gallery, London

Since the painting entered the National Gallery's collection it has rarely traveled. During World War I, the picture was evacuated to Overstone Park, outside of Northampton. During World War II, it went first to Penrhyn Castle, and then in 1941 to the Manod slate mine in Wales. On both of these latter occasions, it was transported upright on its stretcher in a large wooden case strapped to the back of a lorry. On its journey to Manod, the truck had to pass through a tunnel that was not tall enough to accommodate the height of the case. This had been anticipated, and the road had been dug up beforehand to make extra height, but even so there was insufficient headroom for the truck to pass through, and the truck's tires had to be deflated (Clark 1977, 6; Davies and Rawlins 1946, 13). On its return trip to the National Gallery in June 1945, the painting traveled mostly by train. More recently, in January 2018, the painting was lent to the Royal Academy's exhibition *Charles I: King and Collector*, and it again remained on its stretcher for the short journey across London.

EARLY RELINING TREATMENTS

Before the recent treatment, which began with a cleaning in June 2018, the painting had already been lined at least four times; as a result, it presents a potted history of lining at the National Gallery. It was acquired already lined, almost certainly with a glue-paste adhesive, and relined immediately after acquisition with glue-paste by William Morrill, a private liner who regularly undertook work for the gallery. Morrill was the second generation of a dynasty of liners renowned for their tough, durable linings—which, by today's standards, often produced overly flat picture surfaces. In the case of the *Equestrian Portrait,* this was achieved at the expense of squashing the impasto in the picture, leaving moated depressions around these areas.

It is worth emphasizing the durability of the Morrill family's linings, a number of which still remain on National Gallery paintings, and they have stayed in a stable condition despite now being around 170 years old. In 1889, however, four years after his initial lining, Morrill was asked to reline the painting again, because it was considered that the central join protruded too much. This time he did another paste relining but using two lining canvases. However, this lining created further damage. Morrill cut away all the excess canvas at the back of the join and completely removed the stitching in the central section as well but left the stitching intact at the ends of the join. During the relining, the two original pieces of canvas shrank apart, leaving a 4–5 millimeter gap across the center of the join, and at the points where the stitching remained, the painting bulged away from the lining canvas, forming large air pockets. The bulge at the left was ironed flat, leaving a slight depression, but ironing the one at the right created a raised crease in the original canvas and a 50-centimeter-long vertical line of paint loss. A similar crease was made in the center of the bottom edge. Additionally, during the lining removals that Morrill undertook, fragments of old glue became trapped underneath the picture, causing holes and indentations in the picture surface, mostly around the edges.

By 1952, Morrill's lining canvases had embrittled, tearing at the turnover edges, and the surface of the painting had become undulated. By this time the gallery no longer used private restorers, having established a conservation department in the late 1940s. Arthur Lucas, who later became the gallery's chief restorer, decided to remove Morrill's double lining using a mixture of water and ethanol to soften the glue layers, and to then reline the painting with a single piece of linen adhered with a wax-resin mixture (58% plain beeswax, 40% dammar resin, 2% stand oil) using heated hand irons. There was a vogue for wax-lining at the gallery from shortly after the war until the late 1970s, when it was supplanted by Beva 371. Lucas's decision to reline the picture may have been considered legitimate at the time, but nowadays it might be considered more appropriate to flatten the undulations and repair the edges of the lining by adding a strip-lining.

Lucas's lining also had its problems. The water and ethanol used to remove Morrill's lining made the original canvas buckle and undulate, and these problems were not addressed with any flattening treatments before relining. The relining was initially carried out with the painting facedown, and the lining canvas, stretched onto a loom and prepared with the wax resin, was placed on top of it—a standard procedure at the time. The lining canvas was ironed from the reverse, lightly tacking the painting to the lining, which was then turned faceup so that the ironing could continue over the facing tissue covering the front of the picture. The temperature of the irons was reduced, and the wax adhesive did not get hot enough to form an even layer nor form a good bond between the two canvases. The result was that the rippled undulations caused during the delining remained and, due to the considerably uneven distribution of wax, more pronounced lumps and bumps were created in the picture surface (fig. 8.4). By 2018, the painting was detaching from the lining, particularly at the edges.

THE RECENT TREATMENT

Removal of the Old Lining

After cleaning, a template was made of the damages and distortions at the front by marking these areas onto thick sheets of Melinex (polyester film), so that they could be accurately located on the back of the picture during the later stages of the treatment.

The central join was then faced with Japanese tissue adhered with a wheat-starch and sturgeon-glue adhesive to provide extra reinforcement to this area. This was followed by an overall facing of Eltoline tissue and a

Figure 8.4 Van Dyck's *Equestrian Portrait of Charles I*. Detail of the reverse of the lining canvas before treatment showing the uneven distribution of the wax-resin adhesive. Image: National Gallery, London

beeswax and dammar adhesive, diluted in mineral spirit and applied cold. The intention was to enable the removal of the overall facing without affecting the Japanese tissue, so that the join would remain reinforced during a future rolling operation when the painting needed to be turned faceup after the removal of the wax-lining from the reverse.

The painting was taken to the relining studio and placed facedown on a large table covered with silicon-coated Melinex. The stretcher was removed and the lining canvas peeled away in strips—a relatively easy task given that the lining canvas had already become detached in parts and the adhesive had become weak and brittle.

The bulk of the wax resin, particularly the thicker areas—up to 7 or 8 mm thick—was scraped from the back of the original using sharpened metal strips, leaving a thin film of the wax resin, which was then removed with scalpels (see fig. 8.2). A certain amount of the wax-resin adhesive remained impregnated within the original canvas, but no attempt was made to extract this using solvents as the adhesive had not darkened the thick oil-based red ground and gray priming layers. Throughout the treatment, the center of the painting was reached by kneeling on large cushioned pads.

Structural Repairs

Once the old lining adhesive had been removed, the repairs to the canvas were carried out. The splits at the sides of the canvas were repaired with Evo-Stik Resin 'W,' an aqueous PVA adhesive. Many of the splits, as well as losses at the edges and small holes in the center of the picture, required inserts of new, oil-primed linen canvas adhered with the same PVA adhesive and then heated with a hot spatula and placed under weights until dry (see fig. 8.3).

The old, hard oil-based filling material used across the join was generally well adhered, and so was left in place apart from small, localized sections that had cracked and needed replacing with inserts of new canvas. The join was reinforced at the back with a 5-centimeter-wide strip of Stabiltex, a thin, gauze-like polyester that was preimpregnated with Lascaux 375 and attached using a hot spatula.

Abrasions to the back of the canvas caused by the previous delinings had left the red ground visible in several areas at the back, and these were consolidated with an aqueous acrylic adhesive, Primal B60A. The hollow areas were then filled with Mowiol GE 4-86, an aqueous polyvinyl alcohol binder, mixed with chalk and tinted with pigments to match the canvas color.

Moisture-Flattening Treatments

Many of the broader undulations in the canvas had disappeared with the removal of the wax resin, but some remained, particularly in the central area of the picture. The entire painting was given a flattening treatment by locally moistening the back of the canvas and covering it with boards and weights while the areas dried overnight. This was done section by section, starting from the center and working out toward the edges. The Melinex template made at the outset proved useful in locating specific areas of distortion, such as the creased areas of canvas, which were also moistened and massaged flat with a hot spatula. This proved reasonably successful. Attempts were also made to flatten the numerous small depressions in the picture surface caused by the fragments of old glue pressed into the paint surface, as well as the moated depressions around areas of impasto. These treatments, however, had little effect.

Turning the Painting Faceup

The painting was then ready to be turned faceup. It had been planned to do this by rolling the painting onto a large wooden roller, and then unrolling it faceup. However, given the number of splits and the amount of damage at the sides, there was a risk that rolling might cause further splitting. It was therefore decided to adhere a temporary strip-lining to the facing at the front of the painting so that it could be attached to its stretcher and then turned over. The strip-lining consisted of Saatifil PES 120/41, a thin polyester adhered with Beva film heat-sealed with spatulas from the back of the canvas. The stretcher, fitted with a polycarbonate panel, was placed over the reverse of the picture, and the strip-lining was then stapled to the stretcher. A further polycarbonate panel was slid under the front of the painting and taped around the back of the stretcher. The painting, stretched onto the stretcher and sandwiched between the two polycarbonate sheets, was then lifted off the table and turned faceup onto the table, which was covered with freshly siliconed Melinex.

The stretcher, the temporary strip-lining, and facings were all removed, and the losses in the painting were filled with Mowiol and chalk, tinted to match the color of the original gray priming. Following this, the painting was slid faceup onto the paneled stretcher, sandwiched between the polycarbonate panels and Melinex, and set aside while the lining canvas and vacuum envelope were prepared.

Preparation of the Lining Canvas

The lining canvas was prepared in an upper studio, as the ceiling height in the lining studio was too low to accommodate the wooden loom. The canvas—a single piece of linen with double warp and weft yarns—was stretched onto an expandable loom and wetted and prestretched three times to reduce the canvas's potential to shrink. The final wetting was done using a deacidifying solution of magnesium bicarbonate in distilled water with the intention of improving the longevity of the lining and its future removability (Ryder 1986).

The lining canvas was sized with one part Lascaux 375 to three parts mineral spirit, applied by brush. This not only provides a uniform appearance at the back after lining but also aids future reversibility by ensuring that more of the adhesive remains stuck to the lining canvas, rather than to the back of the original. Knots in the canvas were more readily removed (with scalpels) after the sizing, and both sides of the canvas were lightly sanded to give a smooth surface before a further six coats of Lascaux 375, diluted 1:1 in mineral spirit, were brushed onto one side of the canvas, with twenty-four hours drying time allowed between each coat. This produced an even adhesive layer that completely covered the canvas texture. The Lascaux 375 adhesive was not applied to the back of the painting, as that would have produced an overly strong bond between the two canvases and would impair the future removal of the lining.

The lining canvas was then removed from the loom and rolled onto a wooden roller, which was then taken to the lining studio.

Construction of the Vacuum Envelope

The vacuum envelope consisted of three lower sheets of thick Melinex taped together with good-quality cellophane tape and covered with overlapping sheets of silicon-coated Melinex, which were taped at the edges to the thick Melinex (fig. 8.5). The lining canvas was unrolled on top of the silicon-coated Melinex with the adhesive layer faceup, and the painting was then positioned on top of the lining adhesive.

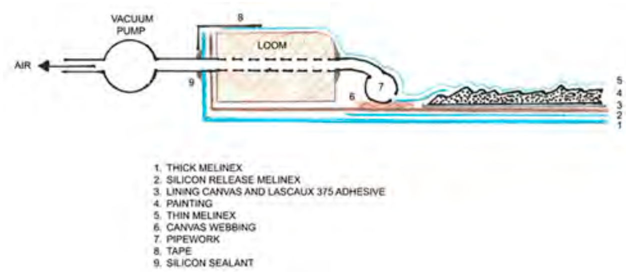

Figure 8.5 Diagram showing the construction of the vacuum envelope used to treat Van Dyck's *Equestrian Portrait of Charles I*. Image: National Gallery, London

The same loom used in the preparation of the lining canvas was positioned around the edges. The two long sides of the loom were reinforced with wooden strips to prevent it from bowing when the materials were stretched onto it, and holes were also drilled through the short sides of the loom to accommodate the tubing, which would later be connected to the two vacuum pumps (see fig. 8.5).

The lining canvas was first stretched onto the loom using staples. The thick Melinex was also stapled to the loom through a layer of tape to stop the Melinex from tearing, and the staples were then covered with more tape to prevent air leakage from within the envelope. The loom was lightly keyed out at the corners so that the lining canvas and Melinex were reasonably taut.

Strips of siliconed Melinex were taped around the edges of the picture to stop the exposed areas of Lascaux 375 at the edges of the painting from sticking to the top sheet of Melinex when the adhesive was heated (see fig. 8.5). This enabled the extraction of air from the central areas of the picture and ensured that the entire painting could be maintained under vacuum pressure throughout the lining process.

The air extraction system consisted of plastic plumbing pipes drilled with holes at regular intervals and placed around the edges of the picture and positioned on top of canvas webbing, which further aided the extraction of air (see fig. 8.5). The tubes connecting the pipework to the pumps were inserted through a hole at each end of the loom and sealed in place with silicon sealant.

The top sheet of thinner Melinex, three sheets taped together, was placed over the picture and taped to the top of the loom. Previously, the wooden keys in the corners had been covered with foam, and the edges of the loom rounded, in order to avoid any sharp edges inside the envelope that might tear the thin Melinex when under vacuum.

Apart from its size and the air extraction system, the construction of the envelope did not differ significantly from the one presented by Gerry Hedley, Stephen Hackney, and Alan Cummings at the Greenwich lining conference in 1974 (Hedley, Hackney, and Cummings 2003). As they discovered, the rigidity of the underlying thick Melinex is important in preventing areas of impasto and surface distortions in the painting from becoming "centered," or partially pushed out to the back of the lining when under vacuum.

The pumps were not fitted with pressure gauges, and three holes were drilled into the tubing at both ends to introduce air leakage and thereby a reduction in pressure. This number of holes was sufficient to allow the top layer of Melinex to be comfortably pushed away from the paint surface.

The Relining

A large Willard Multi-purpose Low Pressure Table with a surface area of 4 × 2 meters was used as the heat source. The painting, being larger than the table, had to be heated in two stages. Heating one half of the painting while the other remains cool presents a problem, however: as the first section is heated, the envelope and the materials inside it expand and can cause undulations between the heated and unheated areas. Several means were used to obviate this:

- The unheated section was warmed with domestic electric blankets covered with foil to retain the heat. This achieved a temperature of around 32°C on the picture surface.
- Four fan heaters were placed under the envelope pointing upward and toward the edge of the lining table. This gave a temperature of 38°C–40°C on the area of the painting above the edge of the table.
- A centimeter-thick strip of Plastazote foam was taped along the edge of the table to raise the envelope away from the tabletop and create an air gap that would reduce the temperature at this point.

The envelope was moved onto the Willard table with the half overhanging (not on the table) supported with adjustable props (fig. 8.6). For half an hour before the table was heated, the vacuum pumps were left running at full strength, with all the holes in the tubing covered with tape. This ensured that any air trapped between the lining canvas and painting was extracted.

Figure 8.6 Relining of the Van Dyck painting inside a vacuum envelope using a Willard Multi-purpose Table as the heat source. Image: National Gallery, London

The holes in the tubing were then untaped and the pressure reduced. The table's heaters, set at 70°C, were switched on, and at around 45°C, the temperature at which the adhesive begins to soften, local areas of the painting were treated with hot spatulas to improve small remaining surface distortions. The temperature at the top surface was independently monitored with thermocouples, and once these had reached 68°C, the envelope was lifted off the table and the second half was then positioned, with a slight overlap between the two sections. The electric blankets were removed and the foil placed over the already heated section.

Despite the measures used to prevent undulations from occurring, these did begin to appear, but they disappeared instantly when the props at the unheated end were raised, increasing the air gap between the envelope and the edge of the table, and thereby reducing the temperature at this point.

Once the entire painting had been heated, it was carried, still under vacuum, to a large table, where it cooled within fifteen minutes. The envelope was dismantled, and the following day the painting was restretched onto its existing stretcher using copper tacks, and the keys were secured.

CONCLUSION

The treatment did much to improve the surface appearance of the painting by removing the lumps and undulations created by the 1952 wax relining and also provided a more durable support for the picture than had been previously achieved. Although improvements were made to the raised creases that were a result of Morrill's second relining, the flattened and moated areas of impasto remained unchanged. After the relining had been completed, the painting was retouched and revarnished before being returned to display in room 31 (fig. 8.7).

Figure 8.7 Van Dyck's *Equestrian Portrait of Charles I* after relining and restoration. Image: National Gallery, London

ACKNOWLEDGMENTS

The National Gallery is grateful to the Getty Foundation for its generous support of the relining of the Van Dyck, which enabled the participation of seven conservators from the United Kingdom and abroad. Thanks are also due to the participants: Gerrit Albertson (Metropolitan Museum, New York), Francesca Bettini (Opificio delle Pietre Dure, Florence), Eva and Lucia Martinez (Museo del Prado, Madrid), Luigi Orata (private conservator, Florence), Camille Polkownik (Hamilton Kerr Institute, Cambridge), and Lisette Vos (Rijksmuseum, Amsterdam), and all my colleagues in the Conservation Department who assisted at various times throughout the project, particularly Lynne Harrison and Juraj Grac.

APPENDIX: TREATMENT DETAILS

Materials

Eltoline tissue: long fibered 100% manila fibers with good wet strength

Resin 'W': Evo-Stik wood adhesive, Bostik Ltd., United Kingdom

Saatifil PES 120/41: Preservation Equipment Ltd., Diss, Norfolk IP22 4HQ, United Kingdom

Lascaux Heat-Seal Adhesive 375: A. P. Fitzpatrick Fine Art Materials, London E1 5QJ, United Kingdom

Linen lining canvas with double warp and weft threads available in 4.2 m roll widths: Claessens Canvas, 8790 Waregem, Belgium

Mowiol GE 4-86: polyvinyl alcohol, Kuraray Europe GmbH

Stabiltex: No longer commercially available

Recipes

Wax-resin facing adhesive made from dammar resin and beeswax: 340 g beeswax/1700 ml dammar varnish (454 g resin/280 ml mineral spirit)/850 ml mineral spirit

Wheat-starch facing adhesive made from 25 g wheat starch/100 ml distilled water/25 ml sturgeon glue (10% solution in distilled water)

Deacidifying solution of magnesium carbonate in distilled water: 8.8 g magnesium carbonate/1000 ml distilled water prepared in a domestic soda siphon in which two carbon dioxide capsules were discharged to form an aqueous solution of magnesium bicarbonate

Mowiol and chalk filler: 240 g Mowiol GE 4-86/1000 ml water with enough chalk and pigment to produce a stiff paste

9

Demystifying Mist-Lining

Kate Seymour, Head of Education, Stichting Restauratie Atelier Limburg (SRAL), Maastricht, the Netherlands
Joanna Strombek, Painting Conservator, Stichting Restauratie Atelier Limburg (SRAL), Maastricht, the Netherlands
Jos van Och, Senior Painting Conservator (retired), Stichting Restauratie Atelier Limburg (SRAL), Maastricht, the Netherlands

Mist-lining was developed by Jos van Och at the Stichting Restauratie Atelier Limburg (SRAL) in Maastricht, the Netherlands, in the 1990s. It has since been used successfully to line numerous paintings, large and small, of different ages, conditions, and techniques. Pretreatments are used to solve distinct problems, leaving the action of lining solely to providing additional support. The mist-lining system avoids the use of heat, moisture, and high pressure and thus respects the integrity of the original structure and texture. Mist-lining provides an alternative, low-cost system to traditional or other modern lining techniques. Careful selection of lining support, the manner in which the lining adhesive is applied, and the means to set the bond differentiates this technique. The acrylic adhesive creates a "bridge" between the two canvases without impregnation. Choosing the right solvent for activation allows the acrylic adhesive to bond well to a wide variety of previously treated canvases, including wax-resin lined paintings. The bond has good shear resistance, though its peel force is lower. Delining of previously mist-lined canvases is therefore facilitated, allowing mist-lined canvases to be removed successfully, even over time.

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INTRODUCTION

Lining canvas paintings has ever been a contentious action. Many canvas paintings have been lined and at times relined. Age and condition have often not been prerequisites for implementing linings, as for a time it was seen as a preventative measure. Linings were intended to carry the load that the original damaged support could no longer bear, as well as solving a multitude of other structural issues, including consolidation and improvement of cupping and planar distortions. This often "one-stop" process was deemed long lasting, beneficial, and cost efficient. The type of lining carried out tended to be dependent on the training of the conservator-restorer, studio practice, and geographic location. Time has shown that the life span of linings is determinable, and the lining cycle continues.

The "moratorium" on lining called for after the 1974 Greenwich Conference on Comparative Lining Techniques (Villers 2003b) never materialized, but the idea encouraged conservators to think of other options for structural repair. Full linings fell out of fashion, and strip-lining as well as thread-by-thread tear mending became standard practice. However, these options cannot be used for severely structurally compromised canvas paintings—thus, full lining continues to be necessary. The mist-lining process is still a relatively new technique and not yet part of many conservators' toolkits. Familiarity with this process can expand the contemporary conservator's repertoire and provide one of a few ethical solutions for structural support.

The mist-lining process was invented and developed by Jos van Och in the 1990s at the Stichting Restauratie Atelier Limburg (SRAL) (Fife, van Och, and Harrison 2017; Seymour and van Och 2005; van Och and Hoppenbrouwers 2003). The term *mist-lining* was coined by SRAL in the early 2000s and is now used to denote the technique, system, and process. The mist-lining system has roots in developments in structural treatments for lining canvases initially presented in the 1970s by Gustav Berger and Vishwa R. Mehra and presented by both at the Greenwich conference in 1974 (Berger 1972a; Mehra 1975a; Mehra 1975b).

Mist-lining is a noninvasive lining technique that involves spraying minimal amounts of an acrylic dispersion resin onto an auxiliary canvas before adhering that canvas to the reverse of the original support, often without tension. This open adhesive network is regenerated from the dry state, eliminating moisture. Solvent vapors (or gentle heat) are used to swell and tackify the adhesive.[1] Bonding occurs under light pressure when the adhesive is activated. The system can be classified as a cold-lining method and forms a nap bond. The lining adhesive remains sandwiched between the two canvases with no impregnation of either textiles or decorative layers, which aids reversibility and negates any alteration of appearance.

MIST-LINING METHODOLOGY

The origins of mist-lining lie in the desire to find an ethical replacement for more invasive lining techniques. Conservators commit to following a code of ethics. These emphasize that cultural heritage should be preserved for future generations while respecting aesthetic, historic, and intangible significances, as well as maintaining physical integrity. Conservators should, thus, limit treatment to necessary actions and strive to use compatible, non-altering products, materials, and procedures. Treatments should not interfere with future actions, examination, or analysis, and should be reversible.[2] The nonimpregnating, easily reversible mist-lining system complies with this ethos.

The mist-lining process is not a stand-alone procedure and must be considered in relation to other treatments that will be carried out on the painting, either before or after lining. The mist-lining methodology requires each problem to be handled independently. Simply put, the issues presented by the painting are analyzed, and solutions to each specific situation are found and resolved independently of lining. The lining action is, thus, kept separate from other required treatments. This enables the process to be highly adaptable and tailored to the individual case.

Mist-lining is typically carried out after any reduction of planar distortions, overall treatment of the support, consolidation of paint layers, individual mending and/or strengthening of tears and holes, and removal of undesired superficial layers. Deformations are first flattened by prestretching the support and applying gentle and gradual lateral tension, often combined with humidification. Conversely, the mist-lining system will conform to any preexisting out-of-plane deformations and thus can be used to support (modern) canvas paintings devised with a more three-dimensional nature.

Consolidation of paint layers occurs as a separate step using an appropriate adhesive. Removal of varnish layers and overpaints is carried out prior to lining, though linings can be effectuated with any nonoriginal coatings left intact. Subsequent treatments often involve filling of paint losses, retouching, and revarnishing. After mist-lining, it is imperative to consider fully the implications of the choice of solvent for varnish application, or the use of heat to impress texture in fills, as both solvent exposure and heat will affect the lining adhesive. Some examples of pretreatments implemented prior to mist-lining are reported in the *Mist-Lining Handbook* (Seymour and Strombek 2022). Mist-lining has been a successful choice for paintings that have a past structural treatment legacy, whether lined with glue-paste or wax-resin adhesives or both. Research has been carried out showing that the sprayed acrylic adhesive adheres well to canvases impregnated with wax resin (Contreras 2015; Fischer 2002). This property enables the use of heat to be avoided on these thermo-sensitive structures.

The mist-lining process allows conservators to make the best choice for the needs of the individual canvas painting, rather than using a standardized technique to solve all issues. The choice to use the mist-lining system, thus, comes at the initial stage of the decision-making process—when considering the treatment plan—although the commitment to using the system can be altered, if necessary, as treatment progresses. The order of treatments, therefore, needs to be fully considered before the plan is confirmed. Our philosophy is to leave options open as much as possible. Each step of the treatment process is thought through, taking into account the consequences for subsequent procedures and future behavior of materials inherent in the system. For this reason, the pretreatments prescribed have great importance.

The decision to use this system comes with a caveat. Expectations for results need to be tempered to accept surfaces that are not as “flat as a board” or linings that are not as “rigid as a plank.” This system does not produce the same degree of surface finish and stiffness provided by traditional linings. The natural drape of the canvas and texture of paint layers will not be significantly altered during lining. Any out-of-plane texture or impasto (including cupping) that exists before lining will be maintained. Consolidation problems are not resolved. The key, as mentioned, is to treat these defects, as necessary, prior to lining and to accept a certain natural “aged” look. (This may mean taking a different approach to dealing with clients or owners of paintings.) Nor does the system provide a stiff lining support. Mist-lining moves away from the idea that the lining should carry all the stress within the laminate structure. Instead, a mist-lining provides “gentle” support to the original materials, helping to mitigate dimensional changes induced by climatic variations, but not preventing them.

These aspects of the system remain open to debate. No complete scientific study comparing mist-lining results to those of other lining systems has been carried out. This “new” approach thus remains unprovable. However, numerous paintings, large and small in scale and presenting a wide variety of past treatments and conditions, have been lined with this system. These have performed well over the last thirty years, so perhaps the “proof is in the pudding.” Ongoing research aims to provide further insight and answers to these issues (Poulis, Seymour, and Mosleh 2020).

THE MIST-LINING PROCESS

As mentioned, the mist-lining technique uses an acrylic dispersion resin sprayed onto a prepared auxiliary textile support. The result is an open network, rather than a continuous layer of adhesive, which is allowed to dry on application. After the lining canvas is placed in position, the adhesive can be regenerated in situ with solvent vapors. Bonding occurs under low pressure without the use of heat or moisture. The system effects a nap-bond with no impregnation of the original textile or migration into the decorative layers. This aids reversibility and avoids any change in appearance. Delining can be effected by applying peel forces (sometimes after solvent exposure) with little or no adhesive remaining attached to the original textile.

The technique requires little equipment and is easy to set up in the studio or on site. The low-pressure envelope can easily be adapted to accommodate paintings of different sizes or orientations (horizontal or vertical). Linings have been effectively implemented on all sizes of paintings, including large, oversize formats.[3] Low-pressure tables can also be used, if a flatter lining surface is needed. Furthermore, the adhesive mixture and application process can be applied to effect strip-linings if a full lining is not desirable.

Canvas Selection and Preparation

Factors influencing the choice of lining canvas are the ability to develop a nap, flexibility versus rigidity (drape), responsiveness to humidity fluctuations, type of weave, and thickness of the canvas. The response rate of warp and weft threads to external conditions should be similar. Open-weave fabrics are preferred, as less tension is required to decrimp the fabric and to remount the painting. More importantly, solvent vapors can diffuse more readily through open-weave textiles so less solvent volume is required during activation.

A wide range of textiles has been used by the SRAL team over the years. Research into the mechanical properties of linen, polyester, and mixed-fiber textiles has been considered (Young and Jardine 2012). Choices are made on a case-by-case basis. The canvas requires a spun-yarn textile fabric, rather than a monofilament. Typically, open-weave lightweight natural linen fabrics or a fire-resistant lightweight spun-yarn polyester textile (Trevera CS) are used. Many other fabric types have also been experimented with and employed (Seymour and Strombek 2022).

The lining canvas may be tensioned prior to the application of the sprayed adhesive. Natural linen textiles are decrimped only if the weave is dense, as the necessity is less for open-weave textiles. The desired tension of the lining textile is dependent on numerous factors. The conservator should determine if the lining process will take place under tension or with either or both canvases in a free state. This decision may depend on logistics (size), the condition of the painting (first lining or relining), and future display (environmental factors). Tension is thus considered a variable in the process and cannot be quantified with a constant number; however, the tension applied when preparing the lining canvas should not be more than what will be required when remounting the painting. The aim is not to overstretch the adhesive when the lining is complete and to effect in an undisturbed point-to-point bond between the two canvases.

The size of the original support (including tacking margins) is masked out on the lining canvas to ensure that the edges of the lining fabric are not coated with adhesive. The surface of the stretched lining canvas is prepared by enhancing the nap. The yarn is disrupted to encourage fibers to protrude from the surface. Nap fibers are fluffed up using sandpaper worked gently in the same directions as the weave. The yarn should not be broken. Care is taken not to disturb the napped surface before spraying on the adhesive.

Interleaf textiles can be inserted as required to provide enhanced local (to support tears or holes) or overall stiffness. Nonwoven polyester or woven glass-fiber interleafs (adhered prior to lining with either Plextol mixtures or Beva 371 film) are typically used at SRAL. These will mitigate the return of viscoelastic, out-of-plane deformations.

The Adhesive

Currently, two methacrylic ester-acrylic ester copolymer dispersions are mixed to obtain desired performance stiffness and solubility characteristics. Plextol D 540 and Dispersion K 360 (adjusted to pH 7) were used in a 30:70 ratio, but other formulations are being further investigated due to the discontinuation of Plextol D 540. The manufacturer of Plextol (Synthomer) has recommended as a substitute Plextol D 512.[4] This and other alternatives (Plextol D 498 and Plextol B 500) are being tested to compare results at Delft University of Technology (TU Delft) (Poulis, Seymour, and Mosleh 2020).[5]

A high-volume, low-pressure (HVLP) compressed-air spray gun is used to spray the adhesive onto the canvas in a fine mist. The spray mist only encapsulates the raised nap and does not impregnate the lining fabric or create a continuous coating. As only the nap is coated, the mechanical-physical properties of the canvas are unchanged; it remains flexible and able to conform to the drape and morphology dictated by the original canvas.

The optimum result is achieved when the adhesive is sprayed from different angles in more than one layer. The aim is to use as little adhesive as possible, something that is currently judged through experience. The coating should remain open and “fluffy” so as to allow the solvent vapors easy access. A thinner layer of adhesive will react more quickly to the solvent vapors and will need less pressure to create a bond, but the bond achieved will be more resistant if the adhesive layer is more substantial. It is, however, never the aim to have a thick layer of adhesive! The ultimate thickness of the sprayed adhesive layer is considered one of the key variables of the system. We suggest those new to the system practice these decision-making processes on mock-ups to gain insight into such variables. Figures 9.1 and 9.2 show an example of the dried adhesive layer applied to an open-woven linen canvas.

Figure 9.1 Close-up of the open-network sprayed lining adhesive. Image: SRAL

Figure 9.2 An open-weave linen canvas sprayed with an acrylic dispersion adhesive. Note the masked-out area, which is the exact dimensions of the painting that will be lined. Image: SRAL

The sprayed acqueous adhesive is allowed to dry before lining occurs. The two canvases are brought together before a subsequent bond is effected within a low-pressure envelope. The original canvas is carefully positioned on the lining canvas in contact with the sprayed area. Smaller paintings can be lined faceup with the lining canvas either loomed or untensioned, while larger paintings are typically lined without being tensioned and facedown. In the latter case, the lining canvas is often rolled into position over the exposed reverse of the original. It is imperative that placement is carried out carefully and precisely, so as not to flatten the fluffed, open network of the adhesive and to ensure that the weave of the lining canvas aligns with that of the original. Dragging the original over the sprayed adhesive surface will deform the adhesive surface and compress it into a continuous coating.

The Low-Pressure Envelope

The low-pressure envelope consists of two differing thicknesses of high-density polyethylene (HDPE) plastic sheeting and a ring of perforated pipes connected to a centrifugal fan (or vacuum cleaner) (fig. 9.3). Both plastic sheets should be solvent (and heat) resistant. The plastic sheeting is typically sourced at local building merchants. The thicker plastic sheet can be stretched to a working frame that is larger than the lining canvas or taped to a flat surface such as a table or floor. The thinner, unstretched plastic sheet should be flexible enough to accommodate surface topography (e.g., impasto, cupping). In some cases, the setup can be reversed.

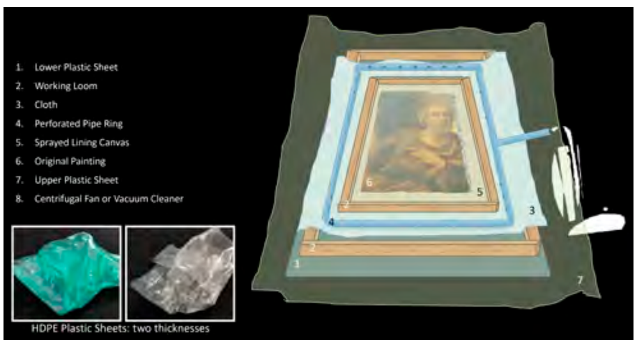

Figure 9.3 Schematic view of the setup for the low-pressure envelope. Image: Kate Seymour

The design of the low-pressure envelope is another key variable of this adaptive system. Varying the thickness and tension of the plastic sheeting will modify the pressure exerted. The flexibility of the plastic sheeting allows an even pressure to be applied over the whole surface area as the plastic conforms to the topography of the structure within the low-pressure envelope. Slight deformations in the canvas can, however, be manipulated, but the system does not exert sufficient pressure to push severe deformations into plane. A stiffer sheet of plastic (such as Melinex) would exert pressure on high points and the force exerted would be imposed on a smaller area. Using a too-stiff membrane could potentially cause moating or even flatten impastos; it could also push out-of-plane structures, such as seams, forward.

Air is extracted from the low-pressure envelope using a ring of perforated pipes (diameter about 2 cm). Typically PVC pipes, intended to house electrical wires in walls, are used. These are sourced from local building merchants. Other improvised versions could be utilized, such as garden hosepipes or washing machine hose. The tubes should not deform when air is extracted. Lengths of up to 3 meters can be bought and modified to the desired size. Connection pieces make it possible to extend beyond this dimension and connect at the corners. The ring should be a good 20–30 centimeters wider than the (loomed) lining canvas. Both plastic sheets used for the envelope should be larger than the ring. Holes are drilled into one side of the pipes at regular intervals. When assembled, all corners and joints are taped together to ensure the ring maintains its shape and does not disconnect during lining. A T-connector is used to attach the ring to the centrifugal fan. When placed in the envelope, the pipes are covered with a textile "sock" to ensure that the plastic sheeting is not drawn into the holes.

Air is extracted from the center of the envelope by including a piece of cloth slightly larger than the ring system. This is called a "breather." It is typically placed on top of the stiffer membrane. Note that there should also be soft material placed under the envelope, outside the system, to ensure the envelope is floating and that, if punctured, it will not be sucked down to the flat surface, which would induce excess pressure during lining.

When the centrifugal fan is turned on, air is extracted from between the two plastic membranes evenly. Sharp edges (e.g., working loom members) should be padded with cloth coverings. These also aid in the extraction of air from the center of the envelope to the ring system. Thin nonwoven fabrics can also be placed over the paint surface if desired; however, these stop the upper plastic membrane from following the morphology of the surface and may diminish the bond achieved. The exact conformation to the surfaces (upper paint and lower textile) by the plastic sheets permits a point-to-point bonding at a low, even pressure.

Although the low-pressure envelope is used in the lining process, it can also be used for a variety of other conservation treatments. Further information on the materials used is provided in the *Mist-Lining Handbook* (Seymour and Strombek 2022). We advise some experimentation prior to determining the setup for the low-pressure envelope.

Bond Formation

As opposed to a continuous coating, when dried the open adhesive network can effect a light bond with a relatively small amount of adhesive. A dried, thick, continuous (stiff) coating of an adhesive will need to deform or soften in order to uniformly connect the two undulating surfaces. In this case, heat and high pressure can expedite and ensure a good bond, but often at the expense of paint modification and impregnation of nonoriginal materials into the original textile and decorative layers. In the mist-lining system, the "fluffy" adhesive layer has a volume that accommodates the distance between the two woven textiles. During lining, gentle pressure is sufficient to ensure that the two canvases remain connected while the bond is being formed.

The adhesive is reactivated in situ using solvent vapors. Solvent exposure induces swelling, allowing the adhesive to regenerate and become tacky. The volume of solvent vapors, inserted into the envelope, required to regenerate the adhesive is carefully calculated to ensure that the adhesive swells and becomes sticky but does not dissolve, ensuring that the adhesive remains between the lining and the original canvas. Solvent selection is dependent upon a number of factors, including the sensitivity of paint and varnish layers, the condition of the reverse of the original support, any remnants of previous lining adhesives, and, of course, the solubility parameters of the adhesive. Acrylic dispersions are sensitive to a range of solvents, including alcohols and aromatic hydrocarbons.[6] Mixtures of these can also be considered. The choice of solvent(s), duration of exposure to solvent vapors, and the pressure exerted within the low-pressure envelope will affect the bond strength achieved and are considered variables in this system.

Testing ensures that the best solvent is selected. We recommend using smaller sections, or swatches, of a representative lining canvas sprayed with a similar amount of adhesive to test for an effective representative bond. Swatches are placed on the reverse of the original and exposed to different preselected solvent vapors for the same amount of time. The sections are left under weight until the solvent has evaporated, and then each is peeled away to evaluate the effectiveness of the bond. Experience builds an expectation of results, but tests ensure a better understanding of the individual variables that can be implemented for particular cases.

EFFECTING A MIST-LINING

The lining is carried out within the low-pressure envelope (fig. 9.4). First, the solvent vapors are introduced into the envelope using a "solvent-delivery cloth"—typically, an open-weave cotton cheesecloth. The ability of the solvent-delivery cloth to absorb the solvents used will dictate the volume of solvent that is needed; the volume used at SRAL is 60 ml of solvent per square meter of cheesecloth. The cheesecloth should be slightly larger than the area of sprayed adhesive, as it will shrink slightly as the fluid solvent is absorbed.

https://vimeo.com/762363049/f22edb5063
Figure 9.4 Video showing the mist-lining process. Video: SRAL

The solvent-delivery cloth is rolled up and encapsulated in plastic (clingfilm/Saran wrap) before the solvent is introduced. The solvent is injected into the package using a needle and syringe. Sufficient time must be allowed before placing the solvent-delivery cloth in the envelope for the solvent to spread evenly throughout the cloth. When the solvent has evenly dampened the solvent-delivery cloth and the lining setup is established, the cloth is rolled out inside the envelope, placed at the reverse of the lining canvas, as can be seen in figure 9.5. Placing the cloth in the envelope and rolling it out inside the envelope should be practiced, prior to the addition of the solvents, until it can be done quickly enough that solvent is not lost through evaporation (during the application process).

Figure 9.5 Mist-Lining Workshop trainees practicing placing the solvent-delivery cloth to reactivate the lining adhesive. Image: Joanna Strombek

The solvent vapors, thus delivered, defuse through the lining fabric to the open adhesive network. Once the adhesive is tacky (but not dissolved), the solvent-delivery cloth is removed; typically, this takes between ten and twenty minutes. Air is extracted from the envelope to expedite the activation time, but continual pressure is not necessary at this stage. The solvent-delivery cloth should be replaced with a dry cloth to facilitate solvent evaporation during bond formation.

Once the solvent-delivery cloth has been removed, the air is extracted from the low-pressure envelope. This causes the two canvases to be drawn together and the reactivated (thin) adhesive spray coating can bridge the distance between the two. Pressure is maintained until the majority of solvent vapors have evaporated and the adhesive is reset. The amount of pressure in the envelope is determined by the degree of air extracted by the centrifugal fan and the thickness/stiffness of the plastic sheeting. Typically, values of 90 mbar are reached and maintained for about sixty to ninety minutes. For safety reasons, as solvent vapors are being passed through an electrical motor, an attendant should be present at all times during the lining. The risk of sparks igniting dust particles within the motor should be prevented by using the motor exclusively for air extraction. Air exchange values can be used to reduce risk.

We recommend that conservators experiment and become comfortable with the system variables before undertaking a mist-lining. Results are impressive (figs. 9.6, 9.7). Aspects to consider are pretreatments, thickness of the adhesive layer, the type of solvents and lining canvas selected, and the setup of the envelope.

Figure 9.6 Deaccessioned painting prior to lining. Note that the out-of-plane deformations are mitigated prior to lining using gentle tension and controlled humidification. Image: SRAL

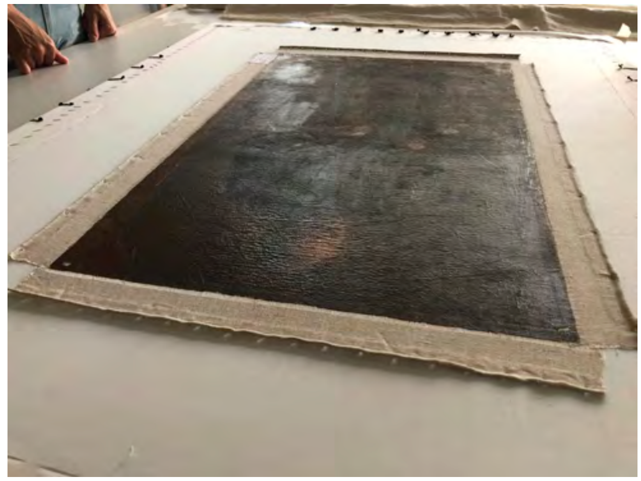

Figure 9.7 The deaccessioned painting shown in figure 9.6 after lining. The strip-linings added to apply tension prior to lining were kept in situ. The lined painting is still mounted on the temporary working loom. Note that the raised horizontal deformations are reduced, but the craquelure pattern is still evident. Image: SRAL

MIST-LINING DISSEMINATION

The SRAL team has imparted their knowledge and experiences of the mist-lining system to the wider conservation field over the years (see the appendix for a chronology of workshops and conferences disseminating the mist-lining system). Students studying conservation in the Netherlands have been instructed in the system since the early 1990s. International interns, fellows, and junior conservators working at SRAL over the past thirty years have all used the system. Papers have been written describing it, and presentations have been given at conferences (see Barbosa et al. and Brandt and Volbracht in this publication; Costantini 2013; Iaccarino Idelson and Garofalo 2019; Ruuben and Robbins 2011). Dissemination has had successes and failures and has led to further modifications in the system. The expertise of the system still remains largely in-house at SRAL, however, and the use of this relatively new system is not widespread. Because the system is adaptive and tailored to the needs of the painting, it is full of variables that may be difficult to grasp if not encountered in practice. Thus, confidence in considering this noninvasive and gentle approach to the structural repair of canvases may be lacking in many conservators less familiar with the system.

In 2019, with the generous support of the Getty Foundation's Conserving Canvas initiative, SRAL organized a Mist-Lining Workshop to further disseminate this technique and share our experiences.[7] The aim was to provide midcareer conservators from different world regions with hands-on experience in this alternative option for the structural repair of canvas paintings. At the same time, this global group also brought new thoughts and inspired further adaptations and developments of the mist-lining system (Nadeau et al. 2020). The workshop was documented in film and print. The video, produced by Bigeye Productions, can be viewed on YouTube for further insight.[8] The resulting *Mist-Lining Handbook* (Seymour and Strombek 2022) provides a valuable resource to the field. It is full of information on case studies, material information, and sources. Once practiced, the mist-lining system's variables become something that the conservator can use to tailor treatment to the particular needs of each case. The materials and equipment needed are low cost and relatively easy to source locally. It is hoped that these resources will give this viable system new traction as a treatment option.

CONCLUSION

The mist-lining system remains frequently used at SRAL. A numerical quantification of paintings treated with this system has not been carried out. However, it is safe to say that over the past thirty years, some hundreds of paintings belonging to local, national, and international collections have been treated by the SRAL team using this process. To date, none of those so treated have been returned due to failure of the lining. This body of work provides empirical confirmation of the success of the system. Of course, failures—or rather, disappointments—have occurred. These setbacks are typically evident immediately after lining, before the artwork is returned to its collection, and thus can be resolved immediately. Reflecting on these complications provides learning lessons for the SRAL team and encourages further developments or adaptations of the system.

Conservation ethics have shifted over the past decades toward a minimalist approach and avoidance of invasive treatments. The change in ethos to the structural repair of canvases allows the conservator to identify and find solutions to separate problems presented by the painting. Lining has become, with the mist-lining system, a custom action. There are, of course, drawbacks to lining with this system, such as covering the original canvas from view and using solvent vapors to regenerate the lining adhesive, because those vapors permeate throughout the painting structure. However, the choice of adhesive and its relatively long-term chemical stability mean that the adhesive bond can be reversed in the future. The original reverse of the canvas can thus be regained, if necessary, as the adhesive remains primarily on the lining canvas when delining.

The idea that the original canvas will never be the same again after a lining is carried out can now be left behind. The mist-lining system is noninvasive and can provide additional support for canvases without changing the stiffness of the original canvas and without influencing the appearance or saturation of the paint layers. While this process may not be the only modern solution to resolve this new way of thinking, it is an effective and versatile technique that has been used successfully for the last thirty years at SRAL and elsewhere to line a vast number of damaged paintings—and to reline paintings previously lined with glue-paste or wax-resin adhesives.

APPENDIX: CHRONOLOGY OF WORKSHOPS AND CONFERENCES DISSEMINATING THE MIST-LINING SYSTEM

1995–2006: Annual workshops for SRAL post-master's students

2006–20: Biannual workshops for postgraduate University of Amsterdam students

2007–8: Workshop and treatment of Hubert Vos's *Empress Cixi* at the Summer Palace, Beijing

2008: Workshop at Academy of Fine Arts, Dresden

2010: International symposium and workshop on lining techniques at SRAL

2010: "Current Practice and Recent Developments in the Structural Conservation of Paintings on Canvas Supports," ICOM-CC Paintings Working Group workshop at Metropolia University of Applied Sciences, Helsinki

2011: Ripping Yarns: Traditions and Advances in the Structural Repair of Canvas Paintings, British Association of Paintings Conservator-Restorers conference at the Courtauld Institute of Art, London

2011–14: Workshops at SRAL for students from the Courtauld Institute, London (2011); Hamilton Kerr Institute, Cambridge (2012); École Supérieure des Arts, Saint-Luc, Liege (2013); and New University (NOVA), Lisbon (2014)

2012: Glue-Paste Linings: Tradition, Performance and Stability, conference at Thyssen-Bornemisza Museum, Madrid

2015–18: Workshops for professions at M. A. Vrubel Museum, Omsk (2015); Indira Gandhi National Centre for the Arts, New Delhi (2016); Indian National Trust for Art and Cultural Heritage, Kolkata (2016); the State Tretyakov Gallery, Moscow (2018); and Brera Academy of Fiine Art, Arcore, Milan (2022)

2019–23: Getty Foundation, Conserving Canvas initiative, Mist-Lining Workshop (2019); Pilot Virtual Online Mist-Lining Workshop (2021); and Regional Mist-Lining Workshop (2023)

NOTES

1. Acrylic adhesives are thermoplastic. Thus, dependant on the Tg, gentle heat (about 50°C) is also sufficient to tackify the dry adhesive and create a bond.
2. European Confederation of Conservator-Restorers' Organisations (E.C.C.O.), "Professional Guidelines I: The Profession" (2002), https://www.ecco-eu.org/wp-content/uploads/2021/03/ECCO_professional_guidelines_I.pdf; "Professional Guidelines II: Code of Ethics" (2003): https://www.ecco-eu.org/wp-content/uploads/2021/03/ECCO_professional_guidelines_II.pdf.
3. *Panorama Mesdag* project (1986–96). The *Panorama* was painted by Hendrik Willem Mesdag and workshop in 1881; it is 14.70 m high × 114.70 m in circumference (van der Donk, de Herder, and van Lier 1996). See also Panorama Mesdag Geschiedenis en restauratie van een schilderij zonder grenzen: https://www.npo.nl/close-up/11-07-2015/AT_2037854. While not technically a mist-lining, the Beva 371 lining adhesive was flocked and the heat-activated bond was set using a low-pressure envelope developed by Jos van Och, and is therefore one of the projects considered evolutionary in developing the mist-lining system. This remains the largest known painting lined (vertically) in situ.
4. Email correspondence between Kate Seymour and Thomas Bernhofer, technical service manager, Coatings, SBU Functional Solutions, Synthomer, March 28, 2018. See also http://www.synthomer.com.
5. Until recently, tests at SRAL have been empirical in nature, conducted on mock-ups or historical material (such as old, removed lining canvases or deaccessioned paintings). The lining process and specifications have been adjusted and tested for specific cases. Samples were analyzed between 2014 and 2017 by Dr. J. A. (Hans) Poulis (director of the Adhesion Institute, TU Delft) and a team of interns at TU Delft, Aerospace Division as well as students from the University of Amsterdam as part of master's thesis research. See Poulis, Seymour, and Mosleh 2020.
6. The toxicity of the solvents can also be considered. Personal protective equipment (PPE) can be used to safely work with toxic solvents. Environmental factors and sustainability issues may also influence solvent selection.
7. To date, two more workshops have been organized under the auspices of the Getty Foundation's Conserving Canvas initiative since the first workshop.
8. "De-Mystifying Mist-Lining," instructional and documentary movie about the mist-lining system (2020), produced by Benjamin Brack and Akkie Brack-Sewalt, Big Eye Productions, https://www.youtube.com/watch?v=jU-QwEfYt44&feature=emb_title.

10

Linking Past and Future: Forty Years a Liner in Italy

Matteo Rossi-Doria, Paintings Conservator, C.B.C. Conservazione Beni Culturali

The author, a liner with extensive experience in structural conservation of paintings, describes the huge changes he has seen over the past forty years, specifically in the Italian context. Along a path that has passed from tradition to alternative synthetic materials and minimalism, the author learned to adopt an attitude of respecting each painting and adapting treatment to its individual needs while maintaining safety. The essay focuses on a reconsideration and reevaluation of traditional methods—whether they can be still used and if their characteristics can be better described from a chemical and mechanical perspective.

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INTRODUCTION

Forty years have passed since I first stepped into a conservation studio. I have spent all those years in Italy, but I have also had the opportunity to travel and build strong friendships with colleagues around the world. Working with them, I realized that each of us comes from a specific background with its own economic issues, culture, and conservation management, all of which has influenced our training, knowledge, approaches, methodologies, and working practice.

Italy is a small and challenging country with a huge heritage to preserve and a very long conservation history that has influenced generations of conservators in Europe. Because of this richness, in 1939 Italy established precise rules and roles to defend and protect its heritage based on central control by the Ministry of Cultural Heritage (Coccolo 2017). The ministry fixes the scale of priorities, the way projects have to be designed, and how cost estimates must be calculated (often by the square meter). It is a low-value economy, with private companies covering 90% of active conservation, competing to reduce prices and trying to work within tight schedules. It's not necessary to describe in detail how this public administration manages conservation needs, but certainly one of the first concerns is how to be sustainable without sacrificing quality of treatments. Our community in Italy has suffered under this condition, and only occasionally has it been possible to share our methods, approaches, problems, and concerns with an international community. For this reason, I am deeply grateful to the Getty Foundation for the great opportunity offered by the Conserving Canvas initiative.

CONSOLIDATION

At the Yale conference in 2019, we all focused on linings, showing different approaches and methods, but only a few presentations mentioned the need for some sort of consolidation of the paint layers. In my practice, I deal with many different cases that show severe deterioration. What I see, most of the time, apart from structural damage (tears, accidents, deformation, etc.) is the loss of strength of all original materials, due mostly to inappropriate environmental conditions. I can't list here all the different forms that the degradation takes, but what worries me most is the increase in porosity of many painting structures, the weakness of the supports, the risk of losses, and in general the fragility of these incredible artifacts (fig. 10.1).

Figure 10.1 Close-up illustrating an overall loss of adhesion and the need for consolidation. Image: Matteo Rossi-Doria

Consolidation is an irreversible process, and for this reason it is viewed as an embarrassment, something that is preferably not discussed. The Center for the Study of Restoration Materials (CESMAR7), an Italian association devoted to research on polychrome surfaces, organized two international meetings on this specific issue in 2006 and 2008 (CESMAR7 2008, 2010). We realized at that time only a few publications covered the subject and little research was being done; it seemed to us that everybody was trying to avoid this field full of uncertainties.

Of course, early lining methods were designed to provide some sort of strength to the grounds and paint film by infusing waxes, resins, and animal glues with the aid of huge pressures and high temperatures. But to definitively step out of this old story, we have to design specific consolidation strategies that are informed by a full understanding of the mechanical stresses and damages and of the degree and speed of deterioration of each component.[1] To do honest work, we should openly discuss many of our totems and try to establish a path toward an adequate decision-making process (Ciatti and Signorini 2007; Michalski and Rossi-Doria 2011; Rossi-Doria 2010).[2]

Consolidation involves a vast amount of knowledge and difficult ethical issues. Each of us has developed a personal framework to understand what the needs are in terms of consolidation, considering future deterioration and designing specific strategies that can guarantee efficacy and respect for the features of original materials—a difficult but necessary task. First we must understand the best way to achieve a reliable result: from the front or from the back? It's a never-ending story, and each of us has our own ideas.

I'm a witness to the changes in Italy on this issue. In the past, we infused animal glues from the reverse, controlling shrinkage dynamics, but then many liners started to consider the increase in sensitivity to moisture and mechanical stresses. After the disasters of the Florentine flood in 1966, our community made a drastic change: the adoption of a total infusion from the reverse of synthetic consolidants, such as Paraloid B-72, Plexisol, Beva, and others. These were able to strengthen the canvas fibers, treat the excessive porosity, and consolidate degraded paint layers. My generation dedicated a lot of effort to establishing how to manage this difficult task—testing and selecting materials, looking for appropriate concentrations and applications, and finding solvents of lower toxicity. This helped to separate the structural treatment into different steps, where consolidation was one part and lining another. The impact of minimalism pushed us to always look for a compromise between respect for original materials and the need for remedial conservation, dependent on the next steps of treatment as well as the quality of the future environment (rarely stable, rarely monitored).

Synthetic consolidants, in general, produced lower mechanical stresses and had lower reactivity to moisture than traditional consolidants; this in turn stimulated the search for glue-paste linings with reduced shrinkage risk.

TRADITION

In my presentation at the Yale conference, I showed how lining history developed in Italy through the centuries by focusing on a specific family who worked for 295 years on Roman heritage. Other contributions in this publication describe in more detail the cultural and methodological environment in which Italian liners designed different methods and approaches, mostly in Rome, Florence, Venice, Turin, Naples, Bergamo, and Bologna. It is an extraordinary history of skills, human capacity, and courage, one that produced some mistakes but also wonderful results, considering the difficulties liners had in those times.

During my career, I have had to remove some of these old linings and many times I could assess how respectful they were, still showing adequate adhesion after three hundred years but also easy to remove (fig. 10.2). The most interesting observation is the stability they often show when mounted on strainers with no means of expansion. These skilled artisans changed and modified their methods over time, and this history still belongs to our cultural environment, despite huge changes in the last fifty years.

Figure 10.2 Removal of a 280-year-old lining. Adhesion was adequate after 300 years, but the lining was also easy to remove. Image: Matteo Rossi-Doria

My practice was influenced by the "Roman method" designed by the Istituto Centrale per il Restauro (ICR). This method was brought to the ICR by assistants to Mauro Pelliccioli, a famous Italian restorer from Bergamo who was called to provide linings for war-damaged paintings. In 1963, facing the restoration of the three large paintings by Caravaggio, Giovanni Urbani, the head of paintings labs, refined the method by introducing the use of temporary expandable metal lining stretchers, instead of the heavy wooden looms that were unable to control tension during the lining process. The original Bergamo recipe went through some modifications, as did the ironing process.

Over the next forty years, Italians continued to line paintings using traditional methods, with some modifications. The big campaigns of restoration after the war, after the Florence flood, in Venice, and in Rome from 1980 to 2000, confirmed the differences between regional traditions. One example of this dynamic is the existence of two official Italian methods—the Florentine and the Roman—designed, respectively, by the Opificio delle Pietre Dure and the ICR, both part of the same institution, the Ministry of Cultural Heritage (Phenix 1995; Stoner and Rushfield 2012).

REEVALUATION OF WATER-BASED ADHESIVES

Working with glue-paste adhesives has been a necessity in my work. It's not that I thought these methods could be applied to all kinds of paintings—many would show problems, so it was necessary to be confident in the use of other methods and materials. It has always been obvious to me that no one treatment can be the magical one that solves all problems without causing any changes. For this reason, I always tried to widen my list of options and to adapt myself to many working conditions, from minimalism and the decision to avoid lining altogether up to (respectful) ways to use synthetic adhesives.

As mentioned above, sustainability is a crucial issue. The traditional glue-paste methods are low cost, easily used on-site, and don't require special equipment. Apart from being the only method that is completely nontoxic, it can be extremely effective, respectful, and totally reversible, and can provide stability and the desired stiffness. This is possible because it is adaptable and open to many modifications, as we will see in this paper.

For these reasons, in 1995 I started to reconsider all aspects of traditional methods. It has been a long process and remains a work in progress. In the last ten years, I intensified my studies, assessed test results, worked with international researchers, and monitored long-term results.

A big concern is mold growth and attack by *Stegobium paniceum* (the only insect we find on linings). All natural materials are hygroscopic and have that element of risk, but our observations in Italy indicate that problems occur only in specific microclimates with long exposure to high RH and poor ventilation. Recent tests (Fuster-López et al. 2017; see also Fuster-López et al. in this volume) demonstrate that the use of close-weave fabrics and some traditional ingredients—such as rye flour and molasses—can increase the risk. A good backing board, some space between the painting and the wall, and some basic control of damp will reduce this risk in a very effective way.

What worries me most about traditional linings is the amount of adhesive applied to the reverse of the painting. Excessive amounts (we might say abusive amounts) of adhesive, of very strong glues, increase sensitivity to humidity variations, resulting in mechanical stresses being transmitted to the paint layers.

The results of the ICOM-CC International Working Group, available in this publication (Fuster-López et al. in this volume), represent the first attempt at a scientific assessment of glue-paste linings. Some conservators have previously published results of experiments with modified recipes (Ackroyd 1995), but a full understanding was missing. Now, for the first time, it has become possible to study the influence of different materials and different application methods from a mechanical, physical, chemical, and biological point of view, and to establish precise parameters for further investigation.

MATERIALS SELECTION

Geographically, the list of materials used in traditional linings is more or less similar, with local variations in the natural fabrics and adhesive mixtures. This section is based on my research and experience.

Fabrics

Over the centuries, liners have never stopped discussing the selection of the best lining canvas to use, and the search continues to this day—although we now use a more quantitative approach (Young 1999). The selection of the fabric affects the method, the adhesive application, and many other factors.

Close-Weave Canvases

Liners have used close-weave canvases across many local traditions, including those of Florence, France, the United Kingdom, the Netherlands, Belgium, and Denmark. The shared concept is uniform glue application between the two canvases: the original and the lining. The canvas behaves as a semirigid support stiffened by animal glue, and adhesion is optimized by ironing, which dries the adhesive while applying pressure on the painting surface to flatten deformation or cupping. The glue layer, applied in an even adhesive film (in some traditions quite thickly), carries most of the load of the painting because close-weave fabrics provide poor grip and have high elastic modulus, but develop more mechanical stresses.

Observations from monitoring insect infestations shows an increase of deterioration in close-weave linings due to the fact that insects living in the glue layer are protected from ventilation, light, and predators.

Open-Weave Canvases

Open-weave fabrics are part of the Italian and Spanish traditions. In Italy, all methods apart from the Florentine apply open-weave canvases. Often, on large, heavy, damaged paintings, two similar fabrics were stretched on the same loom to obtain a stiffer support.

In my experience, open-weave fabrics don't need to be washed (unless thread count exceeds twelve to fourteen threads per square centimeter), so one can keep the stable materials introduced during production that are used to protect the fibers, such as starches, methyl cellulose, and butyl acrylates. They provide a better grip than close-weave fabrics, and the glue film is not continuous, similar to a nap bond. These fabrics are lighter, transmit lower mechanical stress, and are less reactive to RH variation. Mold can develop more easily than on close-weave fabrics, but insects, on the other hand, have a more difficult life.

These results confirmed my decision to use them as lining canvases. Open-weave fabrics can have various fiber densities (from 8 × 8 to 14 × 12), as well as various thread dimensions and torsions, thereby providing a range of performance in terms of support, stiffness, and capacity to stabilize deformations.

Adhesives

The revalidation of traditional materials and methods led me to study and then compare recipes used in glue-paste linings. First, I asked myself if the term *glue paste* properly describes these mixtures. I looked for a more precise name, settling on *water-based adhesive gel.* The name identifies the principal features of the two main ingredients—flour and animal gelatin—and their unique capacity to trap water for a long time. As they were the only adhesive materials available for centuries, it is interesting to assess how restorers varied the way they used them.

Then I started to study what these ingredients are from a chemical, physical-mechanical, and biological point of view. I had to admit that many of the concepts I had learned during training were totally insufficient or, in many cases, simply wrong. It took time to realize that conservation science rarely looked at other fields that research these natural materials, such as the food, cosmetics, pharmaceuticals, and biomedical industries. Multinational companies invest heavily in ongoing studies to optimize their products and their ability to manipulate these natural materials.

Apart from the Russian tradition, where only sturgeon glue and some honey were used, all other methods built their recipes using three main groups of ingredients: fillers (wheat and rye flours), materials with adhesive properties (animal gelatins), and additives that modify some of the mechanical properties (honey, molasses, Venetian turpentine, linseed mucilage, vinegar, oxgall, glycerin, oils). I will not focus on this last class of materials because, in reality, they have a marginal role in mechanical behavior in glue-paste linings. Instead, I think it is useful to focus on the two main ingredients: animal gels and flours.

Animal Gels

These amazing materials are used in many steps of treatment—as an adhesive for facings, a consolidant for paint film decohesion, an ingredient in glue-paste compositions, and as a binder for fillings. In tests over the years, animal glues were chosen for their high strength compared to all synthetic materials. I think it is useful, therefore, to establish some essential information that will guide how and why they can be used (Pearson 2003; Schellmann 2007; Bigi, Panzavolta, and Rubini 2004).

Animal gels are produced in two different ways: Type 1 with acid, and Type 2 with alkaline treatments. Most conservators work with Type 1 for their higher adhesive properties and gel strength. Manufacturers and mostly wholesale sellers and traders established in Europe, the United States, Asia (China, Vietnam, Cambodia, India), and to a lesser extent in North America, produce a wide variety of blends for food, cosmetics, and pharmaceuticals.

Gel strength (GS) is measured in terms of the Bloom grade.[3] Manufacturers produce gelatins with different Bloom values for different intended uses by varying the fundamental steps in biochemical treatments and number of extractions. Of course, the quality of collagen and basic materials plays a significant role, as do other additives.

Depending on Bloom value, gelatins vary their behavior with moisture and their rate of sorption and desorption. Mechanical tests in the conservation literature show curves measured at different RH values but, until now, none of them have specified the gel strength, only the general type of gelatin: rabbit, sturgeon, hide, or bone. Because it's difficult to find precise technical data on gelatin suppliers' labeling, it's probably necessary to develop our manual and sensory skills to (at least) establish a method to estimate gel strength. Specific features can be interpreted and evaluated to correlate with the Bloom scale: speed and quantity of water absorption/release, speed of gel degradation, color, smell, viscosity, time of tack, and gel stiffness. Sturgeon-bladder glue Bloom values have only recently been investigated. All the samples I tried had different Bloom values, as did other gelatins, and any considerations related to flexibility or the higher stability of bladder collagen are not correct if not related to measured Bloom and RH values (fig. 10.3) (Bridarolli et al. 2022).

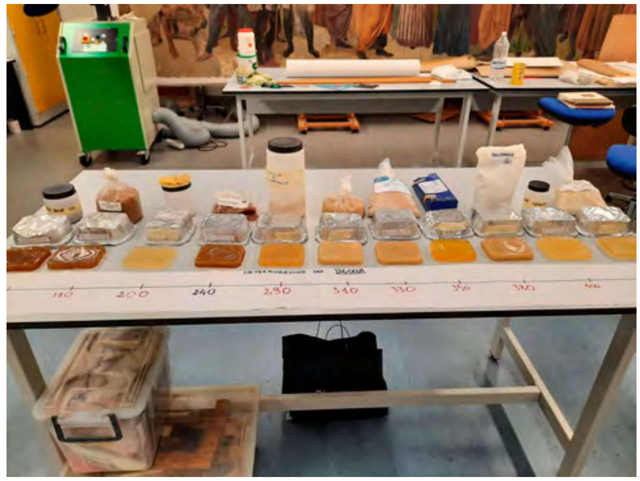

Figure 10.3 Bloom determination of different animal glues in a gel formulation, 1:3 in water. Image: Matteo Rossi-Doria

The range of Bloom values for an animal glue suitable for paintings conservation starts at approximately 150 to 400. Bloom 250 is an average that can be used for most of the purposes mentioned, but it is also possible to define more precise values for each use. Lower Bloom solutions have lower viscosity and longer setting/gelling times (but less strength), so these are useful when better penetration is needed.

Higher Bloom values provide the opposite: higher viscosity at a given concentration, higher adhesive capacities and tack, faster setting times, less response to short-term RH fluctuations, and more resistance to biological deterioration. They also require higher water temperature for dissolution. Bloom 250 can be used for effective facings and for fillings. Higher values, up to 350, can be used in glue-paste mixtures. Working concentrations vary depending on the gel strength. Working temperatures of 50°C–65°C play a crucial role in reducing viscosity so as to facilitate penetration, whereas room temperatures facilitate the gelling process and reduce penetration.

Animal glues lose their properties if exposed to high temperature or if reheated too many times.

Flours

Liners have used flours from various grains since the beginning. The reason is simple: they were easy to find and prepare, they were (and remain) very cheap, and they provide good adhesion, tack, and a nice stiffness. Their unbelievable mechanical properties (Delcour and Hoseney 2010) have been exploited by humans in thousands of different ways, depending on the materials' availability and local culture.

Flour plus water plus heat produces a gel with amazing capacities to trap water and keep it suspended for a long time. Properties can vary depending on the type of grain and the complex biochemical reactions of their preparation. In conservation, only wheat and rye flours were used since they had better mechanical properties than other grains.

Each flour has a different ratio of the two main components: starches and proteins. Wheat flour contains 70%–75% starch, 8%–14% protein, and other substances in small amounts (lipids, polysaccharides, fibers). Cereal and food science produces thousands of research articles about the manipulation of flour properties by the variety of grain and variation in the enzymes of starch and protein.

The capacity to easily manipulate any single component gives the possibility of designing specific blends depending on needs. In 2018, while looking at these possibilities, I thought it would be valuable to follow some of this research to understand if, going outside the limits of edibility, it was possible to design a blend that could be used as an adhesive generally—specifically as a lining adhesive.

Starches contain two different polysaccharides—amylopectin and amylase—in an 80:20 ratio, both insoluble in water without heat (>65°C). By slightly changing this ratio we can change the stiffness: greater flexibility by increasing amylopectin or greater stiffness by increasing amylose. This ratio is reflected in the protein content of a specific flour.

Proteins in wheat starch are mostly composed of glutenin and gliadin, which, when hydrated, form gluten. By changing the ratio of these two proteins or modifying the total amount, the food industry produces different blends that differ in their "strength." Strength is measured by the W index, which tells us how resistant a dough is in the rising process and how long it retains water and fermentation gas (carbon dioxide). For conservation purposes, a low W (120–170) provides a stiffer film when dry; conversely, increasing the protein content and W to 350–400 makes the film softer and more flexible. Results from the ICOM-CC glue-paste project (see Fuster-López et al. in this volume) suggest that a higher gluten content reduces water absorption, provides lower wetting capacities, and reduces reactivity to RH variations.

All additional substances, such as raising agents, baking powders, flavorings, sugars, and the like must be avoided.

MANIPULATING NATURAL MATERIALS

As we grow more confident with these methods and manipulate them better, we will be able to vary them according to our needs.

- Variation of density and viscosity could be achieved by adding or reducing the amount of water or by adding natural and synthetic materials, such as alum salts, chia or carob seed powder, high-gluten flours, Klucel G and carboxymethyl cellulose (CMC), Carbopol, and other thickeners (fig. 10.4).
- Variation of adhesive properties could be achieved by increasing or reducing the amount of natural and synthetic adhesives in the mixtures and, potentially, using specific flour blends.
- Variation of elasticity/stiffness and wetting properties could be achieved by using flours with different strengths (W), greater or less animal-glue gel strength (Bloom), adding synthetic materials such as acrylic emulsions, or pretreating the lining support.

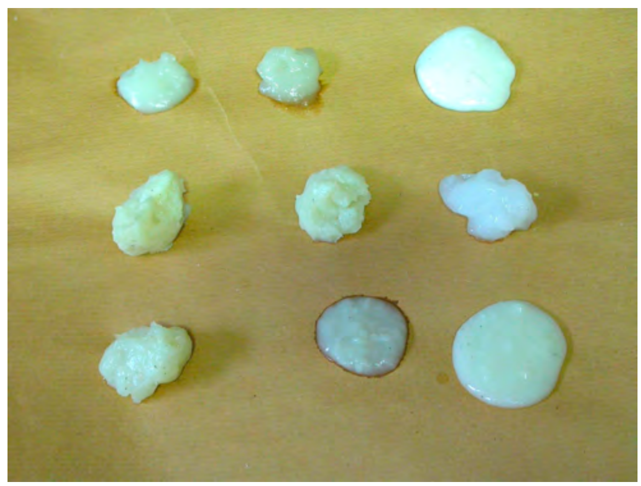

Figure 10.4 Experimental samples of different water-based adhesive gels prepared for tests and workshops demonstrating the varied physical properties that can be tailored to the project with simple ingredients. They contain, in different concentrations, materials widely used in conservation that can be dissolved in water, including different flours (low and high W), starches (wheat and rice), CMC (Tylose 300), HPC (Klucel G), thickeners (Klucel G, carob seeds, Carbopol), as well as adhesives (Plextol B 500 acrylic dispersion) and animal gelatins (low/medium/high Bloom). Image: Matteo Rossi-Doria

Although I avoid standardizing recipes, the mixture described below is more or less in the middle of all the considerations described above.

The filler part is a mixture of two different wheat flours with different gluten content and strength, in a ratio of

70:30. The first is W 180–250 and the second W 350. The flour blend is dissolved in water in a ratio of 1:3, then heated at 65°C–70°C until a gel develops.

Animal-glue gel (Bloom 250–350) that has been previously prepared in water in a ratio of 1:3 at 55°C is then dissolved into the warm flour mixture. A small amount of alum salts is also added at this stage as a biocide and thickener. The amount of animal glue in the recipe can vary but it is always much less than in most traditional methods. This drastic reduction in glue is necessary to decrease reactivity and mechanical stresses. All additional substances are, in my opinion, useless and should be avoided.

Once the mixture has cooled to room temperature, it is possible to add variable amounts of Plextol B 500 acrylic dispersion: 2% to 10%, depending on needs. This product, low cost and easy to find, can improve the adhesive bonding that was lost due to the reduction of animal glue, as well as increase flexibility. At the same time, it drastically decreases water capacity, thereby speeding the drying process, while providing good initial tack. Further research will probably confirm the amount of risk reduction in terms of reactivity and biodeterioration reduction. This adhesive mixture will always be easily reversible, being soluble in water. Any residue can be gently rubbed off.

APPLICATION METHOD

My reevaluation not only addressed the materials but also focused on the way they were used by the traditional liner. My question has always been whether these kinds of procedures are needed in order to guarantee a good result. Following this track as I worked on my experiments, I realized it was possible to change many steps of traditional treatments that I thought were wrong, excessive, drastic, useless, or even damaging.

As noted earlier, liners over time have designed specific strategies to control forces during glue paste application—using pressure, tension, or heat—and further reduced lining canvas reactivity by infusing hydrophobic substances such as wax and synthetic polymers.

Many conservators treat support and surface deformations using a combination of tension, pressure, humidity, and such procedures as low-pressure, vacuum, and others. I do that too, and results can be extremely successful, but without any stabilization, the "memory" of deformations will cause them to reappear sooner or later. It's an old story, but we still need to discuss it.

THE LINING PROCESS

Facing

This crucial step of structural treatment may be necessary if one has fragile paint that is at high risk of loss during subsequent steps of treatment, especially when removing previous lining materials. Any glue or adhesive applied on the front will try to flow through the porosity and fill the gaps caused by cleavage, delamination, and losses. The selection of a respectful facing adhesive depends on the nature of the paint layers, and wrong decisions can cause damage.

As a facing material, I selected a pure-cellulose tissue with 13 grams wet strength that has been calendared to be water resistant. The adhesive is applied through the tissue, as with Japanese paper facings. It sets quickly and adapts well to a variety of surface morphologies. Wrinkles are easy to remove.

The glue can be applied in different ways depending on the needs of the treatment plan—by brush or sprayed gently on the surface. It is easy to manipulate the concentration, Bloom values (200–250), and viscosities to achieve the desired result in terms of adhesion, preconsolidation, or treatment of deformations by exploiting a mix of traditional Japanese paper conservation techniques with similar Italian traditions.

When dry, the wet strength tissue provides good protection from mechanical stresses applied from the back to remove old canvases and glues. It also provides a barrier to infused consolidants, avoiding solvent migration to the front, and also helps in stabilizing surface deformations such as bad crack patterns. In addition, these facings are easy to remove and do not leave fibers on the paint surface.

Lining

The lining process is extremely simplified. The selected open-weave canvas is stretched on a provisional expandable lining stretcher that can accommodate a wide range of dimensions and consistently control canvas tension (fig. 10.5).

The adhesive mixture is then applied on the reverse of the painting in an even coat, and the working stretcher is correctly positioned on top of it. More adhesive is applied to wet the new canvas and provide a first bonding (figs. 10.6, 10.7).

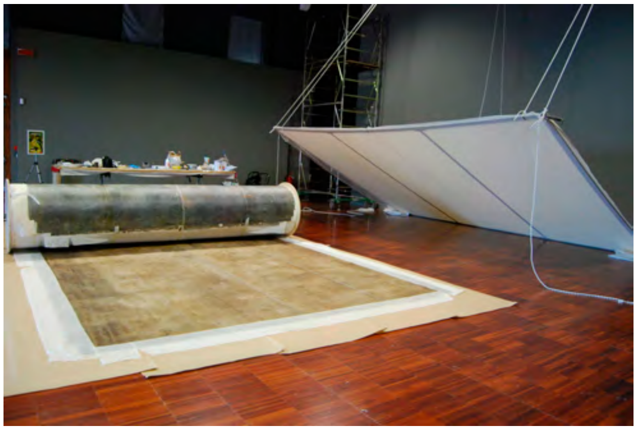

Figure 10.5 Lining preparation using a metal provisional expandable lining stretcher. Image: Matteo Rossi-Doria

Figure 10.6 Application of the selected adhesive mixture on the reverse of the painting. Image: Matteo Rossi-Doria

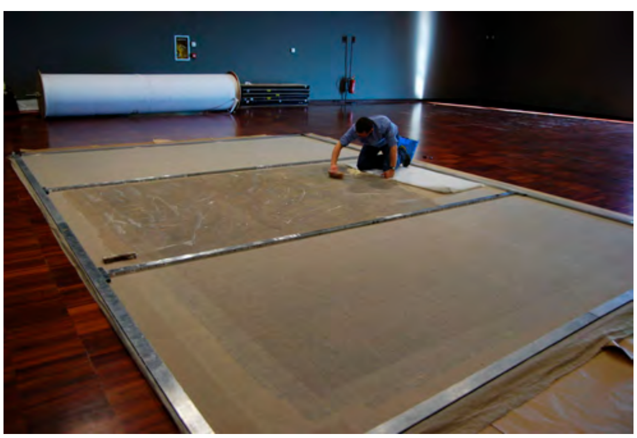

Figure 10.7 Application of adhesive through the selected lining canvas. Image: Matteo Rossi-Doria

The glue application behaves as a very slow humidifier that relaxes deformation and distortions. It is possible to set the time for an even humidification process, depending on the degree of deformation. In cases where deformations have been pretreated and the painting is flat, one can immediately apply gentle tension to the lining canvas and remove excess adhesive by manually pressing with wooden spatulas and other tools for an even application.

Drying time can vary depending on the need for additional humidification to soften hard cracks and surface deformation. In cases where we don't have such needs, the painting can dry without any additional operation, and ironing can be avoided.

Manual ironing is an option to treat surface deformation once it has been humidified by the glue during the lining process. It is possible to achieve great results without using huge pressure or high temperatures. Bad crack patterns can be flattened by locally applying additional moisture.

At the end of the drying process, the facing can be removed easily.

CONCLUSION

Looking ahead, it is possible that these methods will disappear from the accepted list of lining options and be mentioned only in lectures on the history of conservation—or will remain in use only by traditional liners in the private sector. However, I think that omitting this information risks the next generation of conservators losing a full understanding of how to properly preserve many thousands of glue-paste lined paintings all over the world. I hope this paper can contribute to a better understanding of the potentialities, features, and behavior of water-based adhesives, as well as stimulate curiosity to finally assess them in a rational, open-minded way (Rossi-Doria 2013).

As mentioned, I do work with other materials—Beva and acrylics—as other options. These alternative methods have their advantages and disadvantages, the latter mostly due to the use of high temperatures or solvents for reactivation; these linings have low elastic modulus and are quite difficult to remove without additional heat or solvents. The recent habit of using Beva film extensively concerns me, just as Vishwa Mehra in 1970 was scared by wax and its abuse. I hope we can soon reconsider this habit.

Even when using these modern procedures, I try to apply the same approach I use for traditional materials: looking for more respectful applications and avoiding flow of the adhesive inside the painting structure. I hope it will soon be possible to dedicate another paper to this topic.

NOTES

1. Of the various texts on the mechanics of paintings, adhesives, and consolidants from a conservation perspective, I particularly value CCI (Canadian Conservation Institute) 2011, Clarricoates et al. 2012, Mecklenburg and Tumosa 1991b, and Michalski 1991.
2. Ciatti and Signorini 2007 is the postprint of a one-day meeting dedicated to traditional Italian lining methods and is the only resource that contains a good comparison of Florentine and Roman methods.
3. See https://www.sizes.com/units/bloom.htm.

11

Customized Methodologies Developed to Solve Conservation Issues with Large Paintings on Canvas

Barbara Lavorini, Paintings Conservator, Istituto Centrale per il Restauro, Ministry of Culture, Rome
Luigi Orata, Paintings Conservator, private studio, Florence

This paper describes some customized methodologies developed to solve certain complex problems on a large-size painting on canvas by Alessandro Allori, which was restored at Laboratorio degli Angeli in Bologna for the exhibition Ferdinando I de' Medici: Maiestate tantum *at the Medici Chapels in Florence. These methods are used to illustrate the authors' own approach to complex structural problems.*

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INTRODUCTION

"We are firmly convinced that there cannot be a single method valid for every painting—not only for obvious reasons related to the nature of the work, but above all because of the individual 'character' of the painting, with its 'own' fabric, its 'own' ground preparation, its 'own' pigment and its 'own' reaction to the passage of time. It follows that if there is no single method and no single material appropriate to every picture, it must and will be for the painting itself to impose a careful choice between the various methods and materials" (Baldini and Taiti 2003, 115).

The quotation above is an excerpt from Sergio Taiti and Umberto Baldini's address at the Greenwich lining conference in 1974. Sergio Taiti had been chief conservator for structural treatments on canvas at Opificio delle Pietre Dure of Florence for about twenty years, and during his tenure he distinguished himself for having a deep sensitivity toward the specific characteristics of paintings. We didn't have the opportunity to meet him in person, but we had our training in canvas conservation with Luciano Sostegni, who had worked closely with Taiti and became his successor at the Fortezza da Basso's Laboratories. Although our profession led us to test and use new and different materials and methods, his teachings remain the basis for our approach to work and we are still firmly convinced of their validity.

We believe that preliminary study of a painting, in order to deeply understand its materials and technique as well as its present condition, is essential to define customized treatments for conservation. From this point of view, we try not to focus on only a single material or methodology; instead, during the preliminary decision-making phase, we usually take into account a wide range of possibilities. By doing so, we allow ourselves the opportunity to employ different materials in different ways.

Moreover, we consider the minimal intervention approach as our guide, but we believe that some clarification about this matter is needed. We think that the *minimum* should definitely be calibrated to the specific needs of the artwork in order to solve its conservation problems, slow its degradation process, and try to avoid further treatments in the near future. If keeping the treatment to a minimum means minimizing the impact of conservation on the artwork, we should consider only treatments that actually solve the identified problems. For example, neglecting to guarantee the color or the priming layers' adhesion to the original support effectively might lead the painting to undergo another conservation treatment within a short time, and this will probably result in a more stressful and invasive practice in the end. At this point, can we say that we have kept our treatment to the minimum needed, or should we admit that what we have done is not enough appropriate to the conservation needs of that individual artwork?

For a decade we have adopted and promoted a diagnostic protocol[1] aimed at defining a more accurate and objective situation to provide additional information to help the conservator (with his own experience) in choosing a more appropriate methodology, specifically suited to the artwork's structural conservation conditions.

ISSUES WITH THE PAINTING

The painting by Alesandro Allori is *Allegory with the Triumph of Florence* and measures about 30 square meters. It was created in 1588–89 to celebrate the marriage of Ferdinando I, grand duke of Tuscany, to Christine of Lorraine, and was located outdoors, above the arch of the Florentine Porta al Prato. The scene was painted with a leanly bound oil applied in thin and even layers. The fine linen canvas was made of four pieces, whose selvages were positioned horizontally and sewn together. The support was prepared with a thin, light gray ground, probably using animal glue and a little linseed oil as a binder.

When we first examined the painting, it was in storage at the Pitti Palace. The canvas was mounted on a three-part folding wooden stretcher (fig. 11.1), probably provided after the canvas was lined with a glue-paste adhesive in the early part of the twentieth century. The painting suffered new damage during the flood of Florence in 1966: it was partially impregnated with water, mud, and naphtha (which had leaked from buildings' heating systems and was carried by the flood water), and diffused biological growth developed. Repeated handling of the folded painting over time had led to the permanent deformation of the original canvas along the perimeter, resulting in a 15-cm extension at the edges compared to the middle area of the support width. The old lining adhesion was compromised, with evident and diffused blistering. Over two hundred new tears, cuts, and holes weakened the canvas, and some patches had been glued to the back of the lining using animal glue or wax resin.

Figure 11.1 Alessandro Allori (Italian, 1535–1607), *Allegoria con il trionfo di Firenze*, 1589. Oil on canvas, 484 × 630 cm (190 1/2 × 248 in.). Florence, Medici Chapels. The painting before restoration, mounted on a three-part folding wooden stretcher. Image: Laboratorio degli Angeli S.r.l., su concessione del Ministero per i beni e la attività culturali e per il turismo – Museo Nazionale del Bargello (prot. MIBACT_MN-BAR n.1446-P del 01/07/2020). No modification or further reproduction of the image is allowed.

Thick mud residue, molds, and patches were also visible on the front. The original seams appeared partially ripped and deformed, and extensive fillings and retouching on the paint layers were mostly applied on these areas.[2] The painting had been folded with the painted side face in, and this led to the detachment and loss of thousands of paint fragments. After the flood, an attempt to fix unstable paint layers was carried out using wax. This led to the complete waterproofing of some localized areas, especially around the seams joining the pieces of the original canvas.

The main problems to solve were reducing the huge deformations of the canvas, restoring the compromised structural integrity of the support, providing a good adhesion between the paint layers and the original canvas and, finally, evaluating the ability of the support to undergo a new tensioning on the stretcher, considering its large size and significant weight.

CONSERVATION TREATMENT

To define the methodological choices and the materials to use, compatibility with the original materials, use of minimum amounts of new materials, and future reversibility were all considered. Since full reversibility of binding agents for consolidation or adhesives that impregnate the paint layers is often impossible, it was important to us to leave open the possibility to use a wide range of materials in the future.

Three main operating activities to reflect on were identified: the facing, the re-adhesion of the paint layers to the support, and the lining.[3] These three phases are clearly separate, even if strongly interconnected, especially with regard to facing and consolidation. This is due not only to the need for compatibility with the painting materials, but above all to the intimate connection taking place during the intervention. Treating the canvas from the back with an adhesive to fix flaking paint layers will probably lead to the impregnation of the faced surface. It is then crucial to consider products with similar properties and solubility—or at least to evaluate the possible interactions of materials. This is important to ensure correct and easy removal of the facing. For that reason, theoretical considerations were reviewed and tests were run to select the best material to solve the specific problems mentioned above.

In order to facilitate the flattening of the canvas and to be sure of safeguarding the appearance of the lean oil technique, an aqueous method was preferred and adhesives like extra-fine rabbit-skin glue and Aquazol were tested.[4]

Before facing the surface, dust and mud residue were carefully removed using soft brushes and swabs with deionized water. Some local preventive fixing was needed to avoid color losses. Old fills and retouching were eliminated, mold was removed, and the areas affected were disinfected.

During the surface facing, a first flattening of the canvas's deformation was possible, thanks to the moisture added by the aqueous adhesive and to some light tensioning provided by the contraction of Japanese paper while drying (fig. 11.2).[5]

Using a polystyrene roller, the painting was then turned facedown to work on the back and remove the old lining adhered with glue paste.[6] The residue of the old glue paste was carefully removed with a scalpel. In some problematic areas where the adhesive was particularly tough, an agar gel[7] was used to swell and soften it, making removal easier.

Figure 11.2 *Allegoria* during the restoration process. The painting is faced with Japanese paper; sheets fixed around the perimeter were glued to the worktop to prevent shrinkage as the glue dried. Image: Laboratorio degli Angeli S.r.l., su concessione del Ministero per i beni e la attività culturali e per il turismo – Museo Nazionale del Bargello (prot. MIBACT_MN-BAR n.1446-P del 01/07/2020). No modification or further reproduction of the image is allowed.

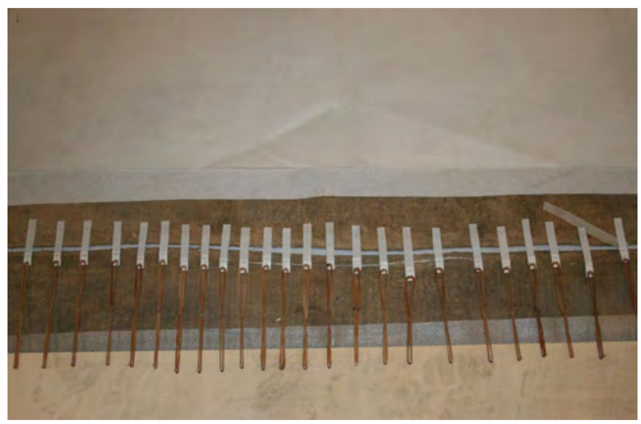

Figure 11.3 Detail of a seam brought back to the correct position with the aid of tension (tie-beams) and moisture. Image: Laboratorio degli Angeli S.r.l., su concessione del Ministero per i beni e la attività culturali e per il turismo – Museo Nazionale del Bargello (prot. MIBACT_MN-BAR n.1446-P del 01/07/2020). No modification or further reproduction of the image is allowed.

All cuts were brought back to the correct position with the aid of tension applied using tie-beams adjusted by rubber bands (fig. 11.3), and moisture released through a Gore-Tex fabric. Polyester fabric tie-beams were adhered to the back of the canvas with original formula Beva 371 film. The humidification, tension, and time needed were related to the extent of deformation being treated. A polyester thread was used to resew the selvages where necessary, passing through the holes of the original seam when possible.

Many cycles of humidification and tension were needed to flatten the canvas. Due to the very large size of the painting, stretching it on a temporary loom was deemed expensive and impractical, so it was decided to tension it on a thin worktop placed directly on the floor. To do this, strips of polyester canvas[8] were fixed to the perimeter with Beva 371 film, reactivated at two different times: the first on the polyester canvas, at 80°C, and the second on the back of the original canvas, at 65°C. This particular procedure is intended to create a stronger bond between the adhesive and the polyester canvas than between the adhesive and the original canvas, ensuring better reversibility in the future. Ideally, no adhesive will be left on the original canvas when the strips are removed; at worst, only a few traces will remain.

A complex problem we needed to solve was recovering the adhesion of paint layers that had been treated with wax or impregnated with nonpolar substances in the past, using an aqueous adhesive. This was preferred to help the flattening of the original canvas and to guarantee the easy removal of the facing. Tests were performed to evaluate the strength of the bond produced by extra-fine rabbit-skin glue, sturgeon glue, and Aquazol 500 and 200 dissolved in water, ethanol, and acetone. Aquazol 500 in acetone showed good adhesion properties on wax samples.[9]

To adhere the paint layers to the original canvas, two coats of Aquazol 500 were applied at two distinct times. First, Aquazol 500 in acetone at 10%[10] was applied to guarantee good adhesion of the areas that presented wax and nonpolar substances. Later, a second application of the same resin dissolved at 5% in a solution of acetone and water (1:1) was used to effectively increase the flattening of the canvas.

After the complete evaporation of solvents, always keeping the painting tensioned,[11] the thermoplastic adhesive was reactivated by heat in a vacuum bag (envelope). Heat was transferred to the adhesive using water at a predetermined temperature, provided by a movable temporary "tub" figure 11.5. The materials needed to carry out this intervention are shown in figure 11.4. The painting was placed facedown in a vacuum bag made of silicone-coated polyester film (Melinex). On the top of this bag, a tub made of a Melinex sheet placed in a wooden loom[12] was prepared. A certain volume of water, preheated to a predetermined temperature, was poured into the tub . After ten minutes,[13] the water was removed and the tub was shifted to treat another area. This operation was repeated to treat the whole surface, always keeping the painting under pressure in the vacuum bag.[14]

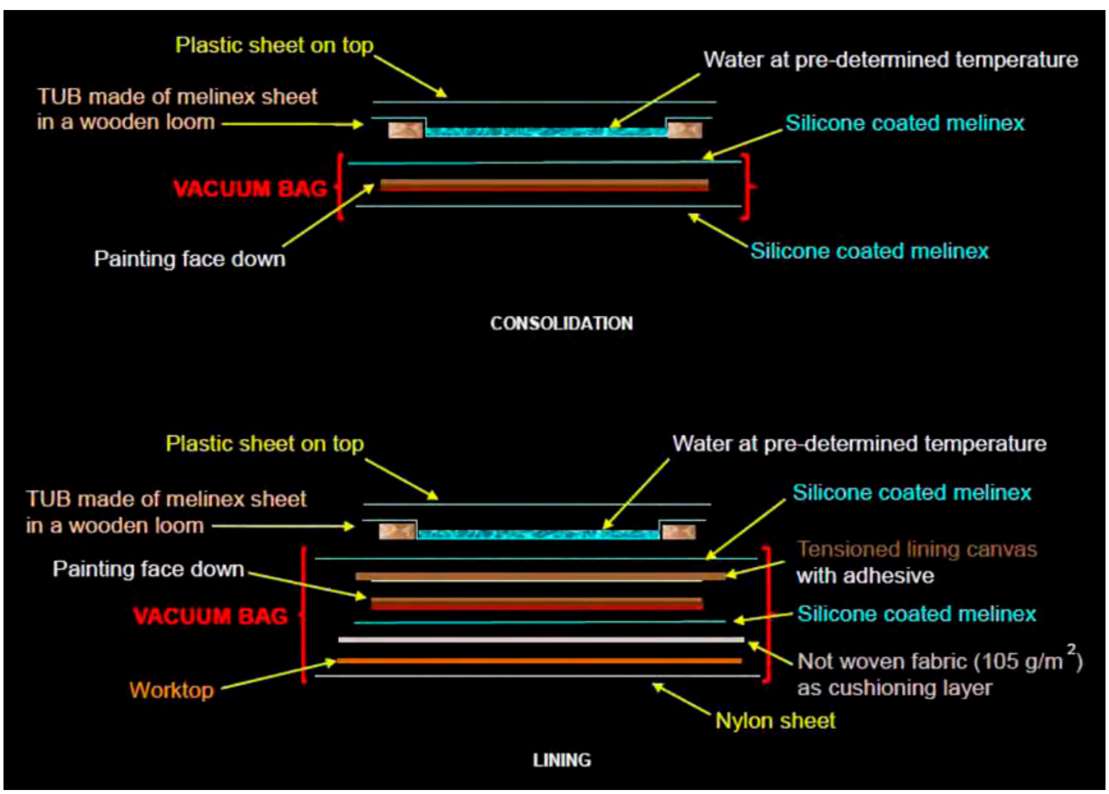

Figure 11.4 The tub system used to reactivate a thermoplastic resin in a vacuum bag. Image: Barbara Lavorini and Luigi Orata

Table 11.1
Tensile test performed on different adhesives used to join strips of canvas 1 inch wide

Resin	Breaking point (kg)			
	Sample 1	Sample 2	Sample 3	Average value
Polyamide	3.320	1.330	1.970	2.206
Akeogard AT35	0.320	0.430	0.496	0.415
Akeogard AT35 + water (1:1)	2.300	1.400	1.400	1.900
Ethylene vinyl acetate (EVA)	1.080	0.850	1.020	0.938

Source: Orata 2009. Used with permission.
Table: Barbara Lavorini and Luigi Orata

https://vimeo.com/801439551/7d9863ee77
Figure 11.5 Video of the tub system. Video: Barbara Lavorini and Luigi Orata

It's important to note that this method is not an alternative to the use of a hot table, but it permits heat transfer from the back when it is necessary to work with the painting facedown.[15] Using a vacuum system and applying heat through a tub containing preheated water guarantees that the whole surface is treated with the same pressure and temperature, substantially reducing the risk of nonhomogeneous performance of the thermoplastic adhesive.

In preparation for mending structural damages, some adhesives were tested (table 11.1). To avoid damage to the original canvas in the future, the breaking point of the adhesive should be equal to or slightly less than the toughness value of the original yarn (Orata 2009), measured by tension test with a dynamometer. The adhesive with a breaking point that is similar to that of the original yarn is highlighted in red in the table.

All the cuts, tears, and holes (more than two hundred) were mended thread by thread using Akeogard AT35[16] applied with a tiny brush, using an optical visor. All the structural damages and the four seams were further reinforced by applying monofilament fabric patches adhered with a mixture made of 80% Plextol B500 and 20% Dispersion K360, reactivated by butyl acetate.

With the first steps of consolidation, tear mending, and humidification complete, we evaluated if lining was necessary. A series of elements, such as the dimension of the canvas in relation to its ability to support itself, the presence of more than two hundred structural damages, the advanced degradation of the cellulose, and the presence of four horizontal seams, led us to the decision to apply an auxiliary support. As mentioned, every case is unique, and sometimes it is appropriate to assess the use of different methods and materials for lining.

Glue-paste lining did not seem suitable, not only because it would increase the weight of the whole structure, but also (mostly) due to the difficulty in maintaining the appearance of the painted surface, preventing the seams' stitches from impressing on the front, and preserving the original seams (Lavorini 2007). Lining with Beva 371 was also disregarded due to the evaporation of a large amount of solvent (such as toluene) during the operation. Cold-lining, using the Mehra system (Mehra 1981a), was just as risky for the large amount of butyl acetate (or similar solvent) needed to reactivate Plextol.[17] Using a thermoplastic adhesive in aqueous dispersion appeared to be a good solution to avoid the use of a fair amount of solvent, with its attendant risks of toxicity and fire.

A study focused on testing different adhesives obtained by mixing Plextol B500 and Dispersion K360,[18] in different proportions, was carried out to obtain a final mixture to be reactivated by heating. Empirical tests were performed to define the approximate reactivation temperature and the reversibility of each mixture (Orata and Capellaro 2013, 57–66) in order to identify the one that would better fit the features and conservative conditions of the painting (table

Table 11.2
Test results for different resin mixtures performed to determine reactivation temperature and evaluate bond and reversibility

Sample	Resin mixture	Temperature				
		40°C	50°C	60°C	70°C	80°C
1	100% Plextol B500	W	W	W	W	W
2	100% Dispersion K360	S	S	G	G	G
3	80% B500 + 20% K360	W	W	W	S	S
4	70% B500 + 30% K360	W	W	S	G	G
5	60% B500 + 40% K360	W	S	G	G	G
6	50% B500 + 50% K360	S	S	G	G	G
7	40% B500 + 60% K360	S	S	G	G	E

Notes:
Adhesion by vacuum bag (700 mbar) and constant heat for 10 min at different temperatures.
W = Weak, S = Sufficient, G = Good, E = Excellent
Source: Orata and Capellaro 2013. Used with permission.
Table: Barbara Lavorini and Luigi Orata

11.2). The possibility of matching specific needs makes this acrylic-based class of adhesives very advantageous in devising innovative solutions.

Samples 1 and 2 are tests on the two pure resins (see table 11.2). Each mixture was sprayed on a polyester canvas mock-up. After solvent evaporation, each was joined to a linen canvas mock-up in order to simulate the real conditions of use. The mock-ups were then placed in a vacuum bag and lined by increasing the temperature incrementally starting at 40°C and going up to 80°C, applying a constant vacuum of 700 mbar. After each 10-degree increase, the bag was opened, each mock-up was tested, and the degree of adhesion was evaluated. Sample 4, composed of 30% Dispersion K360 and 70% Plextol B500, reactivated between 60°C and 70°C (shown in red in table 11.2), showed a good combination of adhesion and reversibility.

This adhesive was sprayed on the stretched polyester canvas.[19] Particular attention was paid to maintaining the correct tension of the lining canvas during the entire process. In fact, during the reactivation of the thermoplastic adhesive, the lining canvas was stretched again on the worktop to maintain the orthogonal orientation of the warp and weft threads and to avoid the transfer of undesirable tensions to the painting during the final stretching phase. If the lining canvas is not tensioned when applying the adhesive and when the lining is adhered to the original canvas, its threads will remain more extensible. When the lined painting is finally stretched on the definitive stretcher, more tension would be required to first stretch those loose threads before transferring tension to the whole lined support. This excessive tension could result in damage to the original canvas, which is usually less elastic than the new lining canvas.[20]

Before lining the painting facedown in the vacuum system, it was necessary to fill the biggest losses with stucco to avoid the original canvas being pushed toward the paint surface, where paint layers were missing.

The adhesion of new canvas was carried out in a vacuum bag (envelope), with the painting placed facedown on a worktop. Nonwoven fabric[21] was used as a cushioning layer to preserve the thin brushstrokes, keeping the seams on the back at the same time. The adhesive was reactivated by placing 70°C water inside a loom and treating circumscribed areas of about 1 square meter using the tub system described above and outlined in figures 11.4 and 11.5. To stretch the canvas on the final expandable stretcher, the painting was positioned facedown to reduce the forces applied at the edges.

Not all the losses were filled and retouched because the art historian who directed the conservation treatment chose to leave a historical memory of the flood of Florence. When the treatment was finished, the painting was exhibited at the Medici Chapels in Florence (fig. 11.6).

Figure 11.6 *Allegoria con il trionfo di Firenze* after restoration. Image: Laboratorio degli Angeli S.r.l., courtesy Ministero della Cultura – Museo Nazionale del Bargello (prot. MIBACT_MN-BAR n.1446-P del 01/07/2020). No modification or further reproduction of the image is allowed.

CONCLUSION

The methodologies described above are only some examples of solutions outlined to solve specific conservation issues on large-size paintings, but they represent the way we approach the work, focusing on the artwork, which always has its own requirements as a result of the properties of its original materials and subsequent history.

We believe that no best or worst methodology exists, but a specific and suitable intervention should be applied based on a deep understanding of both the painting technique and the conservation history of the artwork. A protocol of scientific analysis helps to identify and quantify structural damages and then decide, based on the experience gained with practice, which conservation strategy is more appropriate to solve the specific problem, regardless of tradition, inclination, or current trends.

ACKNOWLEDGMENTS

Thanks to Jennifer Ginevra (TEFL/Cambridge educator) and Dan Butcovich Pieroni (CELTA/Cambridge educator) for providing edits and revisions.

NOTES

1. Measuring the canvas pH, the degree of polymerization (DP), traction testing of the yarn (tensile strength) with a dynamometer, and eventual examination with scanning electron microscopy (SEM) and energy dispersive X-ray spectroscopy (EDS). See Orata 2009, 25–31.
2. The original support is made up of five pieces stitched together along the selvages.
3. Like every conservation treatment, these phases are optional and the restorer evaluates whether it is necessary to perform each one of them from time to time.
4. Both Aquazol 200 and 500 were tested. See Arslanoglu and Tallent 2003, Arslanoglu 2004.
5. Extra-fine rabbit skin glue produced by *Le Franc & Bourgeois* was used to face the painting layers with Japanese paper sheets (Tengujo kashmir 9 g/m^2). The sheets fixed around the perimeter were glued to the worktop to prevent shrinkage while the glue dried. The high refining degree of this glue guarantees good elasticity and very light color, reducing the risk of color changes in a painting made with such a lean oil.
6. Florentine glue-paste adhesive is usually composed of wheat and rye flours, animal glue, water, Venetian turpentine, molasses, and linseed mucilage.
7. 3% in water (w/v).
8. Trevira CS Delay, 100% polyester, 50 g/m^2.
9. As suggested by Leonardo Borgioli, a chemist working at CTS Europe.
10. All solutions were prepared weight/volume.
11. Maintaining the canvas in tension is considered very important to fix the threads in a correct position, to reduce movement, and to give more stability to the whole painting in the future.
12. The tub usually measures about 1 square meter, which is an affordable dimension to easily handle a certain amount of water; 3 cm of water are needed to maintain temperature during the treatment.
13. Ten minutes was the minimum estimated time needed to guarantee that the adhesive reached the desired temperature.
14. This system was first performed by Sergio Taiti in the early 1980s. A video showing the tub system process is available at https://vimeo.com/801439551/7d9863ee77.
15. Working with the painting facedown—during both the adhesion of the paint layers and the lining—prevented the original seams from being pushed onto the paint layers, showing on the front and thus compromising the artwork.
16. A polyurethane-based resin in water dispersion, manufactured by Syremont.
17. Mist-lining technique might have been a choice, but at the time we were not overly confident with it, and the particular environmental conditions (very hot during the summer and without any climate control) would have required some adjustment. Moreover, the large size of the painting would have needed a considerable amount of solvent even using this method.
18. Plextol B500 is an aqueous dispersion of thermoplastic acrylic polymer based on methyl methacrylate and ethyl acrylate. Dispersion K360 is an aqueous dispersion of thermoplastic acrylic polymer based on 2-ethyl-hexyl-acrylate. According to technical data sheets, Plextol B500 and Dispersion K360 are miscible.
19. Trevira CS (Lipari), 100% polyester, 260 g/m^2. The amount of dry resin left on the lining canvas was calculated at about 36 g/m^2.
20. Elastic modulus is a measure of stiffness, defining the relationship between stress and strain in a material. The elastic modulus of the original canvas is usually quite different than the modulus of the new lining canvas. In our experience of tensioning new lining canvases, we have found that new canvas (whether made of natural or synthetic fibers) is usually more elastic than the original.
21. TNT 84: weight 105 g/m^2, thickness 260 µm.

12

Puvis de Chavannes's *Philosophy* Mural: Tactics for the Reversal of a Beva 371b Marouflage Lining from an Aluminum Honeycomb Panel

Ian Hodkinson, Emeritus Professor of Art Conservation, Queen's University, Kingston, Canada
Gianfranco Pocobene, Principal and Chief Paintings Conservator, Gianfranco Pocobene Studio, Malden, Massachusetts
Corrine Long, Associate Paintings Conservator, Gianfranco Pocobene Studio, Malden, Massachusetts

During the 2016 conservation of Pierre Puvis de Chavannes's Philosophy *mural, one of nine canvases commissioned for the Boston Public Library and marouflaged to the wall in 1896, it was discovered that water infiltration had resulted in detachment of up to 80% of the canvas from the wall. After successful stabilization, facing, and removal from the wall, the painting was prepared with a fabric interleaf for marouflage onto a custom-built aluminum honeycomb panel for reinstallation into its niche. The failure of the panel, however, necessitated complete reversal of the marouflage and replacement of the panel constructed with a stronger epoxy adhesive. In this paper, the procedure to safely remove the faced but stiff and brittle mural from the panel is described. The difficulty of carrying out the reversal led to the modification of the Beva 371 formula for the reattachment of the mural in order to facilitate future reversal, should the need arise.*

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INTRODUCTION

Since its introduction by Gustav A. Berger in the early 1970s, Beva 371 has been widely used as an adhesive for the lining of easel paintings and the mounting of murals onto rigid supports (Berger and Russell 2000). As it is a relatively recent introduction to the field of paintings conservation, the necessity of reversing a Beva 371 lining is an uncommon occurrence. While the reversal of paintings lined onto canvas supports with Beva 371 can be somewhat demanding, the removal of a large-scale mural painting adhered to a rigid support with Beva 371 presents the conservator with an extraordinary set of challenges.

With the application of heat and solvents, canvas lining fabrics can be peeled away from the reverse of an easel painting, but rigid support panels cannot, therefore different strategies must be devised. The strong adhesive properties of Beva 371 and its rather high activation temperature further complicate the procedure. The adhesive used for the marouflage procedure described in this essay is Beva 371b, which replaced the original Berger formulation in 2010. Laropal K80 (BASF), a tackifier in the original adhesive, was discontinued in 2008. In the reformulated Beva 371b, "an aldehyde ketone resin" was substituted (Conservator's Products Company 2010).

In 2016, Pierre Puvis de Chavannes's *Philosophy* mural (fig. 12.1), one of nine monumental murals the artist painted for the grand staircase of the Boston Public Library in 1895–96, underwent a major conservation campaign. Delamination of the 436 × 218 cm mural canvas and failure of the underlying plaster necessitated emergency removal of the mural from the wall, mounting of the canvas onto a rigid support panel, and reinstallation in its niche. The project was presented by the authors at the 2017 American Institute of Conservation Conference General Session in Chicago; however, time constraints did not permit a thorough discussion of the unexpected failure of the aluminum honeycomb panel support during the lining procedure. This necessitated the reversal of the marouflage lining and replacement of the panel with one of better design and materials.

In addition to describing the procedure implemented to reverse the marouflage and the successful remounting of the mural canvas, the logistical complications of undertaking such a procedure are presented in this paper. The difficulty of carrying out the reversal led to a reassessment of using Beva 371b as recommended by the manufacturers. Tests conducted on mock-up panels led to a modification of the adhesive to reduce its strength, tack, and melting point—and by extension increased its reversibility—while still retaining its essential properties as a suitable marouflage lining adhesive.

Figure 12.1 Pierre Puvis de Chavannes (French, 1824–1898), *Philosophy*, 1895. Oil-on-canvas mural originally marouflaged onto plaster wall, 436 × 218 cm (171 5/8 × 85 7/8 in.). Boston Public Library. The mural is shown mounted onto new aluminum honeycomb panel and set into its niche after the 2016 conservation campaign. Image: Gianfranco Pocobene Studio

PROJECT OVERVIEW

The murals in the grand staircase of the Boston Public Library were painted on canvas by Puvis de Chavannes in Paris. The artist achieved his famed fresco-like surfaces by using various innovative techniques, including painting on a coarse, plain-weave linen canvas; priming the canvas with animal-glue size; applying an extremely thin, absorbent chalk ground bound in animal glue; draining his oils by placing them on blotting paper; thinning his paints with turpentine; adding extensive amounts of white lead to his color mixtures; and leaving the mural surfaces unvarnished (Hensick, Olivier, and Pocobene 1997).

Upon completion, the reverse of each mural was primed with red lead in oil, rolled, shipped to Boston, and mounted to the plaster walls using the marouflage technique (fig. 12.2). The original method of attachment was to adhere the canvas to the wall with a paste of lead white in linseed oil applied to both the wall and the back of the canvas painting, which was then pressed onto the wall with rollers. While the adhesive was curing, the canvas was secured around the perimeter by a series of metal tacks.

In late 2014, a large canvas bulge and undulations were discovered in the upper portions of the mural. Salt efflorescence observed on the surrounding marble confirmed moisture infiltration. None of this was a surprise, as the mural has had a history of moisture problems, as noted in 1993 when the Puvis de Chavannes murals were last conserved by the Straus Center for

Figure 12.2 Puvis de Chavannes's mural cycle above the grand staircase of the Boston Public Library. Image: Gianfranco Pocobene Studio

Conservation, Harvard Art Museums (Hensick, Olivier, and Pocobene 1997). Mapping of the mural surface revealed that nearly 80% of the canvas had separated from the plaster substrate, yet along the left and bottom edges, the canvas was still very firmly attached to the wall.

Furthermore, a large area of the plaster substrate had also detached from the wall structure and was exerting considerable outward pressure on the canvas, raising fears of catastrophic failure. The plaster substrate consisted of expanded metal lath coated with three plaster layers: scratch coat, brown coat, and finishing coat, all composed of lime plaster of approximately 2.2 cm total thickness. Inserting a microspatula between the canvas and plaster instantly shattered the paint film, indicating that the canvas and ground were extremely brittle. This also confirmed that the adhered portions of canvas could not be separated from the plaster without incurring considerable damage to the paint surface.

Given the brittleness of the mural layers, the stiff white lead marouflage adhesive, and the strong bond where the canvas remained adhered to the wall, detaching and rolling the mural canvas off the plaster was clearly impossible. To prevent damage, the only viable approach was to totally detach the mural canvas along with the attached plaster portions from the metal lath substrate while keeping it as much in plane as possible.

The basic concept of detaching the mural is straightforward: support the mural at the top while detaching it starting at the bottom. Though the approach is simple in concept, numerous challenges became immediately evident.

- As the mural was in a recess, the edges of the canvas could not be accessed.
- Limited access could be provided at the bottom, but only if the marble fascia below the mural was removed.
- It was unclear how to support the painting and failed plaster in the arch area while separating the mural from the wall to reveal the bottom edge.
- It would be necessary to coordinate application of facings and removal of the oak trim within the arch without collapse of the structure.
- At some point, the plaster would need to be severed to release the mural where it was still firmly attached to the metal lath.
- The best type of protective facing materials and adhesives to use to protect the painting during the trauma of removal and subsequent structural work had to be determined.

As rolling the mural off the wall was deemed to be too dangerous, a system had to be devised to keep the mural in plane as much as possible during detachment. After considerable testing and experimentation with scaled mock-ups, the process of detaching the mural from the wall was carried out. The mural was faced first with Kozo (Usu Mino) paper sheets (after thorough testing for reversibility on mock-ups) and a specially formulated emulsion adhesive consisting of the following:

- 20 parts Golden MSA-UVLS Matte Varnish (chosen for its relatively low toxicity, ease of removal, and detectability under UV light)
- 2 parts odorless mineral spirits
- 1 part distilled water

The adhesive was emulsified with water to wet the paper fibers so they could conform to the paint topography.

Belgian linen was chosen as the primary facing material for the mural. Strips measuring 1 x 4 feet were adhered using the same MSA-UVLS mixture used for the Kozo paper facing, strengthened by incorporating 20% Beva Gel. Where maximum stress was anticipated, such as the perimeter of the mural and the vertical joins of the linen facing, additional linen reinforcement strips were adhered with Beva 371b.

At this point, the most nerve-wracking component of the project could begin: the detachment of the mural from the wall. The mural was secured at the top with padded plywood forms and pressure clamps. Working from the bottom up, the mural portions still firmly attached to the plaster wall were detached by severing the plaster from the metal lath substrate using modified slate rippers and vibration applied with a rubber mallet through a padded plywood sheet.

As the mural became detached, linen facing flaps extending beyond the perimeter of the mural were wrapped and stapled to the lightweight support panels. As the work proceeded up the surface, more panels were affixed and locked together to keep the mural in plane. Finally, with much of the mural supported by the locked panel supports, the section within the arch was detached. Once the entire mural was fully detached, full-length vertical and horizontal wood stiffeners were attached to the panel support system (fig. 12.3). A block-and-tackle system was connected from the staging to the rigid frame support on the mural to guide it out. The supported mural was then lowered, slowly coming to rest facedown on the staging deck. The mural was then removed from the deck and transported to a specially modified treatment space within the Boston Public Library.

The history of water leaks behind the mural precluded the possibility of remounting the mural onto a new plaster wall, so the decision was made to marouflage the mural onto a rigid panel support that could be easily installed and deinstalled in the future, if necessary. The plaster remnants on the verso were removed using first a reciprocating multitool to cut through the bulk of the plaster, followed by mechanical removal of the harder 3 mm–finish coat using chisels. The lead-white adhesive was well bound and uniform and strongly adhered to the reverse of the mural canvas, leaving none of the canvas exposed, thus it was left undisturbed. In preparation for lining, the reverse of the mural canvas was sealed with one coat of warm Beva 371b diluted with low-aromatic mineral spirits following the manufacturer's instructions.

Belgian linen canvas (8.7 oz) was then prepared as an interleaf for the lining assembly. A stiffer, synthetic material with a bonded weave (such as polyester sailcloth or Sunbrella fabric) would have been preferable, but fabric wide enough to span the width of the mural was not available. The Belgian linen was stretched on a wood frame and then sized and stiffened with a mixture of equal parts Titebond wood glue and water. A coat of warm Beva 371b was then rolled onto one side of the Belgian linen and allowed to dry. The fabric was then positioned over the back of the mural, adhesive side down, and secured with heat from an iron applied through silicone-coated polyester film (Mylar). A layer of warm Beva 371b was then applied to the exposed side of the linen interleaf and

Figure 12.3 The mural faced with support panels and stiffening wood members. Image: Gianfranco Pocobene Studio

allowed to dry. This surface would be bonded to the honeycomb panel.

The canvas mural, with the linen interleaf attached to it and still on its panel support structure, was then turned faceup and placed onto a specially constructed worktable. The wood braces and support panels were removed to reveal the faced surface of the mural. The canvas facings were removed from the mural surface with combinations of mineral spirits and xylenes to dissolve the Golden MSA-based adhesive and Beva 371b, but the Kozo paper facings were left on the mural for the time being.

ADHESION TO THE NEW RIGID SUPPORT

Considerable thought was given to the approach and materials to be used for remounting the mural. From the outset it was decided to reattach the mural to a rigid support. This would respect the artist's intent to marouflage and would provide continuous support for the heavy canvas. For this, an aluminum honeycomb panel was specially fabricated. In addition to providing the necessary rigidity, the conductivity of the aluminum would also facilitate the transfer of heat through its structure for lining at the recommended temperature of 65°C.

Given the size of the mural, the marouflage was to be carried out in four successive sections. A 122 x 244 cm temperature-controlled, silicone rubber heat sheet placed beneath the panel would deliver the required heat to each section (fig. 12.4). Before heat was applied, trial runs were performed to ensure that enough vacuum pressure could be applied over the entire Dartek film envelope. This was achieved using two small vacuum pumps placed on either side of the panel, which were connected with plastic tubing to 1.25 cm polypropylene cord running along the outer edge of the panel. In the final trial, the mural and all the adhesion components were sealed with Dartek film, and the required suction successfully applied. Once we were confident that this method would work as intended, marouflage of the mural could proceed.

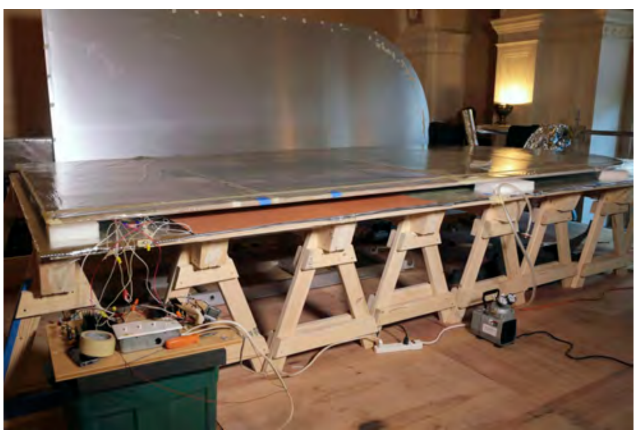

Figure 12.4 Lining system employed to marouflage *Philosophy*. The mural is shown on its aluminum honeycomb panel in a vacuum envelope suspended above an orange silicone rubber heat sheet. Image: Gianfranco Pocobene Studio

In preparation for lining, the worktable was covered with sheets of double reflective insulation (Reflectix) to reduce heat loss during the heating process. The temperature-controlled silicone rubber heat sheet was positioned for the adhesion of the first section at the bottom of the mural. Lastly, a coat of warm Beva 371b was applied to the face of the honeycomb panel, thus ensuring that the surfaces to be bonded were coated with a layer of the adhesive.

The mural was positioned onto the honeycomb panel, sealed with Dartek film, and then transferred onto the silicone rubber heat sheet. The vacuum pumps were attached with quick-release vacuum connectors, the heat sheet was turned on, and metallized reflective Mylar was placed over the section to retain heat. Once the paint surface temperature of all areas of the section reached 65°C, the heat was turned off and the bonded area allowed to cool down.

Everything appeared to have gone exactly as intended, but when the reflective Mylar was pulled back, a series of small bulges not present at the beginning of the heating process had developed along the center structural join of the panel (fig. 12.5). The cause of the deformations was delamination of the aluminum skins. The same problem was also discovered on the reverse of the panel, raising questions about what had caused the panel failure and how to proceed. Would we continue with the process in the hope that the rest of the panel would remain intact, or should the procedure be abandoned? Because the panel was intended to support the mural over the long term, we could not in good conscience continue to adhere the mural to what was clearly a structurally compromised support.

Figure 12.5 A straight edge placed on the failed structural seam of the aluminum honeycomb panel, revealing the protrusion of the aluminum panel skin. Image: Gianfranco Pocobene Studio

The Boston Public Library was informed of this unfortunate setback, and in collaboration with the panel manufacturer we began to investigate the cause of the problem. At the same time, we started to formulate a strategy for the removal of the mural from the failed panel for remounting onto a new, structurally sound rigid support.

REVERSAL OF THE FAILED BEVA 371B MAROUFLAGE

The first order of business was to detach the 122 x 213.5 cm section of mural canvas now adhered to the failed panel. As the linen facing layer had been removed prior to the lining procedure, the section was refaced with linen to protect and support the paint layers. The fact that almost 2.8 square meters of the mural was adhered to the panel while the rest was not greatly complicated the approach to reversing the adhesion. Whereas solvents can be applied to the back of canvas-lined paintings to dissolve Beva 371b, in this case that would not be possible. The notion of delivering heat through the front of the mural to release it was rejected because of the excessive temperature needed to penetrate the paint layers and melt the adhesive.

Some thought was given to the possibility of turning the mural on its face and dismantling the panel behind it down to the aluminum skin it was attached to, but that would be easier said than done. Attempting to then release the remaining adhered aluminum skin with heat from the reverse would have proven extremely difficult, as only a small area could be detached at a time. This approach was also rejected because of the difficulty of handling the aluminum skin and the considerable risk of damage to the brittle paint and ground layers.

The only feasible approach was to reheat the entire bonded portion of mural and then to roll the canvas off the panel when the Beva 371b adhesive reached its release temperature. Before any such attempt was made, however, small-scale replicas of the partially adhered mural were made, and from these tests a suitable approach was devised. Affixing the bottom edge of the linen interleaf under the mural to the equivalent of a very large diameter Sonotube, and then slowly rolling back the mural when the release temperature was reached, was deemed the most sensible tactic: it would support the canvas, minimize distortion, and reduce stress to the paint layers.

It was empirically calculated that a tube with a diameter of 3.7 m would be required to accomplish the task. That being impractical, we decided to fabricate a section of such a tube large enough to cover the area of the adhered section. A form was fabricated by cutting 1.9 cm plywood into curved ribs attached to a frame (fig. 12.6). Lauan board (0.64 cm thick), chosen for its pliable characteristics, was then attached to the ribs to create the outer, curved surface of the form, against which the mural would be supported during the adhesion reversal.

Figure 12.6 Conservators constructing a curved form to be used to roll the partially adhered section of the mural off of the aluminum honeycomb panel. Image: Gianfranco Pocobene Studio

The curved plywood form was set over the mural and tied to 5 × 10 cm framing supports on either end with block-and-tackle pulleys. This arrangement would enable the operators at the four corners to slowly roll the curved form away from the bottom edge in a controlled manner, until the entire section was released. With the interleaf and linen facing tabs along the bottom of the mural secured to the bottom edge of the curved plywood form, the silicone heat sheet was turned on and the surface temperature of the aluminum honeycomb panel raised to 65°C.

As the Beva 371b began to release, the bottom edge of the curved panel form was slowly raised while the other end was lowered, enabling the mural to be gently pulled away from the honeycomb panel (fig. 12.7). This went according to plan; however, cool air flowing between the surface of the panel and the underside of the linen interleaf caused stringing of the Beva 371b adhesive, a well-known occurrence in the hot-melt glue industry. As the strings cooled, the resulting hardening of the adhesive impeded the effort to pull the mural off the panel at an effective pace. Severing the strings with a metal spatula as they formed enabled the procedure to continue. The total time to reverse the lining, from the moment of lifting the curved form to complete detachment, took only four minutes. Critical to the success of the reversal process was the presence of the linen interleaf, which provided much needed support for the mural and took the brunt of the applied stress.

Figure 12.7 Technicians releasing the mural from the aluminum honeycomb panel curved form and block-and-tackle pulley system. Pairs of ropes at either end of the adhered section were used to control the lifting of the canvas from the panel. Image: Gianfranco Pocobene Studio

HONEYCOMB PANEL REDESIGN

With the mural successfully detached from the honeycomb panel, the next step in the process was to determine why the panel had delaminated. The failed panel was fabricated with aluminum skins (0.8 mm) supported with poplar strips for the outer straight edges and medium-density fiberboard (Medex) edges cut to the shape of the arch. The width of the mural, which exceeded the width of available aluminum sheets, required a vertical seam in the center of the panel, which had been reinforced with a 7.6 × 1.9 cm rectangular aluminum tube. The core of the panel was filled with aluminum honeycomb to provide rigidity and heat transfer. When the panel was commissioned, it was made clear to the manufacturer that the panel would be heated to 65°C–70°C and that an epoxy adhesive able to tolerate that temperature needed to be used in the fabrication of the panel.

After a review of the specifications and materials used to make the panel, it was determined that several factors led to its failure, including the type and amount of epoxy adhesive applied to the various surfaces and the choice of edge materials. In preparation for the fabrication of a stronger panel, the manufacturer produced numerous small mock-ups with various combinations of epoxies and edge materials. These were then heated to the lining temperature under vacuum and assessed for their structural integrity. Initially, many of these failed, but based on the results of the experiments two major changes were made to the construction of the panel. First, an epoxy adhesive that would tolerate temperatures of up to 80°C was obtained and successfully tested on mock-up panels. Second, the poplar and Medex edging materials were replaced with aluminum tubing along the edges, which was also used for cross bracing. Additionally, the center vertical seam was reinforced with a 10 cm composite plate that spanned the inside of the seam; it was composed of 1.27 cm Hexcel aluminum honeycomb sandwiched between 1/8 inch aluminum sheets. This composition greatly stiffened the structure, and the new panel was custom fabricated for the lining of the mural.

MODIFICATION OF THE BEVA 371B ADHESIVE

The challenges encountered during reversal of the partially adhered portion of the mural led to a reconsideration of the properties of Beva 371b: namely, its high strength and the temperature needed to release it. Recently, Ploeger et al. considered the strength of Berger's adhesive formulation and proposed the need for further research and development of adhesives with reduced strength and activation temperature (Ploeger, McGlinchey, and de la Rie 2015). As the entire Puvis de Chavannes marouflage may need to be reversed at some point in the future, thought was given to how conservators would go about doing this and what could be done during the present procedure to make that task less challenging. Once mounted onto its rigid support panel, the mural canvas would be in a relatively stress-free state, so such a high-strength adhesive would not be necessary. The question was how to go about reducing the strength and tack of Beva 371b while still providing sufficient adhesion. Additionally, lowering the activation temperature of the adhesive was deemed a desirable characteristic, especially for the brittle paint and ground layers.

As supplied by the manufacturer, paraffin wax makes up 9% of Beva 371b. It was deduced that the addition of a low-temperature paraffin wax to the stock solution would reduce not only the activation temperature of the adhesive but also the percentage of the other resins and tackifiers in the solution, thereby reducing the adhesive's strength. Empirical tests were performed to determine if a modified adhesive with these desirable properties could be produced. Using Beva 371b dry resin mix, batches of the adhesive were weighed out and dissolved in solvents according to the manufacturer's directions. They were then modified by adding 5% and 10% by weight of paraffin wax. A paraffin wax with a melting temperature of 50°C–54°C was chosen for testing. A control sample of unmodified Beva 371b was also prepared for comparison. Scrap samples of thick nineteenth-century decorative canvas, along with linen interleaf fabrics, were adhered to small honeycomb test panels. From the tests, it was determined that it was possible to sufficiently adhere the test samples at a much lower temperature of 54°C measured at the paint surface. The tests also indicated that at the interface between the aluminum panel and linen interleaf, the temperature remained below 60°C.

To determine if the adhered samples could be released with less force, small, rigid cardboard tubes were attached to one edge of the test samples and the panels heated until the surface of the paint reached 54°C. Whereas it was not possible to roll back the unmodified Beva 371b at that temperature, the 5% and 10% samples both released from the aluminum panel, especially the latter, which could be rolled back using relatively little force (fig. 12.8). Based on these empirical tests, it was decided to adhere the mural with a Beva 371b solution modified with the addition of 10% paraffin wax by weight. Because the lead-white adhesive on the reverse of the mural acted as a barrier, there was little concern that the modified adhesive would darken the canvas because of its increased flow.

Figure 12.8 Mock-ups made using different amounts of paraffin wax to find the best mixture to lower the melting point of Beva 371b. Image: Gianfranco Pocobene Studio

COMPLETION OF THE MAROUFLAGE PROCEDURE

Assured that the new, redesigned honeycomb panel would tolerate the lining process, the mounting of the mural proceeded as originally conceived. A coat of the modified Beva 371b solution was applied to the surface of the new honeycomb panel and allowed to dry. The linen and Kozo paper facings were then removed from the mural surface. As previously described, the mural assembly was wrapped in its Dartek vacuum envelope. The first section of the mural was successfully adhered to the panel using the modified Beva 371b adhesive at a paint surface temperature of 54°C. Once cooled to room temperature, the panel was temporarily lifted onto foam blocks to reposition the silicone heat sheet under the next section of the mural (see fig. 12.4). Section by section, the entire mural was successfully adhered using this system. The Belgian linen edges extending beyond the perimeter of the mural canvas were then wrapped around the edges and over the back of the honeycomb panel and adhered with Beva 371b using warm irons. Four heavy-duty metal right-angle brackets (two on each side) were mounted with epoxy and screws to the panel edges and back.

After selective filling and retouching, the mural was transported back to the staging area for reinstallation. With just 3 mm of play on either side, the panel slid easily into its niche. The mural was positioned and checked for level, and the angle brackets were then screwed securely into corresponding wood blocking mounted in the niche recess (see fig. 12.1).

CONCLUSIONS AND FURTHER RESEARCH

Although the reversal of Beva 371 adhesion from rigid support panels is a challenging process, the treatment undertaken on the *Philosophy* mural demonstrates that methods can be devised to carry out this type of procedure. While the midtreatment setback caused by the failed panel was in the end successfully resolved, it raised questions about the present formulation of Beva 371b and its working properties. Research to date has explored certain properties of Beva 371, such as its stability and its potential use on other types of art. The process of reversing adhesion to rigid supports and the resulting effects on the canvas and paint layers, however, have not been thoroughly investigated.

The original formula Beva 371 was specifically developed for the lining and consolidation of paintings on canvas and has been used with apparent success for that purpose for over half a century. The revised formula, Beva 371b, continues to be an invaluable adhesive in the conservation field, but it has its own problems and limitations. Reevaluation of the adhesive, along with systematic testing, is much needed. The replacement of some of its components with new materials and resins could lead to the production of adhesives with properties tailored more appropriately to the job at hand, including adhesives of various strengths. Moreover, an adhesive with a lower activation temperature would be a welcome addition to the lining and consolidation materials at our disposal.

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APPENDIX

Materials List

Aluminum Honeycomb Panel, SmallCorp. https://www.smallcorp.com

Belgian Linen (unprimed 8.7 oz.), Dick Blick Art Materials. https://www.dickblick.com

Beva 371b (thermoplastic, elastomeric polymer mixture), Conservator's Products Company. http://www.conservators-products.com

Beva Gel, Conservator's Products Company. http://www.conservators-products.com

Dartek C-917 Film (nylon 6,6 film modified with a heat-stabilizing adhesive), TALAS. https://www.talasonline.com

Golden MSA Matte Varnish with UVLS (isobutyl and n-butyl methacrylate resin solution with amorphous silica matting agent and hindered amine UV light absorber and stabilizer), Golden Artist Colors. https://www.goldenpaints.com

Kozo Paper (Usu Mino, 15–16 $g/^2$), Hiromi Paper. https://hiromipaper.com

Lauan Plywood, Lowes. https://www.lowes.com

Metallized Reflective Mylar, Grabber Space Emergency Blanket, Recreational Equipment, Inc. https://www.rei.com

Paraffin Wax, Reed Wax. https://reedwax.com

Reflectix Double Reflective Insulation, Reflectix, Inc. https://www.reflectixinc.com

Silicone-Coated Mylar, TALAS. https://www.talasonline.com

Titebond Premium Wood Glue, Franklin International. http://www.franklininternational.com

13

Lining as a Last Resort for a Large-Format Canvas Painting of the Early Nineteenth Century

Julia Brandt, Bayerisches Landesamt für Denkmalpflege
Carina Volbracht, Freelance Conservator, Munich

Over the past decades, lining of paintings has become more and more an ultima ratio *measure in conservation practice. In case of the painting* Das Jüngste Gericht (The Last Judgment) *by Engelbert Zimmermann, assessment showed that only a lining would provide a sustainable treatment. Due to a previous treatment, the support was extremely brittle and had several large tears. The aim of the conservation treatment was to stabilize the support while preserving the original stretching system. To regain stability of the support and readability of the depiction, the heavily distorted support was remodeled, the tears were partially closed, and the painting was lined using the mist-lining technique. Where the original canvas was no longer fixed to the stretcher, the lining canvas was introduced between the support and the stretcher. After lining, the original and the lining canvas were both fixed to the stretcher. In areas where the original stretching system was still intact, the lining canvas was fixed a few millimeters inside the stretcher. The treatment has made the depiction readable again and improved the overall impression of the painting without neglecting its history.*

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INTRODUCTION

After the influential talks by Vishwa Mehra and Westby Percival-Prescott at the 1974 Conference on Lining Techniques in Greenwich, the dangers of lining became clear to everyone. Lining came to be understood more and more as a massive, largely irreversible intervention in the structure of the painting. The dangers of treatments involving heat and moisture to alter the original surface were pointed out by Mehra. Similarly, Percival-Prescott described the lining cycle as leading to constant material loss (Percival-Prescott 2003b). In addition, lined paintings often appear rigid and flat.

As a consequence, part of the conservation world started to further develop lining techniques and do research on the mechanical behavior of canvases to diminish these adverse effects. In contrast, Percival-Prescott himself went as far as to postulate a need for a lining moratorium. A large part of the community, especially in German-speaking countries, adopted this approach and turned away from lining in favor of developing new methods. The most influential of these methods is probably the thread-by-thread tear mending propagated by Winfried Heiber (Heiber 2003).

Today in Germany, the preferred methods for structural treatments are various forms of strip-lining and tear-mending, and it is a common goal to avoid lining altogether. Nonetheless, at the museum where Julia

Brandt did her pre-career internship, she was trained to execute several lining techniques. Penetrating lining techniques were sometimes seen as a time-saving option, as they combined several steps into one, such as stabilizing the support and adhering and flattening the paint layers. Cold-linings and nap-bond methods were seen as a good way to make paintings safe for travel.

Later in our academic training, lining was taught as a historic technique, and the negative effects were clearly pointed out. During our training at the Technical University of Munich (TU München), we were taught not to perform a technique simply because we knew it best; instead we should look at every artwork individually. We were always asked to search for the method that involved the least intervention and least impact on the original substance. We found that this approach proposed a challenge to further develop existing techniques and to invent new ones so that the practical part of the field also grows into an academic discipline.

In most cases, even when paintings at first sight seem beyond recovery, local treatments can offer sufficient and sympathetic solutions. In our last year at university, however, we were presented with a severely damaged painting—it was basically torn in half (fig. 13.1). While we first discussed the possibility of local treatments, it became clear during the investigation that the painting technique and the chosen canvas were probably the main causes for the observed damage. At the same time, the painting didn't show any signs of previous treatment, which led to intensive discussions on how far we could intervene with the original substance.

Figure 13.1 Engelbert Zimmermann (German, 1807–1842), *Das Jüngste Gericht (The Last Judgment)*, 1839. Paint on canvas, 225 × 130 cm (88 3/5 × 51 1/5 in.). Wasserburg, Stadtmuseum Wasserburg. State of the painting before the preliminary treatment in 2012. Image: Stadtmusuem Wasserburg

THE PAINTER ENGELBERT ZIMMERMANN AND HIS TOTENTANZ CYCLE

The painting *The Last Judgment* is the central piece of Engelbert Zimmermann's Totentanz (Danse Macabre) series, which is owned by the Stadtmuseum Wasserburg am Inn, a small community museum in eastern Bavaria. The large-format painting, which dates from the beginning of the nineteenth century, had several horizontal tears, one of which divided the support in half (see fig. 13.1). The series was created in 1839 for the mortuary hall of the Wasserburg cemetery and is based on a model by Hans Holbein the Younger. His series Imagines Mortis (Images of Death)—does not show the dance of Death with his victims as was customary in the Middle Ages, but rather individual, self-contained scenes accompanied by interpretative verses and Bible quotations (Wunderlich 2010). The Totentanz from Wasserburg is considered one of the few remaining monumental cycles of this kind from the first half of the nineteenth century (Sörries 1998, 276).

Zimmermann was born in Wasserburg in 1807, the son of a carpenter. He was enrolled in figure drawing at the Munich Art Academy in 1827, but nothing is recorded about his further career and very few paintings by him are known. The mortuary hall was built in 1830 as part of the expansion and renovation of the Wasserburg cemetery, and a few years later Zimmermann was commissioned to furnish it. The cycle he created consists of six rectangular paintings (135 × 85 cm) and a central painting depicting the Last Judgment (225 × 130 cm).[1] Initially, a cycle of eighteen paintings was planned. In a declaration from August 24 of the same year, however, the number was reduced by half (and in the end, only seven seem to have been executed); the free wall surfaces were to be filled with aphorisms.

Zimmermann states in the declaration that he wanted to paint the paintings "for the sake of better durability [with] oil paints on metal sheets." But in the end all seven paintings were executed on canvas. The painter added the corresponding quotations from the Bible directly on the plaster under the small paintings. For the central *Last Judgment*, the text appears at the bottom of the canvas. The Bible quotations and aphorisms are taken from an 1832 edition of Holbein's Imagines Mortis with texts by Joseph Schlothenhauer, a professor at the Munich Art Academy (Von Perger 2013, 201–3). Seen from the entrance of the hall, the four small paintings depicting Death dancing with different individuals hung to the left and right: on the left the child and the bride, on the right the couple and the old man. At the front wall, in a semicircular niche, hung *The Last Judgment*, flanked by *Expulsion from Paradise* on the left and *Skeletons Playing Music* on the right.

The paintings were individually photographed in 1919 and published in the illustrated magazine *Das Bayerland*. These are the only known photographs of the cycle in their original arrangement in the mortuary hall. During the course of the hall's renovation in 1924, the Zimmermann cycle was taken down and moved to the attic of the mortuary hall, and the aphorisms were overpainted. After a publication by Otto Kögl, who pointed out the importance and quality of Zimmerman's Totentanz, the Stadtmuseum Wasserburg took the cycle into its collection in 1940 and exhibited it for some time.[2]

Possibly in the 1960s, but at the latest in the 1980s, the cycle was placed in storage at the museum.[3] In 1998, two of the small-format paintings (*Skeletons Playing Music* and *Death and the Old Man*) were shown in the exhibition *Tanz der Toten—Todestanz: Der monumentale Totentanz im deutschsprachigen Raum* at the Museum für Sepulkralkultur in Kassel, Germany (Sörries 1998, 41). The museum had requested a loan of the whole cycle, but the other paintings were too damaged to be exhibited.

In 2013, the painting was offered to the chair of conservation-restoration to be treated by students, as the museum did not have the funds to pay for the restoration. By this point, it had not been accessible to the public for several decades.

AN UNUSUAL SUPPORT WITH AN UNUSUAL DAMAGE—TECHNOLOGICAL INVESTIGATIONS

The weave of the textile support of *The Last Judgment* resembles a weft rib but actually is a plain weave. The weft rib effect is created by the use of a much thicker thread for every second weft (fig. 13.2). This fabric structure can be found in all paintings of the Totentanz. The canvas is made of jute and flax. Zimmermann possibly opted for this type of fabric with its riblike weave because he wanted to create an effect similar to a so-called tapestry painting: "[A] technique which aims at the imitation of woven tapestries by painting. One uses a riblike material corresponding to the texture of the real tapestries and paints on it with water, tempera or oil paints diluted with turpentine, after one has traced the drawing beforehand or applied it with a charcoal pencil."[4]

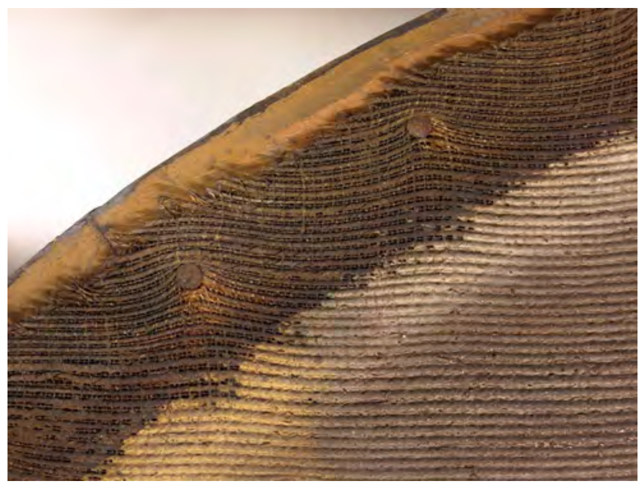

Figure 13.2 Detail of the riblike weave of *The Last Judgment*. Image: Julia Brandt

A few samples were taken to learn more about the painting technique. In the cross section, a layer of binding media between the canvas and the ground was clearly visible. Fourier-transform infrared spectroscopy (FTIR) analysis[5] of a microprobe of the ground and binding media layer suggested that shellac was used to prepare the canvas and that the preparation contained chalk. The thin ground layer was applied after embedding the canvas with shellac, and the painting was then painted thin and lean, without varnish coating. As is usual for tapestry painting, this allowed the striking fabric structure to remain clearly visible. The support was nailed frontally to the wooden strainer without a tacking margin. The frame (which did not have a rabbet) was nailed on top such that the support is sandwiched between the strainer and the frame.

The shellac probably led to increased oxidation of the already thin warp threads, which had broken in numerous places under the weight of the textile. Horizontal tears pervaded the painting, and this damage phenomenon can also be observed on the other paintings of the cycle. It was probably further increased by the high temperatures in the attic where the paintings were stored (temperatures up to 40°C were recorded). The resin becomes soft at higher temperatures, so the support loses its stiffness and begins to sag. This caused the canvas in the larger central painting to detach from the strainer, especially in the lower half, as the canvas ripped around the nails, which allowed the lower half of the painting to droop. At normal room temperature, the fabric was hard and brittle and had completely lost its textile character. The condition considerably impaired the readability of the representation.

The painting was found in this state in 2012, when the museum's inventory was updated. A conservator who was called to see if the painting could be rescued determined that the support was so completely stiff and brittle that it was impossible to bring the canvas back to its original shape without causing further damage (see fig. 13.1). He decided to wait for the warmer temperatures of summer to loosen the stiffness before turning the painting onto its side to slightly reduce the strong deformations. The measure was successful up to a point, but it was unclear how to go about further stabilizing the support and reaffixing it to the strainer (fig. 13.3).

Figure 13.3 State of the painting after the preliminary treatment in 2012. Image: Stadtmusuem Wasserburg

THE BIGGER PICTURE—SETTING GOALS AND ASSESSING LIMITATIONS

After taking a closer look at the support of this painting and the other paintings from the cycle, we came to the conclusion that the drastic damage was primarily caused by technical factors inherent to the work and less to external influences. Even if it would not be part of our project, we would need to find a method that would be easily applicable to all seven of the paintings. We were told by the museum that they did not have any storage space other than the one in the attic, which had very high temperatures in summer and very low, almost freezing conditions in winter. Additionally, the difficult financial situation common to many small community museums implied the need for a low-cost solution; otherwise, it would be very unlikely that the rest of the cycle could ever be restored. Keeping all of this in mind, we also hoped that a neater appearance would perhaps grant the large (and therefore more vulnerable) central painting a spot in the collection, which would mean better storage conditions. Hence our preliminary goal was to make the depiction readable again and to stabilize the support.

As the painting had never undergone any major restoration treatment in the past, we wanted to keep the impact on the original substance as minimal as possible, and that meant retaining the original stretching system. Due to the nature of the support, thread-by-thread tear-mending, or even patches, would not have provided a long-term solution. We were afraid that the thin, brittle vertical threads would break in other places if we did not reinforce the support as a whole. After looking at all the options and taking into account the sparse financial resources, lining seemed to be the only option.

The concept envisaged remodeling the deformed canvas, securing the tears, and then lining the painting. This last step was essential to stabilizing the support and relieving the strain on the warp threads. Where the stretching system had already failed, the lining canvas would need to be pushed between the strainer and the original canvas and tensioned together with the painting. In areas with an intact stretching system, the lining canvas would be adhered just a few millimeters inside the strainer. Both the securing of the tears and the lining should be reversible, and it should also be possible to remove the lining without further opening the tears. The aim of the treatment was not a perfectly smooth surface but rather a condition that would make both the depiction and the history of the painting visible.

FINDING A SOLUTION—DEVELOPING A METHOD

From the first-aid measure taken in the attic in 2012, it was known that the rigid canvas and the paint layer would become more flexible under the influence of heat, but using a hot spatula and moisture did not lead to a satisfactory result. We decided to try heating a larger part of the surface, but it still did not work as well as we had hoped. As the FTIR analysis suggested shellac had been used to prepare the canvas, we conducted some microtests with ethanol, which resulted in a swelling of the resin layer. Given these indications, we decided to use ethanol-drenched cardboard along with a Gore-Tex membrane under the painting, and an infrared lamp as heat source from above, while the painting was fixed to a Lascaux stretching frame.

The following requirements were formulated for securing tears:

- The adhesive should be easily reversible and yet withstand shear and tensile forces. It should adhere to the shellac-soaked backside and not be alcohol-based to prevent the resinous layer from dissolving.
- The fabric should be thin but also dimensionally stable in order to bring the tears together and keep them in plane. Patches should not become apparent in the paint layer or in the lining.

Stabiltex was chosen because it is very thin and at the same time stable. This fabric was made of pure polyester and was used in textile conservation for a long time, although it is no longer available.[6]

The following requirements were formulated for the lining:

- The lining fabric should be thin and yet stable, to enable it to reduce the tensile load on the warp threads.
- It should be flexible enough to adapt to the likely remaining deformations in the canvas.
- The fabric should be available in the format of the painting and, ideally, have a plain weave.

For lining, both cotton and linen were considered at first. The greater dimensional stability of linen was the decisive factor for preferring it over the cheaper cotton.

The requirements for the lining adhesive were the same as those for the patch adhesive, with some additions:

- It should be possible to apply the adhesive over a large area.
- A sprayable medium was considered advantageous to reduce the amount of adhesive used.
- The health and environmental risks posed by the solvent should be kept as low as possible.
- Finally, given the limited financial resources and the size of the painting, the adhesive (as well as the fabric) needed to be affordable.

A selection of natural and synthetic adhesives was tested for these requirements: Beva 371 film (thin), Lascaux 360 HV and 498 HV acrylic adhesives in different proportions, Plextol D 540[7] and Dispersion K 360[8] mixed in different proportions, and Plexigum PQ 611[9] in ShellSol D 40 were tested as adhesives for patches and lining. The Beva 371 film was rejected due to its thickness and the resulting low flexibility. Producing a thinner film from Beva gel was considered to pose a serious health risk due to the necessary solvent. The Lascaux acrylic adhesives and the Plextol mixtures gave the same results. As the Lascaux products were more expensive, we decided to use a mixture of Plextol D 540 and Dispersion K 360 in a 7:3 ratio. The mixture was taken from literature on mist-lining (Seymour and van Och 2005).

Plexigum PQ 611 fulfilled to a large extent all requirements, but it is more difficult to process on large surfaces than Plextol D 540. It was therefore chosen for the patches, and Plextol D 540 in mixture with Dispersion K 360 for the lining. The different solubility of Plextol D 540 and Plexigum PQ 611 made it possible to remove the lining without removing the patches from the tears.

FROM THEORY TO PRACTICE

After consolidating and cleaning the paint layer, we started to put the support back into plane. Where the stretching system had already failed, the loose edges of the painting were clamped between two wood blocks upholstered with felt, which had a piece of polyester strap attached to them. These straps were fixed to a Lascaux stretcher (fig. 13.4). An isopropanol compress—consisting of a Melinex film with isopropanol-soaked blotting cardboard and a Gore-Tex fleece—was put under the jacked-up painting. While the alcohol vapors acted on the painting from below, the surface was heated with an infrared lamp for five minutes. An infrared measuring device showed that the surface of the painting heated up to approximately 40°C–45°C during this period. The stretcher allowed us to stretch the remodeled parts little by little while keeping them under tension.

Figure 13.4 The authors forming the support back into plane. Image: Catharina Blänsdorf

Once the tension relaxed after a couple of days, we softened the support and paint layer using the above-described method and restretched the heavily deformed and buckled parts of the painting. Large waves were carefully modeled into plane by hand. These steps were performed over the course of several weeks. When the heaviest deformations were leveled, a substructure was built under the painting to allow the use of sandbags to press down on the reformed support. In the end we were able to close the horizontal tear by using Trekkers.

The painting was then turned over, and smaller deformations were worked over from the back with heat and weighted down with sandbags. Some tears in the lower half of the painting could not be joined together without causing new deformations, because the canvas was warped and could not be re-formed due to its brittleness.

Securing of the Tears

The Stabiltex was laid out on a siliconized paper, and Plexigum PQ 611 40% in ShellSol D 40 was applied with a spatula. After the adhesive had dried, the fabric was cut into strips individually for each tear and ironed on with a heated spatula at approximately 50°C (fig. 13.5).

Figure 13.5 Painting with secured tears seen from the back. Image: Julia Brandt and Carina Volbracht

Lining

A thin, bleached canvas by Nordmeyer & Kortmann was used as lining canvas. The adhesives used were Plextol

D 540 and Dispersion K 360 in a ratio of 7:3. The Plextol mixture was sprayed onto the lining canvas with a compressed-air gun at 3 mbar and allowed to dry. The result was an adhesive fluff that allows superficial bonding to the original canvas without penetrating it. The adhesive has a very low peeling force, which allows easy removal of the lining canvas. This procedure corresponds to mist-lining (Seymour and van Och 2005). Using calculations from preliminary testing, 1 liter of adhesive was needed to line the painting.

The prepared lining canvas was pushed from the right side between the stretcher and the support and then ironed onto the back at a temperature of approximately 45°C. In the curved segment at the top, the lining canvas was fixed with staples onto a strip of acid-free cardboard that became an intermediate layer on the inside of the stretcher (fig. 13.6).

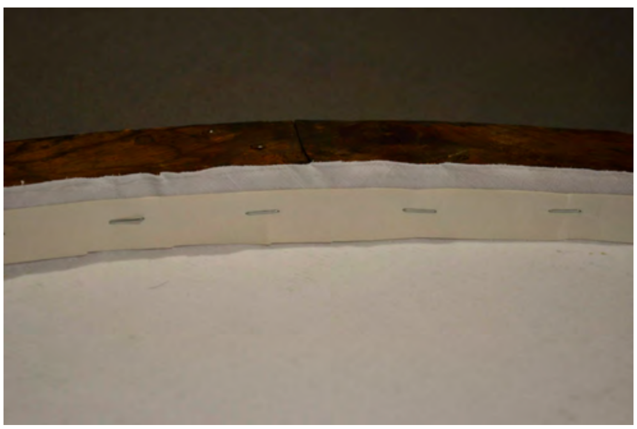

Figure 13.6 Lining canvas fixed to the curved top segment with staples through acid-free cardboard. Image: Julia Brandt and Carina Volbracht

The lining canvas had been cut to size so that it protruded where the original stretching system was no longer in place. The protruding canvas could then be folded over to the front in order to border and stabilize the support at the edges and to provide a new surface for stretching. Suede leather was put under the nails. Jute threads were inserted into the remaining tears and ironed onto the adhesive of the lining canvas. Finally, the missing areas were filled in and retouched.

CONCLUSION

In *The Last Judgment*'s final state, the depiction is visible again, and further damage to the painting has been prevented (fig. 13.7). At the same time, the history of the painting and its technological peculiarities remain visible as some reshapeable deformations were left. The tears were visually pushed back using restrained retouching. Despite the extensive intervention in the structure of the painting, it fits well into the cycle without making the other six less damaged, unrestored paintings look inferior.

a

b

Figure 13.7 *The Last Judgment* after treatment in 2014: (a) verso; and (b) recto. Image: Julia Brandt and Carina Volbracht

The lining of a painting always represents a massive—often irreversible—intervention. However, the example of *The Last Judgment* shows that, in rare cases, a lining can be the only way to save a painting from further decay. In this case, lining did not mean abandoning the original stretching system and pressing the support as flat as a board. Even a more careful intervention with respect for the much-cited *Alterswert* (age value) can achieve the desired success.

It should not go unmentioned that the restoration has made it possible to display *The Last Judgment* for the first time since the 1980s. Before the restoration, we had been told that it was a "restoration for storage," as there was no room in the small museum for a permanent presentation of the cycle. However, the extensive restoration and the aesthetically satisfying result led to the main painting (at least) now being on display in the museum—which also means better storage conditions.

We revisited the painting in 2019 and found it in good condition, with the lining still in place. The only drawback we could observe thus far is that the lining canvas does not seem to adhere well to the Plexigum PQ 611–coated Stabiltex. As a result, some of the tears have opened slightly, and dirt may fall in. So far this does not seem to be destabilizing the lining. We plan to revisit the painting on a regular basis to see how the restoration stands up to time and climate.

ACKNOWLEDGMENTS

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NOTES

1. According to the *Kostenvoranschlag* (estimate) from June 23, 1838, kept in the Wasserburg City Archives, Zimmermann was also commissioned to paint the walls.
2. Matthias Haupt, “Denkmalgeschützte Aussegnungshalle im Altstadtfriedhof im Hag, Sanierung durch Stadt Wasserburg a. Inn, Grunddaten zur Baugeschichte, Archivrecherche, Baugeschichtsforschungen des Stadtarchivs Wasserburg” (unpublished material, 2009). City Archives of Wasserburg, BBFO127.
3. Director Sonja Fehler, Stadtmuseum Wasserburg, to Catharina Blänsdorf, TU München, email, October 22, 2013.
4. *Meyers Großes Konversations-Lexikon* (1907), vol. 8, 70.
5. FTIR analysis performed by Dr. Thorsten Allscher at the Institut für Buch- und Handschriftenrestaurierung (IBR) at the Bayerische Staatsbibliothek.
6. “Formerly produced by Swiss Silk Bolting Cloth Manufacturing Co, Zurich. Stabiltex is a trademark for a sheer, lightweight, open weave, polyester fabric. Stabiltex was used as a support backing for covering fragile textiles and as an alternative to silk crepeline. As of 2004, the production of Stabiltex has been discontinued. An alternate product, Tetex TR was supplied as a replacement, but it was discontinued in 2009.” http://cameo.mfa.org/wiki/Stabiltex. The Stabiltex we used was given to us by a colleague who still had some in stock.
7. “Finely dispersed, aqueous emulsion of a methacrylic acid ester-/acrylic acid ester-copolymer. The emulsion contains an anionic emulsifier system and is free from film forming auxiliary agents, solvents and plasticizers.” http://www.kremer-pigmente.com/media/pdf/76202e.pdf. The product is no longer produced but is still commercially available through Kremer Pigmente.
8. Formerly named Plextol D 360 (consisting of n-butyl methacrylate and methyl acrylate). Kremer sells a substitute under the name Dispersion K 360 without giving specifications about the chemical composition other than it being an “aqueous dispersion of a thermoplastic acrylic polymer.” https://shop.kremerpigments.com/us/shop/mediums-binders-glues/76101-dispersion-k-360.html. However, it has a lower pH than Plextol D 360, and according to FTIR measurements it consists of polybutyl acrylate, polynitrile, and phthalate, thus containing a softener. See Reuber 2010, 36. The products we used were bought from Kremer Pigmente.
9. Plexigum PQ 611 is an isobutyl methacrylate and officially named Degalan PQ 611 N since 1999. Both names refer to the same material. Until 2009 it was produced by Röhm & Haas, a company that now is part of Evonik Industries, which continued its production until 2019. It is currently produced by Röhm (not Röhm & Haas), a company that was part of Evonik Industries until August 2019 but is now independent. Since 2009 it is produced through continuous direct polymerization (CDP), making additives unnecessary. However, Kremer still sells the product under the name Plexigum PQ 611. The reason is unknown. This information was provided by Mona Konietzny by mail in May 2020. Mona had contacted staff from Evonik Industries. The product we used was from the university’s stock and labeled Plexigum PQ 611, purchased from Kremer Pigmente at an unknown date.

14

Structural Stabilization of Large Paintings on Canvas: A History of Approaches in the Kunsthistorisches Museum Vienna

Elke Oberthaler, Chief of Paintings Conservation, Kunsthistorisches Museum Vienna

The collections of Vienna's Kunsthistorisches Museum have a long tradition, reaching back at least four centuries. Many large-scale paintings originally were conceived to decorate walls of the castles of the Habsburg family but have lost that function over the centuries, so there are large holdings of oversize paintings in storage. However, many large paintings are still in situ as decorative pieces in offices or museums housed in former imperial palaces and in other public spaces, and a certain number of large-scale paintings are on display in museum galleries. This paper explores various strategies for preserving these holdings, from improving storage conditions to in situ structural interventions to in-depth treatments in the studio. As any treatment of large-scale paintings is a major commitment, consuming space, time, and labor, much remains to be done.

◆ ◆ ◆

INTRODUCTION

In any museum conservation studio, strategies and methods are based on the collection's condition and demands, so let us start with a brief introduction to the character and history of the paintings collection of the Kunsthistorisches Museum Vienna (KHM). In terms of numbers, only a small selection of its holdings is on display in the galleries of the main museum building at Burgring 5, but large parts of the collection are on view at other locations: the Hofburg Palace, housing the Imperial Treasury; the Imperial Armory and the Collection of Historical Musical Instruments; and the Imperial Carriage Museum, at Schönbrunn Palace. Ambras Castle near Innsbruck houses an important collection of portraits. The KHM has also sent paintings as long-term loans to satellite museums set up by other public organizations—mainly former imperial palaces such as Schönbrunn, Laxenburg, Eckartsau, and Schloss Hof. Around eight hundred paintings are on loan to government offices in historic buildings and Austrian embassies. Located about 20 km south of Vienna, the KHM's central storage facility houses over three thousand paintings and around a thousand frames.

This paper examines treatments performed during the past decade on paintings measuring over 2 meters, which have been selected to document typical conditions and approaches.[1]

ROLLING, FOLDING, AND OTHER PROVISIONAL INTERVENTIONS—CONSERVATION PROBLEMS OF LARGE CANVAS PAINTINGS

Vienna's first imperial gallery displaying large canvases was established in 1656 at Stallburg Palace, which housed Leopold Wilhelm's collection after his return from Brussels. Continual changes in selection and display means paintings were (and still are) transported between the main gallery and the other venues (Swoboda 2008, 110–23).

Handling is key in the preservation of large canvas paintings. Canvases are rolled onto tubes for transport. Such manipulations are difficult, and improper handling or storage techniques (kinking, folding) often cause damage and paint losses.

Ideally, a rolled canvas should soon be restretched, but our storage houses numerous rolled paintings: sixty-seven paintings on nineteen rolls, including two ceiling paintings by Nicola Maria Rossi, *Pallas Abducts Juventus from the Arms of Venus* (1730; 500 × 500 cm, GG 7665) and *Allegory of the Human Spirit* (GG 7666) from the Harrach garden palace, which was bombed in World War II. They were rolled and acquired by the KHM in 1968.

As early as the eighteenth century, inventories list paintings without a strainer (or stretcher).[2] Even today, twenty-nine paintings are stored unstretched and not rolled (flat), including a portrait of Philipp IV by a Spanish artist (210 × 143 cm, GG 9269). Until the 1990s, these paintings had been stored for a long period piled on top of one another in a storage facility formerly used to house the KHM's tapestry collection in Hofburg Palace. Lacking the resources to stabilize and stretch these damaged paintings properly, in the 1990s we mounted them clamped between sheets of corrugated cardboard.

Canvas paintings with paper facings—partial or covering the entire surface—testify to the lack of time and space for proper conservation treatments. Bonifazio Veronese's *Raising of Lazarus* (early sixteenth century; 148 × 205.5 cm, GG 6679) has a typical mid-twentieth-century facing with newsprint paper. In the mid-1980s, Philippe de Champaigne's *Lamentation for Abel* (1656; 312 × 394 cm, GG 371)[3] was faced with sheets of Japanese paper. However, restoration was delayed much longer than planned, and the facings—applied with an aqueous medium—may have caused damage, such as blanching of the varnishes. Often loose paint chips adhere better to the paper facing than to the support, making the paper's removal difficult. Our efforts to remove facings and properly consolidate flaking paint layers are ongoing.[4] This experience over time has led to a much more critical view of facings.

As mentioned, our collection is housed at different locations, but earlier decades saw attempts to centralize all holdings. The KHM's new central storage facility, built in 2011, proved vital for storing large canvases (Götz and Oberthaler 2013). All paintings are now stored on racks and are accessible without direct handling. The racks in the storage room for large-scale canvas paintings measure 5 × 8 meters and can accommodate even the largest canvases, including those still rolled or stored between cardboard sheets (fig. 14.1).[5] At present, the KHM storage holds 3,142 paintings and about 1,085 frames. Hopefully, soon all canvas paintings will be accessible and mounted on stretchers.

Figure 14.1 Room housing large paintings in the Kunsthistorisches Museum's central storage facility, installed in 2011. Image: © Kunsthistorisches Museum Wien

A significant number of lined canvas paintings suffer from infestation by *Stegobium paniceum* (biscuit beetle), which primarily affects canvases lined around 1900, when a thick layer of glue paste with a high content of animal glue was used. To avoid new infestations, all objects or paintings are treated in an anoxic nitrogen chamber prior to storage. Both conservators and our building department focus on integrated pest management. We use traps to monitor insect activity, some with lights to attract insects. Since 2011, we have had one case of reinfestation in the central storage building, which we countered with tiny parasitoid wasps, *Lariophagus distinguendus*, which parasitize the beetle's larvae, ending the infestation (Querner, Oberthaler, and Strolz 2019).

TITIAN'S *ECCE HOMO*: AN EIGHTEENTH-CENTURY LINING—PARTIAL INTERVENTIONS INSTEAD OF RELINING

For centuries, lining was used to preserve canvas paintings. Our earliest extant linings presumably date from the late eighteenth century. Their typical loosely woven lining canvas is fixed to the original canvas with glue-paste ironed on from the reverse.[6] A recently treated prominent example is Titian's *Ecce Homo* (1543; 242 × 361 cm, GG 73).[7]

We believe the painting was placed facedown on a table, without the strainer, for lining. Then the lining canvas, fixed to the (new) strainer and impregnated with glue paste, was placed on top of the original canvas. The painting's original tacking edge was affixed with separate nails, covering the earlier rows of tacks and the ironed lining. The multiple rows of nails are visible only in X-ray images and when the painting is removed from its stretcher. If paintings with such linings are removed from the stretcher, the rougher texture of the lining canvas is visible where it has not been ironed, as it was covered by the strainer. The marked bevel of the strainer bars allowed the edges beneath the stretcher to dry better.

Normally these eighteenth-century linings are quite stable, and the surface texture of the original paint layers is well preserved, as on Titian's *Ecce Homo*; there only the tacking edges were torn, and the canvas had come loose from the stretcher, suffering some deformations in the corners. Since the damage mainly affected the edges of the lining canvas, we decided to remove the stretcher and stabilize the torn borders but not remove the lining the painting.

Delaminated areas between the original and the lining canvas were reglued. We used inserts of old or similar canvas to restore the losses and the coherence of the lining (fig. 14.2). Smaller holes from previous insect infestation were filled with a mixture of canvas fibers and sturgeon glue.[8] For the strip-lining, which was needed to remount the painting on a stretcher, we glued natural canvas—frayed and thinned to avoid sharp edges—to the lining with an acrylic emulsion.[9] The stretcher was structurally stable but much keyed out and too small when assembled; we added strips of wood to align it exactly with the painting's format. Restretching was done the traditional way (i.e., with small pieces of cardboard beneath the nails to facilitate their removal, if necessary). Structural treatment was followed by cleaning and removal of old overpaints, procedures we hope to publish soon.

Figure 14.2 Titian (Italian, ca. 1488–1576), detail of *Ecce Homo*, 1543. Oil on canvas, 242 × 361 cm (95 1/3 × 142 1/8 in.). Vienna, Kunsthistorisches Museum, GG 73. Detail from the reverse during structural stabilization. Prior to strip-lining, localized areas of damage to the 18th-century lining canvas were repaired. Image: © Kunsthistorisches Museum Wien

CARAVAGGIO'S *ROSARY MADONNA*: RELOCATIONS AND FORMAT CHANGES

The nineteenth century favored using types of canvas with a finer and denser texture for lining. One example of a painting lined this way is Caravaggio's *Rosary Madonna*[10] (ca. 1601; 364.5 × 249.5 cm, GG 147), which also exemplifies the frequent format changes imposed over the years to adjust a painting's size to a new location. In this case, a "revised revision" occurred a century later.

Rubens and other prominent Antwerp artists purchased Caravaggio's *Rosary Madonna*, first documented in Antwerp's Dominican church around 1620. In 1781, the painting was presented to Emperor Joseph II, and in 1786 it was transported to Vienna. The painting was presumably rolled (Prohaska and Swoboda 2010, 71) for the 1786 transport from Antwerp to Vienna. In 1809, during the Napoleonic Wars, it was rolled on a big drum for evacuation (to save it from the French troops in case of invasion).[11] It was probably relined before being installed at Belvedere Palace in the early nineteenth century. We do not know why its size was reduced by folding about 30 centimeters of the original canvas over the upper strainer edge. This strip remained unlined until 1913, when the format change was reversed.[12]

To avoid risk and costs, large-scale paintings are rarely moved. In 2019, when the painting was moved for the exhibition *Caravaggio & Bernini*, we took the opportunity to thoroughly examine it.[13] Unframing revealed damage to the canvas from the tacking edges but also more information on format changes. The 1913 intervention concerned only the top edge, as indicated by the different, more modern tacks used there. The nineteenth-century lining canvas did not cover the entire original canvas, as the strip folded over had remained unlined.[14] In 1913, when the strip was reintegrated to the picture plane, the upper stretcher bar was temporarily removed to access the area for treatment. The border of the lining (the area of the previous tacking edge) was removed. This probably helped flatten deformations caused by the former tacking edge. The previously unlined original canvas was partially lined, but only to the edge of the previous lining, and a random strip of original canvas again remained unlined. The side bars of the stretcher were extended to compensate for the missing centimeters in its height, and the old upper bar of the stretcher was reinserted (fig. 14.3). Finally, the upper portion of the painting was restretched, returning the entire composition to its original size.

Figure 14.3 Caravaggio (Italian, 1571–1610), *Rosary Madonna*, ca. 1601. Oil on canvas, 364.5 × 249.5 cm (143 1/2 × 98 1/5 in.). Vienna, Kunsthistorisches Museum, GG 147. Detail from the reverse showing the format changes at the top of the painting, seen here at upper left. Image: © Kunsthistorisches Museum Wien

In 2019, we found that the edges of the older areas of lining, untouched since the early nineteenth century, were frail, with several detached/delaminated or torn pieces of canvas. The paint layers of the previously folded portion were considerably more cupped than those of the well-preserved main picture surface. In addition, the area had suffered deformations in the support. A small, unlined area was smothered in glue remnants from the first lining.

Removing the nails from the upper edge and the upper stretcher bar revealed the top edge (again). The thick glue remnants mentioned above could then be scraped away with a scalpel, and deformations were flattened using local humidification and weight. Unlined areas received small inserts of old canvas of a weight and weave similar to the nineteenth-century lining that were attached to the original canvas with methyl cellulose. Finally, the upper edges were reattached to the stretcher. Other detached canvas pieces along the edges were reglued with a mixture of wheat-starch paste and sturgeon glue and dried under pressure. Without much effort, the painting with its two-hundred-year-old lining was restored to a structurally safe condition.

SALVATOR ROSA'S *BATTLE OF THE ROMANS*: REVISITING AN ABANDONED TREATMENT—STABILIZATION OF A CANVAS WITH A LINING DAMAGED BY INSECT INFESTATION

We do not know why the cleaning of Salvator Rosa's *Battle of the Romans* (1645; 229 × 345 cm, GG 1641) was interrupted—perhaps it proved too difficult or too much work, or priorities shifted, or its condition or quality did not meet expectations.

The painting was stored for more than fifty years until research by Gudrun Swoboda, alongside ongoing attempts to improve the condition of all stored paintings, suggested a reevaluation. Its condition was compromised: the painted surface comprised overpaints, overcleaned areas, and structural problems, including flaking paint layers that were partially covered with paper facings, and fragile tacking edges from earlier (now inactive) insect infestations.[15]

The thick glue layers of linings dating to around 1900 had provided attractive breeding grounds for *Stegobium paniceum*, which likes to lay its eggs in the narrow, dark, sheltered space between stretcher and canvas, where its larvae can remain hidden. These beetles had damaged the edges of Rosa's composition so badly that only some areas remained attached to the stretcher. Removal of the stretcher revealed the extent of the infestation: large areas beneath the stretcher were eaten, and most of the lining canvas had degraded to fibers and powder (fig. 14.4). Lining in unaffected areas, however, remained firmly attached. The original canvas, where visible, appeared quite thinned—probably it had been scraped down prior to the lining to obtain a "clean" surface.

Figure 14.4 Salvator Rosa, *Battle of the Romans*, 1645. Oil on canvas, 229 × 345 cm (90 1/8 × 135 4/5 in.). Vienna, Kunsthistorisches Museum, GG 1641. Detail from the reverse after the stretcher was removed showing severely damaged lining canvas with insect infestation (*Stegobium paniceum*). Image: © Kunsthistorisches Museum Wien

We decided to attempt a partial treatment rather than a complete removal of the lining, removing only the eaten areas of the old lining and replacing them with a new strip-lining in order to safely restretch the painting. Removing the entire lining, with its strong adhesion and massive glue layer, would have stressed the original canvas and paint layers and would have required a new lining.

We used a semisolid gel of agar to remove the lining glue along the damaged edges, which peeled off with the old glue embedded. Remnants of glue on the canvas were removed mechanically with a scalpel. We chose acrylic emulsion Lascaux 498-HV as the adhesive. The fringes of the strip-lining were later attached atop the old lining using wheat starch with rabbit-skin glue and pressure. Once cleaning and restoration are completed, we hope to install the painting in the gallery.

JOHANN FRANZ GREIPPEL'S *FOUR DAUGHTERS OF MARIA THERESIA PERFORMING THE OPERA* PARNASSO CONFUSO *BY CHRISTOPH WILLIBALD GLUCK IN 1765*: IN SITU TREATMENT OF TWO LARGE CANVASES LINED AROUND 1900

Many paintings from the collection embellish government offices, the most prominent of which is the Office of the Austrian President in Hofburg Palace, which boasts two large eighteenth-century canvases depicting a performance of Gluck's *Parnasso Confuso* at Schönbrunn on January 24, 1765, in which four of Maria Theresia's daughters participated.

The two monumental paintings were installed after World War II. Over the years, their canvas supports had lost tension and they appeared almost like flapping draperies. We had to organize our interventions carefully, as the Presidential Chancery is closed for only six to eight weeks each summer. It took us two summers, one for each painting.[16] We removed all the furniture and placed the canvas carefully on the prepared floor. Removing the stretcher revealed that the lining canvas was not infested by *Stegobium paniceum*, although the lining was of the type discussed above, but there was some delamination between the original canvas and the lining canvas around the edges.

After cleaning the reverse with a brush and vacuum cleaner, the delaminated parts of the lining and the original canvas were reglued with a paste comprising wheat starch and rabbit-skin glue.[17] For strip-lining, we used natural canvas, thinned on the inside by removing threads (parallel to the tacking edge) and by sanding the remaining threads to avoid sharp edges.[18] The top-left part of the painting, showing the interior of the opera house (GG 6826), was disfigured by an old, coarse repair of a tear in the original and lining canvases. Following a partial humidity treatment, we opened the overlapping areas of the lining canvas. The threads around the tear in the original canvas were then aligned and mended (fig. 14.5).[19] Bridges of hemp threads impregnated with Beva were attached to the original canvas in the torn area using a soldering needle.

Figure 14.5 Johann Franz Greippel, *Four Daughters of Maria Theresia Performing the Opera* Il Parnasso Confuso *by Christoph Willibald Gluck in 1765*, 1765. Oil on canvas, 400 × 480 cm (157 1/2 × 189 in.). Vienna, Kunsthistorisches Museum, GG 6826. Detail from the reverse during treatment. After partially opening the lining canvas in the damaged/torn area, the old tear in the original canvas was mended (thread to thread). Finally, the tear in the lining canvas was sewn closed and the bond between the canvases reestablished. Image: © Kunsthistorisches Museum Wien

The tear in the lining canvas was closed with stitches sewn by using a semicircular needle and nylon and polyester threads. The bond between lining and original canvas was achieved by injecting starch paste with a syringe and then adding weights while it dried. For additional stability, noncorrosive steel wires (0.3 and 0.38 mm) were attached at several points with thick, adhesive acrylic emulsion (Lascaux 498 HV). The stretcher was numbered and then dismantled in our workshop, where it was stabilized and structurally weak areas repaired. Once the structural canvas treatment was completed, the repaired stretcher elements were returned to Hofburg Palace to be assembled, and the canvas was stretched and the painting reinstalled.

TWENTIETH-CENTURY LINING PROCEDURES

Lining methods changed little over the centuries—restorers were trained by their predecessors and trained their own successors. For many years, there was a strict division of labor between structural and “artistic” work. Though that is still enforced in some studios, the KHM abandoned it in the early 1980s. So-called artistic restoration work included cleaning, retouching, and varnishing and was the preserve of painter-restorers until 1934, when the conservation program was established at the Academy of Fine Arts Vienna and trained restorers started to take over.[20] Structural treatments (lining, cradling, filling) were considered less important and presumably were carried out by technicians who had mostly trained as cabinetmakers and were probably supervised by restorers.

Irons were replaced by a veneer press in the late 1930s. The aim was to minimize the physical impact during lining procedures—humidity, heat, and pressure—by omitting heat. Once cleaned and filled, the paintings were pressed in the veneer press between wooden boards and several layers of felt and molino, a plain cotton cloth. Due to the use of an aqueous lining adhesive, the painting needed to be pressed before the unstretched canvas reacted to humidity—timing was of the essence. For these linings, however, the paintings were pressed repeatedly—apparently, the period favored a flatter surface texture than we do today.

There is very little documentation of such lining procedures. A rare exception is the photographic documentation of the lining of Cagnacci’s *Suicide of Cleopatra* (1661–62; 153 × 169 cm, GG 260) carried out by Hubert Dietrich and Gerald Kaspar in 1985. The latter stressed the importance of documenting the structural treatment procedures, rather than only the state before cleaning and after restoration, as was the practice before. The existence of photographic evidence from treatment procedures is largely owed to Kaspar.

Lining was routine and something of a go-to conservation treatment for damaged canvas paintings. The storage facility houses many cleaned, lined, and filled—but not restored—paintings, such as Gottfried Libalt’s *Garland of Fruits and Carpet* (1664; 212 × 195 cm, GG 2933) and Pietro de Pomis’s *Archduke Maximilian Ernst on His Deathbed* (1616; 118.5 × 227.5 cm, GG 9275).[21]

Until the 1990s, starch-paste lining remained standard in the KHM Vienna, which is why we have almost no paintings with wax linings or synthetic materials.[22] Since then, lining has been almost completely abandoned: from 1980 to 2000, fifty-two paintings were lined; from 2000 to 2020, only four paintings were lined. Conservators in a museum generally prefer a noninvasive approach. Whereas artworks in churches and private homes are often at the mercy of their surroundings, the controlled environmental conditions of museums protect works of art and slow their deterioration. If a conservator can monitor the conditions of a critical painting on a regular basis, treatments can frequently be postponed. This, however, requires a trained conservation staff and—apart from sufficient documentation—a good institutional memory. But a preference for fewer and less-invasive treatments also means the skills to perform in-depth structural interventions are gradually lost.

GOTTFRIED LIBALT'S *STILL LIFE WITH A BUST OF ARCHDUKE LEOPOLD WILHELM*: STRUCTURAL STABILIZATION OF AN UNLINED SEVENTEENTH-CENTURY PAINTING

Although lining was standard practice for centuries, quite a few canvas paintings remained unlined. One such is Gottfried Libalt's *Still Life with a Bust of Archduke Leopold Wilhelm* (1660; 253 × 119 cm, GG 7795) (fig. 14.6). Over the years, the painting suffered extensive structural damage: the tears in the original canvas measure 5 meters in total. In storage for centuries, its width was reduced by almost half when large parts of the composition were folded back.

Figure 14.6 Gottfried Libalt, *Still Life with a Bust of Archduke Leopold Wilhelm*, 1660, before treatment. Oil on canvas, 253 × 119 cm (99 3/5 × 46 7/8 in.). Vienna, Kunsthistorisches Museum, GG 7795. Shown in raking light. The painting has been removed from the strainer and unfolded. Image: © Kunsthistorisches Museum Wien

A new installation at the Kunstkammer gave it a new lease on life; it is paired with the bust that is depicted in the painting.[23] Libalt's still life must have been commissioned by Leopold Wilhelm himself. It is listed in his 1659 inventory, though it is dated a year later on the painting itself.

Unlined seventeenth-century paintings are rare and the still life's surface texture, with its illusionistic, almost 3D-rendering of the carpet, motivated us to find a way to stabilize the picture without lining it. Pressed for time, we collaborated with a specialized freelance team who performed the treatment in time by organizing several round-the-clock shifts of tear-menders.[24] (For details of the treatment, see Walde, Wernitznig, and Oberthaler 2014.)

To begin, we removed the painting from the strainer and examined the various interventions and format changes (see fig. 14.6). In addition to the painting's reduced width mentioned above, its height had been extended by the addition of two strips of canvas.[25]

Because the painting is listed in the archduke's inventory, this gave us a contemporary record of its original size, although this includes the frame.[26] The canvas scalloping and other key features, such as the selvages within the original seam (presumably once in the center) as well as on the left edge and the black paint covering the unpainted canvas at the left edge provided evidence of its original format. Our research also suggested that the top extensions were later additions. This and the size recorded in the inventory allowed a conclusive reconstruction of the original, and we decided to reestablish this format.

To flatten the deformations, the canvas was treated with indirect humidity.[27] The most labor-intensive interventions were thread-by-thread tear mending and thread-by-thread inserting (and weaving) new threads to reconstruct the losses of original canvas (fig. 14.7).[28] The open areas in the original seam were connected with stitches or bridges from the reverse.[29] The strip-lining with a new natural

Belgian canvas, prepared by fringing and coated with a layer of self-made Beva film, was then sealed to the original canvas.

Figure 14.7 Libalt, *Still Life*. Detail of the right part (center) during treatment. The original canvas was repaired by inserting and weaving in new threads. Image: © Kunsthistorisches Museum Wien

To reconstruct the original format, we needed to "lose" the top, nonoriginal strip of canvas. We decided not to remove these nonoriginal (though old) additions but to flip them. To protect both the old canvas and brittle paint layers, a rounded wooden (slightly larger) profile was added to the top edge of the stretcher. The upper edge of the support was fixed to the stretcher on the reverse with adhesive at the strip-lining. The canvas and paint layers on the reverse are protected with acid-free corrugated cardboard. The painting was then framed and glazed for display, with its unlined but fragmentary character preserved.

CONCLUDING THOUGHTS AND FUTURE OUTLOOK

Extensive treatments of large paintings depend on many preconditions, which sometimes are difficult to achieve even in established institutions. These preconditions are free studio space for an extended period of time and the long-term collaboration of trained professionals—conservators, curators, scientists, technicians, directors—making treatment decisions a big commitment. Unfortunately, such commitment is increasingly difficult to attain in times marked by the quick turnover of paintings forced on conservation studios by exhibition schedules and reduced museum staff.

With the focus increasingly on preventive conservation and technical research (and the time needed for administration), museum conservators are in danger of losing their structural intervention skills. In contrast, freelance conservators need to complete conservation treatments, but they may not always be able to carry out the necessary research, resulting in divergent skill sets between restorers working in museums and freelancers. This fact makes it imperative that museum staff and freelancers join forces and institute a regular exchange of ideas. Collaboration between professionals with a wide range of skills and strong institutional support for conservation are key to preserving artworks for future generations.

ACKNOWLEDGMENTS

Conservation of large paintings requires teamwork, and many colleagues have contributed to the interventions presented here. I would like to thank Eva Götz, Michael Odlozil, Ina Slama, Gudrun Swoboda, Stefan Weppelmann, Wencke Deiters, Sylvia Ferino, Sonja Kocian, Ingrid Hopfner, Flaminia Rukavina, Markus Geyer, Rudolf Hlava, Monika Strolz, Sanela Antic, Michael Aumüller, Michael Eder, Andreas Uldrich, Katharina Hatzl, Rita Berg, Bernadette Henke, Julie Sutter, Rhe Suykens, Laura Hack, Gerlinde Gruber, Gerhard Walde, Simone Wernitznig, Ute Tüchler, Carmen Lenoir, Helena Brosch, Sarah Danhauser, Jonathan Debik, Sarah Jahns, Mona Konietzny, Joan Lee, Caroline Ocks, Christina Robens, and Herbert Maurer.

NOTES

1. More than a thousand (1,046) paintings in the collection are over 200 centimeters in at least one dimension.
2. A prominent example is Giorgione's *Three Philosophers*, which is listed as stored and without strainer ("ohne Blindrahm") in the 1772 inventory.
3. See https://www.khm.at/en/objectdb/detail/3392/?offset=0&lv=list.
4. Facings covering the entire surface were removed on the following paintings: *Jacob with Esau*, by Johann Heinrich Schönfeld (98 × 181 cm, GG 1145); *Georg Castriota, Called Skanderbeg, Duke of Albania*, Northern Italian (213.3 × 98.3 cm, GG 7954, treatment by Claire Toussat in 2012); *Resurrection of Christ*, by Garofalo (314 × 181 cm, GG 9551, treatment by Ingrid Hopfner in 2015); and *Franz I Stephan and Maria Theresia with Eleven of their Children*, by the School of Martin van Meytens the Younger (200.7 × 179.3 cm, GG 3149).
5. The largest canvas is 400 x 800 cm: Pierre Benevault des Mares, *Diana Commands to Hunt* (1672; GG 6890). It is stored on a roll.
6. The same type of lining is seen on Titian's *Nymph and Shepherd*, 1570–75 (150 × 187 cm, GG 1825), with an inscription on the reverse: "Hickel rep. 1774" (Oberthaler 2008, 192).
7. See https://www.khm.at/en/objectdb/detail/1944/?offset=12&lv=list. The treatment was performed by Michael Odlozil and Katharina Hatzl in 2013–14, and generously supported by American Bank.

8. Filling material: linen fibers cut, precooked, and bound with sturgeon glue (20%) and wheat starch (13%).
9. Consolidation of flaking paint layers: sturgeon glue (7%) with surfactant Surfynol 61 (3,5-dimethyl-1-Hexen-3-ol). Strip-lining: natural canvas (flax fibers) and the copolymer butyl methacrylate dispersion Lascaux 498 HV.
10. Caravaggio, *Rosary Madonna*, ca. 1601 (364.5 × 249.5 cm, GG 147). https://www.khm.at/en/objectdb/detail/425/?offset=8&lv=list. Treatment was carried out in September 2019 by Eva Götz, Michael Odlozil, and Ina Slama.
11. According to art historian Alice Hoppe-Harnoncourt, the painting was evacuated on a "big drum" (i.e., cylinder) together with seven other Italian and Netherlandish paintings in 1809 (email correspondence, February 27, 2020). I am grateful to Alice Hoppe-Harnoncourt for this information.
12. The earliest record of the *Rosary Madonna*'s size from 1824 (room 6, no. 20) already gives the reduced height, as does the 1837 catalogue (Krafft 1837, 33).
13. *Caravaggio & Bernini—The Discovery of Emotion.* KHM Vienna, October 15, 2019–January 19, 2020.
14. This was indicated by the reduced height of 337 cm in the 1837 catalogue (Krafft 1837, 33).
15. Treatment by Eva Götz and Michael Odlozil; structural assistance by Rhe Suykens and Laura Hack, November 2017–February 2020.
16. Each canvas measures 400 × 480 cm (GG 6826 and GG 6829). Treatment by Eva Götz, Elke Oberthaler, Michael Odlozil, Ina Slama, Rita Berg, Julie Sutter, and Bernadette Henke, July–August 2012, respectively. In addition to structural stabilization, the surface was cleaned and discolored retouches were adjusted.
17. Ratio of wheat starch (1:4) to rabbit-skin glue (10%) = 10:1.
18. Adhesive: Lascaux 498-20X.
19. Adhesive: mixture of sturgeon glue, glucose, glyoxal acid, and tylose.
20. Today two institutions in Austria offer academic conservation training programs: the Academy of Fine Arts and the University of Applied Arts, both in Vienna.
21. Lining of Gottfried Libalt's painting is not documented. Pietro de Pomis's painting was lined in 1963.
22. Rare exceptions exist in late acquisitions or treatments performed outside the KHM.
23. Jêrome Dusquenois, *Archduke Leopold Wilhelm*, 1650, marble, KK 8932.
24. Treatment performed by the team of Atelier Walde Vienna, October 2012–February 2013.
25. Size before treatment was 253 x 119 cm.
26. "827. Ein grosses Stuckh von Öhlfarb auff Leinwaeth . . . In einer schmallen, schwartzen Ramen, hoch 10 Spann 9 Finger vnd braidt 9 Spann / 5 Finger./ deponiert" (A large oil painting on canvas . . . in a narrow black frame, ca. 300 by ca. 188 cm / stored). Size listed in 1659 inventory is 226.72 x 197.6 cm, including frame. Size after treatment (stretcher) is 225 x 196 cm.
27. Indirect humidification above nonwoven Gore-Tex fabric, and subsequent drying under pressure (sandbags). Severely distorted areas of canvas were rearranged after vaporization using insect pins.
28. Thread-by-thread tear mending with sturgeon glue 20% and wheat starch (ratio 1:2). New thread material: linen (flax), color-adjusted to original canvas threads and coated with 3% Kollotex.
29. Same adhesives as in tear mending, see preceding note.

III

Open Questions and Research

15

Canvas Complexity: The Life of a Complex Composite

Christina Young, Professor, Glasgow University, Kelvin Centre for Conservation and Cultural Heritage Research

This paper discusses the ways that different fabrics, weaving, and structures of a canvas influence its mechanical and hydromechanical behavior. It goes on to consider how this already complex composite is further modified by subsequent layers, whether in a new or degraded state. In particular, it highlights the conditions in which the weave structure—and behavior related to that structure—still influences the overall response of a painting on canvas. The paper also reviews research relevant to conserving canvas in the fields of polymer mechanics, fiber-reinforced composites, and smart materials, looking at research related to both the modeling of canvas and composite properties and at experimental studies. Often, there appears to be a big gap between research carried out in science, engineering, and conservation science and the research that conservators feel will help them solve practical problems and devise effective treatments. This paper suggests directions for future research—pure and applied—that may aid in the structural conservation of paintings on canvas.

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INTRODUCTION

The woven structure of canvas, although modified by the subsequent layers of the painting, still influences the mechanical and hydromechanical behavior of this complex composite. To highlight the issues of complexity, this paper brings together and reevaluates collaborative research conducted over twenty-five years that addresses these issues in the context of the structural conservation of canvas paintings. It discusses the methodologies of research related to experimental work, practical conservation implementation, and the modeling of canvas and its composite properties. The key findings, with examples, and the methods used to obtain useful data and practical insights are given, along with the references for the experimental details and results.[1]

Recent research in the fields of polymer mechanics, fiber-reinforced composites, and smart materials that are relevant to conserving canvases of the past (and future) is highlighted, as are directions for future research—pure and applied—that will aid in the structural conservation of paintings on canvas.

PHYSICAL STRUCTURE

Types of Canvas

In the context of artists canvas and lining fabric, most fabrics are made from natural materials. For painted cloth, silk, calico, cotton, and linen have been the most common fabrics both geographically and historically. However, other natural materials—for instance, bark cloth (Lennard, Tamura, and Nesbitt 2017)—are part of rich traditions of painting, and we are only beginning to understand their behavior as painting supports (Smith, Holmes-Smith, and Lennard 2019).

The choice of canvas by artists is often made for pragmatic reasons, including local production, availability, expense, and size. Important features of these natural materials are their flexibility, texture, and absorbency (see "Moisture Response" below), which make them suitable for the application of paint. For fabric supports, some of these features are a product of the preparation, but most originate from the fiber type, yarn structure, and weave structure (flexibility and texture). It is reasonable to suggest that in all but the most prestigious commissions the artist had little control, or even interest, in these factors, but instead innately, or through treatises and word of mouth, thought of a canvas as either suitable or not suitable for the execution of a particular painting.

The discussion below focuses on cotton and linen but acknowledges the use of silk, both in traditional non-Western and Western art and in contemporary contexts. In a few cases, it has been possible to trace the evidence of artists choice through letters, colormen archives, and anecdotes (Johnson et al. 2010), but rarely has the production of the canvas been under their control. Historically, cloth was a commodity for household furnishings, military and naval outfitting, and ecclesiastic and court events. It is with the advent of industrial weaving that different weights of cloth became more accessible through artists suppliers, and the small-batch production of artists canvas started to occur. However, there is mounting evidence through technical examination and conservation records that, prior to industrialization, artists had access to different types and weaves, and in some cases clearly chose some over others (Heydenreich et al. 2008; Seccaroni 2012). Sources, including the National Portrait Gallery's list of British artists suppliers (1650–1950),[2] individual websites, and publications that include research into the trade in artists materials (Kirby, Nash, and Cannon 2010), provide invaluable information from which to build up a better understanding of the context in which artists choose their materials.

Contemporary artists make both conscious and pragmatic choices to use best-quality artists canvas (usually fine plain-weave linen or cheaper cotton duck, which is also available in wider widths), sacking (jute, usually plain weave), bank money bags (cotton and linen, plain or twill weave), and mattress ticking (an old favorite, usually linen with a herringbone twill weave), as well as older, traditional materials used in a contemporary context, such as bark cloth (Schneider 2021).

Artists use canvas in a variety of ways: unstretched, sewn, pierced, or formed into three dimensions. Canvas is also woven from polyester specifically for art and conservation. This is manufactured/supplied by companies such as Fredrix in the United States, Haywards in the United Kingdom, and Lascaux in Germany.[3] In the performing arts, there is more painting on plastic gauzes and projection cloths made from woven and nonwoven synthetics, including polyester, nylon, and Kevlar. The range of fabrics used and available is best appreciated by visiting the website of J. D. McDougall, a company that has supplied fabrics for over a hundred years.[4]

Types of Weave

A woven fabric made from a single type of fiber (e.g., flax) is a composite influenced by the way it is grown or synthesized and then processed into yarn ready for weaving. The various levels of hierarchy in the structure influence, to differing degrees, the overall fabric behavior. The yarn type, diameter, flatness, and stiffness affect flexibility and moisture response. The density of fiber yarns and type of weave influence yarn mobility, stiffness, drape, fracture toughness, and permeability (Young and Jardine 2012). The fabric permeability affects moisture response, consolidation, impregnation, and lining treatments (Young and Ackroyd 2001).

Additionally, surface or impregnating coatings (e.g., size, paint, and consolidants) affect tensile, shear, bending properties, yarn mobility, and fracture toughness. For traditional Western paintings, we have a good experimental and empirical understanding of the complex composite of woven fabric and coatings. Research into the behavior of double-sided painted cloth such as trade union banners (fig. 15.1) (Smith, Thompson, and Hermens 2016; Sanchez Villavicencio, Young, and Thompson 2022) or the behavior of twill and more complex weaves, however, is in its infancy (see "Reconstructing Weaves" below). Certainly, more research is required to determine the dominant contributing factors in the mechanical and hydromechanical behavior of canvas when new materials and techniques are used in contemporary art or used in mixed media and with new synthetic artists materials such as water-mixable oil paint, inks, or acrylic-primed spun polyester canvas (see "Reconstructions for the Contemporary Use of Canvas" below).

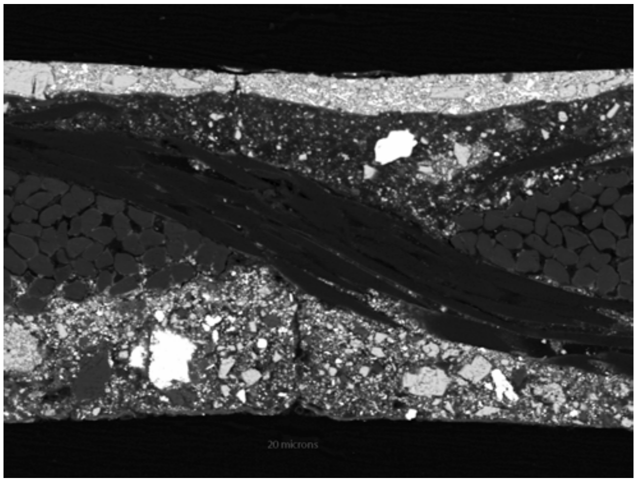

Figure 15.1 Cross section at 5× magnification of a 1930s British trade union banner: silk painted on both sides with size, oil paint, and silver leaf. University of Glasgow. Image: Christina Young

Prediction of painted canvas properties from experimental mechanical and chemical data is the first step. Testing on single-constituent yarns, free films, single layers, and/or simple multilayers provides invaluable information that relates to both the present and past and to changes in properties caused by natural aging and conservation treatments. However, these are relatively simple interactions and therefore only partially representative. Conservation treatments themselves are a valuable source of "live" empirical data of the real complex interactions, but they are not easily reproducible. Nevertheless, many years of experience add up to a powerful knowledge base of possible outcomes.

Analytical or computational studies for fabric/canvas behavior have developed models that can account for one level of hierarchy—fiber level, yarn level, weave pattern level—or with continuous, homogeneous layers with simplified superposition of layers. Ideally, however, to model fabric permeability, for example, it is necessary to consider both microporosity (fiber spacing) and macroporosity (yarn spacing) (Zeng et al. 2014). Models based on geomechanical structures (soil and rock) have been suggested as a useful approach to studying consolidation (Michalski 2008). Certainly, many of the phenomena—such as crack networks, diffusion, and complex interacting layers—are common to both fields. Therefore, applying such models would be beneficial to canvas conservation studies.

Similarly, to predict biaxial behavior of woven fabric, the model of the weave needs to consider friction at the yarn crossover. These more complex multilevel models are yet to be fully developed (Aliabadi 2015). Past attempts to model the complex structure of canvas paintings and fabrics have used a finite element analysis (FEA) approach (Guanzhi et al. 2017; Mecklenburg, McCormick-Goodhart, and Tumosa 1994). By using analytical models developed for tensioned fabric structures, the problems normally encountered with accurately modeling complex curved surfaces are mitigated. Bicubic-spline models developed originally for architectural applications (Brew and Lewis 2007) are the most representative way to model a woven stretched canvas on a stretcher (Young 2013; see "Strain Distribution" below). However, the interaction of the uppermost layers can be successfully modeled with FEA, taking into account their viscoelastic properties (Tantideeravit et al. 2013).

DEALING WITH COMPLEXITY

In what ways is it possible to complement the existing research? One approach is epidemiological studies of collections and promotion of documentation protocols that include canvas weave pattern and count, fiber type, and duty/colorman stamps. This information not only helps in the identification of the date and source of the canvas but also is invaluable for understanding the artist's intent and the provenance of artists materials (Johnson et al. 2010; Murillo-Fuentes and Alba 2018). It is also important for conservation, as the weave structure still influences the overall response of a painting, whatever its age. Combined with consistent materials characterization, such information may allow further insights to be gained into the mechanical and hydromechanical behavior of real paintings.

While it is not always possible to be historically accurate at every level of the canvas structure, weave, painting, and lining reconstructions allow for repeatability and for endless combinations to be experimentally tested and trends in behavior to be established (Daly Hartin et al. 2011; also see "Moisture Response of Linings" and "Reconstructing Weaves" below). Lined paintings, as well as modern and contemporary use of "canvas"—wherein if a material exists, an artist will use it, and unconventionally—require an understanding of geometry, construction, and potentially the properties of many different materials. Reconstructions play a crucial role in understanding these elements.

STRAIN DISTRIBUTION

Several factors make the strain distribution within canvas complex: it is a woven rather than a continuous, homogeneous layer; the strain response of the yarns is usually different in the weft and warp; and factors including friction, density, and weave pattern influence the strain distribution. Additionally, on a strainer or stretcher, the attachments and the stretcher construction (corners) induce uneven loading. While the stress distribution that this loading creates cannot be directly measured, the strain distribution can be measured by techniques including electronic speckle pattern interferometry (ESPI), digital image correlation (DIC), and photogrammetry. ESPI can be used to obtain accurate quantitative measurements of strain distributions of primed canvas on a stretcher that replicate a real painting configuration. Biaxial tensile properties of a painting and its constituents can be obtained by mechanical testing. By combining biaxial tensile testing with two-dimensional strain mapping, however, it is possible to gain an understanding of the composite behavior of a stretched canvas and the forces to which it is subjected.

The biaxial restraint of the canvas alters the strain distribution around the tacks or staples, becoming progressively more complex toward the corners. At the macro level, the strain patterns induced by the attachments are similar, with closer spacing resulting in more even strain distribution. If the attachments pass through preprimed canvas, there is reduced local cusping because of the greater resistance of uncracked primed canvas to distortion in the bias direction of the canvas. The restraint imposed by tight corner folds reduces the high load that would be imposed on the attachments near the corners if a loosely folded corner was keyed out. Nevertheless, shrinkage of the canvas or keying out will lead to significant strain concentrations in these areas. The strain irregularities become significantly less if the canvas is attached on the rear face of the stretcher rather than the side. Staples are effective attachments until the canvas between the legs begins to slip; tears may then occur because the staple leg creates very high strain concentrations. Tacks appear to be as effective in restraining the canvas and less likely to cause tears (Young and Hibberd 2000).

Bicubic-spline modeling (validated by ESPI) was the first computational model of a painting to incorporate the stretcher, staples, corner folds, and frictional forces. The inclusion in the model of the measured coefficient of friction of 0.63 for a pine stretcher bar showed that areas of high strain move outward toward the edges of the stretcher. Figures 15.2 and 15.3 compare the measured strain obtained using ESPI with the modeled strain for the same canvas properties and loading conditions. The close correlation of the two distributions in terms of overall magnitude and specific features is very good. This gives a high level of confidence in using a bicubic-spline model to predict modes of failure and improve upon the present methods of tensioning canvas by simulating the strains induced in canvas under different conditions (Brew, Lewis, and Young 2016).

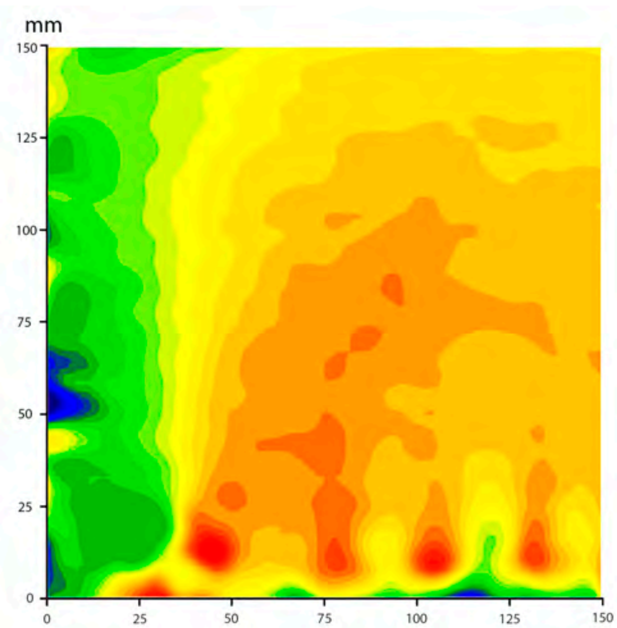

Figure 15.2 Measured weft strain distribution in one quadrant of a 30 cm^2 stretched canvas (red: 5.5 μm/mm). Image: Christina Young

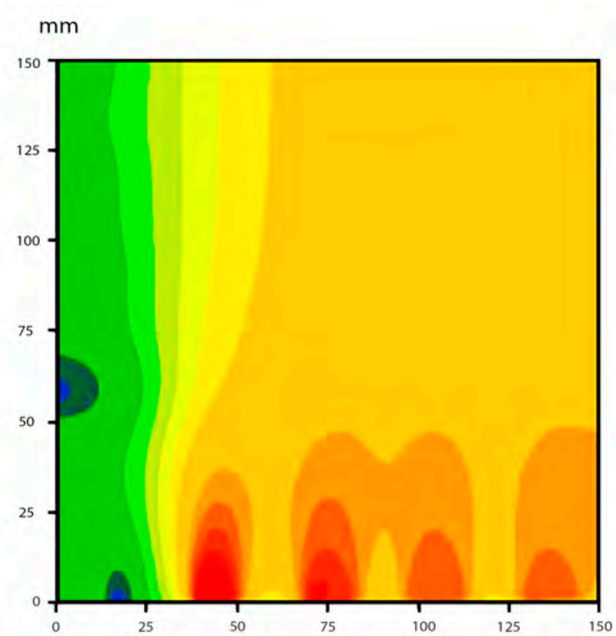

Figure 15.3 Modeled weft strain distribution in one quadrant of a 30 cm^2 stretched canvas (red: 5.5 μm/mm). Image: Christina Young

ESPI has also been a useful tool for evaluating structural conservation treatments, for instance, tear mending. A painting will have high strains near the tear and strain concentrations at the ends of the tear, which are sites for potential propagation of the tear. If a tear is close to a corner or a tack/staple, this situation will be exacerbated because of the nonuniform loading. Implicit in restoring the mechanical integrity of a painting is the requirement to reestablish a uniform strain field across the painting—or at least one whose average strain is commensurate (Young 2003). This can be seen for the Heiber (thread-by-thread) tear-mend strain map shown in figure 15.4 for an acrylic-primed canvas under 50 N biaxial tension. Redistribution, reduction, or eradication of strain concentrations (one color in the map) implies a uniform strain field. Both the patch (fig. 15.5) and the Heiber mend demonstrate that this can be achieved to some degree.

In both cases, residual strain concentrations are present. For the Heiber—or any equivalent tear mend—reducing these concentrations below these levels is very hard to achieve by visual inspection alone. A "perfect" mend would eliminate strain concentrations around the original fracture site, preventing potential propagation of the tear. Similarly, any patch should have high fracture toughness and minimal stiffness. The patch strain map (see fig. 15.5) shows that the level of strain concentrations has been reduced, but small discontinuities in strain occur at the edges of the patch.

Patches, which impart additional flexural stiffness with the aim of keeping the tear flat, are likely to result in an area of lower strain across the patch, but also larger discontinuities. The adhesive and type of adhesive interface will be the major factors in determining whether a tear mend is strong enough to withstand "normal" stress distributions within the canvas. The onset of failure will be evident as an increase in strain concentrations while loading.

Apart from assessing which techniques are mechanically most successful, future research needs to look at how the materials used in the subsequent layers of fill and retouching alter the balance of forces in and around the tear. This includes looking at interfacial tensions built up by the drying of fills and coatings (Daly Hartin et al. 2011), as well as the ability of the filled mend to withstand fatigue caused by cycling of temperature and relative humidity (RH) (Young 2013).

Strip-lining is another structural treatment perceived as minimally invasive that aims to reinstate, as far as possible, the structural integrity of the painting. The various configurations and methods to prevent a sharp change in stiffness at the edge of a strip in the picture plane have been evaluated by ESPI. For example, strip-lining with Beva 371 and polyester sailcloth (00169, manufactured solely to order by Richard Hayward & Co., United Kingdom)—with pinked edges to prevent a hard transition—actually results in strain concentrations within the picture plane at the point of the pinked triangle of polyester (Brew, Lewis, and Young 2016). As expected, under the same loading conditions a feathered edge transition results in lower strain concentrations. However, if too much adhesive is used, the stiffness of the adhesive (even Beva 371) dominates, and a strain concentration along the edge of the feathering occurs.

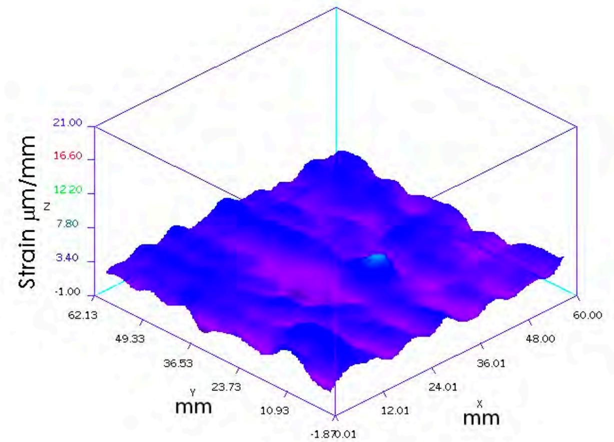

Figure 15.4 Weft strain map (average strain) 3 µm/mm of a Heiber (thread-by-thread) tear mend on a 20 mm tear (6 cm^2 central region of a 30 cm^2 canvas). Image: Christina Young

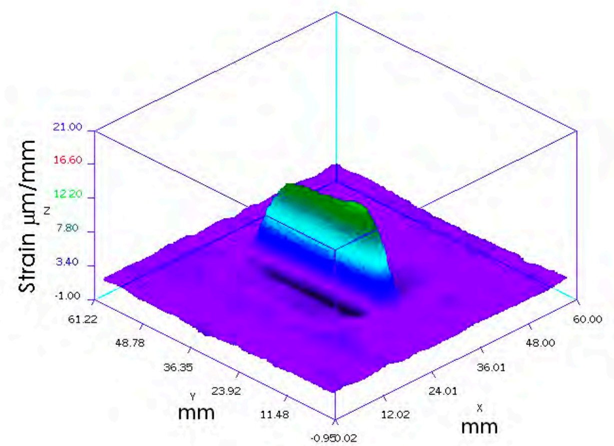

Figure 15.5 Warp strain map (average strain) 3 µm/mm of a 3 cm tear with patch on a 20 mm tear (6 cm^2 central region of a 30 cm^2 canvas). Image: Christina Young

ESPI is a very sensitive technique and does not always work well for real paintings, especially those with glossy varnishes or that are in situ where exterior vibrations occur. For the application of strip-linings and other structural conservation treatments, DIC with a relatively inexpensive, fast-frame-rate, high-resolution camera can produce good results. Such systems are standard in engineering and offer a complementary technique for nondestructive evaluation of structural conservation treatments.

MOISTURE RESPONSE

The literature on the moisture response of canvas paintings and the key findings are covered in *On Canvas* (Hackney 2020). For emphasis, some specific points from some of the published literature follow.

Moisture Response of Original Supports

Most of the data in the literature on moisture response relate to uniaxial testing. The results, however, can be misleading, as uniaxially the canvas is unconstrained in one direction, and this is not representative of the stresses that build up under biaxial constraint on a stretcher. Nonetheless, careful experimental design and interpretation can mitigate this difference. One of the most valuable resources for measuring moisture response has come from deaccessioned paintings and from nineteenth-century primed loose-linings. Figure 15.6 shows the typical load response in the weft and warp direction for a primed loose-lining produced by Roberson colormen (Carlyle, Young, and Jardine 2008). The tension in the two directions drops until an inversion occurs at 70% RH, where the tension starts to rise as RH increases.

This pattern occurs for many oil-primed canvases (loose-linings), as was demonstrated by Hedley under uniaxial tension (Hedley 1988). The initial drop in tension is attributed to the size layer becoming softer as it absorbs moisture until it reaches a gelatinous state. Simultaneously, the fibers in the canvas are absorbing moisture. At some point, the swollen fibers cause the canvas to contract, and because it is tacked in place the tension rises. Typically, the tension in the weft direction increases significantly more than the warp because it has less crimp. The major influences on where this inversion occurs are weave density and the glue-size application. Inversions have been measured from between 65% and 85% RH for nineteenth-century English commercially glue-sized oil-primed canvases and glue-sized new canvas. Figure 15.7 shows the response of another Roberson

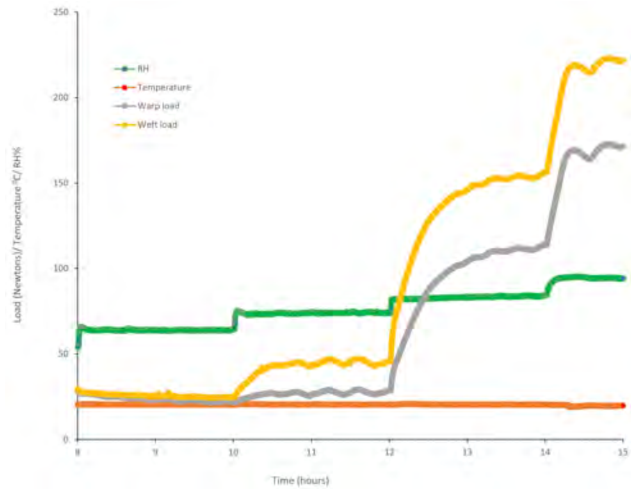

Figure 15.6 Change in tension with 70% RH inversion for a nineteenth-century primed loose-lining. Image: Christina Young

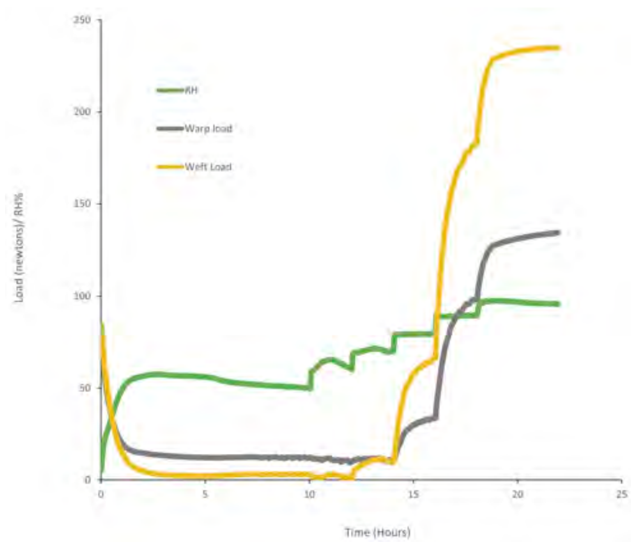

Figure 15.7 Change in tension with 65% RH inversion for a nineteenth-century primed loose-lining. Image: Christina Young

primed loose-lining with the inversion at 65% RH (Carlyle, Young, and Jardine 2008; Carr et al. 2003).

Moisture Response of Linings

A database of moisture response for archival canvas, reconstructions, and new types of canvas is useful in deciding on a moisture treatment (how long and at how much moisture), especially when the complexity of two canvases is involved, as is the case with lined paintings. As a first approximation, one can think of the problem as a superposition of two canvases, and hence two moisture responses that induce expansion and contraction, leading to stresses within the canvases and induced stress distributions in all the layers. This can be modeled with appropriate boundary conditions using FEA and/or analytical models—if the properties of each layer are known. However, there is often added complexity because the lining adhesive (especially traditional glue-paste and wax) has impregnated the original canvas, cracks, and interfaces of the painting. Nevertheless, it is possible to see trends in behavior when there is sufficient archival material to characterize degradation and mechanical properties (Young and Ackroyd 2001).

Moisture Response of Modern Materials

The use of synthetic/modern materials in painted textiles can be traced to the patents for textile coatings of the nineteenth century (Young 2012). Research into their properties began to have a direct influence of practice with the work of Hedley and Hackney in the 1980s (Hackney 2020). Artists' use of new materials, plus the conservator's desire to find a suitable lining canvas, means we need to continue to characterize a wide selection of natural and synthetic fabrics. It is insufficient to characterize only the type of canvas (linen or polyester), because even for synthetic fabrics the yarn processing, fabric weave density, and coatings (e.g., fire retardants) influence moisture response (Young and Jardine 2012). More disconcerting for those choosing materials for treatments is the generic naming of canvases; for example, "12 oz Belgian linen" is a name, not a description; it does not even mean it comes from Belgium. This is confusing and misleading if one assumes certain properties are dependent on the material's source country. Similarly, cotton duck data produced over twenty years ago (Young 1996) will generally be valid today, but changes to the source—and therefore the twist of the yarn, sizing, tension during weaving, and subsequent regulatory coatings and processes—can change the hydromechanical response.

Of course, this has always been the case. For instance, in the eighteenth century, weavers in the east of Scotland branded their linen fabrics "Osnaburg" (or Osnabrigg) an imitation of Osnaburgh (also known as Osnabrück) (Young 2012). Similarly, Lascaux P360 polyester (a linen look-alike) has changed properties since it was introduced (Young and Jardine 2012). Ideally, one should characterize (or at least empirically test) each new batch if one cannot guarantee its response.

RECONSTRUCTING WEAVES

Reconstructions of painted textiles in general—starting at the yarn level and proceeding through weaving, stretching, preparation layers, and subsequent artists materials/ techniques relevant to the work—are invaluable for understanding how the manufacturing process, subsequent preparations, and materials influence the aesthetic, kinesthetic, and physiochemical behavior of the painting. Fraught with uncertainty as to how authentic or historically accurate they may be, reconstructions still allow one to explore which properties have the biggest influence on behavior by trying different variations and through repeated testing.

Reconstruction of canvas weaves is a relatively new approach. It has come about in part from a greater awareness of and interest in the weave's significance in the provenance, interpretation, and conservation of a painting. For example, during the conservation treatment at the Cleveland Museum of Art of *The Crucifixion of Saint Andrew* (1606–7) by Caravaggio, it was possible to retrieve some information about the original canvas from the X-radiograph, even though it had been lined with a plain-weave canvas.[5] This painting may have been cut down, which would mean less cusping would be visible. Inferences drawn from the cusping had been extrapolated from simple plain-weave canvases, rather than the complex weave of Caravaggio's original canvas.

While the clarity of the original weave was hard to discern, a trained eye (in this case, that of Dr. Dan Coughlan, curator and master weaver at Paisley Museum, Scotland) identified the weave as a huckaback, which is a plain weave with a floating warp. Hence, he was able to set up the weaving pattern for a traditional four-frame hand loom. Linen and jute yarn samples were sourced from Jos Vanneste, a Belgian linen company. The closest match to a yarn fragment from the painting was a linen yarn, which was then woven into a canvas by a local Scottish weaver. Empirical testing found that the canvas was more stable on the bias than an equivalent plain weave without a floating warp, and it developed less cusping when tacked onto a stretcher.

The canvas was also prepared with a traditional double ground layer, and, interestingly, drying cracks within these layers were of a very similar size and pattern (Brunton 2018). A more systematic and controlled set of tests is now being performed on these samples using the biaxial tensile tester in the Conservation Research Laboratory at the Kelvin Centre, Glasgow University. Such reconstructions are useful not only for understanding the complexity of canvas but also for possible use as fabrics for structural treatments. Having control over the weaving process allows for a bespoke pattern (see Loermans's poster in these proceedings) and, combined with testing, the ability to tune its properties.

RECONSTRUCTIONS FOR THE CONTEMPORARY USE OF CANVAS

The value of reconstructions for conservation/preventive issues related to contemporary works as well as older works cannot be underestimated. Either by working directly with the artists, gallery, artists studio, fabricators, or documented interviews, much can be gleaned, if not always volunteered, that enable the use of the same materials and technique in the reconstruction. This approach has been used in cleaning (Barker and Ormsby 2015; Krueger 2017; Diamond et al. 2019), very effectively for tear mending (Piotrowska and Amann 2009), and assessment of structural stability and preventive treatments (Griffin, Young, and Hale 2014).

One example is a series of acrylic preprimed linen and polyester canvases on which acrylic paint and screen-print ink had been applied either directly or through a screen. These works were unstretched on arrival for a display of the artist's work at a gallery in London. Several features were considered undesirable: a general buckling of the canvas with sharp cupping in certain areas, cracking in the upper paint layers, and some buckling remaining in the works, once stretched, with an overall lack of tension. By matching the canvases as closely as possible and applying the inks used by the artist, it was possible to conduct a series of tests on the biaxial tensile tester to re-create the phenomenon and to understand its cause.[6] This allowed recommendation of an appropriate treatment and possible ways to mitigate the effects in the future. It was found that the liquid phase of inks caused local shrinkage of linen. In the synthetic canvases, the liquid phase interacted with the acrylic priming, softening it, unlocking the woven polyester yarns, and allowing distortions to occur.

Possibly more challenging to conservators of the future is the embedding of materials within canvas (Nahum, McGuirk, and Watson 2019) and haptics (Bianchi 2016).[7] The testing of contemporary materials that an artist might use as a "canvas" or in a sculpture/installation or that might be a suitable alternative to traditional lining materials should be an ongoing, proactive area of research within conservation. While attempts have been made to work with manufacturers to produce materials to our specifications, commercial production of bespoke lining fabric is not viable. A proactive approach is required to understand textiles manufactured for other industries and to specify/design fabrics, as well as an investment in our profession if we are to drive research and production.

Future directions for the conservation of canvas could include:

- Designing, fabricating, and assessing canvas for artists and conservators
- Collecting more data on material properties to make available through master classes and online resources, including how to interpret the data
- Devising better simple, studio-based evaluation tests before and during treatment or when using new materials

FUTURE OPTIONS: COMPLEX CANVAS COMPLEXITY—GOOD CANDIDATES FOR ARTISTS CANVAS AND LINING FABRICS

The largest drivers of the development of new materials come from the aerospace, military, and apparel industries. The fact that woven fabrics are part of contemporary composite engineering materials attests to their success in increasing the fracture toughness of structures. Fracture toughness prevents cracks (tears) from propagating: in degraded canvas, it is the brittleness of the yarns due to chain scission and increased crystallinity of the cellulose (for flax and linen) that substantially reduces the fracture toughness. Cotton duck has a much lower fracture toughness even when new because of its short staple length. Interestingly, natural materials, including linen, are still part of active research into improving the service life of structural composites, as they have properties yet to be fully replicated by other methods (Pandian and Jailani 2019).

Nonwoven fabrics have been used by both artists and conservators, typically as part of collage pieces or, in conservation applications, as interleaves in linings. Such fabrics can be made to be homogeneous and heterogeneous, so it would seem their relative lack of use is due to the lack of texture, drape (ability to bend and form shapes, e.g., around a stretcher bar corner), and "responsiveness" when painting. However, the low absorbency of many synthetic materials may be considered a good property for linings.

State-of-the-art fabric structures use surface modifications to give the desired properties, such as hydrophobicity using vapor deposition on fabric (Xu et al. 2019). Filled yarns have been developed to increase stiffness and fracture toughness (Gilchrist, Svensson, and Shishoo 1998). Triaxial weaves, which have two sets of warps at 60 degrees to the weft, give increased stability and stiffness on the bias and better fracture toughness (Wang et al. 2018).

Embedded sensors in fabrics have been the subject of experimentation for over twenty years and offer the possibility of in situ monitoring of canvas properties: moisture content via electrical resistance and induced strain via fiber optics (Zawadzki et al. 2012). The problem from a conservation/preventive point of view is that embedded optical devices considerably stiffen the fabric. However, with the present development of haptics and wearable sensors in the military, sports, and gaming industries (Muhammad Sayem et al. 2020), it is likely that the technology will evolve to enable development of embedded sensors for structural conservation and the monitoring of canvas complexity. Shape memory sensors may also offer an additional option. For example, self-regulating structures that respond to environmental conditions could be woven into fabric (Ibrahim et al. 2010)—and at the least they are bound to be part of future artworks.

Driven by the need to reduce our carbon footprint, energy-harvesting fabrics are being developed that convert ambient energy into electrical energy. These include dye-sensitized solar cells fabricated into functionalized yarns and made into films that can be spray-coated onto textiles (Torah et al. 2018), as well as screen-printable polymer film and polymer fibers that can harvest mechanical energy from textiles. Maybe the canvas paintings of the future could provide their own "active" microclimate.

ACKNOWLEDGMENTS

I would like to thank Tim Green, retired paintings conservator, Tate; Dean Yoder, senior conservator, Cleveland Museum of Art; Dr. Dan Coughlan, curator and master weaver, Paisley Museum; Jean Mabon, for her expertise and for weaving the Cleveland canvas reconstructions; Jennifer Brunton, technical art history student, Glasgow University; Janey Zagreb (London); and my colleagues at the Kelvin Centre, University of Glasgow.

NOTES

1. For an up-to-date, comprehensive review of the published research in the conservation field, see Stephen Hackney's *On Canvas: Preserving the Structure of Paintings* (Hackney 2020).
2. See https://www.npg.org.uk/research/programmes/directory-of-suppliers/.
3. Fredrix: https://fredrixartistcanvas.com/product-category/canvas-rolls/polyflax-poly-cotton-rolls-acrylic-primed; Haywards (now part of Heathcoat): https://www.heathcoat.co.uk/contact; Lascaux: https://lascaux.ch/fabrics/polyester-fabric-p110.
4. McDougall: https://mcdougall.co.uk/fabric/fabrics/. The company's longevity is described in Ian McDougall's biographical statement at https://powertotransform.gla.ac.uk/interviewees/.
5. Private communication with Dean Yoder, senior conservator, Cleveland Museum of Art, 2018.
6. Testing performed in the Conservation and Technology Department at the Courtauld Institute of Art.
7. Haptics is any type of technology that provides a tactile response. The technology can be embedded in fabrics or directly fabricated as a woven structure.

16

A Novel Technique to Determine the Strength of Canvas and Its Correlation with the Degree of Cellulose Polymerization

Theresa A. Bräunig, Conservator, Old National Gallery, Berlin
Anna von Reden, Professor, Stuttgart State Academy of Art and Design
Dirk A. Lichtblau, Director, Lichtblau e.K., Dresden
Christoph Herm, Professor, Dresden University of Fine Arts

This study presents a novel technique to determine the tensile strength of single flax yarn of canvas, using zero-span strength analysis. The technique was applied to both artificially aged fabric and naturally aged canvas from historical artworks, yielding reproducible and representative results. Subsequently, the degree of polymerization of the cellulose was determined by capillary viscometry. A linear correlation could be shown between the degree of cellulose polymerization obtained from capillary viscometry and the tensile strength obtained from zero-span tensile strength measurements. These results demonstrate the value of this technique, which is more straightforward than capillary viscometry and requires significantly smaller samples. This approach offers great potential for determining the mechanical properties of an original canvas and for supporting the decision-making process about conservation treatments.

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INTRODUCTION

In order to make educated decisions about the ability to transport paintings and the potential need for an appropriate conservation treatment, it is crucial to know the mechanical strength of a canvas. However, methods to measure this and related parameters are scarce. Even today, the assessment of original canvas is often based only on its optical appearance, such as browning and yellowing, and pH value. However, these parameters are not directly related to age and mechanical properties.

Flax is frequently used for the canvases of historical paintings. It is a natural fiber and consists mainly of cellulose. The most dominant degradation process of such canvases is the depolymerization of cellulose by hydrolysis, which in turn influences their mechanical strength (Timar-Balazsy and Eastop 1998). In 1939, Staudinger and Reinecke investigated a potential correlation between aging, cellulose depolymerization, and the mechanical strength of historical canvas (Staudinger and Reinecke 1939). So far, however, this correlation has not been experimentally proven. For paper, in contrast, a link between the mechanical properties and the degree of cellulose depolymerization has been found (Zou et al. 1994).

In textile engineering. the tensile strength of fabrics is determined by using standard protocols that require a minimum length of 200 mm; for the testing of yarns, a minimum length of 250 mm is needed. Those requirements limit their application to conservation research. If large amounts of sample material are available, such as for artificially aged canvas, it is possible to determine the strength of the material using methods such as the standard tensile test method on fabric or yarn, which gives a maximum tensile strength value (Reumann 2000), but to date no direct correlation between the age-related chemical alterations of the cellulose molecular constitution and the physical consequences for the fabric has been established (Young 2005). The reason for this is the lack of methods to investigate original canvases. Thus, the determination of the degree of cellulose depolymerization by viscometry was until now the only method available to investigate the constitution of original canvas (Stoll and Fengel 1981). However, the measured degree of polymerization is difficult to assess with respect to the aging process and the mechanical properties. Therefore, a technique for measuring the mechanical properties on smaller components of a canvas such as yarns or fibers is needed.

Yarns are structures composed of fibers, and a yarn's geometry is determined by the fibers' diameter, gradient angle, density, and homogeneity of the material (Peirce 1937). It is likely that the strong influence the fabric geometry has on the measurements may prevent a direct correlation of the age with tensile strength as determined by the above-mentioned standard methodology. It seems conceivable that the thinnest site of the sample ruptures first, or that thinner single fibers are displaced from longer single fibers during the measurement. Thus, we conclude that to determine a correlation between the degree of polymerization of cellulose and the mechanical properties, a novel technique for measuring the tensile strength is needed—one that largely excludes the influence of the textile geometry on the measurement.

To date, three standard methods are used to determine the strength of cellulosic fiber material: (1) the band-pulling method on plain textile structures (DIN 1999); (2) the determination of the maximum tensile strength on single fibers (DIN 2009); and (3) the determination of the maximum tensile strength on staple fibers (DIN 1996). However, as already mentioned, none of these standard techniques fulfills the requirements applicable to original canvas samples. The comparison of the degree of cellulose polymerization with the maximum tensile strength of artificially aged linen (flax fabric), measured with the band-pulling method on plain-weave fabrics, did not yield a correlation (Von Reden 2018). In this study, we propose that the influence of the fabric geometry during these measurements prevents the resulting values from faithfully resembling the molecular condition of the cellulose, and that the same applies to the determination of the maximum tensile strength on single yarn.

In the research field of paper analysis, an alternative method for the analysis of single fiber strength is frequently applied to this problem: the determination of the zero-span tensile strength (TAPPI 2007). The special feature of this method is the fact that the clamping distance is reduced to almost zero, and hence the strength of the fibers is measured at a defined position. In this way, measurement errors arising from the heterogeneity of the material along the overall length of the sample are minimized. In the international literature, the resulting value is called zero-span tensile strength (Henniges and Potthast 2000, 2015). Applying the zero-span tensile strength test method to yarn would represent an important technical advancement.

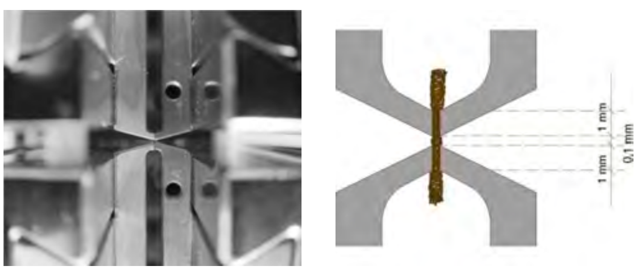
Previous studies have reported on this topic, but to date no standardized protocol or validation of the method exists (Hackney and Hedley 1984; Leene et al. 1975). Transferring this technique to the conservation of paintings, however, would be highly desirable. The goal of our work was to investigate the applicability of the zero-span tensile strength method to single yarns and to develop a standard protocol. The second aim was to use this technique to study samples derived from original canvas to assess its implementation in conservation research. The overarching question was whether a correlation exists between the intrinsic viscosity and the maximum tensile strength. This study was conducted at Dresden University of Fine Arts, Germany.

METHODS

Development of a Standard Protocol to Determine the Zero-Span Tensile Strength of Yarns

The general workflow of this study is as follows: yarn samples were taken from both new and artificially aged fabrics as well as from original canvas paintings. The maximum tensile strength at zero length of single yarn samples was determined using the newly developed method described in more detail below. Then identical sample material was disassembled into single fibers and the intrinsic viscosity (limiting viscosity number) determined.

The existing protocol for the zero-span tensile strength determination of paper was modified for its application to yarn samples, and a standard protocol was developed. The general rules for measuring maximum tensile strength also apply to the zero-span tensile strength. The critical difference between the protocols is the clamping distance. In reality, the clamping distance for determining the zero-span tensile strength is set to 0.1 mm in order to avoid compression of the sample. Here, we used a modified version of a testing machine that was originally developed for the analysis of historical paper (Lichtblau 2007). We used a zwickiLine Z0.5 TS material testing machine equipped with an Xforce precision force sensor (nominal force = 500 N), pneumatic sample holders, and an adjustment system for a highly precise arrangement and guidance of the specimens. Figure 16.1 shows the front view of the four special clamps for the zero-span tensile strength, which are arranged in pairs at a vertical distance of 0.1 mm.



a b

Figure 16.1 (a) Zero-span clamps of the tensile strength testing machine. (b) Schematic representation of the clamps and their dimensions, side view. Images: Dirk Lichtblau (a); Theresa A. Bräunig (b)

In order to apply this technology to yarn samples and use it as a standard method for the study of paintings, it was modified for this project. The basis for the study is provided by the standards listed in table 16.1, from which relevant aspects were adopted. The following criteria were developed:

- Theoretically, three different types of samples were conceivable: twisted yarns, untwisted yarns, and single fibers. However, in the case of twisted yarn, premature damage of the sample can be excluded. In addition, for this configuration, a maximal correlation of the results with the strength of the canvas is expected.

Table 16.1
Standards for tensile strength measurements

Standard	Content	Published
TAPPI T 231 cm-07	Zero-Span Breaking Strength of Pulp (Dry Zero-Span Tensile)	2007
ISO 2062	Textiles—Yarns from Packages—Determination of Single-End Breaking Force and Elongation at Break Using Constant Rate of Extension (CRE) Tester (ISO 2062:2009)	2009
ISO 2060	Textiles—Yarns from Packages—Determination of Linear Density (Mass per Unit Length) by the Skein Method	1994

Table: Theresa A. Bräunig

- The minimum sample length was determined considering the following points: The sample length should be as short as possible to (potentially) be applicable to original canvases. Samples needed to be long enough to be reproducibly held by the clamps, which require a 2.1 mm operational distance. Hence, a sample length of 5.0 mm for each sample is necessary for the vertical application.
- A standardized technique for the vertical application of the sample into the clamps with a magnetic clip was developed. Here, the sample was positioned vertically on a metal ruler and fixed inside the clip using an elastic magnet. Then the sample was applied into the clamps of the machine.
- Thread slippage of the yarn section should be avoided.
- The rupture of the yarn section had to be complete and homogeneous.
- The measurements should also be applicable to samples of original canvases.
- The measurements should be reproducible within an acceptable error range.
- The stress-strain curves should be analyzable until the yarn breaks.
- The time effort for the whole experiment should be minimized.

To develop the standard protocol, test measurements were conducted on a new fabric using the above criteria. The use of an identical fabric ensured the comparability of the different settings of the testing machine. The resulting standard protocol is outlined in table 16.2, which shows the final parameters that allowed us to fulfill our criteria.

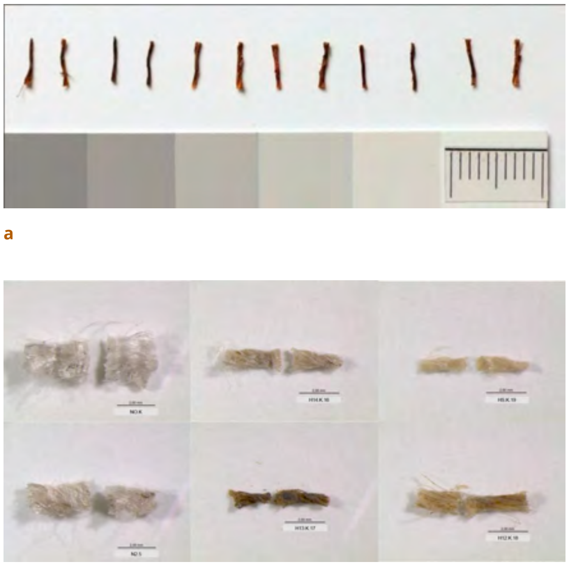
Table 16.2
Standard protocol for the tensile strength measurement of yarn at zero length

Brief description	A yarn section is manually inserted into the upper clamp using an appropriate clip and fixed in position by closing the lower clamp. For measurement, the sample is stretched with constant deformation speed until break, and the maximum tensile strength and maximum tensile strength elongation are recorded.
Sample	Yarn section (twisted).
Sample length	5.0 mm
Clamps	After TAPPI T 231 cm-07.
Clamp distance	0.1 mm
Contact pressure	6.0 mbar
Speed of measurement	0.1 mm/min.
Preload	None
Sample condition	Diameter as homogeneous as possible.
Sample preparation	For samples of original paintings, primer and paint residuals must be excluded and sizing reduced.
Adjusting to the standard climate	After ISO 139.
Diameter-normalized maximum tensile strength	After ISO 2060.
Number of measurements per point	12 (minimum).
Number of measurements used for calculation	Number of measurements per point minus 2 (highest and lowest values excluded).
Statistical analysis	After DIN 53804-1.

Table: Theresa A. Bräunig

For conducting a measurement for one canvas, the following steps were performed:

1. After determining the sample mass and length, the tensile strength was measured on twelve yarn sections (5 mm each) following the standard protocol (fig. 16.2).



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b

Figure 16.2 (a) Yarn sections (5.0 mm long) derived from one original canvas. (b) Different representative ruptured samples from artificially aged fabrics and original canvases after zero-span tensile strength measurement. Images: Theresa A. Bräunig

2. To obtain a statistically significant result for the tensile strength for one canvas, it was necessary to measure twelve yarn sections with 5 mm length each. From the maximum tensile load measured in newtons, the diameter-normalized maximal tensile strength (f_H) was calculated following f_H = F/Tt with Tt = fineness (in units of tex) in order to compare yarns of different fineness (Reumann 2000).
3. To determine the fineness, the mass was divided by the length of the yarn (Hartwig and Reumann 2000).
4. For the final data analysis, the highest and the lowest values were excluded, and the average and the corresponding standard deviation were calculated from the remaining ten values.

Determination of the Limiting Viscosity Number (Staudinger Index) Using Capillary Viscometry

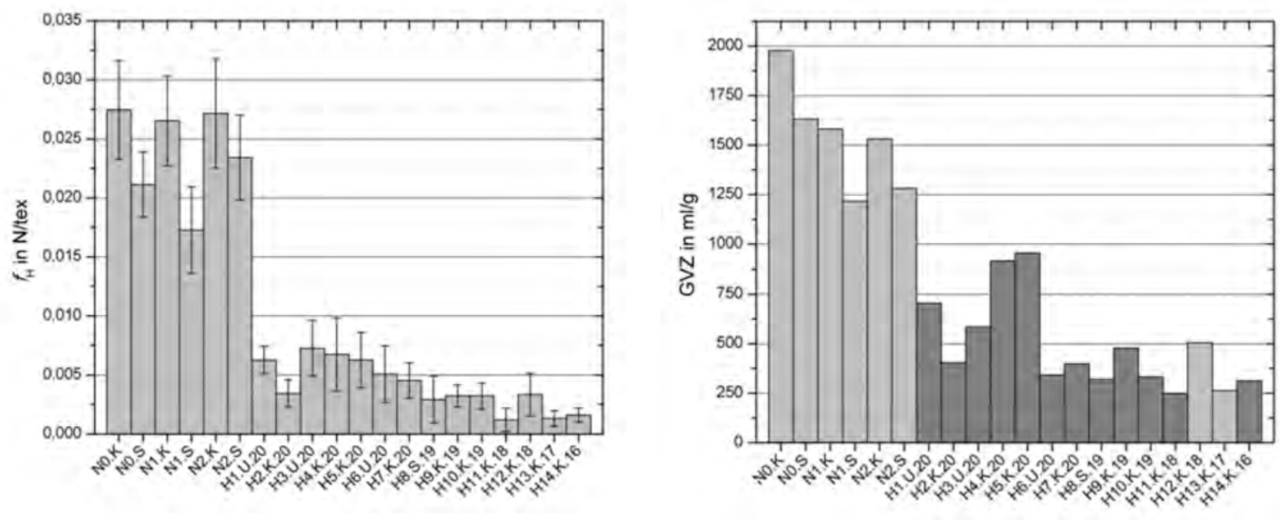
The average degree of polymerization has been established in the field of conservation research to describe the degree of decomposition and the molecular condition of cellulose (Stoll and Fengel 1981). The degree of polymerization is calculated based on the experimentally determined limiting viscosity number. However, for this calculation different methods have been described, leading to different results (Stoll and Fengel 1981). Thus, in order to directly compare results from different studies, the standard DIN 54 270 part 1 suggests omitting the calculation of the degree of polymerization and instead using the limiting viscosity number as the reference value (DIN 1976). Just like the degree of polymerization, the limiting viscosity number increases as the chain length of the cellulose molecules increases.

The intrinsic viscosity of all yarn samples was determined using capillary viscometry. This method allows investigation of original sample material as well, since the necessary sample amount is less than 15 mg. All experiments were performed according to the standard DIN 54 270 part 3 (DIN 1977), with minor modifications (Bräunig et al. 2016). The basic principle is as follows: the yarn sample is disassembled into single fibers, then dissolved in alkaline iron tartrate system (in German $EWNN_{mod(NaCl)}$), and the viscosity of the resulting solution is determined using a Micro-Ubbelohde viscometer. The time required for a defined volume of a test liquid to pass a defined distance in a capillary of a known diameter is used to calculate the kinematic viscosity of that liquid. The dissolved cellulose sample is inserted into the viscometer, aspirated, and then the flow time back through the device caused by gravity is measured (twice per sample) with two independent fillings. The result given here is the mean value of the two measurements.

Sample Material and Preparation

Overall, seventeen different flax fabrics were analyzed: one new fabric, with two additional levels of artificial aging, and fourteen canvas samples from original paintings. Artificial aging was achieved by exposure to light in a Xenotest (42 W/m², filter: < 320 nm, 35°C and 30% RH), followed by a temperature increase (70°C) and cyclically alternating humidity (from 30% to 80% RH over twelve hours). The samples from original paintings—dating from the sixteenth to the twentieth century—originated from paintings that were processed in the framework of teaching at Dresden University of Fine Arts. The choice of the paintings was driven by the aim of reflecting a broad spectrum of aging. All paintings were generally untreated and had not been stored in a constant climate.

From the new and artificially aged fabrics, samples of warp and weft were taken from the middle of the fabric. The position and thread direction of the samples from the original canvases differed depending on the condition of each individual painting. For preparation, the samples from the original canvases were soaked in a bath to increase the homogeneity of the starting material. The resulting coloring of the extract showed that dirt, small particles, and (most likely) the sizing could be dissolved.



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b

Figure 16.3 (a) Diameter-normalized maximum tensile strengths (f_H) of the measured samples, average of ten measurements. (b) Limiting viscosity numbers (GVZ) of the measured samples. Experiment temperatures: 18°C (light gray) and 19°C (dark gray). N0: new, N1: artificial aging, N2: longer artificial aging, H: original, K: warp, S: weft. Images: Theresa A. Bräunig

Then the yarns were cut into twelve sections of 5 mm each. To maximize the comparability of the results from the two different methods, identical samples were first used for the tensile strength measurement and then dissolved for the capillary viscometry experiment.

RESULTS

The results of the tensile strength measurements confirm that the standard protocol we developed is applicable without any limitation to all yarn samples tested. Figure 16.3a shows the average of the diameter-normalized maximum tensile strength (f_H in N/tex) with the corresponding standard deviation for all measured samples. All results for the tensile strength lie between 0.000120 and 0.02744 N/tex. The new fabric before and after artificial aging shows the highest values, thus these samples cover the range of weak aging. The samples from the original canvases are found in the range of middle and show strong aging, making it apparent that the artificial aging was not sufficient to reflect the values of the original samples. For the artificially aged fabrics, the warps were generally more stable than the wefts—either those that were unaged or those that had been aged for shorter periods.

For the historical yarn samples from the nineteenth and twentieth centuries (H1U20–H10K19), the strength decreases with increasing age. In the region with the lowest strength, measured on the samples from the sixteenth to eighteenth century, the strength does not correlate with the age. Probably, the strength of these samples is more strongly influenced by further factors, such as aging conditions, pretreatment, and painting technique.

Figure 16.3b shows the results of the capillary viscometry experiments. The analyzed yarn samples cover a broad spectrum of limiting viscosity numbers (GVZ in units of ml/g), which, in contrast to the diameter-normalized maximum tensile strength values (f_H; see fig. 16.3a), show a smaller gap between the artificially and historically aged samples. Overall, the values lie between 250 and 1976 ml/g. High values were obtained from the new and artificially aged samples. In line with the results of tensile strength (see fig. 16.3a), the warps show higher values than the wefts. This phenomenon can be explained by the different yarn quality of the two groups. While the warps in these samples consisted of doubling folded yarns with long single fibers, the wefts were yarns with short single fibers.

Surprisingly, we observed an anomaly for the artificially aged wefts that is consistent throughout both methods: the wefts that were aged longer show slightly higher values than wefts aged for shorter periods. Since this phenomenon appears with both methods, the result seems to be sample specific. This anomaly could be caused by the inhomogeneity of the material. In comparison, the historical samples generally show lower values. For technical reasons, the viscosity measurements were conducted at two different temperatures (18°C and 19°C, shown in fig. 16.3b in light and dark gray, respectively).

The correlation of the data determined by the two different methods is plotted in figure 16.4: the degree of polymerization of the cellulose, represented by the limiting viscosity number (GVZ), and the strength of the tested yarn samples (f_H), measured by our newly developed protocol. Due to the strong dependence of the viscosity measurement on temperature, the experiments at 18°C and 19°C are plotted separately. For both temperatures, a clear correlation of the limiting viscosity number with the diameter-normalized maximum tensile strength can be found. The data points can be grouped into two separate populations: low strength ($f_H < 0.008$ N/tex), consisting of the naturally aged samples, and high strength ($f_H > 0.017$ N/tex), consisting of new and artificially aged samples. In summary, a linear correlation is observed over the whole data set.

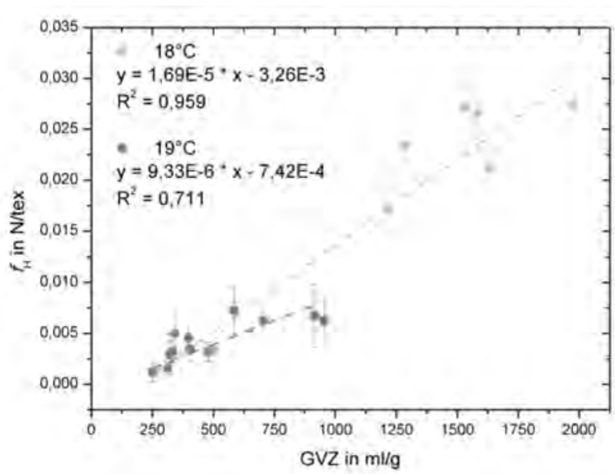

Figure 16.4 Correlation of the diameter-normalized maximum tensile strength (f_H) with the limiting viscosity number (GVZ) of the measured samples. Image: Theresa A. Bräunig

In contrast to capillary viscometry, the tensile strength of the yarn measured with zero-span distance still could be influenced by yarn geometry. In addition, for the historical samples, remaining material such as a binding agent may influence the tensile strength. For the low values, the results of both methods do not completely align with the dating of the samples. In other words, a canvas from the sixteenth century may show a higher tensile strength than a canvas from the seventeenth century. This shows that the dating by itself is not sufficient to draw a conclusion on the tensile strength. The pretreatments of the canvases and the respective conditions under which the paintings were stored may have a significant influence on their material state.

Comparing our tensile strength results and the empirical impression of the canvases reveals an interesting finding. Generally, the lowest values for intrinsic viscosity and strength reflected the empirical impression of the fragility of the corresponding canvases. In these cases, the canvases were obviously brittle. In contrast, within the major range of the values, for all nonaged and aged samples, no correlation between the values and the empirical impression could be observed. There are no explicit empirically identifiable characteristics that point toward a medium or even a higher loss of tensile strength. An empirical evaluation of the canvas stability is only possible when it already reached a state of fragility that leads to breaking or cracking at low application of a force, such as during handling. These results suggest that an empirical assessment as a basis for a conservational treatment has only limited scope and that an exact method to determine the stability of the canvas is needed.

CONCLUSION AND OUTLOOK

In this study, we developed a novel, standard protocol for the determination of the zero-span tensile strength of yarn sections. It delivers, for the first time, trustworthy results for the strength of the cellulose because the influence of the yarn geometry is reduced to a minimum. Compared to capillary viscometry, the zero-span tensile strength measurement is easier and faster to conduct. The necessary amount of sample is similar, and the time effort is reduced. For example, thirty tensile strength measurements can be conducted in an hour.

A direct correlation of the intrinsic viscosity with the tensile strength of historical canvases could be established. It could be confirmed that the mechanical strength of yarn depends directly on the degree of degradation of cellulose. The mechanical properties are directly measured, as opposed to determining the degree of polymerization by the intrinsic viscosity of the dissolved material. Hence, this method has great potential to mechanically evaluate the degradation of a canvas as a valuable alternative to viscometry.

Following up on our studies, the measurement of lower strength values would be of value. Therefore, the use of significantly finer microstrength sensors is recommended. By increasing the number of investigated paintings, we may be able to obtain a broader set of comparative data.

In comparison to the current standard techniques of tensile strength determination, the required sample material could be significantly reduced to 60 mm of fiber per canvas in total. Nevertheless, ethically, such an intervention represents a significant decision for an original painting. Thus, in its current state, this method is best suited for scientific research. For its application as a standard method for original paintings, further optimization and reduction of sample requirements are needed. Furthermore, it must be taken into account that, depending on the painting, the samples are usually taken from the tacking margin and not from the center of the canvas. Due to differences in degradation mechanisms in tensioned and nontensioned canvases, different results can be expected in the two areas (Von Reden 2018).

The measurement of zero-span tensile strength serves the overarching goal of being able to reproducibly extrapolate from the strength of the measured position to the strength of the whole original canvas. For this, the influence of yarn and fabric geometry on canvas strength must be investigated. By knowing these relationships, an assessment of the strength of the canvas should be possible, which can then serve as a basis for decisions on stabilization treatments, such as tear mending, strip-lining, or lining, which are of utmost relevance to the conservator.

ACKNOWLEDGMENTS

We would like to thank Dr. Ursula Haller from Dresden University of Fine Arts for providing samples from original paintings, and Jens Danneberg for support with tensile testing.

17

Chronicles in Wax-Resin Lining: A Historic Look at Lining Practices and Their Effectual Legacy on Paintings in the Smithsonian American Art Museum Collection

Amber Kerr, Head of Conservation and Senior Paintings Conservator, Smithsonian American Art Museum, Washington, DC
Gwen Manthey, Paintings Conservator, Smithsonian American Art Museum, Washington, DC
Keara Teeter, Postgraduate Fellow, Smithsonian American Art Museum, Washington, DC
Kristin DeGhetaldi, Paintings Conservator, Independent Researcher
Brian Baade, Paintings Conservator and Associate Professor, University of Delaware
W. Christian Petersen, Volunteer Conservation Scientist and Affiliated Associate Professor, Winterthur Museum, Garden & Library, Winterthur, Delaware
Catherine Matsen, Scientist and Affiliated Associate Professor, Winterthur Museum, Garden & Library, Winterthur, Delaware

Paintings conservators at the Smithsonian American Art Museum survey conservation records to gather the historical recipes, treatment protocols, and materials used over the past fifty years to build a reference database connected to specific works in the collection. From this information, the authors show how the database is being used to re-create both historical wax-resin recipes and application techniques through lining mock-ups. This material reference set is being used for analytical and physical testing to learn more about the materials used and how they degrade, and what influences mechanical as well as environmental conditions have on both the lining recipes and reconstructions as they age.

INTRODUCTION

The Smithsonian American Art Museum (SAAM) in Washington, DC, together with its branch museum, the Renwick Gallery, stewards a national collection containing thousands of paintings that span more than three centuries of American art. Established in 1829, the collection at SAAM moved to its current location in the Old Patent Office Building in 1968. This was just two years after paintings conservator Charles Olin formed the first conservation lab for the collection. The paintings in the collection have been cared for by four generations of conservators over the past fifty years.

The conservation records reflect evolving approaches to the methodology and protocols used in the structural treatment of paintings, as they encapsulate the training, experience, and philosophical approaches to treatments brought by each paintings conservator. Research into these past treatments continues in order to gain a greater understanding of the materials used as well as the application methods and overall intent of the treatments. The initial phase of research focused on wax-resin linings and their effectiveness and longevity as a treatment option for paintings in the collection, and, through the use of instrumental analysis, compared specific recipes recorded in treatments with samples from the paintings exhibiting lining deterioration.

The impetus for the focus on wax-resin linings began several years ago, when a significant number of those lining treatments completed in the mid- to late twentieth century were beginning to fail or showed early signs of failure. Modes of failure included but were not limited to pocketed delamination of the lining substrate, returned cupping and flaking within the paint and ground layers, and raised craquelure in the painted surface. Of note was the delamination of linings related to works that were on prolonged view in the galleries or had traveled on loan. The latter was of particular concern, as these paintings were considered the best for loan based on the very fact that they were wax-resin lined, and therefore considered stable and nearly impervious to environmental fluctuations or mechanical stresses.

COLLECTION SURVEY AND LINING RECONSTRUCTIONS

A survey of the Lunder Conservation Center treatment records was initiated to identify lined paintings in the museum collection. As of April 2019, this survey yielded a preliminary data set of 958 linings carried out at the museum from the 1950s to present. The data set was then filtered to exclude paintings mounted to solid supports, adhesives irrelevant to this study (glue paste and synthetic), and wax-resin adhesives where the materials were unidentified. The final data set yielded fifty oil-on-canvas paintings lined between 1950 and 1993. The paintings were by thirty-seven different artists and on a variety of fabric supports (linen, cotton, and burlap). All were wax-resin lined but nearly a dozen different recipes had been used. The linings were added to address a variety of condition issues, including tears, generalized flaking, or as a preventive measure (no condition issues noted).

Six recipes were frequently used in the twentieth-century lining treatments and were found in forty-three of the fifty surveyed paintings (table 17.1). These six recipes were then selected for comparative and categorical reasoning in order to answer the following queries:

- Had other institutions also observed wax-resin lining failure? This would be determined by examining a recipe frequently used by conservators working in a range of institutions: SAAM 1.
- Was the type of resin, type of wax, or their relative proportions a source of failure? Two sets of recipes would be compared to evaluate this question: SAAM 2 and 3 versus SAAM 4 and 5.
- Did the use, substitution, or absence of a particular resin or an organic wax contribute to failure? This would be determined using SAAM 6.

The six recipes were each reconstructed to better understand how the lining adhesives were aging and for comparison against aged samples from known examples of use (the case studies listed in table 17.1).

One case study was selected to represent each lining recipe, and samples of excess wax-resin adhesive were taken from each. The case studies represent a variety of painting techniques, as well as previous condition issues. In the case of both William H. Johnson paintings, they had been exposed to extremely poor environmental and storage conditions prior to acquisition. In the case of *The Lesson* by Hugo Ballin and *Plenty* by Kenyon Cox, those works entered the collection almost immediately after their completion by the artists. In addition, the case studies reflected differences in lining supports, and lining recipes that are often repeated on other works by the same artist (particularly in the works by Johnson and Bannister).

Ingredients used in the recipes were sourced from various vendors, inventory at the Lunder Conservation Center, and donations coordinated with institutions and private practice conservation studios.

The six reconstructed recipes were used in mock-up linings of thirty-six test paintings. The test paintings consisted of commercial acrylic-primed cotton, acrylic-primed linen, and oil-primed linen canvases mounted to 20 × 25.5 cm (8 × 10 inch) wooden stretchers (twelve each). The authors marked each canvas with graphite (underdrawing) and

Table 17.1
The six case study paintings and their historical lining recipes (SAAM 1–6)

Case study painting	2019 re-created recipe	Collection survey
Sun Setting, Denmark William H. Johnson, ca. 1930, oil on burlap Lined to linen (1969) Accession: 1967.59.720	SAAM 1 (Keck recipe): • 6 parts unbleached beeswax • 6 parts Multiwax W-445 • 2 parts dammar resin • 2 parts colophony rosin • 1 part gum elemi	SAAM 1 represents: • 1/50 lining recipes • 1/6 Johnson paintings • 1/10 linings to linen
Oak Trees Edward M. Bannister, 1876, oil on canvas Lined to fiberglass (1983) Accession: 1983.95.155	SAAM 2: • 3 parts unbleached beeswax • 3 parts Multiwax W-445 • 2 parts Zonarez B-85	SAAM 2 represents: • 29/50 lining recipes • 7/7 Bannister paintings • 14/18 linings to fiberglass
Cagnes-sur-Mer William H. Johnson, ca. 1928–29, oil on burlap Lined to unidentified textile (1971) Accession: 1967.59.702	SAAM 3: • 1 part unbleached beeswax • 1 part Multiwax W-445 • 1 part Piccolyte S-85	SAAM 3 represents: • 5/50 lining recipes • 5/6 Johnson paintings • 5/19 unidentified textiles
The Lesson Hugo Ballin, 1907, oil on canvas Lined to unidentified textile (1979) Accession: 1910.9.1	SAAM 4: • 3 parts Multiwax W-445 • 1 part Zonarez B-85	SAAM 4 represents: • 2/50 lining recipes • 1/1 Ballin paintings • 1/19 unidentified textiles
Plenty Kenyon Cox, 1910, oil on canvas Lined to fiberglass (1974) Accession: 1910.9.6	SAAM 5: • 3 parts Multiwax W-445 • 1 part Piccolyte S-85	SAAM 5 represents: • 2/50 lining recipes • 1/2 Cox paintings • 1/18 linings to fiberglass
The Windmill Jenne Magafan, ca. 1937, oil on canvas Lined to unidentified textile (1979) Accession: 1971.447.66	SAAM 6: • Multiwax W-445	SAAM 6 represents: • 4/50 lining recipes • 1/1 Magafan paintings • 1/19 unidentified textiles

Note: Each case study painting represents a different historical lining recipe (SAAM 1–6). The third column compares each case study to surveyed lining adhesives, prevalence of its use on other works by the same artist, and prevalence of its use with the same secondary support. The breakdown of secondary supports is as follows: linen (10/50 linings), fiberglass (18/50 linings), combination of linen and fiberglass (3/50 linings), and unidentified textiles (19/50 linings). Supports for *Cagnes-sur-Mer*, *The Lesson*, and *The Windmill* were unidentified in April 2019; visual examination later revealed that all three supports were linen.

Table: Amber Kerr, Gwen Manthey, Keara Teeter, Kristin DeGhetaldi, Brian Baade, W. Christian Petersen, and Catherine Matsen

applied Weber Permalba zinc and titanium white, Gamblin yellow ochre, or Old Holland red ochre oil paints; four of each canvas type were painted out with each pigment type. These pigments were chosen based on the practical experience of the authors and conventional wisdom that they dry quickly.

Viscosity was divided into three categories: thin, moderate, and thick oil paint. The thin layer was diluted in mineral spirits and applied lightly using 2.5 cm (1 inch) nylon flat brushes so that the graphite underdrawing remained visible. The moderate layer was conservatively applied from the tube by brush (brushed gently to an even layer with little brush marking), obscuring the underdrawing. The thick layer was liberally applied from the tube by brush and palette knife to build up impasto. All mock-ups were aged for four days at room temperature and then desiccated for fifteen days in a Lab-Line L-C oven set between 32°C and 40°C (90°F and 105°F). Once the oil paint was completely dry, each mock-up was photographed before treatment, removed from its stretcher, and lined to 38 × 43 cm (15 × 17 inch) fabric supports, distributed evenly between linen and fiberglass.

Ingredients for each reconstructed lining recipe (see table 17.1) were measured by weight and bundled in cheesecloth in packages weighing 1 kg each. The six cheesecloth packages were added to 24 × 24 × 9.5 cm (9.5 × 9.5 × 3.75 inch) Gotham Steel nonstick fry pans and heated on an iSiLER CHK-S1809NE portable induction cooktop to 126°C–238°C (260°F–460°F). Large impurities were separated out as the molten wax-resin components permeated through the cheesecloth. Once filtration was complete, cooktop temperatures were reduced to 82°C (180°F). The molten mixture was transferred to the mock-ups (canvas reverse) and secondary support fabrics using polyester paint rollers. The cotton/linen/fiberglass edges were masked in 10 cm (4 inch) wide strips with silicone-release Mylar to prevent excess buildup of lining adhesive.

Once coated with the wax-resin mixture, each mock-up painting was centered on its secondary support, placed on the vacuum hot table, and sealed inside a silicone-release Mylar envelope. The vacuum suction pressure was set to 1 Hg (0.49 psi) and the heat to 74°C (165°F). Emergency thermal blankets were used to cover the Mylar envelope to encourage even heat distribution. After fifteen to twenty minutes of monitoring, the heat was turned off and the emergency thermal blankets removed. Then the mock-ups were hand-pressed in a Union Jack pattern through the Mylar envelope to push out excess wax-resin adhesive. Brayers were used over the thin and moderate paint layers, and cloth diapers were used over the thick impasto. The lining procedures followed for the research project reflect treatment reports as well as oral history interviews with former staff conservators.

SAMPLE PREP AND ANALYSIS

Scraped lining adhesive samples were collected from eighteen of the fifty surveyed paintings (including all six case study paintings), raw wax and resin ingredients, and each lining reconstruction adhesive. Technical examination was carried out in May and June 2019 at the Winterthur Museum's Scientific Research and Analysis Laboratory (SRAL).

For the first stage of analysis, samples were prepared for Fourier transform infrared spectroscopy (FTIR). The samples were flattened onto diamond cells to be analyzed with a Thermo Scientific Nicolet 6700 FTIR spectrometer. The samples were spread out as a translucent film using a stainless steel microroller, and the diamond cell placed on the platform of a Nicolet Continuμm Infrared Microscope. One or two target sites were selected on the diamond cell, and data were collected in transmission mode. Spectral resolution was set at 4 c^{-1} for 128 scans (each scan ranged from 4000 c^{-1} to 650 c^{-1}). The resulting spectra were interpreted using OMNIC Series Software (version 8.0) and compared to the Infrared and Raman Users Group (IRUG) spectral database.

During the second stage of analysis, samples were transferred to Thermo Fisher Scientific autosampler vials to be analyzed with an Agilent Technologies 7820 gas chromatograph and Agilent 5975 Mass Selective Detector (GC/MSD). The autosampler vials were treated with 1 part Grace Alltech Meth-Prep II reagent in 2 parts benzene (≤100 μL) and warmed in a Lab-Line Multi-Blok heater at 60°C for an hour. The derivatized sample was pipetted into a vial insert and cooled to room temperature. From each vial, 1 μL of the sample was injected into the HP-5ms GC column (5% phenyl methyl siloxane; flow rate of 1.5 mL/minute; film thickness of 30 μm × 250 μm × 0.25 μm). After injection of the sample, Agilent G1701EA GC/MSD ChemStation software was used with Winterthur RTLMPREP method set to the following conditions:

- Inlet temperature set at 320°C in "splitless mode" with a nine-minute solvent delay
- GC oven temperature set at 55°C for two minutes and then ramped up 10°C per minute to 325°C, followed by a ten-minute isothermal period
- Transfer line temperature to the MSD in scan mode at 280°C, the source at 230°C, and the MS quad at 150°C.

Chromatograms and mass spectra were interpreted using Agilent MSD Enhanced ChemStation data analysis software with NIST MS Search v.2.0 database.

During the final stage of analysis, samples were derivatized with 3 μL tetramethylammonium hydroxide (TMAH; 25 wt.% in methanol) and placed in a stainless steel Eco-Cup (50 μL). The Eco-Cup was inserted into a Frontier Lab Multi-Shot EGA/PY-3030D for pyrolysis with a Hewlett Packard 6890 gas chromatograph and HP 5973 mass selective detector (Py-GC/MSD). The Eco-Cup was fitted with an Eco-Stick and inserted into the pyrolysis interface, where the sample was purged with helium using a single-shot method at 600°C for twelve seconds. Separation was achieved with an Agilent J&W DB-5ms 19091S-433 capillary column (30 μm × 250 μm × 0.25 μm) with helium carrier gas set to 1.2 mL/minute. The split injector was set to 280°C with a split ratio of 30:1 and no solvent delay (9.26 psi). The GC oven temperature program began at 43°C for two minutes, ramped up by 10°C per minute to 325°C, and then set a five-minute isothermal period (total run time = 34.7 minutes). The MSD transfer line was set at 320°C, the source at 230°C, and the MSD quad at 150°C. The mass spectrometer was scanned from 33 to 600 amu at a rate of 2.59 scans per second. Total run time was 29.4 minutes.

RESULTS AND DISCUSSION

Each case study painting, SAAM reconstructed recipe, and raw material sample was analyzed using FTIR and GC/MSD. The goal of FTIR analysis was to compare the transmission band pattern of the historical linings to the reconstructed recipes (fig. 17.1). This comparison helped measure the efficacy of replicating SAAM's historical lining recipes. FTIR was not used to confirm the presence or absence of the raw material components, as that step would require a more discerning analytical technique.

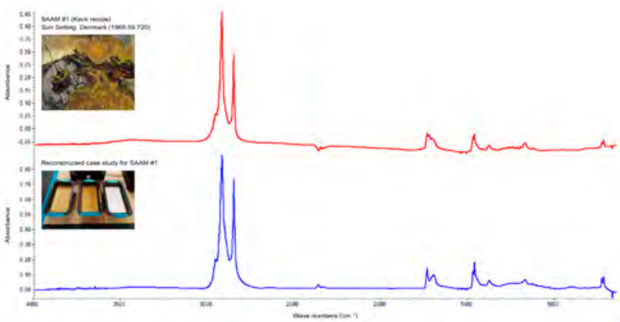

Figure 17.1 FTIR spectra comparing *Sun Setting, Denmark* (top) and the re-created recipe SAAM 1 (bottom). The painting was lined in 1969 with "wax adhesive (Keck)" to Belgian linen. SAAM 1 was prepared in 2019 following the Keck recipe from the "Lab Formulas—Mixtures" binder (ca. 1967–74). Spectral similarity between these results indicates the success in reconstructing this historical wax-resin adhesive. Spectra: SRAL, Winterthur Museum, Winterthur, Delaware / Composite image: SAAM, Washington, DC

GC/MSD provided supplemental information about the material composition of each adhesive mixture. Odd-numbered chain length hydrocarbons and certain fatty acids (including palmitic, stearic, and lignoceric acids) identified beeswax in the sample. Odd- and even-numbered hydrocarbons with a reduced fatty acid content indicated the presence of microcrystalline wax in the unadulterated samples such as *The Windmill* and SAAM 6. However, the presence of microcrystalline wax was more difficult to detect in samples containing a mixture of ingredients. Multiwax W-445 was present in all twelve samples; however, it was detected in only three case study paintings (*The Lesson*, *Plenty*, and *The Windmill*) and four re-created recipes (SAAM 2, and 4–6). In this data subset, beeswax was absent from six of the seven samples.

Some natural resins were successfully identified with GC/MSD: 5-dammarenolic acid methyl ester signaled the presence of dammar, dehydroabietic acid and 7-oxo-dehydroabietic acid[1] signaled colophony, and α- or β-amyrin signaled gum elemi. The two proprietary resins Zonarez B-85 and Piccolyte S-85 were not conclusively detected with GC/MSD (fig. 17.2, table 17.2). This could be the result of shortcomings in the sample derivatization process or sensitivity of the GC/MSD instrument. Other research publications have also cited discrepancies in identifying resins due to oxidation, depolymerization, or cross-linking of the material as it ages (Bleton and Tchapla 2009; Lluveras et al. 2010; Martín-Ramos et al. 2018; Modugno and Ribechini 2009).

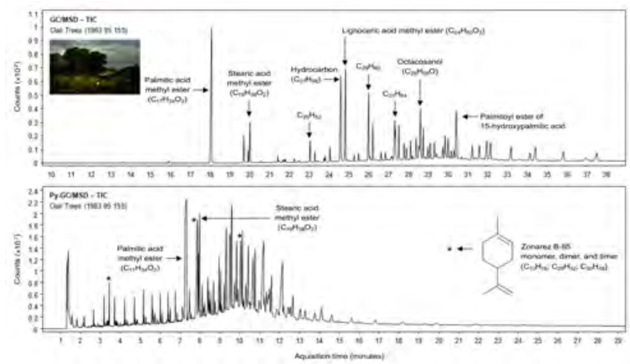

Figure 17.2 Total ion chromatograms (TICs) for the *Oak Trees* lining recipe as shown in GC/MSD (top) and Py-GC/MSD (bottom). *Oak Trees* was lined in 1983 with "1.5 p. Multiwax 445, 1.5 p. beeswax, 1 p. Zonarez B-85 resin" to fiberglass. In GC/MSD, microcrystalline wax was not detected (lack of even-numbered hydrocarbon peaks), and Zonarez B-85 was also not detected. In Py-GC/MSD, peaks span from C_8H_8 to $C_{35}H_{72}$, indicating the presence of both Multiwax 445 and beeswax; additionally, Zonarez B-85 was detected at 136 m/z, 272 m/z, and 408 m/z. Chromatograms: SRAL, Winterthur Museum, Winterthur, Delaware / Composite image: SAAM, Washington, DC

For the final stage of this research, three historical linings and associated SAAM recipes were analyzed with Py-GC/MSD: *Oak Trees* and SAAM 2; *The Lesson* and SAAM 4; *Plenty* and SAAM 5. Raw samples of Zonarez B-85 and Piccolyte S-85 were also pyrolyzed as a control standard for data comparison. The results indicated that Py-GC/MSD was more successful in detecting the odd- and even-numbered hydrocarbons present in microcrystalline wax. This method was also more proficient in detecting the polylimonene monomers, dimers, and trimers associated with the two proprietary resins (table 17.3; see fig. 17.2). After reviewing the GC/MSD data in comparison with the Py-GC/MSD data, the GC/MSD extracted ion chromatograms (EICs) were found to contain "humps" along the baseline that matched the pattern for polylimonene (fig. 17.3). Other recipe ingredients—beeswax, dammar, colophony, and gum elemi—were also clearly identified with Py-GC/MSD.

Table 17.2

Wax and resin ingredients confirmed with GC/MSD to be present in the six case study paintings and re-created lining recipes

Ingredient	Compounds in waxes/resins detected with GC/MSD	Retention time (min.)	Ions (m/z)
Unbleached beeswax	Odd-numbered hydrocarbons (peak at $C_{27}H_{56}$) Fatty acids (most peak at $C_{24}H_{48}O_2$)	24–25 (peak)	71, 74
Multiwax W-445	Odd- and even-numbered hydrocarbons (peak at $C_{33}H_{68}$ or $C_{34}H_{70}$)	28–29	71
Dammars	5-dammarenolic acid methyl ester ($C_{31}H_{52}O_3$)	29–30	454
Colophony	Dehydroabietic acid ($C_{20}H_{28}O_2$) 7-oxo-dehydroabietic acid ($C_{20}H_{26}O_3$)	21–24	316, 328
Gum elemi	α-amyrin / β-amyrin ($C_{30}H_{50}O$)	29–30	426

Note: Each ingredient is identified by the presence of specific compounds at a particular molecular weight (m/z). GC/MSD seemed to have difficulty detecting microcrystalline wax (particularly when beeswax was present in the recipe) as well as the proprietary resins Zonarez B-85 and Piccolyte S-85 (not listed in table).

Table: Amber Kerr, Gwen Manthey, Keara Teeter, Kristin DeGhetaldi, Brian Baade, W. Christian Petersen, and Catherine Matsen

Table 17.3

Resin ingredients confirmed with Py-GC/MSD to be present in three of the case study paintings and three re-created lining recipes

Ingredient	Compounds in resins detected with Py-GC/MSD	Retention time (min.)	Ions (m/z)
Zonarez B-85	Limonene monomer ($C_{10}H_{16}$), dimer ($C_{20}H_{32}$), and trimer ($C_{30}H_{48}$)	3–10	136, 272, 408
Piccolyte S-85	Limonene monomer ($C_{10}H_{16}$), dimer ($C_{20}H_{32}$), and trimer ($C_{30}H_{48}$)	3–10	136, 272, 408

Note: Both Zonarez B-85 and Piccolyte S-85 were identified by the presence of the acid-catalyzed dimerization and trimerization of limonene.

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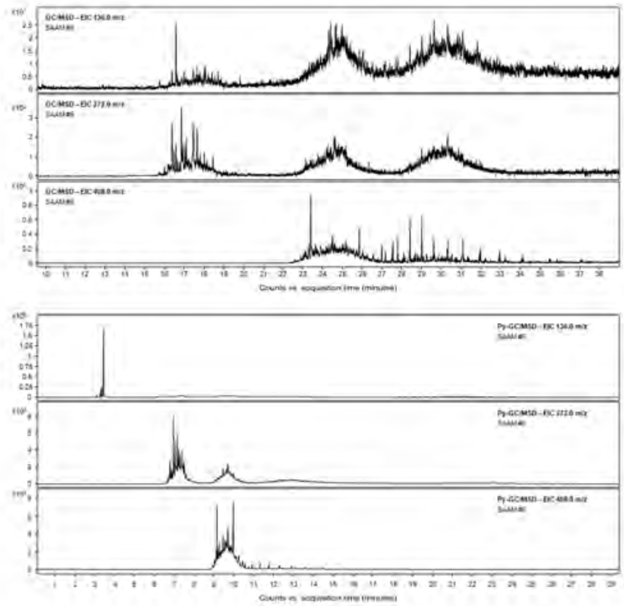

Figure 17.3 SAAM 5 extracted ion chromatograms (EICs) in GC/MSD (top) and Py-GC/MSD (bottom). Limonene in Piccolyte S-85 is detected as a monomer at 136 m/z, dimer at 272 m/z, and trimer at 408 m/z. GC/MSD barely detected the compound, as indicated by the jagged appearance of the baseline in all three EICs. Py-GC/MSD yielded better results, with clearly defined peaks for the compound. Chromatograms: SRAL, Winterthur Museum, Winterthur, Delaware / Composite image: SAAM, Washington, DC

CONCLUDING THOUGHTS AND MOVING FORWARD

In most cases, FTIR is simply not suitable for characterizing most of these potentially complex recipes. It was also difficult to detect the presence of synthetic waxes in many of the samples using GC/MSD. This may depend on the type of wax, the amount, or even the age of the sample itself. Sampling excess wax-resin adhesive from all unidentified textile linings is impractical, but the reconstructions and analysis prove that even when known materials are present, they are not readily identified. It is possible lining mixtures may be characterized by sensorial qualities to the examiner, particularly if they can be compared against the reconstructions. This rough characterization may allow for a generalized prediction of a particular lining's failure potential, when considered in tandem with the exhibition history and previous condition issues of the painting in question.

This study has provided an understanding of how pervasive wax-resin linings are in the collection, and how late the practice remained in use. The frequency of lining treatments was likely prompted by extensive loan requests and the contemporaneous belief that wax-resin linings were a suitable preventative measure. While this analysis has been useful, many initial questions remain unanswered. We have a foundation with which to test future hypotheses on how these materials deteriorate, although the methods for testing these hypotheses must still be designed. Since the reconstructions were lined, areas of impasto have already been observed to contribute to lining delamination in the unstretched lined mock-ups, raising new questions about environment, tension, and percussive movement.

It is the hope of the authors that these mock-ups and this preliminary study will provide a resource and reference for future fellows and researchers to enrich our collective understanding of the aging and failure mechanisms of wax-resin linings.

ACKNOWLEDGMENTS

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External institutions and private practice conservation studios also donated their time and materials to the SAAM wax-resin lining research project. Most of these donations were coordinated in response to SAAM's April 2019 "Call for Wax-Resin Materials" posting on the American Institute for Conservation Higher Logic community platform. External collaborators included Lauren Bradley and Josh Summer at the Brooklyn Museum, Barbara Ramsay and Elizabeth Robson at the John and Mable Ringling Museum of Art, Andrea Chevalier and Charles Eiben at the Intermuseum Conservation Association, Ann Creager Conservation, Nina A. Roth-Wells LLC, and Pinova Inc., a subsidiary of DRT (Dérivés Résiniques et Terpéniques).

NOTES

1. 7-oxo-dehydroabietic acid always accompanies dehydroabietic acid, but not vice versa; the former tends to be present only after a sample has degraded and/or been subjected to extreme heat.

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Gacha Lining's Treatment Viability: The Spanish and European Glue-Paste Adhesive Used since the Seventeenth Century

Ana Calvo, Conservation Professor, Faculty of Fine Arts, Complutense University of Madrid
Ana Macarrón, Conservation Professor (retired), Faculty of Fine Art, Complutense University of Madrid
Rita Gil, Conservator, National Museum of Natural Science (MNCN-CSIC) and in private practice, Madrid
Julia Betancor, Principal Conservator, JB Art C&R, and Head Art Conservator, Colección SOLO, Madrid

A research project was carried out between 2011 and 2015 at the Complutense University of Madrid, the aim of which was to suggest improvements to guarantee future conservation of canvases lined with a glue-paste adhesive called gacha*. We started with three objectives: documenting the origin of recipes and the different methods used for this treatment in Spain and Europe, as there is still little knowledge about this kind of lining; choosing case studies; and finally, carrying out a series of experimental tests to evaluate the performance of the basic materials in the recipes and of some variants in the textiles often used as lining supports.*

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INTRODUCTION

The proposal to carry out a research project on glue-paste linings arose during a course on structural treatments of paintings on canvas led by Vishwa Mehra and Matteo Rossi-Doria at the Universitat Politècnica de València. The scarcity of scientific knowledge about linings carried out in the past with glue paste (in Spanish, traditionally called *a la gacha*) was exacerbated by the gradual abandoning of this procedure, now replaced by modern synthetic adhesives.

The project—titled Materials and Methods of Glue-Paste Linings for the Reinforcement of Canvas Paintings: Documentation, Functionality, and Conservation—was a coordinated effort carried out between 2011 and 2015 by a group of sixteen international specialists, a number of Spanish institutions, and the support of several companies.[1] It was coordinated from Spain by the Complutense University of Madrid and funded by a grant[2] from the Ministerio de Economía y Competitividad (MINECO).

THE NEED FOR LINING THROUGH THE AGES

It is evident that lining has allowed many paintings on canvas to survive into the present. Some linings are as much as three hundred years old. In Spain and most of the rest of Europe, linings were carried out since the seventeenth century on using linen cloth and glue paste as an adhesive (fig. 18.1). This procedure remained in practice until the 1990s, when synthetic adhesives came to prevail in the field of conservation. Especially in Holland and the humid Atlantic countries, glue paste was often replaced by wax resin from the nineteenth to the early twentieth century.

Figure 18.1 Adhesive made with glue paste (*gacha*). Image: Julia Betancor

In Spain, it was not only the passing of time and the lack of care that caused the poor condition of the works but also the historical vicissitudes of the country, some of which, we now know, led to the need for numerous treatments to the paintings' supports. For example, on Christmas Eve in 1734, a fire broke out in the Real Alcázar de Madrid, which housed the royal collections, many of which are now in the Museo del Prado. Many paintings burned, and others were in such a bad state that they had to be cut into pieces—and as a result many canvases were lined. Juan García de Miranda and Andrés de la Calleja were the first court painters put in charge of restorations. Their inventories recount the works saved, for example, Titian's *Charles V at the Battle of Mühlberg*, which they identified as being in very bad condition (Barreno Sevillano 1980).

Between 1808 and 1814, during the Napoleonic Wars, many works were taken to Paris from different parts of Spain (Cádiz, Sevilla, Madrid) and arrived in terrible condition. Before being returned to Spain, some canvases were treated with linings in France, such as *Juan the Patrician's Dream* by Murillo. Similarly, some paintings on panels were transferred to canvas, including, among others, Raphael's *Christ Falls on the Way to Calvary*, also known as *El Pasmo de Sicilia* (González Mozo and Alonso 2011).

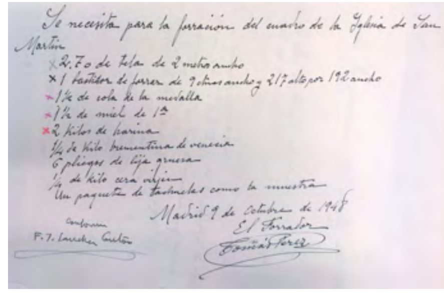
During the Spanish Civil War (1936–39), the great works of art at the Museo del Prado and other areas on the front line were evacuated to avoid damage during the fighting. Despite the care with which they were packed and transported, incidents occurred that caused some canvases to tear, and they were later lined; these include Goya's *The 2nd of May 1808 in Madrid*, also known as *La carga de los mamelucos.*

In 1828, the Sala de Restauración at the Museo del Prado was created by royal decree. Official posts for liners were set up and filled by competitive examination. The fact that there were professional specialists in lining shows that this kind of treatment was frequently being carried out. We can therefore count on a huge quantity of works lined with glue paste in Spain, many of which are very well preserved. For example, of the forty-nine Velázquez paintings studied in the Museo del Prado, only seven (about 14%) had not been lined, and of the paintings attributed to El Greco, fifty-one were studied and only six had not been lined (about 11.7%).[3] If we apply an average percentage of 13% to the 6,367 paintings on canvas held by the Museo del Prado at the end of 2019, we can hypothesize that more than eight hundred have not been lined, and more than five thousand could have been lined. These numbers lead us to reflect on the durability of these linings and the future conservation of all those works: Which conservation conditions are the most appropriate for their preservation, and what should be done when the adhesives start aging and failing?

DEVELOPING THE PROJECT

Among the aims of the project was to get a better understanding of the historical glue-paste recipes and methods of applying treatments. We then proposed using a sample recipe and making models and tests that would allow us to determine their possible efficiency and the process of deterioration—that is, to study and verify the present suitability of a reinforcement treatment that evolved over more than three hundred years in Europe, especially its suitability for paintings that were treated with this adhesive previously. We know that this method presents little toxicity, employs materials similar to and compatible with most paintings on canvas, and is reversible, inexpensive, and sustainable compared with modern synthetic adhesives, which have certain advantages and disadvantages; some plastic materials need high temperature to activate the adhesive, for example. In addition, we wanted to use the experimental results to suggest improvements and guidelines for preventive conservation and future preservation of paintings lined in this way.

The project was organized in three parts: a documentary work or study, an experimental study, and the sharing of the research as it was carried out (fig. 18.2, table 18.1).



Se necesita para la forración del cuadro de la Iglesia de San Martín
2.70 de tela de 2 metros ancho
1 bastidor de forrar ... 217 alto por 192 ancho
1 k de cola de la medalla
1 k de miel de 1ª
2 kilos de harina
1/4 de kilo trementina de venecia
6 pliegos de lija gruesa
1/4 de kilo cera virgen
Un paquete de tachuelas como la muestra
Madrid 9 de Octubre de 1948
El Forrador
Tomás Pérez
Conforme
F. J. Sánchez Cantón

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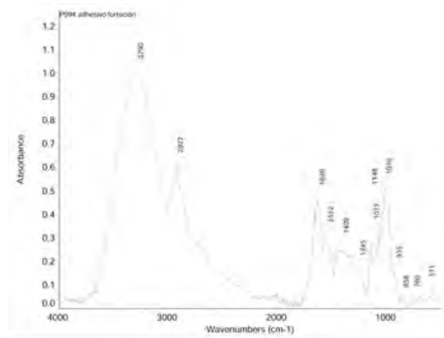

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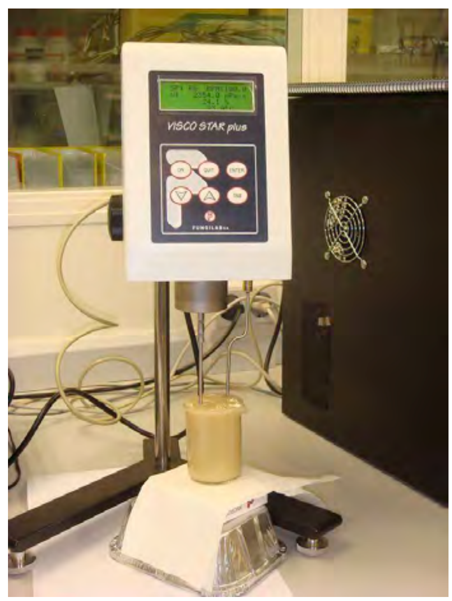

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Figure 18.2 (a) A recipe for *gacha* used in 1948 by Tomás Pérez Alférez, liner at the Museo del Prado for the lining of an unspecified painting of the Church of San Martín. (b) Fourier transform infrared spectroscopy (FTIR) analysis of the adhesive used to line *El sueño del Patricio Juan* (*Juan the Patrician's Dream*), by Bartolomé Esteban Murillo. (c) Measure of viscosity in a *gacha* recipe taken during the experimental study in the project. Images: (a) Archivo del Museo Nacional del Prado, (b) Laboratorio de Análisis del Museo Nacional del Prado, (c) Lining Project HAR 2011-24217 and Universidad Politècnica de València.

Table 18.1
Components of recipes from documents and analytical studies

Glue-paste component	Type of material	Function	Materials named in the glue lining paste recipes
Basic components	Skin glue	Adhesive	Rabbit, cartilage, technical gelatin. Trademarks: “glue of the Medalla” (extra strong glue D. Pedro Álvarez SA Chemical), “glue of Salamanca”
	Flour	Adhesive, thickener	Wheat, rye, refined candeal. Trademarks: Manitoba, EI Corte Ingles, DOM, Gallo
	Water	Diluent	Tap, deionized
Additives	Vinegar	Disinfectant, surfactant, pH corrector	Vinegar from wine
	Honey, molasses, sugar, syrup	Plasticizer	Honey, molasses, sugar, syrup, or maple syrup (employed in the National Gallery of Denmark in first half of 20th century)
	Plants (garlic)	Disinfectant, adhesion strengthening, siccative	Garlic (old recipes: Andrés de la Calleja recipes; recipes from 19th and first half of 20th centuries at the Museo del Prado)
	Salts, chemicals	Disinfectant	Sodium pentachlorophenate or alum and Nipagin (sodium salt of p-hydroxybenzoate); Micospec (econazole nitrate) in ethanol, quaternary ammonium salts, sodium fluoride, benzoic acid
	Pigments	Disinfectant	Verdigris (Denmark in 19th century)
	Beer	Diluent	Beer (François-Toussaint Hacquin recipes)
	Mucilage, oil, turpentine	Plasticizer	Linen grain (French recipes), linseed oil, Venice turpentine
	Gum	Strengthen adhesiveness	*Grasilla* (gum juniper: ground yellowish resin used for the preparation of varnishes, recipes from Spanish authors in the 16th century, recipes of Juan García de Miranda)
	Oxgall	Surfactant, wetting	Oxgall (liquid or paste)

Table: Rita Gil

DOCUMENTARY STAGE

For the documentary stage, we consulted treatises, archival documents, and various bibliographies and sent questionnaires to various European professionals and institutions. We used two types of questionnaires: one for the cases treated in the more distant past and another for lining treatments carried out in the twentieth century. More than sixty questionnaires were sent, although the amount of information received varied greatly.

It was not easy to find all the recipes used. In some cases, old documentary information presented the ingredients in invoices, but it did not detail how they were prepared and applied. Similarly, we met with certain reticence from conservator-restorers when it came to explaining the recipes they were currently using, since many of them were personal variations developed by the professionals themselves.

The Origin of the Use of Gacha*, or Glue Paste*

Knowing the materials used to prepare a canvas is essential to understanding the behavior of the lining treatment. With reference to the recipe, materials, and ingredients used in canvases in Spain, interesting research has been done (e.g., Gayo and Jover de Celis 2010), but we still have a lot to learn. For example, the presence of ashes in the preparatory layers has only recently been confirmed in paintings (Jover de Celis and Gayo García 2014; Carò, Centeno, and Mahon 2018), although it appeared in recipes and treatises.

Through the documents, we know that from the moment people started painting on canvas, a flour paste was used to prepare the canvas. Giorgio Vasari has written about flour with walnut oil, glue, and white lead for preparing the canvas (Vasari [1568] 1998, 119). An anonymous Spanish manuscript from the end of the sixteenth century also mentions preparing the canvas with glue, flour, and gypsum and states that "if it were all flour, it would be better" (Bruquetas Galán 1998).

We find the same in Francisco Pacheco's treatise from the mid-seventeenth century: "Some work with flour or mill-dust paste, cooking oil and a little honey (which you can eat even if you are not hungry); they apply a coating of this to a well-stretched canvas to cover over the pores . . . But experience has taught me that any paste of gypsum, flour or ash gets damp and with time rots the canvas and the painting comes out in scabs" (Pacheco [1638] 1990, 481). Antonio Palomino raises similar concerns in 1715, when explaining how to prepare the mixture by boiling and shaking it to avoid lumps: *gacha* paste with flour and water, honey, and a little linseed oil (Palomino [1715] 1947, 483). In some cases, the presence of flour paste has been identified by scientific analysis (Helwig and Daly Hartin 1999).

A treatise by the Spaniard Vicente Poleró published in the mid-nineteenth century points to the lining of the canvas as an essential operation (Poleró [1853 and 1866] 2018). He describes the procedure: cover the paint surface with paper and apply the adhesive to both the lining fabric mounted on a loom and to the original canvas on the back, then iron until it is completely dry. The idea was not simply to reinforce the support but also to fix the layers of color with an impregnation of glue paste (which was surely much more compatible with the original materials than modern plastic adhesives).

Using the information gathered and the results of the questionnaire, we were able to establish the different ingredients used in the recipes and their function in the mixture: thickener, adhesive, fungicide, humectant, and so forth (see table 18.1).

In older recipes for *gacha* paste, such as those of Juan García de Miranda in 1735 (fig. 18.3), we find flour (the main component of which is starch), honey, walnut oil, and *grasilla* (juniper resin). Among the ingredients of the Poleró recipe we also find garlic, glue, and linseed oil. Later formulas mention molasses, Venetian turpentine, oxgall, vinegar, Italian *colletta*, alum, flax seeds, and phenol. In Spain, wheat flour was typically used, but in France, Italy, and Portugal we find mention of rye flour. The glue used varies from strong or bone glue (called in Spanish what translates to carpenter's glue) to hide or rabbit-skin glue. More recent recipes add Plextol B 500 as an adhesive and plasticizer.

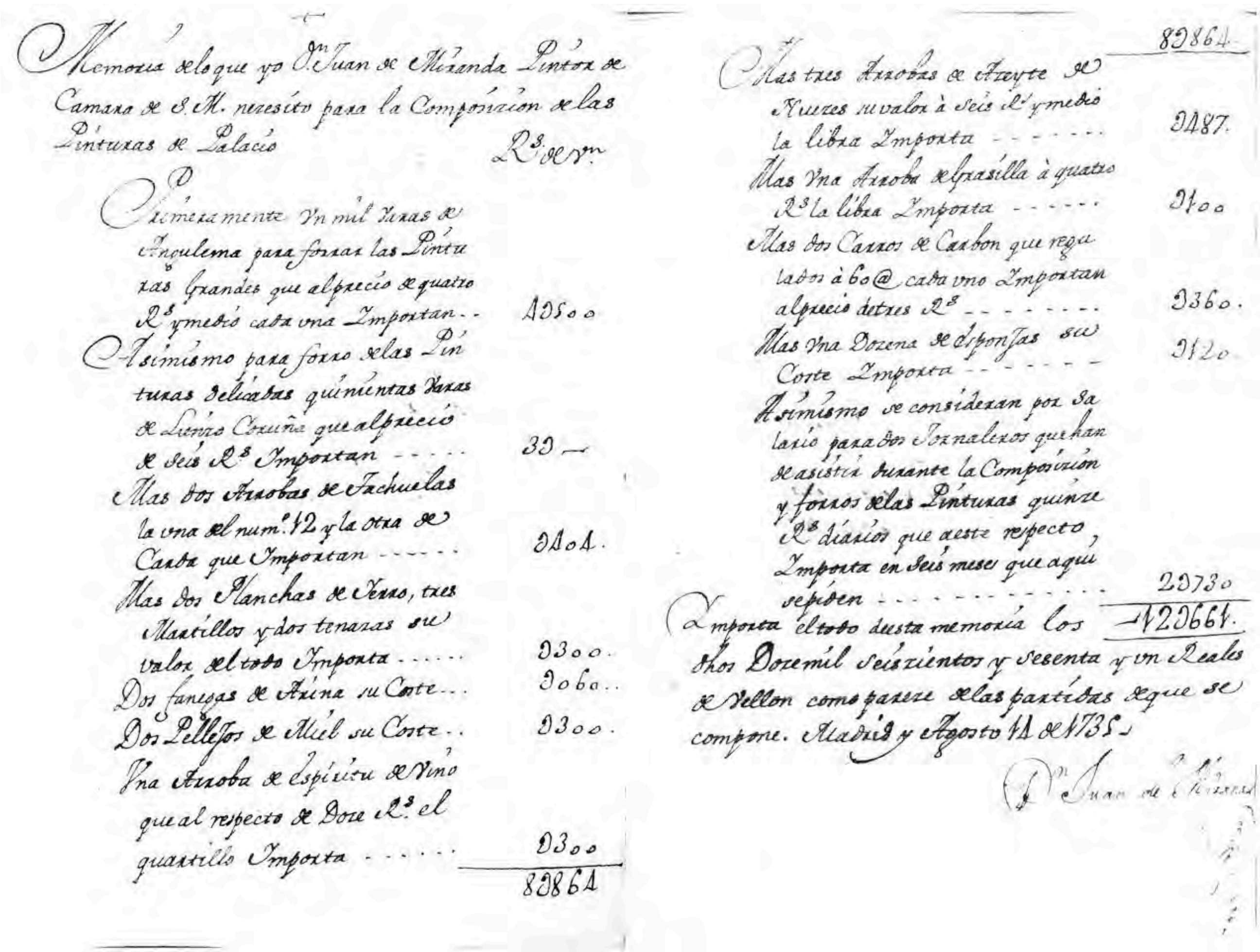
María Luisa Gómez has noted several characteristics of lining with *gacha* paste (Gómez 1998), for example that "there is no change in color, or only very slight change. Also, that the high moisture content allows for the smoothing out of cracks. However, the mixture is very hygroscopic and sensitive to humidity. There is a risk that the original canvas will shrink. There is a danger of fungal growth. Adhesion reduces rapidly in bad weather conditions, and it becomes hard and fragile. It has an acid pH. It requires the applying of heat."[4] She concluded that the use of Venetian turpentine and other resins was not justified because they were insoluble in water, darkened, and became more fragile, and therefore suggested simplified recipes made up of only starch and animal glue with a few drops of fungicide, and that they be applied cold and used only for lining in dry climates.

Case Studies

For some cases of lined works, we were able to find references to the date and to the restorers who carried out the treatment, and we were even able to analyze the *gacha* adhesive present in them, such as those analyzed by María Dolores Gayo at the Museo del Prado, those in the Instituto del Patrimonio Cultural de España, and Ribera's *Crucified Christ*, analyzed by Andrés Sánchez Ledesma (Arte-Lab S.L.) (Diputación Foral de Álava 2018). Analyses of the *gacha* are complex because sometimes it is difficult to determine the exact composition. Apart from the difficulty of accessing representative samples, they are possibly not very homogeneous adhesives, and the quantities of certain additives were too small to be identified. We should also bear in mind other treatments and products applied to the paintings over the years, which may interfere in the analytical results.

Examples of case studies include:

- Ribera's *Crucified Christ*, in the Diputación Foral de Álava.



Memoria de lo que yo D.n Juan de Miranda Pintor de Camara de S. M. necesito para la Composicion de las Pinturas de Palacio — R.s de v.n

Primeramente Vn mil Varas de Angulema para forrar las Pinturas Grandes que al precio de quatro R.s y medio cada vna Importan .. 4500

Asimismo para forro de las Pinturas delicadas quinientas Varas de Lienzo Coruña que al precio de seis R.s Importan ..... 3D —

Mas dos Arrobas de Tachuelas la vna del num.o 12 y la otra de Caxa que Importan ...... D404.

Mas dos Planchas de Yerro, tres Martillos y dos tenazas su valor del todo Importa ...... D300.

Dos fanegas de Arina su Coste ... D060..

Dos Pellejos de Miel su Coste .. D300.

Vna Arroba de Espiritu de Vino que al respecto de Doze R.s el quartillo Importa D300

8D864

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Mas tres Arrobas de Azeyte de Nueces su valor à seis R.s y medio la libra Importa ...... D487.

Mas Vna Arroba de Grasilla à quatro R.s la libra Importa D100

Mas dos Carros de Carbon que regulados à 60@ cada vno Importan al precio de tres R.s .... D360.

Mas Vna Dozena de Esponjas su Corte Importa ...... D120.

Asimismo se consideran por salario para dos Jornaleros que han de asistir durante la Composicion y forros de las Pinturas quince R.s diarios que a este respecto Importa en seis meses que aqui se piden 2D730

Importa el todo de esta memoria los 12D661.

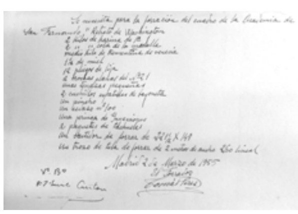
Doze mil seiscientos y sesenta y un Reales de Vellon como parece de las partidas de que se compone. Madrid y Agosto 14 de 1735.

D.n Juan de Miranda

Figure 18.3 Order for materials made by the court painter Juan García de Miranda for lining and repairing the paintings damaged by the fire at the Real Alcázar de Madrid in 1734. Image: Archivo General de Palacio, Patrimonio Nacional de España

- Perovani's *Portrait of George Washington*, in the Real Academia de Bellas Artes de San Fernando in Madrid, which was lined by Tomás Pérez, restorer at the Museo del Prado, in 1955 (fig. 18.4). For this painting, we also were able to locate the original 1955 *gacha* recipe and to examine the state of the lining via cross sections (fig. 18.5).
- Murillo's *Juan the Patrician's Dream*, in the Museo del Prado.[5]
- *The Spinners* and *Philip III on Horseback* by Velázquez, in the Museo del Prado.

Figure 18.4 Joseph Perovani (Italian, 1765–1835), *Portrait of George Washington*, 1796. Oil on canvas, 220 × 145 cm (86 5/8 × 57 1/16 in.). Image: Real Academia de Bellas Artes de San Fernando de Madrid



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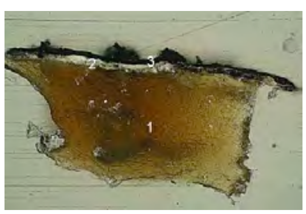

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Figure 18.5 (a) Recipe for *gacha* used in 1955 by Tomás Pérez Alférez, liner at the Museo del Prado, on the painting shown in fig. 18.4. (b) Cross section of glue-paste lining, corresponding to the left sleeve. Layers from the bottom: (1) glue-paste, (2) ground, (3) black paint. Images: (a) Archivo del Museo Nacional del Prado; (b) Real Academia de Bellas Artes de San Fernando de Madrid (E. Parra, Larco Química y Arte; conservation report: Silvia Viana, Ángeles Solís, and Judit Gasca)

The two latter paintings have additional canvas strips to widen them. We know that *The Spinners* was lined in 1785 by Jacinto Gómez, and perhaps he carried out the widening of the painting, although its measurements vary from one inventory to another at different periods, probably due to adaptations for specific locations. During the last intervention on the painting, many repaints were detected, covering damage that may have arisen from shrinkage when using a new close-weft canvas or may have been caused by burns during ironing (Macarrón, Calvo, and Gil 2017).

Creating the Database

For the documentary study, we gathered recipes, materials, and tools used for *gacha* linings. We collected invoices for products bought for lining and as much data referring to these as we could find, such as the restorer's signature on the back of some canvases. Thus, in the Royal Palace we found an order for materials bearing painter-restorer Juan García de Miranda's signature from 1735, in which the materials for the lining are listed (Macarrón, Calvo, and Gil 2013).

We also collected analyses and studies carried out in the collaborating institutions for certain selected case studies, according to their characteristics. All this information was stored in a Microsoft Access database, divided into several sections:

- A general catalogue of works—paintings on canvas with lining and interventions
- Recipes, treatises, and other documentary sources
- Appendices: records of restorers, work tools, ingredients in the recipes, glossary

The version of the Access software allowed us to filter by countries and dates, as well as by the ingredients, tools, and materials used. However, the amount of information gathered in Spain was much larger than that from other European countries taking part in the project. Likewise, the amount and kind of data gathered in the case studies were not comparable due to the different information gleaned: analysis, recipes, methods, and restorers.

EXPERIMENTAL STAGE

Following in the wake of other experimental studies (Daly Hartin et al. 2011), we decided to start a scientific study of the materials of a glue-paste lining, starting with the basic ingredients: flour, glue, and cloth. Thus, a number of tests and mock-ups were carried out to assess the behavior of the lining.

We used an animal glue chosen from previous tests because of its Bloom strength of 240–250. Four types of flour with differing protein content were used: two kinds of finely ground white wheat flour (different brands), coarse-ground semi–whole wheat flour, and coarse-ground semi–whole rye flour. Two kinds of linen fabric were also used: open and closed weft.[6] The adhesive was prepared at the Universitat Politècnica de València, adhesive films were made for analysis, and the linings were carried out. Some of the samples were placed on stretchers and some were not.

The samples were sent to the Centre Interdiciplinaire de Conservation et de Restauration du Patrimoine (CICRP) in Marseilles for accelerated aging and study of susceptibility to biodeterioration (estimate of mold growth and pest infestation). They were also sent to Valencia (for morphological studies using optical and scanning electron microscope [SEM]), Copenhagen (examination of cross sections of mock-ups with optical microscopy [OM] and tensile and peel tests), and Maastricht (investigation of cracking using reflectance transformation imaging [RTI]). Members of the research team who specialized in the different techniques worked in each of these places. Some of the samples were studied before and after artificial aging: we measured viscosity and pH, used FTIR for the characterization of the original materials and lining adhesives, and carried out morphological analysis using OM, SEM, and RTI. We also conducted tests of mechanical traction performance and peeling.

The partial results of these tests included chemical characterization, morphological analysis, studies on mechanical behavior, and biodeterioration (Fuster-López et al. 2017).

DISSEMINATION

The third phase of the project was to share the work by disseminating it widely so as to familiarize professionals with this kind of canvas lined with glue paste. The first objectives of the project were shown at the Museo Thyssen-Bornemisza in Madrid in 2012, along with the state of knowledge on the subject at that time.[7]

In 2012, we also presented a poster to the TechnoHeritage Congress and published some of the documentary work (Macarrón, Calvo, and Gil 2013). The following year, at Lo Stato dell'Arte 11, Matteo Rossi-Doria presented a paper on the critical recovery of traditional lining methods (Rossi-Doria 2013). In a similar context, an article was published comparing the lining systems used in Portugal and Spain (Calvo, Maltieira, and Barbosa 2014).

In 2014, we put forward some case studies at the Association des Restaurateurs d'Art et d'Archéologie de Formation Universitaire (ARAAFU) Colloquium in Paris (Macarrón, Calvo, and Gil 2014, 2017). That same year we also produced a poster for the Art Technological Source Research working group's congress at ICOM-CC in Amsterdam, whose contents we published in 2016 (Macarrón, Calvo, and Gil 2015).

The partial results of the experimental section were presented and published at the ICOM-CC in Copenhagen in 2017 (Fuster-López et al. 2017).

In 2018, we presented a summary of the project at the II Colloquium in Lisbon: Investigación en Conservación del Patrimonio (Heritage Conservation Research) (Macarrón, Calvo, and Gil 2018). More recently, in June 2019, the four authors of this essay organized and taught a workshop at the Complutense University of Madrid, titled Applications of Traditional and Modern Lining Methods, with the assistance of museum professionals, private practitioners, and students (fig. 18.6). During the workshop, a wide range of adhesive formulations was tested on facsimiles. Thanks to the Avangrid Foundation grant, Ana Calvo and Julia Betancor were able to present this research during the Conserving Canvas symposium at Yale University in October 2019.

Figure 18.6 Participants in the Applications of Traditional and Modern Lining Methods workshop, June 2019, at the Faculty of Fine Arts at the Complutense University of Madrid. Image: Julia Betancor

CONCLUSIONS

In certain historical cases, we found linings with glue paste that had changed and completely lost the glue paste's adhesiveness, which led to its removal. We also found that there are now new alternatives and methodologies for structural treatment of paintings on canvas (such as strip-lining, tear mending, and suction tables), but importantly, there are also new criteria regarding structural canvas treatments. This should not, however, justify a loss of understanding and knowledge of linings with glue paste.

Thanks to the project described in this essay, we have learned that hundreds of paintings in Spain are lined with glue paste—some three centuries ago and others more recently. Most are in good condition. However, more information is needed about works lined *a la gacha*: the recipes and application methods used and the environmental conditions of conservation.

In experimental studies (Fuster-López et al. 2017), we discovered variables in biodegradation, which depends on the fineness of the flour, the proportions of flour and glue, and the kind of starch and protein when the proportion of flour to glue is constant. *Gacha* recipes with semiwhole flour are more likely to biodeteriorate than those made with finely milled white flours, and the protein content of the cereal used affects the degradation process. Regarding the mechanical and dimensional stability of linings with glue paste, we found differences related to the kind of flour used, the degree of milling or grinding, and the thickness of the weft in the canvas used for lining. This suggests that conservation strategies for the long-term care of lined paintings must be carefully assessed, taking into consideration the kind of flour used in the adhesive.

It would be useful to continue testing to determine the different additives in the traditional recipes (garlic, oxgall, Venetian turpentine, disinfectants) to understand the role these products played in the lining and their effects. But on the basis of our findings and in light of the current condition of works lined *a la gacha*, we must raise the following questions:

- Might a version of this adhesive be appropriate nowadays?
- Could it be used as a cold, or almost cold, contact adhesive?
- Might it be advisable for cases where fixing paint layers is necessary?
- Which are the most appropriate conservation conditions for works lined in this way?
- Might it be an alternative for the necessary relining of paintings that already have this kind of adhesive?

NOTES

1. The main researcher on the project was Ana Macarrón and the following were part of the team: Ana Calvo, who started out as a member of the School of Arts at the Universidade Católica Portuguesa and then moved on to the Complutense University of Madrid (UCM), Spain; Rita Gil, technical support for the project at the UCM and coauthor of the database; Laura Fuster, Sofía Vicente, and Dolores Yusá from the Universitat Politècnica de València, Spain; Matteo Rossi-Doria, in private practice in Italy; Cecil K. Andersen and Mikkel Scharff from the KADK School of Conservation in Copenhagen, Denmark; Kate Seymour from the Stichting Restauratie Atelier Limburg (SRAL), Maastricht, Netherlands; Nicolas Bouillon and Fabien Forher from the Centre Interdiciplinaire de Conservation et de Restauration du Patrimoine (CICRP), Marseilles, France; Aurelia Chevalier, in private practice in France; Paul Ackroyd from the National Gallery, London; Joan Reifsnayder from ICOM-CC; and Marion Mecklenburg from the Smithsonian Institution. Spanish institutions that took part as contributors are Museo del Prado, Patrimonio Nacional, Museo Thyssen-Bornemisza, Instituto del Patrimonio Cultural de España (IPCE), Real Academia de Bellas Artes de San Fernando, and Diputación Foral de Álava. Funding was provided by CTS Spain, SIT Spain, PC Conservation Products Spain, and canvas manufacturer Claessens in Belgium.
2. I+D+i HAR 2011-24217.
3. Personal communications with Laura Alba and Jaime García-Maiquez.
4. “No hay cambios de color o son muy ligeros. Su elevado contenido en humedad permite aplanar ciertos cuarteados. Sin embargo, la mezcla es muy higroscópica y sensible a la humedad. Existe riesgo de encogimiento de la tela original. Presenta peligro de crecimiento de hongos. Su adhesividad disminuye rápidamente en malas condiciones climáticas, y se hace dura y frágil. Tiene un pH ácido. Requiere aplicación de calor” (Gómez 1998, 386).
5. We would like to thank the conservator-restorer of the Museo del Prado, María Álvarez Garcillán, for all the information she provided us on the condition of this painting.
6. For details of all materials, see Fuster-López et al. 2017.
7. “Reinforcement Treatments of Canvas Paintings: Studio Cases, Evolution and Behavior,” seminar presented at Complutense University of Madrid and Museo Thyssen-Bornemisza, October 15, 2012.

19

The Influence of Research and Innovative Development on Laboratory Practice in the Structural Treatment of Paintings over Four Decades

Debra Daly Hartin, Senior Conservator (retired), Fine Arts, Canadian Conservation Institute, Ottawa
Stefan W. Michalski, Senior Conservation Scientist (retired), Canadian Conservation Institute, Ottawa
Eric Hagan, Senior Conservation Scientist, Canadian Conservation Institute, Ottawa

Lining treatments and ideas about these treatments are reviewed, with a focus on the innovative period following the 1974 Greenwich conference. Three decades of research at the Canadian Conservation Institute on the mechanics of paintings and the mechanics of linings are summarized. The relevance of peel testing and the results of recent tests of the bond strength of Beva 371b film by a colleague at the Centre de Conservation du Québec are also included. The text focuses on the perspective of the conservator: lessons learned from theory and data, from direct observation of samples, and from real structural treatments, as well as perspectives gained regarding the role for preventive conservation strategies.

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INTRODUCTION

The developments in the structural treatment of paintings in the late 1970s and early 1980s had a tremendous influence on subsequent practice and research. Conservators trained during the late 1970s, including Debra Daly Hartin, an author of this paper, were immersed in the content of the 1974 Greenwich Conference on Comparative Lining Techniques and its follow-up, Lining of Paintings—A Reassessment, held in Ottawa in 1976. Recognition of the deficiencies of past lining treatments, combined with the rise of preventive conservation, led to a less interventive, less aggressive, and more considered approach to structural treatments. New methods, equipment, adhesives, and lining supports were introduced. New research into the mechanical behavior of paintings sought to inform the aims and impact of our treatments. Written from the point of view of a paintings conservator working with conservation scientists at the Canadian Conservation Institute (CCI), this paper will discuss specific examples of how research influenced laboratory practice.

OVERVIEW OF DEVELOPMENTS IN THE STRUCTURAL TREATMENT OF PAINTINGS DURING THE 1970S AND 1980S

It is important to recognize the research and innovation that influenced the field in the 1970s and 1980s, setting the stage for our own research program and treatment development at CCI.

Papers and discussion during the 1975 ICOM-CC conference in Venice led to a reevaluation of treatment practices. "All at once" structural treatments, using heat and significant vacuum pressure, were the norm before the 1970s. Vishwa Mehra countered with a much less interventive, stepwise approach (Mehra 1975a, 1978, 1981a). Each painting was considered as structurally unique, each aspect of the structural treatment (out-of-plane distortions, tears, flaking, flattening, lining, etc.) was a separate step, and only the necessary treatment steps were undertaken.

As part of his system, Mehra used a low-pressure "cold" table.[1] Like the tables introduced by Bent Hacke in the 1960s, it pulled high volumes of air through a perforated surface into a plenum below. This enabled drying of an aqueous adhesive while maintaining (low) pressure on the painting (Hacke 1978, 1981b). The design of these "suction" tables proliferated, allowing for controlled humidification for relaxation and flattening treatments of paintings, both on and off their auxiliary supports. (See Jim Coddington's article in these proceedings.)

New lining fabrics and new adhesives were also introduced. Mehra used a woven polyester fabric and a thickened acrylic dispersion (Mehra 1981a). Conservators in Europe turned to acrylic dispersions for cold or low heat, nap-bond linings; Alois Diethelm commercialized these adhesives under the mark Lascaux. In the United States, conservators turned to heat-seal adhesives: Rabin developed a nap-bond system based on PVA adhesives,[2] and Berger developed Beva 371 based on ethylene vinyl acetate. Fieux developed Fabri-Sil linings, a pressure-sensitive silicone adhesive cured onto Teflon-impregnated fiberglass (Fieux 1978; John G. Shelley Co. 1985). (Initially, Fabri-Sil looked like an excellent option, but bonds failed within a few years [Schwartzbaum 1993; Belloli 1993].)

To avoid the use of heat or moisture to activate adhesives, solvent activation was studied (Phenix and Hedley 1984, 1993). Unfortunately, safety issues with electric blowers and pumps prevented us from fully incorporating this into our practice at the time. With the current mist-lining techniques of Jos van Och, we see the resurgence of solvent activation (van Och and Hoppenbrouwers 2003).

Mehra, Hedley, and Villers began systematic studies of available synthetic fabrics and their properties (Hedley, Villers, and Mehra 1980, 1993). They encouraged a manufacturer to produce a wide, heat-set sailcloth without the usual impregnants (Hedley and Villers 1982). In Canada and the United States, respectively, Roger Roche (R. Roche 1976) and Blakney and Sutton introduced industrial monofilament fabrics and stiff filter and belt fabrics (Blakney and Sutton 1983; Blakney 1993).[3] Methods of stiffening fabrics by using sizing or retaining Mylar on the reverse of linings were explored. Marouflage onto aluminum honeycomb supports was common, and laminates to increase rigidity were explored.[4]

THE INFLUENCE OF RESEARCH BY OTHERS

In 1982, Mecklenburg's unpublished report "Some Aspects of the Mechanical Behavior of Fabric Supported Paintings: Report to the Smithsonian Institution" circulated widely (Mecklenburg 1982). This had us thinking about how everything fit together; the hygro-thermo-mechanical properties of the individual materials and their contribution to the behavior of the painting as a whole; the influence of the geometry and behavior of the wood stretcher, and the effects of our interventions, such as lining and stretching.

Mecklenburg introduced three concepts: First, that the total tension in a painting (the double red arrow running across the painting in fig. 19.1) was simply the sum of the individual tensions in each layer (the smaller arrows on the far right in fig. 19.1). Second, that the response of each layer to changes in RH was not simply a change in dimension but also a change in stiffness. And third, that "force realignment" (later phrased as stress alignment) could explain many deformations of paintings while under tension, as in figure 19.1a. (Curl, a separate mechanism for cupping, is described by Hough and Michalski in these proceedings.)

Mecklenburg demonstrated the power of his model by predicting the response of a painting to wide swings in RH; his plot of tension in a sample from a 1912 painting is shown in figure 19.2 (solid black line). Within a few years, various authors had repeated this measurement, including another sample from Mecklenburg's 1912 painting, measured by Hedley while at CCI (solid green line). Although different authors used different materials and

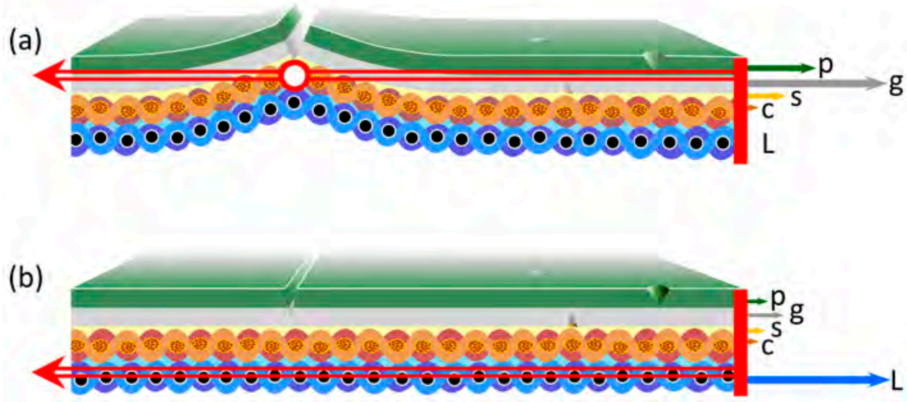

Figure 19.1 (a) If the lining is much less stiff than any of the painting's layers, the laminate cups at cracks in the painting due to stress alignment. Flaws in the painting are subject to the overall tension in the painting. (b) If the lining is much stiffer than any layer in the painting, stress alignment pulls the laminate flat, and flaws in the painting are not subject to the overall tension. (p) paint, (g) ground, (s) size, (c) canvas, (L) lining. Image: © Government of Canada, Canadian Conservation Institute

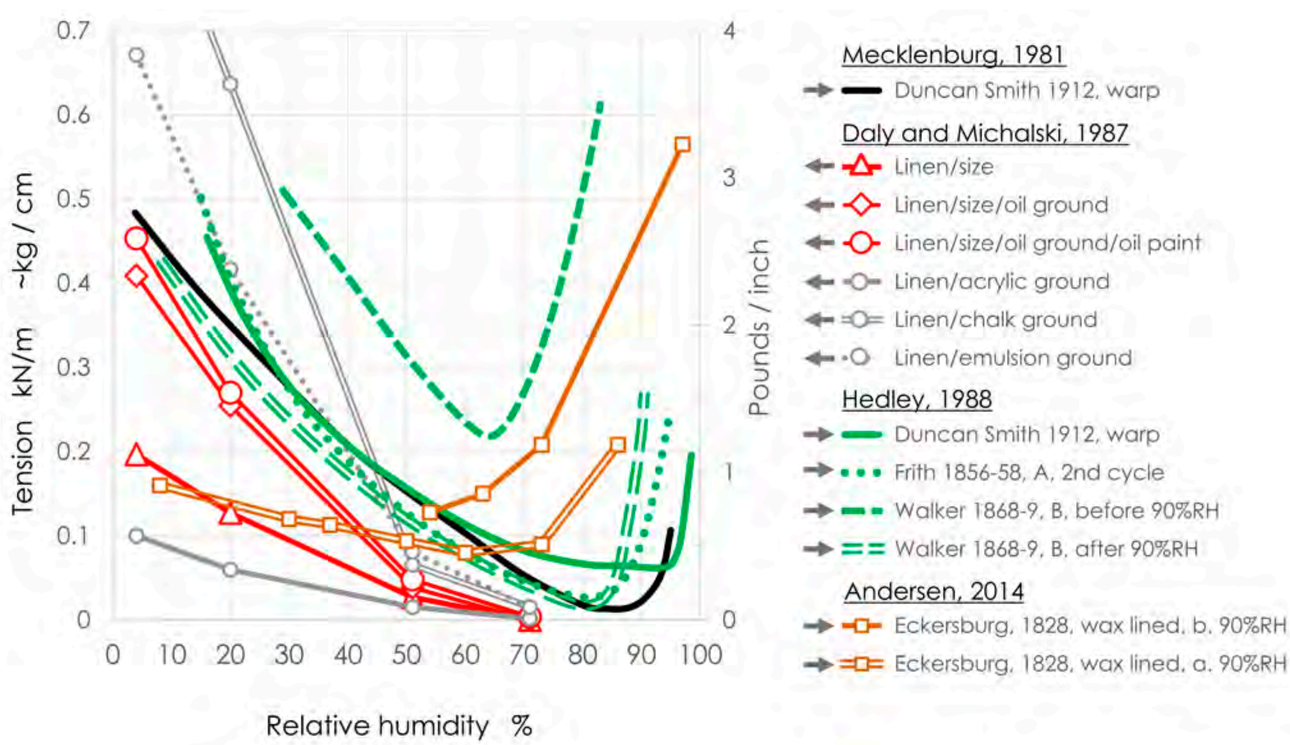

Figure 19.2 Tension in paintings as RH varies (in the direction shown by the gray arrows in the legend). Mecklenburg, Hedley, and Andersen reported full cycles (hysteresis loops). (For clarity, only selected paths from low to high are shown.) Image: © Government of Canada, Canadian Conservation Institute

different procedures, the result was a universal "hockey stick" curve, with a minimum somewhere between 65% RH and 95% RH, depending on prior history and the amount of prestrain.

This new knowledge informed our decisions; specifically, it influenced our pursuit of better lining supports and improvements in noninterventive options, such as backing boards, enclosed case/frame design, and protection during transit. At that time, conservators and conservation scientists at CCI and other institutions were focusing on noninterventive preventive conservation measures for the broad heritage community, recommending best practices to improve the management of the museum environment and the handling, display, storage, and transit of museum objects. Controlling the physical risks and environment around the painting—with minimal alteration of the painting's appearance or its materials—was an important option in the conservator's repertoire.

In terms of lining, however, the question was whether the new materials were capable of preventing deformation or fracture of the painting. This question led to the CCI Lining Project, a collaboration between a conservator (Daly Hartin) and a scientist (Michalski) that lasted over a thirty-year period.[5]

THE INFLUENCE OF THE CCI LINING PROJECT

Humidification and Canvas Shrinkage

In the first phase of the Lining Project (1980s), we prepared samples with successive layers applied: linen canvas, linen canvas + size, linen canvas + size + oil ground, linen canvas + size + oil ground + oil paint. At the time, we used manual testing equipment to measure the weight, length, and tension of the samples during changes in RH (Daly and Michalski 1987), and it was the conservator who made the measurements (fig. 19.3). This intimate tactile and visual engagement of the conservator with the samples as they underwent rapid changes influenced her practice as much as the measurements being collected.

Figure 19.3 Measurement of the free-hanging dimensional response due to changes in RH. A scale was photographed on 35 mm high-contrast film and attached to glass slides adhered to the end of each sample. The scales slid past the reference edge of a metal strip bolted to the rack. Image: © Government of Canada, Canadian Conservation Institute

In our dimensional response study of 1985–86, we were surprised to see that samples taken from 47%–71% RH did not stabilize at their peak but began to shrink after only two hours at 71% RH. This was significantly lower than the ~85% RH we had presumed for onset of shrinkage based on tension studies prior to that date. By 1987, however, Hedley's measurements (Hedley 1988, 1993) in our labs at CCI confirmed that a severe "shrinker," when significantly prestressed, and before experiencing the permanent relaxation that occurs at 90% RH, could experience onset of shrinkage as early as 65% RH (see fig. 19.2, double green broken line [10]). Such potential for shrinkage led to great caution in our use of humidity treatments in general.

When using humidification tables for relaxation and flattening treatments, it is easy to produce higher humidity conditions than intended, particularly when that is combined with heat, even at low levels. Early monitoring of the Willard Multipurpose Table[6] at CCI showed that even with a moderate setting of 76% RH and duct heating at 30°C, the humidity under the painting can rise to 90% RH and higher, due to the temperature difference between the warmer ducts and the cooler table surface. To reduce this risk, the conservator requested a monitoring system for RH under the painting (Daly Hartin et al. 2011, 2015b). By glancing at the computer display of conditions under an experimental painting—placed to one side of the painting being treated—the conservator could adjust the table settings to maintain safe levels of humidification.

Sensitivity of the Size Layer and Preventive Conservation Measures

The response of the linen + size sample was fast, whether there was a change in weight, dimension, or tension. When exposed to a jump in RH, half the eventual change of length occurred within five to seven minutes, and total change happened within one to two hours. Under the binocular microscope, one could literally see the scale attached to the end of each sample moving past the reference point (see fig. 19.3). This instilled a deep appreciation of the reactivity of sized canvas, and the consequent importance of backing boards and enclosed frames to reduce RH fluctuations.

Controlled humidification is sometimes used to reactivate glue size in paintings, re-adhering incipient cleavage without adding another adhesive. During one such treatment on the Willard table, areas of missing paint allowed us to observe the glue-size bridging canvas interstices. Before humidification, the glue size was fractured; during humidification, the fractures disappeared. The size coalesced into a continuous film that moved under slight pressure from a probe. While that was a desired outcome, the reactivated size layer was once again a source of stresses. As demonstrated in previous research (e.g., Mecklenburg 1982; Daly and Michalski 1987; Hedley 1988), the coherent size is reactive to low RH conditions and thereby particularly vulnerable to stretching and shock under these conditions. This understanding further reinforced our emphasis on the passive control of RH by enclosures, that is, the importance of preventive conservation.

Bond Strength of the Lining

In the 1980s and early 1990s, conservators reported bond strengths of the newly introduced fabrics and adhesives using peel tests. In our peel tests, we often found it difficult to reproduce results even within our own studies (Daly Hartin, Michalski, and Pacquet 1993), and inferring comparison between studies or from one lab to another is even more difficult. We concluded that although published results could provide guidance, trial mock-ups of new materials and procedures in one's own lab are essential. For example, when trying to reproduce the results of solvent activation tests described by Phenix and Hedley (Phenix and Hedley 1984, 1993)—with Gerry Hedley himself present to guide us—we were unable to obtain the acceptable results that he had published. We had to use mock-ups, modifying the procedure by varying the amount of solvent used and allowing time for swelling of the adhesive, to obtain an adequate bond. We learned that peel tests provide guidelines, but they do not necessarily reflect actual practice. Peel tests can inform us which combinations of materials and procedures do not work and which do work or have the potential to work. Trial linings, using test or model paintings and the equipment and procedures in one's own lab, must be undertaken to refine the method and ensure the resulting lining will be satisfactory.

Trial or mock-up linings are not only important when new materials or procedures are used, or when there is a change in lab equipment such as purchase or refurbishment of a new hot table, but they have become increasingly important with our design of more customized linings for the specific needs of a particular painting. To allow for repetition or improvement to the trial, or mock-up, lining, there must be careful attention to, and documentation of, all details of the lining materials and procedures. This includes the amount of adhesive used, details of its application to the lining fabric, the method and conditions of adhesive activation (activation temperature, time of heating, time at activation temperature, time of cooling), and the lining pressure.

Conservators were aware of the high sensitivity of bond strength to temperature, particularly when attempting to heat a thermoplastic such as Beva 371 until it is tacky while avoiding its nearby melting point. Monitoring the temperature uniformity of hot tables during peel tests heightened our awareness that hot tables were notoriously uneven in heat distribution over the surface. This instigated practical measures to ensure appropriate temperatures over the work area, and multiple-point monitoring of the surface became essential.

An example of the importance of mock-ups and of monitoring temperature uniformity of hot table surfaces was adapting to the change in Beva 371 film from its original formulation to Beva 371b. In 2010, we were informed by the manufacturer that despite this change, the new product had the same properties.[7] Many conservators, however, had found differences in performance.

Élisabeth Forest, a paintings conservator at the Centre de Conservation du Québec, had used peel tests to study Beva 371 film while a student (Forest 1997). She found that 65°C and a ten-minute holding time gave an acceptable bond.[8] This formed the guideline for many successful linings. However, using the new formulation under the same conditions, she found there was a high probability of local detachment during restretching of both linings and strip-linings.

In 2018, Forest compared the two formulations in a study undertaken at the Centre de Conservation du Québec (Forest 2019). As in the previous tests, two reactivation temperatures (65°C and 70°C) and two holding times (0 and 10 minutes at the activation temperature) were used (fig. 19.4). The nap-bond strength of both formulations was strongly influenced by temperature, more than doubling in force between 65°C and 70°C. Based on what was considered a reliable bond, 0.33–0.41 kN/m,[9] shown by the red lines in figure 19.4, only lining at 70°C with a duration of ten minutes was successful.

These results corroborate an earlier study by Ploeger et al. of the two formulations used in solution as a consolidant for painted surfaces (Ploeger, McGlinchey, and de la Rie 2015). The original Beva 371 was shown to have a larger tack window with a gradual increase in tack, while Beva 371b had a narrow tack window with a sudden increase in tack. In summary, if the tack window (of any adhesive) becomes too narrow, or if time at the activation temperature is a determining factor in obtaining an acceptable bond, then temperature uniformity and monitoring become even more critical.

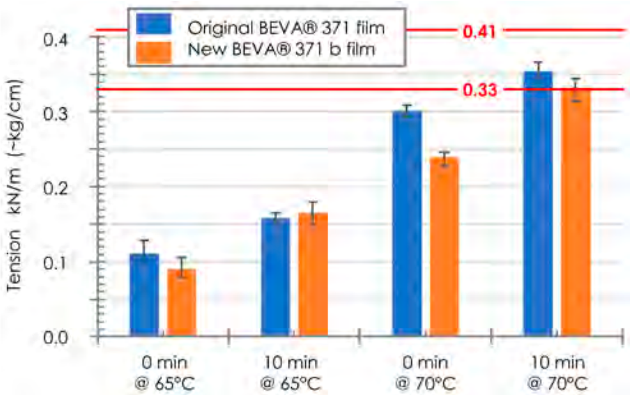

Figure 19.4 Results of peel tests by Élisabeth Forest (Centre de Conservation du Québec). Due to the unevenness of the hot table, Beva 371b samples were always lined at a temperature 1°C higher than Beva original samples. The red lines at top show an acceptable range in bond strength. Image: © Élisabeth Forest, Centre de Conservation du Québec, Ministère de la Culture et des Communications

Stress Relaxation of Linings and Paintings

The overall goal of the Lining Project, besides understanding the fundamental mechanics of a painting plus a lining, was to determine whether linings can actually be considered a support for the painting: Can they reduce cupping and cracking, or can they only be considered as a bridge for ruptures in brittle and broken canvas?

The primary measurement for answering this question is stress relaxation—the loss in tension of a restrained sample over time. The primary concept within which to place such measurements is that of viscoelasticity in polymers (see also Hagan and Hough and Michalski in this volume). Conservators intuit this concept in their use of the terms *relaxation* and *memory* of deformations. In the initial research on mechanical properties of paintings, such as the tension versus RH studies (see fig. 19.2), or stress-strain plots, authors were not overly concerned with reporting time issues: How fast was the test? How much time had passed since the initial stretch? Tension and its underlying parameter elasticity depend on time, not just temperature and RH.

By 1991, we were placing our review of published data on the mechanics of paints within the framework of polymer viscoelasticity. Specifically, we introduced the primary tool of that framework—the "master curve"—which plotted elasticity over the full range of a polymer's behavior, from glassy through leathery to rubbery as a function of temperature, plasticizer, and time (Michalski 1991).

To understand whether a lining will actually support the painting and by how much, analysis of results focused on whether the lining is at higher tension than the painting during stretching, during shock and vibration, and during fluctuations in RH and temperature—and on whether the lining can maintain this support over many years. Sample preparation and experimental procedures have been published elsewhere (Michalski and Daly Hartin 1996; Daly Hartin et al. 2010, 2011, 2015a; and Michalski et al. 2014). The 2015 article also summarizes the results of the project and their implications for linings.

Tension was measured continuously over time. If the sample is undergoing stress relaxation, then the tension drops over time, as shown by all curves in figure 19.5. The process of building these master curves that extend to very short and very long times is described by Hagan in this volume.

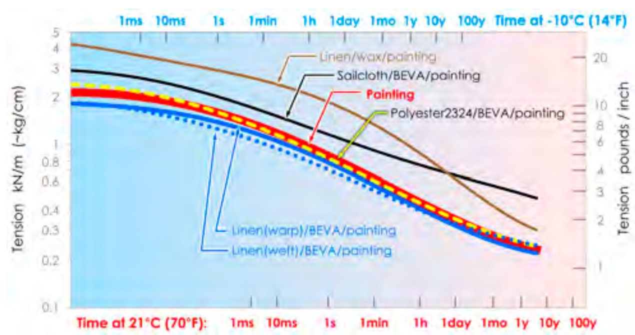

Figure 19.5 Master curves of selected lined paintings, compared to an unlined painting, at 50% RH, shown for various time periods at room temperature (lower scale) and at a cold temperature (upper scale). By the time of these measurements, the oil painting was twenty years old and the linings were eighteen years old. These master curves help us understand which layer is carrying the tension over long periods of time and during short events like a shock (from 1 millisecond to 100 years), and in cold and hot environments. Image: © Government of Canada, Canadian Conservation Institute

The big takeaway from figure 19.5 is that one group of linings had curves that differed only slightly from the red curve for the unlined painting, whereas a second group lifted the curve significantly. The first group, nap-bond Beva linings onto linen and onto multifilament, non-heat-set polyester, represents linings providing negligible tension/support (see fig. 19.1a). The second group—sailcloth + Beva and linen + wax—represents linings that add significant tension/support (see fig. 19.1b). Wax impregnation changes both the linen lining and the original canvas into a significant reinforced composite, quite unlike linen adhered simply with Beva. However, even though the linen + wax-lining initially contributes more support (additional tension) than the sailcloth + Beva lining, at around one second it starts to quickly lose tension, and at one day it is providing less support than the sailcloth + Beva lining.

The question of whether these stiffer linings provide enough support to reduce defects in a painting is examined in figure 19.6. What percentage of the total tension is the lining alone contributing to the lined composite? In the region of transit shock, whether at room temperature or low temperature, linen + wax has double the contribution of sailcloth + Beva, but both linings offer some support, thus cracking may be reduced. For slightly slower events, such as initial stretching or keying out, both linings gain in percentage, offering slightly more support. As days and years pass at room temperature, the contribution of linen + wax collapses. The supportive contribution of sailcloth + Beva continues to increase, but never enough to dominate tension (see fig. 19.1b). To dominate tension and to reduce defects in the painting, the lining (not the painting) must contribute over 50% of the tension. Although sailcloth + Beva is relatively better in the long term, neither sailcloth + Beva nor a linen + wax-lining truly dominates tension; neither does much better than reach half of the total tension.

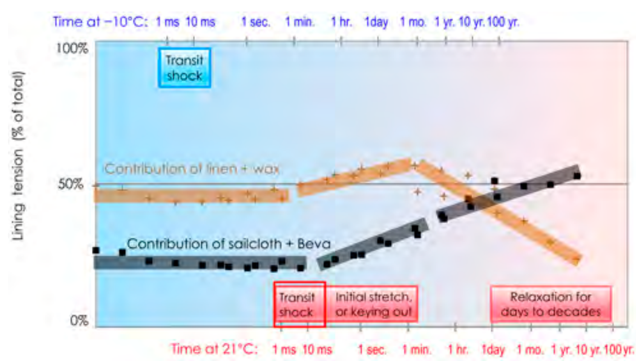

Figure 19.6 The relative contribution of linen + wax and sailcloth + Beva linings to the tension in a lined oil painting. Calculated by subtracting the painting tension from the lined painting tension shown in fig. 19.5. Image: © Government of Canada, Canadian Conservation Institute

The influence of the lining in reducing cupping was studied using a set of square samples prepared with a T-shape cut in the center of the model painting prior to a nap-bond Beva lining (Daly Hartin et al. 2015a). After eighteen years, the model painting lined with Beva onto a rigid aluminum plate showed no cupping as depicted in figure 19.1b. The cupping along the "tear" of the sailcloth lining could be described as minimal to none; the sailcloth lining did not prevent cupping along the tear as well as the rigid aluminum, but it performed much better than the loosely woven linen and polyester linings which appeared in figure 19.1a. This is consistent with sailcloth's performance over days and years (see fig. 19.6).

RH Change

We measured the response of samples to RH fluctuations up to 70% RH to give comparative data on the ability of the lining to support the stress in a painting during daily humidity cycles (Daly Hartin et al. 2015a). Some of these data are shown elsewhere in these proceedings (see fig. 2.4 in Hagan in these proceedings). The sailcloth + Beva lining, unaffected by RH, provides a constant absolute level of support during RH fluctuations, but during periods of very low RH (20%), rising tension in the oil painting overwhelms that of the sailcloth + Beva (i.e., the system goes from fig. 19.1b to fig. 19.1a). Linen + wax is very different; it completely blocks response to one hour of 70% RH, and blocks response to a twelve-hour exposure by two-thirds. (It is not our intent to promote wax linings, but to understand them as historic treatments with advantages as well as known disadvantages.)

This ability of wax linings to reduce sensitivity to short RH fluctuations (1–12 hours) must be placed alongside the increased sensitivity to longer RH fluctuations shown by Andersen and colleagues (Andersen et al. 2014). They showed that a restrained sample of an old wax-lined painting that had not yet been exposed to the permanent relaxation that occurs at 90% RH (fig. 19.2, double brown line) increased dramatically in tension at RH above ~60% when exposed for at least eighteen hours. Whereas our short-term data showed the moisture barrier effects of wax linings, Andersen's data showed the transformation of the canvas from porous yarns, which need to swell considerably before they tighten the textile, into a composite of fibers embedded in a wax matrix that tightens as soon as any fiber swelling occurs. The longer exposure permitted this to happen. Andersen's eighteen-hour exposures also showed a second phenomenon: in the second cycle, after the exposure to 90% RH (fig. 19.2, dashed double brown line), the V-shape response seen in the graph reverted to more of a hockey-stick shape. Something was transformed irreversibly in the canvas by a single exposure to high RH while restrained.

We can see a similar but slightly less pronounced example of these two phenomena in a painting that was not wax lined: the Walker 1868–69 painting (fig. 19.2; compare before exposure to 90% RH, single dashed green line, to after exposure to 90% RH, double green dashed line). In both cases, when a canvas is impregnated with a liquid that solidifies, whether wax or size, it becomes a composite of fibers in a matrix. If the size, wax, or any adhesive just sits on top, we have instead a laminate. In practice, in a painting, one probably has a hybrid. The increase in tension (due to fiber swelling and crimp) of a restrained textile as RH climbs will occur at lower RH if those fibers are locked within a matrix. But if the tension in this composite gets high enough for long enough, a viscoelastic matrix will irreversibly slip, slide, and even exude, leading to a change in subsequent behavior.

CONCLUSION

Of the different types of linings we tested, though some offer more support than others, all share the load with the stiff layers of the painting. A support with mechanical properties similar to the heat-set sailcloth may reduce defects in certain situations: cupping over the years, and cracking in ground and paint from initial stretching, keying out, shock and vibration, and cold temperatures. However, sailcloth will not totally eliminate defects. The best choice combines a sailcloth lining, or its mechanical equivalent, with passive RH control. Loosely woven multifilament fabric supports will bridge ruptured layers—but alone will not reduce cupping and cracking.

Linings have decreased over the last twenty years due to the desire for less intervention with the painting and due to the development of effective, noninterventive options that provide support and protection. Where linings are necessary, research on the mechanical behavior of lined paintings has informed us of the limitations and benefits of the materials available to us, allowing us to assess and select the best option available. Our research has shown that to prevent defects in a painting, we are forced to integrate lining choices with preventive conservation choices—specifically, the use of passive RH control strategies, such as backing boards and tight enclosures, which fortunately coincide with efforts to develop more sustainable solutions.

Research over the past forty years, by CCI and others, has provided us with the knowledge to assess and refine our practices, such as relaxation, flattening, and lining, so they are undertaken with greater effectiveness combined with less intervention and less risk to paintings. Though institutions with more control over their environments and painting enclosures can avoid lining in many instances, there are situations, such as extensive damage or instability and little control over the painting's environment, when lining is necessary. As a result of our studies, sailcloth has been considered and used as a lining support, though it does present practical difficulties such as its inauthentic appearance and problems along the tacking margin fold. We do not have the perfect option, but we are more aware of what a lining can and cannot do.

Our profession is in the position to observe the impact and effects of treatments undertaken in the past decades and to develop even better solutions with the knowledge, materials, and tools available to us today. We are fortunate that our field encourages and enables conservators and conservation scientists to work together to address the technical issues and observations arising in the conservation lab. This collaboration and direct involvement in practical research promotes appropriate, practical, knowledge-based solutions.

ACKNOWLEDGMENTS

Our thanks to Élisabeth Forest, paintings conservator, Centre de Conservation du Québec, for her willingness and collaboration in the use of her Beva film study as an example of research influencing laboratory practice.

NOTES

1. Diane Falvey, who worked with Mehra during her training, introduced this system into practice at CCI around 1979.
2. Formula: 454 g AYAA and 454 g AYAC, dissolved in 1.4 l toluene. Add per 1 liter proportion, 4 g melted microcrystalline Multiwax 445; stir until dissolved. Source: unpublished notes and precis by Caroline Keck from Conservation Practitioners Course, Cooperstown Art Conservation Center, New York, summer 1973.
3. The 1993 paper had previously been introduced at the 1986 American Institute for Conservation poster session and was presented at the Toronto Area Conservation Guild by Margaret Sutton in 1991.
4. To achieve rigidity and increased stiffness, laminates could consist of multiple layers of fiberglass fabric, or linen and Mylar, or layers of woven polyester, possibly with the addition of monofilament fabrics.
5. The CCI Lining Project was initiated in 1983 by Debra Daly Hartin and Stefan Michalski, with the input of Ian Hodkinson. There were three major testing phases: testing of model paintings, peel testing, and testing of lined model paintings.
6. Now the Multi Function Suction Table; see https://www.willard.co.uk/product-page/multi-function-suction-tables.
7. Conservator's Products Company, "Announcement: BEVA 371 Reformulated in 2010," http://www.conservators-products.com/pr01.htm.
8. The hot table was quick to heat (13 minutes to 65°C and 18 minutes to 70°C) and quick to cool to 25°C (20–21 minutes). During heating and cooling, the samples remained under low pressure (the Dartek membrane could be easily lifted from the linings with the fingers).
9. Forest referenced two articles that described adequate bond strengths; a bond strength between 0.33 and 0.41 kN/m was considered reliable without being excessive, and 0.1 N/mm was a minimum, very weak lining adhesive bond (Phenix and Hedley 1993). A bond strength of 0.5 kN/m was considered strong; and 0.7 kN/m, too strong (Daly Hartin, Michalski, and Pacquet 1993).

20

A Short History of Suction Tables

Jim Coddington, Independent Scholar

The development and use of suction tables as an alternative to preexisting lining practices was introduced in the 1970s and 1980s. Vocal dissatisfaction with the aesthetic results of many linings had grown in the preceding years, resulting in numerous designs for suction tables that were more versatile and controllable for conservators undertaking structural treatments of paintings. The principal versions of these tables came to be known by the names of the conservators who designed them–Mehra, Hacke, and Willard. These tables, while similar in many ways, each had unique features that incorporated the designer's theory of lining and, more generally, structural treatments.

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INTRODUCTION

The history of the suction table is an interesting story of ideas sometimes driving technology and at other times technology driving ideas. However, it is reasonable to say that the technologies and designs of the tables that were developed in the 1970s and 1980s are remarkably similar, with the driving rationale of the designer being probably the most critical difference between any of the tables. Indeed, these suction tables are routinely referred to by the name of the principal or co-principal designer. The tables this paper focuses on are those designed by Mehra, Hacke, and Willard. Each emerged at the time of, or shortly after, the Greenwich lining conference, with the Willard table becoming the design most widely distributed over the years.

The stated goals and final designs of each provide useful insight into how the mechanics of paintings were understood at the time of design. They also provide some understanding of our aesthetic criteria for paintings then—and how much (or even little) each of these differs from our understanding and thinking today. Finally, these designs also illustrate how knowledge gained in the conservation studio—craft knowledge—is often later articulated in the scientific laboratory, affording greater refinement to those studio practices.

MEHRA'S DESIGN

Vishwa Mehra, who had been working at the Central Research Laboratory for Objects of Art and Science in Amsterdam, since 1966, began his public discussion of lining treatments at the 1972 ICOM meeting in Madrid. There, he examined the prevailing orthodoxy of lining and posited a set of new criteria for structural restoration. His observations and evaluation of the functional and aesthetic shortcomings of glue linings and wax-resin linings are familiar, and questions of reversibility, weave interference, stability of treatment materials, and visual alteration of fabric, ground, and paint were particularly critical ones.

He also suggested that leaving visible traces of a painting's age, such as some cupping and cracking, was viable, as opposed to trying to make them disappear as completely as possible (Ackroyd 2002, 4).[1] Mehra's critique led him to conclude that structural problems should be understood through more systematic analysis and more precise treatment—or a series of treatments—rather than through a single global treatment like overall consolidation or lining. The first need, then, was to determine with greater accuracy the actual strength of the materials in a painting composite, which would allow the conservator to tailor treatments to individual paintings.

Mehra's ideas had been in the air for some time.[2] A reading of the ICOM replies to the lining questionnaire distributed in 1972 and published in 1975 offers some revealing insights into concerns that practitioners had for both glue and wax-resin linings (Rees Jones, Cummings, and Hedley 1975). Wax-resin lining had been the subject of some considerable research and development in Britain, resulting in 1948 in the construction of what is deemed the first hot table. In 1955, this mechanization of lining (and consolidation, of which much will be made later) was furthered by the introduction of vacuum to the hot table (Hackney 2020, 84). By 1960, it was noted in an ICOM report that many paintings fared poorly under such treatments. With this background in mind, Mehra had, by 1972, set down what might be called his first principles, of which there are eight, summarized as follows (Mehra 1972):

1. Full reversibility
2. No alteration of the structural character of the painting
3. Select materials for the specific problems of the actual painting
4. Flexibility
5. Avoid or minimize heat
6. Minimal weight increase after lining
7. Nonpenetrating lining adhesive (note similarity to item 2)
8. Adhesives should be stable with RH and have variable strength and application properties

He then went on to specify that the materials used for structural restoration should be synthetic in order to fulfill stability and reversibility criteria. Putting all of this together was, in Mehra's thinking, a fundamentally new approach that was outside the glue and wax-lining traditions. The practical application of this theoretical position required the separation of consolidation from lining. In this way, it was possible to meet criteria of lightness and to select materials appropriate to the mechanical and aesthetic properties of the painting under treatment.

Considering the question of consolidation, Mehra established the following criteria for a successful consolidant (Mehra 1972):

- Light in weight but having good cohesion
- Solvent will not swell paint layer
- Internally plasticized
- Colorless and resistant to temperature and RH changes
- Compatible with the painting structure

The consolidants he chose were Plexisol and Bedacryl, which he then ultimately coupled with Plextol as a cold-lining adhesive. By using these consolidants, Mehra found he could achieve adequate consolidation results with less adhesive and could then use relatively lightweight fabrics when lining.

The use of these aqueous materials, as well as the need to minimize lining defects such as weave interference and moating (i.e., no alteration of the structural character of the painting), dictated the development of a suction table, and in 1975 Mehra published the design of a table to dry the painting under controllable low pressure. The function of the table is predicated upon high airflow capabilities and thus required a significant plenum, which is covered by a perforated sheet of metal. The airflow is controlled by varying the blower speed and by opening and closing the bleeder vents at one end of the table. The table thus has directional flow, the air being brought in one end of the table and out the other. On the surface of the perforated sheet is an open cell polyurethane sheet that can conform to the topography of the rear of the painting, although not too readily.

Ultimately, Mehra developed a three-stretcher system for use on the table when lining. The first stretcher, significantly larger than the painting, has the lining fabric attached to it. The reason for this oversize lining fabric is Mehra's estimation that the center of a stretched fabric has fewer asymmetric strains than the edges, so the extra lining fabric minimizes introduction of new stress patterns on the painting after lining. The second stretcher has a screen stretched onto it, with the sight size of the painting marked off. Through this screen, the adhesive is squeegeed onto the lining canvas, and then the screen is lifted, leaving on the lining fabric a measured dose of adhesive. The amount of adhesive can be varied by using different types of screens (fine to coarse). The painting, previously strip-lined onto the third stretcher, is carefully placed onto the adhesive, and the painting is then dried on the suction table. The presence of a membrane during drying would be optional. The strip-lining would later be removed if it had adhered on top of the tacking edge.

It should be noted that at certain points in the development of this system, Mehra was relying on the moisture in the adhesive to help relax the painting—as one coming from a background in glue lining might well do. Over time, he moved more toward pretreating these distortions and toward using less and less adhesive for lining. Mehra was nothing if not relentlessly logical in the development of each step of his process; thus, it is not inconceivable that another motive for his ultimately incorporating Saran beads into the lining adhesive was as a means of lowering the adhesive strength to the level of a nap bond.

The advent of technological advancements such as the Mehra table led others to develop other new procedures and to refine the lining adhesive strength problem. At the Courtauld Institute of Art, Gerry Hedley, Alan Phenix, and Vicky Leanse investigated the use of solvent activation of a variety of synthetic adhesives. Such approaches further refined the process, raising the possibility of further controlling lining adhesive strength via control of solvent dosage prior to lining (Phenix and Hedley 1984).

HACKE'S DESIGN

As mentioned earlier, Mehra regarded his approach to the lining and structural treatment of paintings as a fundamental departure from the tradition of glue and wax-resin linings. Similar technology was being developed at roughly the same time by Bent Hacke, who at the 1981 ICOM meeting noted that his goal was to "construct an instrument based on the tradition of our profession" (Hacke 1981a). More specifically, his was an effort to call attention to the practical and useful elements of glue-lining while still being aware of the potential problems. This is fundamental to the discussion of the next two tables—Hacke and Willard—because both were developed with an eye toward mechanizing or adapting the glue-lining tradition—quite explicitly so in the case of the Willard table.

Hacke published his first paper on "untraditional" lining, as he called it, in 1964. By the time of the 1978 ICOM meeting, many of his table's essential features were already in place (Hacke 1978). His system evolved to incorporate four principal features—heat, moisture, tension, and pressure—the manipulation of which Hacke once described as "like playing my piano."[3] By varying these factors during treatment, he was also able to arrive at the goal of tailoring the treatment procedure to the painting's needs. Like Mehra, Hacke found that as he focused on pretreatment he could use less adhesive for lining. It should be noted, however, that although Hacke preferred synthetics for their durability, he did not wholly reject natural fabrics and adhesives as Mehra did. Similarly, the use of heat was not eschewed but rather incorporated to facilitate plasticization of the paint film. Ethylene glycol mixed with water was occasionally used for the same purpose.

The structure of Hacke's table is a plenum with an eggcrate structure inside through which heating elements pass. Air is removed from the plenum to create low pressure beneath the painting, and this air is moved via heaters along the edge of the table. On top of the eggcrate structure is an aluminum sheet with fairly large holes. Atop this is placed a moist blanket for the humidifying part of the treatment, and then onto that is placed a fine-holed screen that will hold the loomed painting. Ultimately, the wet blanket is replaced by a humidifier that introduces humid air beneath the painting via the plenum during the pretreatment stage. As with the Mehra process, before lining—or even as a substitute for lining—pretreatment of distortion, cupping, and flaking is done, all facilitated by the suction table to humidify and/or pull consolidant into the paint film.

When overall consolidation was necessary, a consolidant like Plexisol was used. For lining, Plextol was used, principally for its low-temperature heat activation. The strength of the lining adhesive could be varied by the number of coats of adhesive applied: typically, one or two coats, which were allowed to dry overnight. In contrast to Mehra's system, Hacke's is not purely a cold-lining method.

WILLARD'S DESIGN

Similar to Bent Hacke, Anthony Reeve saw a need to standardize or mechanize the process of glue lining, and from this the Willard table was developed (Reeve 1984). This table is one rather more explicitly designed to execute—and, more importantly, control—glue linings. As glue linings rely greatly on the skill of the liner and the liner's experience, many of the features of the Willard table integrate controls that rely on such knowledge to bring the table to full operation. The heating is not too different from the Hacke table, although the flow is considerably more complicated. The idea of humidifying from the rear is the same and is also mechanized, as Hacke's table ultimately was. Hacke rather dryly noted that "it proves to be very complicated to work out a system which makes it possible to blow in moist air which can be accumulated in the structure of the painting."[4] The mechanization of humidification through the ducting of a suction table is indeed a technically difficult proposition, and therefore an abundance of controls are built into the Willard table. The potential for damage by too much moisture is well known to glue liners and thus the system incorporates a dehumidifier as well. Early versions of the Willard table were tested quite rigorously at the National Gallery, London, and at Tate, with extensive modification of the initial design to accommodate a number of difficulties encountered, such as condensation in the ducting and on the surface of the table (Reeve, Ackroyd, and Stephenson-Wright 1988).

One of the critical features of this design is the two independent flow patterns. One set of channels introduces the conditioned air to the backside of the painting or, theoretically, up into a closed chamber; the other flow system holds the painting flat on the table. As with the Hacke table, there are removable aluminum sheets. This table has since been produced commercially and is widely distributed.

OTHER TABLES

It is significant that without a glue-lining tradition to rely on, but with rather more experience using synthetic adhesives for lining and consolidation, the United States lagged behind in the development of suction tables devoted to both mechanizing plasticization of the paint film and lining paintings. Ultimately, research developments informed these efforts more than did an adaptation of long-standing traditions. It is difficult to overstate how critical Marion Mecklenburg's research on the mechanical properties of the materials in a painting were to these and many other advances in structural treatments both in the United States and Europe.[5] It is then not surprising to see how similar key elements of suction table design were and whether they emerged from older traditions or from laboratory research—illustrating once again how basic research converges on established practice.

One of the first U.S. suction tables for paintings was the Versi-Vac tabletop device, developed by Albert Albano and Bill Maxwell (Albano 1984). Fundamental to the design of this was the idea to use the existing base of hot tables as a heat source, but to use suction instead of vacuum as a pressure source. In addition, an inflatable dome would be used to control the environment around the painting, thereby putting into practice Mecklenburg's work on optimal humidification levels to plasticize paint films (Colville, Kilpatrick, and Mecklenburg 1982). The principal drawback to this table design is that as a tabletop device, the plenum is shallow—basically the depth of the two wire screens attached to the frame, thus limiting the rate of flow beneath the painting and making the system incapable of some treatments.

The question of efficient airflow in suction tables was an area of investigation that has been most fully addressed by Stefan Michalski in a number of papers that are both theoretically and practically focused (see, e.g., Michalski 1984). Of particular note are the textile suction tables he demonstrated during the early 1980s and several papers on the theory of how suction tables work. Michalski drew out the critical points of the power of capillarity in moving moisture in and out of paper (or more generically cellulosics), the relationship of airflow and pressure curves in suction pump specification, the concept of creating low pressure beneath an object to thereby create downward pressure on it from above, and the use of alternate flow channels to minimize drying fronts when drying textiles.

This latter point makes an important distinction between such a flow design and that of Mehra's table design, which had a unidirectional laminar flow. By making the airflow a series of short paths across the entire surface, as Michalski did, the drying capability of the table is enhanced; each of the many short air paths avoids becoming saturated. Notably, this kind of flow pattern is also incorporated into the Willard table discussed above. If in addition a screen is present on top of the channels, the air will be made more turbulent, and this will further enhance drying efficiency. Such a flow pattern also allows drying of a painting or textile from underneath, thus allowing membranes to be used during drying and letting the practitioner maintain a desired level of planarity for the object throughout the drying process.

Of course, unless something is wet, one doesn't need to concern oneself with how to get it dry (on a suction table or otherwise). Mecklenburg's fundamental work on the influence of moisture on the strength and stiffness of canvas, sizing, and paint is basic to understanding—and subsequently mechanizing—the humidification process (Mecklenburg 1982)—basic because it begins to quantify the plasticization of paint and identifies mechanisms by which moisture can be dangerous and is thus richly suggestive of how to design effective structural treatments with or without lining. Specifically, Mecklenburg's research demonstrated that at high RH, damage occurs because the canvas shrinks, and at the same time the glue size and paint have become so low in stiffness that they cannot resist the movement of the canvas. He also demonstrated that pigments have a profound effect on the uptake of moisture by a paint film, and that at low RH the glue-size layer is capable of generating stresses in the paint film that could lead to failure (cracking). The implications for the treatment of paintings—and for controlling that treatment—are enormous.

Humidifying paintings to aid in the plasticization of the paint film, whether using damp blankets or blotters or via the water in a glue-paste adhesive, was of course a well-established practice prior to the basic research cited above. Both practice and tradition made clear the need to control the amount of moisture introduced into the composite structure of a painting. A mechanized system of humidification would thus seek to maintain a level of RH that will give the conservator confidence that plastic changes are occurring only in desired layers of the painting—the size and paint film—while not exceeding dangerous levels of moisture in the canvas.

All of this theoretical background was fundamental to the design of the final table I will discuss, one of which was built for New York's Museum of Modern Art (MoMA) by Bill Maxwell. The table design was initiated by Albert Albano and sought to address the specific needs of MoMA, specifically that the table should be fungible: effective for both paper and paintings conservation. Indeed, as Caroline Villers notes in reviewing the state of affairs at the time of the Greenwich lining conference, "The practical problems posed by contemporary paintings were an important driver for change" (Villers 2003a). The nature of MoMA's collection—which includes many large works, composite works, and essentially raw canvas works—dictated that the table would be large, with a high airflow for the "textile" problems but sufficiently flexible to treat local distortions or flaking or even to do straight hot table linings for "traditional" paintings. To achieve all this, the experience and ideas of a number of people, including Stefan Michalski and Gerry Hedley, were consulted on the design.

The base of the 8 × 12 foot (2.4 × 3.7 m) working surface is basically an aluminum-top hot table with heaters attached underneath and double heaters at the sides to minimize any edge heating gradient. On top of this are 1-inch-square aluminum channels that run the length of the table and have holes drilled in the top at regular intervals. These are alternate intake and exhaust channels with an intake header at one end and exhaust at the other, where four 100 CFM fans run in parallel. On top of the channels is an aluminum heat exchanger, which is effective at distributing the airflow from the channels to the top surface (a perforated aluminum sheet) while also aiding in transfer of heat to the table surface. Pressure and flow are controlled by leakage, a rheostat that varies the voltage to the pumps, an intake valve at the intake header end of the table. By opening an additional valve, this intake air can also be passed through an auxiliary heater, and this provides an effective means of minimizing loss of the heat conducted up through the layers to the airflow layers.

The flow pattern is thus a sweeping of air up from underneath (if the intake valve is open) and the pulling of air down from above. It is this movement of air from underneath that allows for drying under a membrane; it also increases the efficiency of heat transfer from the heating plate. Pressure, of course, will depend on how much air is introduced via the intake valve, as well as the porosity of the support, whether it is canvas or paper, the density of the paint film, or other variables.

Humidification is done inside a chamber that attaches to the table proper, with a steam humidifier as the moisture source. The humidity is introduced through the tent support poles, which are inserted into ducting that runs around the edges of the table and is fed by the steam humidifier. Clearly, the use of a moist felt or blotter beneath the object is also feasible. The rationale for this method of humidification from above is dictated by Mecklenburg's research, which demonstrates that (1) the canvas is the point at which significant damage can occur (due to canvas shrinkage) if too much moisture is present, and (2) that the paint film and/or glue size are the sources of stresses that lead to cracking, flaking of the paint, and general distortions. Thus, it was deemed in this table design that it was unnecessarily hazardous to introduce moisture through the canvas if the primary goal was to use the moisture to plasticize the paint film. To humidify a painting, a tent is built on the table using predrilled holes at the corners for inserting the supports. Humidity is measured by a dew-point sensor located in the tent, which then maintains an RH set point by switching the steam humidifier on and off. The tent has openings on all four sides, which are tabbed with Velcro to facilitate working on the painting during humidification.

CONCLUSION

This paper has outlined the basic features of the early generation of suction tables for the treatment of paintings, along with a discussion of the context of each design. This history reveals the similarities of the designs yet also pinpoints the differences between them in how they articulate the role of tradition within innovation. Additionally, it provides a broader perspective on how knowledge is gained in conservation through the development of studio practices and its associated craft. These findings, while empirically derived, reveal a highly sophisticated understanding of materials that is later articulated through scientific research.

NOTES

1. According to Ackroyd, Mehra "maintained that the preservation of the painting's appearance and the positive aspects of its age (e.g., cupped or raised cracks) were more important than the choice of lining materials" (Ackroyd 2002, 4).
2. Indeed, other papers presented at Greenwich, such as that of Chittenden, Lewis, and Percival-Prescott on low-pressure lining (Chittenden, Lewis, and Percival-Prescott 2003), trace similar analyses and practical approaches as those outlined here summarizing Mehra's thinking.
3. Bent Hacke, interview by the author, 1983.
4. Bent Hacke, interview by the author, 1983.
5. For instance, Mehra's insistence on understanding the strength of the materials of a painting is more fully quantified by Mecklenburg's research.

21

Mehra's Eight Requirements for Linings, Revisited: Evaluation of Linings for Canvas Paintings—Then and Now

Cecil Krarup Andersen, Associate Professor, Head of Paintings Conservation, The Royal Danish Academy of Fine Arts, School of Conservation, Copenhagen

In this paper, Vishwa Mehra's eight requirements for linings—as written in a report from 1972—are reviewed in a contemporary context nearly fifty years later. Special emphasis is placed on concepts like flexibility, compatibility, and physical integrity, which are still part of conservation discussions. Some of the concepts discussed by Mehra did not have a clear definition, or his understanding of them either was not given or differed from a more contemporary understanding. This means that his concepts can be used for many different purposes and to justify many different actions. Requirements in conservation were perhaps necessary at a time when the profession was undergoing significant change, but now requirements are generally replaced with recommendations, guidelines, or analysis of the risks involved in a considered action. A way of looking at risk analyses for structural paintings conservation is proposed as a way forward for assessing these treatments.

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INTRODUCTION

The aim of this paper is to revisit and evaluate some early requirements for linings of canvas paintings proposed by Vishwa Mehra (Mehra 1972) and review them in a contemporary context. The requirements have been very influential within the field of conservation. They were used as guidelines for working conservators and teachers in structural conservation (see Mikkel Scharff's paper in this publication), and the recommendations have been referenced in normative discussions about conservation praxis. Mehra's ideas inspired a whole generation of conservators and influenced best practice considerations in structural conservation of canvas paintings for decades (Beltinger 1995; Hackney et al. 2012; Phenix 1995; van Och and Hoppenbrouwers 2003).

Vishwa Mehra is an Indian conservator of paintings and an art historian born in 1931. He studied conservation in India, Yugoslavia, and Rome and worked in Israel before he acquired a position at the Central Research Laboratory for Objects of Art and Science, in Amsterdam.[1]

Through the 1960s there was an increased effort to strengthen and professionalize the field of conservation of cultural heritage. The first ethical guidelines for conservators, the Murray Pease report, were written for IIC-American group (later the American Institute for Conservation [AIC]) in 1963 (Pease 1964), and in 1964 the Venice charter expanded on these thoughts (charter and introduction can be found in Jokilehto 1998). The founding of ICOMOS (International Council on Monuments and

Sites) in 1965 and of ICOM-CC in 1967 and the adoption of the 1972 UNESCO World Heritage Convention are also key events in the effort to protect cultural heritage, in light of which Mehra's paper should be seen.

One event that also had enormous influence on this development was the catastrophic flooding of Florence on November 4, 1966. It became a milestone in the history of conservation for many reasons, one of them being that the need for education and conservation norms became evident as a result (Federspiel 2015). At the second plenary ICOM-CC meeting in Amsterdam, the Italian conservator Giovanni Urbani called for a more systematic and rational approach to lining canvas paintings (Urbani 1969). In 1972, Mehra presented his eight requirements for linings in an interim report for the ICOM-CC meeting in Madrid on behalf of the Central Research Laboratory, "Comparative Study of Conventional Relining Methods and Materials and Research towards Their Improvement" (Mehra 1972). In this report, Mehra discussed concepts that to this day remain essential to conservation. Some concepts were relevant for the general field of conservation-restoration, such as structural integrity of objects, reversibility, and compatibility of treatments. Other concepts in Mehra's paper, including flexibility/stiffness, hygroscopicity, and permittivity, were especially important for lining paintings.

Mehra argued that traditional lining techniques using glue paste and wax resin were too invasive and nonreversible, as they caused the whole painting structure to become embedded in adhesive. Furthermore, he warned against the use of heat in linings, the forces exerted by retensioning a painting, and the extra weight of a wax-resin lining.

THE EIGHT REQUIREMENTS AND THE INTENTIONS BEHIND THEM

In his paper, Mehra proposed eight basic requirements for linings. Table 21.1 lists the requirements as they were formulated in the report fifty years ago. The questions that drive this paper are whether they are still useful and what they can tell us about our present attitude toward structural treatment of canvas paintings.

This paper was presented at the 2019 Conserving Canvas symposium held at the Institute for the Preservation of Cultural Heritage at Yale University.[2] The symposium title, Conserving Canvas, echoes the core of the discussions around Mehra's paper. Mehra, in the Netherlands, and Bent Hacke (Hacke 1963–64), in Denmark, became advocates for treatment strategies that were designed to treat one problem at a time rather than the complete range of problems in a painting at once. Problems related to the canvas were now seen as a separate part of the canvas painting, and the treatments proposed (*nap bond* in the Netherlands and *lamination* in Denmark) were designed to deal with this layer. The ideas behind this concept of separation were presented in Mehra's paper (Mehra 1972), where he warned against the long-held tradition of linings impregnating the structure. In this paper, the specific requirements written by Mehra are discussed in a contemporary context.

Reversibility

The first requirement is that the materials used should remain fully reversible (see table 21.1). According to Appelbaum, the "principle of reversibility" was written into the AIC Code of Ethics and it was advised that the conservator "should avoid the use of materials which may become so intractable that their future removal could endanger the physical safety of the object. He also should avoid the use of techniques the results of which cannot be un-done if that should become desirable" (Appelbaum 1987). However, fully reversible treatments are rarely possible, and the concept has been subject to much discussion. Muñoz Viñas has argued that the greater the reversibility, the less the conservator's responsibility (Muñoz Viñas 2005). Concepts such as removability and retreatability (Appelbaum 1987; Charteris 1999) have been suggested as alternatives, but these still require an understanding of issues including surface tension, penetration, solubility with age, and peel strength—all topics that are still not properly investigated with respect to lining techniques. Despite the debates around the concept, reversibility is still written into the E.C.C.O. Professional Guidelines, in article IX of the Code of Ethics (E.C.C.O. 2003).

Changing the Structure

The second requirement is that lining, or relining as Mehra called it (Andersen 2012), may not in any way cause alterations to the structural character of a painting. Although it is not completely clear what he means by "the structural character," it is known that he wanted to avoid heat and high pressure, which may change the shape of the paint. He therefore described the nap-bond treatment that targeted the needs of the canvas specifically.

The reality, now and then, is probably that most active treatments change the structure slightly, but some changes are more invasive than others, and some create

Table 21.1
Mehra's eight requirements for lining canvas paintings

1.	Whatever the nature of the materials used, they should remain fully reversible with regard to additional relining eventually needed in the future
2.	Relining* may not in anyway cause alterations in the structural character of a painting
3.	The materials used should have passed the selection in direct reference to the specific problems of the painting involved
4.	Flexibility must be guaranteed for an unlimited period of time
5.	The use of heat should be avoided altogether or must be considerably minimized
6.	Increase of weight as a result of relining should be minimal
7.	The adhesive selected should not be allowed to permeate the canvas, ground and paintfilm alike. Instead, it should form only a film between old and new canvases
8.	It must be optional to use the selected adhesive in different degrees of cohesive strength and it is imperative that it will have proper resistance to fluctuations in temperature and humidity. It should be compatible with the other materials used for the relining which it serves

Source: Mehra 1972 (verbatim).
**Relining* means lining; see Andersen 2012.
Table: Cecil Krarup Andersen

more potential for future damage than others. The traditional adhesives for lining, glue paste and wax resin, were intended to penetrate the painting structure, but Mehra's new thoughts were to avoid the penetration.

The seventh requirement—that the adhesive selected should not be allowed to permeate the canvas, ground, and paint film—is closely related to Mehra's second requirement. Mehra wanted the adhesive to form only a film between old and new canvases, instead of penetrating the structure. This idea has prevailed in many traditions, and the nap-bond lining (or, in Scandinavia, lamination, inspired by Bent Hacke) became popular among progressive conservators of the time. The nap-bond technique was considered minimal intervention and was intended to ensure reversibility. Saving the physical integrity of an object is written into E.C.C.O.'s Professional Guidelines, in article V of the Code of Ethics (E.C.C.O. 2003) as well as AIC's Code of Ethics, article 21 of the Guidelines for Practice (AIC n.d.). Thus, the requirement could probably still be seen as having significant weight, even though both glue paste and wax-resin lining are still practiced, as is impregnation of canvas paintings with glue and Beva.

This is much in line with the sixth requirement that increase of weight due to lining should be minimal. This, of course, was in comparison to a wax-resin lining, which was very heavy. A large format could be deformed simply by the weight of a heavy lining material if it was not supported. Lightweight treatments are still preferable, including stretchers and backing boards—especially for large formats—in light of increased loan activity between museums. In these situations, extra weight makes the painting more difficult to handle and increases the risk of high forces due to impact if the painting is dropped during transportation. Furthermore, a heavy structure can increase the risk of failure in the hanging system.

The Flexibility Requirement

The fourth requirement (see table 21.1) is that flexibility must be guaranteed for an unlimited period of time. It is not specified if Mehra means in the complete lining structure or in the canvas, the adhesive, or a possible interleaf. An argument for a flexible lining adhesive was mentioned as early as 1931, when the Canadian painter and sculptor Percyval Tudor-Hart advised that a lining adhesive should provide unlimited flexibility and recommended the "Dutch" adhesive (Tudor-Hart 1931), and that same year two American conservators remarked that a wax-lining is "the best that is yet found for relining . . . It is flexible, never becoming brittle" (Durham and Leser 1931, 38). The unlimited flexibility mentioned by Mehra should be seen in light of these sources and the long historical experience with brittle glue-paste linings. However, flexibility in lining adhesive and flexibility in lining as a whole are two very different concepts. In his requirements, Mehra mentioned the lining as a whole and not just the adhesive. In 1981, he contradicted this requirement in a paper on lining canvases, where he wrote that lining canvases should be as stiff as possible (Mehra 1981b).

A year later, Mecklenburg summed up his approach to providing stability in a painting: “to support a painting, the material chosen must: 1) be capable of developing and maintaining a large percentage of the total force of a stretched painting; 2) be able to restrain in-plane displacement as developed by desiccated glue and paint films; 3) restrain out-of-plane distortion such as cupping and buckling” (Mecklenburg 1982, 27). He furthermore advised that a high modulus[3] of the lining material was preferable and that thickness would provide support against out-of-plane distortions.

Thus, research has shown that stiff linings can reduce the risk of further cracks and cupping in a painting (Mecklenburg 1982; Hedley 1988; Andersen 2013), which contradicts Mehra’s 1972 report. However, it is worth remarking that Mehra had been measuring the bending stiffness of the linings he tested, as opposed to the later studies, which measured stiffness in tension. For paintings, this means the difference between in-plane and out-of-plane forces.

With this development in mind, it is interesting to observe how Mehra’s early thoughts on flexibility have inspired conservators to require flexible linings (Heiber 1987; van Och and Hoppenbrouwers 2003). Thus, the properties of lining canvases remained a cause for disagreement within the conservation profession for many years after Mehra’s report, despite the fact that he was the first to change his statement.

Degradation Agents—What Is Worse?

The fifth requirement (see table 21.1) was that the use of heat should be avoided altogether, or at least must be considerably minimized. Heat could deform the painting and increase the chemical degradation rate. While this is true, high moisture/water, pressure, and solvents can also have a lasting negative effect on paint layers, and all are used in paintings conservation. The question of what is causing more degradation remains unanswered and relies heavily on the materials and properties of each individual painting. Solvents can cause swelling and leaching in paint and ground layers (Phenix 2002), and the development of metal soaps can be accelerated by moisture (Garrappa et al. 2020). However, all of this is a question of the extent and duration of exposure to these factors. The discussion of what is worse for a paint layer—exposure to fluctuating climate or exposure to water or solvents while cleaning, lining, or other conservation treatments—is still unresolved. New research is, however, starting to tackle these questions with, for example, nanoindentation, which allows for the study of the mechanical properties of paint surfaces (Andersen et al. 2019).

Choice of Materials for Specific Purposes

Mehra’s requirements for linings were widely seen as an argument for nap-bond linings only, but the third and the eighth requirements are actually pointing to the need to adapt each treatment to the specific problem at hand. Thus, the last requirement is that it must be optional to use a selected adhesive, in different degrees of cohesive strength, and that it is imperative that it has the proper resistance to fluctuations in temperature and humidity.

Mehra advised that the materials used in conservation should have passed selection in direct reference to the specific problems of the painting involved. While this is a nice principle, more specific failure/success criteria are needed in order to make such decisions. Very little advice is provided for choosing the amount of strength, stiffness, moisture, solvent, pressure, and so forth needed; thus, the choice of materials and methods largely remains a matter of practical experience and tacit knowledge.

Consider the case of a very torn canvas painting with frayed tacking edges. Different conservation traditions would imply different solutions to this problem. Everything from tear mending to glue-paste, wax-resin, and synthetic adhesive linings would be used and justified as the right treatment for this specific problem, depending on the tradition in which the conservator was trained. This is a testament to the reality that conservation is still a craft when it comes to structural treatments and that very little science-based consensus is found.

Compatibility

In the eighth and last requirement, Mehra wrote that the lining adhesive should “be compatible with the other materials used for the relining which it serves.” The meaning of “compatible” is not clear, and Mehra does not define it. It remains an open question whether poor compatibility means that the material does not bond well, that it is historically or ethically wrong, or perhaps that it has different properties from the original materials. It is also not clear how compatibility may be judged in a scientific manner. And yet the word is frequently used.

In E.C.C.O.'s Code of Ethics article IX, compatibility is included as a requirement, but it remains undefined. The European Committee for Standardization (CEN) standard defining the most important general terms used in conservation of cultural heritage, EN 15898:2011, defined *compatibility* as the "extent to which one material can be used with another material without putting significance or stability at risk" (CEN 2011, 10). Acknowledging that this was still a rather vague definition, Revez proposed the following definition: "Compatibility corresponds to the extent to which a product, method or action may be used upon a heritage object without putting its present or future significance at risk" (Revez 2016). In the updated version of the CEN standard from 2019 (EN 15898:2019), the definition was clarified further: "extent to which one material can be used with another material without compromising *significance* or *stability* of the object. Note 1 to entry: this relates to conservation materials or to components of the *object*" (CEN 2019, 25).

Useful compatibility indicators have been proposed for stone conservation and the conservation of archaeological sites by Rodrigues and Grossi (Rodrigues and Grossi 2007), but due to the difference in materials, these are not easily translated to paintings conservation. One indicator that might be useful, however, is physical content, which represents "intrinsic properties responsible for the performance of the intervention action, considered in its material side" (Rodrigues and Grossi 2007). The other indicators are the operational background, the sociocultural context, and the environmental constraints. Assuming that compatibility is a multifaceted concept that can be broken down into a number of simpler categories, Rodrigues and Grossi propose a rating system (from 1 to 10) for each action taken, which would then be translated to an incompatibility degree for a proposed treatment of stone and buildings. The question remains whether this concept works for structural paintings conservation.

It seems that in the context of Mehra's paper, the physical indicator was probably what was more on his mind. If for the sake of simplicity one stays with this concept, it may be possible to propose compatibility indicators for mechanical and structural properties of conservation materials. Problems with the concept of compatibility in the context of canvas paintings include that the materials of canvas paintings (canvas, glue, ground, paint, etc.) have very different properties, and research suggests that lining material should not have the same mechanical and structural properties as the original canvas, as described above. Stiffer and less hygroscopic materials have been found to provide better supports, so perhaps compatibility of structure should be considered in relation to the paint and ground layers. Another, and possibly more comprehensive, approach to assessing treatment options is risk assessment, which is considered in the next section.

EVALUATION OF RISK FOR LININGS

In structural conservation of canvas paintings, very little research progress has been made in the last decades, especially when it comes to predicting the risks of structural conservation treatments. Instead, the tendency has been to avoid treatments. However, one tool that can help us move toward rational risk assessment is computational finite element modeling to predict stresses and the resultant strain and failure in the painting structure with fluctuating ambient climate conditions. A comprehensive computational model and subsequent parametric studies are missing for lined paintings, as is validation of the results through epidemiological paintings collection studies.[4] Computer-generated prediction requires not only detailed model design but also reliable experimental data on material properties that can help answer specific questions about structure and mechanical properties. The potential is promising and can point the way to more solid guides for conservators, but until such a tool exists—with validated results—the best option we have is to rely on risk assessment for guidance.

In cleaning literature, the concept of star diagrams for evaluating specific parameters was developed and used repeatedly (Daudin-Schotte et al. 2013; Chung et al. 2017; Ormsby et al. 2019; Bartoletti et al. 2020). This approach could be useful for other conservation treatments as well, and would follow the trend of preventive conservation that moves away from requirements and recommendations or guidelines and toward risk assessments.

Linings and related structural treatments are still performed widely, and the different alternatives should be evaluated when choosing a treatment option or considering paintings that have already been lined. A star diagram shows risk factors situated around the center (fig. 21.1). A value from 1 through 5 is given for each risk factor, with 1 as low risk and 5 as high risk. This is different from the approaches proposed in the articles referenced above in that it is intuitive that the higher the rating number, the higher the risk, and vice versa. Thus, a smaller shape means lower risk, as shown in figure 21.1. Of course, the scale is a matter of interpretation and must be discussed for each factor.

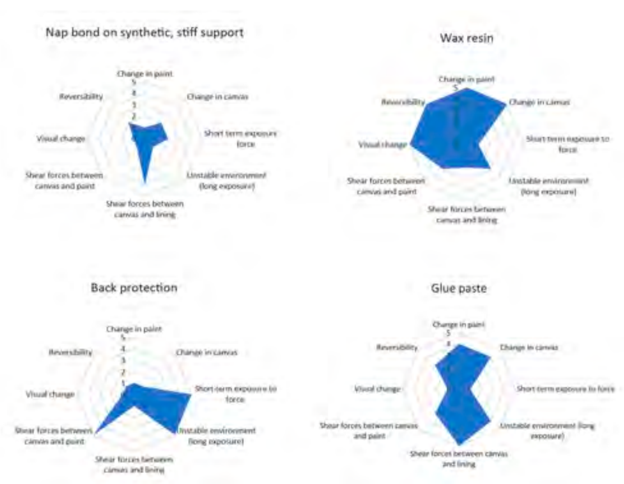

Figure 21.1 An example of star diagrams of risks for linings of an example painting. The smaller the area covered, the lower the risk for each treatment considered. Incidentally, in this case Mehra's nap-bond lining was considered the option with the lowest risk and the wax-resin lining the highest risk, but this could change with a different painting in a different context. (Diagrams drawn using a radar plot in Microsoft Excel.) Image: Cecil Krarup Andersen

The first step is to identify the risks. Using Mehra's guidance and some updated information, the list in table 21.2 could be proposed as examples of eight factors that may imply an increased risk of change in a lined canvas painting. The chosen parameters are inspired by current discussions in the field, such as stresses, color change, change in properties, and so forth.

In the example of star diagrams for a lining in figure 21.1, the risk for each parameter for a particular painting has been assessed. The nature of specific paintings and treatments will change the nature of the risk, of course. Risk factors can be added or subtracted as appropriate, and different options can then be compared. Other risks, such as weight change, out-of-plane forces, infestation, and mold growth can also be assessed as needed. In some cases, the values for various parameters can be measured in a lab, and the outcome can then be adapted to the same scale, as seen in Fuster-López et al. in this publication.

CONCLUSION

Fifty years after Mehra formulated his requirements, the concepts he discusses largely remain relevant, even though the context and the understanding of some of them have changed. The eight requirements became very influential, but they must be seen in the context of the lining techniques in use at that time, when wax-resin and glue-paste linings dominated. However, the imposition of requirements for conservation treatment is not a contemporary way of approaching conservation—partly because each painting is different, as Mehra acknowledges, and partly because best practice requirements call for a common understanding of the concepts they codify.

Many of the concepts used in conservation are elastic. They can be interpreted in various ways and have multiple meanings, and this can prompt endless discussions. The specific interpretation in each case can be attributed to differences in culture, social parameters, stakeholders, technical knowledge, and practical indicators. This means they can be bent and understood differently depending on the context. In case of misinterpretations of the concepts used, requirements may be worthless or even misleading. Tacit knowledge is deeply embedded in local conservation traditions, which, of course, complicates the matter further.

Until a comprehensive prediction tool is created, assessment of risks remains the best option. An update of Mehra's approach was proposed in this paper, in which risks are assessed from certain criteria for each case individually by the conservator who needs to decide between different options.

NOTES

1. https://www.mehra.nl/vishwa-raj-mehra/.
2. Funded by the Getty Foundation.
3. E-modulus is derived from a stress/strain test representing change of stress divided by the change in strain in the elastic (Hookean) region. High modulus can be understood as high stiffness.
4. Since this paper was written, we have proposed a computer model for untreated paintings; see Lee et al. 2022.

Table 21.2

Eight lining risk factors and example ratings

Change in paint properties or structure—due to solvent exposure (including water) or temperature change

1. No risk or very low risk.
2. Small risk of subtle change.
3. Medium risk of flattening or stiffening the paint due to the use of solvents or temperature.
4. High risk of visible flattening areas with impasto and changing paint properties permanently.
5. Very high risk of flat impasto or paint loss and permanent change of properties.

Change in canvas properties or structure—due to impregnation of adhesive or moisture/water exposure

1. No change or slight effect of adhesives bonding to surface.
2. Slight change due to adhesives penetrating the surface.
3. Decrease in strength or changed response to RH due to impregnation.
4. Significant brittleness or weakness and/or change in response to RH due to the effect of the adhesive, or risk of shrinkage.
5. Serious chemical and/or physical weakening and deformation of canvas due to impregnation with adhesive, or high risk of shrinkage.

Unstable environment (long exposure)—creep due to lack of support

1. No change with change in RH or temperature.
2. Risk of increased cracks over 50 years.
3. Risk of increased cracks and cupping over 10 years.
4. Risk of bulging, cupping, and delamination over 5 years.
5. Risk of delamination after 1 year of climate exposure.

Short exposure to forces—lack of support with fast climate events, keying out or restretching

1. Support is as stiff as the paint layer—fully supported.
2. Support is stiff, but not as stiff as the stiffer paint layers.
3. Lining provides some support, but not enough to prevent damage with significant use of force (e.g., keying out in corners).
4. Lining provides very little support, and there is risk of cracks and cupping.
5. Treatment provides no support, so any slight or significant increase in forces will affect the paint layer directly.

Shear forces between canvas and lining—due to stiffness in lining and shrinkage forces in canvas

1. No forces.
2. Slight forces with changes in RH.
3. Some shear forces with change in RH in case of canvas contraction.
4. Local delamination of lining with change in RH if canvas contracts and the binder is not strong.
5. High forces with delamination of lining if canvas contracts and the binder is not strong.

Shear forces between canvas and paint—due to free movement of the canvas and stiffness in paint

1. No forces.
2. Slight forces with changes in RH.
3. Some forces and risk of long-term development of cracks in paint layer due to compression or tension.
4. High forces and risk of cupping and delamination.
5. Very high forces and risk of tenting and delamination of paint in high RH situations.

Visual change—due to impregnation and subsequent change of refraction index

1. No change.
2. ΔE = below 1: Change cannot be seen with naked eye.
3. ΔE = 1: Change is just noticeable.
4. ΔE = more than 1: Change is obvious, but the artwork can still be enjoyed.
5. Significant change and seriously compromised appreciation of the artwork.

Reversibility—due to materials used or construction of structural treatment

1. Easy to remove both canvas and adhesive (if present).

2. Can be removed with little effort.
3. Canvas is easy to remove while adhesive is more difficult, but low risk for original materials if care is taken.
4. Canvas and adhesive can be removed only with some risk of damaging original materials.
5. Canvas and adhesive cannot be removed without causing significant damage to the original painting.

IV

Case Studies

22

Self-Portrait as Saint Catherine of Alexandria by Artemisia Gentileschi: A Recent Glue-Paste Relining Treatment at the National Gallery, London

Lynne Harrison, Conservator, National Gallery, London

An important recent acquisition to the collection of the National Gallery, London, is the oil-on-canvas painting Self-Portrait as Saint Catherine of Alexandria *(ca. 1615–17) by Artemisia Gentileschi (1593–1654), one of only a handful of works by female painters in the collection and the first painting by this artist to be represented at the gallery. Upon its acquisition in 2018, the painting underwent full conservation treatment in the gallery's conservation studios and was presented to the public later that year. The treatment was filmed for the gallery's website and made available on YouTube as part of the museum's public engagement program. The National Gallery has long undertaken structural treatments of its paintings collection, and traditional aqueous glue-paste hand-lining (among other techniques) remains part of its arsenal of lining methods. Research undertaken at the gallery in the late 1990s led to adaptations in the recipe and lining methodology, and glue-paste hand-lining continues to be used when considered appropriate for a painting's requirements. This paper presents the structural treatment of Gentileschi's* Self-Portrait *to remove the existing aged and failing glue-paste lining, repair the torn damage to the original canvas support, reinforce the original canvas join, and reline with glue-paste adhesive. Also addressed is the issue surrounding the painting's original format, thought to have been reduced in size at some point, and resolved to some extent in collaboration with the curatorial department. The preparatory steps for lining, including tear repair and moisture-flattening treatment, and the various stages of the hand-relining process are described in detail. Techniques unique to the National Gallery's glue-paste hand-lining processes are discussed, such as the use of wax-resin facings and beeswax moisture barriers, and details of the materials and equipment employed (e.g., the low-pressure vacuum table) are included.*

◆ ◆ ◆

INTRODUCTION

In July 2018, the National Gallery, London, acquired a self-portrait by the Italian Baroque artist Artemisia Gentileschi, one of only a handful of works by female painters in the collection and the first painting by this artist to be represented at the gallery. The painting, *Self-Portrait as Saint Catherine of Alexandria* (ca. 1615–17), depicts the artist herself as Saint Catherine of Alexandria, the Christian saint martyred in the early fourth century (fig. 22.1). Her right hand holds the martyr's palm close to her chest, while she rests her left hand on a broken wheel with iron spikes, the instrument of Catherine's torture and the saint's standard attribute. The painting dates from Gentileschi's period of activity in Florence, where she lived and worked from 1613 to 1620, establishing herself as an independent artist and becoming the first woman to gain membership to the

Figure 22.1 Artemisia Gentileschi (Italian, 1593–1654), *Self-Portrait as Saint Catherine of Alexandria*, ca. 1615–17. Oil on canvas, 71.5 × 71 cm (28 1/8 × 28 in.). The National Gallery, London, NG6672. Before treatment. Image: The National Gallery, London

Accademia della Arti del Disegno, in 1616 (Bissell 1968, 154; Bissell 1999, 141; Whitlum-Cooper et al. 2019).

Upon acquisition, the canvas painting was treated in the National Gallery conservation department, where the decision was made to reline the painting and to clean and restore the image. The entire treatment was filmed for the National Gallery's website and made available on YouTube as part of the gallery's public engagement program.[1] Conservation was led by Larry Keith (chief restorer and keeper), and the structural treatment was undertaken by Paul Ackroyd (senior restorer) and the author.[2]

The painting was originally executed on a medium-weight, plain-weave canvas, with a horizontal seam approximately 7 cm up from the bottom edge. The seam is uneven and rather wavy in appearance (fig. 22.2) and is likely to have been sewn by the artist: it is known that at this time Gentileschi was poor—"she was beleaguered with financial problems," and probably therefore was preparing and reusing her own canvases for painting (Barker 2017, 59; Keith et al. 2019, 8n23, 16n24).

Figure 22.2 Gentileschi, *Self-Portrait*, before treatment. Detail of the seam, likely sewn by the artist. Image: The National Gallery, London

Around the late nineteenth or early twentieth century, the painting was glue-paste lined onto another linen canvas and attached to its existing mortise-and-tenon joint stretcher. At the time of acquisition by the National Gallery, the painting had old, discolored restorations and was coated with a significantly yellowed and poorly saturating varnish (see fig. 22.1). Impact damage in the lower left of the painting had resulted in an irregular 3.8 cm long tear to both the original and lining canvas. The original seam was pronounced and potentially weak, as the seam flap at the back would have been cut away for the previous lining treatment. The remains of the sewing stitches were now visible on the front, partially hidden by restoration (see fig. 22.2). The lining was found to be generally degraded, fragile, and easily detachable.

Three original edges remained relatively intact, with exaggerated cusping present along the bottom edge and some cusping present on the two vertical edges. The right edge also had evidence of being modified; it had been previously folded, such as over a stretcher edge, and then later flattened (Keith et al. 2019, 6, 16n11).[3] There was also evidence to suggest the top edge had been previously cut down slightly: the tip of the martyr's palm and the central pearl of the saint's crown were both missing (see fig. 22.1).

HISTORY OF LINING AT THE NATIONAL GALLERY

The National Gallery has a long history of undertaking structural treatments, including lining, and is active in maintaining traditional practices as well as researching and developing new methods and technologies (Bomford

1978; Reeve, Ackroyd, and Stephenson-Wright 1988; Young and Ackroyd 2001). Aqueous glue-paste hand-linings were first undertaken for the gallery by private liners who were commissioned by the gallery. In a letter from the gallery archive (date unknown), the gallery's first director, Sir Charles Eastlake, writes to inform colleagues that "Mr. William Morrill of 3 Duck Lane, Wardour Street is ordinarily employed for the re-lining of pictures in the collection."[4] In 1880, Morrill himself writes to the director: "The price of double lining the large Weenix picture will be about 14 pounds. I should have written before but I have been very busy with the Crivelli picture which I hope very soon to complete."[5]

While the gallery established its conservation department in 1946, it wasn't until the late 1940s and early 1950s that its conservators were directly employed by the gallery (Bomford 1978, 3).[6,7] Glue paste was the only lining adhesive used at the gallery until around 1947, when wax-resin adhesive began to be used as an alternative adhesive until the late 1970s and the advent of Beva 371. All linings were done by hand until the studio bought its first vacuum hot table in 1976 (Reeve, Ackroyd, and Stephenson-Wright 1988).

Traditional aqueous glue-paste hand-lining remains part of the conservation department's methods for structural treatments for canvas paintings and is chosen when appropriate for a painting's requirements, for example, when considering the type and extent of damage, the painting's overall condition, and its treatment history. Its use, however, has evolved over the last thirty years. The current modified glue-paste recipe is the result of research undertaken at the gallery in the late 1990s by Paul Ackroyd that evaluated the bond performance and relative stiffness of glue-paste linings. Tests revealed that a low ratio of glue to flour paste proved desirable, providing a lining that is more dimensionally stable than those with a higher glue content (Ackroyd 1995, 89). The proportion of glue now used, at 1 part glue to 6 parts flour paste, contains far less glue than traditionally used in the United Kingdom and is more akin to European formulations.

The gallery's current technique is also distinct from other traditional methods in that natural beeswax is used in the process: as part of the facing adhesive, as a lubricant during the lining phase, and as a moisture barrier applied after lining (Phenix 1995, 26). A cold wax-resin facing adhesive is used at the gallery for paintings that do not have absorbent ground or paint layers. It is made with dammar resin, beeswax, and mineral spirit (a low-aromatic petroleum-based solvent) and is brushed out thinly onto the painted surface as a cold liquid over a paper tissue facing (fig. 22.3), usually over a temporary varnish (see the appendix for the recipe).

Figure 22.3 Gentileschi, *Self-Portrait*, during treatment. The painting was faced with a piece of Eltoline tissue brushed over with the cold wax-resin facing mixture. Image: The National Gallery, London

There are distinct advantages to using a wax-resin facing as part of the glue-paste lining methodology. It becomes semitransparent during ironing and can be easily removed with mineral spirit during the lining process, allowing the painting's surface to be visibly inspected without disturbing the lining adhesive. This cannot be done, for example, with an aqueous adhesive facing. Cold wax-resin facings are also simple to apply and pose minimal risk of dimensional change to the painting or of any potential for inducing shrinkage (of either the painting or the facing tissue). They create a weak but effective bond to protect the painted surface from accidental abrasion during delining and provide a soft, slightly cushioning surface. They can also be applied over other facings if additional protection is necessary.

Treatment Strategy

The treatment to reline Gentileschi's *Self-Portrait* was chosen over other treatment options, such as strip-lining and loose-lining, as its overall condition was perceived as too fragile to be left unlined. The level of degradation of the original linen (being over four hundred years old), together with damage to the original seam and the tear through the original and old lining, had compromised the original canvas's ability to support the ground and paint layer at the required tension when the painting was reattached to its stretcher. Relining would also support the new canvas addition to the top edge (see "New Canvas Addition" below) and help keep it in alignment with the original. The painting was also impregnated with animal glue from the previous glue lining, which could lead to future problems with the painting's response to moisture if it were not supported with a new lining canvas and moisture barrier.[8] Remaining unlined would thus leave the painting in a vulnerable state. Additionally, the unusual planned loan conditions for the painting after treatment—including a multivenue tour—would also be of concern if the painting were left unlined.

STRUCTURAL TREATMENT OF THE PAINTING

Facing and Stretcher Removal

After cleaning to remove the old varnish, restoration, and fills, the painting was taken to the gallery's structural studio for relining. First, the tear deformations were reduced, the torn canvas fibers were realigned, and the area was treated with local moisture and weight. The loose paint fragments at the tear edge were consolidated with sturgeon glue, and the tear was locally faced with fine paper tissue and wheat-starch paste, with the tissue edges feathered out. The whole painted surface was then faced with a piece of Eltoline tissue brushed over with the cold wax-resin facing mixture (see fig. 22.3).

The painting was then removed from its stretcher, the old lining tacking margins were cut through at the turnover edge, and the painting was lifted clear. This process was hampered somewhat, as the old lining canvas was stuck to the stretcher along the bottom edge and left corner. Evidence of water staining on the back in these areas indicated the lining adhesive may have been reactivated by water, causing the back of the lining canvas to adhere to the wooden stretcher bar. Fortunately, these areas were easily released by sliding a thin metal spatula between the old lining canvas and the stretcher and easing the two apart.

Delining and Repairs to the Original Canvas

The painting was turned facedown and its edges taped to a Melinex (clear polyester film) covered plywood board to prevent dirt and hard grains of brittle glue-paste residue from getting under the painting and embedding in the facing during the removal of the old lining. (This is one noteworthy disadvantage of wax-resin facings to guard against: debris can easily get trapped in its waxy surface, risking damage to the paint surface, especially during mechanical scraping.) The old lining was then reversed, the lining fabric peeled away in strips by hand, and the remaining glue-paste residue scraped from the surface with a scalpel (National Gallery 2019, video 6).[9]

Old insect damage, in the form of woodworm exit holes, was found within the back of the original canvas corresponding to the likely position of a previous wooden stretcher or strainer (the current stretcher has no insect damage). Luckily, this damage did not penetrate through to the paint surface, so the holes in the canvas could be filled from the back with an adhesive mix of Mowiol GE 04-86 (polyvinyl alcohol), chalk, and pigment using a small metal spatula. Mowiol remains soluble in water, so care is needed during the lining process not to disturb the fills. Rather usefully, Mowiol is also thermoplastic when dry and can be softened and flattened out—with, for example, an electric spatula—to conform with the lining process, thereby avoiding the creation of any undulations or hard bumps behind the original canvas.

The original seam was strengthened with a PVA (polyvinyl acetate) adhesive, Resin 'W,' bulked with cellulose powder to fill any small gaps. Small losses in the original canvas (including parts of the seam) were filled with canvas inserts cut from new primed linen canvas and adhered in place with the same PVA adhesive. This new primed canvas was wetted and stretched before use to reduce its response to moisture. The tear was then butt joined from the back with the PVA adhesive, and cellulose powder and a few additional linen fibers were also used to fill any small holes and gaps and add strength.

Resin 'W' remains sensitive to water when first dry and is softened by heat once fully dry. When used either alone or mixed with small proportions of cellulose powder, it makes a good malleable adhesive/filler that will allow inserts and repairs to be perfectly aligned with the original and conform well with the lining process. Although PVAs are known to become brittle with age (Down 2009; Howells et al. 1993), Resin 'W' has been used at the gallery for some time for discrete canvas repairs. It does harden on aging, making it difficult to remove entirely, but it has proved durable—more so than other, similar adhesives.[10]

Moisture Treatment

After the repairs were complete and the facing was removed, the painting was treated with moisture using the studio's low-pressure suction table to reduce any undulations in the original canvas and any cupping and deformations in the paint layer (fig. 22.4). The painting was sprayed on the back with distilled water and laid faceup on the table on top of a layer of sailcloth (polyester) fabric, which was used as a permeable release layer to prevent the painting from sticking to the tabletop. The painting and the whole of the table was then covered with a sheet of thin Melinex.

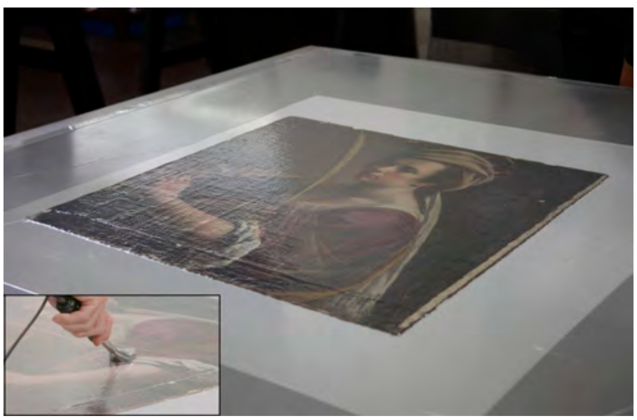

Figure 22.4 Gentileschi, *Self-Portrait*, during treatment. The painting was treated with moisture using the studio's low-pressure suction table and additional pressure applied locally using a heated spatula. Image: The National Gallery, London

The table was heated to 40°C, at 28 mbar (0.83 "Hg) for about twenty minutes. During this time, additional pressure was applied locally to the surface of the painting using a heated spatula set to the same temperature as the table (National Gallery 2019, video 7; see fig. 22.4). Raised areas and dips in the surface topography were marked up on a Melinex template for further examination from the back once the painting was removed from the table. The painting was dried out under pressure.

Using the low-pressure suction table in this way has become an integral part of the glue-paste lining process at the gallery. First, moisture treatments using the table provide the opportunity to witness under controlled conditions how the painting responds to moisture, in preparation for the upcoming aqueous relining treatment. Second, it enables critical inspection of the surface topography of the painting under acute raking light and provides the chance to work on some of the most raised areas that are considered disturbing to the overall surface appearance.

Once dry, the painting was removed from the suction table and returned, facedown, to the Melinex-covered board. With the aid of the Melinex template, the marked-up areas were further investigated and, where necessary, scraped or filled to reduce their impact on the final surface appearance the painting would have once lined. The filling was done with the same Mowiol-pigment mix used for the wormholes.

New Canvas Addition

The lack of cusping along the top edge and the appearance of the closely cropped composition led to discussions of the original format of the painting and whether it had been cut down or altered in shape and size (see fig. 22.1). The decision was made to extend the top of the painting to accommodate the tip of the martyr's palm frond and the central pearl in her crown (National Gallery 2019, video 9). A piece of new primed linen canvas, similar in weave to the original, was prepared by first wetting and stretching it, and then a strip was cut with the weave oriented with the warp thread vertical and the weft horizontal.[11] This strip was then profiled to match the top edge of the original canvas and attached with the same PVA adhesive–cellulose powder mix used for the inserts and tear mend. A heated spatula was used to secure the strip just below the original canvas surface.

Preparation of the New Lining Canvas

Next, the lining canvas was prepared. A piece of fine-weave linen larger than the painting on each side was stretched onto a wooden loom, wetted, and restretched to reduce and unify the crimp of the canvas yarns. This produces a stiffer and more isotropic support and reduces its tendency to shrink if exposed to high humidity. Wetting and stretching was done three times; on the third time a deacidification solution of magnesium carbonate was added to the water.[12] The linen lining canvas was then left tensioned on the loom throughout the lining process.

Preparation of the Glue Paste

The day before lining, the adhesive was prepared. The gallery's standard recipe uses rabbit-skin glue, wheat flour, and water only. The glue is dissolved in some of the measured water by warming gently or being left overnight. The remaining water is warmed in a bain-marie, and the flour added and whisked. This flour-water mix is then added to the dissolved glue and stirred until it is thick with no lumps. The final mix is poured into a plastic tub, covered with Melinex to prevent a skin forming, and set aside to cool. The adhesive should be used within twenty-four hours as no preservative is included (see appendix below).

The Lining Process

Prior to lining, the surface of the painting was faced again with Eltoline tissue and cold wax resin. Every step of the lining process was then planned out, the equipment gathered, and the method run through. This is particularly important with a glue-paste lining, because when the painting is wet with the glue paste it is at its most vulnerable to movement and change, so it is important to work precisely and quickly. The work surface was covered with newspaper (as a blotting paper), the position for the lining canvas loom was marked up on the paper, and the lining irons were set to around 35°C–40°C. A "lining surface" of a raised Melinex-covered base board (the depth of the loom and with dimensions larger than the painting) was also prepared and put to one side. The painting was then laid facedown on the newspaper, and the glue paste was smeared over the back of the painting by hand and worked to a smooth, thin, even layer using a brush (fig. 22.5).[13] Hand application of glue paste allows for close assessment of the surface as the adhesive is applied, and any changes can be felt immediately.

Figure 22.5 Gentileschi, *Self-Portrait*, during treatment. Applying glue paste to the back of the painting. Image: The National Gallery, London

Next, the loomed lining canvas was placed directly on top of the painting, following the premarked registers on the newspaper. The lining canvas was pressed onto the back of the painting by hand to lightly attach the painting so that it could be turned over and placed, faceup, on the (Melinex-covered) raised board. The painting surface was then ironed over the tissue facing for forty minutes or so, with the warm lining irons using only the weight of the irons and no additional pressure. Once the whole surface was worked over and the back fully saturated, the painting was placed vertically for a couple of hours so the structure could begin to dry. Then the painting was returned to the table and, with the iron temperature increased slightly to 50°C–55°C, the painting was ironed for a second time (fig. 22.6). It was then again placed vertically for a further period to dry.

Figure 22.6 Gentileschi, *Self-Portrait*, during treatment. The painting was ironed for a second time using the hand-held iron set at 50°C–55°C. Image: The National Gallery, London

The painting was returned to the table and the wax-resin facing removed with mineral spirit so the paint surface could be inspected for any faults, undulations, or problems with the lining.[14] A fresh piece of facing tissue was then laid on the painting, and the surface ironed for a final time, with the iron temperature increased to 65°C–70°C and with melted wax on the iron plate to lubricate the iron across the tissue facing. Work proceeded over the painting, keeping the irons moving to prevent any hot spots and with the iron being returned to the beeswax block to pick up more wax to keep the iron well lubricated. This achieved a smooth and controlled lining process. Once complete, the painting was lifted from the lining board and propped up to allow air to circulate and the painting to thoroughly dry out overnight.

The following day the facing tissue was removed with mineral spirit. The tabletop was prepared with a thin blanket and Melinex release layer, and the loomed, lined painting was placed facedown on top of the Melinex. Beeswax was ironed into the back of the lining canvas as a barrier to moisture. The wax does not impregnate the original reverse because the coherent glue-paste adhesive layer prevents this (National Gallery 2019, video 8; Ackroyd 1995, 89; Young and Ackroyd 2001, 101).

Modifications to the Old Wooden Stretcher and Restretching

The old wooden stretcher was modified. Wooden battens were added to the edges to accommodate the new addition and slightly increase the overall size of the stretcher. This ensured that the original edges of the painting were kept away from the edge of the stretcher to reduce the risk of delamination from the lining during restretching. The excess visible lining would be framed out, as a new frame, contemporary to the painting, was sourced. New keys were made to replace the old damaged and missing keys.

The painting was cut from the loom, leaving about a 12 cm tacking margin, and reattached to its stretcher with copper tacks tapped into the stretcher at regular intervals. Finally, as with all lined paintings at the gallery, the keys were tied in with nylon wire and brass screws and cups. The tacking margins were trimmed, folded, ironed flat against the back of the stretcher, and attached with galvanized staples. The painting was then returned to the restoration studio to complete the treatment (fig. 22.7).

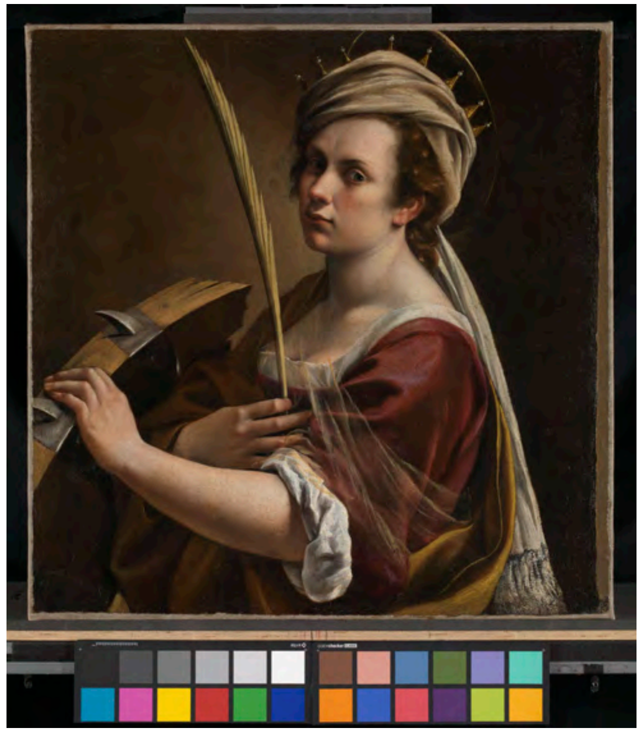

Figure 22.7 Gentileschi, *Self-Portrait*, after treatment. Image: The National Gallery, London

CONCLUSION

Self-Portrait as Saint Catherine of Alexandria by Artemisia Gentileschi was a significant acquisition and conservation project for the Gallery. A film series of the full treatment process, including cleaning, structural treatment, and restoration, was made and published on both the gallery's website (National Gallery 2019) and YouTube and was well received. Further investigations into the painter's process were also undertaken (Keith et al. 2019; Melchiorre Di Crescenzo et al. 2019).

After treatment, the painting embarked on a nationwide tour to unusual venues across the United Kingdom, the first venue coinciding with International Women's Day on March 8, 2019, traveling in total to two libraries, a doctor's surgery, a school, and a prison.[15] Thereafter, the portrait was included in the gallery's major exhibition, *Artemisia*, October 2020–January 2021, which included forty-one works from public and private collections and showcased the artist in the first major exhibition of her work in the U.K.[16]

ACKNOWLEDGMENTS

I would like to express my sincerest thanks to the Getty Foundation for its generous support of the Conserving Canvas initiative and my participation in it, to the Yale symposium organizers for accepting this contribution to the Conserving Canvas symposium and publication, and to my work colleagues for their support and expert advice, in particular my colleague and mentor Paul Ackroyd.

APPENDIX: MATERIALS AND RECIPES

Materials List

- Eltoline tissue, long-staple 100% manila fibers with good wet strength
- Resin 'W', Evo Stik wood adhesive, Bostik Ltd., U.K.
- Mowiol GE 04-86 (polyvinyl alcohol), Kuraray Europe GmbH

Recipes

Wax-resin facing made from dammar and beeswax: 340 g beeswax, 1700 ml dammar varnish (454 g resin, 2800 ml mineral spirit), 850 ml mineral spirit.

Deacidifying solution of magnesium carbonate dissolved in carbonated distilled water: 8.8 g magnesium carbonate, 1000 ml water.

Glue-paste adhesive, 6:1 wheat flour and animal glue: 240 g wheat flour, 40 g animal glue (rabbit), 1440 ml water (6 × 240 = 1440).

Mowiol and chalk mix filler at 25%: 240 g Mowiol GE 04-86, 1000 ml water, enough chalk and pigment to form a stiff, colored paste.

NOTES

1. The conservation treatment is described in a series of short films on the National Gallery website: https://www.nationalgallery.org.uk/behind-the-scenes/restoring-artemisia.
2. This paper complements the contribution in this publication by Paul Ackroyd, National Gallery, London.
3. The flattened right edge was to be retained in the current treatment. See also Keith et al. 2019, 6, 16 (n.11).
4. National Gallery Archive, NG/7/507: https://www.nationalgallery.org.uk/archive/record/NG6/7/507.
5. National Gallery Archive, NG7/18/11:https://www.nationalgallery.org.uk/archive/record/NG7/18/11.
6. National Gallery Archive, NG10: https://www.nationalgallery.org.uk/archive/record/NG10.
7. Conversation with Paul Ackroyd, 2020.
8. Conversation with Ackroyd, 2020.
9. On inspection of the original canvas, it was considered unnecessary to undertake any overall consolidation of the original canvas.
10. Conversation with Ackroyd, 2020.
11. It was important to consider the weave orientation of the strip. Having the warp thread vertical restricts its horizontal movement when wet, thereby reducing the risk of imposing dimensional change on the original during this stage of treatment. When wet, the new machine-woven canvas curls in a convex manner to the surface in the warp direction while also shrinking in the warp direction.
12. Magnesium carbonate is not soluble in water. It is mixed with a small amount of water into a paste, put in a soda siphon with a quantity of distilled water (up to 1 liter), and then the release of two carbon dioxide capsules into the siphon turns the magnesium carbonate into bicarbonate, which is soluble in water. The resulting water mixture is applied to the canvas. When dry, the magnesium bicarbonate reverts to magnesium carbonate, and this is what is left within the structure of the canvas. See Ryder 1986.
13. Rollers can also be used.
14. It’s not necessary at this stage to remove all the wax resin, as any residue aids the next tissue application.
15. https://www.nationalgallery.org.uk/whats-on/artemisia-visits and https://www.nationalgallery.org.uk/about-us/press-and-media/press-releases/artemisia-visits-glasgow-womens-library.
16. https://www.nationalgallery.org.uk/exhibitions/past/artemisia; see also https://artuk.org/discover/stories/artemisia-an-interview-with-curator-letizia-treves.

23

Conserving the History and Fabric of the New Bedford Whaling Museum's *Grand Panorama of a Whaling Voyage 'Round the World*

Kathryn S. Tarleton, Principal, ConText Inc., Rochester, Massachusetts
Charlotte Hamlin, Principal, ConText Inc., Rochester, Massachusetts

The Grand Panorama of a Whaling Voyage 'Round the World *is an 8 1/2 × 1,300 foot painting worked in distemper on cotton muslin that is owned by the New Bedford Whaling Museum. The primary objective of this conservation project was to stabilize the panorama to enable its safe handling and storage and static vertical display. The conservators developed protocols for physically supportive, minimally intrusive, and visually nondisruptive stabilization treatments; a means of documenting the conservation work; and a storage system for the conserved panorama. Treatment included removal of adhered Mylar, retention of select previous repairs, ordering of previously disrupted panels, local stabilization utilizing custom-dyed underlays, and when needed, bobbinet overlays.*

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INTRODUCTION

The Grand Panorama of a Whaling Voyage 'Round the World is an 8 1/2 × 1,300 foot painting worked in distemper on cotton muslin (fig. 23.1). Completed in 1848, it was painted by Benjamin Russell and Caleb Pierce Purrington and begins in the busy harbor of New Bedford, Massachusetts, taking the viewer on a world tour highlighting the adventures and terrors of the nineteenth-century world of whaling. Designed to be a moving panorama mounted on upright spools and attached to a structure that allowed it to be scrolled across a stage, it traveled the country and entertained audiences from the 1840s through the latter decades of the nineteenth century. In 1918, it was donated to the New Bedford Whaling Museum (NBWM), in New Bedford, Massachusetts, where various sections of it were temporarily exhibited throughout the twentieth century.

Divided into four separate rolls, it is constructed from two lengths of muslin whipstitched together by hand along their selvages, creating a central horizontal seam that runs the length of the painting. The painting on each roll has an approximately 5-foot-long section of unpainted cotton at its beginning and end. A 3/16-inch-diameter cotton bolt rope is whipstitched along the upper edge.

The primary objective of this conservation project was to stabilize the panorama to enable safe handling and storage and static vertical display of the object. ConText Inc. was responsible for treating all the textile condition issues present on the painting. This paper details the many

Figure 23.1 Roll 3 of the *Grand Panorama* on exhibition during the summer of 2018, after the conservation treatment was completed. Image: Courtesy of the New Bedford Whaling Museum

challenges of treating the massive painting and how the scale and format of the object factored into the treatment decisions made throughout the project. The approach to developing treatment protocols for the range of known condition issues present on the painting is described, as well as how previously unknown condition issues uncovered during the stabilization process were managed. The treatment discussion includes decisions regarding the retention of historical repairs, the reversal of prior stabilization and mounting treatments, and the rejoining of previously separated sections.

CONDITION PRIOR TO TREATMENT

In 2001, the NBWM conducted a condition survey of the panorama, the first such survey of the object ever undertaken. Each roll was examined on a flat surface by a group of trained volunteers who filled out condition checklists for each 10-foot section of panorama. In all, twenty-six types of condition issues were recorded; the detailed written documentation and accompanying photographs are housed in four binders at the museum.

The entire painted surface of the panorama was documented as unstable; according to the survey findings, the paint was powdering and flaking. Throughout, the cloth was wrinkled or creased to varying degrees, distorting the painted imagery and promoting the flaking of the painted surface. Although the cotton panorama fabric was reported to be in stable condition overall, numerous examples of textile damage were noted across the four rolls, including stains, holes, tears, seam breaks, full vertical cuts, unpicked seams, and prior mends and patches. Possible mold damage was also noted. At the time of the condition survey, the panorama was in thirteen separate pieces, some of which were out of sequence. Of these thirteen pieces, two 8 1/2 by approximately 50-foot sections were adhered to a heavyweight Mylar backing with an unknown adhesive.

TREATMENT PROTOCOLS

In 2012, the NBWM convened a team of experts to study the best museum and conservation practices in order to develop a protocol for preserving the panorama. The group visited institutions and interviewed professionals who had previous experience with similar objects. The National Endowment for the Humanities–funded project resulted in the 2013 NBWM Panorama Advisory Group Report, “Preserving an American Treasure: A Proposed Treatment Protocol for Purrington & Russell’s Original Panorama Painting of a Whaling Voyage ’Round the World, 1848–1851.”

The report’s treatment protocol for reducing the wrinkles in the panorama’s fabric and consolidating the painted surface was adopted for this project. The recommended treatment encompassed spraying the painted cloth with a gelatin-based consolidant, which was found to simultaneously reduce the extensive wrinkling and stabilize the flaking paint. The treatment also had the advantage of posing fewer ventilation concerns than the use of an acrylic consolidant such as Paraloid B72.

No specific textile stabilization treatment protocols were recommended in the 2013 report. ConText Inc. developed a series of protocols to ensure the use of uniform treatment methods for the many different types of textile condition issues known to be present on the panorama (broken stitching, holes/loss, tears, vertical cuts, etc.). The focus of protocol development was to design physically supportive, minimally intrusive, and visually nondisruptive treatment methods.

A number of “damaged” textile samples were fabricated from medium-weight cotton muslin of similar weight and thread count as the panorama fabric. Each sample represented a different documented condition issue found on the panorama (holes, tears, etc.). These samples were stabilized with both stitched and adhesive treatments, using a variety of fabric and thread types. The stabilized samples were then evaluated based on strength, appearance, and suitability to the project.

The chosen treatment methods included the use of custom-dyed cotton fabric underlays stitched in place using sheer polyester thread in the painted portion of the panorama and cotton-polyester thread in the blank and rope-edge areas of the panorama. Custom-dyed bobbinet was chosen as an overlay fabric for areas of extreme fabric weakness or deterioration. Although tested, no adhesive treatments were chosen for inclusion in the project.

A localized approach to stabilization was taken, treating individual condition issues as needed. Lining the panorama as a means of stabilization and support was not considered necessary, nor was it recommended. Lining the panorama would have essentially doubled the weight of the monumental object, concealing details on the object's reverse and adding to the complexity of rolled storage. The panorama is not a truly flat textile: the fabric tension varies from the upper rope edge to the middle horizontal seam to the selvage lower edge, so imposing a flat lining on the object could lead to planar distortion of the panorama fabric.

DOCUMENTATION

A streamlined documentation system was designed to ensure consistent treatment reporting throughout the stabilization project. First, a standard list of condition and treatment terms was compiled; these terms were amended over the course of the project to include all condition issues encountered and treatments utilized. Worksheets were designed for documenting treatment on each 10-foot section of panorama; this system was based on the 2001 condition reporting project worksheet so that data from both projects could be easily compared. These worksheets were organized in four binders, one for each roll of panorama. Additional treatment notes and photos were added to the binders as necessary.

Although each treated area was described, noted, and mapped on the worksheets, not every treated area was photodocumented. By not photographing every single treatment (many of which were repeated numerous times within each 10-foot section), the documentation process was streamlined. Instead, a representative sampling of all condition and treatment types was digitally documented throughout the project. Lastly, a treatment checklist for each 10-foot section of panorama was developed to ensure all treatment practice was standardized throughout the project.

WORK LOCATION AND SUPPORT APPARATUS

The panorama was stabilized on-site at the NBWM. This arrangement allowed the conservators access to key museum staff throughout the duration of the project and minimized transport and handling of the rolled panorama sections.

Following recommendations in the 2013 NBWM Panorama Advisory Group Report, a custom-built table was constructed for consolidating the panorama's painted surface. The smooth, horizontal table surface was equipped with hardware at each side to hold the large storage drums on which the panorama was rolled. A roll of untreated panorama was mounted to one side of the table, unrolled and scrolled across the horizontal surface for consolidation spraying, and then rolled onto an uptake drum at the opposite side of the table.

A tension frame was designed in order to implement the textile stabilization treatments on the panorama. The frame was constructed in four separate sections for maximum versatility. This apparatus consisted of four rolling horizontal beams that could be held under tension: a rear beam, which held the untreated panorama roll; two upper beams, which supported and separated the pretreatment and posttreatment sections of the panorama; and a front beam, which was the take-up roll for the treated panorama.

Textile treatment took place in the space between the upper and front beams. The face and reverse of the panorama were fully accessible to the conservators in this space (fig. 23.2). Having access to both sides of the painting not only facilitated stabilization treatment but also revealed condition issues that were not visible during the 2001 condition survey. These were mainly additional areas of weakness and patched repairs. The approximately two hundred areas of the panorama recommended for treatment in the 2001 survey swelled to over 2,050 treated areas by the time the project was completed.

Figure 23.2 Panorama on tension frame during stabilization treatment. Both face and reverse of the panorama were accessible to conservators. Image: ConText Inc.

CONSERVATION PROCEDURES

The surface media was consolidated by NBWM staff before the textile stabilization process commenced. The latter work was accomplished in two phases. The first involved separating the two lengths of panorama adhered to Mylar from their backings in order to stabilize and then rejoin them into their proper sequence in the panorama. The second was to stabilize all the textile condition issues present on each panorama roll. This was achieved by systematically treating and documenting each panorama roll in 10-foot sections, following the treatment protocols developed at the start of the project.

Media Consolidation

The method employed for consolidating the panorama's flaking paint was based on a treatment first developed at the Saint Louis Art Museum by paintings conservator Paul Haner during the conservation of the *Monumental Grandeur of the Mississippi Valle*y panorama. Further testing and refinement of the method was conducted by NBWM staff prior to treatment. The panorama's painted surface was sprayed with a 0.75% solution of conservation-grade gelatin and distilled water using a Dahlia sprayer. One 10-foot section at a time, the painted surface was sprayed with the solution until saturated and then allowed to air-dry flat on the horizontal spray table before the panorama was rolled ahead and the next section treated.

The treatment successfully consolidated the painted surface and reduced the overall wrinkles and creases in the fabric. Two small areas on roll 1 required additional consolidation treatment during the textile stabilization phase of the project. In these areas, the original surface had been overpainted, and the resulting thick paint layer was not fully consolidated by the initial gelatin treatment. A 1.5% gelatin–distilled water solution was brushed onto these areas and allowed to air-dry.

Mylar Removal

Several methods were tested for removing the heavy Mylar backing adhered to two 50-foot sections of the panorama (roll 3, sections 33–37, and roll 4, sections 11–15). Mechanical means, heat, and solvents were all tested, with varying degrees of success. The most effective method, and the one chosen for the project, was using methanol vapor to soften the adhesive. The panorama was placed facedown on the work surface for this treatment; the front and rear rolling beams of the tension frame were used to advance the panorama as the work progressed. Methanol-dampened blotters (6 × 18 inch) were slipped between the work surface and the panorama face, and the vapor was allowed to penetrate the substrate for several minutes. After the adhesive softened, the plastic backing was mechanically separated from the panorama in small strips. Most of the adhesive residue remained adhered to the Mylar backing during this process. Adhesive residue remaining on the panorama fabric reverse was softened with the application of methanol via cotton swabs and mechanically removed using a small spatula. The adhesive was not uniformly applied throughout the two lengths of panorama. In some sections, the application was light, making removal relatively simple. In areas of dense application, the removal process was much slower.

In addition to the adhesive described above, at least one other adhesive and a variety of double-sided tapes had been used to attach the Mylar backing to the upper edge of the roll 3 panorama length. The backing was removed from this area in the manner noted above, and adhesive residue remaining on the panorama reverse was mechanically removed after softening with acetone applied with a cotton swab.

During removal of the Mylar backing from the roll 3 panorama length, an area of especially strong adhesive was encountered. It was darker than the adhesive removed from the panorama up to that point, and much more resistant to removal attempts. This adhesive swelled in contact with methanol but did not easily roll up or scrape off. Unlike the other adhesive, the residue of this adhesive was embedded in the weave of the panorama fabric. After testing methods of removal (heat and solvents), it was determined that the amount of mechanical action (scraping) necessary for complete removal put too much stress on the panorama fabric. This area of tacky adhesive residue was left in place on the panorama reverse. To prevent the panorama from sticking to itself during rolled storage, a length of scoured cotton muslin was laid on the panorama reverse to cover the area of residue and then rolled with the panorama onto the roll 3 storage drum. This area covered approximately 10 feet of roll 3, sections 35 and 36. The placement of the muslin underlay was marked on the panorama with twill-tape tags stitched to the upper (rope) edge.

In all, approximately 850 square feet of backing were removed from the two lengths of panorama. After removal, the two sections were rolled onto separate storage tubes to await stabilization treatment.

Textile Stabilization

The tension frame was used to implement the textile stabilization phase of the project. After a roll was loaded onto the frame, each 10-foot section of panorama was examined, and all condition issues were measured and noted on the documentation worksheets. A twill-tape label was stitched to the reverse upper (rope) edge to mark the beginning of each section. Each condition issue was stabilized following the treatment protocols set at the start of the project. These protocols were modified and expanded throughout the project to best suit the variety of condition issues that presented themselves.

The majority of conditions requiring stabilization were holes, tears, seam breaks, and small areas of weakness in the panorama fabric (figs. 23.3, 23.4, 23.5). These were stabilized with custom-dyed, stitched cotton underlays. All underlay edges were pinked to prevent fraying. Figure eight stitch was used to rejoin most tears and seam breaks; a row of running stitches with intermittent back stitches was worked around the perimeter of all underlays to lend additional stability. Dyed nylon bobbinet stitched overlays were used to stabilize severely abraded and weak areas of the panorama fabric. One particularly large underlay (8 1/2 × 5 feet) was stitched to the blank lead edge of roll 4 due to multiple tears, holes, and areas of fabric loss.

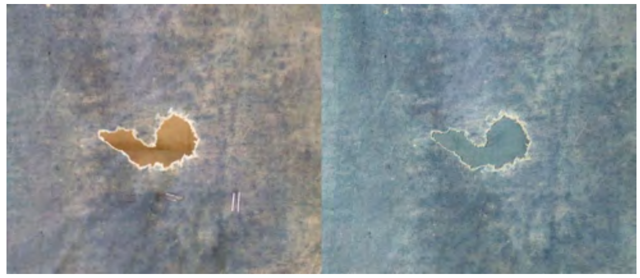

Figure 23.3 Hole in roll 4, section 1, before treatment (left) and after (right). Image: ConText Inc.

Figure 23.4 Small hole at the rope edge in roll 1, section 2, before treatment (left) and after (right). Image: ConText Inc.

Figure 23.5 Holes and fabric weakness in roll 4, section 12, before treatment (left) and after (right). Image: ConText Inc.

The panorama had patches (both glued and stitched) and previous stitched mends on all four rolls. These repairs were likely made throughout the working life of the panorama as it traveled from venue to venue for exhibition, and they were considered part of the history of the piece. In most cases, these patches and repairs were left intact, with additional stitched stabilization added as necessary.

Two types of glued-on patches were present on the reverse of roll 4. The first was a plain-weave, undyed cotton fabric glued onto the reverse with an unknown adhesive. These were generally stable and relatively flexible and so were left intact. The second type was a “Band-Aid” style patch made of cloth book tape with an added layer of cotton fabric in the center. These were loosely adhered at the edges and quite stiff. They were no longer supporting the panorama fabric, and in some cases were putting stress on it. These were mechanically removed and replaced with dyed cotton underlays. The few patches that required removal were photo-documented, labeled, and stored in the treatment documentation binders.

All four rolls had small areas of weakness scattered throughout, especially at the rope edge, but rolls 2, 3, and 4 exhibited several large areas of significant weakness that were not documented in the original condition survey. These areas, ranging from 10 to 40 inches in height and width, were mainly clustered in the lower half of the panorama fabric. Many of the areas of weakness had small holes and/or tears scattered throughout. These were stabilized with dyed cotton underlays and, in some cases, dyed bobbinet overlays as well (fig. 23.6). The larger underlays were stitched around the perimeter and in vertical rows spaced 4 to 6 inches apart to lend stability to the weak fabric.

Figure 23.6 Details of weakness and scattered holes in roll 3, section 28, before treatment (left) and after stabilization with a dyed cotton underlay and dyed bobbinet overlay (right). Image: ConText Inc.

As previously noted, the panorama was in thirteen sections before stabilization began. Several of these pieces required rejoining along vertical cut lines or unpicked vertical seam lines. This was accomplished by butting the adjoining edges together and stitching them to a dyed cotton underlay (fig. 23.7). In all, ten vertical joins were stitched.

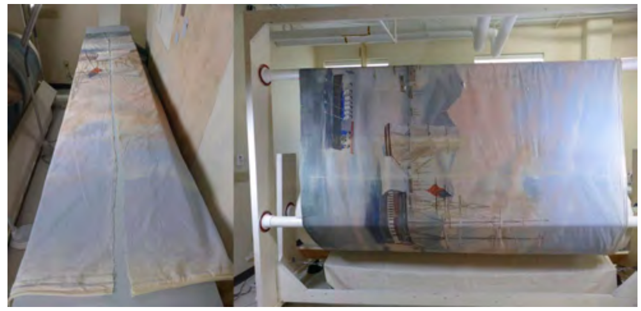

Figure 23.7 Vertical cut A on roll 2, section 27, before treatment (left) and after (right). Image: ConText Inc.

On roll 1, sections 9, 10, 12, and 13 each had a large three-sided cut (8 × 48 inches) along the upper edge. These date from the 1964 New York World’s Fair, when a 175-foot section of the panorama was hung for exhibition around the interior walls of a restaurant in the New England States Pavilion. After installation, it was discovered that the panorama’s upper edge was blocking the air-conditioning registers, so the cuts were made to allow the air to flow freely (New Bedford Whaling Museum 2018, 79). The cuts in these areas went through the fabric, but the rope was left intact. To stabilize these large areas, the cut edges were aligned as closely as possible (the panorama fabric had stretched slightly along the cut lines during previous vertical exhibition) and stitched to dyed cotton underlays. These dyed underlays filled the small voids where the cut edges of the panorama cloth did not quite butt together during stabilization treatment.

Roll 2, section 1, received two treatments not applied elsewhere in the project due to its unique condition issues. As found, this approximately 7 × 9 foot section was not attached to any roll; the proper right edge was an unstitched vertical seam and the left was a full vertical cut. The original upper part of this section was missing and had been replaced with a band of white sheeting. It was labeled “miscellaneous section” in the 2001 condition notes, but during the course of this project its proper right edge was found to match the lead edge of roll 2, section 2, revealing its proper placement in the panorama sequence. The sheeting in the upper part of section 1 was replaced with a dyed cotton panel to return the section to its full original height, and section 1 was subsequently reattached to roll 2, section 2. The other treatment this section received was joining it to a new blank lead, to protect its cut leading edge during handling and storage.

Storage Drums

The final step in the treatment process was to place the four stabilized rolls of the panorama onto storage drums. The drums were constructed from four 24-inch-diameter Sonotube concrete forms measuring 9 feet 3 inches in length. The open ends of each tube were fitted with wood plugs that had holes drilled through the center so that the drums could be suspended on metal rods during storage. Each tube was wrapped with a 4-mil barrier layer of Mylar and a layer of Volara foam, secured with double-sided tape.

Each length of stabilized panorama was rolled onto a storage drum with the lead edge outermost, wrapped in polyethylene sheeting, labeled, and stored on a dedicated storage rack at the NBWM. In conjunction with a customized mount, the conservation treatments described here stabilized this enormous textile for its first complete exhibition in over a hundred years (see fig. 23.1).

APPENDIX: MATERIALS AND SUPPLIERS

Stabilization Fabrics

- Desized, unbleached, scoured, cotton print cloth, style #400 U: Testfabrics, Inc.
    - No resin finishes
    - Approx. weight: 3.18 oz./sq. yd.
    - Approx. width: 44 in.
    - Approx. same weight and thread count as panorama fabric
- 20 denier nylon bobbinet, style N800: Dukeries Textiles & Fancy Goods, Ltd.
    - Mesh size approximately 1/16 in. diameter
    - Width: 205–213 in.
    - 30 warps/in.
    - 2 diagonal wefts: 24 wefts/in.

Threads

- Gütermann Skala 360 sewing thread: Testfabrics, Inc.
    - Extra fine tex 8
    - 100% polyester sewing thread
- Coats cotton-covered polyester core sewing thread: locally purchased
    - 35 weight

Dyes

- Pro MX Fiber Reactive Dye: Pro Chemical and Dye
    - Designed to permanently dye cellulose fibers
    - Excellent wash and light fastness properties
- Pro Washfast Acid Dye: Pro Chemical & Dye
    - Designed to permanently dye protein and nylon fibers
    - Excellent wash and light fastness properties

Rope

- 100% cotton, three-strand rope, 3/16 in. diameter: manufactured by Bohannon Textiles Inc.; purchased from R&W Rope, New Bedford, MA

Gelatin

- Technical grade, 200 Bloom, Type B, 40 mesh gelatin: Polistini Conservation Material

Storage Drum Materials

- 24 in. Sonotube: locally purchased
- Mylar film, 4 mil: Talas, Inc.
- Volara foam, 1/16 in.: Talas, Inc.
- 3M 415 double-sided tape and 3M 850 tape: Talas, Inc.

24

Working around *The Hours*: The Structural Treatment of a Twelve-Foot-Round Ceiling Painting by Edwin Austin Abbey

Cynthia Schwarz, Senior Associate Conservator of Paintings, Yale University Art Gallery
Kelsey Wingel, Assistant Conservator of Paintings, Yale University Art Gallery
Julianna Ly, Assistant Conservator of Paintings, Cleveland Museum of Art
Ian McClure, Chief Conservator (retired), Yale University Art Gallery

In preparation for an upcoming exhibition featuring preparatory works by Edwin Austin Abbey (1852–1911) for major mural commissions, conservators at the Yale University Art Gallery treated a 12-foot-diameter study for Abbey's ceiling mural Passage of the Hours *(1904–11). The unvarnished, matte surface of* The Hours *is well preserved, but improper storage in the early twentieth century caused structural damages to the canvas, including undulating deformations and sharp creases. This case study describes a series of innovative solutions to challenges presented by the structural treatment of this painting, which will travel internationally. A 14-foot-round aluminum working strainer was fabricated to help conservators resolve canvas deformations under tension. The painting was loomed temporarily onto this strainer using Velcro attachments. Once on the working strainer, structural damages and deformations were addressed vertically, providing access to both the recto and verso with minimal handling. The painting has been reunited with its original stretcher, itself a collapsible design that disassembles into two loose-lined hemispheres for travel. A segmented edge-lining, again using Velcro attachments, was designed to enable the painting to be efficiently and gently stretched at each venue, while adding little additional bulk to the fold-over edges.*

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INTRODUCTION

Painted between 1904 and 1911 by the American artist Edwin Austin Abbey (1852–1911), *Cartoon for the Passage of the Hours* (henceforth referred to as *The Hours*) is a 12-foot 6-inch-diameter painting in the collection of the Yale University Art Gallery (YUAG) (fig. 24.1). Created as a half-scale study for a 24-foot ceiling painting in the Pennsylvania State Capitol building, this work will feature prominently in an upcoming exhibition of Abbey's preparatory studies for murals in American public buildings during the Gilded Age, a period referred to by artists of the time as the American Renaissance. Opening at YUAG in the fall of 2024 and traveling to the National Gallery, London, the following spring, this exhibition led conservators to devise unique solutions for the structural treatment, transport, and display of *The Hours*. These solutions included the fabrication of a custom aluminum working strainer, the use of Velcro hook and loop systems for stretching the painting to a temporary loom and its final strainer, the use of a silicone heating mat for attaching temporary looming strips, and the design of a segmented edge-lining template using computer-aided design (CAD) and computerized numerical control (CNC) cutting technology.

Figure 24.1 The conservation team lifting the loomed painting on its adapted strainer. Image: Yale University Art Gallery

Although largely unknown today, Edwin Austin Abbey was one of the most prominent American painters working in British and American artistic circles at the turn of the twentieth century. Having begun his career as an illustrator in the publishing firm of Harper and Brothers in New York City, Abbey adopted oil painting in 1889 after moving permanently to England (Lucas 1921, 1:22–196). Over the next twenty years, he exhibited several acclaimed paintings of Shakespearean subjects at the Royal Academy, eventually becoming an academician in 1898 (Lucas 1921, 2:317). Like many painters of the time, Abbey also possessed a keen interest in mural painting and completed several commissions for British and American public buildings, his most famous being *The Quest and Achievement of the Holy Grail*, held in the Boston Public Library.

An essential component of Abbey's artistic process was the creation of hundreds of preparatory studies for each mural or easel composition, many of which are now part of the Edwin Austin Abbey Memorial Collection at YUAG.[1] Certainly one of Abbey's largest studies, *The Hours* may also be one of his most ambitious and visually striking preparatory works. The painting was created as a half-scale study for a 24-foot ceiling painting currently in situ in the House of Representatives Chamber of the Pennsylvania State Capitol building in Harrisburg. In a composition that Abbey described as "one of the most successful designs I have ever made," the painting depicts twenty-four women, personifications of the hours, moving around the perimeter of a celestial sphere filled with forty-eight constellations of the Northern Hemisphere (Lucas 1921, 2:436). Heavily influenced by one of the star maps Peter Apian (1495–1552) published in his *Astronomicum Caesareum,* the constellations are indicated with carefully placed mordant-gilded stars (Ricci 2015, 52). With the sun passing from Virgo to Libra, the carefully balanced composition may reference the position of astronomical bodies around the fall equinox, when day and night are equal.

PAINTING TECHNIQUE AND CONDITION

The Hours was painted on a fairly open and evenly woven linen canvas (26 × 22 threads per inch) prepared with a commercially primed lead white ground. Abbey used the full width of the cloth, measuring 160 inches from selvage to selvage. As with many of his preparatory works, Abbey applied leanly bound paints in transparent, overlapping washes to create a matte, velvety surface. Dry media are present underneath, between, and on top of the paint layers, as Abbey used charcoal and white chalk to place and later modify the figures and constellations. Gold and silver leaf were applied over impastoed white paint and mordant to create the shimmering effects of the moon, sun, stars, and Milky Way.[2]

Early inventories of the Abbey collection indicate that *The Hours* remained stretched from the beginning of its creation in Abbey's London studio until his possessions were packed for shipment to New Haven in 1937, when the work was rolled for transport across the Atlantic and subsequently placed into storage for eighty years. *The Hours* has never been exhibited or treated since its arrival, although it was surveyed and sympathetically rehoused twenty years ago by paintings conservator Anne O'Connor during a rehousing project funded by the Institute of Museum and Library Services.

The canvas remains supple and strong, but it displayed severe undulations from decades of tightly rolled storage, creating a corrugated pattern of planar deformations most visible in raking light (fig. 24.2). Several strong creases from past folding of the canvas extended the width of the painting and were made more visible by associated ground and paint loss. The tacking and fold-over edges display the most abrasion and loss to the canvas, ground, and paint layers, much of it corresponding to the particular fold patterns of a circular painting. Some of the abrasion and losses along the tacking edges may also have been caused by Abbey rolling the painting back and forth as he worked.

Figure 24.2 Raking-light images of the painting before (left) and after (right) humidification and tensioning. Image: Yale University Art Gallery

The paint and ground layers are inherently stable, with flaking occurring primarily along canvas creases in the painted surface and fold-over edges. The painting retains its unvarnished, matte surface. Minor burnishing of the surface is visible as small, glossy high points scattered throughout, where the paint film likely rubbed against the roll interleaf. The burnishing is most noticeable in the night half of the painting, where a thin layer of hazy white efflorescence is also present on the robes of the figures.[3]

TREATMENT

Initial Considerations

The large size, unusual shape, and unique condition concerns of *The Hours*, along with the particular travel and display requirements of an internationally traveling exhibition, presented several treatment challenges for the conservation team. The matte, underbound paint layers required a minimally saturating, adequately strong, flexible consolidant. Humidity and tension were required to resolve canvas deformations before fitting the painting to its stretcher, necessitating the temporary looming of the painting onto a working strainer. The large size of the painting and its anticipated international travel dictated that *The Hours* would need to be either rolled during transport and restretched at each venue or stretched onto a folding stretcher. Having located the original stretcher, a design that comes apart in two halves for travel, we decided to use the original and thus transport the painting rolled. The weakened tacking edges and the act of restretching the painting several times during the course of travel required conservators to devise an edge-lining system that would facilitate the safe and efficient stretching and unstretching of the painting while adding minimal extra bulk.

To prepare for treatment, a 16 × 16 foot platform of particle board pallets and Masonite was constructed to provide a clean, elevated workspace on the studio floor. The surface was prepared with blotter, Pellon, and tissue to provide a firmly padded surface for structural work. A rolling wooden bridge was also fabricated to span the length of the work, facilitating access to the center of the painting. The painting was unrolled on the platform for examination and documentation, including detailed digital condition maps.

Consolidation

Solvent testing indicated that the paint surface was highly soluble in aromatics and blanched with aqueous solutions. The matte surface was visibly saturated and darkened with many consolidants. A solution of 10% Aquazol 200 in isopropanol and water (1:1), mixed 3:1 with 0.25% funori, achieved adequately strong adhesion for the flaking ground and paint layers. The incorporation of funori reduced the gloss of the consolidant, achieving an appropriately matte surface with no visible difference.[4] After initial introduction of isopropanol to the losses to aid flow, the consolidant was delivered with a small brush.

Looming

Once the ground and paint layers were stabilized, a temporary strainer, or loom, was devised to enable safer handling and the treatment of the planar deformations. Looming the painting allowed it to be humidified upright and under tension and enabled conservators to continuously adjust canvas tension as planar deformations were resolved. To account for the wide (up to 1 foot across) flattened fold-over edges, a 14-foot aluminum strainer was designed and fabricated from 1 1/2 inch hollow square stock by a local metalworking shop.[5] The strainer was designed with an internal bisecting stabilizing structure that could be removed for uninterrupted access to the verso. Flanges around the outer edges allowed it to be bolted to the floor for additional stabilization, if necessary, when the cross members were removed. The use of aluminum instead of wood provided rigidity and a lighter structure. To enable the efficient and gentle stretching and unstretching of the painting during travel, a Velcro system was selected in lieu of tacks or staples, thereby minimizing damage that would be caused by repeated piercing of the tacking edges. Velcro also provides a much faster method of stretching a large painting, enabling conservators to attach a 12-foot painting to a stretcher in a matter of minutes.[6]

The intermediate looming step presented a valuable opportunity for conservators to test the capabilities of the Velcro attachment system before incorporating it into the final edge-lining and stretching design. The strength of the nylon Velcro attachment as applied was calculated (with the help of mechanical engineer Dr. Lukasz Bratasz) and shown to be well over twice the shear strength that would be needed should the painting ever be displayed as a ceiling, taking into account both the weight of the canvas and an average stretching tension of 270 N/m.[7]

Fifty-six looming strips, each 4 1/16 inches wide, were fabricated to be placed 4 inches apart around the circumference of the painting. The strips were cut from polyester sailcloth. At one end, where the strip was to be attached to the painting, two layers of Beva 371 film were adhered and the edge pinked. Four-inch-wide "loop side" Velcro (Loop 1000) was sewn to the opposite end of the strips to attach the painting to the strainer. Nylon Velcro was selected over polyester Velcro because of its demonstrated use in conservation and longer cycle life.[8]

The looming strips were attached while the painting was faceup. Strip placement was guided by the use of a cardboard template to ensure that the attached strips established a radial line of tension from the center of the painting outward (fig. 24.3). To minimize flexing of the canvas support and to avoid applying heat to the easily burnished paint film, a flexible silicone heating mat was assembled using a commercially available product and basic wiring. Wired to a standard plug and connected to a rheostat for regulating the temperature, the mat could be slipped underneath the painting and looming strip to activate the Beva adhesive. The temperature of the mat and the surface of the painting were monitored with an infrared noncontact thermometer, and the rheostat could be adjusted accordingly. During Beva activation from the back of the painting, a metal plate cushioned with Volara and wrapped with Marvelseal was used to apply gentle pressure from the front and reflect heat back toward the painting. After the Beva was activated, the strips were cooled under a cushioned metal plate and weights.

The looming strips were attached 2 inches in from the tacking edge, over the tacking edge, and 2 inches past the tacking edge. The strips were not attached to the full length of the wide fold-over edges, as this was deemed unnecessary and some areas of canvas shrinkage prevented it. Rare earth magnets, cushioned with blotter and wrapped in Tyvek for easier removal, were used to

Figure 24.3 Cardboard templates, used to ensure that the attached looming strips established a radial line of tension. Image: Cynthia Schwarz

prevent flexing of the unattached tacking margins when the painting was placed upright.

The aluminum strainer was prepared by attaching the hook side of the Velcro (Hook 88) to both the side edges and verso with West Systems marine epoxy, providing two points of contact for the looming strips. Temporary cardboard supports were fabricated to level the front of the strainer so that the painting would not slump during stretching. These pizza slice–shape cardboard inserts were removable from the back. The painting was gently slid onto the strainer and stretched faceup with the Velcro looming strips—a process that, remarkably, took only a matter of minutes. This attachment system allows for minor adjustments to tension around the circle. Once stretched, the 14-foot loomed painting was placed upright on a large in-house fabricated easel, repurposed from another project (see fig. 24.1).

Humidification

Following looming, planar deformations and creases were resolved through humidification and drying under pressure. This step was completed with the painting upright, enabling access to the front and back of the work and allowing conservators to monitor the painting's surface. Upright humidification also allowed the painting to be periodically retensioned with the looming strips as the canvas deformations relaxed.

Three clear vertical panels composed of polycarbonate sheet stabilized with wooden frames were fabricated to provide a surface for the front of the painting during upright humidification (fig. 24.4). These panels were easily adjusted and movable using photographic light stands and adapted easels. The panels were covered in silicone-release Mylar and positioned against the face of the painting to provide a stable working surface during treatment. Damp blotters were positioned on the verso of the canvas and layered with Mylar and a metal plate. As one conservator held the blotter and metal plate in place, a colleague applied rare earth magnets to the panel on the front. The strength and number of magnets could be adjusted to apply variable amounts of pressure to the canvas and blotter.[9] The clear panels allowed conservators to monitor the front of the painting (fig. 24.5).

Figure 24.4 The painting during upright humidification treatment, using polycarbonate platforms as a flat surface and a variety of magnets as weights. Image: Cynthia Schwarz

Figure 24.5 Magnets holding a metal sheet on the verso of the painting during humidification (left) and the metal plates on verso (right). Image: Cynthia Schwarz

The canvas responded well to this system of controlled humidification. Conservators found that ten-minute exposures to a damp blotter, followed by controlled drying under dry blotters—forty-minute cycles of dry blotters switched three times—resolved many planar deformations. In areas where canvas creases and folds caused tented paint, a suction platen was used concurrently to coax the deformed paint layers into plane.

Modifications to the Original Strainer and Edge-Lining

Due to its large size, *The Hours* needed to be either rolled for travel and stretched at each venue or stretched onto a custom-built folding stretcher that allowed it to be shipped in its folded orientation. Fortuitously, the original wooden strainer, long dissociated from the painting, was discovered in YUAG's architectural fragments collection months before the treatment began. Conservators decided to reunite the painting with its original strainer for the exhibition of this work.

Although Abbey sometimes used folding stretchers for other paintings, such as *Columbus in the New World* (1906) in the YUAG collection, the strainer for *The Hours* disassembles into two half circles for transport. It is composed of six curved outer members joined together with bridle joints. The strainer was constructed to fit together in two halves along two long crossbars. The two halves were likely originally secured together with metal hardware, but the hardware and crossbars did not survive and had to be reconstructed in house.[10] The newly constructed middle crossbars join together lengthwise with a series of heavy-gauge bed bolts and threaded crescent washers, as well as biscuits for positioning. Additional heavy mending plates are used to reinforce all joins. Before stretching the painting, the original strainer was cleaned with cosmetic sponges, and minor splits were repaired with hide glue. Several damages to the perimeter of the strainer were filled with Araldite epoxy putty to ensure a smooth fold-over edge.[11]

The decision to use the original strainer requires that the painting travel on a roller and be restretched at both exhibition venues. To restretch the painting as noninvasively as possible at each venue, and encouraged by the success of the looming strips, conservators decided to use a nylon Velcro attachment for the final stretching. The softer, loop side of the Velcro is attached to an edge-lining, with the hook side attached to a Dibond panel screwed into the back face of the strainer. The two halves of the strainer were loose-lined with Trevira CS fabric to lend additional support to the canvas and provide a surface on which to unroll and stretch the painting during installation.[12]

Edge-lining was pursued to provide additional support to the tacking edges during stretching and unstretching and to serve as a means by which the painting could be attached with Velcro to the strainer. Mock-ups indicated that the circular shape of the painting, its wide fold-over edges, and the extra bulk from the Velcro would present several challenges during stretching. Conservators aimed to design an edge-lining system that would not add significant bulk to the edges of the painting, as it might become a hindrance during rolling.

To minimize excess material, the edge-lining was designed to take the form of segments, or strips, rather than one continuous piece of canvas. Edge-lining strips were designed to fit around the circumference of the circle and have tabs that fold over the back of the strainer. Twenty-four strips were constructed from Trevira CS fabric, Beva 371 film, and 6-inch-wide loop-side Velcro (Loop 1100) (fig. 24.6). The strips were designed to attach to the entire diameter of the tacking edge and 3 inches behind the face of the painting, providing continuous support around the edge of the work. To avoid creating excess bulk at the fold-over edges, the strips were designed with three tapered Velcro tabs calculated to fit together with no overlap when folded around and attached to the back of the strainer.

Figure 24.6 Uniform edge-lining strips cut based on a template created from acrylic sheet using a CNC unit. The template was then traced onto the fabric, ensuring that the Trevira warp direction was always oriented radially from the center of the painting to the center of the middle tab. Image: Kelsey Wingel

Using the ideal geometric measurements of the painting, a CAD design for the edge-lining was developed and, with the help of a CNC unit, a template was cut from acrylic sheet.[13] The template was traced onto the fabric, ensuring that the Trevira warp direction was always oriented radially from the center of the painting to the center of the middle tab. Two layers of Beva 371 film were applied to one side of the edge-lining strips, and the interior edge was pinked. Three strips of 6-inch-wide loop-side Velcro were sewn with heavy-duty polyester thread to the tabs on the opposite end of the edge-lining strip. To assist with the sewing process, the Velcro was first tacked in place with one layer of Beva 371 film.

The loomed painting was placed facedown onto a fresh bed of blotter and tissue for the edge-lining attachment. The looming strips were removed incrementally with a tacking iron, and the edge-lining strips were attached side by side, also with a warm tacking iron. Conservators used tacking irons of several different sizes and shapes to ensure that the edge-lining strips were well adhered to existing canvas folds and creases along the tacking edges. The Trevira conformed well to these small deformations. After attachment, the strips were cooled under metal plates and weight. Additional strips of Velcro were used to attach the edge-lining tabs to the aluminum loom, allowing the painting to remain under tension during most of the edge-lining process.

The 6-inch-wide hook-side Velcro (Hook 89) was attached to the back of the strainer by epoxying the Velcro to four curved pieces of Dibond aluminum composite panel. Attaching the Velcro to the panel rather than directly to the strainer presented several advantages: One, the aluminum panel, cut to match the shape of the strainer and to bridge the bridle joints, served to further stabilize the strainer. In addition, adhering the Velcro to the panel rather than directly to the strainer protected original chalk markings, inscriptions, and labels. The panel pieces were secured to the strainer with several strategically placed screws.

Stretching

In a carefully planned series of steps to prepare for stretching, the edge-lined painting was unloomed and the aluminum strainer removed (fig. 24.7) The two halves of the original wooden strainer were then placed on the verso of the painting to ensure a close fit. After it was ensured the painting would fit onto its strainer, the two halves of the strainer were loose-lined with Trevira CS fabric, and the painting was successfully stretched onto its strainer using the Velcro edge-lining.

CONTINUING WORK AND CONCLUSION

During the COVID-19 pandemic, treatment was halted on this painting for most of 2020, and it progressed slowly to accommodate social distancing guidelines. With the structural treatment nearly complete, the next steps include surface cleaning, filling losses with a flexible material, retouching, fabricating a travel roller, working with fabricators to construct a modular frame, navigating the logistics of international travel, and, finally, ensuring the painting is housed appropriately in long-term storage.

This treatment has been and continues to be a product of a team of conservators, fellows, interns, engineers, curators, fabricators, and consultants from across the museum and Yale University community. The complex treatments associated with this exhibition have led to technical innovation, as conservators have striven for

Figure 24.7 The painting in normal light in its present state. Image: Yale University Art Gallery

minimally interventive approaches that enable the international travel and display of Abbey's delicate, untouched works for the first time. Treatments have also facilitated the in-depth study of Abbey's unique painting technique and materials, contributing to an increased understanding of the working practice of American and British mural painters at the turn of the twentieth century.

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APPENDIX: SUPPLIES

Beva 371 film, Pellon, blotter

TALAS
https://www.talasonline.com

Velcro

Looming Velcro: 4 in. Loop 1000 and 1 in. Hook 88
HookandLoop.com
https://www.hookandloop.com

Edge-Lining Velcro: 6 in. Loop 1100 and 6 in. Hook 89
Industrial Webbing Co.
https://www.industrialwebbing.com

Rare earth magnets

For tacking edges: #NSN0683
For humidification: #NSN0582, #NSN0635, #NSN0642, #CUP0303
MAGCRAFT
https://www.magcraft.com

Trevira woven polyester fabric

Crea (previously Theatex)
https://www.creatheatertextiel.nl

West Systems epoxy

Epoxy resin #104 and Epoxy Hardener #206 and #209
West Marine
https://www.westmarine.com

Dibond 3 mm aluminum composite panel

3A Composites
https://3acompositesusa.com/products/dibond/

Silicone heating mat

Omega Engineering Inc.
No longer available from manufacturer; purchased on eBay

NOTES

1. *The Hours* is one of over three thousand studies on paper and canvas that came directly from Abbey's studio to Yale University in 1937. For more information on the history of the Abbey collection, see Hamilton 1939.
2. The metal leaf was characterized with X-ray fluorescence spectroscopy (XRF) by Dr. Pablo Londero and Dr. Marcie Wiggins using the facilities and equipment of the Yale Institute for the Preservation of Cultural Heritage. For more information on Abbey's materials and techniques, see Wingel et al. 2019.
3. Surface efflorescence is noticeably present on about half of Abbey's preparatory studies in the YUAG collection. The efflorescence on this painting was not analyzed, but it has been characterized on other Abbey

paintings as free fatty acids and metal soaps of zinc or lead. For more information, see Wingel et al. 2019.

4. The funori was prepared by an adapted purification process similar to the rinse, soak, heat, filter, and purify methods described in Swider and Smith 2005.

5. The aluminum strainer was fabricated by Promoco Manufacturing Co., 300 Morgan Lane, West Haven, CT 06516.

6. Many of the advantages of using Velcro for stretching large, traveling paintings are also discussed in McMillan 2005.

7. This value was chosen as a high estimate of tensions on a stretched painting from relevant literature, such as Iaccarino Idelson 2009. The shear strength of Velcro, 8 pounds per square inch, was provided by the manufacturer.

8. According to Velcro manufacturer specifications, nylon Velcro is rated "high" for cycle life, whereas polyester is rated "medium" (Velcro Brand Woven Fasteners Product Guide, https://www.hookandloop.com/media/wysiwyg/pdf_content/Woven-Fasteners.pdf). Gardiner and Weber reported that a "high" cycle life is able to withstand 10,000 closures (Gardiner and Weber 2010).

9. Although rare earth magnet vendors supply pull-force specifications, the force exerted on the canvas varies by the number and thickness of layers involved in a conservation treatment. For the purposes of this treatment, the magnets had to be strong enough to suspend the metal plate and blotters against the painting surface.

10. New pine crossbars and the center joining mechanism were fabricated by museum technician Paul Panamarenko.

11. This portion of the treatment was completed by conservator Sydney Nikolaus.

12. Trevira CS fabric is a woven polyester selected for its nice hand, low stretch on the bias, and inert qualities. Manufactured for the theater industry, it is available in 3 and 5 meter widths, making it ideal for loose-lining and lining large paintings. One of the authors was introduced to this fabric at the SRAL Mist-Lining Workshop in 2019.

13. The authors would like to thank Olav Bjornerud and Jason DeBlock for calculating and fabricating the edge-lining template. The template was cut with a custom ShopBot CNC unit in the YUAG fabrication shop.

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Issues with Congolese Paintings in Belgium's Africa Museum: Condition Assessment and Research in Transparent Lining

Emilie Desbarax, Freelance Conservator, Brussels, Belgium

As part of a master's program, the author examined a recently acquired collection of contemporary Congolese paintings at the Africa Museum in Tervuren, Belgium. After describing the context in which the paintings were made and their methods of production, often involving the use of unconventional materials, this paper considers the challenges for the collection's long-term safe handling, display, and storage. Possible approaches to its conservation are considered, including the use of transparent linings, as many of the paintings have important information on the reverse. Different techniques for transparent linings were researched. A representative treatment case study, where an appropriate transparent lining was required, is presented.

◆ ◆ ◆

INTRODUCTION

As part of the master's program at the École Supérieure des Arts (ESA) Saint-Luc University in Liege, I had the opportunity to research the collection of contemporary Congolese paintings at the Africa Museum in Tervuren, Belgium. This unique collection of two thousand paintings, including works by well-known artists such as Ange Kumbi, Chéri Samba, Tshibumba, Shula, Moke, Chéri Cherin, Thango, and Lubaki, chronicles the lives of Congolese citizens from 1968 to 2012. They were collected by Bogumil Jewsiewicki-Koss[1] and purchased in 2012 by the Africa Museum.

The first year of my master's thesis focused on historical research and the assessment of the recently acquired collection, including entering details of inscriptions and condition into a database. The main objective was to gain an understanding of the overall condition of the collection. This eclectic collection consists of paintings made with both typical and local recycled materials. The second year of my thesis involved the research of appropriate structural treatments to preserve the paintings for the future. (This led me to the studio of Olivier Nouaille[2] to follow Marion Guillermin's research on Petex and Nitex, synthetic, transparent canvases (Guillermin 2012).[3] Many of the paintings have inscriptions on the back, making the transparency of the lining materials a primary concern. A range of test samples was made and tested with synthetic adhesives, and the most promising results were used to treat one of the paintings in the collection.

This article is divided into three main sections. The first introduces the collection—its historical background, themes, and materials. The second outlines the collection's current condition. The third describes the treatment of one painting and its lining onto a transparent support.

THE COLLECTION

Popular Art—Art about People

> The term *popular art* comes from me; it's to say that our artwork is about the people's lives and will always be understood by everyone wherever they come from. You don't have to have been in academic school, because the message is direct and easy to understand. I wish I would have found a better word, because after a few years I realized that it was misunderstood. In the Western world, this word *popular* has another meaning, without any thoughts behind it, something without any research, and I was upset about it, because there is a research! Concerning the paintings, I'd like that everyone looks at the paintings without any judgment, prejudice, or anything and wherever they come from.
>
> —Chéri Samba (Our Choices Art 2017)

Congolese popular art originated from street advertising art (billboards), which began to appear in the late 1910s to early 1920s. The artists Lubaki and Djilatendo, whose work was noticed by gallerists in 1926, used natural pigments on the walls of houses that were made with clay and leaves. Unfortunately, these pictures didn't last, due to the fragile supports and materials chosen. They were painted to publicize stores or to denounce something in particular: painful, moral, and historical events that had caused concern. The biggest production of mural art was in Kinshasa. Through this art, the city—known as "Kin trash can" because of the quantity of waste materials found in the street—was revitalized.

The popular mural artists were encouraged to paint on canvases instead of the walls of houses, and that was the beginning of easel paintings in Congo. They were displayed in front of houses to attract clients. Once sold, the paintings were usually nailed to walls in bars or houses, and each painting sold funded the purchases of new painting materials.

Because the paintings were now portable, they were also able to travel around the world. Their inclusion in the Universal Exhibition of Brussels in 1958 attracted wide interest both locally and abroad. The Congolese became more aware of the importance of taking care of and conserving their paintings. At this time, the artists began to sign their artworks, and many exhibitions were organized to display these fascinating paintings throughout the United States and Europe. Concurrently, several academies of art were established.

- In the south of the country, the French artist Pierre Romain Desfossés (1887–1954) created the Elisabethville[4] School in 1946. Bela, a famous artist, was its first member. This was more a studio than a school, where everyone was free to paint what they wanted. Twenty years after the discovery of Lubaki, the precursor, Desfossés created the Hangar School with other well-known artists such as Pili-Pili, Mwenze, and Kibwanga. Desfossés died in 1954, and the Hangar fused with the Academy of Fine Arts of Lubumbashi.
- The Belgian artist Victor Wallenda (Frere Marc-Stanislaus) created the Saint-Luc School in 1943, in the western part of Congo. In 1948, the artist Laurent Moonens (1911–1991) arrived from Belgium, and the Saint-Luc School moved to Leopoldville (now Kinshasa). In 1957, it was renamed the Academy of Fine Arts.
- Farther north, in Brazzaville, the French collector Pierre Lods created the Poto Poto School in 1949.

As a result of these different schools, two categories of artists appeared: the self-educated and the academically educated. These artists were put under the spotlight by many patrons (Gilungula Pela Koy 1995; Turine 2007).

Ongoing Research

Jewsiewicki-Koss published extensively on Congolese art in the 1990s during his trips to many cities, including Kinshasa, Bunia, and Lubumbashi. He noted that the cities looked like huge art galleries of paintings. Three documentaries describing the artists' working conditions were made: two by Jewsiewicki-Koss in 1991, and one by the Flemish film director Dirk Dumont in 1989. Prints of these documentaries are stored in the Africa Museum in Tervuren, Belgium.

While many other relevant publications about Congolese popular art exist, I found few studies and little research focusing on the exact type of materials used and the deterioration of these paintings. The Africa Museum's collection was only recently acquired, and as there had been no prior condition assessments, I had the opportunity to take a closer look. I recorded the extent of the damage to the paintings in a database to focus any research on future conservation. My desire was to provide a conservation approach based on materials, rather than primarily theoretical art history.

To learn more about the deterioration of the collection, I needed more information about the materials these artists used and their techniques: How did they work? How did they choose their materials? Why did they choose these types of canvases? How did they apply their mixtures, and in which order? How did they view their artwork? What were their purpose and expectations? To answer these questions and others, I interviewed Jewsiewicki-Koss (Desbarax 2016), the previous owner, and Ange Kumbi,[5] one of the famous artists represented in the collection. It was essential for me to understand the collection before undertaking the research.

Themes in the Collection

> I was mimicking comic scenes. There was a magazine that everyone loved called *Jeunes pour jeunes*, and I would copy scenes from it and sell the drawings to my friends at school. But I told myself that drawing didn't allow me to earn much more money, so maybe I should do painting. Editors were looking for somebody who used a style that could be found in billboards in their paintings, and what I was doing was putting writing in my paintings.
>
> I named this kind of style the Sambain style. It meant paintings with writing. It seems that before me, such paintings didn't exist. Each of us has to have a specific style and be considered as a model, and my aim was to make what hasn't been made before. I noticed that people who were walking in the street didn't stop to look at the paintings, so I had to find a way to catch people's attention, to be more attractive. The real connoisseurs, my audience, was in the street. Especially those who stood in front of my paintings for a long time. If they read more slowly than me, they would stay a lot of time in front of it, so it was a success! What I'm interested in is to call conscience to mind and to give a moral meaning. I paint a reality that everybody knows. If it leads me to getting arrested because I tell the truth, it doesn't upset me, because this is what I want to paint.
>
> —Chéri Samba (Our Choices Art 2017)

The museum's collection features famous self-educated artists such as Ange Kumbi, Chéri Samba, Tshibumba, Shula, Moke, Chéri Cherin, and others from the Academy of Fine Arts, including Thango and Lubaki. The paintings by self-educated artists depict historical and moral topics (fig. 25.1) as well as the daily lives of the Congolese. The subjects represent the real lives of people: colonialism, prostitution, scenes of violence, AIDS and other diseases, political views, and the opinions, feelings, and sensitivities of people, as well as moments of daily lives—a visit to the hairdresser, an argument between a husband and his wife, a battle against mosquitoes, and many more quotidian scenes. They also show the humor in some situations.

Figure 25.1 Unknown Congolese artist, *Colonie Belge*, ca. 1960. Paint on canvas, 80 × 60 cm (31 1/2 × 23 3/5 in.). Described as "African; found in Kinshasa, in Democratic Republic of Congo." Africa Museum, Tervuren, Belgium. Image: Emilie Desbarax

The artists used very bright swaths of colors and painted pictures that expressed their own feelings and life experiences. Their messages were clear and direct, and they expressed themselves very simply to make sure that everyone could understand. This popular art is more experimental—and entirely opposed to—academic art, which has many rules and requires formal training. In contrast, the artists who graduated from academies preferred to paint botanical and animal subjects.

Materials and Condition

Several supports

> You know the working conditions were very bad before. I couldn't buy any canvases in art stores, because it was too expensive. I bought empty flour sacks with the money I got from working in serigraphy for a company.
>
> —Ange Kumbi[6]

I learned from Jewsiewicki-Koss that the artists had to sell a few paintings a week to survive. Their clients were poor. Jewsiewicki-Koss compared the price of a painting to the price of a few beers. This limited artists' choice in materials to what they could afford. They worked outside or in indoor areas, mostly using discarded materials that were found locally (Desbarax 2016).

The supports in the collection varied from flour sacks and other used fabrics, from curtains or tablecloths to torn clothing such as jeans. They were made from different types of yarn—cotton, flax, or hemp—of different thicknesses, density, colors, and states of preservation. There were both small- and large-size formats.

It is impressive that the backs of the paintings contain so much important historical information (fig. 25.2)—and sometimes the faces do as well—showing dates, inscriptions about the purchase, patterns, and brand details such as the trademark on flour sacks. Often the canvas had been crudely repaired by the artists, to strengthen the support before painting on it. When the support was already damaged and weakened, these tears form an integral part of the paintings. Fortunately, the unstretched paintings are now preserved in a stable environment and stored flat in large drawers.

Paint layer and techniques

> I stretched the flour sack during the process, and I put one or two layers of cold glue and let it dry. The second layer was a layer of house paint, which was watercolor. The meditation could start at this time; it wasn't easy to find a subject. I sang and went into a trance sometimes to be in my own world. When I'm inspired with a good theme it's like a gift, I'm so glad when it comes to me. I drew some shapes with a pencil, and after that, I used my brushes and painted with some inks found at the printer shop. It took a few months to finish a painting, because I liked to paint slowly, and with the inks it needed a few layers to be bright enough.
>
> —Ange Kumbi[7]

Figure 25.2 Reverse of a late 20th-century painting. Paint on canvas, 70 × 50 cm (27 1/2 × 19 5/8 in.). Described as "African; found in Democratic Republic of Congo." Africa Museum, Tervuren, Belgium. Image: Emilie Desbarax

According to Jewsiewicki-Koss (Desbarax 2016), a few artists made their own brushes and strainers. A painting without a strainer is cheaper, thus many of the paintings were unstretched. They didn't use varnish because it was too expensive. Apparently, some artists also used manioc flour mixed with water to make a ground layer, but often this coat cracked very quickly. Jewsiewicki-Koss reported that sometimes the artists made their own mixtures composed of acrylic or gouache, most likely house paint and maybe other unknown constituents added to palm oil. They mixed paint in pails and freely and quickly applied it to the canvas, the edges of which often show drips of paint. Paint layers were either thinly applied or had thick layers of impasto. Often the paint layer penetrated through the canvas due to the lack of a ground layer or because of the thinness of the support.

> By the way, I never tried to make my own brushes, because I bought them at the art store, not even the paint mixture with manioc flour or oil palm as Bogumil told. The famous artists, such as Moke, Bodo, Chéri Cherin, and others from the Academy of Fine Arts used the same paint found at the printer shop.
>
> —Ange Kumbi[8]

The heterogeneous mixture used looked plastic and grainy. The artists, in particular Chéri Samba, occasionally added fabrics with patterns or glitter that was stuck onto the paint layer. Since their aim was to spread a message, they didn't prioritize longevity in choosing their materials or focus on how the paintings were conserved or stored.

> The most important thing was the image, and everyone knew that the paintings lasted just a few years. When the paintings became too damaged, they were discarded.
>
> —Bogumil Jewsiewicki-Koss (Desbarax 2016)

THE COLLECTION'S STATE OF DETERIORATION

> It was expensive to exhibit my work in galleries, so I often had to display my paintings at the famous Bikeko market in Kinshasa-Gombe. The paintings were exposed to the hot sun the whole day, and the problem is that the inks I used weren't resistant to the sunlight, so the paint cracked very quickly. I think that was the reason behind the accelerated deterioration of the paint.
>
> —Ange Kumbi[9]

The consistent features of these artists' technique are that the supports are used without any preparation, and they are often frayed; the ground layer is a mixture that cracks quickly; and the paint layer is ink from a printer or composed of a heterogeneous mixture of house paint, palm oil, and other compounds. This combination has considerable potential for rapid degradation. To date, my observations are based on close visual examination, but this has led to a better understanding of the damage. Due to the diverse techniques and materials found, each of the paintings is unique and the alterations and the effects of deterioration differ greatly.

The paintings have aged and changed quickly over time. They are ephemeral, which is understandable considering the artists' intent was simply to spread their message and communicate with people through their art. However, this poses a real problem for conservation due to the use of recycled materials, which are not designed to be stable over time and not strong enough to support the variable movement of the materials during handling and climate fluctuations.

Supports

Supports were used as found and contained a lot of dust and grime. There are surface distortions, sagging, and loosening. There are corner draws and tension cusping. The edges and corners are frayed. The artists used what they could find for the canvas, and so the substrates are damaged from the beginning, many with significant tears. All these tears are made worse by frequent transportation and repetitive blows. There are a few networks of punctures and holes from nails. Generally, supports were not strong enough to support the weight of the painting.

Paint Layer

The materials used are not compatible enough to construct a stable painting. The composition and the conditions of the paint layers cause many issues, such as significant adhesion deterioration, leading to a loss of pictorial matter. The artists often painted on a canvas that was not cleaned before use and sometimes lacked a ground layer, so the paint layer didn't adhere well to the support or underlayers. There are many cracks in the paint layer and over the many seams. It is possible that those cracks are due to the mixtures used or to numerous movements during handling of the painting. Abrasions can be observed on the surface, as well as imperfections such as stains, drips, and grime. There are many lacunae in addition to flaking, powdering, or lifting, suggesting the paint mixture is probably underbound. As with much contemporary art, the conservation of such paintings is challenging and requires a new approach, in contrast to more traditional works where there is a series of layers that function more or less predictably and respond consistently to treatment.

Treatment Proposals

The origin of the supports, frequent transportation, and poor handling of the paintings have caused serious tears and cracks. Often the canvases were hung with nails in bars and houses, and they were moved without precaution. The artists exhibited the paintings on stretchers in front of their houses, then removed the stretcher and rolled up the canvases to be transported. Afterward, these paintings were not kept in a stable environment.

We know that there is never a standard recipe or procedure for treating a painting, and we are constantly being introduced to new materials, techniques, and insights to preserve paintings for the future. We also know that contemporary art conservation can be different from traditional forms of conservation. The paintings in this collection were not designed to last, and I saw that the collection was in desperate need of conservation. The main challenge for the conservation of ephemeral art is devising a treatment that will avoid changing the appearance of the artwork, which presents a huge range of issues. Many of the paintings have an adhesion problem that requires consolidation, and others need a strip-lining or a lining to stabilize the whole painting.

During my study, and after seeing the extent of the damage, I decided to focus my research on structural conservation in hopes of finding a suitable lining. The lining is necessary for the safe handling of these paintings for a loan—or even to remove the canvas from the sliding drawer for examination—and is essential to enable their future transportation. I selected one of the paintings in the collection, *Mami Wata* by Nkulu Tommy Emman, because it had a paint layer still in a good state, which allowed me to focus on a unique problem: the consolidation of the support.

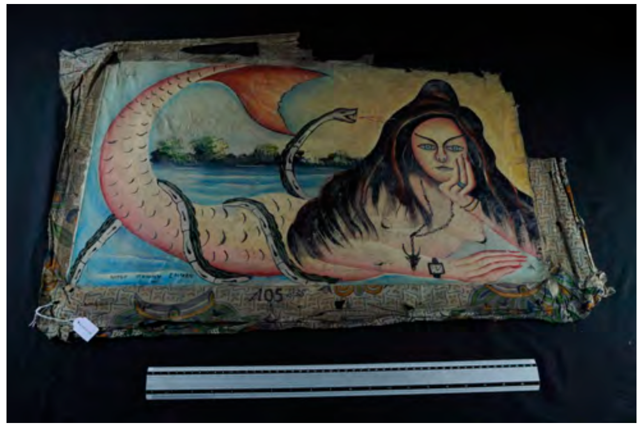

Figure 25.3 Nkulu Tommy Emman (Congolese), *Mami Wata*, ca. 1960. Paint on canvas, 83 × 54 cm (32 5/8 × 21 1/4 in.). Described as "African; found in Kinshasa, in Democratic Republic of Congo." Face, before treatment. Africa Museum, Tervuren, Belgium. Image: Emilie Desbarax

CASE STUDY: *MAMI WATA* BY NKULU TOMMY EMMAN

The painting chosen from the collection is a depiction of the water spirit Mami Wata (fig. 25.3) dating from 1960. It is signed by Nkulu Tommy Emman, an unknown artist. Jewsiewicki-Koss said that the name Nkulu was used by many painters, and it was a common name in Lubumbashi. The artists changed their signatures frequently, which makes attributions complicated. This painting might have been bought by a Congolese owner, probably in the Kasumbalesa market in the Democratic Republic of the Congo. Mami Wata is the goddess of rivers, revered in Congo, other parts of Africa, and Haiti and Brazil—and feared by fishermen. In the painting, she looks like a European mermaid, with white skin and blue eyes, the temptress of Western luxury, her idealistic beauty further signified pictorially by her wristwatch and jewelry.

The painting is executed on a thin cotton support patterned with flowers and measures 83 × 54 cm. Some information is written on the back: numbers, details of acquisitions, and notes (fig. 25.4). The paint layer appears to be acrylic that was thinly applied. There is no ground layer, varnish, or stretcher. It is currently stored and laid flat in a sliding drawer.

State of Preservation

A large area of the support was missing from the upper right corner, making handling difficult. There were also many rusted punctures due to the nails used to hang it. The edges and corners were frayed. There were some small tears to mend, lacunae in the paint layer, and some

Figure 25.4 Emman, *Mami Wata*, back, before treatment. Image: Emilie Desbarax

surface imperfections on the front side. The painting was grimy, there were a lot of cracks, and the canvas was distorted. The painting needed to be cleaned and lined (see fig. 25.4). The fact that we needed to keep the inscriptions on the back visible precipitated my research into transparent lining.

Transparent Lining: Past and Continuing Research

Some of the past research about transparent lining provided me with valuable information. In Knut Nicolaus's book, we read that in 1961 Boissonnas[10] proposed the use of fiberglass with a wax-resin lining or with Beva 371 (Nicolaus 1999). But fiberglass has some disadvantages: it is not stretchy enough, and it is almost impossible to repair holes or damage to the substrate. In 1981, Pacoud-Reme, with “three types of transparent linings done by G. Ten Kate for the paintings for the National Museum,” tested the fiberglass canvas with wax resin and a rigid support of methyl methacrylate (Pacoud-Reme 1981). In 1996, Berger referenced different kinds of synthetic canvases, such as Pe-Cap (polyester monofilament screen), but they were not transparent enough (Berger 1996).

In 2015, I followed the research by Marion Guillermin at Olivier Nouaille’s studio in Paris (Guillermin 2012). She used Petex[11] (polyester PET) and Nitex[12] (nylon PA), synthetic canvases that are monofilament open-mesh fabrics from Sefar Inc.[13] From the material properties provided by the manufacturer, both are stable in solvents. For abrasion and alkaline resistance, Nitex is better, whereas Petex is more resistant to acid. Unfortunately, their stability to light exposure is poor. However, the synthetic canvases are thin, elastic, easy to use, and almost completely transparent. Guillermin tested them with natural glue, but she didn’t apply her tests to real paintings.

For the paintings in the Africa Museum’s collection, I eliminated natural adhesives and traditional canvases due to their yellowing tendency and their lack of transparency, opting for the Sefar synthetic canvases and synthetic adhesives. The aim was to find a lining that had the necessary compatibility with the materials used in the paintings. The lining fabric had to be transparent, reversible, resistant to solvents, elastic, and inert (like Petex and Nitex), and the adhesive needed to be stable and reversible, transparent after drying, and easy to apply, such as Beva 371 film (65 µm) or Plextol B500 synthetic adhesive. One of the issues was to find a technique that did not smudge the ink on the back of the painting.

Accelerated Aging and Tensile Tests

Some samples were made in cotton with inscriptions written on the back in different types of ink to imitate the original painting. Some of these were adhered with Plextol B500 and others with Beva 371 film, and onto both Petex and Nitex. To control and assess the stability and sustainability of the materials for the lining, the samples were tested using Climacell accelerated aging equipment and through tensile testing with a dynamometer. The Climacell equipment simulates environmental conditions, and I chose to run the tests with 55% RH at 70°C over two weeks. Conducting these tests in extreme conditions—beyond what is normally recommended in conservation—allows us to quickly observe ambient changes due to heat and moisture.

After the period of exposure in the Climacell, noticeable changes were observed in dimensions, such as shrinkage, as well as change in appearance, such as yellowing, uncontrolled peeling, cracking, blistering, and other alterations. The results showed that Plextol B500 is not stable enough: the adhesive peeled off the canvas and air bubbles formed between adhesives and substrate. Beva 371 film stayed stable and uniform but yellowed slightly. With both adhesives, Nitex shrank slightly more than Petex. For the tensile tests, Plextol B500 on Nitex was more resistant; however, when I tested Nitex and Petex without adhesive and cotton, Petex was more resistant. These results helped me to choose Petex as a lining fabric for its good stability and strength, with Beva 371 film as adhesive for its good tackiness and uniformity. The painting was treated based on these results.

Treatment of the Painting

To prepare for the lining, the face of the painting was treated (see fig. 25.3). The first step was to smooth out local distorted areas using moisture, pressure, and heat, in particular on the face and around the edges. Afterward, I removed the dirt and dust and cleaned the paint layer with swabs moistened with demineralized water. The reverse was cleaned with a dry latex sponge.

For the lining, I laid the Petex on the hot table with one layer of Beva 371 film (65 µm), cut to the same dimensions as the painting. These two coats were heated for twenty-five minutes at 65°C, then I let them cool down to seal them. Next, I carefully positioned the original painting on the synthetic layers (Petex and Beva 371 film) and heated it at the same temperature and for the same duration. This treatment was successful. The lining is thin, easy to apply, transparent, and resistant to degradation over time (figs. 25.5, 25.6).

As a last step, I continued with the restoration: filling lacunae with the synthetic compound Modostuc and texturing some of the losses. The retouches were made with Gamblin Conservation Colors. From now on, the painting can be handled safely and easily. The support is consolidated, and the extra layer supports the whole painting without hiding the inscriptions (fig. 25.7).

CONCLUSION

The Africa Museum’s collection is fascinating due to the many characteristics and issues involved. The most important problem to solve was safe handling, which is why the research concentrated on the structural

Figure 25.5 Emman, *Mami Wata*, reverse, showing the transparent lining. Image: Emilie Desbarax

Figure 25.7 Emman, *Mami Wata*, face, after treatment. Image: Emilie Desbarax

Figure 25.6 Emman, *Mami Wata*, the transparent lining/canvas after treatment Image: Emilie Desbarax

treatment. The trial samples in cotton made with the transparent canvases Petex and Nitex, Plextol B500, and Beva 371 film were assessed using accelerated aging and tensile tests to discover the strength and the sustainability of these materials. Beva 371 film with Petex showed good properties. The results obtained were determined through the treatment of one of the paintings from the collection, which worked very well.

As this conservation treatment was unusual and atypical, my research allowed me to question my views on traditional methods of conservation and restoration. It also underlined the importance of painting materials and the importance of handling artworks with care for their future preservation. Today, restoring contemporary art is all about research and innovation, and we will always have to battle with ethics to find the best way to restore a painting. It was challenging to treat this ephemeral painting, and I gave it my best.

ACKNOWLEDGMENTS

I would like to thank the Africa Museum in Belgium for their trust and belief in me, which helped to make this work possible. Thanks to its paintings restorer, Françoise Van Hauwaert, for her knowledge and experience and for encouraging me to participate in the Conserving Canvas symposium. I would also like to express my special thanks and gratitude to the Getty Foundation and Conservation Institute and Yale University Art Gallery. They gave me the golden opportunity to display and publish this research.

In addition, for the amazing experience at Olivier Nouaille's studio with Marion Guillermin, I thank them both for sharing their research in transparent lining. My warmest thanks to Bogumil Jewsiewicki-Koss and Ange Kumbi for their interviews, which informed me about the collection. Thanks also to my professors, especially to M. Broers for his guidance and advice during the project. Finally, thanks to my precious reader, Martha Cox, for reviewing my text.

NOTES

1. Bogumil Jewsiewicki-Koss was born in 1942 in Poland. He is a historian, archivist, and art collector, and a specialist on Central Francophone Africa. He is also emeritus professor of history at Laval University, in Québec, and a researcher at Laval's Cultures–Arts–Societies Research Center. See Desbarax 2016.
2. Nouaille is a French teacher in art conservation at École de Condé in Paris.
3. Nitex and Petex are brand names of open-mesh fabrics from Sefar Inc.

4. Named for the city, now called Lubumbashi.
5. Ange Kumbi, interview with the author, April 4, 2019. Kumbi, a Congolese artist, was born in Kinshasa, and in 1970 was the first contemporary artist to set up a studio in Kinshasa.
6. Kumbi interview.
7. Kumbi interview.
8. Kumbi interview.
9. Kumbi interview.
10. H. P. Boissonnas (1894–1966) was an artist, art restorer, and photographer from Geneva.
11. Polyester = polyethylene terephthalate (PET).
12. Nylon = polyamide (PA).
13. Sefar Inc. headquarters are located in Switzerland. See https://www.sefar.com/en/.

26

Eighteenth-Century Canvases of Easel Painting from New Spain: The Case of the Apostolate Series of Atizapan, Mexico

Claudia Alejandra Garza Villegas, Head Conservator, Archdiocese of Tlalnepantla and Mexico
Naitzá Santiago Gómez, Conservator, Garza & Santiago Restauración, Mexico

The Church of Saint Francis of Assisi Atizapan, located in the Mexican state of Mexico, houses a series of mid-eighteenth-century easel paintings made in the Viceroyalty of New Spain representing eleven apostles, Saint Paul, Christ, and the Virgin Mary. The paintings all correspond with one another aesthetically and technically. The artworks were restored during a six-month period in 2018, during which time it was possible to study them in depth. It was noteworthy to be able to analyze this pictorial set from a single anonymous author who was in tune with artists such as Miguel Cabrera, Francisco Vallejo, and Patricio Morlete, among others. The paintings are exceptional documents that give us very specific information on the technical and material challenges faced by an artist from New Spain in the middle of the eighteenth century.

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INTRODUCTION

A series of mid-eighteenth-century easel paintings depicting eleven apostles, Saint Paul, Christ, and the Virgin Mary, housed in the Church of Saint Francis of Assisi Atizapan, in the Mexican state of Mexico, were restored in 2018. This afforded the authors the opportunity to study the set of paintings in depth.

The paintings, which appear to be the work of a single artist, date from Mexico's Viceregal period, and it is important to consider them in that context. The Spanish arrived in the Mexican territory in 1519, and two years later conquered the Aztec Empire. In 1524, the Franciscans reached the Americas—launching the Catholic evangelization process in the former Aztec capital of Mexico-Tenochtitlan (now Mexico City) and surrounding territories (López Mora 2011, 14).

Immediately after their arrival, the Franciscans started their evangelizing to the north of Mexico City, reaching the lands of Tlalnepantla, where they constructed their first church—the Church of the Corpus Christi—in the 1530s. About ten chapels that belonged to the Corpus Christi church were built some decades later. One of them was the chapel of San Francis of Assisi Atizapan, although the first chapel with that name was later demolished. The current church of Saint Francis was built in the 1750s.[1] That decade corresponds with the creation of the paintings, which suggests that the Apostolate series was made for the new church (fig. 26.1). In addition to these paintings, the church houses another group depicting saints known as the Doctors of the Church, which was painted by Carlos Clemente Lopez, a *cacique*[2] artist active during the eighteenth century (Ramírez Montes 2001, 106).

Figure 26.1 Interior of the Church of Saint Francis of Assisi Atizapan with four of the Apostolate series flanking the altar. Image: Claudia Garza / Archdiocese of Tlalnepantla

THE APOSTOLATE SERIES

We restored the apostolate easel paintings from June to November of 2018, during which time we were guided by the words of Cesare Brandi: “The restoration—always understood in the professional field—is the ideal methodological moment to ask new questions to the works and, with it, add knowledge around them” (Brandi 2000, 6).

The opportunity to analyze a pictorial set painted by a single anonymous author—not just a single painting—was remarkable. Among the advantages that a group of works such as this presented us were summarized by conservator and researcher Elsa Arroyo: “The artistic process and the way the materials were prepared for each strata of the paintings are indicative factors of the tradition of every artist and workshop of New Spain; therefore, technical studies are more relevant when they consider analysis of pictorial series, from the same artist or from the same context” (Arroyo Lemus 2017, 42).

The series represents the apostles with the instruments of their martyrdoms: Saint Peter, Saint Andrew, Saint James the Greater, Saint James the Lesser, Saint Bartholomew, Saint Philip, Saint John, Saint Jude Thaddeus, Saint Matthew, Saint Simon, and Saint Thomas. In addition to the apostles, Saint Paul, the Virgin Mary, and Jesus Christ were also painted. After cleaning the paintings, we realized that each included a part of the Apostles’ Creed. According to a legend based on the Acts of the Apostles, while gathered for Pentecost, they began to recite each of the articles of the Creed one by one (Schäfer 1983, 14) (fig. 26.2). (In addition to this series, a painting of Pentecost by Antonio de Torres hangs in the church, completing the discourse, even though it is the work of a different artist.)

The paintings correspond with one another aesthetically and technically and share the same basic materials. In each painting, the character appears full length and occupying the foreground and most of the composition. This type of representation recalls the way in which the Spanish painter Francisco de Zurbarán painted some of his characters, and it stands as one of the key features inherited from the Spanish pictorial tradition.

RESEARCH AND ANALYSIS

The artist began the composition and the coloring of the paintings on the reddish iron oxide ground layer. The brushstrokes are soft, and the artist used glazes in dark tones and more painting in the light colors despite the fact that the pictorial layer is very thin and has no impastos. As well as these features, the way in which the compositions were solved, along with the technical and pictorial sequence, correspond to eighteenth-century painting production (Mues Orts 2017, 57). Among the material evidence that helped us date the paintings is the presence of Prussian blue.[3] Although it is unknown when the pigment was first used in New Spain, a painting studied by the Diagnostic Laboratory of Works of Art at the National University of Mexico evidenced its presence by the mid-eighteenth century (Zavala Cabello 2013, 144). This anonymous series is also similar in painting technique to

Figure 26.2 *Saint Simon* painting with part of the Apostles' Creed in the lower right corner. Image: Claudia Garza / Archdiocese of Tlalnepantla

Figure 26.3 Canvas and strainer of the *Saint Simon* painting. Image: Claudia Garza / Archdiocese of Tlalnepantla

the works of contemporary artists such as Miguel Cabrera, José de Alzibar, Francisco Vallejo, and Patricio Morlete.

As some researchers have pointed out, information is lacking about the practice of painters in documents, so approaching the subject through material analysis is the best way to expand our knowledge of New Spanish artists' techniques (Mues Orts 2017, 57). For this reason, during the restoration we collected all the information we could about the paintings' materials and technique: they have the same format and measurements, stratigraphy—strainers, priming layers, color layers, and varnishes—and chromatic palette. All the paintings have a linen textile support attached with animal glue to the edge of wooden strainers composed of five elements (fig. 26.3). Forming the fabric are 12 × 11 threads per square centimeter, and there is a Z-twist in the threads in both warp and weft (fig. 26.4).

We also noted very specific information regarding the technical and material challenges our mid-eighteenth-century artist faced and solved, specifically the relation of the textile support to other elements of the paintings, including the following:

- The artist used the same method for all the paintings to attach the support to the strainer—using glue to adhere the support to the edge—but in some paintings he had to apply the original ground to the wood of the strainer to level the edges, because the fabric did not reach the outer edge of the strainer. This is painted over by the artist, so this process gives us important information that the paint was applied directly onto the canvas fixed to the permanent strainer. There are no extended edges in any painting.
- He also had to stitch together two different pieces of fabric to achieve the desired size to fit the strainer. All the paintings measure 160 × 120 cm.

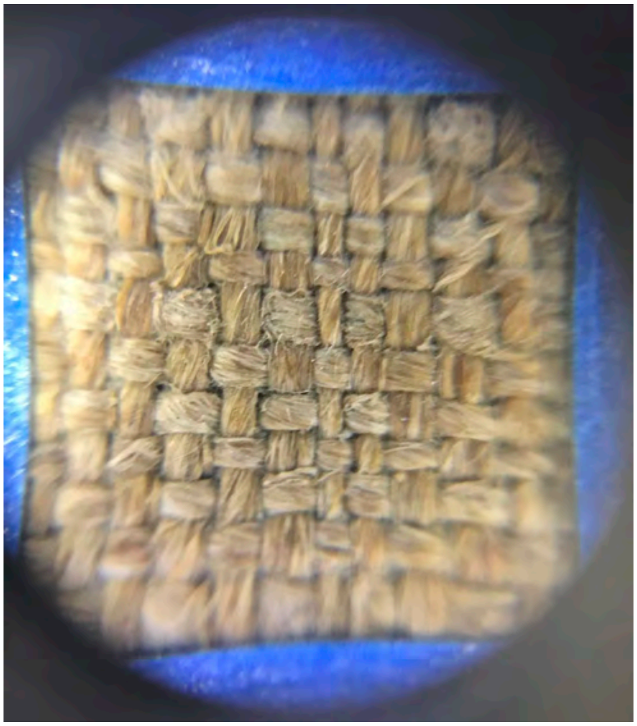

Figure 26.4 *Saint Simon* painting with fabric formed by 12 × 11 threads/c^2. Image: Claudia Garza / Archdiocese of Tlalnepantla

Figure 26.5 *Saint Simon* canvas showing ferro-gallic ink marks and patterns of perforations. Image: Claudia Garza / Archdiocese of Tlalnepantla

- Twelve of the paintings have regular patterns of perforations and marks made with iron gall ink (fig. 26.5).
- All the perforations and sewing were covered with cotton-rag paper by the artist.

After registering all these characteristics and doing additional research, we realized that the analysis of canvases had not been granted the importance it deserves. For example, many invasive processes have been carried out unnecessarily, such as wax-resin relining, practiced in Mexico since the 1970s, which resulted in important information being hidden or lost. The same thing happened to the original strainers: in almost every conservation treatment applied to a painting, they were discarded and a new one was substituted.

It is also important to establish the context of the canvases in New Spain as background, which refers back to the history of canvases in Spain. Rocío Bruquetas, in her important book *The Technique of Painting in the Spanish Golden Age*, writes that almost all the canvases used in Spain were imported from Germany, France, and the Netherlands, although some regions of Spain produced linen, such as Galicia, El Bierzo, and Medina de Rioseco (Bruquetas Galán 2007, 104).

Panel painting was gradually replaced by easel painting starting in the reign of Charles I (1516–56), but contracts and other documents are not very specific regarding the material characteristics of the canvases. However, it is possible to find allusions to certain processes, such as the tension of the canvas to the frame or strainer and the construction of corners and crossbars (Bruquetas Galán 2007, 232, 248).

In late seventeenth-century New Spain, some artists still painted on wood panels, depending on the painting's intended placement. If it were to be placed in an altarpiece, a wood panel probably would have been preferred. About such preferences, the painters' guild ordinances of 1587 mentioned that canvases shouldn't be reused and prohibited painting over an existing painting (Carrillo y Gariel 1946, 95).

With regard specifically to canvases in Viceregal Mexico, art conservator Rita Súmano is the only person to have studied in detail the canvases of New Spanish paintings. Her research was enriched by the analysis of more than a hundred paintings restored in the National School of Conservation. Thanks to her research, we know now that almost all New Spanish canvases from the seventeenth and eighteenth centuries were made from linen (Súmano González 2010, 4, 5). We also know that 13% of the canvases analyzed from the eighteenth century have patterns of perforations and, of that percentage, 40% do not have selvages, which she interpreted as a sign of a lack of materials (Súmano González 2010, 33). Importantly, the information we can obtain from the analysis of canvases also gives us information about their origin, distribution, and the loom that was used to make the textiles (Siracusano 2005, 18).

Trade between Spain and New Spain was fundamental in many aspects. Textiles were exported from Spain and other parts of Europe to New Spain, as were other materials, including pigments, lacquers, oils, and brushes (Arroyo Lemus 2017, 37). In the case of the canvases we studied, twelve of the fourteen paintings have reused textile supports, evidenced by the patterns of perforations and ferro-gallic ink marks already mentioned. These features provide specific clues as to the fabrics' acquisition by the artist: as mentioned, the paintings.

Objects traded between Spain and New Spain were marked by the cargador (importer). For example, lightweight sculptures made of cornstalks from the sixteenth and seventeenth centuries in New Spain are found in Spain. Pablo Amador found the mark of the cargador who brought such a sculpture of Christ from New Spain to Spain in 1673 (Amador Marrero 2012, 744). Many goods at the time were transported in bales wrapped in fabric (including linen), which were numbered and marked with the importer's initials. Artists obtained the linen wrappings to use as the canvas supports for their paintings.

A painting titled *The Customs Yard* from 1775, by Nicolas-Bernard Lépicié, depicts traders with their merchandise bundled in bales that have similar marks.[4] Another painting, one from the Basilica de la Virgen de la Soledad in Oaxaca, painted in 1740, depicts an ex-voto (votive offering) that expressed the donor's gratitude to the Virgin for her intercession after an earthquake. The donor of this interesting painting was a wealthy merchant, and, in accordance with his trade, the scene takes place inside his house, where some marked bales lie on the floor.

In light of this evidence, we concluded that the canvases of the Apostolate paintings were made from the linen coverings of bales, which the artist bought to paint on. These merchant marks are also found in other important New Spanish paintings, such as *The Release of Saint Peter* by Pedro Ramirez and Miguel Cabrera's *Holy Family* (both in the National Museum of the Viceroyalty), in works by Juan Correa, and in other, anonymous paintings, such as a Virgin of Guadalupe from the Convent of Santa Brígida in Mexico City.

In addition to the merchant marks, perforations in the canvases are related to the supports' original use. According to Paula Mues, "Repurposing canvases was also a common practice, whether by painting over existing works or by using fabrics that had defects or had been reclaimed from industrial processes. This explains why we often find canvases with a regular pattern of perforations, which were generally repaired by covering the holes with pieces of paper" (Mues Orts 2017, 57).

These features provided the guidelines to the conservation treatments applied to the canvases.

TREATMENT

We started by cleaning the surface of the canvas by removing dust and debris using a vacuum and brushes. Then we proceeded to eliminate newer interventions on the canvases, such as several patches made from different types and colors of textiles. When we removed them, we realized many were not the appropriate size, and some weren't even covering a hole or tear but were simply adhered to strengthen the surface. Over some small holes we applied linen fibers with glue paste.

Most of the canvases had deformations. To eliminate them, we applied moisture and pressure, allowing the canvas to return to its original flat state.

The corrosive nature of the iron gall ink markings on the back of the supports caused some deterioration and tears in the textile. To care for this damage, we had to find a method that allowed for the stabilization of the canvas without covering the information in the marks (fig. 26.6a). We used silk crepeline, with Beva as an adhesive. As a thin, transparent textile with good mechanical resistance, the silk crepeline made it possible to conserve both the materials and the information (fig. 26.6b).[5] Finally, for the holes of the paintings without iron gall ink marks, we used linen patches with frayed edges, adhered with glue paste.

a b

Figure 26.6 *Saint Matthew* painting: canvas with iron gall ink marks. (a) Before treatment. (b) After treatment. Image: Claudia Garza / Archdiocese of Tlalnepantla

CONCLUSION

Conservators usually treat isolated paintings or less numerous sets than the Apostolate series. In this case, having in our hands a series of fourteen paintings, we were able to find similarities and correspondences between technical and material solutions. Although several of these characteristics are common in the pictorial production of New Spain, it is very important to emphasize that these features determine the kind of intervention to be performed, which must always respect the original materials and should strive for minimal intervention.

Most studies on Viceregal painting focus on the works by important known painters. However, as our case study demonstrates, anonymous paintings have much to offer as well. This series, which could have gone otherwise unnoticed, has allowed us to collect important information that provides valuable historical data concerning the artist, how he worked, and the ways in which he obtained his materials almost three hundred years ago. Finally, we would like to emphasize the importance of sharing knowledge and experiences in publications such as this one, which allows us to disseminate results, both positive and negative, because it enriches us not only as individuals but also as a community.

ACKNOWLEDGMENTS

We would like to thank the organizers of the Conserving Canvas symposium, Yale University and the Getty Foundation, for their efforts and interest in our work. We are also very grateful to Monsignor Carlos Samaniego, who was the parish priest of the church that houses the series of paintings discussed in this presentation. Our thanks also to Cardinal Carlos Aguiar Retes for his trust, and to Dr. Pablo Amador for being a friend and for sharing his knowledge with us.

NOTES

1. Documents about the construction of the new church are housed in the Historical Archive of Tlalnepantla; they deal with a lawsuit involving the benefactors of the church. Personal communication with Rebeca López Mora, historian in charge of the archive and a specialist in the history of Tlalnepantla, May 5, 2018.
2. A high-caste Indigenous person. See https://read.dukeupress.edu/hahr/article/76/3/475/144916/The-Caciques-of-Tecali-Class-and-Ethnic-Identity.
3. We did not carry out analyses, but the blue shades achieved are typical of this pigment.
4. Collection of the Thyssen-Bornemisza Museum in Madrid; see https://www.museothyssen.org/coleccion/artistas/lepicie-nicolas-bernard/patio-aduana.
5. In 2017, we visited the studio of Matteo Rossi-Doria, in Rome. He kindly shared his knowledge and materials with us for the treatment of textile supports, and we are very grateful to him for sharing this silk crepeline technique with us.

V

The Adhesives Question

27

Nanocellulose and Multilayered Nanoparticles in Paintings Conservation: Introduction of New Materials for Canvas Consolidation and a Novel Multiscale Approach for Their Assessment

Alexandra Bridarolli, Eastman Dental Institute, University College London
Marianne Odlyha, Department of Biological Sciences, Birkbeck College, London
Oleksandr Nechyporchuk, Department of Chemistry and Chemical Engineering, Chalmers University of Technology, Gothenburg, Sweden
Krzysztof Kolman, Department of Chemistry and Chemical Engineering, Chalmers University of Technology, Gothenburg, Sweden
Romain Bordes, Department of Chemistry and Chemical Engineering, Chalmers University of Technology, Gothenburg, Sweden
Krister Holmberg, Department of Chemistry and Chemical Engineering, Chalmers University of Technology, Gothenburg, Sweden
Gema Campo-Francés, Facultat Belles Arts, University of Barcelona
Cristina Ruiz-Recasens, Facultat Belles Arts, University of Barcelona
Manfred Anders, Zentrum fur Bucherhaltung, Leipzig, Germany
Aurélia Chevalier, Aurelia Chevalier Atelier, Paris
Piero Baglioni, Department of Chemistry and Center of Colloid and Nanoscience (CSGI), University of Florence
Laurent Bozec, Eastman Dental Institute, University College London; Faculty of Dentistry, University of Toronto
Giovanna Poggi, Department of Chemistry and Center of Colloid and Nanoscience (CSGI), University of Florence

In recent years, nanocellulose-based products and multilayered nanoparticles have emerged as new solutions for the consolidation of canvas-supported paintings. This paper focuses on these recently developed treatments as applied in the framework of the European Commission's Horizon 2020 project Nanorestart. It provides a summary of their properties, advantages, and disadvantages in terms of ease of application, reinforcement provided, visual appearance, and stability. Physicochemical and mechanical results of the tests performed in the past couple of years are presented. The treatments can be divided into three categories—pure nanocellulose, nanocomposite, and multilayered nanoparticles—characterized by different compositions, degrees of penetration, and modes of consolidation. This project has used a systematic multiscale approach to review the potential of new consolidants for the structural consolidation of canvas-supported paintings. An overall account of the benefits of each consolidation approach is presented on the basis of previously published work. It is anticipated that these treatments will offer an alternative to lining and consolidants currently in use and prevent the recurrence of the issues highlighted at the Greenwich conference.

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INTRODUCTION

Recently, new developments in paintings conservation have seen the introduction of nanocellulose (NC; nano-size clusters of cellulose chains) and multilayered nanoparticles as more compatible treatments for the consolidation and deacidification of canvases of modern and contemporary paintings (Nechyporchuk et al. 2018; Xu et al. 2020; Baglioni et al. 2013). These nanoparticles have raised significant interest for their astonishing mechanical, optical, and barrier properties, as well as their high tunability through functionalization (Ly et al. 2008; Dufresne 2017). More specifically, the shared cellulosic nature of the nanocellulose-based treatments and the treated material, together with the small particle size, ensures a high compatibility between nanocellulose and canvas substrates to be treated. In that respect, they can offer an alternative to current adhesives used in conservation (e.g., animal glue, wax resin) and the risks associated with their poor reversibility and degradation (Bomford and Staniforth 1981; McGlinchey et al. 2011; Feller, Curran, and Bailie 1981). However, the mode of interaction between these new biopolymers and existing canvas cellulose fibers needs to be understood in far greater detail in order to advise both materials scientists and conservators about the merits and limitations of these new materials.

In the framework of the Nanorestart project,[1] a range of nanoproducts were developed as consolidants (Bridarolli 2019; Nechyporchuk et al. 2018; Palladino et al. 2020; Xu et al. 2020). They included, first, nanocellulose-based products with the aqueous dispersions of cellulose nanofibrils (CNFs), carboxymethylated CNFs (CCNFs), and cellulose nanocrystals (CNCs), as well as composite materials made of mixtures of CNF or CNC and cellulose derivative (e.g., methyl cellulose) in polar or apolar solvents. They also encompassed multilayered nanoparticles with a central inorganic core and two organic layers, the outer one being of cellulosic nature.

The mechanical and physicochemical properties of the nanocellulose-based consolidants for canvas were assessed and compared to traditional consolidants used in conservation such as natural (animal glue) and synthetic polymers (Paraloid B-72, Plexisol P 550, Beva 371, Aquazol 200) (Bridarolli et al. 2020; Nechyporchuk et al. 2018). Preliminary tests were performed on a model aged cotton canvas. The morphological, chemical, and mechanical properties of the canvas samples before and after treatment were evaluated by field emission gun scanning electron microscopy (FEG-SEM), tensile tests, and dynamic mechanical analysis under controlled RH cycling (DMA-RH) (Bridarolli et al. 2020; Bridarolli 2019; Bridarolli et al. 2018b). Additionally, atomic force microscopy (AFM) was used to nondestructively quantify the adhesion between the different compounds of this multilayered structure (Bridarolli et al. 2018b).

Finally, assessment of the newly developed consolidants, including the nanocellulose and multilayered particles, was performed on sacrificial historical paintings to validate the results obtained on the cotton canvas mock-ups. The consolidation achieved was also quantified by DMA-RH. Variations in the visual and aesthetic appearance of the treated paintings and the handling properties of the different nanoproducts were evaluated, as they were also deemed essential by conservators.

MATERIAL AND METHODS

Canvases

Two plain-weave canvases were selected (modern cotton and historical linen). Cotton canvas, 341 $g/^2$ density and 9 and 11 threads/cm in the warp and weft directions, respectively, was purchased from Barna Art (Barcelona, Spain) and artificially aged before testing, reaching a degree of polymerization of 450. This was to mimic the state of degradation of a painting canvas for which consolidation treatment would be required (Oriola et al. 2011). The aging protocol involved immersing the canvas in concentrated hydrochloric acid and hydrogen peroxide for three days, as reported elsewhere (Nechyporchuk et al. 2018).

Linen canvas (ca. nineteenth century), previously used as a lining canvas, with dense weaving (20 and 23 threads/cm in warp and weft, respectively) and density of ~310 g/^{2} was also tested. The canvas was dusty and impregnated with glue (probably proteinaceous), and was therefore washed in hot water (50°C–60°C) prior to the experiment. Excess glue was scraped off the surface with a scalpel, and the canvas was left to dry under no tensioning. The threads of this canvas were thinner than the threads of the new cotton canvas and of irregular diameter.

Treatments

Three treatments were used: pure nanocellulose, nanocomposite, and multilayered nanoparticle (NP) consolidants, as presented in figure 27.1. Details of the treatments can be found in the Technical Information appendix.

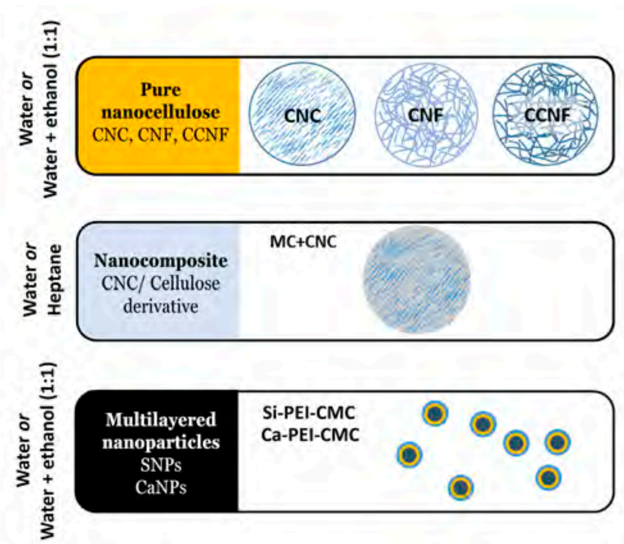

Figure 27.1 The three nanocellulose-based treatments developed and tested for canvas consolidation: pure nanocellulose dispersions (from Chalmers University of Technology, Gothenburg, Sweden), CNC nanocomposites (from Zentrum fur Bucherhaltung (ZFB), Leipzig, Germany), and multilayered nanoparticles (from Chalmers University of Technology, Gothenburg, Sweden, and CSGI, Florence, Italy). Image: Alexandra Bridarolli

Pure nanocellulose treatment (solution 1)

The consolidating materials consist of cellulose nanoparticles dispersed in water or a 50:50 water-ethanol solution. These can be highly crystalline, as for CNC, or less crystalline, as for CNF and CCNF. Originally extracted from wood, the particles' size and surface properties depend on the extraction methods used and chemical functionalization. CNFs and CCNFs (chemically modified CNF) are long cellulose fibrils. In contrast, CNCs, obtained after the dissolution of the amorphous phase of cellulose through acid hydrolysis, are typically smaller NPs in the shape of a rice grain. CNCs are 7.5 ± 2.8 nm in diameter and ~0.5 μm in length; the CNFs are 7.0 ± 2.8 nm in diameter and longer than CNCs, with lengths of several micrometers. CCNF corresponds to CNF particles chemically modified to obtain CNF with carboxymethyl groups along the cellulosic chain. The particles are usually similar in size to CNF with fibrils of several micrometers in length but are also much thinner (2.4 ± 0.9 nm diameter) (Nechyporchuk et al. 2018). Combined with a higher surface charge density, CCNFs yield thicker suspensions.

Nanocomposite treatment (solution 2)

The second solution consists of a methyl hydroxyethyl cellulose–CNC nanocomposite (MC+CNC) in water (w) or in heptane (h) following silylation (Böhme et al. 2020). Methyl hydroxyethyl cellulose is an adhesive commonly used in paper conservation and has proven to be stable over time (Feller and Wilt 1990). It is a very hygroscopic material with excellent adhesion properties but reduced stiffness. As a result, its use as a consolidant is inadequate, and it requires the addition of a nanocellulosic filler. A small amount of nanofiller (from 5% to 15% in weight) added to materials in diverse areas from construction (concrete) to food science has been shown to improve their mechanical properties and reduce hygroscopic behavior (Azeredo et al. 2010; Kaboorani et al. 2016; Svagan, Hedenqvist, and Berglund 2009).

Multilayered nanoparticle treatment (solution 3)

The last solution proposed for canvas consolidation consists of polyelectrolyte-treated silica nanoparticles (SNPs) and $CaCO_3$ NPs (CaNPs). Silica nanoparticles have already proven to be good candidates for textile and paper reinforcement (Gärdlund, Wågberg, and Gernandt 2003; Tan, Tay, and Teo 2005) due to their small particle size and the possibility to chemically modify their surfaces to tune their affinity for cellulose fibers, while alkaline nanoparticles have been widely used for the deacidification of textiles and paper (Giorgi et al. 2002; Baglioni et al. 2013). The mixture of CaNPs and SNPs was designed to address mechanical reinforcement and deacidification with a single-step treatment. Both types of nanoparticles are functionalized first with a cationic polyelectrolyte (PEI) and then, as the outer layer, by the anionic sodium carboxymethyl cellulose (CMC). The detailed preparation procedure is reported elsewhere (Kolman et al. 2017, 2018; Palladino et al. 2020).

Table 27.1
Results of tensile tests performed on degraded cotton samples treated with the three solutions of nanocellulose-based consolidants and information on samples.

Solution	Sample preparation	Sample	Concentration in solution (% w/w)	Weight uptake (%)	Applications (no.)	Tensile test conditions	Young's modulus (MPa)*
1	Spray	Untreated	—	—	—	• Preconditioning at 20% RH • Testing under controlled environment (20% RH, 25°C) • Speed = 0.4 N/min. • Warp direction	2
		CNF	1		3		24
		CCNF	0.25		3		8
		CNC	3		3		36
	Brush	Untreated	—		—		2
		CNF	1		4		23
		CCNF	1		4		24
2	Brush	MC + CNC (water)	1.98		3		16
		MC + CNC (heptane)	1.98		Unknown		7
3	Spray	Untreated	—	—	—	• Preconditioning at 60% RH • Testing under controlled environment • Speed = 300 N/min. • Weft direction	26
		SNP	4.5	8.6	2		55

Sources: Solution 1—spray preparation: Nechyporchuk et al. 2018; brush preparation: Bridarolli et al. 2020. Solution 2—preparation: Bridarolli 2019. Solution 3—preparation and data: Kolman et al. 2018.

*The stiffness (Young's modulus) reported for solutions 1 and 2 samples was measured in the region of interest (0%–2% elongation). The data shown for solution 3 were taken from Kolman et al. 2018 and Young's moduli calculated from the beginning of the curves (0%-4% elongation).

Table: Alexandra Bridarolli

Solutions 1 and 2 were applied to degraded cotton canvases by spraying and brushing and solution 3 by spraying only. The amounts applied resulted in weight uptakes of the canvases between 1.8% and 22.1% (table 27.1).

FEG-SEM

The structural analysis of the treated samples was carried out using a Philips XL30 field emission scanning electron microscope (SEM) (FEI, Eindhoven, Netherlands) equipped with an energy dispersive X-ray analysis (EDX) detector (Oxford Instruments [United Kingdom]). The system was operated at 5 kV accelerating voltage. Samples (3 × 5 mm) were mounted on aluminum stubs (Agar Scientific, Essex, U.K.) and sputtered with a gold-palladium alloy (Polaron E5000 sputter coater) for one and a half minutes.

Tensile testing: Quantification of the reinforcement

Samples of degraded cotton canvas were measured by tensile testing at 20% RH (25°C) in the warp direction to investigate the impact of the treatments on the less stiff direction of the canvas. They were typically 0.7 thick × 7 × 15 mm and cut so that the width contained 10 warp threads. The measurements were performed using dynamic mechanical analysis (DMA) (Tritec 2000B, Lacerta Technology, U.K.) with a load applied at 0.4 N/min. up to 6 N.

DMA-RH cycling: Assessment of the hygroscopic behavior of untreated and treated canvases through measurements of their mechanical response to RH variations

DMA-RH cycling was performed under programmed RH and fixed temperature (25°C) conditions to assess the mechanical response of the canvases to fluctuations in RH.

Canvases made of natural or synthetic fibers are viscoelastic materials, meaning that their mechanical response to external stress depends on the rate of stress applied in tensile tests or frequency. It also means that they can exhibit both elastic and viscous behaviors. DMA was introduced into the evaluation of paintings conservation to measure both the elastic (storage) modulus, *E′*, and viscous (loss) modulus, *E″*, components in the mechanical response of samples from paintings. Its first use was to measure the glass transition temperature of paint films (Hedley et al. 1991), and was subsequently used in studies of painting canvases (Odlyha, Chan, and Pages 1995; Foster, Odlyha, and Hackney 1997).

For this study, a new protocol was developed (involving programmed RH cycling between low and high RH levels) based on studies of the viscoelastic response to RH variations of electrospun nanocellulose composite nanofibers by Peresin et al. (Peresin et al. 2010). This protocol was recently applied to evaluate the effects of environmental conditions and conservation treatments on painting canvases (Bridarolli et al. 2018a, 2020). The RH range for the tests (from 20% to 80% RH) was selected so that the current study could be correlated with previous studies on the response of painting materials to moisture, which often take values between 10% and 90% RH (Andersen 2013; Hedley 1988; Mecklenburg 2007a; Wood et al. 2018).

Canvas samples, typically 7 × 15 mm, were tested in tension at 1 Hz in the warp direction. A preload (1 N) was applied to avoid buckling of the samples.

DMA at fixed RH: Assessment of the mechanical consolidation of historical lining canvas

A protocol was developed specifically for the historical linen canvas to enable testing the sample nondestructively before and after application of the treatments. DMA testing was used instead of tensile testing (for the latter, plastic—hence irreversible—deformation is usually applied). This was essential due to the irregular structure of the canvas and inhomogeneous distribution of remains of glue. Samples (15 × 7 mm)—cut in the same direction and impossible to identify as warp or weft—were clamped before the treatment application on a weighing boat cut into a frame to avoid shrinkage or deformation. The same amount of treatment, resulting in a 3% added weight, was applied to each clamped canvas sample and spread using a spatula. The storage modulus (*E′*) of the linen canvas samples was measured three times before and after the application of the treatments (left to dry for two days) at constant RH and temperature (30% RH, 25°C), chosen as typical room conditions. Each sample was preconditioned overnight at 20% RH prior to the tests.

RESULTS

Appearance, Mode of Deposition, and Role in Consolidation Achieved

Pure nanocellulose treatments (solution 1) form a thin layer of a few microns on top of the canvas (fig. 27.2). Previous studies also reported this observation, adding that the CNC coating was particularly dense compared to the two other treatments (Nechyporchuk et al. 2018). They also observed the formation of interfibrillar bridges between fibers of the treated surface (Bridarolli et al. 2018b). The roughness of the canvas also seems visually reduced. For this specific treatment, the results in terms of deposition/penetration showed were independent of the mode of application (spray or brush), but this was not the case for results with solutions 2 and 3. Greater penetration of the treatment was achieved for the aqueous nanocomposite treatment MC+CNC (w) when brushed on (see fig. 27.2). In a separate study, a fluorescent dye (rhodamine B) was used mixed with the treatments (Bridarolli 2019). This approach enabled us to follow the penetration of the treatment in the canvas and observe that an almost complete impregnation of the canvas could be achieved. Spraying the treatment, instead of brushing it on, limited the penetration to the very first micrometers of the treated surface, resulting in a surface coating similar to that obtained with the pure nanocellulose consolidants. The hydrophobic MC+CNC (h) also showed limited penetration, probably caused by the high viscosity of the treatment and its fast drying time.

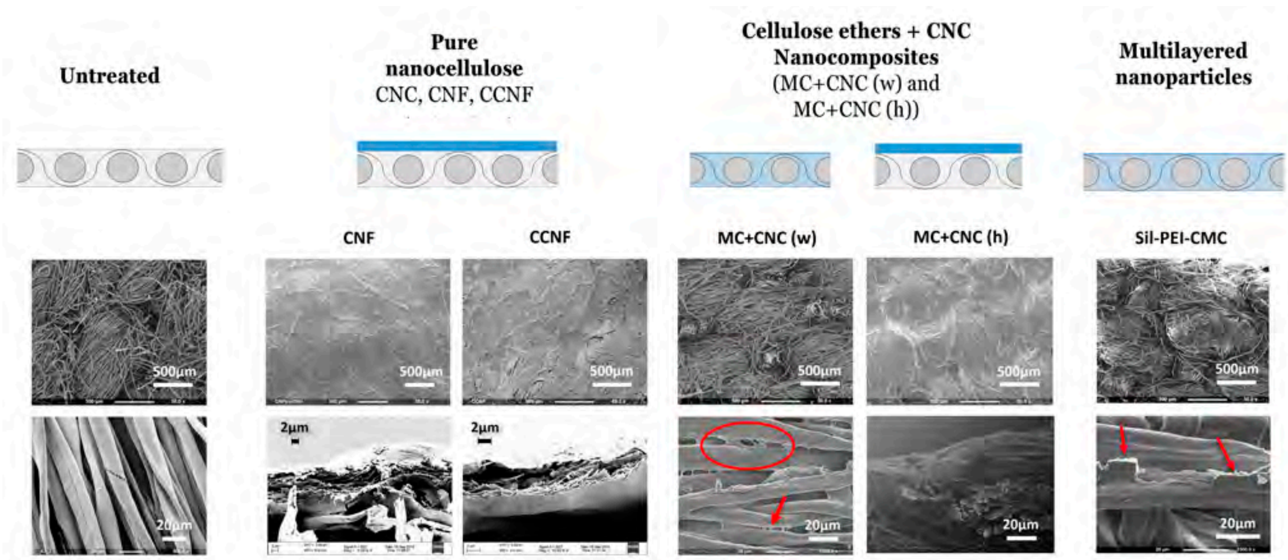

Figure 27.2 SEM images of the modes of deposition for the consolidation treatments. Presence of interfibrillar bridges is indicated by red markings. (w) water; (h) heptane. Image: Alexandra Bridarolli and Oleksandr Nechyporchuk

Multilayered NPs sprayed onto degraded cotton canvases tend to be homogeneously distributed across the surface of the canvas's fibers and to form homogeneous monolayers (Kolman et al. 2018). Interfibrillar bridges made of dense agglomerate of NPs were also observed by SEM (red arrows in fig. 27.2, solution 3) and could participate in the consolidation by locking the fibrous structure. Kolman et al. also observed the high penetration achieved for the NPs using micro-X-ray fluorescence but stressed the role of viscosity as a limiting factor (Kolman et al. 2018). For concentrations above 4.5% w/w in water, the NPs remained on the canvas surface.

CONSOLIDATION

The increase in stiffness was used to rank the effectiveness of the consolidation provided and was calculated in the range of 1%–2% elongation, which is what is typically used to restretch canvases (Mecklenburg 1982). This decision was driven by the understanding that in any painting in need of consolidation due to a very weak canvas, both the paint and ground layers are no longer supported by it, and it is the ground layer that acts as a supporting medium. Effective consolidation of the canvas should, therefore, ensure that the stiffness of the canvas matches that of the ground and paint layers it supports. A similar response to moisture as that of the original canvas or ground and paint layer should also be favored, as any deviation in this response may result in the creation of significant internal stresses, which ultimately lead to mechanical failure. The Young's moduli reported in table 27.1, and measured from the tensile curves, show that higher stiffness (hence consolidation) was attained with the pure nanocellulose treatments than with the nanocomposites. The reinforcement provided was not influenced by the method of application (brushing or spraying).

Kolman et al. also reported higher consolidation achieved on degraded cotton canvas for the multilayered NPs than for the CNF treatment (Kolman et al. 2018). However, these results cannot be directly compared to those shown for solutions 1 and 2, as the experimental conditions and direction of testing used differed between the tests (see table 27.1). The stiffness achieved by all the treatments proved to be adequate, as considered by the conservators. Nechyporchuk et al. reported similar values of stiffness for CNF-, CCNF-, and CNC-treated degraded cotton canvases compared to sized and primed degraded cotton canvases measured in the weft direction (Nechyporchuk et al. 2018).

Penetration, Cohesion, and Adhesion

The performance of the consolidants relies mainly on their penetration, adhesion, and cohesion, which could, therefore, be tuned to improve the reinforcement provided. The penetration of the treatments can affect the reversibility of the treatments, but it also plays a role in the consolidation achieved, its efficiency, and its stability. As reported in table 27.1, a lower consolidation is achieved by the nanocomposite treatments compared to the pure nanocellulosic treatments for the same weight added. This could be explained by the fact that because of the higher penetration of the MC+CNC (w) treatment, a greater amount of treatment is required to fill up the canvas volume and reach a reinforcement equivalent to the one provided by CNF, CCNF, and CNC. Regarding the pure nanocellulose treatments, which behave as surface coatings, the consolidation is provided by this additional stiff layer.

The role of adhesion was demonstrated in a study on CNF-reinforced cotton canvases (Bridarolli et al. 2018a). Using atomic force microscopy (AFM) to quantify the adhesion forces between canvas and treatments, it was demonstrated that the addition of a cationic polymer between the canvas and the CNF improved adhesion and resulted in increased efficiency of the nanocellulosic consolidation. However, since the polymer was also associated with a strong yellowing of the canvas, this consolidation strategy was discarded.

The last important factor affecting the consolidation is the cohesive properties of the material. Examples are the pure nanocellulose treatments, whose efficiency could be undermined by their loss of cohesion due to brittleness. As highlighted in past studies (Bridarolli et al. 2018b; Nechyporchuk et al. 2018; Bridarolli et al. 2020), sudden discontinuities in the stress-strain curves result from rupture of coatings formed by the pure nanocellulose, whether sprayed or brushed on the canvases. The mechanical failure of the treatments could occur at elongations above 1.5%, which is within the 1%–2% range typically used to restretch canvases (Mecklenburg 1982). These observations highlight the risks of gradually losing the reinforcement provided over time due to repetitive handling, transport, and mechanical stresses caused by significant environmental variations. However, if they are applied in large enough quantities, it is expected that the rupture of the coating might occur at greater elongation—beyond the typical 1%–2% range used in conservation.

By observing the high penetration and bulk consolidation reached by multilayered NPs in degraded canvas, Kolman et al. suggested the use of this treatment in combination with pure nanocellulosic treatments (Kolman et al. 2018). The canvases tested with this mixture showed increased consolidation, as they benefited from a multidepth consolidation both in bulk and at the surface.

DMA-RH: Hygroscopic Response from a Mechanistic Perspective

Mechanical stresses experienced by a painting are also often caused by environmental factors, such as variations in RH and temperature. Some constitutive layers of a painting are hydrophilic and highly responsive to RH, while others are less so. Cotton and linen canvases are moisture-sensitive supports. At 65% RH, linen and cotton can take up moisture to 12% and 8.5% in mass, respectively (Hill, Norton, and Newman 2009). The individual layers also present differential mechanical responses to fluctuations in RH and temperature. Mecklenburg and Hedley have shown that canvas and glue layers, being responsive to moisture, will swell or contract and respond to RH changes faster than other layers (Mecklenburg 1982; Hedley 1988). The glue layer will become more brittle or more plastic at low and high RH levels, respectively. The canvas in contrast will develop greater forces above 80% RH. A more hydrophobic material, such as the paint layer, will be more sensitive to change in temperature. These differential behaviors toward RH and temperature variations observed between constitutive layers of a painting can lead to the building up of strong shear and tensile stresses, which are stresses that are coplanar and perpendicular, respectively, to the face of the material on which the load is acting. As a result, delamination or the rupture of the different layers resulting from the release of the accumulated tension can occur and spread onto and across the entire painting (Bergeaud, Hulot, and Roche 1997; Karpowicz 1989).

The response of samples to moisture was tested using DMA with RH cycling. Figure 27.3 demonstrates the similar mechanical behavior of the treated samples—CNF, CCNF, and MC+CNC (h)—characterized by successive decreases in storage modulus (E') (stiffness) with RH increase (80% RH), and then increases in stiffness with RH decrease (20% RH). The magnitude of the response, however, varies between samples (table 27.2). Differences in E' between 20% and 80% RH plateau over the three RH cycles ($\Delta E'_{20\%–80\%\ RH}$) show the highest value for the CNF-treated sample ($\Delta E'_{20\%–80\%\ RH}$ =12.9±1.8 MPa) and lower values for untreated and MC+CNC (h) samples ($\Delta E'_{20\%–80\%\ RH}$ =7.6±0.2 MPa and 8.3±0.9 MPa, respectively). Overall, these results and previous studies have shown that the change in stiffness of the treated samples remains higher than for the untreated canvas, except for CNC-treated samples tested using 20%–60% RH cycles (Bridarolli et al. 2018b; Bridarolli 2019). It is yet to be understood whether the magnitude of these changes in stiffness would pose a risk to paintings.

Table 27.2
Variations in storage modulus *E′* (stiffness) between 20% and 80% RH calculated using values at equilibration (end plateau)

Solution	Sample	$\Delta E'_{20\%-80\%}[E'_{20\%\ RH} - E'_{80\%\ RH}]$
	Untreated	7.6 ± 0.2
1	CNF	12.9 ± 1.8
	CCNF	9.9 ± 2.1
2	MC+CNC (heptane)	8.3 ± 0.9

Table: Alexandra Bridarolli

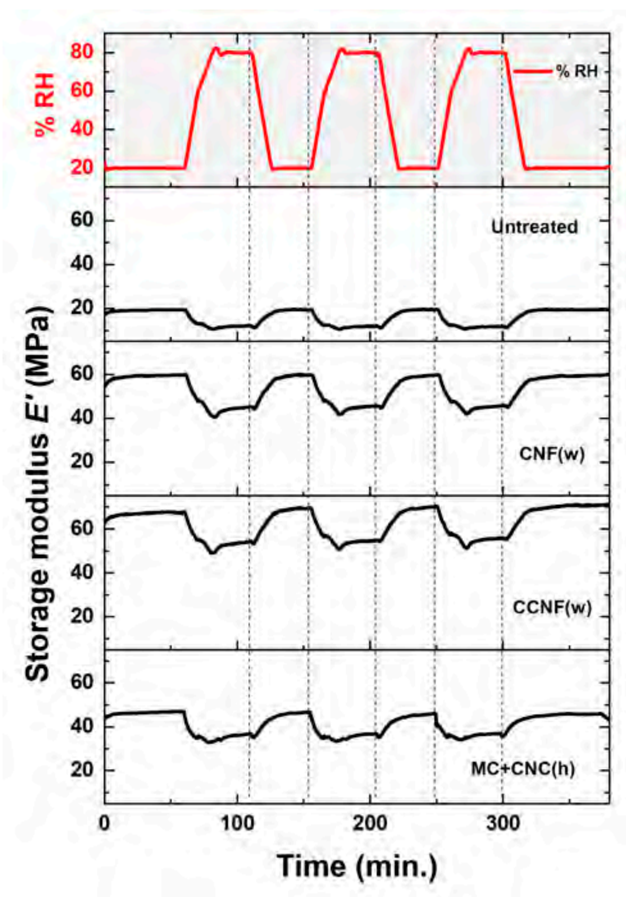

Figure 27.3 Mechanical response of untreated and treated degraded cotton canvases subjected to RH cycling (20% to 80% to 20%, 25°C). (w) water; (h) heptane. Image: Alexandra Bridarolli

Testing on Historical Canvases

Visual assessment as well as handling properties of the treatments were evaluated on different occasions in the framework of the Nanorestart project by a small group of paintings conservators, and results were recently published (Oriola-Folch et al. 2020; Böhme et al. 2020).

Tests were carried out on modern linen, cotton, and jute canvases; on historical lining canvases (linen); and on nineteenth- and twentieth-century acrylic- and oil-based paintings on linen and cotton canvases. Overall, the authors reported that all the new products performed well on white cotton canvases. On darker canvases, most of the treatments showed minimal color change, especially compared to the traditional animal-glue consolidant, which darkens canvases (Oriola-Folch et al. 2020). The only exceptions were the heptane-based nanocomposites, which strongly whiten the canvas, especially the formulation mixed with nanoparticles of MgO. (This was part of a strategy combining consolidation with canvas deacidification.) Change in gloss was also observed only for the heptane-based nanocomposites.

Following these evaluations, further mechanical tests were carried out using one of the lining canvases found in Böhme's study (Böhme et al. 2020). The protocol developed for these tests enabled assessment of the treatments on more representative canvases (historical material, naturally aged, soiled, and with traces of one or more glues), while minimizing the variability due to the inhomogeneous nature of these materials. For these final tests, the water-based and heptane-based nanocomposites tested were mixed with deacidification agents: $CaCO_3$ and MgO, respectively. The presence of $CaCO_3$ had been shown not to affect the reinforcement provided by MC+CNC in water (Bridarolli 2019). Canvases treated with the solvents used in the treatments were also tested in order to isolate the impact of the treatment from the solvent itself.

Figure 27.4 shows the calculated percentage increase in storage modulus *E′* (30% RH, 25°C, 30 min. equilibration) measured for the linen canvas samples and resulting from the application of the treatments. All led to the consolidation of the historical canvases, seen in the increase in stiffness (*E′*). The greatest increase in *E′* was reached with the MC+CNC+$CaCO_3$ (w) treatment (increase of 126% ±30%), followed by CNF (83% ±24%) and CCNF (53% ±17%). The high level of stiffening reached using MC+CNC+$CaCO_3$ (w) was not observed for its counterpart, the heptane-based treatment MC+CNC+MgO (h) (25 ±10%), nor was it for the multilayered NPs (20% ±17%). The limited consolidation conferred by the latter on the historical linen canvas calls for further research, as this contradicts previous tensile testing results performed on degraded modern cotton canvases (see table 27.1).

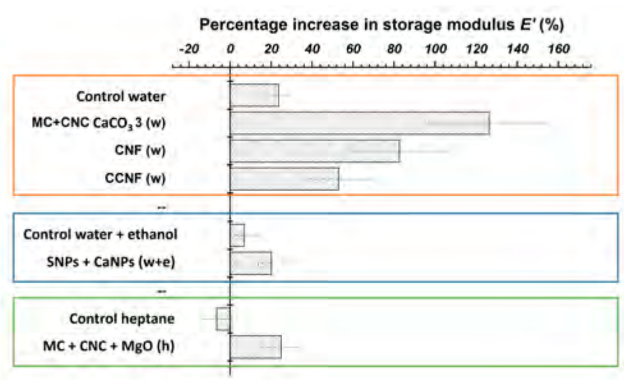

Figure 27.4 Percentage increase in storage modulus (*E′*) measured at 30% RH and 25°C resulting from the application of 9 g/^{2} of treatment on historical lining canvas. The impact of the different solvents used with the treatments (water, 50:50 water + ethanol, and heptane) was also tested separately. The results are grouped by solvent: water (orange), 50:50 water + ethanol (blue), and heptane (green). For each category, five samples were measured. (w) water; (h) heptane; (w + e) water + ethanol. Image: Alexandra Bridarolli

The results gathered on historical lining canvas confirm those obtained on degraded modern cotton canvases. They also show that the inherent presence of traces of glue or oil-based substances on historical canvases may inevitability lead to modifications of their mechanical properties through the application of solvent alone. The application of water alone led to a significant increase in canvas's stiffness (~22%) in comparison to heptane, which tends to soften the canvas (see fig. 27.4). This could explain the higher consolidation reached for the MC+CNC+$CaCO_3$ (w) treatment compared to CNF, CCNF, and CNC treatments, which was not observed when testing the degraded modern cotton canvas (see table 27.1). Due to the higher viscosity of MC+CNC+$CaCO_3$ (w) at 2% w/w in comparison to CNF and CCNF, it is possible that the canvas might have been exposed for a longer time to the water present in the MC+CNC+$CaCO_3$ (w) gel. This would have given more time for the remains of glue present in the lining canvas to swell and reform in a renewed sizing layer.

Summary of Effects of the Treatments on Modern Degraded Cotton and Historical Linen Samples

These studies have demonstrated the effectiveness of the nanocellulose-based and multilayered nanoparticle treatments for the consolidation of degraded cotton and historical linen samples from linings. A wide range of products has been studied in both polar and apolar solvents and with different handling properties and physical behavior (viscosity, penetration, response to RH) (table 27.3), which makes them suitable for various substrates. The reinforcement provided is also greater, with less weight added, in comparison with the traditional consolidants of animal glue and Beva 371 (Bridarolli et al. 2020; Nechyporchuk et al. 2018).

This research marks the first step in the introduction and evaluation of three different types of treatments using nanocellulose and multilayered nanoparticles as potential consolidants for canvas-supported paintings. Further developments and improvements of their capabilities have been shown to be possible by mixing treatments together (e.g., multiscale reinforcement mixing solutions 1 and 3), by combining deacidification and consolidation strategies (e.g., nanocomposites, multilayered NPs), or simply by changing the application method, treatment viscosity, or treatment-to-canvas adhesion. In this latter case, the adhesion could be improved through modification of the surface chemistry of the NPs used for consolidation.

CONCLUSIONS

This work has successfully evaluated the effects of the three treatments. The acceptance and validation of the products could not have been possible without the input of conservators. This fact highlights the importance of organizing future workshops using this range of nanoproducts with practicing conservators. It has also highlighted the importance of supporting the findings with quantitative assessments of the physical and mechanical properties of the consolidants. The ability to perform quantitative analysis on historical samples has been shown to optimize the evaluation protocol and to complement subjective testing procedures, and this may in turn help to speed acceptance of these new treatments. Further testing is, however, still needed to establish if the mechanical response to fluctuations in RH is within acceptable limits and, in the long term, sustainable for the safe preservation of paintings. Development of new strategies to reduce the

Table 27.3
Summary of properties, advantages, and characteristics of the nanocellulose-based consolidants for canvas reinforcement as identified from the chemico-physico-mechanical studies carried out in the framework of the Nanorestart project

	Nanocellulose-only	Nanocomposite cellulose ether/CNC	Multilayered particles
Advantages	• Powder (CNC) or paste form (CNF and CCNF); dispersions in water or water + ethanol (50:50) • **Mode of application:** Spraying, brushing, or blade coating • Superficial treatment layer ("nanolining") • **Reinforcement** provided at low weight added (3%) • No color or gloss change on jute, linen, or cotton canvases	• Aqueous and heptane-based solutions (viscous liquid at 2% w/w, gel) • **Mode of application:** Brushing or blade coating, spraying (only for aqueous treatment highly diluted) • **Bulk penetration** (aqueous treatment) and **surface deposition** (heptane treatment) • **Better control** over solvent penetration • **Reinforcement** provided at low weight added (2%) (lower than nanocellulose-only) • Possible combined strategy: consolidation and deacidification	• Aqueous or water + ethanol (50:50) dispersions • **Mode of application:** spraying (preferred) or brushing • **Bulk penetration** if used at low concentration (<4.5% w/w) • **Reinforcement** provided at low weight added (8.6%); higher reinforcement but lower elongation at break and breaking force than CNF-treated sample when tested on a modern degraded cotton canvas
Observations	• Amount of water introduced during treatment can be reduced by using highest possible concentration or spraying • Brittle superficial layer • **Increased mechanical response** to **RH variations** after treatment ***except CNC treatment***	• Amount of water introduced by using aqueous-based treatments can be reduced by spraying • Change of gloss and whitening of dark canvases (in particular when deacidification agent MgO added) • Lower mechanical response to RH than CNF, CCNF treatments; similar to lower response than untreated was measured (20%–60% RH and 20%–80% RH cycles)	• Amount of water introduced during treatment can be reduced by spraying • Multiscale consolidation (bulk and surface) by combining treatment with CNF (mixed in solution) • Low reinforcement measured on a historical lining linen canvas (to be further investigated) • Mechanical response to RH variations to be measured

Table: Alexandra Bridarolli

amount of solvent applied with the treatments is also essential.

ACKNOWLEDGMENTS

This study was cofunded by the H2020 Nanorestart European Project (grant 646063) and the United Kingdom's Engineering and Physical Sciences Research Council (EPSRC) through University College London's Centre for Doctoral Training in Science and Engineering in Arts, Heritage, and Archaeology (SEAHA).

APPENDIX: TECHNICAL INFORMATION

The CNF was produced from softwood pulp (~75% pine and 25% spruce, containing 85% cellulose, 15% hemicellulose, and traces of lignin, as determined by the supplier). Carboxymethylated CNF (CCNF), also in the form of an aqueous suspension, was kindly provided by Research Institutes of Sweden (RISE) Bioeconomy (Sweden). The CCNF was produced from a softwood sulfite dissolving pulp (Domsjö Dissolving Plus, Domsjö Fabriker AB, Sweden) by carboxymethylation, as described by others (Wågberg and Bjőrklund 1993), followed by mechanical fibrillation. Nanocrystalline cellulose (CNC) in powder form was purchased from CelluForce (Canada). It was produced from bleached kraft pulp by sulfuric acid hydrolysis.

The nanocomposites are made of a mixture of Tylose MH (methyl hydroxyethyl cellulose), purchased from Shin-Etsu Chemical Co. (Japan), and cellulose nanocrystals (CelluForce NCC), obtained from CelluForce. For the heptane-based MC+CNC, hydrophobic groups were introduced by silylation (Böhme et al. 2020). The deacidification agents consist of calcium carbonate and magnesium oxide particles of less than 1 μm.

Other research details preparation of the SNPs (Kolman et al. 2018) and CaNPs (Xu et al. 2020) and their mixture (Palladino et al. 2020).

NOTES

1. http://www.nanorestart.eu/.

28

Reliable Adhesives in New Shape: Canvas Bonding with Self-Supporting Adhesive Meshes

Mona Konietzny, Dresden University of Fine Arts
Karolina Soppa, Professor, Bern University of Applied Sciences, Switzerland
Ursula Haller, Professor, Dresden University of Fine Arts

Adhesive meshes are thin, flexible microstructure nets made from pure methyl cellulose or sturgeon glue—and in the future possibly poly(isobutyl methacrylate). Whereas ready-made glue mixtures like acrylic dispersions or heat-seal adhesives may contain changeable and uncertain ingredients, adhesive meshes consist of homogeneous, constant materials with convincing aging resistance. The bonding procedure is carried out by positioning the mesh in its dry state, activating it with a controlled supply of moisture or solvents, and applying pressure to generate the adhesion. Thus, instead of penetrating the canvas, the adhesive remains discretely in the joint, assuring a regular, permeable adhesive pattern. The method's advantages further include adjustability of the adhesive strength and increased reversibility. Case studies implementing water-soluble adhesive meshes illustrate the range of application techniques and bonding properties, depending on the choice of adhesive.

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INTRODUCTION

In order to preserve paintings' authenticity, lining today has become the exception rather than the rule. Nevertheless, the application of a complete or partial textile support is indispensable in the case of severe degradation or damage phenomena. But this presents challenges concerning the choice and application of adhesives. The development of a new canvas bonding technique using microstructure adhesive meshes described in this paper aims at solving complex conservation issues while fulfilling criteria such as purity and long-term stability of adhesives, controllable application, and reversibility.

The choice of materials includes unblended adhesives that have been tested extensively and are established in conservation practice: methyl cellulose, sturgeon glue, and poly(isobutyl methacrylate) (PiBMA). Application is carried out by positioning the dry adhesive mesh on the object or lining fabric, then activating the adhesive with water or organic solvents, and finally joining the parts under pressure until dry. This technique provides a diffusive and reversible bonding, using low amounts of adhesive, water, or solvent, thus assuring a minimally invasive and highly controllable treatment. Strip-lining, attachment of small patches on the back of small holes (e.g., nail holes along the tacking margin), and re-adhering historical linings have all been successfully accomplished.

Production and application of adhesive meshes was the objective of a research project between Bern University of Applied Sciences and APM Technica AG, both Switzerland, and Dresden University of Fine Arts, Germany. The project began in 2018 and was financed by the Swiss Federal Innovation Agency. This paper introduces the development, characteristics, and choice of materials used for adhesive meshes, as well as activation strategies recently tested, based on case studies.

CURRENT LINING TECHNIQUES AND MATERIALS—OPPORTUNITIES AND LIMITS

Looking back at the evolution of lining techniques over the last decades, one finds multiple approaches that attempt to reduce the amount of adhesive applied and adhesive penetration, as well as the impact of elevated temperatures, water, or solvents, all of which enable increased reversibility. The most important achievements include Mehra's nap-bond cold-lining (Mehra 1975b), Heiber's *Geweberasterhaftung* (grid adhesion) technique (Heiber 1987), and the more recent mist-lining (van Och and Hoppenbrouwers 2003). Their common characteristic is the application of the adhesive compound as an openly structured layer on the lining canvas rather than on the original canvas. When dried and solid, it is reactivated by means of heat or solvents.

Adhesives based on synthetic polymers are popular for those and most other lining applications today, including heat-seal adhesives like Beva 371 and different polymer dispersions. However, all are composed of highly complex formulations, prone to segregation, altering mechanical properties, and they often exhibit poor long-term stability.[1] Surfactants in acrylic dispersions, for instance, can degrade or migrate from the bulk adhesive, whereas the plasticizer in Beva 371 is basically able to migrate into the painting structure (Cimino et al. 2020; Lazzari et al. 2011). Of utmost concern, though, are modifications of the composition without indication by the manufacturer, as well as renaming and discontinuation of products, resulting in altered working and aging properties (Cimino et al. 2020; Ploeger, McGlinchey, and de la Rie 2015). In addition, application of synthetic polymer adhesives requires high temperatures (in excess of 60°C) or harmful solvents, which might also pose a risk to paint layers. Although modern techniques emphasize reversibility, inevitable residues may limit options for further treatments.

TOWARD A NEW APPROACH TO CANVAS BONDING

Based on the concerns outlined above, pure, extensively tested adhesives with good aging properties are preferable as materials for canvas bonding. Methyl cellulose, sturgeon glue, and PiBMA, which so far have not been commonly used for this particular purpose, show good long-term aging behavior and have found broad application in the field of conservation for several decades (see "Characteristics and Materials of Adhesive Meshes" below). However, these adhesives are mostly applied in liquid form, commonly as weak solutions. Owing to the high proportion of water or solvent, such solutions tend to penetrate porous materials like canvas. This may result in a weak bond (Soppa et al. 2014), heterogeneous adhesive distribution, stiffening and darkening of the canvas, or water-induced shrinkage of the canvas, with subsequent paint delamination.

To overcome the risks related to the application of liquid solutions, solid and dry adhesive films that can be activated have been developed, of which Beva 371 films are the most common. With the aim of minimizing adhesive input and reducing heat-induced risks, we developed adhesive meshes rather than films, made from the materials mentioned above. These can be activated with controlled supply of water or solvent. The method originates from a diploma project's approach to fix an old lining with sturgeon glue meshes. In this thesis, the manual production and a first application of mesh prototypes were implemented, followed by preliminary tests of the bond strength using different activation parameters (Konietzny 2014, 2015). The highly promising results initiated the idea to pursue this approach with a dedicated research project.

CHARACTERISTICS AND MATERIALS OF ADHESIVE MESHES

Adhesive meshes are flexible structures made from a single adhesive. Their initial square mesh geometry was recently replaced by a honeycomb design that provides an optimized bonding pattern (fig. 28.1), while reducing adhesive input even further. The material thickness of the adhesive mesh is about 200 µm, and the interspaces have an average diameter of 500 to 600 µm. One square meter of an adhesive mesh weighs between 15 and 30 g, depending on the production process and adhesive.[2] The defined honeycomb shape enables an exceptionally uniform distribution of the adhesive throughout the bonding surface. Despite the lack of a carrier material, the meshes have a certain stiffness that allows access to detached layers through gaps or slits.

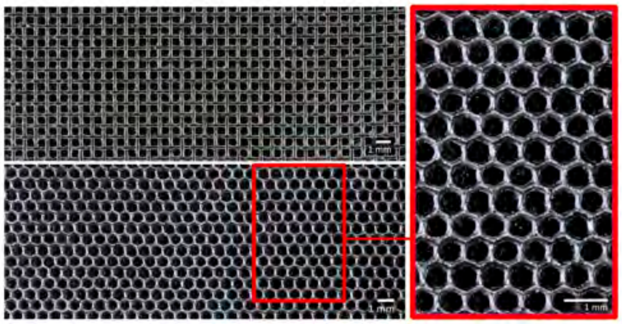

Figure 28.1 Adhesive meshes with square and more recent honeycomb structures. Image: Mona Konietzny

In contact with water or solvent, the solid meshes become tacky, thereby requiring lower amounts of a liquid phase than solutions do to achieve sufficient adhesion. Proper activation causes only swelling, not dissolution of the mesh, assuring the adhesive remains discretely in the joint without penetrating into the textile. The bond strength can reach similar values to Beva 371 films (65 µm), depending on the activation parameters.[3] The bonding characteristics can be adjusted by varying the amount of water or solvent: the more solvent that is applied—up to the point of liquefaction—the stronger the activation and the higher the bond strength tends to be.

Thanks to the mesh structure, a more homogeneous bonding can be achieved, while maintaining higher flexibility and permeability and presumably less tension compared to the adhesive's application as solution or gel. Furthermore, the reversibility of the bond will be improved due to lower tendency of the adhesive to migrate and penetrate. Depending on the requirements of the individual painting and treatment, the adhesive can be tailored using three materials that differ mainly in activation time and bonding properties.

Methyl cellulose is among the most durable adhesives used in conservation (Feller and Wilt 1993). The water-soluble, semisynthetic carbohydrate exhibits constant material properties due to its standardized industrial production. Hydrophilic and hydrophobic substituents along the polymer chain can develop affinities to a broad range of substrates of polar and nonpolar nature. The material has been investigated extensively for conservation treatments, with the conclusion that its common perception as a weak adhesive is obsolete (Sindlinger-Maushardt and Petersen 2007). Convincing results have been reported for adhering paint flakes on canvas (Soppa et al. 2014, 2017) and for canvas bonding (Sindlinger-Maushardt and Petersen 2007).

For adhesive meshes, two types of Methocel were chosen.[4] They differ mainly in degree of polymerization—and thus viscosity. Methocel A15LV is of low viscosity and hence requires a short activation time with low amounts of water. It proved suitable for inaccessible bonding surfaces and water-sensitive materials where only a minimum of humidity is acceptable. Methocel A4C is of medium viscosity but requires more time and water to be activated. The bond strength exceeds that of Methocel A15LV and seems to be equivalent to Beva 371 film (65 µm) bonding (Sindlinger-Maushardt and Petersen 2007). Consequently, its use is recommended in cases where bonding surfaces are accessible, water input can be controlled, and a high bond strength is desired. Due to the delayed response to humidity, Methocel A4C might be advantageous for larger areas that need to be bonded, as well as objects that do not require climate control. Methyl cellulose meshes are particularly suitable for paintings that are sensitive to heat, as no elevated temperatures are required for activation.

Sturgeon glue is a traditional adhesive and still in frequent use in conservation.[5] Sturgeon glue is gaining popularity in modern paintings conservation thanks to its good adhesive properties and has been investigated for paint adhesion on canvas (Sindlinger-Maushardt and Petersen 2007; Soppa et al. 2014), tear mending (Flock 2014), and canvas bonding using glue solutions (Geißinger and Krekel 2007; Mecklenburg, Fuster-López, and Ottolini 2012). As a material of natural origin, with variations in raw material and processing (Soppa 2018, 42), it can display a range of bonding properties. The glue does slightly discolor over time, unlike methyl cellulose (Pataki-Hundt 2018). Sturgeon glue remains sufficiently water soluble over time, and its adhesive strength barely changes (Geißinger and Krekel 2007; Przybylo 2006). It is prone to rapid response to fluctuating RH and, in the long run, to increased crystallinity in films (Schellmann 2007). This fact limits the application of sturgeon-glue meshes preferably to smaller areas or objects in controlled environmental conditions. On the other hand, considerable tack develops within a very short activation time with only small amounts of activation water. Thermal energy (35°C) further mobilizes the gel, leading to better adhesion—albeit at the cost of propagating penetration into the canvas (Konietzny 2015). Elevated temperatures can thus help to reduce the amount of activation water required. Like methyl cellulose, sturgeon glue is capable of adhering to various materials, including natural wax (Fischer and Eska 2011).

PiBMA Degalan PQ 611 (formerly Plexigum PQ 611)[6] is soluble in aliphatic hydrocarbon solvents such as isooctane or petrol ether without any aromatics. Therefore, acrylic meshes qualify for water-sensitive painting structures, such as canvas that tends to shrink or water-soluble paint layers. Activation of the acrylate requires comparably small amounts of solvents that can be sprayed or vaporized. Lower bond strength can be achieved without solvents by applying elevated temperatures just above the glass transition temperature of 33°C (Brandt and Volbracht 2018). Owing to the brittleness of PiBMA, a stiffening effect occurs when used for canvas bonding. This might be an advantage when the movement of a highly degraded textile support needs to be reduced. Degalan PQ 611 N provides very good adhesion to polar and nonpolar substrates alike, for instance, to both wax (Fischer and Eska 2011) and cellulosic materials. Concerning long-term material behavior, PiBMA-based adhesives are stable in terms of discoloration, but they may cross-link to a certain amount. Nevertheless, the solubility likely remains in aliphatic hydrocarbon solvents with a small proportion of aromatics (Feller 1984; Down 2015). However, PiBMA has not yet been processed into stable adhesive meshes due to its brittleness, which would require extensive adjustments to the method.

PRODUCTION OF ADHESIVE MESHES

So far, we have manually produced sturgeon-glue and methyl cellulose meshes by using silicone molds. For this purpose, the structure of a polyester monofilament mesh is imprinted in the flattened surface of a kneadable two-component silicone mass. After complete vulcanization, the mesh is taken off and adhesives (in the form of a 20 w/w gel) are filled in using a spatula. Excess material is scraped off. After two to three hours the dried mesh is removed.[7]

This early technique of producing adhesive meshes can easily be implemented with materials available in conservation studios. However, obtaining uniform results is more difficult with respect to mold and mesh shaping. Greater precision and homogeneity can be achieved by computerized numerical control (CNC) machining, such as laser cutting of the silicone molds (fig. 28.2). A feasible process for a standardized, larger-scale production of adhesive meshes has been refined within the course of the current research project.

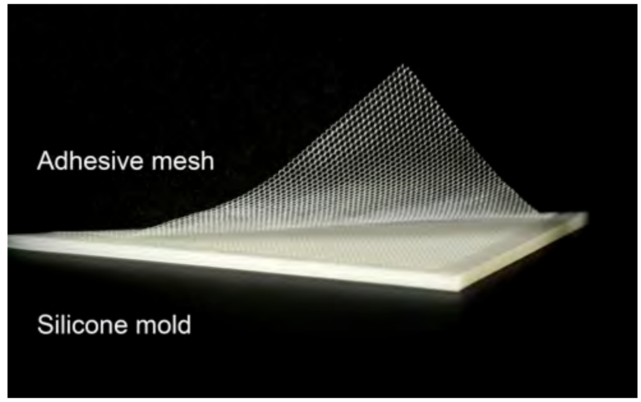

Figure 28.2 Removing a dried methyl cellulose mesh from a laser-cut silicone mold. Image: Mona Konietzny

APPLICATION OF ADHESIVE MESHES—TWO CASE STUDIES

The application of adhesive meshes aims at reinforcing degraded canvas with an auxiliary support, such as strip-lining, or reattaching of loosened parts along the edges of detached historical linings. The technique was successfully applied in case studies using meshes made from sturgeon glue and methyl cellulose. Examples of treated paintings can be found at the Swiss National Museum and the Fondation Beyeler, both in Switzerland, and the Bayerische Staatsgemäldesammlungen in Germany. In addition, different European universities and private conservation studios implemented adhesive meshes for canvas stabilization—and even for full-scale lining.[8] In the following, two case studies are described to exemplify activation procedures according to the conservation target and the accessibility of the bonding surfaces.

For strip-lining, the bonding interfaces are readily accessible. This intervention was realized on a medium-format double-sided canvas painting (fig. 28.3).[9] A sandwich system of two nonwoven polyester strips was chosen.[10] Methyl cellulose meshes made from Benecel A4C[11] were used, since high bond strength and adhesive stability in variable environmental conditions were required and the canvas was not sensitive to water. To prepare the bonding material, methyl cellulose meshes made with laser-cut silicone molds were partly activated by slightly moistening the nonwoven polyester before placing the adhesive meshes on the nonwoven strips and drying them under pressure (fig. 28.4). Activation was then initiated by spraying water with a precision pump sprayer (fig. 28.5). The meshes were left for ten minutes as methyl cellulose takes up water slowly.[12] Coverage with a Melinex

Figure 28.3 Otto Möller (German, 1883–1964), *Untitled*, ca. 1900–1950. Oil on canvas, 68.3 × 54.5 cm (26 7/8 × 21 1/2 in.). Private collection. Placing a nonwoven strip with activated methyl cellulose mesh on the tacking margin for strip-lining. Image: Estate of Otto Möller / Photo: Jonathan Debik

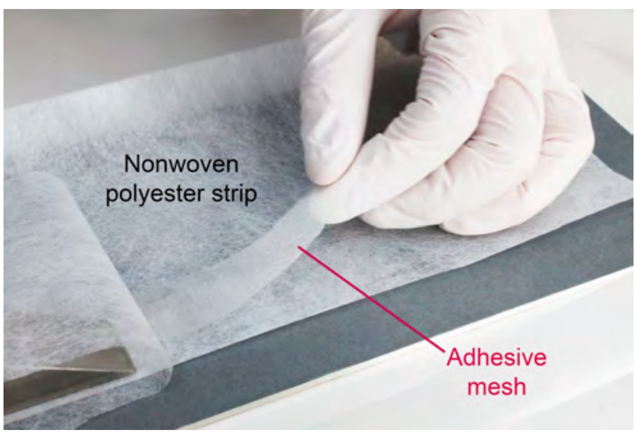

Figure 28.4 Preparation for strip-lining: placing a methyl cellulose mesh (Benecel A4C) on nonwoven polyester strips. Image: Jonathan Debik

film without direct contact prevented the meshes from drying (see fig. 28.5).

The activation process was repeated twice to apply a total amount of about 3 ml water per 100 square centimeters of mesh, resulting in a relatively high water input that was almost completely absorbed by the mesh. To achieve the bonding, the activated strips were then placed below and on top of the tacking margin of the painting's canvas (see fig. 28.3) and left to dry for twenty-four hours under pressure (20 g/cm²) with blotting paper interleaves. After complete drying, it was possible to pull the tacking margin taut enough to remount the painting on a new stretcher, proving that methyl cellulose meshes are capable of generating a sufficiently strong bond between two textiles.

A different activation approach is necessary when access to the bonding surface is limited. This phenomenon often occurs with lined paintings, such as that shown in figure 28.6, where the edge of the original canvas is detached locally from the lining canvas. To maintain the historical lining and stabilize loosened areas, insertion of the adhesive was possible only through small gaps, which is why adhesive meshes provided a suitable approach. Activation has to be carried out quickly to avoid excess water in the painting structure. Therefore, Methocel A15LV meshes and sturgeon-glue meshes are suitable due to the short time required and the reduced need for water for activation.

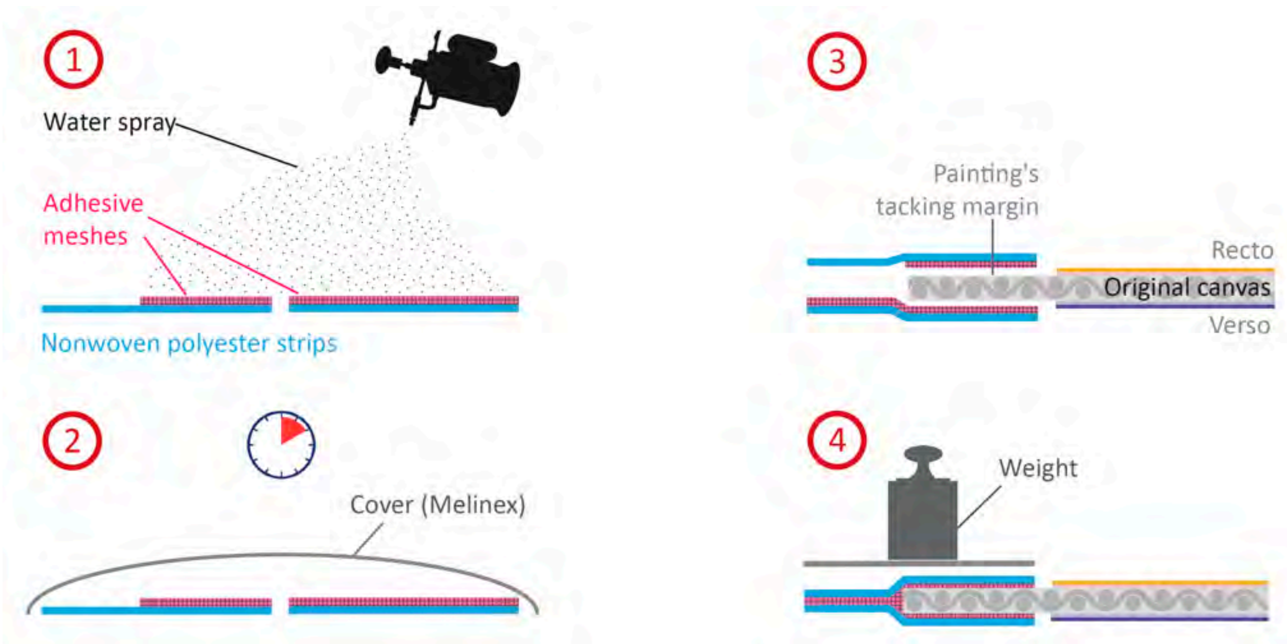

Figure 28.5 Activation and application of adhesive meshes for readily accessible bonding surfaces (strip-lining with sandwich of nonwoven polyester and adhesive mesh). Image: Mona Konietzny

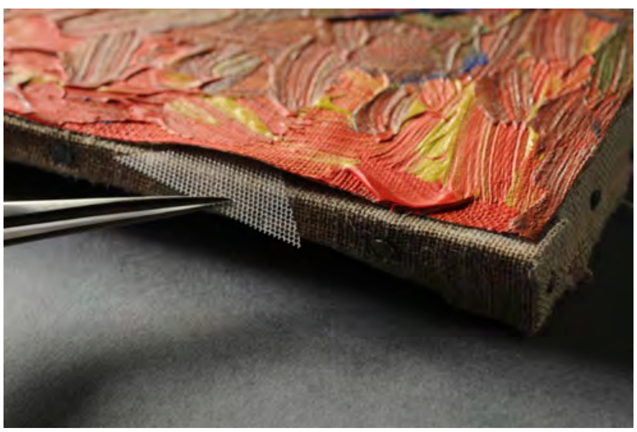

Figure 28.6 Inserting a methyl cellulose mesh (Methocel A15LV) between detached canvas layers. Image: Mona Konietzny

The application is identical for both adhesives. To uniformly activate the inserted dry mesh, a nonwoven capillary fabric[13] is used. This material can transport water along its directed fibers and then disperse it onto the mesh. A protrusion of some millimeters allows access for the water to be applied. The adhesive mesh and the capillary fabric are first cut to match the shape of the detachment. Then both the mesh and the capillary fabric are inserted between the canvas layers (fig. 28.7). An additional layer of Melinex on top is advisable to protect the original canvas from being wetted, and a light weight is used to keep the layers in contact during the procedure.

Then water is added onto the nonwoven fabric's edge until it is completely saturated. Immediately after complete saturation—within about five seconds—the fabric and Melinex are removed with a quick pull to prevent the mesh from sticking to the fabric. Finally, pressure is applied (10 g/cm²) until the adhesive has dried. This activation method reduces the amount of water twentyfold compared to the spray activation described above. The resulting bond was found to be strong enough to fix the canvas to the lining fabric anew, yet for reversibility, the lining can easily be peeled off.[14]

These case studies demonstrate two possible methods of adhesive mesh activation. Further strategies for water or solvent application to accessible bonding surfaces include brushes, especially those with a high absorptive capacity. However, repeated brush applications should be avoided, as the meshes might break, whereas onetime application produces a water film on the mesh without penetrating the underlying canvas. Instead of the nonwoven capillary fabric, other absorptive materials can be used for poorly accessible bonding surfaces. Blotting paper works well for small areas, but since it takes up water rather slowly the risk of sticking to the mesh is higher.

Spray-activated adhesive meshes that were frozen prior to application were also successfully implemented. Frozen meshes are stable for a short period but can be inserted into narrow gaps, where they immediately melt and trigger

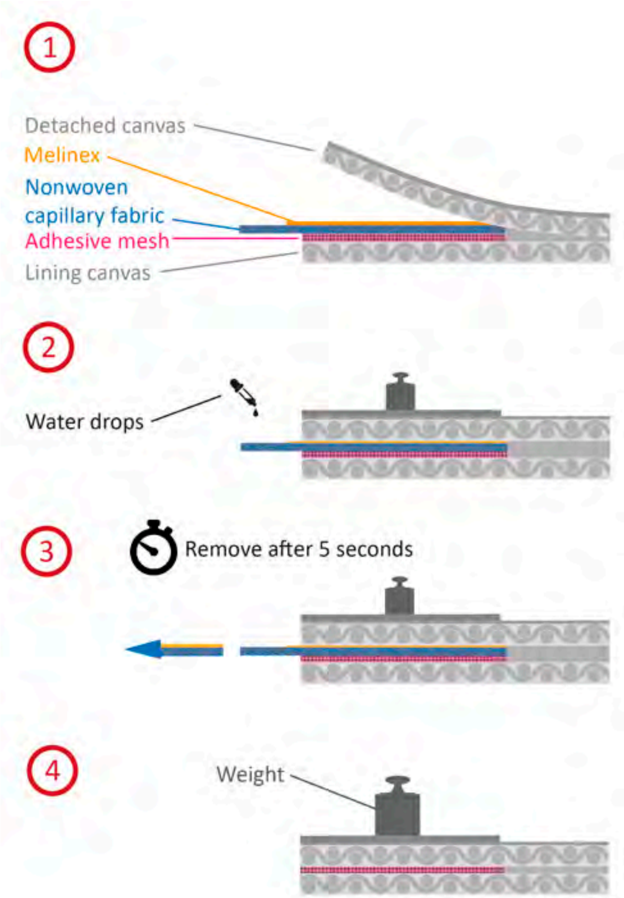

Figure 28.7 Application of adhesive meshes to poorly accessible bonding surface by means of a nonwoven capillary fabric. Image: Mona Konietzny

the bonding.[15] Other tools, such as ultrasonic or high-pressure nebulizers and airbrushes, are suitable for both accessible and inaccessible areas. Water drops for a punctual activation can be achieved by microdosing systems. In combination with acrylic meshes, activation with solvent vapor is another feasible option.

CONCLUSION

The development of adhesive meshes for canvas bonding aims at minimizing the amount of adhesive and solvent required and achieving a homogeneous adhesive distribution, while preserving high reversibility with minimal residues. Commercial lining adhesives suffer from well-known problems, including undisclosed ingredients, changes in formulation, and aging behavior. Adhesives commonly used in painting conservation, on the other hand, tend to comply with decisive criteria such as proven long-term stability and good adhesion to a broad range of common substrates. This has set the choice for their use as suitable mesh materials. Each of the three adhesives chosen—methyl cellulose of two viscosity types, sturgeon glue, and PiBMA—exhibits individual qualities for making them suitable for specific applications, and the three available options together cover a broader range of applicable cases.

The activation technique by which water or solvent is applied as spray, through nonwoven capillary fabrics and the like, ensures excellent control and adjustability of the adhesive bond. Bonding characteristics are determined by activation parameters like amount of water or solvent and optional application of elevated temperatures. So far, the technique using water-soluble adhesive meshes has proved suitable for canvas painting treatments such as lining, strip-lining, and the repair of detached historical linings.

To provide adhesive meshes for conservators, a reliable production process for the manufacturing of methyl cellulose and sturgeon-glue meshes was developed during the recent research project, and these are now provided by APM Technica AG.[16] Further investigations to evaluate adhesive meshes for canvas bonding will be the focus of an ongoing PhD project[17] covering activation strategies and bonding characteristics, particularly adhesive strength and penetration as a function of activation parameters, as well as the long-term behavior of adhesive mesh bonds. The results will provide fundamental application guidelines and help to define the potential of adhesive meshes. Apart from canvas bonding, fixing loose paint[18] and treating other materials, such as textiles[19] or paper,[20] are other application fields that seem highly feasible.

ACKNOWLEDGMENTS

The authors would like to thank the following persons and organizations for their assistance with our research: APM Technica AG, Heerbrugg, Switzerland; Innosuisse – Swiss Innovation Agency Art Technological Laboratory; Conservation Program and Materiality in Art and Culture research focus at Bern University of Applied Sciences, Switzerland; Bern University of the Arts, Switzerland; Swiss National Museum, Collection Center, Affoltern am Albis, Switzerland; Fondation Beyeler, Riehen, Switzerland; Doerner Institute, Bayerische Staatsgemäldesammlungen, Munich, Germany; Museumslandschaft Hessen-Kassel, Germany; Jonathan Debik and Sonja Bretschneider of Dresden, Germany; and Christina Robens and Verena Graf of Vienna, Austria.

NOTES

1. See Bianco et al. 2015; Cimino et al. 2020; Witte, Florquin, and Goessens-Landrie 1984; Down 2015; Howells et al. 1984; Lazzari et al. 2011; McGlinchey et al. 2011; Ploeger, McGlinchey, and de la Rie 2015; Silva, Doménech-Carbó, and Osete-Cortina 2015.
2. This is less than the weight of Beva 371 film (25 μm): 43 g/m².
3. The bond strength has also been evaluated for sturgeon glue meshes (Konietzny 2015) and methyl cellulose meshes (Konietzny et al. 2022 and ongoing research).
4. Methocel has been produced by DuPont since 2019, and formerly by Dow Chemical (until 2017) and DowDuPont (2017–19).
5. Sturgeon glue is commonly made by conservators from the sturgeon's swimming bladder. The German company Störleim Manufaktur manually produces ready-made sturgeon-glue pellets.
6. Degalan has been produced by Röhm GmbH since 2019. Before that, manufacturers were Degussa AG (until 2007) and Evonik Industries (2007–19).
7. A detailed description of the process can be found in Konietzny 2014 and Konietzny, Soppa, and Haller 2018.
8. Lining was performed by Sonja Bretschneider in 2019, in a private studio in Dresden, Germany, with adhesive meshes made from a mixture of Benecel A4C and sturgeon glue.
9. Strip-lining performed in 2018 by Jonathan Debik and Mona Konietzny, in a private studio in Kassel, Germany.
10. The following materials consisting of 100% polyester were used: nonwoven polyester (70 g/m²), purchased from GMW–Gabi Kleindorfer, D-84186 Vilsheim (on the painting's reverse); and Parafil RT 20 (20 g/m²), produced by TWE Dierdorf GmbH & Co. KG, D-56269 Dierdorf, purchased from Deffner & Johann, D-97520 Röthlein (on the painting's front).
11. Benecel A4C corresponds to Methocel A4C and is produced by Ashland Inc.
12. A shorter time of one to five minutes was later found to be sufficient for proper activation.
13. We used the nonwoven capillary fabric Paraprint OL 60, consisting of viscose and acrylic binder, produced by TWE Dierdorf GmbH & Co. KG, D-56269 Dierdorf, purchased from Deffner & Johann, D-97520 Röthlein.
14. Peel tests on canvas joined with sturgeon-glue meshes confirmed that activation with minimal water results in easily separable bonds (Konietzny 2015).
15. Frozen sturgeon-glue meshes were implemented for partially re-adhering an old lining during a semester project at Bern University of the Arts' conservation program in 2018.
16. https://www.apm-technica.com; send inquiries to info@apm-technica.com. Adhesive meshes are also available from Störleim Manufaktur: http://www.stoerleim-manufaktur.de/.
17. The PhD project of Mona Konietzny is based at Dresden University of Fine Arts, Germany.
18. The adhesion of wax-based paint on canvas on an artwork by Hermann Nitsch was performed with methyl cellulose meshes made from Benecel A4C by Christina Robens and Verena Graf in a private studio in Vienna, Austria, in 2019.
19. The reattachment of silk decorations on a textile support was performed by Julia Dummer in 2019 at Museumslandschaft Hessen-Kassel, Germany.
20. Different paper objects have been treated using Klucel G meshes during semester projects at the Bern University of the Arts' conservation program in 2019, and for a bachelor's thesis at the University of Applied Sciences in Cologne (Hehl 2019).

29

The Thread-by-Thread Tear-Mending Method: New Insights into the Choice of Adhesives and Their Application

Hannah Flock, Scientific Associate, Conservation of Paintings, Sculpture and Modern Art, Cologne Institute of Conservation Sciences (CICS), Technische Hochschule Köln, Cologne, Germany
Petra Demuth, Technical Lecturer, Conservation of Paintings, Sculpture and Modern Art, Cologne Institute of Conservation Sciences (CICS), Technische Hochschule Köln, Cologne, Germany
Stefan Diebels, Head, Chair of Applied Mechanics (LTM), Saarland University, Saarbrücken, Germany
Elisabeth Jägers, Head, Department of Natural Sciences (retired), Cologne Institute of Conservation Sciences (CICS), Technische Hochschule Köln, Cologne, Germany

Tears and cuts in textile painting supports are often closed with thread-by-thread mending to reconstruct the mechanical properties and visual appearance. Selected results of tests on adhesives for single-thread bonding in cellulosic fabrics are summarized. The data presented is based on uniaxial tensile tests of bonded canvas strips. The investigation also covers different bonding techniques. Under the wide range of adhesives tested, the most promising types are shown, taking the requirement profile into account. The classic recipe of Winfried Heiber, a mixture of sturgeon glue and wheat-starch paste, and dispersions based on PVA and EVA were evaluated. In particular, the reinforcement with cellulose fibers is addressed: investigations about the influence of fiber length of selected commercial Arbocel products, in a mixture with sturgeon-glue solution, were carried out. In addition, a new heating device for a controlled application of adhesives based on animal glues is presented.

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INTRODUCTION

This contribution from the 2019 Conserving Canvas symposium gives insight into the selection and application of adhesives for the thread-by-thread tear-mending method to close tears and cuts in textile supports of canvas paintings. A more accurate term for this method is *single-thread bonding technique.*[1]

Single-Thread Bonding Technique

The single-thread bonding technology has become well established as a minimally invasive alternative for the treatment of local damages in the canvas, in contrast to the application of patches or the lining of paintings. The aim of the method is to restore the mechanical properties and the optical appearance while preserving the inherent properties of the original textile canvas support. Different bonding techniques are used, depending on the damage patterns that form distinct fracture patterns, as shown schematically in figure 29.1.

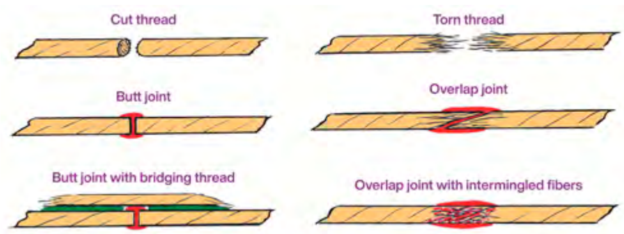

Figure 29.1 Adherends and various bonding techniques. Image: Hannah Flock, 2019

In the case of cuts or very brittle canvas supports, straight fracture edges often occur, occasionally without any local deformations or gaps. Butt joints are the only option for these fracture phenomena since no overlapping of the thread ends can be achieved. Such bonds are weaker than overlapping joints due to their mechanical force transmission. Therefore, individual supplementary bridging threads are often applied onto the back of the canvas.

In contrast, overlapping often occurs with "younger," more "flexible" (in the sense of movable), pliable, and stretchable canvases: stretched and frayed thread ends enable overlapping joints. In these cases, the thread ends can be arranged one above the other without level displacements, comparable to a scarf joint. The intermingling of the individual fibers of both thread ends while overlapping is ideal: it improves mechanical anchoring, optimizes force transmission, and leads to most reliable bonds with less tendency to creep.[2]

The general motivation and procedure, up to the presentation of the individual bonding steps using a stereo microscope and fine instruments, are described in detail elsewhere.[3]

Depending on the bonding technique and state of degradation, different adhesives are suitable. To achieve the best possible bonding, the adhesive application method must be chosen wisely and individually for each painting.

Adhesive Requirements

The general profile of requirements for adhesives used in tear mending is very complex and appears to be somewhat contradictory.[4] In particular, the different adhesion properties of adhesives for fabrics based on plant fibers (e.g., linen, cotton) and fabrics produced from synthetic fibers (e.g., polyester, polyamide) need to be taken into account. Other individual surface properties caused by, for example, impregnation from former linings or glue residues due to removed patches also influence the adhesion. However, the general criteria for an ideal adhesive can be summarized as follows:

- The aim is to achieve, with a minimal dosage of adhesive, a high level of adhesive strength.
- The adhesive must completely wet the fibers of the thread ends despite the small amount used.
- The bond should have a strength[5] similar to that of the surrounding thread material. If the bond strength is too high, there is the risk that in the event of mechanical impact the mending will not open, and new fractures in the intact fabric adjacent to the joined tear will occur.
- The aim is a "mechanical balance" in relation to the canvas properties. The bond should be strong enough to withstand the "normal" tension distribution and maintain the "flexibility" of the threads within the canvas. The stiffness of the bond should be similar to that of the original canvas.[6]
- Comparatively high glass transition temperatures are desirable in order to avoid creep at room temperature under continuous load.
- It is preferable to use adhesives with a neutral pH value in order to prevent acid-induced degradation of the original fibers.
- A suitable, comparatively high viscosity is needed to avoid the adhesive drifting into the threads. In addition, the highest possible solid contents of the adhesives is sought in order to achieve reliable bonds.
- Suitable working properties are necessary, in particular an appropriate open and drying time, so that the adhesive "sets" neither too slowly nor too quickly.
- The option to reopen of the bond and the reworkability with water are preferred.

- In this context, there is also the need for compatibility with subsequent treatments, for example, filling and retouching.
- Generally, good optical properties are the goal, such as no gloss or darkening. A mended tear with single-thread bonds should almost be invisible to the naked eye.[7]
- Finally, good long-term aging behavior is mandatory.

ADHESIVE TESTING

Preliminary successive test series by Hannah Flock[8] showed the following important findings regarding the general evaluation and further experimental setups:

1. It should be emphasized that, contrary to frequent publications, thread-by-thread mending cannot be scaled to forecast bond strengths. Initial systematic investigations have already shown that the properties of intact textile structures cannot be easily estimated by simple size scaling, due to their complex structure. Particularly with regard to the establishment of possible correlations between fiber, thread, and fabric structures (uni- as well as biaxial), caution is advisable.[9] Furthermore, strengths of single-thread bonds cannot be easily scaled to estimate, for example, longer tears. Here, it would be necessary to examine the possibilities and limits of scaling correlations first, in order to draw conclusions from tested samples about the painting's behavior. Ultimately, possible correction factors can be determined and named only in this way. Hence, no conclusions may (yet) be drawn between mended single threads and canvas strips or mended canvas strips of different widths. Unfortunately, it is often found in literature that bond strengths are scaled up, but this provides no reliable conclusions.[10]
2. Furthermore, only multiple single-thread bonds in canvas specimens should be evaluated. References can be made only to the behavior of the fabric structure, when the single-thread bonding technique is used in canvas samples. All previous results of uniaxially testing single bonded threads allow only the relative comparison of the adhesives with each other in this specific setup. Therefore, the results must be interpreted with caution. Even though they offer credible tendencies as valuable guidance, no reliable data about the tensile strength of mended tears and cuts with multiple bonded threads in canvas paintings have been presented.
3. Uniaxial tensile tests on canvas strips are comparatively easy to carry out and allow one to make an initial assessment. However, there is usually biaxial tensile stress in the stretched painting. Uniaxial and biaxial short-term tests are suitable for depicting extreme values of the bonds with regard to maximum tensile force and elongation, and thus to draw first general comparisons among adhesives or bonding techniques. Ultimately, however, there is a deviating long-term load in a permanently stretched painting. Only by testing the bonds in the biaxial long-term structure[11] can the durability and reliability of the bonds be observed, as well as, for example, the extent to which bonds exhibit (disadvantageous) viscous creep tendencies.
4. In general, material tests should have a strong practical relevance from which recommendations for treatments and materials can be derived. Consequently, the evaluation of materials and measures should be linked as closely as possible to the subsequent application. This results in the need to test single-thread bonding not only in biaxial long-term tests but ideally also in the coated fabric composite, that is, in the closest possible approximation to different painting conditions.

For these reasons, uni- and biaxial short-term tests were carried out on uncoated and coated linen fabrics (new, unaged quality). In addition, biaxial long-term tests on larger specimens of coated fabrics with different bonds were carried out.[12]

For better comprehensibility, a selection of tested adhesives is presented on the basis of the uniaxial tensile tests carried out on strips of one type of uncoated linen canvas.

Adhesive Selection

This paper focuses on adhesives for canvases made from flax fibers. Previous investigations into different adhesives have taken place, in particular on the basis of bonded single threads that have been uniaxially tensile tested. For example, modifications of sturgeon glue; dispersions based on acrylates, polyvinyl acetates (PVA), or ethylene vinyl acetates (EVA); hot melt adhesives; or epoxy resins were tested.[13] It should be noted that not all of these material groups are equally suitable and that the

Table 29.1
Selected adhesives and recipes

Selected Adhesives	
Adhesive	**Recipe (all parts by weight)**
Lineco + Methocel A4C	EVA dispersion + cellulose ether 5% in water (9:1)
Mowilith DHS S1 + Methocel A4C	PVA dispersion + cellulose ether 5% in water (9:1)
Sturgeon glue + wheat = starch paste (precooked)	Animal glue 20% + starch paste 13% in water (1:1)
Sturgeon glue + Arbocel BWW 40	Animal glue 25% + cellulose fibers (20:1)

Table: Hannah Flock

properties also differ within the groups, depending on the specific adhesive and its individual composition.

The following four water-based adhesives are some of the most promising on the basis of the successive test series by Hannah Flock (for recipes, see table 29.1):

- A pH-neutral EVA dispersion from the company Lineco (also marketed under the names Pel and Arcare with the same composition) was modified with cellulose ether solution (with gel-like consistency) for improved re-solubility and optimized viscosity for wetting and penetration during bonding as well as a certain associated stiffening.
- The PVA dispersion Mowilith DHS S1, which performed best among the various PVA dispersions tested,[14] was also modified by the addition of cellulose ether solution (with gel-like consistency).
- For the classic “Heiber recipe,” the sturgeon glue–wheat starch paste mixture, precooked wheat starch was used because it has a more uniform quality due to industrial pre-gelatinization.
- A mixture of sturgeon glue and Arbocel cellulose fibers, which consist of pure, lignin-free cellulose, was used.

Experimental Setup

These four adhesives have been repeatedly tested over the past years.[15] The adhesives were examined in the four different bonding situations shown in figure 29.1:

- Butt joint mending (BJ)
- Butt joint with additional bridging thread (BJ+BR)
- Overlap joint mending (OV)
- Overlapped thread ends with intermingling of the fibers (OV+IN).

The uniaxially tested fabric strips were twelve threads wide, and each thread was mended individually. A comparatively large, reproducible overlap of 1 mm was selected for the test series. For butt joints, the two thread ends were positioned without any visible gap, as close as possible, for bonding. A uniform adhesive volume per thread (0.6 µm adhesive droplet) was used for bonding using a microdosage device. The bridging threads were coated with Beva 371 (25 µm film thickness) and attached after bonding by sealing, 10 mm to the left and 10 mm to the right of the bond, with no contact to the actual bond point in the middle. For the bridging threads, weft threads of the chosen test canvas were used. More material details can be seen in table 29.2.[16]

EVALUATION OF SINGLE-THREAD BONDS

To illustrate the tendencies, all figures show only the average maximum tensile forces (F_{max}) as the result of uniaxial short-term testing until bond failure. These results are suitable for indicating a maximum strength as part of a general *relative adhesive comparison*: in general, all types of tests are dependent on the parameters selected, so that absolute measured values must always be embedded in the context of the respective tests and their details, while relative comparisons of adhesives and bonding techniques also reveal transferable tendencies.

However, it must be considered that in reality the resulting stresses[17] and strains are crucial. Moreover, a suitable bond is characterized not only by the highest possible maximum tensile forces (in the short-term test): the viscous, time-dependent material properties of canvas

Table 29.2
Material details and manufacturers

Adhesive Materials		
Product	**Manufacturer**	**Details**
Lineco Neutral pH Adhesive (abbreviation: Lineco)	Preservation Equipment Ltd.	Declared as PVA, but FTIR shows EVA with high amount of vinyl acetate. Identical products: PEL Neutral pH Adhesive / Arcare J55 Neutral pH Adhesive
Mowilith DHS S1	Celanese Emulsion GmbH	Homopolymeric PVA dispersion
Methocel A4C	Dow Chemical Company	Methyl cellulose ether Alternative: Benecel A4C, Ashland Inc.
Sturgeon glue	Störleim Manufaktur	Obtained from dried swim bladders according to Flock 2014, A.5.2, see table 29.1.
Gaylord wheat starch (precooked)	Gaylord Bros.	Cold soluble due to pre-gelatinization Alternative: Precooked wheat paste No. 301, Talas
Arbocel BWW 40	Rettenmeier & Söhne GmbH & Co KG	Same manufacturer for all other mentioned Arbocel types
Beva 371 film (25 µm)	CPC Conservator's Products Company	Purchased via Deffner & Johann GmbH
Evacon-R	Conservation by Design Unlimited	Compare to updated company name Conservation by Design (CDX) International FTIR shows EVA with high amount of ethylene
Test Fabric		
Type	**Manufacturer**	**Details**
Pattina L 13 puro lino (pure linen)	Tessitura Enrico Sironi	Weave structure analysis presented by Flock 2020a, 451

Table: Hannah Flock

paintings and single-thread bonds, even with much lower long-term exposure, are ultimately decisive.

Inherent Scatters

Since the test series have been repeated several times over the last years, two average measured F_{max} values are shown in figure 29.2. For each of the different adhesives and bonding techniques, the lowest and highest F_{max} mean values from all test series up to 2019 are presented. The order does not correspond to any chronological sequence. Although the exact same test setup and experimental design (test specimen preparation, testing,[18] and evaluation) were always followed, and at least ten to twenty test specimens of one type were tested each time, the average mean values are hardly reproducible due to scattering results.

Because figure 29.2 shows overall low and high average measured values, standard deviations as absolute scatter measures in the diagrams were omitted. Instead, figure 29.3 shows the relative coefficients of variation corresponding to figure 29.2. The variation coefficients of F_{max} lie within a range of approximately 6%–30% (in one case almost 40%), which corresponds to quite a large range of individual measured values from which the mean value is derived. In comparison, the variation coefficient of intact canvas samples shows a value of only approximately 6%, which probably results from variations in the natural fiber and the canvas production. Therefore, bonding

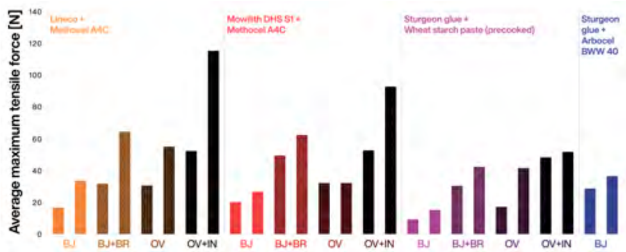

Figure 29.2 Maximum tensile forces (Fmax [N]) of uniaxially tested canvas strips with bonds. BJ: butt joint, BJ+BR: butt joint with bridging thread, OV: simple overlap joints, OV+IN: overlap joints with intermingled fibers of the thread ends. Image: Hannah Flock, 2019

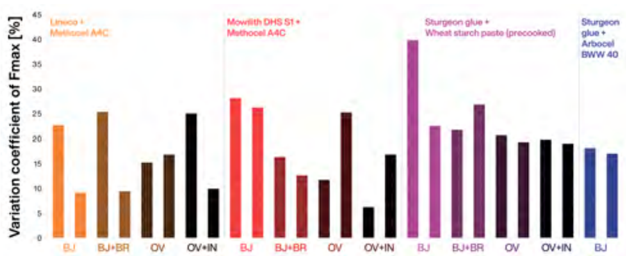

Figure 29.3 Coefficients of variation (CV of Fmax [%]) of uniaxially tested canvas strips with bonds. BJ: butt joint, BJ+BR: butt joint with bridging thread, OV: simple overlap joints, OV+IN: overlap joints with intermingled fibers of the thread ends. Image: Hannah Flock, 2019

causes the scattering of the measured values of all adhesives tested.

Extensive investigations into this problem made clear that the scattering is to be regarded as inherent in the technology: irrespective of the greatest possible standardization of the substrate to be bonded, there are always unknown differences in the individual sectional structure, geometry, length, torsion, and porosity of fibers and threads. All these aspects result in different wetting, penetration, and formation of the adhesive joint and its interphases as well as in different mechanical behavior under tensile testing, even with a standardized quantity and application of the adhesive. Thread-by-thread bonds inevitably scatter in their bond strengths. In practice, conservators must therefore always consider both the best case and the worst case, since the strengths of single-thread bonds can differ.[19]

Bonding Technique Evaluation

To aid the clarity of the figure scaling, the intact references without bonds are not shown in figure 29.2: the F_{max} of the intact canvas strips was approximately 270 N on arithmetic mean.[20] The average F_{max} of the bonded joints, using the four different adhesives in different joining situations, is always less than the strength of the intact canvas.

Regarding the different types of bonding, a successive increase can be noted for all adhesives from butt joints to butt joints with bridging threads to simple overlapping joints and to overlapping joints with intermingled fibers of the thread ends. The enlargement of the bonding surface and the mechanical anchoring result in an improved force transmission and thus higher maximum strengths.

Hence, overlapping bonds are more reliable than butt joint bonds and should therefore be preferred in principle. In case of overlap joints, care should be taken to ensure good mechanical anchoring and intermingling of the fibers of the two thread ends. Simply joining the thread ends on top of each other leads to a weaker bond. The minimum overlap is considered to be approximately 0.5 mm.[21] Shorter overlaps should be regarded and treated as butt joints. If possible, butt joints should be secured and stabilized with additional bridging threads. This also ensures a gentler tear opening in the event of adhesive failure.

Adhesive Evaluation

Butt joints without an overlap are the most challenging bonds, due to lower tensile strengths. In the past, these cases were frequently bonded with epoxy resins, which are rigid and irreversible and sometimes become brittle due to aging. Today, more suitable adhesives have been found. However, Heiber's "classic mixture" of sturgeon glue and wheat-starch paste is not suitable for this bonding technique,[22] as shown in figure 29.4, which represents a simplified section of data from figure 29.2. Particularly high bond strengths on butt joints could be achieved with the mixture of sturgeon glue and cellulose fibers. At the same time, this adhesive mixture is also less suitable for overlapping-intermingled bonding techniques, since the bonds quickly turn out to be too strong. The condition of the painting or canvas must always be taken into account: very brittle, degraded fabrics may also be too weak for the application of this adhesive mixture in butt joint technology. In such cases, it may be advisable to switch to the pH-neutral EVA dispersion Lineco with cellulose ether additive (cellulose fibers can also be added here for additional reinforcement and minimization of creep tendencies).[23]

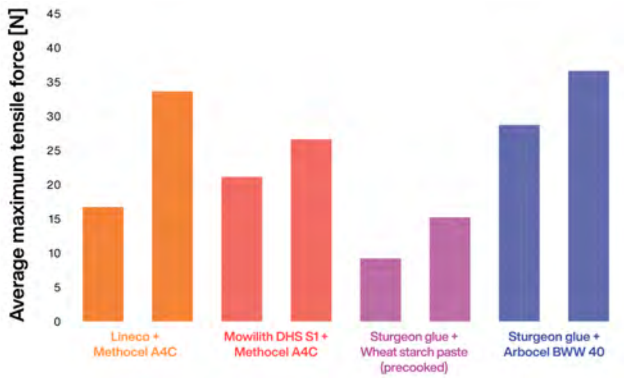

Figure 29.4 Butt joints with different adhesives: F_{max} N of uniaxially tested canvas strips with bonds. The lowest and highest mean values of the different adhesives and bonding techniques from all test series until 2019 are presented. Image: Hannah Flock, 2019

The support of butt joints by using bridging threads applied to the back can be recommended due to the significant increase in the average bond strength as well as slower opening in the event of adhesive failure. It is important to point out that the mechanical requirements for bridging threads are completely different from those for single-thread bonding: adhesives used for thread-by-thread mending would be too stiff and "inflexible" in terms of low ductility for bridging threads. Such bridges can become detached or, in the worst case, cause out-of-plane deformations. Bridging threads should function as a "flexible" additional force transmission line and support the stronger, actual bond. The main force transmission should take place in the bonded original thread material. The bridging threads should serve only as an additional transmission line through shear force interaction and not be explicitly chosen to be stiffening or similar through the choice of material. Ideally, this requires a rather soft, stretchable adhesive that can react in a compensating manner to movements of the textile support. Good adhesion with comparatively weak cohesion under high elongations, as in the case of thermoplastic reactivation of Beva 371 film (25 µm film in the test series), is ideal. As an alternative, the liquid pH-neutral EVA dispersion Evacon-R (with optional addition of methyl cellulose ether) could be considered for very rigid fabric structures. Dried Evacon-R films are less stretchable in comparison and are resoluble in water in terms of reversibility.[24] Acrylic dispersions might also be an option, though they are known to be unsuitable for single-thread bonding[25] due to their comparatively soft and extensible properties.[26]

Wherever possible, the fibers of the thread ends should be intermingled in overlapping bonding to achieve a larger bonding surface, improved mechanical anchoring, and optimized force transmission. As far as the final adhesive selection is concerned, the painting and fabric requirements are decisive: in practice, the Heiber recipe for the sturgeon glue–wheat starch paste mixture has become established for overlapping-intermingled bonding. With this classic adhesive, more degraded fabrics can also be bonded, while the cellulose-ether modified dispersions Lineco and Mowilith DHS S1 may allow also higher bond strengths for more stable fabric conditions with the overlapping-intermingled technique.

On some fabrics, strong darkening or gloss formation can occur when using the mixture of sturgeon glue and wheat-starch paste. The presented synthetic resin dispersions modified with methyl cellulose ether may help in these cases. Under especially high stresses or higher temperatures, the homopolymeric PVA dispersion Mowilith DHS S1 might be preferred to the copolymeric EVA dispersion Lineco due to expected lower creep tendencies.[27] The sturgeon glue–cellulose fiber adhesive tested is unsuitable for overlapping-intermingled bonding as it can result in a bond strength that is too high, especially in aged and degraded canvases. Furthermore, a reduction in the amount of adhesive to counter this problem is not a solution, as complete wetting of the thread adherends is essential for reliable bonding. Modifications of the adhesive formulation of sturgeon glue–cellulose fiber adhesives, by reducing the sturgeon-glue concentration and/or changing the fiber type, also proved not to be suitable for overlapping-intermingled bonding.[28]

Adhesive Modification

The mixture of sturgeon glue and Arbocel fibers is a comparatively new adhesive that can compete even with presumably strong epoxy resins.[29] Arbocel cellulose fibers are high-purity industrial products and are available in various lengths and thicknesses. This quality and standardization has many advantages over individually cut linen fibers. In the presented tests, Arbocel BWW 40 with a fiber length of 200 µm was used. Flock also investigated the question of whether shorter or longer fibers, or a mix, could also be suitable as fillers to improve embedding and force transmission properties, using canvas strips with butt joints for uniaxial short-term testing.[30] The basic recipe of a 25% sturgeon-glue solution and added cellulose fibers (20:1 by weight) was tested.

The results show the weakest bond strengths when using very short (Arbocel BC 600-30, average length 40 µm) and, especially, very long fiber types (Arbocel BC 200, average length 300 µm), as can be seen in figure 29.5.[31] Therefore, these types are less suitable as adhesive fillers for achieving high bond strengths in butt joints. The sturgeon-glue mixtures with pure Arbocel types of medium fiber lengths (B 00, B 800, BWW 40) are quite comparable with regard to the achieved bond strengths and averaged total strains of the test specimens.[32] The fiber length of 200 µm (Arbocel BWW 40) should be highlighted, as it seems to enable an ideal compromise in embedding and force transmission. The mixture has been in regular use at CICS since 2014 for butt joints in textile painting supports and has proven itself as an alternative to epoxy resins, especially for cuts.

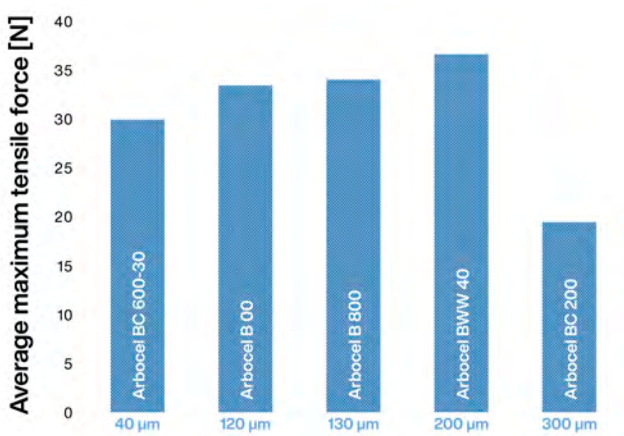

Figure 29.5 Butt joints with sturgeon glue–cellulose fiber mixtures: F_{max} [N] of uniaxially tested canvas strips with bonds. Image: Hannah Flock, 2019

The investigated fiber blends show a mechanical behavior similar to that of the original recipe only with fibers of type BWW 40: for this purpose, 1:1 mixtures (by weight) of Arbocel BWW 40 with a type of shorter fiber length were produced. The differences in the test results due to mixing with the types BC 600-30 (40 µm), B 00 (120 µm), and B 800 (130 µm) were marginal.[33] The different recipes, whether the pure fiber types of medium length or the other mixtures mentioned, show slightly different viscosities. Thus, in individual cases, depending on the required processing properties, it is possible to use one of these alternatives instead of the proven type Arbocel BWW 40.

ADHESIVE APPLICATION

The choice of a suitable application method has a particularly high influence on the reliable and constant quality of bonds, as well as the reduction of the scattering of the bonding qualities in the case of sturgeon glue–cellulose fiber mixtures. The successful application of, especially, those adhesive mixtures containing fibers is directly linked to the correct application. Therefore, use of the newly developed Consolidation Pen Winnie is recommended as an application method for sturgeon glue–cellulose fiber adhesives (fig. 29.6). The Consolidation Pen Winnie was used for standardized adhesive application of 0.6 µl droplets in the tests to examine the influence of different cellulose fiber lengths.

Figure 29.6 The Consolidation Pen Winnie. Image: Petra Demuth, 2019

The standardized application of small adhesive droplets of comparable volume, especially for adhesives that are applied warmer than room temperature, is typically a great challenge. This is especially true for the sturgeon glue–cellulose fiber mixture since the uniform fiber distribution in the adhesive droplet presents an additional difficulty. For example, an initial test series in 2015 produced highly inhomogeneous results without any conclusive reference to the properties of the different Arbocel types. In the course of the error analysis, it became clear that the previous application by means of a microdosage device[34] caused excessive fluctuations in the fiber content and therefore had to be optimized. After numerous preliminary tests and extensive product development, a heatable sleeve for a minisyringe with a low-binding pipette tip was developed by Star Tec Products, which enables the dosing of finest adhesive droplets of constant volume and homogeneous adhesive composition with regard to fiber distribution.[35]

THE CONSOLIDATION PEN WINNIE

The Consolidation Pen Winnie, named after the pioneer of thread-by-thread mending, Winfried Heiber, is a heat sleeve in which aqueous adhesive solutions can be heated in a special syringe. The temperature of the heating sleeve (which contains the heating element) can be regulated with the control unit, as shown in figure 29.6.[36] The heatable adhesive application device allows for precise and fast application of even highly concentrated animal-glue solutions, including, for example, 20%–30% solid content sturgeon glue and mixtures with wheat-starch paste or Arbocel cellulose fibers. The great advantage is that despite heating, the adhesive concentration in the syringe does not change. The Consolidation Pen Winnie can be comfortably operated with one hand without any appreciable effort, as shown in figure 29.7.

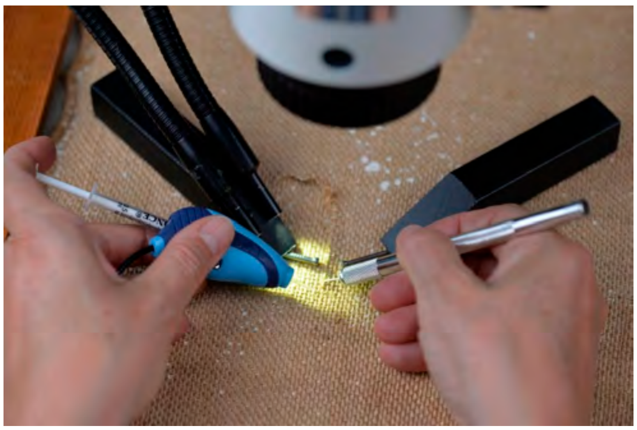

Figure 29.7 Working under a microscope using the Consolidation Pen Winnie. Image: Petra Demuth, 2019

The highlight that makes the Winnie a precision instrument is the selected low-binding pipette tip: its special conical shape ensures fine dosing. The transparent plastic nozzle made of polypropylene ensures a controllable material discharge at the approximately 0.8 mm diameter opening. This special low-binding tip, inert and coming from pipetting "long sticky molecules" in microbiology,[37] is indispensable for the application of finest droplets of highly viscous adhesive solutions, as the comparison with numerous cannulas and other pipette tips showed. The syringe and pipette tip are connected with a silicone tube. This simple connection provides sufficient tightness and stability for safe removal of the entire adhesive syringe from the heating sleeve. At the same time, quick assembly and disassembly is ensured.

The entire adhesive application takes place directly at the damaged area under the stereo microscope.[38] This is accompanied by a more relaxed and rapid bonding process. The adhesive is transferred from the tip of the pipette to the thread ends with a polystyrene strip or a Weston probe (see fig. 29.7). In some cases, for example, with particularly large thread diameters, the adhesive can be dripped or placed directly onto the thread ends with the pipette tip. The adhesive flow, and thus the droplet size at the pipette tip, can be regulated by the pressure on the syringe plunger and, to a certain degree, by temperature control. The incorporation of the adhesive between the fibers with fine instruments remains indispensable in case of closing tears and cuts in canvas supports.

The Consolidation Pen Winnie was initially developed for single-thread bonding to close tears and cuts in canvas supports.[39] Consequently, it is equally suitable for bonding processes when it comes to fabric inserts[40] for canvas supports. Further investigations will show to what extent the new adhesive application method with the Winnie will influence future choices of adhesive for single-thread bonding. The Winnie system opens the possibility that gelatin might be considered for the first time as an adhesive for tear mending; possibly suitable gelatin types are still to be tested.[41] Until now, the low gel temperature of sturgeon glue was indispensable for the traditional application method in practical conservation, which involved the transfer of the adhesive from a small glass jar outside the painting with the head of an insect pin. This application technique has many disadvantages and can now be avoided in the future.

CONCLUSION

Depending on the state of degradation and fracture pattern of a canvas, different bonding techniques and adhesives are suitable for the thread-by-thread tear-mending technique to close tears and cuts. The bond strengths of butt joints are significantly weaker than the strengths of overlapping joints. In the case of overlapping thread ends, intermingling of the fibers is recommended to generate particularly high bonding qualities.

In a comprehensive series of tests, four adhesives proved to be particularly suitable for common cellulose-based textile supports. The mixture of sturgeon glue and wheat-starch paste and the two synthetic resin dispersions, pH-neutral adhesive Lineco (EVA) and Mowilith DHS S1 (PVA), both modified with Methocel A4C cellulose ether, are suitable for overlapping-intermingled bonding. The two modified dispersion adhesives are also suitable for butt joint bonding. For high tensile strength of butt joints, the mixture of sturgeon glue with cellulose fibers (specifically Arbocel BWW 40) is recommended. Furthermore, butt joints should be additionally stabilized with bridging threads. For bridging threads, other adhesives than for tear mending should be used; especially suitable is Beva 371 (25 µm film).

Single-thread bonds are subject to technical and material immanent scatterings, which must be taken into account. To reduce the fluctuation range of the bond qualities, a suitable method of applying the adhesives is essential. For the warmed sturgeon-glue mixtures, especially the modification with cellulose fibers, the Consolidation Pen Winnie is highly recommended.

ACKNOWLEDGMENTS

The investigation into adhesives for thread-by-thread tear mending and suitable testing systematics was subject to the cooperative doctoral project of Dr.-Ing. Hannah Flock, MA, scientific associate at the Cologne Institute of Conservation Sciences (CICS), together with the Chair of Applied Mechanics (LTM) at Saarland University. The doctorate was supervised at LTM by Prof. Dr.-Ing. Stefan Diebels and at CICS by Prof. Dr. Elisabeth Jägers. In addition, Prof. Dr. Wulff Possart from the Chair of Adhesion and Interphases in Polymers at Saarland University was involved as scientific attendant. Dipl.-Rest. Petra Demuth accompanied the project as mentor and expert. Special thanks go to Volker and Eva Koch of Star Tec Products. Their great cooperation and technical input made the invention of the Consolidation Pen Winnie possible. We would like to thank everyone involved for their support, and in particular the Studienstiftung des Deutschen Volkes (German Academic Scholarship Foundation) for its individual sponsorship and financial support of the doctorate.

NOTES

1. Details about the general technique were described by Winfried Heiber, the pioneer of the thread-by-thread tear-mending method (Heiber 1996, 2003; Heiber et al. 2012).
2. Compare with statements by Christina Young published in context of the 2003 Alternatives to Lining Conference (Young 2003, 55–56), as well as Flock 2014, Flock 2020, Flock et al. 2021, and Flock et al. 2022.
3. The publications of Winfried Heiber are basic information sources about the general technique of single-thread bonding: see, for example, Heiber 1996, 2003; and Heiber et al. 2012. Individual essential aspects and more recent developments have been summarized by Petra Demuth (Demuth 2020). Details of the bonding procedure can be found in publications by Hannah Flock (Flock 2020, 23–28; Flock et al. 2022, 173–80).
4. Several authors have described adhesive criteria, including Flock 2014, 25–33; Reuber 2010, 17–20; Young 2003, 56; Flock 2020, 45–49; and Flock et al. 2022, 182–86.
5. It is often stated as a rule of thumb that the adhesive should have a lower cohesion than the original fabric to prevent further damage, so that the bonded joint opens instead of new defects forming. However, this requirement must be specified to the effect that the resulting bond must have a lower cohesion than the surrounding material. This is of great relevance, as the adhesive behavior in the joint sometimes differs greatly from the pure adhesive material (compare to Flock 2014, 134–35). Thus, for example, both increased and reduced, of previously assumed, bond strengths can occur (based on the pure adhesive properties). Adhesive and cohesive behavior are therefore to be understood and considered as mutually influencing (compare to Flock 2020, 46–47).
6. Especially regarding the often hygroscopic behavior of fabric, the bond achieved should have a certain tolerance to stress changes caused by climatic changes as well as transports of artworks or the like. The bonded area ideally accompanies the fabric's movements instead of promoting local tension differences and thus markings. Hygroscopic adhesive properties are therefore often preferred. In this context, the rather fuzzy term of *required flexibility* is often used. It would certainly be desirable that the adhesive joint behaves in the sense of spontaneous, completely reversible shape change (elasticity, comparable to an ideal constant spring). However, a certain flexibility in the sense of adaptive behavior, which can have viscous or even plastic-ductile components within certain limits, is sometimes sufficient. Slight viscous creep tendencies of adhesives, which are similar to those of the original fabric, are therefore not necessarily a disadvantage, as long as the transfer of force through the bond can be guaranteed and no deformations or the like result. Brittle properties should be avoided. Elastic or "flexible" automatically leads to the need for suitable stiffness, that is, the corresponding resistance to (elastic) deformation: the adhesive joint should not be too soft or stretchy and should be able to transfer stresses without deformation. At the same time, overly rigid bonds should be avoided. Here in particular, the idea of the ideal adhesive material, which is sometimes perceived as contradictory, becomes clear. However, there is not so much a contradiction as a very specific individual ideal that depends on the object, and is thus a hardly achievable mechanical property profile (compare to Flock 2020, 47–48).
7. This means that, for example, the optical density, light refraction, transparency, translucency, or even opacity, and degree of gloss of the bonded area ideally correspond to the individual optical surface properties of the surrounding fabric.
8. Compare to Flock 2014; Flock et al. 2019; and Flock et al. 2021.
9. For more details on scale effects, see, for example, Flock 2020, 51, 55; Flock et al. 2021; and Flock 2014, 130–39.
10. This problem has already been published (Flock 2014); a more recent article in English describes the facts in the context of inevitable scattering results in bonding qualities (Flock et al. 2021).
11. Only in the biaxial long-term test can the durability of the bonds for the practical application be conclusively tested, and a potentially disadvantageous creep behavior of the bonded joints be understood with sufficient test duration. A new type of creep test under constant load was designed for this purpose: the test setup enables the imitation of tensioned painting structures, testing of high sample numbers, and a quantifiable evaluation of the bond behavior. For this purpose, a tensile frame was developed that allows constant biaxial tensile loading of the samples; digital image correlation (DIC) is used for local and global strain evaluation of the bonded area and the entire sample. In addition to serial testing, the developed long-term test setup allows optional test extensions, for example, to include different tear geometries or external climatic influences. More details on the biaxial long-term test setup can be found in Flock 2020, 73–77, 124–29, 399–416, 445–49.
12. The results are published in the dissertation of Hannah Flock, "Einzelfadenverklebung in der Gemälderestaurierung: Klebstoffe, Prüfsystematik und Ergebnisse" (Single-Thread Bonding in Painting Conservation: Adhesives, Testing Systematics and Results); see Flock 2020. The collaborative PhD project was located at the Chair of Applied Mechanics (LTM) at Saarland University, Saarbrücken, and the Cologne Institute of Conservation Sciences (CICS) at Technische Hochschule Köln, Cologne. The project was supervised by Prof. Dr.-Ing. Stefan Diebels (LTM) and Prof. Dr. Elisabeth Jägers (CICS). Defense of the dissertation, May 7, 2020 (summa cum laude). An English translation of the dissertation thesis is in preparation.

13. The results of previous test series have been published in different places: sources such as Reuber 2010, Demuth et al. 2011, and Flock 2020 feature references to other publications.

14. Among the PVA dispersions considered, Mowilith DHS S1 showed satisfactory film properties, particularly homogeneous adhesive properties, and very good processing characteristics. It formed the most reliable bonds (compare to Flock 2014 and 2020).

15. Detailed information on the chosen setup has been published previously (Flock 2014, 2020). The details of the experimental design are therefore omitted from this section. Valuable advice for future test series, the experimental design, and all the details, can be found in Flock 2020.

16. Precise information on the materials and equipment used, as well as precise, illustrated instructions for the manufacture of bridging threads, can be followed in detail (Flock 2014, A.4–A.5; Flock 2020, 436). The Beva 371 film was applied only on the single threads, not as a continuous layer. This idea refers to Winfried Heiber's technique *Geweberasterhaftung* (fabric grid bonding): the melting of the thin adhesive film with a hot-air gun leads to adhesive-free interstices and an accumulation of adhesive on the surface of the threads (Heiber 1987, 72–76; Heiber 1999, 362–63).

17. The specification of tensions for textile painting supports is problematic: values given in conservation literature usually cannot be compared or generally transferred. The cross sections of the painting's layers are not known, therefore a substitute "line-stress" related to the fabric's width (N/m) is often given. However, this value is given regardless of the individual structure; for example, details about the weave and fabric, type and homogeneity of the upper layers, or interaction of the layers, are not taken into account. Furthermore, with fabrics there are also specific uncertainties when using the stress term, due to the "open-pored" structure: the fibers, which are made up from individual fibrils, are twisted together to form the threads. The threads, depending on the type of weave, interact at binding points (friction) or leave free interstices. In fact, there is no continuum either in the individual thread or in the fabric. Strictly speaking, no tension as stress can be defined. Hence, the approximation of the fabric as a continuous layer represents a high degree of abstraction. For this reason, also in textile technology and testing, the calculation of cross-sectional stresses (N/mm^2) is uncommon. Instead, the maximum tensile forces (N) or the width-related maximum tensile force (N/m) is often used (compare to Flock 2020, 34; Flock et al. 2022, 199). However, such absolute values must always be embedded in the context of their details and cannot be used for simple comparisons of different sources, as is unfortunately still done (see, e.g., Michalski 2022, 230–31). The authors would like to distance themselves explicitly from such compilations.

18. The testing parameters of all mended samples as well as of intact reference samples were as follows: clamping length 100 mm, minor pre-load of 0.1 N with 5 mm/min, and test speed rate of 20 mm/min (compare to Flock et al. 2021). Important note: in later tests a more suitable, increased pre-load of 1 N was implemented (Flock 2020, 62–63).

19. For more detail about investigations of inherent scatters, see Flock et al. 2021.

20. The tested reference canvas strips were each twelve threads wide or approximately 12.5 mm fabric width. Although a certain scaling effect can be seen for intact fabrics (Flock 2014, 84), it should not be concluded that 270 N per 12.5 mm leads to a maximum load capacity of ~21,600 N/m. Nevertheless, it is clear that even 270 N/m is a value to which many canvas paintings are probably not permanently exposed.

21. The minimum overlap of 0.5 mm is according to Winfried Heiber (Heiber 1996, 132–33): as a rule of thumb, the longer the overlap, the better for reliable bonding. In practice, the minimum overlap also depends on the thread structure, such as the shape and number of individual fibers and the thread thickness.

22. The mixture of sturgeon glue and wheat-starch paste is also unsuitable for simple overlapping joints, due to the sensitivity of the bonds to shear stress: here, the bonds open abruptly and completely in case of failure. The adhesive mixture is only suitable for overlapping-intermingled joints. In addition, no attempt should be made to compensate for the inadequate properties of butt joints with this mixture, for example, by applying additional bridging threads: the adhesive must not be used in these cases (Flock 2020, 142, 184).

23. Tested recipe: mixture of EVA dispersion with methyl cellulose ether solution (Lineco + Methocel A4C 5% in water, 9:1 by weight) plus cellulose fibers (Arbocel BWW 40), 20:1 by weight (compare to Flock 2020, 94, 150–51).

24. According to Fourier-transform infrared spectroscopy (FTIR) analyses by Elisabeth Jägers, the copolymeric EVA dispersion Evacon-R has a much higher proportion of ethylene, which acts as an internal plasticizer. Therefore, Evacon-R is much more stretchable and softer than the pH-neutral adhesive Lineco (the product could be identified in the spectrum as an EVA dispersion, but its much lower proportion of ethylene could be the reason it is incorrectly identified as a homopolymeric PVA dispersion on the container bottle (Flock 2014, 28–29, A.3.2).

25. These results were presented at the 2011 Canadian Conservation Institute symposium "Adhesives and Consolidants for Conservation: Research and Applications" (Demuth et al. 2011).

26. See Flock 2014, 52–56, 130–32; compare to Flock et al. 2021.

27. Due to ethylene as internal plasticizer; see note 24 above.

28. Different formulations of the mixture did not solve the problem of damaged thread adherends after breakage of overlapping-intermingled bonds (Flock 2020, 147–48).

29. Butt joints with the two-component epoxy UHU Plus Schnellfest had less tensile strength in comparison and also showed an increased scatter range of the bonding qualities. Epoxy resins are therefore not preferred for conventional linen fabrics. Presumably, the poor processing properties lead to lower bond strengths by comparison, unlike what would be expected from these high-strength adhesives (Flock 2020, 97, 153–55).

30. This topic is described in detail in Flock et al. 2019 and thus is briefly summarized here.

31. Arbocel fibers were considered as midlength fibers with 120–200 μm: a minimum length of 40 μm and a maximum length of 300 μm were investigated. However, this does not directly indicate what the critical lower and upper fiber length limits are.

32. The coefficients of variation (CV of F_{max}) slightly differ between approximately 15% and 21% (Flock et al. 2019, 122).

33. Regarding average bond strengths, total strains of the test specimens, and variation coefficients; see Flock et al. 2019, 122.

34. Done by measuring 0.6 μl per thread with a fine pipette and reproducing the droplet volume with a microdosing device. See Flock 2014, 308–21 for details on device, materials, and procedure for adhesive dosing.

35. See Flock et al. 2019 and Demuth and Flock 2019. For a summary in English, refer to https://www.th-koeln.de/mam/downloads/deutsch/hochschule/fakultaeten/kulturwissenschaften/_englisch_.pdf, pp. 6–10 (accessed April 26, 2022).

36. The Consolidation Pen Winnie comes with two sizes of syringes (0.5 ml and 1 ml); the maximum internal temperature is approximately 63°C–68°C. The precise fit of the reusable syringe allows optimal heat transfer. Syringes with a diameter of up to about 6.5 mm can be inserted. The use of a particularly short syringe is extremely handy, with a maximum length of approximately 11 cm including plunger. The flow and the droplet formation of the adhesive solution are caused by the extremely low pressure of the syringe plunger. All the individual parts described, for example, syringes, low-binding pipette tips, and silicone tube, are included in the Winnie starter kit.

37. Compare to information from Sorenson TM BioScience Inc.: http://www.sorbio.com/index.php/low-binding-polymer (accessed April 26, 2022).

38. Working under the stereo microscope is indispensable to be able to implement the single-thread bonding technique with the required precision and to achieve excellent bonding qualities (compare to Flock et al. 2022, 173).

39. The Consolidation Pen Winnie enables controlled adhesive application under a stereo microscope as well as with the naked eye; the field of application thus ranges from single-thread bonding to, for example, consolidation of paint layers. Another possible application is for filling of losses in paint layers. Classic animal glue–chalk filling material as well as methyl cellulose ether–chalk filling material can be applied to close the defects.

40. For the application of inserts using the single-thread bonding technique, see also Flock 2020, 27–28; and Flock et al. 2022, 178–79.

41. Exemplarily, Flock considered mixtures of one type of gelatin: a gelatin typically used in other contexts of conservation practice was included in the adhesive selection (Gelita Imagel 185 Bloom, inert photographic gelatin, pH 5), to be specifically compared with sturgeon glue. The selected gelatin type showed significantly lower bond strengths and increased scattering ranges when mixed with wheat-starch paste and cellulose fibers, and therefore cannot be preferred. Due to the large number of different gelatins, however, this cannot be understood as generally representative. A more suitable type of gelatin could therefore still be found for alternative use in single-thread bonding (Flock 2020, 85–86, 145–46).

VI

Local Interventions and Collections

30

Targeted Strategies for Structural Treatments: The Law of the Instrument, Occam's Razor, and Minimal Intervention

Robert Proctor, Co-owner, Whitten & Proctor Fine Art Conservation

The practice of minimal intervention came about as a response to invasive and prophylactic treatments of the past. Since it is the principal responsibility of the conservator to intervene, perhaps a better term would be targeted intervention*. This paper seeks to illustrate how two adages, "Occam's razor" and "the law of the instrument," can help define a more targeted strategy wherein standard procedures can be simplified by both reexamining the causes of damage and modifying tools to better suit the task. Originally conceived as a slide presentation with multiple images, the intent of this paper is to encourage a generation of developing conservators to trust in their own hand skills and knowledge. Examples illustrate that by employing critical thinking and ingenuity, simple and more direct solutions can often be found to replace formulaic methodology and sophisticated equipment.*

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HISTORICAL CONTEXT

The 1974 Greenwich Conference on Comparative Lining Techniques might be called the seminal meeting for the field of painting conservation in the twentieth century. Implicit was an international agreement that the craft-oriented methods used for the structural treatment of paintings in the past, specifically lining paintings, be reviewed in the context of scientific investigation, and that new, informed methods must be adopted for our profession to evolve and avoid the mistakes of the past.

New tools like vacuum hot tables, low-pressure suction tables, and regulated humidity chambers were being developed and employed. Modern technology offered an expanding variety of new synthetic materials, which were being anxiously embraced, along with high-tech testing methods to evaluate these materials. All of this elicited excitement and confidence in all that was new to our profession. However, an underlying movement was stirring as well, mostly associated with a conservator named Westby Percival-Prescott, who was concerned about the notion that we must act prophylactically, and that we may be simply replacing the how and what without first addressing the why (Villers 2003b).

Over the next couple of decades, a more cautious approach known as minimal intervention was becoming the mantra of more and more paintings conservators. When I began my training in the mid-1980s, I was one of the young converts to this approach, even though some of my mentors considered Percival-Prescott an alarmist whose call for "a lining moratorium" was holding back progress in our field. While Percival-Prescott was advocating for caution and further investigation into both the efficacy and unintended consequences of lining, other critics soon came forward with much more scathing accusations of conservators destroying artworks due to their lack of connoisseurship and a rush to adopt new materials and methods (Walden 1985; Beck and Daley 1994).

A cadre of conservators were similarly advocating for what might be described as a gentler approach to treating paintings. Take, for example, the 1988 American Institute for Conservation (AIC) meeting in New Orleans. Sandwiched between the presentation of technical reports by two engineers, Gustav Berger and Marion Mecklenberg, Lance Mayer and Gay Myers presented a paper titled "Thoughts on Unlined Paintings." In this presentation, they pondered "the ways in which conservators wrestle . . . with the actual treatment of unlined paintings" (Mayer and Myers 1988, 222) and stated that "the trend toward treating paintings conservatively implies . . . changing ways of thinking . . . [toward] . . . minimal treatment of problems as they develop, rather than thinking that any conservation treatment can solve all of a painting's past, present and future problems" (Mayer and Myers 1988, 227).

Probably the conservator most associated with this minimal approach was Winfried Heiber (fig. 30.1), a mentor for many students and like-minded colleagues even before he became a professor at the Hochschule für Bildende Künste (Academy of Fine Arts) Dresden. Today the "Heiber method" of tear mending is widely accepted as the primary technique for avoiding the "need" to line a torn painting.

Oddly enough, through my discussions with Heiber over the years, he rejected the term *minimal intervention* to describe the philosophy he followed, pointing out that simply adhering a new canvas to the reverse of a painting, and then filling and retouching a tear, could be considered *less* of an actual intervention than manipulating each thread of a tear and addressing all of the physical demands and tensile stresses throughout the multiple layers of a torn painting.

His approach might be better described as targeted intervention. The goal is to treat the damage locally, restore each and every layer of the painting, and limit the work to the specific area of damage. His process could almost be described as putting time in reverse to bring the painting back to a predamaged state. At the Tear Repair Seminar and Workshop held at the Art Institute of Chicago,

Figure 30.1 Heiber (right, at microscope) demonstrating his tear-mending technique at a 2004 workshop at the J. Paul Getty Museum. Image: Robert Proctor

September 7–9, 2000, Heiber compared a lined painting to a Ming Dynasty vase filled with cement and placed on a shelf. He observed that while it might be next to impossible to break the vase and that the cement remains visibly undetectable to the viewer, the inherent nature of the vase had been terribly compromised. In broader terms, he would remind us that one thing to be cherished about most paintings is their inherent fragility.

The subtitle of this paper is based on two common adages. The first is the law of the instrument: "When all you have is a hammer, everything looks like a nail"—a caution against letting the tool define the treatment rather than the treatment defining the tool. The second is Occam's razor: "When faced with a problem, the simplest solution is usually the best." Applied to conservation treatments, this translates to providing simple but effective solutions by looking more closely into the materials and actual mechanics of how something becomes damaged.

This paper presents some simplified methods and tools I have either developed or modified to facilitate local, targeted structural treatments of canvas paintings.

WORK STRETCHERS

Work stretchers can be indispensable when treating tented paint caused by a shrunken canvas, particularly when the damage is in an area where the stretcher bars get in the way.

Figure 30.2 illustrates the design of a work stretcher developed by Heiber. The painting's tacking margins are flattened and clamped between two padded wood blocks. On the end of one of each pair of blocks is a nylon strap by which the painting is suspended in a stretcher. This modular work stretcher is made from sections of aluminum with wood edges. The painting can be tensioned overall in the four corners using a hex wrench or locally by pulling the straps and restapling them.

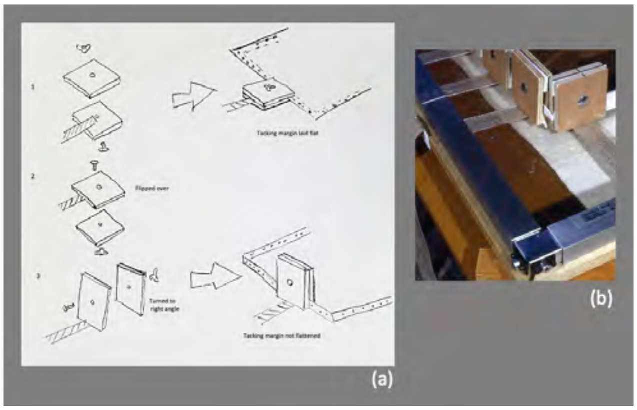

Figure 30.2 Modification of Heiber's work stretcher attachment to maintain tacking margins without flattening. (a) Diagram illustrating the process of modification. (b) Detail of a painting attached to a work stretcher using this modified method. Since the tension is equilibrial, the tacking margins will remain at a right angle (see figs. 30.2 [a] and 30.3 [b]). Image: Robert Proctor

I modified the system to avoid flattening the tacking margins by flipping the blocks over and turning them on edge. Since the tension is equilibrial, the tacking margins remain at a right angle (fig. 30.3). Alternatively, easily sourced items (such as Hollytex, packaging tape, and bulldog clips) can be used to suspend paintings in standard artist's stretchers (see fig. 30.3). Beva film is applied to the Hollytex and the stretcher to ensure that the tape sticks.

Often, damage is seen only along the bottom of a painting. In these cases, only the bottom stretcher member may need to be removed. A stretcher can be assembled to "hug" the three unaffected sides—either clamped together or held with mending plates. (Tip: Place holes where they can be reused for the backing board.)

RELAXING TENTED PAINT

Heiber modified the so-called burnt finger technique commonly used to treat tenting paint (fig. 30.4). After infusing the canvas with an adhesive (usually wax works best), a light bulb is used on the reverse of the canvas to liquify the adhesive and stretch out a small area of canvas so that the paint can be set down without overlap using

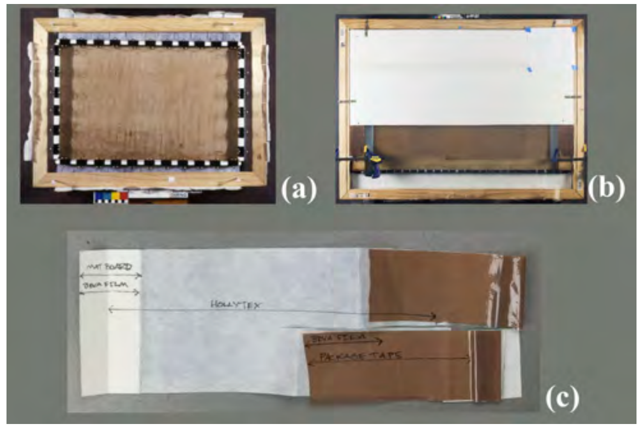

Figure 30.3 Examples of different methods of suspending a painting in a work stretcher while maintaining the tacking margins without flattening. (a) Painting in a standard stretcher with tacking margins preserved using bulldog clips. (b) Painting suspended in a new stretcher to allow access only to the lower edge of the painting; note the clamping and mending plates from the reverse. A stretcher can be assembled to "hug" the three unaffected sides—either clamped together or held with mending plates (see b). (c) Mock-up illustrating how to attach Hollytex and tape to suspend the painting in the stretcher. Image: Robert Proctor

pressure from a padded clay shaper—or better yet, silicone shapers or a handmade Teflon tool. After a day's work, tension is increased along the bottom member to reduce the bulges created by the light bulb. The light bulb can be attached to a handle to extend the user's reach and a spoon attached to the opposite side to provide a cool surface for the adhesive to set under pressure.

Figure 30.4 The author using a spoon and light bulb (inset) to employ the modified burnt finger technique. Image: Renate Poggendorf

Another alternative that is particularly useful when the reach is too far is to use a watch glass to press on the back of the canvas (fig. 30.5). A board is cut to fit behind the back of the painting, and two lengths of twill tape, running vertically and horizontally, are taped to the bottom of the glass. A piece of silicone-release Mylar is placed over the glass to cover the entire surface. When the painting is in place, the twill tape can be used to move the glass without excessively moving the painting. (The painting is slightly lifted each time the watch glass is moved, then gently set down.)

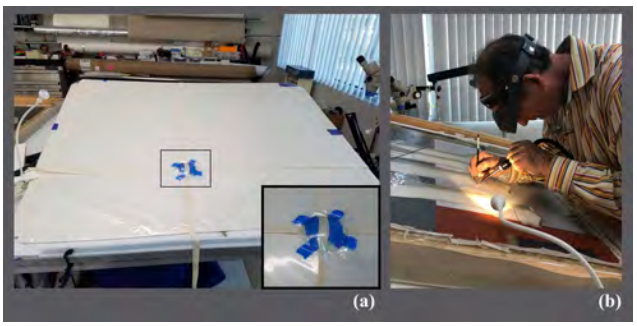

Figure 30.5 Setup for technique with watch glass to set down cupped paint. (a) Detail of glass with twill tape for manipulating placement. (b) The author setting down paint with hot air and a silicone shaper using this watch glass support setup under the painting. Image: Whitten & Proctor Fine Art Conservation

Next, adhesive is locally fed into cracks and under lifting paint while a hot-air tool and silicone shaper are used to set the paint down on the front. To remove the distortion created by the watch glass, a reptile warming mat (purchased at a pet store) is placed behind the painting. A piece of silicone-release Mylar is used to protect the painting and a small sandbag weight is used for pressure (fig. 30.6).

SUCTION PLATEN

A suction platen may be the most versatile tool for local interventions. My design has a thin profile to fit under stretcher members and a baffle system inside to keep the suction even across the surface (fig. 30.7). The 8 × 8 inch size keeps it lightweight while maintaining a usable surface area and allowing it to fit within most stretchers, even those with tight crossbars. The advantages over full-size suction tables include nimbleness and ease of treating smaller areas. Furthermore, the tacking margins need not be flattened and rebent.

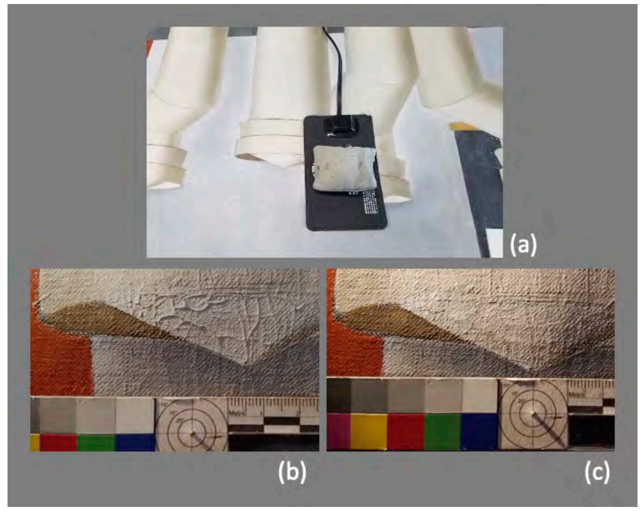

Figure 30.6 Final step in watch glass support setup. (a) Detail of the reptile warming mat over recently consolidated area. (b) Detail under raking light before treatment of an area treated using this method. (c) Detail under raking light of same area after consolidation treatment and relaxation of paint using this watch glass support setup. Image: Whitten & Proctor Fine Art Conservation

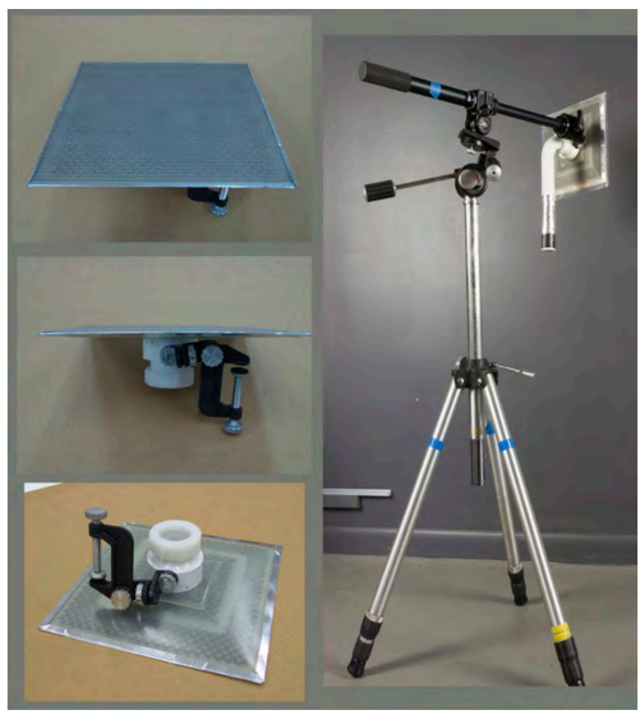

Figure 30.7 Various views of suction platen designed by the author. The platen can attach to a tripod like the one shown at right for ease of placement and alignment on the reverse of the canvas. Image: Whitten & Proctor Fine Art Conservation

RETENSIONING TEARS

While the Trecker, designed by Heiber (Demuth and Heiber 2000), is very useful for pulling the edges of tears together, its weight and size can make using it awkward, particularly in tight spots close to the stretcher bars.

As seen in figure 30.8, a simple aluminum corner brace can be attached directly to the stretcher, with a piece of Fome-Cor used as a spacer so that the edge of the aluminum does not quite touch the reverse of the canvas. A thin piece of plastic G-10 is slipped under the stretcher to protect the canvas from the edge of the aluminum. Unwaxed dental floss is attached to opposing sides of the tear with either Beva film or Command strips, then threaded under the aluminum. Pushpins are tied to the other ends of the threads. Tension can be incrementally increased to bring the edges of the tear together by pulling on and repositioning the pins.

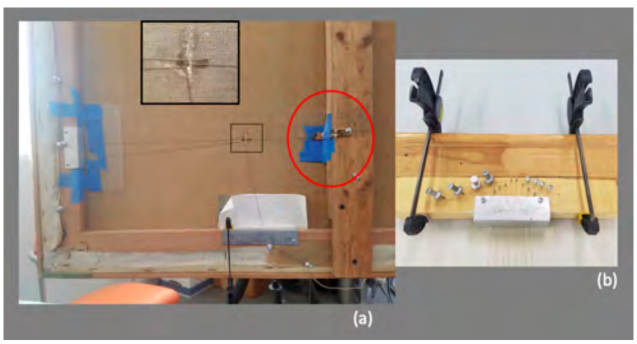

Figure 30.8 (a) Example of a setup using aluminum edging on a stretcher and minimal floss/thread attachments to close the gap in an existing tear on a canvas. Note the mending plate (circled in red) used to anchor to the crossbar of the stretcher when only one thread was required for tensioning. (b) Mock-up of possible tensioning mechanisms of screws and pushpins with clamped attachment to stretcher. Image: Robert Proctor

Alternatively, a small board can be clamped to the inside of the stretcher to avoid putting any holes in the painting stretcher, as shown in the mock-up in figure 30.8. Screws can be used in place of the pushpins, with the threads wound around the screws. The tension can then be increased with greater control by slightly turning the screws.

Figure 30.9 includes before-treatment details of a large painting (60 × 90 inches) with a small but fairly distorted tear where this technique was applied. Where only one or two threads are needed to pull a small puncture together, bent mending plates (see fig. 30.8) can be used instead of angled aluminum edging or fabricated Treckers.

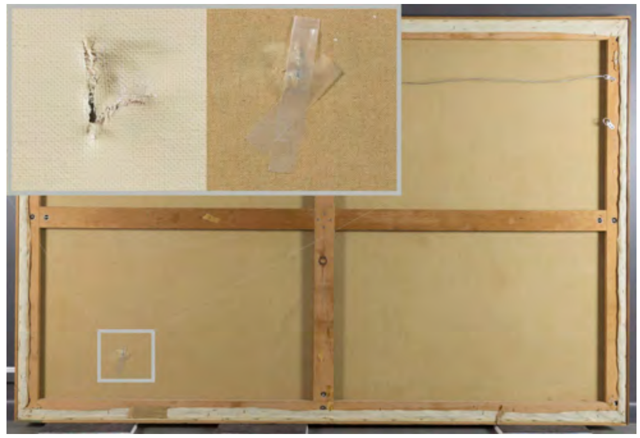

Figure 30.9 Before-treatment details of a complex tear; the condition is as the painting arrived in the studio. Partial image of the reverse showing the relative size and location of the tear. Inset details the front and reverse of the tear. Image: Whitten & Proctor Fine Art Conservation

A suction platen was used during the tear mending to humidify the area to remove planar distortions, and again while filling. Using the platen at low suction during filling allows the wet fill material to be drawn into the canvas voids—which helps keep the tear in plane—and to take on the weave texture of the canvas. A small, thin piece of Stabiltex impregnated with Beva can be used to cover the mend both to act as a moisture barrier for the repair and to add a second line of security if the mend were ever to fail (fig. 30.10). Figure 30.11 shows the difference at the tear site before and after treatment.

CONCLUSION

Honoring the artist's intent, understanding the forces that hold paintings together and those that make them fall apart, and having a keen respect for the original materials and an understanding of modern materials, reversibility, and retreatability are the factors to keep in mind when caring for damaged or changed paintings on canvas. Over the years, it has become clearer that our profession does not lend itself to a one-size-fits-all approach, no matter how technically sophisticated or well engineered these materials or equipment may be (the law of the instrument), and that the better we understand the nature of the problem at hand, the more it can lead us to simpler and more refined solutions (Occam's razor).

Those of us involved in structural canvas treatments are constantly discovering better methods and adjusting what we do to suit each painting we treat. For instance, since presenting at the Conserving Canvas conference at Yale, Petra Demuth, who teaches Heiber's tear-mending

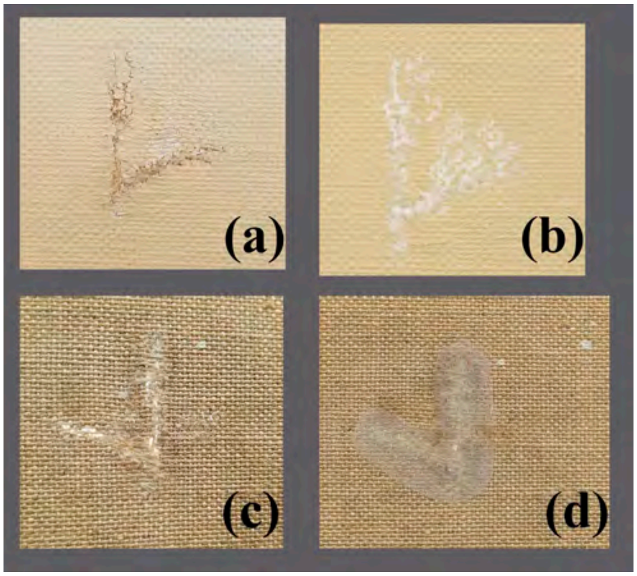

Figure 30.10 Details at the tear site after retensioning showing the progression of filling and stabilization. (a) Front before filling. (b) Front after filling. (c) Reverse with fill in voids. (d) Reverse after Stabiltex with Beva has been applied. Image: Whitten & Proctor Fine Art Conservation

Figure 30.11 Comparison of details at the tear site before treatment (top) and after (bottom). Image: Whitten & Proctor Fine Art Conservation

techniques, has demonstrated substitutions for the Trecker that are more nimble and far easier to set up and use. It was an honor to be invited to share my current techniques, but my work continues to evolve, and what I do next year may be different from what I have done in the past.

APPENDIX: MATERIALS

Hollytex: spun-bonded nonwoven polyester fabric, TALAS, New York.
https://www.talasonline.com/Hollytex

Beva 371b film: ethylene vinyl acetate–based film adhesive. A variation on the mixture of Beva 371. Beva 371b is composed of ELVAX (500 g), aldehyde resin N (300 g), A-C copolymer (ethylene vinyl acetate adhesive), Cellolyn 21 (40 g/l), and paraffin dissolved in 1000 g of toluene. Available from Conservator's Products Company.
http://www.conservators-products.com/products.htm

Mending plates and corner angles. Available from most hardware stores.

Silicone color shapers. Available from Jerry's Artarama and similar art supply stores.
https://www.jerrysartarama.com/brushes-tools/color-shapers/colour-shapers/colour-shaper-sets

Mylar: pure D polyester in a clear, uncoated state. Sourced from TALAS, New York.
https://www.talasonline.com/Mylar-Rolls

Reptile warming mat. Available from most pet stores, such as Petco.

Fome-Cor: rigid polystyrene core laminated with paper or plastic on both sides. The rigid, strong, flat panels are water resistant and dimensionally stable. The foam is acid-free, but the laminated surfaces may contain acidic material. Sourced from Laird Plastics, Houston.
https://lairdplastics.com/all-products/fome-cor-board/

G-10: high-pressure fiberglass laminate soaked in epoxy resin. Sourced from Allied Plastic Supply, Dallas.

Stabiltex fabric: fine polyester multifilament fabric. Originally manufactured by Sefar AG, Switzerland but discontinued. Silk crepeline can be used as an alternative, as can prepared Beva-Tex. Available from Conservator's Products Company.
http://www.conservators-products.com/products.htm

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Weaving into Heiber: Further Treatment Steps for Tear Mending

Emily Mulvihill, Conservator and Co-founder, Current Art Conservation, New York
Sandra Amann, Head Painting Conservator, Amann + Estabrook Conservation Associates, New York
Elizabeth Estabrook, Head Painting Conservator, Amann + Estabrook Conservation Associates, New York
Megan Berkey, Painting Conservator, Amann + Estabrook Conservation Associates, New York
Sayaka Rozsa, Painting Conservator, Amann + Estabrook Conservation Associates, New York
Gail Mitchell, Painting Conservator, Amann + Estabrook Conservation Associates, New York

Structural damage to a canvas, such as tears, presents unique problems when considering and conducting conservation treatments and can be compounded when working in private conservation, as a consistent and stable environment for the exhibition, storage, and travel of a painting is not assured. When Heiber's thread-by-thread tear-mending technique is selected as the preferred treatment method, further treatment steps, such as reinforcements to the mend, are often necessary to maintain integrity and planarity and ensure a successful outcome. This paper argues for the necessity for reinforcements to be added to tears repaired using Heiber's technique. Four case studies of tears encountered in a private painting conservation setting are presented. These case studies present examples in which structural reinforcements of tear repairs were implemented, informed by the canvas's material properties; the type of damage to the canvas threads; and the size, direction, and location of the tear. The reinforcements discussed focus on the incorporation of Gore-Tex sutures into the weave matrix.

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INTRODUCTION

In the field of paintings conservation, there are long-established treatment techniques for addressing structural repairs, such as tears in the canvas support. These techniques range from more invasive treatments, such as linings (Bailey 2017; Berger 1974, 1975; Bernstein 1974; Fieux 1974; Goist 1977; Levenson 1974; Slabczynski 1960; Stoner 1994; Wales 1968), to less-invasive treatments, such as patches and localized thread-by-thread repairs (Barnett 1992; Bustin 2003; Heiber 2003; Piotrowska and Amann 2009; Proctor 1994). After the 1974 Greenwich conference (Villers 2003b), there was a shift in thought away from invasive techniques and an effort to devise less-invasive techniques (Hackney 2004a; Keck 1977).

The development of the thread-by-thread tear-mending technique, published by Winfried Heiber (Heiber 2003; Proctor 1994), enabled a new phase of less-invasive treatments of structural repairs in paintings conservation, which were more sympathetic to the canvas, did not alter the surface appearance of a painting, re-created the aesthetic properties of the canvas, and were reversible. Heiber's technique involves the retwining of the torn and splayed threads and reintegrating them into the weave matrix to reestablish the overall tension of the canvas in the torn and damaged area. It is well established that a fluctuating environment causes the canvas fibers to swell and contract (Cornelius 1967), placing stress on the canvas, paint layers, and any structural damage and repairs (Berger and Russell 1990). The theory behind Heiber's repairs is that when individual fibers are reconnected, the integrity of the canvas is restored, and the whole canvas responds uniformly to environmental fluctuations; this in turn reduces localized stress on the mend.

The success of a Heiber mend is dependent on factors such as the type of damage to the canvas threads, as well as the size, direction, and location of the tear. The two most common categories of damage to the threads are tearing from the canvas weave and cuts, and the associated bonds for each affect the ability of the mend to withstand stresses. Tears involving torn threads can be reconnected by overlapping and intermingling fibers from opposing threads and adhering them with a small amount of adhesive. This type of join creates the strongest bond and can withstand greater amounts of stress. Tears where the threads have been cut are reconnected to the opposing thread with a butt join and a small amount of locally applied adhesive. This type of join relies mostly on the strength of the adhesive rather than the combination of the canvas fibers and adhesive; it is less successful when placed under stress and less able to maintain planarity.

The size or length of the tear impacts the overall structural integrity of the canvas support. Horizontal and vertical tears are both affected by stress inherent to the overall canvas, but horizontal tears are vulnerable to the added effects of gravity and the weight of the canvas pulling on the mend. This stress is increased when the tension of the canvas is loose and there is a thick, heavy paint layer. Finally, the location of the tear and potential stress from increased vibrations may compound the stress created by all the other factors.

For all of these reasons, it is important to build on Heiber's theories and develop additional localized treatment strategies that can be used to strengthen tear mends while being sympathetic to the canvas support. Verso reinforcements are an important last step to a tear repair when the bonds in the repair are not strong enough to withstand stress from environmental fluctuations, which can be exacerbated by the damage.

This paper presents four case studies undertaken at Amann + Estabrook Conservation Associates to describe the option of verso reinforcements as a way to bridge and support thread-by-thread mends. The process of deciding whether verso reinforcement is necessary, and if so, what materials may be appropriate, is discussed in each case.

VERSO REINFORCEMENTS

At Amann + Estabrook, Gore-Tex sutures[1] sewn into the weave matrix have been found to provide a passive, inert, and flexible support network that helps counter mechanical forces (Hartman 2017; Piotrowska and Amann 2009). They are fully reversible and can be removed easily if required. The sutures also lend themselves to variations and can be adapted to suit each individual case. They can be varied in length, concentration, and sewing methods, thereby reducing the potential for telegraphing through to the face.

Gore-Tex sutures, commonly used in dental surgery, are a microporous, flexible polytetrafluoroethylene monofilament with a stainless-steel needle fused to either end of the monofilament. They are soft and easy to manipulate. They can also be dyed to match the fabric support of a painting, and thus be a discreet addition to a conservation treatment. They come in a variety of monofilament thicknesses, needle gauges, and needle types. Generally, the preferred Gore-Tex suture for most treatments where suture reinforcements are needed is the thinnest gauge: monofilament CV-8 with a needle gauge of TTc-7 and a tapered needle shape.

Gore-Tex sutures may not be suitable for every painting. For sutures to be successfully integrated into the canvas weave, they need to be sewn between overlapping warp and weft threads. The canvas fibers need to be supple enough to allow the needle and suture to pass through. If the canvas has deteriorated and become brittle, sutures can shatter the canvas fibers within the threads. For this reason, Gore-Tex sutures are more suited to modern and contemporary paintings, because they have less deterioration than considerably more aged canvases. However, each canvas must be assessed on an individual basis. In some cases, when deterioration of the canvas is not uniform, Gore-Tex sutures can be used in combination with other methods to bridge tears. Other verso reinforcements used in combination are Japanese paper "sutures" and patches infused with Beva 371.

CASE STUDY 1: TEAR MEND WITHOUT REINFORCEMENT

Painting Description and Condition

The first painting presented is by a Japanese artist and was painted in the mid-1970s. The painting measures 120 × 77 inches (304.8 × 195.6 cm) and is one of two from a diptych. The painting was executed on a plain-weave, medium-weight cotton duck canvas that was stretched onto a sturdy seven-member wood expansion-bolt stretcher. The stratified structure of the paint layer consists of a thin, evenly applied white ground layer followed by layers of sparsely applied acrylic paint, graphite, and art markers.

The painting had a 5 1/2-inch vertical tear located in the bottom left corner, 1 inch from the left turning edge. Four vertical-running threads were severed and hung loosely, while several other vertical threads, although intact, were stretched and pulled out of the weave matrix. The horizontal threads were torn the length of the tear and had splayed ends. The torn ends appeared to meet their opposing threads, which indicated that a gap between the edges of the tear had not developed. The canvas had rippled distortions that ran down both edges of the tear. Fractured paint radiated from the tear, with associated lifting and loss to the paint and ground layers. Paint fragments were also attached to the hanging vertical threads.

Discussion

The tear's size, direction, location, and type within the overall painting are fundamental when determining the damage to the overall structural integrity of the canvas support caused by the tear. Once assessed, this helps determine how to proceed with conservation treatment. In this case, the tear was 5 1/2 inches long (13.9 cm), ran vertically, and was 23 3/4 to 28 5/8 inches (60.3–72.7 cm) from the lower edge and 1 inch (2.5 cm) from the left turning edge. The threads in the tear were torn rather than cut bluntly. The length of the tear was relatively small in proportion to the overall height of the painting—only 5%.

Under observation while in the studio, the tear did not increase in size or form distortions within the support. From this, it was determined that the overall impact of the tear on the integrity of the canvas was minimal. As the tear ran vertically, it was estimated that the tear did not bear significant weight from the canvas and was not greatly affected by gravity. The location of the tear, close to the left turning edge and approximately 25 inches from the lower edge, was predicted to be under a low amount of strain—an estimate that was again supported by the lack of distortions in area (Berger and Russell 1988). Finally, threads within the tear were torn and pulled out of the weave, which meant that, when rewoven, opposing threads would overlap and create a strong repair. As the tear's size, direction, and location had minimal impact on the overall integrity of the canvas, additional verso reinforcements to the tear were not necessary; the treatment was more aesthetic than structural. This minimal approach provided the flexibility to potentially add reinforcements in the future should it be necessary.

Treatment

The painting was treated in situ while the fabric remained attached to the stretcher. The canvas was mended using the Heiber thread-by-thread repair method, working only from the face under stereo magnification, as the reverse was not available due to its being behind the stretcher bar. Broken and frayed threads were retwisted and sized with a dilute solution of methyl cellulose in distilled water. The dampened threads were then rewoven into the weave matrix to aesthetically match the original weave. The adjoining threads were connected and adhered with a bead of dilute Vinamul 3252 (ethylene vinyl acetate–based adhesive) and secured with a needle-tipped heated spatula.

CASE STUDY 2: BUTT-JOIN TEAR MEND WITH GORE-TEX SUTURE VERSO REINFORCEMENT

Painting Description and Condition

The second painting presented was completed in the late 1960s by an artist prominent in the Abstract Expressionist movement. The painting measures 92 1/2 × 128 inches (235 × 325 cm) and was executed on a heavyweight cotton duck canvas that was stretched onto a sturdy wooden stretcher. The ground layer is an evenly applied white layer, and the paint layer, estimated to be oil, was applied in limited areas within the top half of the painting in a thin brush application.

The face of the painting was accidentally slashed with a box cutter when the work was being unpacked, which left a slightly wavering, horizontal, sharply cut tear through the fabric support (fig. 31.1). The tear was located 48 1/16 to 48 3/4 inches (122–123.8 cm) from the upper edge and 3 3/8 to 17 5/8 inches (8.6–44.8 cm) from the right edge. The tear exhibits minute loss of the thin ground layer. There was some fraying of the exposed threads, and the opposing threads along the edge of the tear were not aligned. The edges of the tear tented forward, were slightly distorted, and gaped. The overall tension of the canvas was loose.

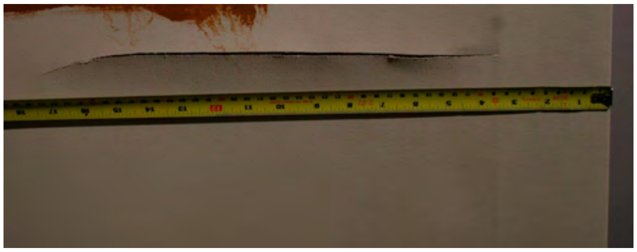

Figure 31.1 Detail of the tear in case study 2. Image: Amann + Estabrook Conservation Associates

Discussion

Here again, the size, direction, location, and type of tear were major factors that influenced the treatment steps and consideration of verso reinforcements. The size of the tear was 13.5 inches (34.3 cm), which was 11% of the overall length of the edge of the painting. Because of this length, combined with the horizontal direction of the tear and its central location, it was estimated that there would be significant stress placed on the tear mend from the weight of the canvas. Another factor to consider in this case was the type of tear: a blunt cut, which meant no "reweaving" of the canvas would be possible due to the lack of overlapping threads. Mends for this type of tear mostly rely on the adhesive to bridge the tear, which makes them, generally, very weak mends (Flock et al. 2020). With these combined factors and the inherent flexibility of the canvas, it was determined that verso reinforcements of Gore-Tex sutures woven into the canvas weave were necessary to bridge the mend and create a lasting repair.

Treatment

The tear mend proceeded with a Heiber thread-by-thread repair. To facilitate this, the painting was placed facedown on a table. To access the end of the tear, which continued under the stretcher bar, a small section of the stretcher member measuring 3/4 × 3 5/8 inches (1.9 × 3.6 cm) was routed out (this was a less-invasive approach than removing a section of the stretcher or taking the painting off the stretcher entirely). Two sets of RH Engineering Trekkers[2] were mounted on the horizontal crossbars that ran parallel to the tear. The Trekkers were used to reduce the gap and bridge the tear by pulling the edges together using lateral tension. When aligned, the corresponding abutted threads were connected with a minute bead of an adhesive solution, 25% sturgeon glue in distilled water combined with Solka-Floc 10 Cellulose powder at a 20:1 v/v ratio. The adhesive was then heat-set using a heated needle.

As the tear mend progressed under tension provided by the Trekkers, Gore-Tex sutures were sewn across the tear in a perpendicular direction to bridge the mend, reinforcing the torn weft threads. The suture thread was initially anchored by looping twice around a warp thread approximately 1 1/2 to 2 inches from the tear (fig. 31.2).

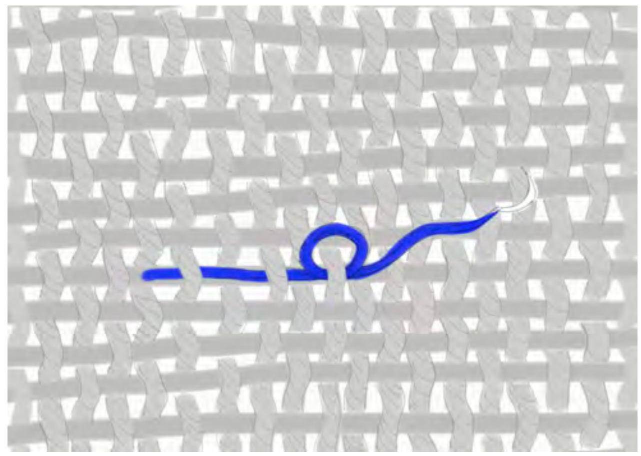

Figure 31.2 Suture anchoring technique. Image: Emily Mulvihill

The suture was passed over three to six threads and was threaded under the next horizontal warp thread (fig. 31.3). This continued until the suture had bridged the tear, and the suture was anchored again on the opposite side. Importantly, the length of each bridging thread and the distance between each threaded warp thread was staggered so as not to form a visible pattern. In this case, the length varied from 4 to 6 inches across the tear and three to six canvas threads between each bridging suture. It was theorized that this should prevent any ridges, lines, and/or patchlike forms from telegraphing through to the face of the painting.

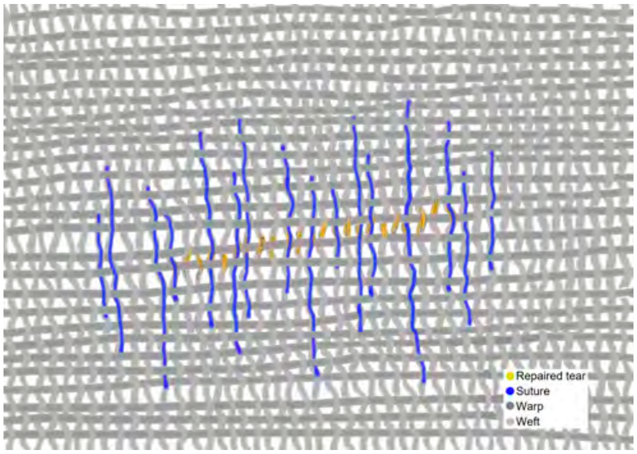

Figure 31.3 Suture sewing technique used in case study 2. Image: Emily Mulvihill

CASE STUDY 3: TEAR MEND WITH GORE-TEX SUTURE VERSO REINFORCEMENT OF OVERSIZE PAINTING

Painting Description and Condition

The third example was painted in the mid-1980s by a well-established contemporary European artist who works across mediums and uses an array of materials. The large-scale painting, measuring 84 × 150 inches (216 × 381 cm), was executed on a heavy-duty, coarse, densely woven linen. The auxiliary support was an underbuilt, seven-member wooden strainer with one horizontal and two vertical crossbars. The paint and ground layers consisted of textured multimedia layers ranging between 1/2 to 1 inch thick (1.3–2.5 cm); consequently, the painting is incredibly heavy. The ground was initially applied in a heavy impasto layer, followed by subsequent thinner layers of paint added in various manners, including drips, splashes, and by brush. The ground and paint layers had a characteristic drying-crack pattern that developed due to the artist's process.

The work was damaged during transport, causing the center crossbar to break and tear through the face of the painting (fig. 31.4). This resulted in two horizontal tears measuring 43 inches (109 cm) and 5 inches (12.7 cm) in the canvas support, located left of the center. There was significant paint loss around the tear; fortunately, the paint fragments were saved and later collected from within the travel frame. The canvas was very loose when it came to the studio, forming a belly along the lower edge. In addition, there were distortions surrounding the edges of the tear.

Figure 31.4 Detail of tear in case study 3 during treatment. Image: Amann + Estabrook Conservation Associates

Discussion

The damage to the canvas support in this case study was significant. This combination of the size, direction, location, and type of tear impacted the structural integrity of the canvas and justified the treatment steps, which included the addition of reinforcements to the reverse. The larger, 43-inch tear ran horizontally and was located slightly left of the painting's center; the warp and weft threads had been torn and stretched from within the weave matrix. The length of the tear was significant, at 29% of the width of the painting.

It was estimated that due to the length and position of the tear, the area of damage was under significant mechanical stress from the weight of the paint layer and canvas. The heaviness of the paint layer added an extra level of complexity and potential fragility to the repair. The fact that the torn threads were available to be overlapped and reintegrated into the fabric structure, allowing for a strong mend, was the only reason a localized treatment could be considered in such an extreme case. In context, it was determined that verso reinforcements were necessary for a successful treatment, and the characteristics of the relatively new canvas would allow this to be done.

Treatment

The intention of the treatment was to reestablish the structural integrity of the canvas matrix and to ensure the longevity of the mend. This treatment was conducted in two stages: the structural features of the treatment, which required the painting to lie horizontally and faceup, and the second stage of aesthetic treatment, which required it to be positioned vertically. Due to the scope of this paper, only the tear mending and reinforcement procedures of this treatment are discussed here.

The treatment advanced with a Heiber thread-by-thread tear mend. Due to the size of the painting and the location of the tear, work was not able to progress under magnification. Fortunately, the canvas weave was coarse and magnification was not vital for the treatment. Before reweaving could commence, all the broken threads were groomed, as they unfurled readily when manipulated, becoming too thick and unruly to sufficiently interlock within the weave matrix. To improve their malleability, the threads were sized with a weak solution of isinglass with an addition of Vinamul 3252 and retwisted with tweezers.

The threads were then rewoven, connecting the overlapping and intertwining weft threads with a bead of dilute Vinamul 3252, and secured with a heated, needle-tipped microspatula. Broken weft threads that did not meet their opposing threads were extended with a small section of thread harvested from the edge of the tacking margin. The harvested threads were groomed with the same isinglass-Vinamul solution and intertwined with the torn weft threads and connected to opposing threads within the tear. The repair work progressed from both the face and reverse.

As sections were completed, Gore-Tex suture reinforcements were interwoven into the back of the weave matrix to bridge the tear (fig. 31.5). Gore-Tex monofilament size CV-5 was selected as the most appropriate suture due to its size, flexibility, and strength. Before being woven into the canvas, the Gore-Tex threads were tinted to match the tone of the canvas using Orasol dyes dissolved in ethanol. Locking forceps were used to handle the needle, and starting approximately 2 inches before the beginning of the tear, the sutures were threaded into the canvas following the weave pattern of the weft threads, which ran perpendicular to the direction of the tear. The ends were anchored and looped in the same fashion as described in case study 2 (see fig. 31.2).

The sutures were introduced every third, fourth, and fifth weft thread, and all were staggered in length. It was determined that the sutures would be threaded under every warp thread. First, this was because the canvas weave was so large the sutures could easily pass through without disrupting the bond between the ground layer and the canvas. Second, the closer and more aligned to the weft thread the sutures were, the more sympathetic the support from the reinforcements would be to the canvas

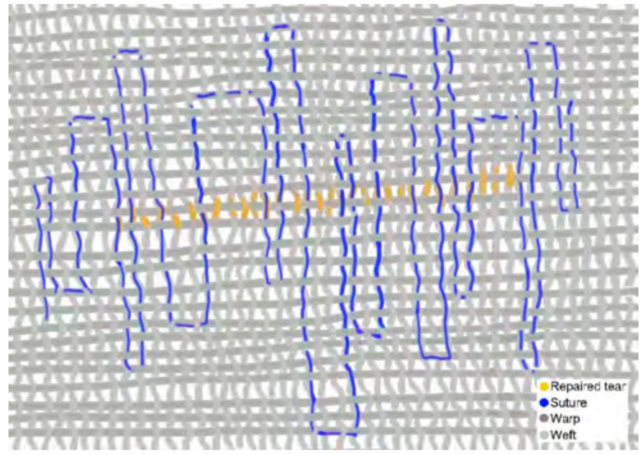

Figure 31.5 Suture sewing technique used in case study 3. Image: Emily Mulvihill

weave structure, ultimately creating a stronger and more stable bridge.

CASE STUDY 4: TEAR MEND WITH A COMBINATION OF VERSO REINFORCEMENTS

Painting Description and Condition

The final case study is a circular painting measuring 7 feet in diameter, completed by an American abstract artist in the early 1950s. The support is a moderate-weight, plain-weave cotton duck canvas. The canvas is unprimed, and the paint layer consists of intermittently brushed and poured oil paint in various consistencies. The major damage, located at the center bottom, was a 13 1/2-inch (34.3 cm) tear in a roughly C shape with right angles and with a section running along the turning edge (fig. 31.6). Numerous threads had been torn and pulled out of the weave matrix in both the warp and the weft directions. The loose flap of the support within the torn region had developed a mild crease from hanging in the folded position. The severed and pulled threads within the tear appeared to line up and meet their adjacent threads. Due to the lack of a priming layer and aging, the oil medium from the paint layer appeared to have leached into the unprimed canvas, embrittling and undermining the fabric. The overall tension of the canvas was also very loose.

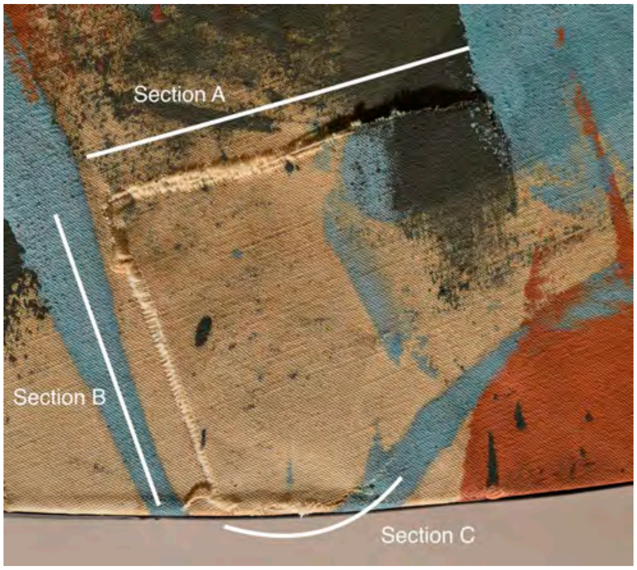

Figure 31.6 Detail of tear in case study 4 before treatment, indicating the three distinct sections of the tear. Image: Amann + Estabrook Conservation Associates

The painting had been previously treated before the tear occurred, and the turning edge was strip-lined with muslin adhered with a Beva-like material. When the strip-lining was removed to fully access the tear, the revealed canvas was particularly degraded, discolored, and very brittle, possibly as a result of either the strip-lining adhesive or the application process. The painting also had a loose-lining, which was not torn at the time that it was damaged.

Discussion

This last case study presented another unique challenge in that each of the three sections of the C-shaped tear had different properties that needed to be considered when determining the suitability for verso reinforcements. Each direction of the tear was evaluated individually to assess the impact of the direction on the tear and the painting as a whole. This resulted in a variety of reinforcements that were unique to each problem. For clarity, I will discuss each section of the tear separately: section A represents the top, horizontal tear; section B, the vertical section; and section C, the lower horizontal section along the turning edge of the painting (see fig. 31.6).

Section A was a straightforward assessment. Because the threads had been torn out of the weave matrix, the tear was able to be repaired by overlapping the threads, creating a mend that would be strong enough to mitigate the stresses placed on it by the size and direction of the tear. Section B was initially thought to be similar to section A, but as the mend progressed, it became apparent that the overlapping threads were not bridging the tear effectively. The area where the two sections intersected was also very weak and pulled open when stretched. This indicated that section B required further reinforcements to aid the stretching of the canvas in order to complete the treatment.

When assessing section C, the location and the past conservation treatment of this section were the determining factors for this part of the mend. First, the canvas fibers were in a very brittle state that was difficult to work with, as they fractured and shattered when manipulated. This meant that creating a strong bond from overlapping threads was not possible. This section was also the most vulnerable area of the tear because of the mechanical stress placed on it when the painting was stretched. Ideally, sutures would have been considered, but the brittle threads could not withstand even the mild stress of the threading process.

Treatment

Before Heiber's thread-by-thread tear-mending technique could be applied, torn threads were groomed, organized, and sized with dilute methyl cellulose. Once the threads were organized, the broken threads were rewoven back into the weave matrix and adjoining threads were secured with a small bead of dilute Vinamul 3252. New cotton threads of a similar weight and tone to the original threads were added when adjoining threads were not long enough to reconnect or when a secure bond could not be created. To aid with the manipulation of the cotton threads and limit shattering of original fibers, the new threads were lightly moistened with distilled water, which enabled them to be maneuvered into the matrix with relative ease.

Once the mend had been completed, verso reinforcements could be added to appropriate areas (fig. 31.7). Staggered and irregular lengths of Gore-Tex sutures were threaded through the weave, running perpendicular to section B of the tear. Areas of canvas with paint on the surface were avoided because the fabric was too brittle and degraded for the sutures.

To support areas where the Gore-Tex sutures could not be integrated into the weave, Japanese paper "sutures" were used as an alternative. These sutures, approximately 1/32 inch (0.8 mm) in width and varied in length, were infused with liquid Beva 371 and minimally heat-set to the back of the canvas where sections A and B of the tear intersected, perpendicular to section B.

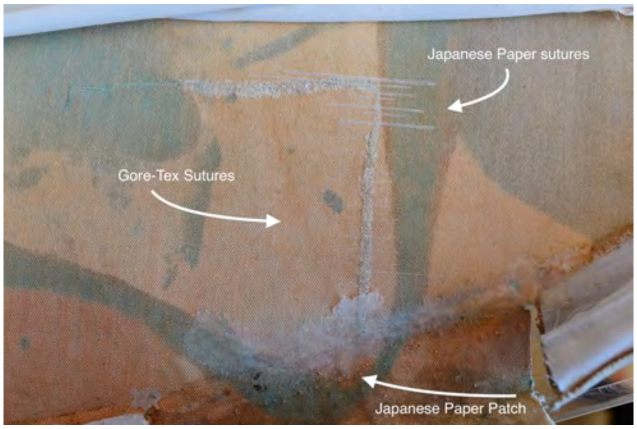

Figure 31.7 After-treatment detail of tear and verso reinforcements in case study 4. Image: Amann + Estabrook Conservation Associates

Section C of the tear was reinforced on the reverse with a patch of Japanese paper, the edges of which were softened by tearing and by splaying individual paper fibers. The patch was infused with Beva 371, lightly coating the individual paper fibers at the edges. Finally, it was secured using a warm tacking iron.

CONCLUSION

The purpose of this paper has been to introduce new methods that help bridge thread-by-thread tear mends and enhance Heiber's method. Specifically, these methods, conducted from the reverse, create a sympathetic bridge across a thread-by-thread tear mend, using Gore-Tex sutures woven into the weave matrix. These treatments were described through four case studies, each case study demonstrating a particular application of the Gore-Tex sutures and how their application is influenced by the specific nature of the painting and the type of damage. The treatments ranged from a tear mend of a butt join with Gore-Tex suture verso reinforcement to a tear mend with Gore-Tex suture verso reinforcement of an oversize painting to a tear mend with a combination of verso reinforcements.

As demonstrated in the case studies, the Gore-Tex sutures can be altered to suit the specific painting and canvas to achieve the most successful results. However, they are not always needed, as demonstrated in the first case study, and it is important to assess the need for verso reinforcements in individual situations, as every painting is different; thus, it is important to take into consideration the characteristics of the painting. Sutures are one option available to the conservator, an important tool in the toolbox of conservation.

NOTES

1. W. L. Gore & Associates. Gore Medical. Accessed March 29, 2022. https://www.goremedical.com/products/suture.
2. RH Conservation Engineering. http://www.rhconservationeng.com/.

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Less Is More: Juxtaposing the History of Lining and Alternative Treatments as Found in the Neue Pinakothek and the Sammlung Schack in Munich

Renate Poggendorf, Head of Conservation, Neue Pinakothek and Sammlung Schack, Doerner Institut, Bayerische Staatsgemäldesammlungen, Munich

The collections of the Neue Pinakothek and the Sammlung Schack—two important collections of nineteenth-century art in Munich—contain a large number of paintings that have remained relatively untouched since their creation. Initially this was just an empirical observation by conservators. Despite incomplete data, a study verified that out of more than 1,700 paintings investigated, about seventy percent are unlined. This has been proven through an evaluation of technological information and restoration reports. One of the results of this study is that conservators decided—in addition to traditional lining—in favor of very restrained interventions early on. The documented restoration techniques, including lining and other treatments, are generally explained and contextualized in relation to developments in the field of paintings conservation. The results of this study accord with the trend toward minimal intervention that began in German-speaking countries more than forty years ago.

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INTRODUCTION

Publications offer us only a fragmentary understanding of developments in conservation. One such fragment is the plea to "do in future only that which is absolutely necessary, and if in doubt, do nothing at all—always heeding the fact that each intervention is in and of itself irreversible" (Weddigen 1980, 30). This statement represents a shift witnessed in the field of paintings conservation in German-speaking countries around 1980.[1] This new approach called into question the suitability of lining canvas paintings as the default method for treating many types of defects. As a result, lining was indeed largely replaced by less-invasive alternatives in the following years. Retaining an artwork's "untouched" condition, thus enabling later generations to uncover clues whose significance may not yet be understood, gained importance as a value in its own right.[2] Around the same time, an occupational profile was developed for conservation-restoration that defined academic training as a future standard. Considering the treatment of canvas paintings, this change took place over years and—depending on the country—at different times, influenced by leading conservators and university teaching. Nowadays, more than a generation of German-speaking conservators see lining as an almost exclusively historical technique that is only taught to elucidate its various methods.

At the 1974 Conference on Comparative Lining Techniques in Greenwich, lining was not yet challenged per se; the focus was on improving materials and methods. While the exchange of ideas across language borders was still quite limited at this time,[3] the impact of this conference is nevertheless evident in some German publications thereafter.[4] By the annual meeting of the Deutscher Restauratorenverband (German Association of Conservators-Restorers) in 1980, however, lining was fundamentally questioned and alternatives sought (von Manteuffel-Szoege 1980). Here, probably for the first time in such an arena, thread-by-thread tear mending was presented (Gabler 1979). In Switzerland, too, criticism was being leveled at traditional lining techniques under the caption “Gaining experience through failure” (Weddigen 1981). Occasional discussions of improved lining methods followed,[5] but from the 1990s onward it was all about tear mending with adhesives, and later stitching (see, e.g., Heiber 1996; and Beltinger 1992). In this context, retrospectives published in 1983 on the history of lining, marouflage, and paintings transfer assume an almost epitaphic quality (Marty 1983; Schaible 1983a, 1983b; Schiessl 1983).

At a conservation conference in 1984, Winfried Heiber used a microscope linked to a projection screen to give a live demonstration of thread-by-thread tear mending.[6] In his comprehensive description of the method published in 1996, Heiber noted in amazement that “an idea can quietly assert itself—with little to no publication, very modest practical instruction on the part of the protagonists, no indoctrination attempts and no divisive fundamental discussions” (Heiber 1996, 117).

As the author began her conservation career at the time of this turning point, the minimal intervention approach was natural to her from early on. Reviewing countless paintings that were “overrestored” (from today’s perspective) across centuries was a painful experience. This made the discovery that Munich’s two nineteenth-century state painting collections—the Neue Pinakothek and the Sammlung Schack (for whose conservation the author is responsible)—seem to contain an unusually large number of paintings in a fairly original state of preservation all the more inspiring. This study was conducted in order to support this empirical observation and to better understand and provide access to the restoration history of the collections. It is limited to a summary record of the treatments carried out on the canvas paintings, as far as these are documented, and their placement within the temporal context. Verification of the data or specific follow-up examinations of individual paintings was not possible within the scope of the project.

THE COLLECTIONS

The restoration history of a work depends on the specifics of how it was made as well as its provenance and history. Use and whereabouts determine its aging process, while the particular expectations of various owners and the professional convictions of conservators have a bearing on treatments undertaken. Thus, we begin with the history of the collections considered in this study.

The Bayerische Staatsgemäldesammlungen (Bavarian State Paintings Collections) houses Bavarian art holdings dating from the fourteenth century to the present day. Currently, the collection is divided across seventeen museums, with the Doerner Institut responsible for conservation. Of the five galleries located in Munich, two specialize in nineteenth-century artworks: the Neue Pinakothek and the Sammlung Schack. The two galleries have much in common but differ in significant ways.

The Neue Pinakothek was founded in 1853 by Ludwig I (1786–1868). The former king of Bavaria was passionate about art. During his reign (1825–48), he developed the state capital of Munich into a cultural gem. He had numerous monumental structures erected, including the Glyptothek and Alte Pinakothek, museums built to house the royal collections of antique sculptures and old master paintings. Ludwig I also supported the arts by amassing a collection of paintings and sculptures by artists of his time. His Neue Pinakothek was one of the very first museums ever to be dedicated exclusively to contemporary art.

The Sammlung Schack is also a private collection, founded by Count Adolf Friedrich von Schack (1815–1894), a wealthy, well-traveled poet and historian of art and literature. When he settled in Munich in 1855, the vibrant local art scene inspired him to begin building a collection of contemporary art. Schack had his own ideas regarding suitable themes, and he commissioned local artists to create paintings for him in keeping with his artistic and literary ideals. In addition, he commissioned young artists to create eighty-four full-size copies, predominantly of Venetian Renaissance paintings.

The two museums have in common that they were founded as private collections; however, while Schack’s collection has remained an almost unaltered ensemble, the Neue Pinakothek continued to expand after Ludwig’s death (fig. 32.1).

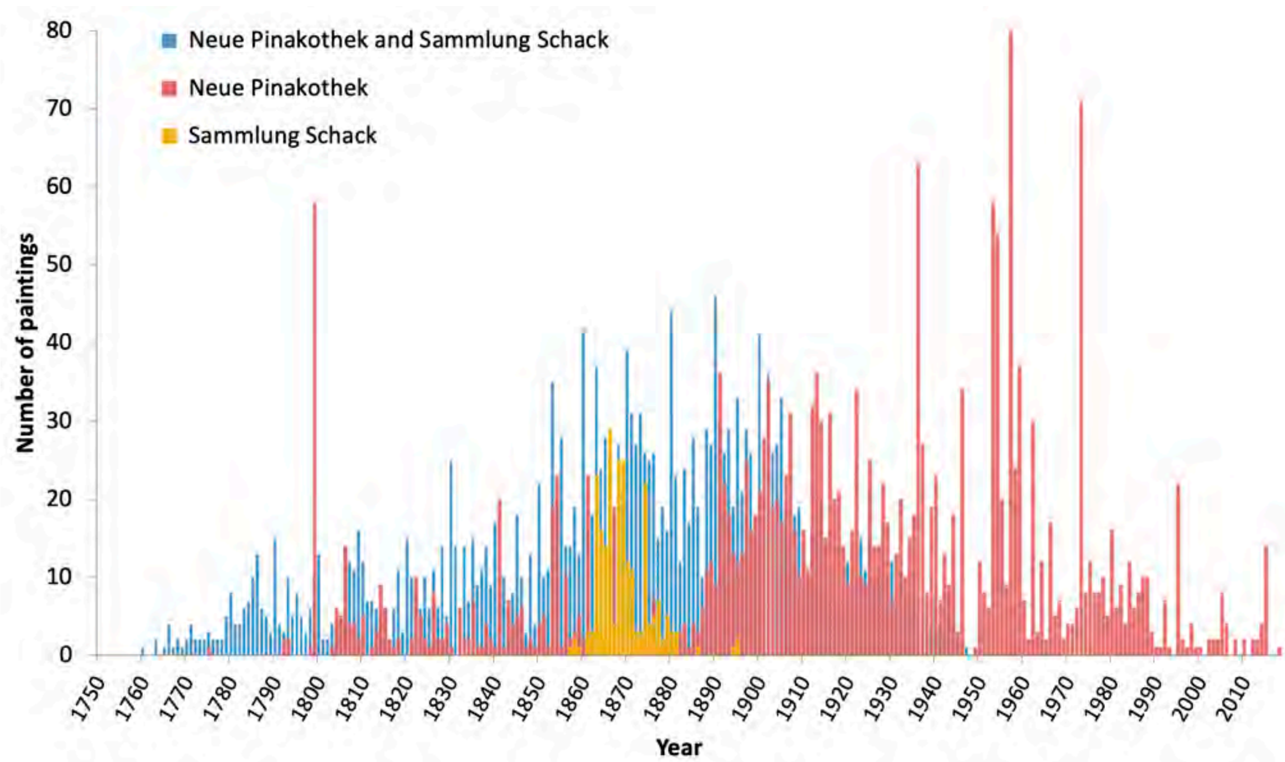


Figure 32.1 Distribution of the origin (blue bars) and acquisition (pink and yellow bars) of canvas paintings over time. Image: Renate Poggendorf, Doerner Institut, Bayerische Staatsgemäldesammlungen

The Sammlung Schack comprises 267 paintings, mostly made over the course of about twenty-five years, in the 1860s and 1870s. After Schack's death, the collection became public property, and it has been part of the Bayerische Staatsgemäldesammlungen since 1939.

By contrast, the Neue Pinakothek's collection consists of over 3,300 paintings in addition to various sculptures, photographs, and graphic art. The works date from a period spanning some two hundred years, from the mid-eighteenth to the mid-twentieth century, that is, well beyond the nineteenth century. From the last quarter of the nineteenth century onward, Ludwig I's collection was increasingly expanded using state funds. Artists estates were accepted and new artifacts purchased, in particular from major Munich art exhibitions. While the initial focus of the acquisitions was on local artists, it gradually became more international. A significant enhancement was the acquisition of recent French art, which began in 1909. With World War II came the destruction of the museum building, marking a turning point in the collection's history. For the opening of the new building in 1981, the museum again strengthened its international orientation by acquiring French, English, and Spanish paintings.

A decisive difference between the two collections is their acquisition history. Schack acquired at least 70% of his works more or less directly from the artists themselves, with about 90% of his paintings bought within ten years of being painted. Their aging and restoration backgrounds are thus directly tied to the history of the collection itself.

By contrast, only about a third of the paintings in the Neue Pinakothek were acquired soon after they were painted, while the rest entered the collection with individual histories going back up to two hundred years (fig. 32.2).

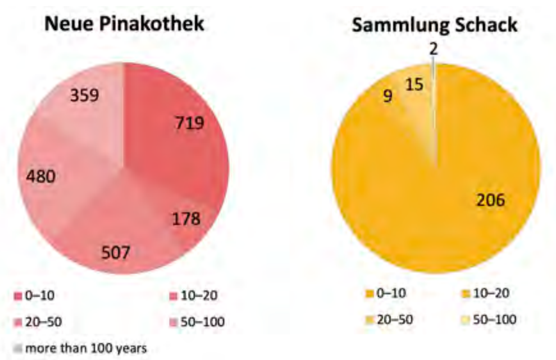


Figure 32.2 Distribution of the age of canvas paintings at the time of acquisition. Image: Renate Poggendorf, Doerner Institut, Bayerische Staatsgemäldesammlungen

CONSERVATION HISTORY OF THE COLLECTIONS

Initially, the paintings were still "young" and had little need for conservation. Any necessary treatments were carried out by Alte Pinakothek conservators (see also Wiesmann 2007). Some fifty years ago, with a growing number of museum buildings and an increase in staff, the responsibility of caring for certain collections was divided up among the conservators—a structure that is still in place today. This specialization reflects the altered professional profile of the conservator, who continues to step in once intervention is required but now also acts preventively by overseeing a host of museum processes, including exhibitions and loans.

Following World War II, the Doerner-Institut was affiliated with the Staatsgemäldesammlungen. Two separate restoration workshops then operated side by side until they were united under the name Doerner-Institut in 1977.[7] Reports of previous differences in working methods can be simply summarized: The museum conservators tended to practice more "considered" collection care, preferring to rely on tradition and experience and thus taking a more cautious approach to new developments. The conservators at the research facility Doerner-Institut, on the other hand, were more open to experimental approaches using new materials and methods.

A distinction between conservators specializing in treatments carried out on painted surfaces versus those who work exclusively on supports seems never to have been made, as is usual at other institutions. However, it was not uncommon in the past for work on wooden panels and linings to be passed to the carpenters, even if such a division of labor is only rarely traceable in the reports.

Today there are a dozen permanent positions at the Doerner Institut for conservators specializing in paintings, contemporary art, new media, and frames.

DATA COLLECTION

This study is built on several pillars:

- The museum database made it possible to sort the paintings in this study and transfer their basic data into an Excel spreadsheet with the following columns: inventory number, artist, title, date of origin, date of acquisition, provenance, and medium.
- Between 1969 and 2003, the majority of paintings in both collections were reindexed in inventory catalogues.[8] For this purpose, the technical details of each painting were systematically recorded, in most cases only by visual assessment, and a brief description was noted in a form. These questionnaires included questions on lining and whether or not the canvas attachment was original, but not about partial treatments of the support. Only core information (e.g., "oil on canvas") was entered into the database.
- Conservation reports date back to the 1830s. Most of the time, standardized forms were used that initially divided the data only into "findings" and "work report." In 1972, multiple-choice forms were introduced that included the option of adding notes. These comprised both a section on technical findings (e.g., previous lining and lining method) and a section for noting condition and current conservation treatment. With the introduction of digital word processing in the 1990s, the work of conservators was increasingly documented in their own words and with growing attention to detail.
- When a museum database was initiated in 2002, data-entry fields for technological findings, condition, and treatments were included, although filling them out was entirely optional. This tempted people to forgo entries on the technical details of a work in straightforward treatment cases.

As we know, conservation perspectives and methods change over time. On the whole, it can be said that reports were often filed with too little regard for whether they would be comprehensible for later generations.

After processing the canvas paintings from both collections, the related files were viewed and relevant information on the restoration history was entered into the spreadsheet both as text and as yes/no answers under the following categories: lining, type of lining, marouflage, loose-lining, impregnation, strip-lining, tear mending, conservator, and date of intervention. This made it possible to generate graphs from the data.[9]

The results for Neue Pinakothek and Sammlung Schack are summarized below. Differences are illustrated by the graphs. Alongside the systematic analysis of the data, the author also presents a subjective evaluation based on her twenty-five years of experience caring for both collections.

RESULTS

Taken together, the two collections contain 2,475 canvas paintings, which make up 71% of the total number of paintings (fig. 32.3a).

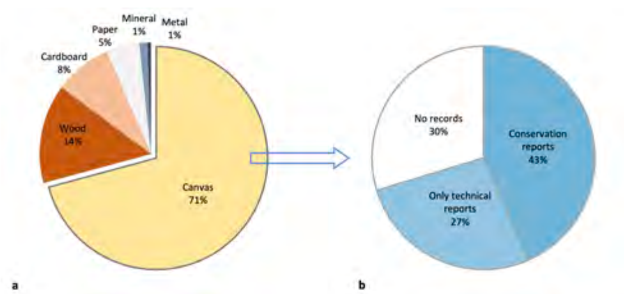


Figure 32.3 (a) Distribution of support materials used in the paintings in the two collections. (b) Types of documentation in existence for canvas paintings. Image: Renate Poggendorf, Doerner Institut, Bayerische Staatsgemäldesammlungen

Unfortunately, the existing records for these paintings turned out to be less complete than hoped. Thirty percent of the canvas paintings have no files or reports; for a further 27%, only technological information is available, whereas 43% have at least one restoration report (fig. 32.3b). Many reports mention earlier interventions for which there is no documentation, even though the work must have been carried out while the piece was in the museum's possession. Apparently, despite the long tradition of documenting conservation treatments and a simplified procedure using forms, the obligation to record interventions was often not met. Furthermore, information regarding measures undertaken prior to the museum's acquisition is almost always missing. Consequently, the study had to be reduced to the 1,740 canvas paintings (70%) for which evaluable reports are archived—a selection that is nevertheless considered sufficient for the evaluation carried out here.

The different measures considered in detail (figs. 32.4, 32.5) are as follows:

- 88 of the canvases are glued onto rigid supports, 15 of them on wood and 73 on cardboard. Knowledge of the collection indicates that the wooden supports were attached as restoration measures. For the paintings described as "canvas on cardboard," the date of and reason for the cardboard backing cannot be confirmed. Is it a prefabricated, two-layered support or an unstretched canvas—typical for oil sketches—which for various reasons was subsequently glued onto cardboard?
- 409 of the paintings are lined. Of these, 242 were lined using a paste, 30 using a wax-resin mixture, and in 137 cases, the method used was not documented.[10] Paste was probably most likely used, as it was already a common nineteenth-century method and thus not specifically mentioned. Alternatives to traditional techniques that appeared following the 1974 Greenwich conference, such as nap-bond cold-lining or mist-lining, the use of fabrics made of synthetic or glass fibers, or the use of newer adhesives such as acrylic resins or Beva 371, were not in evidence.
- The lining information in the evaluated reports seems highly reliable. However, data about the following techniques do not appear to be statistically evaluable, since the data were not systematically recorded using forms but derive solely from individual reports. (The figures should still be shown here, however, as they at least reveal overall trends.) For 33 paintings, we have documentary evidence of strip lining; 5 paintings received a loose-lining with a second canvas and 1 with paper (some of these were possibly original reinforcements); 5 paintings were mounted onto plywood panels without adhesive to help stabilize particularly thick layers of paint or extensive damage to the canvas; and 18 of the paintings were impregnated with wax.
- 1,181 of the paintings are thought to be unlined. Documentary analysis and experience show that measures may still have been carried out on the canvases. Even before thread-by-thread tear mending established itself in the 1980s, tears were often only mended locally, for example by attaching patches of tow or fabric to the back. Tacking-edge repairs can range from local tear stabilization to restretching a painting after complete strip-lining—without necessarily having been documented.

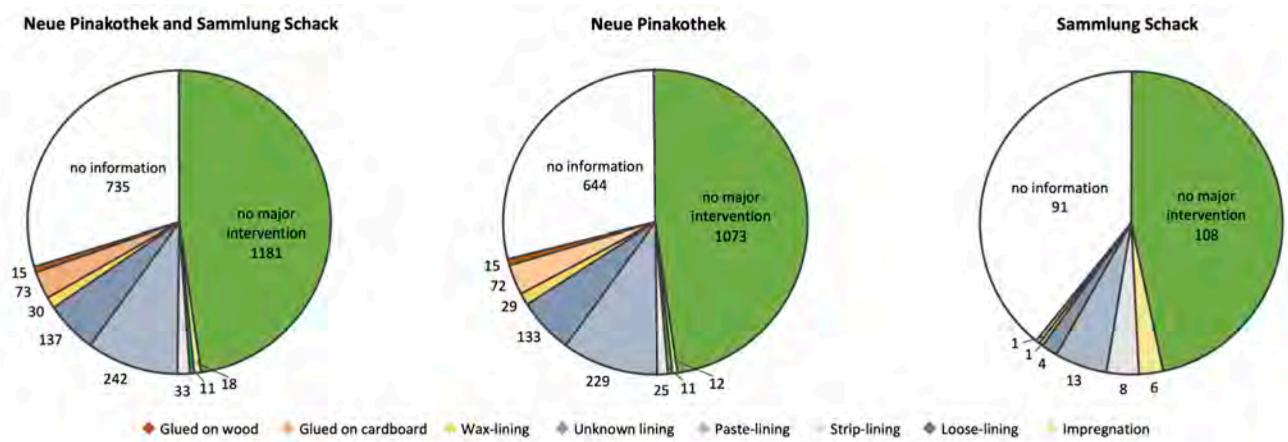


Figure 32.4 Types of information recorded about the interventions carried out on canvas paintings. Image: Renate Poggendorf, Doerner Institut, Bayerische Staatsgemäldesammlungen

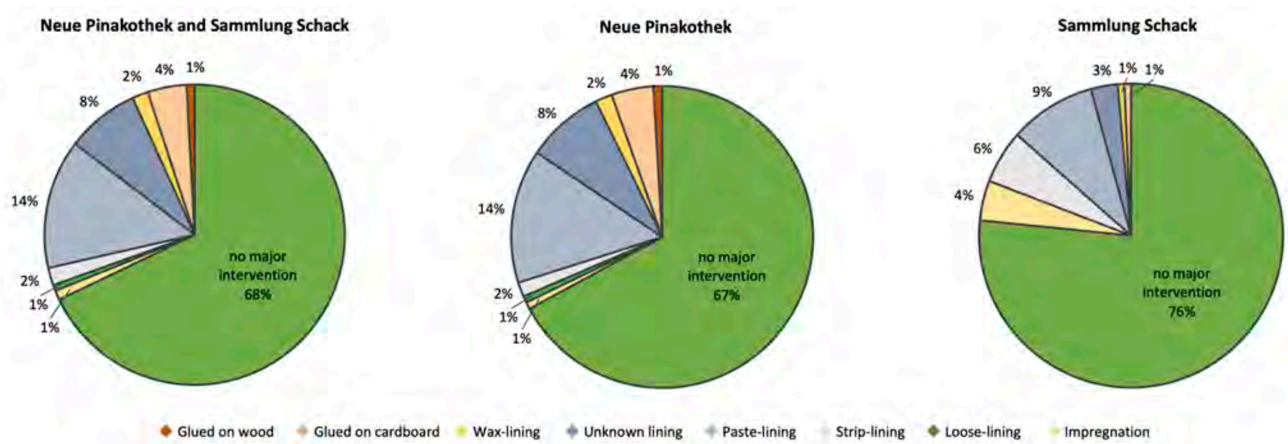


Figure 32.5 Types of interventions documented. Image: Renate Poggendorf, Doerner Institut, Bayerische Staatsgemäldesammlungen

According to a subjective impression of the entire collection, the above result—that approximately 70% of the 1,740 documented paintings have not yet been lined, marouflaged, or impregnated—appears to be on the low side. The reason is that the 735 canvas paintings (30% of the total number) without documentation are predominantly pictures that have been kept in storage for decades and not exhibited. On the whole, if there were no plans to show the paintings, they were not restored.

Despite the limited informative value of the data found, its temporal distribution will be presented graphically (fig. 32.6), as it reveals certain trends. For two-thirds of the 1,740 verifiable treatments, we know the year of execution. Considering the distribution along the time axis, we see a gradual increase becoming more apparent from the 1970s onward. Knowing that interventions were not consistently documented, this increase cannot be equated with an increase in conservation measures. Rather, it shows the professionalization of conservation, and that trend led to more systematic documentation. The graph does not indicate the scope of the measures either: minimal intervention is represented in the same manner as extensive conservation work. Taken separately:

- None of the marouflages can be definitively dated. The same applies to a large number of the linings; 60% of the wax-linings but only 19% of the paste-linings can be classified by date. The first documented wax-lining took place in 1952, with the first recorded use of a heating table in 1965.[11] The years leading up to the last documented wax-lining—carried out in 1976, shortly after the Greenwich conference—mark the heyday of this method. The fact that this period coincides with a general increase in documentation explains why the number of unreported cases of wax-linings is lower than that of paste-linings. Paste was also used to line paintings during and after the boom in wax treatments, recorded for the last time in 1995.[12] The exact formulation of the adhesive or a description of the working method is very rarely provided.[13]

- Around 1915 and again around 1930, there are several references to canvases being impregnated with a wax mixture called "Dutch mass." This was an alternative to the usual glue lining used to consolidate and flatten paintings with intact fabrics and protect them against moisture. From the mid-1960s to the mid-1970s, when wax-lining and heating tables were in their prime, several paintings were also impregnated with wax.

- Strip-lining has been documented since the 1920s, sometimes only applied partially. Beva 371 has been the preferred adhesive since 1975.[14]

- As mentioned earlier, localized methods for treating canvas tears can be inferred only from individual restoration reports. Knowledge of the collection indicates that far more partial repairs to old tears have been carried out than were ever documented. Perhaps local treatments had to be somehow unusual to merit being described in a report. In 1935, for instance, a 20-centimeter tear was repaired using only thin tissue patches. Treating such a sizable tear without lining seems to have been unique. It was not until the 1970s that tears were regularly mended with adhesive or holes closed with fabric inlays without the additional application of a patch. For about ten years, Calaton CB[15] was the adhesive of choice. It was replaced by a standard white glue[16] commonly used by joiners. An alternative was a two-component epoxy resin adhesive[17] that was considered advantageous not least because of its resistance to solvents used in subsequent work steps. By the time of Heiber's 1996 publication on thread-by-thread tear mending, a mixture of sturgeon glue and wheat-starch paste had become the predominant adhesive in use.

- For the first time, in 1917, and occasionally thereafter, we find reports specifically mentioning that a painting had been left on its old strainer or stretcher, or that these had been repaired. Again, this approach was probably written down because it was unusual. Common practice was to replace old stretchers when they were regarded as insufficient, particularly in cases where the canvas had to be taken off its stretcher anyway. As awareness grew of how much information could be gleaned from various types of stretchers, historical labels, and original canvas attachments, stretchers stopped being replaced around 1980. Remaining stretchers that no longer carried their original painting but had not yet been discarded were gathered together to form a collection.[18]

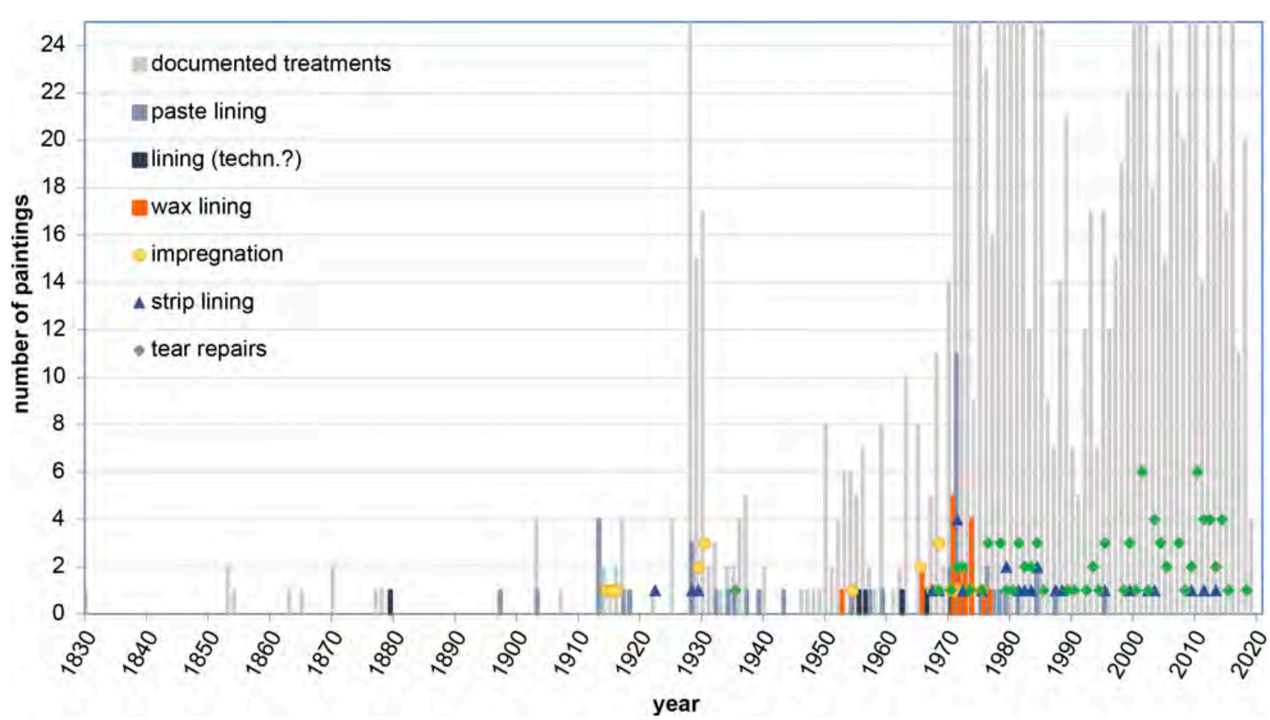


Figure 32.6 Distribution of interventions over time. Image: Renate Poggendorf, Doerner Institut, Bayerische Staatsgemäldesammlungen

EVALUATION OF THE RESULTS

This study confirms the general development in German-speaking countries outlined at the beginning of this paper: the move away from the traditional and regular use of lining to almost complete abandonment of the method. Evaluation of the individual reports, however, also indicates that this was not a linear process. Even if certain methods were preferred during certain periods, there seems to have been no fixed rules; instead, it seems that conservators were generally free to make their own decisions. For example, certain names stand out for taking a particularly considered and cautious approach. It is also noticeable that, at the time of the transition to minimal intervention, exemplary reports were often written by younger colleagues, perhaps because they were especially open to exploring new developments.

In contrast to the canvas paintings examined here, the majority of those in the old masters collections have been lined. Reasons for this may include their age and that restoration was already required at a time when lining was still the obvious choice. That being said, the works considered here are now already up to 270 years old.

Which factors determine that a painting requires restoration—the quality of the workmanship (some paintings are surprisingly well preserved despite their great age), the environmental conditions in which a collection is housed (only over the last few decades has the potential for damage been significantly reduced for paintings in the Neue Pinakothek and Sammlung Schack, thanks to ongoing improvements), the extent to which the works have been displayed (generally, disregarded paintings were treated less often than those on permanent display or that traveled regularly to exhibitions); the availability of staff and funds, or other variables? A decisive factor seems to be the expectations held by owners and conservators regarding the condition and appearance of a painting. These vary depending on the period in question and, to this day, on location, as different schools of thought or trends in conservation still coexist around the world.

This conclusion is exemplified by some of the French and British paintings acquired for the Neue Pinakothek. Of thirty late nineteenth-century paintings by Courbet, Cézanne, Manet, Monet, Van Gogh, Gauguin, and others, two-thirds had already been lined when they were acquired between 1909 and 1916, when the paintings were only fifteen to fifty-five years old and had barely any damage of the kind that, from today's perspective, would justify lining. This treatment must have been regarded as some kind of improvement by the artists themselves or by art dealers or collectors at the turn of the century. By way of comparison, of fifty-seven artworks, mostly by German painters, painted and acquired at exactly the same time, less than a third have been lined to date.

In 1799, the Bavarian court bought its very first painting by an English painter: *The Pointer*, by George Stubbs, dated 1766. In 1929, the painting was removed from its stretcher and pressed to reduce cupping, but it was not lined—an early example of a conservative approach to restoration. In contrast, almost all thirteen British paintings dating from 1750 to 1850 that were purchased on the art market from the 1960s to the 1980s had been lined previously. For some, the lining seems to have been carried out shortly before the museum acquired the painting; that is, it was possibly done especially for the sale.

The Neue Pinakothek's entire collection, including works from the Sammlung Schack not currently on display, was examined by conservators in 2018–19 in preparation for the museum building to be completely cleared for renovation. Some of the paintings featured localized paint-layer delamination, poor attachment of the canvas, or evidence of old tears—damage that often appears to have occurred decades ago and has slowly worsened under the storage conditions. Localized stabilization was all that was needed to prepare the paintings for transport and additional years of storage. Proof—if proof were needed—that "only doing what is absolutely necessary" for a long period of time has suited the paintings very well indeed.

CLOSING THOUGHTS

It would be interesting to examine on a broader scale what triggered the shift toward less-invasive treatments. As far as canvas paintings are concerned, it seems that the habit of using heating tables to apply wax-linings in the 1960s and 1970s may have been too much of a supposedly good thing. But perhaps it was also the growing need to restore paintings of the past hundred years featuring deliberate matte-gloss variations and textured surfaces that opened conservators' eyes to the limitations and "crudity" of applying a uniform treatment that was customary for older paintings at the time.

A comparative look at developments beyond the world of conservation also seems appealing. At around the same time, awareness was growing of the fact that technical applications never merely fulfill their intended objective but can also have undesirable side effects. Examples include the emergence of the ecological movement and the development of technology assessment as a field of research.

The appreciation for artworks that have remained relatively untouched over time also seems to have grown outside the conservation field, be it in the art trade or among museum curators—even though this can restrict possible uses for the paintings. A piece might, for example, be stable enough to be exhibited without the need for conservation, while at the same time being so fragile that lending it out is not advised. Greater authenticity, however, also makes possible the discovery of traces pertaining to the artwork's creation and history that are essential for understanding the piece in its entirety.[19] Added to which, the experience of viewing an artwork that appears to be untouched is always uniquely special.

These two collections, maintained with a more "conservative" approach to restoration, are presented in the hope of inspiring others. In the knowledge that to this day conservators' opinions still differ concerning the best approach, this study hopes to gain support for the author's own conviction that less is more.

Minimal intervention demands that conservators control the need to lay their hands on the object and limit the perfectionist streak that most share (though that is a laudable trait to have). Why? Because both can be more dangerous for the artwork than the ravages of time. One should always bear in mind that aging is a very slow process.

ACKNOWLEDGMENTS

Great appreciation is due to my teachers Winfried Heiber and Hans Brammer, who in different ways pioneered a more cautious approach to conservation. My predecessor Konrad Laudenbacher is credited for the extent to which he valued and maintained the high degree of original preservation of the two collections. My thanks go to Veronika Poll-Frommel and Jan Schmidt for reviewing the manuscript, and to Josephine Beney for the translation.

NOTES

1. Limiting the reference point to German-speaking countries seems sensible, given how little exchange there was between conservators across language borders in the past. Of vital importance to developments in conservation were conferences in Germany, Austria, and Switzerland, as well as publications such as the *Mitteilungen Deutscher Restauratorenverband* (1980–86), *Mitteilungen des Österreichischen Restauratorenverbands* (since 1986), and magazines such as *Maltechnik Restauro* (1972–87), *Restauro* (since 1988), *Zeitschrift für Kunsttechnologie und Konservierung* (since 1987), and *Beiträge zur Erhaltung von Kunst- und Kulturgut* (since 2003). However, it must also be acknowledged that, due to the political situation at the time, the exchange between conservators in the German Democratic Republic (GDR) and the Federal Republic of Germany (FRG) was very limited until 1989. This report is written from an FRG point of view.
2. Examples include provenance research or current art technological issues: a database with some five hundred manufacturer's labels or stamps was compiled.
3. Sixteen West Germans, sixteen Swiss nationals, and two Austrians took part in the Greenwich Conference, including Veronika Poll, a conservator from the Bayerische Staatsgemäldesammlungen.
4. For example, articles by G. A. Berger, V. R. Mehra, and A. Ketnath, among others, appeared in such publications.
5. For example, articles by B. Hacke, A. Ketnath, V. Schaible, W. Heiber, and V. R. Mehra, among others.
6. Annual conference of the Deutscher Restauratorenverband, 1984, in Marburg.
7. For the history of the Doerner Institut, see Burmester 2016.
8. Bayerische Staatsgemäldesammlungen, Gemäldekataloge (Bavarian State Paintings Collections, catalogues), vols. II (1969), III (1978), IV (2003), V (1984), VI (1977), VII (1990), VIII/1–3 (2003).
9. If only a time period was available, not a specific year of creation or acquisition, these data are shown in the graphs as average values. Percentages have been rounded for the sake of legibility.
10. *Paste* and *wax* are the usual collective terms, although mixtures were generally used; see note 13 below.
11. The first heated vacuum table was acquired in 1959 (Wolters 1960).
12. The Doerner Institut still possesses a veneer press used for paste-linings in the past.
13. Components of wax-resin mixtures: beeswax + rosin, Venetian turpentine, dammar or AW2 in various proportions. Components of paste: rye flour + animal glue and possibly Venetian turpentine.
14. Previously, traditional lining adhesives were used, as well as commercially available PVA adhesives.
15. Calaton CB, manufactured by ICI, United Kingdom.
16. Trade name Ponal: a polyvinyl acetate (PVA) adhesive developed for gluing wood in 1959, manufactured by Henkel, Düsseldorf, Germany.
17. UHU Plus Endfest 300, manufactured by UHU GmbH, Bühl, Germany.
18. We have my predecessor Konrad Laudenbacher to thank for this collection of around fifty stretchers.
19. Reference is made to two examples of the author's own research, in which analysis of the canvas attachments provided important information regarding artistic intention and history of the painting: Poggendorf 2015; and Boitelle, Poggendorf, and Stevenson forthcoming.

33

Conservation of Canvas Paintings at the Victoria and Albert Museum: Past, Present, and Future

Nicola Costaras, Head Paintings Conservator (retired), Victoria and Albert Museum, London

This essay provides a personal perspective of a collection the author has studied and worked on over a period of twenty-five years. It discusses the early conservation history of the paintings collection at the V&A, especially preventive conservation, and the impact that has had in their good preservation. The purpose of the collection—to provide excellent examples to improve industrial design—explains the varied nature of the roughly two thousand paintings, which span two thousand years. There is a continuity of purpose: the collection still provides inspiration for the creative industries. How paintings are prioritized for treatment relates largely to the museum's public program. The paper describes the recent treatment of a selection of canvas paintings that gives an idea of the range of treatments and materials as well as the difference in scale, from an oil sketch by Constable to a theater backdrop designed by Picasso.

THE V&A HISTORY AND COLLECTIONS

Conserving canvas at the Victoria and Albert Museum (V&A) started with its earliest acquisitions. Opened as the South Kensington Museum (SKM) in 1857 and given its current name in 1899, the museum's purpose was to improve British industrial design by collecting excellent examples. Paintings and other works were lent to art schools throughout Britain for students to copy, an effort organized by the appropriately named Circulation Department. Many paintings were acquired for their suitability as models for copying, and the ensuing years brought gifts and bequests of collections of paintings. Education for a range of audiences is still a primary focus, and the collection is valued as a source of inspiration for those in the creative industries.

This essay discusses setting priorities for treatment and will show how early preventive conservation practices at the SKM have had a profound effect on the condition of the paintings collection. I will describe some recent treatments of a variety of canvas paintings and end with thoughts on their future conservation needs.

The paintings at the V&A are quite varied. They number around two thousand works and span two thousand years—from first-century Roman frescoes to contemporary paintings from India and Southeast Asia. There are some remarkable German medieval paintings, the fourteenth-century *Apocalypse Triptych* from Hamburg by Master Bertram (d. 1415),[1] and a fifteenth-century oil on canvas from Cologne by the Master of the St. Ursula Legend (fig. 33.1). Italian Renaissance works include panels by Carlo

Crivelli (ca. 1430–1495) and Sandro Botticelli (1444/45–1510). There are seventeenth- and eighteenth-century Netherlandish paintings and significant collections of nineteenth-century Continental and British paintings, including ninety-two oil sketches by John Constable (1776–1837). Among the twentieth-century additions are a large collection of theatrical cloths, including backdrops used by the Ballets Russes.

Figure 33.1 Master of the St. Ursula Legend (German, active ca. 1485–1515), *The Martyrdom of St. Ursula and the 11,000 Virgins*, ca. 1492. Oil on canvas, 163 × 232.4 cm (65 × 91 1/2 in.). London, Victoria and Albert Museum, 5938-1857. Image: © Victoria and Albert Museum

In recent years, paintings have been acquired that have a particular relevance to some other part of the collection or have been bought as a pair of objects; for example, portraits together with the item of clothing or jewelry that the sitter is wearing, such as the *Portrait of Edward Curtis* (1750), by Marco Benefial (1684–1764) (E.381-2019), together with Curtis's splendid brocaded silk waistcoat (T.22-2019).

Roughly three-quarters of the paintings in the collection are on canvas. Paintings are displayed throughout the museum, notably in the Medieval and Renaissance Galleries, Europe 1600–1815, and the British Galleries 1500–1900. The Paintings Galleries were reopened in 2003 in a part of the museum that was built to house the first gift by John Sheepshanks (1787–1863) in 1857.

HOW PAINTINGS ARE PRIORITIZED FOR TREATMENT

Most of the work of the Conservation Department, roughly 90%, is driven by the museum's public program: gallery projects (redesigning and refurbishing galleries), exhibitions, displays, and loans to other institutions. We try each year to devote at least 10% of our time to work on the core collection, on objects that have been identified as needing conservation, although there is no plan to display them. Many sections, including Paintings, find this difficult to achieve. With paintings that are requested for loan, we take a minimal approach to try to preserve resources for the museum's own longer-term projects. In 2019, sixty-seven paintings were requested for loan. Most years, preparing paintings for loan and the associated administration takes up a quarter of my time, for instance.

The rehousing of the V&A's reserve collection from premises in West London to a new collections and research center in East London, in the Queen Elizabeth Olympic Park at Stratford, has been a major project for the last few years. This planned move spurred the completion of a condition survey of the reserve collection. From the survey we identified just over two hundred paintings that would benefit from some attention before the move. The main issues were flaking paint, very slack canvases, paintings poorly fitted into frames, and frames with no backboard. Remedial work to address these problems was carried out between November 2018 and March 2020 with the help of two colleagues on contract and a technician doing the reframing and backing.[2] Without the deadline of the move, the work would not have had the same priority. The paintings in the reserve collection, over 1,500, are only a small part of the 250,000 objects that will have to be moved out of the store. COVID-19 has caused some delays to the move; the new collections and research center is now due to open in 2024.

EARLY PREVENTIVE CONSERVATION

The first curator of paintings at the SKM, Richard Redgrave (1804–1888), had a protocol for dealing with newly acquired paintings that we would now describe as preventive conservation (Costaras 2013). Redgrave's acquisition procedure involved cleaning the reverse of paintings as well as the front, and putting a backing on the frame. A few years later, putting glass in the frames became a policy. During the years that I have worked at the V&A, a great many of the paintings in the collection have passed through the studio, and I have had the opportunity to observe their condition. It is striking how many canvases are unlined. I noted, thanks to helpful labels on the reverse, that the treatment of almost all the paintings that were lined was carried out in the 1890s or early 1900s by F. Haines & Sons (more on Haines & Sons later). Redgrave described the state of the Sheepshanks paintings on their acquisition in 1856:

When in the spring of last year the pictures were given over to the Department, the greater number had been left, during the years they had been in Mr. Sheepshanks' possession, in the state in which they had been purchased direct from the studios of the various artists or elsewhere . . . and all had gradually accumulated dirt and discoloration on their surface, and much dust behind the canvases (a source of mischief too often neglected). (Committee of Council on Education 1858, 64)

Redgrave went on to describe the measures taken after the dirt had been removed from front and back:

In order to secure the picture on canvas from the injury arising from the accumulation of dust behind them, they have all been protected by painted canvas stretched over them, so as to exclude both damp and dust. (Committee of Council on Education 1858, 65)

The painted canvas backing has the appearance of imitation leather; it was stretched over the reverse of the painting and tacked to the back of the frame. Narrow wooden fillets were pinned along the edges to improve the seal. An example of this method can be seen on a painting by Johann Gottfried Steffan (1815–1905), *The Torrent*, 1844/1848 (1545–1869), and probably dates from 1869, the year it was acquired (fig. 33.2).

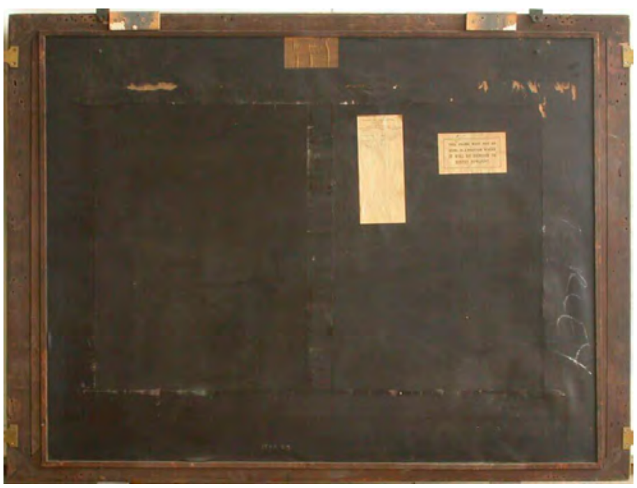


Figure 33.2 Johann Gottfried Steffan (Swiss, 1815–1905), *The Torrent*, 1844/1848. Oil on canvas, 80.6 × 118 cm (31 3/4 × 46 1/2 in.). Reverse of the frame showing a nineteenth-century painted canvas backing. London, Victoria and Albert Museum, 1545-1869. Image: © Victoria and Albert Museum / Photo: Nicola Costaras

As mentioned earlier, paintings from the collection were regularly sent to art schools around the country for students to copy. The destinations were noted on labels on the reverse, possibly stamped on arrival at the art school. One such label on the reverse of *The Torrent* records that it went to Northampton and Salford in 1913, and Truro in 1922. An adjacent label contains an injunction not to hang the painting in direct sunlight. The galleries at South Kensington were carefully designed to ensure that the viewer was not disturbed by reflections from the central roof light (skylight), described as "glitter," including those high up on the walls in a dense double or triple hang (fig. 33.3) (Committee of Council on Education 1858, 62).

Figure 33.3 A view of the British Picture Gallery, South Kensington Museum, London, April 15, 1862. London, Victoria and Albert Museum, 67:234. Image: © Victoria and Albert Museum

In the recent survey, we found twelve paintings that still had these nineteenth-century painted canvas backings, including two from the Sheepshanks gift in 1856, one of which is *The Hermit*, ca. 1841, by Charles Landseer (1799–1879) (FA.105[O]). The canvas is in plane and appears sound; until the painting is requested for display or loan or exhibits some structural problem, there seems no pressing need to unframe it.

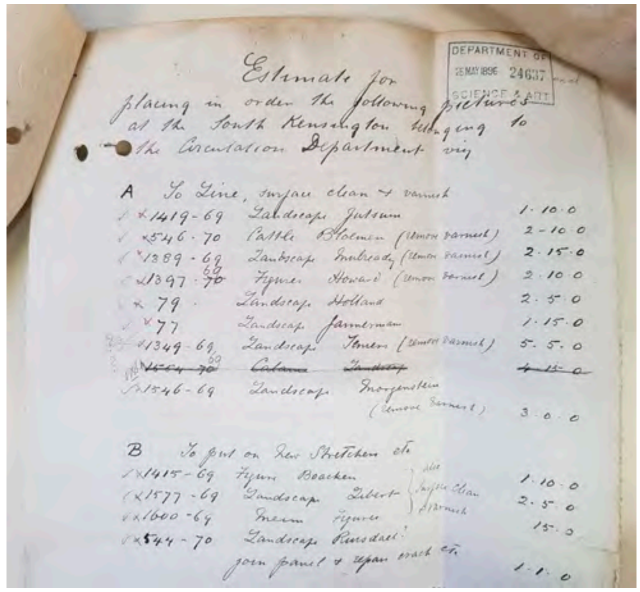
TREATMENT HISTORY AND PHILOSOPHY

In the early twentieth century, the use of painted canvas backing gave way to plywood; a thin three-ply was used. In the mid-twentieth century, plywood was superseded by hardboard (the same sort of material as Masonite), which we still use. Since the 1990s, we have been lining the hardboard with Melinex, due to anxiety over its acidity, but I wonder whether, left exposed, the hardboard would be more useful as a buffer against fluctuating RH. An alternative, such as acid-free card, was considered but was too expensive for the project.

With the exception of a limited number of paintings for redesigned galleries, our approach has been for minimal intervention. It is perhaps an advantage of working in a museum that we can take the risk of doing minimal treatments, knowing that if they fail, we can always do something more. We can afford to wait until the more interventive treatment is absolutely necessary. Between the nineteenth-century preventive conservation, which has given the collection an extraordinary number of unlined paintings, and the nineteenth-century glue-paste linings, in the twenty-five years that I have been at the V&A I have only come across one painting that I felt needed lining: on top of weakened canvas, the ground adhesion was poor over the whole surface.

I have carried out many strip-linings, where the tacking edges of the lining canvas were starting to fail. I have been so impressed with the skill of the Victorian liners, F. Haines & Sons, who had premises very close to the museum, off Thurloe Square.[3] Haines & Sons carried out various conservation treatments on paintings for the museum, as well as lining, although their treatment of canvas is the focus here. A painting by William Redmore Bigg (1755–1828), *A Cottage Interior: An Old Woman Preparing Tea*, 1793 (199-1885), came into the studio recently, prior to going on loan. The label on the reverse reads, "199-1885 Bigg / Lined, covered with thin / coat of varnish, new stretcher / by Messrs Haines & Sons / 21st July 1893." I am a great admirer of these labels with their succinct treatment reports.

The correspondence between the SKM officials and Haines & Sons is in the museum archives and includes many estimates for proposed work.[4] In an estimate dated May 25, 1896, section A lists eight paintings for lining (fig. 33.4). The reason for my good opinion of the Haines & Sons' glue-paste linings is that I have rarely seen weave emphasis, squashed paint, or moating around impasto—damage to the paint surface that could be attributed to the lining. They used a fine linen for the lining canvas, always a finer weave than the original canvas, although admittedly they did remove the original tacking edges. Over one hundred years later, the support within the picture plane is still sound. The only problem I have encountered is that on some paintings the lining canvas is starting to fail along the fold line. The thin fabric that was used and its brittleness where impregnated with the glue-paste adhesive combine to create lines of weakness at the place of closest contact with the wooden stretcher—hence the strip-linings.


DEPARTMENT OF
25 MAY 1896 24637
SCIENCE & ART

Estimate for placing in order the following pictures at the South Kensington belonging to the Circulation Department viz

A To Line, surface clean & varnish

×1419-69	Landscape	Jutsum	1.10.0
×546-70	Cattle	Bloemen	2-10-0
×1389-69	Landscape		2.15.0
×1397-69	Figures	Howard	2.10.0
×79	Landscape	Holland	2.5.0
×77	Landscape		1.15.0
×1349-69	Landscape	Teniers	5.5.0
~~1504-70~~	~~Cattle~~	~~Landscape~~	~~1-15-0~~
×1546-69	Landscape		3.0.0

B To put on New Stretchers etc

×1415-69	Figures	Beacken	1.10.0
×1577-69	Landscape	Zuber	2.5.0
×1600-69		Figures	15.0
×544-70	Landscape	Ruysdael	
	join panel & repair crack etc		1.1.0

Figure 33.4 Estimate from Haines & Sons, May 25, 1896. London, Victoria and Albert Museum. Image: © Victoria and Albert Museum / Photo: Nicola Costaras

One of the paintings listed in the estimate, by David Teniers the Younger (1610–1690), *Rocky Landscape with Figures*, ca. 1660–1690 (1349-1869), came into the studio in 2014 prior to going on loan. The canvas support was sound and in plane. The label on the reverse reads, "1349-1869 Lined, the surface cleaned by / sponging. The old varnish removed by / friction and the picture thinly varnished / by Messrs F. Haines & Sons June 27, 1896." There were two very small areas of lifting paint and a thin film of surface dirt, showing some air exchange into the frame. I fixed the paint with sturgeon glue and removed the dirt from front and back. It is satisfying to be able to link the estimate to the painting and see that the treatment was carried out and was effective.

In the early days, paintings were sent to Haines & Sons' premises. It was from Jacob Simon's talk at the British Association of Paintings Conservator-Restorers conference, A Changing Art, held in London in 2016, that I learned of the correspondence with Haines & Sons regarding the equipment for setting up a lining studio within the SKM in 1892 (Simon 2017). The requirements included a 41 1/2 × 33 inch (105.4 × 83.8 cm) slate, four irons, and a set of looms of different sizes—at a cost of £5 for the slate, 25 shillings for each iron, and £6.15s for the looms.[5]

In an estimate for lining and other treatments for four pictures, dated October 28, 1892, is a painting by John James Chalon (1778–1854), *Hastings: Boats Making the Shore in a Breeze*, 1819 (168 × 245 cm) (FA.234[O]).[6] The cost of the lining was £1.10s; to remove the surface dirt and thinly varnish the painting was to cost £1.5s. The painting is still in good condition; both support and paint layers are sound. Interestingly, Haines & Sons may have preferred to continue to carry out the work on their premises rather than at the museum. A postscript to the estimate states, "The price quoted—for doing them away from the Museum: if done at the Museum the cost would be somewhat more."

In the *Seventh Report of the Science and Art Department*, from 1860, Redgrave recorded that he had started to place paintings at eye level under glass to protect them (Committee of Council on Education 1860). From the frames themselves we can see that the glass was placed in a removable, narrow, gilded frame that was inserted into the picture frame from the front. Protection front and back, even if not fully sealed, appears to have provided a useful buffer to fluctuating RH and significantly slowed the deposition of dirt, particularly on the reverse.

The first donations and bequests in the 1850s to 1880s, which were near-contemporary art at the time, have benefited the most from the preventive conservation practices. Scanning a list of paintings acquired in 1869, the Townshend Bequest, I noted that many were less than ten years old. Similarly, of the ninety-five paintings acquired in 1886, a large number were between ten and twenty years old. It is true that some exhibit drying cracks from the use of materials popular at the time, but the significant point is that no age cracks are yet obvious on many of these paintings. The recent work preparing the reserve collection for its move to East London has shown that most of the paintings with problems are those that either had no backing or had lost it.

I have not been able to establish exactly when the Art Work Room was created, nor how many people worked there, but it was active in the first half of the twentieth century and was the beginning of an in-house conservation department. Harry Rogers was head of Paintings Conservation in 1973, when my predecessor Susannah Edmunds joined the V&A. Rogers had started work at the museum in the Art Work Room (A.W.R.) at sixteen. His employment at the V&A spanned over fifty years, with a break during World War II, when he was in the armed forces. We frequently find handwritten labels on backboards such as "Glazed and backed up, A.W.R." along with the date. When a painting by Daniel Hardy, *Sunday Afternoon* (F.16), was prepared for loan a few years ago, I found a label in Rogers's handwriting on the reverse: "Frame cleaned, re / paired and Backed up / By A.W.R 22.4.21."

Of the 102 canvases hanging in the Paintings Galleries at the V&A, forty are unlined, while a further eleven have original linings. Within the Paintings Galleries are three rooms dedicated to oil paintings from the Sheepshanks, Dyce, Townshend, Forster, and Ionides gifts or bequests. In many cases, the collectors had bought the paintings directly from the artists (fig. 33.5). I am certain that the reason so many of these paintings are well preserved, with many canvases still unlined and not in need of lining, is due to the early policy of glazing and backing.

Figure 33.5 The Paintings Galleries at the V&A, Room 82, displaying works from the Sheepshanks, Dyce, Forster, and Townshend gifts and bequests, 2003. London, Victoria and Albert Museum. Image: © Victoria and Albert Museum / Photo: Peter Kelleher

RECENT TREATMENTS

Having covered the V&A's treatment history, I'd now like to discuss some recent treatments—both preventive and interventive. With only one exception, the following were undertaken in the last decade.

The *Portrait of Frederick Louis* (Prince of Wales from 1707 to 1751), painted in 1716 by René Auguste Constantyn (active 1712–26) (627-1901), is an unlined eighteenth-century canvas still on its original strainer. The painting was requested for loan in 2014. As my initial check of its suitability for loan was done in the off-site store without taking the painting out of its frame, it was only when it came into the studio that I saw it was unlined. I repaired the small tear near the upper edge, as well as two tears on the tacking edges using a mixture of wheat-starch paste and sturgeon glue, and treated the slight canvas deformations. There is no doubt that the canvas is weakened: aside from the tears, the strainer bar marks are pronounced, and there is overall cupping of the ground and paint layers. The canvas was also starting to tear around the nails securing it to the strainer.

I used Japanese paper (*sekishu*), adhered with wheat-starch paste, to give some additional support to the tacking edges after first coloring it with a wash of acrylic emulsion. I felt that these local treatments would be sufficient for the time being. Tastes have changed; we are more tolerant of surface defects as the price of avoiding lining.[7]

The Opening of the Great Exhibition by Queen Victoria on 1 May 1851 (1851; oil on canvas; 329-1889), by Henry Courtney Selous (1803–1890), has a glue-paste strip-lining rather than a full lining. I recently found a reference to a payment of £3 17s 6d to Haines & Sons in 1904 for repairing and cleaning this painting, so it seems likely that they carried out the strip-lining.[8] After three incidents of treating small dents and tears, the Selous has been glazed, despite its size (169.5 × 241.9 cm) and the delicate composition frame. In addition to the backboard, it has a stretcher bar lining of polyester sailcloth. Typically, we give unlined paintings stretcher bar linings, and if there are no cross members, as was the case with Prince Frederick's portrait, we will attach polyester wadding to the backboard with Velcro so that it is held within the stretcher or strainer window.

The *Train Bleu* theater cloth (S.316-1978) was commissioned by Diaghilev for the Ballets Russes for the ballet of the same name. The image is an enlarged version of a sketch of *Two Women Running along a Beach*, painted in 1922 by Pablo Picasso (1881–1973). The sketch measures 32.6 × 41.2 cm (gouache on plywood, Musée National Picasso, Paris). There is a large off-white border around the image on the stage cloth; nevertheless, it represents an extraordinary transformation in scale: the stage cloth measures 10.4 × 12.75 m. It was painted by Prince Alexander Schervachidze (1867–1968), who made designs for several Ballets Russes productions. Picasso was so impressed with the result that he signed it with a dedication to Diaghilev.

The stage cloth proved very popular and was subsequently used as a front cloth and flown before every performance. Usually, stage cloths have a reinforced border with tie points along the upper edge to allow them to be easily attached to a fly bar in each theater. Instead, the *Train Bleu* front cloth had been nailed directly through the upper edge, often after being folded to adjust its height to fit different theaters. The repeated nailing of the upper edge to battens and subsequent removal had taken its toll, and there were so many tears in the upper 150 centimeters that, added together, they came to 200 centimeters in length. The weight of the canvas and the fact that all the tears were at the top raised fears of a zipper effect if the tears started to propagate.

This was the less recent project: it was twenty years ago that Éowyn Kerr, then a student intern, prepared various adhesive samples for tensile testing, which was carried out by Christina Young at Imperial College.[9] The results suggested that repairing the tears with polyamide welding powder[10] would be strong enough to support the weight of the canvas without any patches or lining the upper section, which we wanted to avoid. The support is a jute fabric consisting of nine horizontal strips sewn together. It was helpful that the ends of the threads along the tears were frayed, providing more surface area for the adhesive.

At it happened, the loan that started the investigation was canceled, and it was not until 2005 that the treatment took place. It was a joint project with Jim Dimond, who recruited several other colleagues to help.[11] The *Train Bleu* has since been flown in five exhibitions and is holding up so far. It was in the V&A exhibition *Diaghilev and the Golden Age of the Ballets Russes 1909–1929*, in London in 2012, and at the final venue in Washington, DC, in 2013.

Three Korean paintings on cotton were acquired recently, which date from the early 2000s.[12] They arrived rolled and had many distortions. They were returned to plane through moisture treatments while on a loom. Strips of kraft paper were attached to the canvas edges and then wetted and attached to the loom (fig. 33.6). Humidity was introduced to the reverse of the canvas with damp blotting paper through Gore-Tex. The paper shrinkage exerted tension as the whole structure slowly dried. Fiona Rutka, a student intern, did most of the work on these paintings. They were put onto new stretchers over loose-linings of polyester sailcloth.

Figure 33.6 Ch'ol Muk Ri (North Korean), *Uri chungdae sosik*, 2005. Oil on cotton canvas, 81 × 77 cm (31 7/8 × 30 1/3 in.) on stretcher. The canvas painting is returned to plane through moisture treatments while on a loom. London, Victoria and Albert Museum, FE.89-2009. Image: © Victoria and Albert Museum / Photo: Nicola Costaras

Preparations for a touring exhibition of the works of John Constable meant that fifty oil sketches passed through the studio in 2010.[13] *Landscape with Double Rainbow*, 1812 (33.7 × 38.4 cm) (328-1888), is on a mixture of supports, paper adhered to canvas as well as an original lining. Constable used a variety of supports for his oil sketches: frequently a homemade paper laminate, primed in different colors. At other times he reused his own canvas paintings, cutting them into small sections (Costaras and Richardson 2010). It is possible that in this instance he tried to peel off one layer of paper to get a fresh surface to paint on; the surface is irregular, with sections of paper missing. Clare Richardson and I speculated that Constable used the nearest support on hand to capture the fleeting atmospheric effect. An X-ray image shows at least one other composition within the support (Costaras and Richardson 2010, 151).

Constable painted over the top of the torn paper and canvas support regardless, lined it, and continued to work on it. When it came to the studio, the canvases were delaminating and the edges were frail. Wheat-starch paste was used to reattach the two canvases and left to dry under weight. With the help of Susan Catcher, our colleague in Paper Conservation, we strip-lined the painting with wheat-starch paste and Japanese paper (fig. 33.7). Wheat-starch paste was also used to attach the paper to the strainer. Serendipitously, the shrinkage of the paper as it dried exerted a gentle tension on the canvas without making it too taut.

Figure 33.7 Clare Richardson and Susan Catcher strip-lining *Landscape with Double Rainbow* by John Constable (English, 1779–1837) using Japanese paper and wheat starch paste. Paintings Conservation Studio, V&A, London. Oil on paper and canvas, 33.7 × 38.4 cm (13 1/4 × 15 1/8 in.). Victoria and Albert Museum, London, 328-1888. Image: © Victoria and Albert Museum

The above are just a few examples of types of canvas treatments undertaken at the V&A in recent years, and they give a sense of the variety of the works in the collection.

ACCESS VERSUS PRESERVATION—FINDING A BALANCE

The Ballet Scene from Meyerbeer's Opera "Robert le Diable," 1876, by Edgar Degas (76.6 × 81.3 cm) (CAI.19), is another unlined canvas painting; it provided a catalyst for a change in approach to lending. The painting is frequently requested for loan and had traveled to fifteen venues with five exhibitions in eighteen years.

My attitude about what constitutes a suitable condition for a painting to go on loan has changed over time. Once, I would be concerned if a painting already had a documented problem, but then it occurred to me that I should be more protective of paintings that are still in good condition. This led me to propose to my curatorial colleagues that we try to limit the amount that unlined canvases travel. I argued that the Degas has an important quality, in that it has not had any interventive treatment, and that this is a state we should try and preserve. The curators agreed with me, particularly in the context of this group of gifts and bequests from nineteenth-century collectors, and since 2007 that has been our unofficial policy.

Now, if paintings are unlined, this is immediately flagged, often by the loans curator, and an alternative offered if possible. There isn't always an acceptable substitute, as is the case with the Degas. However, if such a painting is requested for a multivenue loan, we might agree to just one venue, one accessible by a single-truck journey, and decline it for the rest. At the time of the symposium, in October 2019, the Degas was at an exhibition in Paris, and this is the reason it did not go to the second venue in Washington, DC. We receive more loan requests for the Degas than for any other painting in the collection.

Traveling does cause wear and tear. An unlined canvas by Lawrence Alma Tadema (1836–1912)[14] had recently gone on loan when it was requested again two years later. On checking it for the second loan, I found tears had developed along the fold line. Even if a well-designed packing case does a good job of reducing shocks and vibration, they can be greater during the movement of paintings on A-frames within museums at either end of the journey, as shock loggers have shown (Saunders, Sitwell, and Staniforth 1991, 320). By limiting the number of trips these unlined canvases make, we are trying to postpone the moment when lining or strip-lining becomes necessary, and this is another aspect to our approach to conserving canvas.

CONCLUSION

Inevitably, the public program sets conservation priorities to a large extent, but we do aim to devote time to the core collection each year. The evidence from the recent survey of the reserve collection highlights the importance of backings in the preservation of canvas paintings. There was a strong correlation between the paintings with evidence of weakened canvas—shown by pronounced cupping, stretcher bar marks, and flaking paint—and those that had no backing. In contrast, many of the canvases that have had backings since they were acquired in the nineteenth century (in a few cases the same backings) appear sound and often have no obvious age cracks.

The decant of the reserve collection provided an opportunity to apply preventive conservation wherever it was lacking. Between the unlined canvases and the nineteenth-century glue-paste linings, with due credit to the work of my predecessors throughout the twentieth century, I have not had to carry out a single lining in the twenty-five years that I worked at the V&A. I carried out many strip-linings and tear repairs. Collaborating with my colleagues in Paper Conservation, I have found many uses for Japanese paper and wheat-starch paste.

In the foreseeable future, I expect *The Martyrdom of St. Ursula and the 11,000 Virgins,* mentioned earlier, will need relining. This fifteenth-century painting was one of the V&A's earliest acquisitions, in 1857, and it was already lined when it arrived at the museum. The tacking edges of the lining canvas are frail, and it is fairly large: 163.3 × 232.4 cm (see fig. 33.1). When the time comes that this and other canvases do need lining, will there be anyone who does enough paste-lining to be skilled at it? Although minimal treatments have their place, I am concerned about a gap in skills due to lack of practice.

Beyond paste-lining, it is better still to have experience with a range of different lining techniques—and thus to be able to choose the most appropriate method in each case. After hearing the talks at the 2019 Conserving Canvas symposium, I am hopeful that the Getty Foundation initiative, of which the symposium was a part, will ensure that the expertise continues to exist.

ACKNOWLEDGMENTS

I would like to thank all the colleagues past and present who have worked on the projects I have mentioned and who responded so generously to appeals for details of references and sources while access to files and libraries was limited by the coronavirus pandemic lockdown.

NOTES

1. *The Apocalypse Triptych.* Oil on oak panel, transferred to canvas prior to acquisition, 137 × 336 cm (5940-1859).
2. Carolina Jiménez Gray and Cerys Fry, with the valuable assistance of Lee Emmett.
3. For further information, see the National Portrait Gallery's index of British picture restorers: https://www.npg.org.uk/research/programmes/directory-of-british-picture-restorers/.
4. V&A Collections, Paintings Department, general correspondence ED 84/134, conservation measures 84/375.
5. V&A Collections, Paintings Department, general correspondence ED 84/134, 13919.
6. V&A Collections, Paintings Department, general correspondence ED 84/134, 13485.
7. During the recent survey, we discovered another unlined eighteenth-century canvas, *A Member of the Howard Family of Ashstead*, by a follower of Sir Godfrey Kneller, ca. 1700, oil on canvas (P.30-1970). The paint surface is cupping on this painting too, and there is a pronounced oval stretcher or strainer mark, but the paint appears secure, and I would not consider it in need of structural treatment at this stage.
8. V&A Collections, Paintings Department, general correspondence ED 84/134.
9. Éowyn Kerr, Project file: Tear mend testing, 1999. V&A Conservation Department.
10. 4040 Lascaux Polyamide Textile Welding Powder 5065 (now 5350).
11. Julia Nagle, Catherine Nunn, and Sam Hodge.
12. Ch'ol Muk Ri (North Korean), *Uri chungdae sosik*, 2005. Oil on cotton canvas, 81 × 77 cm (FE.89-2009). Hyong Sik Rim (Korean), *Ch'ukcheoneul aptugo,* 2007. Oil on cotton canvas, 72 × 100 cm (FE. 90-2009). Sang Mun Ri (North Korean), *Mount Paektu and Heaven Lake*, 2008. Oil on cotton canvas, 91 × 131 cm (FE 93-2009). All dimensions are for paintings after stretching.
13. The Constable project funded some assistance, which was provided by Rachel Turnbull and Clare Richardson and for a short time by Kate Stonor.
14. *Cleopatra at Philae*, ca. 1850–1912. Oil on canvas, 149.9 × 106.4 cm (P.40-1921).

34

The Traditional *Colla Pasta* Lining in the National Gallery in Rome: Examples and Early Evidence

Chiara Merucci, Head Conservator, National Gallery, Rome

Going back in time through the collections of the National Gallery in Rome, material traces can be found in the ancient linings that are evidence of the modus operandi of the first restorers. However, few examples are preserved from the nineteenth century, probably due to the excessive use of glues. More numerous are the older testimonies, and these show greater care in the choice of canvas, more discreet use of glues, and less impact of pressure and heat. Observation of the material data finally allows us to link a defined modus operandi to restorers hitherto only known by name through documents. The path backward allows us to assess evidence dating back to the mid-seventeenth century. Alongside the in-depth study of minimal methodologies, the study of this method appears to us to be a fundamental premise for a complete reevaluation of traditional methodologies, as they are not only functional to the test of centuries but also environmentally friendly and totally reversible.

◆ ◆ ◆

INTRODUCTION

Rome’s National Gallery, composed of the Palazzo Barberini and Galleria Corsini, was born at the end of the nineteenth century, the fruit of an institutional will to create a national museum in the capital soon after the creation of the unified Italian state. Its masterpieces have different origins,[1] the histories of which it is often difficult to reconstruct. The collection is rich in historical technical material, as in many works in our collection ancient linings are still preserved.[2] However, it is not always easy to uncover the archival sources. We have followed two parallel lines of inquiry to better understand the linings from a technical and historical standpoint. On the one hand, we have observed the technical details relating to the canvas and stretcher for works that have never been lined or that have documented ancient linings linked to the Roman context. On the other hand, we have researched the shadowy figures of the craftsmen, who are now difficult to characterize, belonging to anonymous social classes,[3] but who back then must have been celebrities. It is among them that we can identify the first restorers.

These two lines of inquiry allow us to reconstruct the work of restorers going back to the seventeenth century and to flesh out these figures. It is not surprising that we find the first restorers in Rome, where many famous collections were concentrated. Not only do these men now have a history and biography, but their technique also can be reconstructed in much the same way that artists are identified by their style, thus bringing life to archival sources.

Starting from the 1950s and going back in time, this paper focuses primarily on the eighteenth century in Rome, which saw a great upsurge in restorations, providing ideal conditions for the development of restoration techniques.

THE TWENTIETH CENTURY: A FOCUS ON POSTWAR INTERVENTIONS

Leaving aside the most recent and better-known years, the first period I want to discuss is the massive campaign of restorations that took place after World War II, when works were retrieved from the hiding places where they had been stored. However, if we look at the numbers involved, only a relatively small percentage of these required structural restoration. As a result, many examples of old linings are still in existence.

At the end of the conflict, it proved necessary to repair the damage caused by inappropriate and often inclement conservation conditions. Lists were drawn up indicating urgencies and priorities for restoration. Many works are mentioned several times in these lists, perhaps because they are still awaiting intervention. Documents requesting estimates and assessments for the acquisition of materials provide us with information on the techniques employed in these interventions.

Among the most active restorers were without doubt the Podio family, originally from Bologna. We have at least a dozen documented linings executed by them, and most of these date from the 1950s (fig. 34.1) and are still effective as supports for the paintings.[4] In their estimates, the Podio family often indicate hemp as the lining textile used, but more importantly we note that they often repeated the operation they had just concluded with a second lining that involved a double or even a triple layer of glue paste, which would be filtered through the weave and the excess removed by applying great pressure; the ironing operation, on the other hand, was not repeated.[5] The result was a lining of great rigidity and of high susceptibility to changes in humidity and temperature because of the amount of glue on the reverse.

That these linings should still be in place and largely effective is all the more notable. However, it is true that the environment of our galleries is essentially a dry one, with a rather low RH of around 40%—and therefore suitable for the preservation of this kind of restoration. In this context, I should mention a curious estimate given by D. Podio for work to be carried out on a *Virgin and Child* attributed to Raphael, in the Accademia di San Luca. Having recognized it as a transfer, he proposed an initial lining on a hemp canvas, with the consequent ironing and filling, then a second lining using not less than three hemp canvases and another ironing: “This would give back to the painting the appearance of a painting on wood.” His aim was therefore a rigidity that was not only functional but also aesthetic.[6]

a b

Figure 34.1 G. F. Barbieri, called Il Guercino (Italian, 1591–1666), *Flagellation*, 1657. Oil on canvas, 244 × 187.5 cm (96 × 73 4/5 in.). (a) Before lining. (b) After Podio’s 1947 lining. Images: Barberini Corsini National Galleries, Rome. (a) ICCD-Gabinetto Fotografico Nazionale, Fondo GFN, n. inv E47623, with authorization of Istituto Centrale per il Catalogo e la Documentazione, MiBACT, further reproduction not authorized / (b) Gallerie Nazionali di arte antica (MiBACT)–Biblioteca Hertziana, Istituto Max Planck per la storia dell’arte/ Enrico Fontolan

THE NINETEENTH CENTURY: PRESERVED EXAMPLES OF LININGS AND OF MINIMAL INTERVENTION

In the nineteenth century, we find an earlier massive campaign of restoration, which occurred at a time of many acquisitions as a result of bequests. The public aspects of Roman restoration during this period are well known due to the activities of the Camuccini brothers: Pietro, a restorer, and Vincenzo, an inspector of public paintings (Giacomini 2007). Among his collaborators, Vincenzo chose Pietro Palmaroli (Köster [1827] 2001, 123; Rinaldi 2004) and Giuseppe Candida, who moved to Rome from Venice in 1803. Candida brought with him such cultural knowledge as his experience in the workshop of Pietro Edwards (Conti 2003, 185, 229; Köster [1827] 2001, 121).

Restoration practices in various private collections are less well known. Again, archival documents are of help. In those of the Corsini family, we find paintings on which G. B. Beretta worked (Ventra 2016)—a restorer who also collaborated with Minardi—and going back in time, Palmaroli (Cosma 2016, 180ff.) and Principe (Magnamini 1980a, 1980b). The same names come up in both the private and public sectors, and through these we will get a better picture of the Roman system.

In the National Gallery, we have few examples of linings dating back to the nineteenth century, even though the period is rather well known through the historical research cited. Such documentation tends to be of a more theorical (almost sterile) nature, and we are unable to match it with the technical evidence. Just a few linings from the nineteenth century or even the earlier part of the twentieth are preserved—a result of the general use of greater quantities of glue paste and of coarser and heavier canvases for linings, which has made them more fragile and more susceptible to changes in RH and temperature (Mecklenburg 2007c; CESMAR7 2008; Ciatti and Signorini 2007; A. Roche 2003) than the earlier linings described in some detail in later sections of this paper.

One example of a painting with a nineteenth-century lining is *Glory of Saint Ignatius* (fig. 34.2), by A. Pozzo (inventory 1426). The restoration is dated 1884 on the stretcher, the canvas is of a heavy and tightly woven herringbone weave, and the adhesive is rich in animal glue. On the canvas are marks that seem to be the result of burns from the application of hot irons. The stretcher is pine, with crossbars and keys, but it is essentially inadequate; clearly evident on the picture surface are the stretcher marks, as well as flattening of the paint. The inscriptions that accompany the restoration, on the stretcher, are grammatically incorrect, once again relegating the restorers to the "mechanical," uneducated sphere. Another *bozzetto* for Pozzo's trompe l'oeil dome of the church of Saint Ignazio (inventory 1425) has very similar characteristics and was also lined in 1884, so one can infer that it was carried out by the same restorer.

Figure 34.2 A. Pozzo (Italian, 1642–1709), *Glory of Saint Ignatius*, sketch for the ceiling of Saint Ignazio in Rome, 17th century, 324.5 × 171.5 cm (127 3/4 × 67 1/2 in.). Lined in 1884. Image: Barberini Corsini National Galleries, Rome / Gallerie Nazionali di arte antica (MiBACT)–Biblioteca Hertziana, Istituto Max Planck per la storia dell'arte/Enrico Fontolan

Many restorations coincided with the acquisition of the painting, for example, Giordano Luca's *Ritratto di capomasteo (Cratete)* (inventory 1254), lined by Luigi Bartolucci in 1898. The stretcher may have been preserved from a previous intervention but adapted to make space for keys. The lining canvas is coarse, thick, and stained and has a large seam. It is interesting to compare this canvas to those in use by painters at the same time: the same kind of canvas was used for Horace Vernet's *Portrait of Filippo Agricola*, painted in the 1820s and never lined.

During the nineteenth century (although not as frequently as during the eighteenth century), we find evidence of a desire for minimal intervention, both in mending of tears and in strip-linings. It was also Bartolucci who carried out the 1909 strip-lining of Bernardo Cavallino's *Saint Peter and Cornelius the Centurion* (inventory 1485), for which (according to his report) he "consolidated the old lining," thus wisely preserving a lining dating to the end of the eighteenth century that was still functional. Another example is Guido Reni's *Magdalen* (inventory 1437) (fig. 34.3), which was never lined but has a very old strip-lining, surviving at least in the upper section.[7]

Figure 34.3 Guido Reni (Italian, 1575–1642), *Magdalen*, 1631–32. Oil on canvas, 234 × 151 cm (92 1/8 × 59 1/2 in.). Never lined but has an ancient strip-lining. Image: Barberini Corsini National Galleries, Rome / Gallerie Nazionali di arte antica (MiBACT)–Alberto Novelli

Proceeding backward through the historical stages, and at the same time reconstructing the techniques, we arrive at the turn of the eighteenth century, at a moment when Rome was an important center in the history of restoration. It is not by chance that this was the case. Rome had a very high concentration of private collections, and the first public ones were coming into being. Nor was it by chance that this occurred almost two centuries from the initial diffusion of canvas as a painting support. The central position of Rome for restoration history is highlighted by the fact that it was the place of origin of many restorers who were responsible for the spread of Roman restoration techniques. In 1787, Andres left for Naples, and ten years later Vittorio Sampieri left to join Puccini in Florence, although the two had already met in Rome (Incerpi 2011; Mazzi 2007). A few decades later, in 1826, Palmaroli also left, to go to Dresden.

TECHNICAL DATA: TOWARD THE EIGHTEENTH CENTURY

In contrast to the nineteenth century, in our collection we have a large number of old linings that we can date to the eighteenth century. These are recognizable by their technical characteristics, which we can match with the historical documentation and thus understand the lining process involved.

A first group includes canvases with a more compact and coarser weave that have oxidized and darkened because of the amount of glue used. The canvas weave is impregnated with glue, and the lined painting is typically mounted onto chestnut strainers with half lap joints blocked with either nails or pegs, and with stretcher members that have a rectangular cross section. The joints of these strainers have not always been filled (when used, filler forms a barrier against changes in temperature and humidity).

The wood is not always of top quality; stretcher members with different colorings are often found in the same strainer, an indication of the presence of both heart-wood and sap-wood. This group also includes strainers that are less refined, evidently constructed with remainders of wood, with members made with either chestnut or poplar.

A second group includes older linings, dated to the first half of the eighteenth century, that have rather pale lining canvases. They have a plain, light, open weave not impregnated with glue and are mounted onto chestnut strainers. The stretcher members are rectangular in cross section and have shouldered bridle joints, which have been filled.

The Prestretching of the Lining Canvas

Upon closer observation of paintings in the collection, I deduced that the lining canvas was stretched by attaching it to the strainer with sprigs or brads. The lining would then be wetted to slacken the canvas, which could be made taut again with the same sprigs, hammered back and bent to secure the canvas (fig. 34.4). This preparation of the lining canvas would greatly weaken it, making it more like the original canvas.

Figure 34.4 B. Cesari (Italian, 1571–1622), *Adoration of the Shepherds*, 1610–15. Oil on canvas, 44 × 55 cm (17 3/4 × 21 3/5 in.). The sprigs used to stretch the lining canvas are visible under the painted canvas edges. Image: Barberini Corsini National Galleries, Rome / Gallerie Nazionali di arte antica (MiBACT)–Alberto Novelli

I use the term *system* for lining with glue paste rather than referring to it simply as an adhesive, because the recipe in itself, with all its variants, does not cover the description of the process involved and its effects. In the Roman system, the original canvas is simply attached to the pretensioned lining canvas, which, when impregnated with the glue, acquires a certain rigidity. This entails the transfer of the tensions of the original canvas onto the lining canvas, which therefore truly acts as a new support for the work.[8] This is the main difference between the Roman and the Florentine systems, as they are still practiced today.[9] As a rule, the lining canvas chosen should be as similar to the original as possible in terms of weight and weave count,[10] but preferably finer and thinner. Canvases of the same period that have never been lined have the same characteristics.[11]

To carry out the lining, the original canvas—probably faced in order to consolidate the paint layers and protect them—would be laid facedown and the adhesive would be spread on the reverse. The lining canvas—already stretched onto the strainer as described above—would then be placed over this and made to adhere to the original canvas simply by massaging the reverse with the hands, which would also exert pressure.

Recipes

Because recipes were considered workshop secrets, we do not know their details, but we can imagine that the main ingredients remained constant while the additives would vary, and these were the elements that were the workshop's "secret."

It is likely that the use of animal glue became necessary when serious structural problems were encountered, such as how to reduce serious deformations, tears, or blistering of the paint layers. The adhesive properties of flour-paste glues are linked to the presence of gluten, which is extracted after fifteen minutes of cooking at 70°C–80°C. The addition of glues can therefore only occur after this operation has been carried out, as the temperature used would alter the collagen and therefore its adhesive properties. In the Roman recipe, one uses bone glue, *colla cervione.* It is rich in impurities, short-chained, and both fragile and stiff, while also having great adhesive strength and resistance to sudden shocks.

The ratio of flour to glue is the critical element in the formulation of the glue-paste adhesive, which will affect its response to changes in humidity and to biological attack (Fuster-López et al. 2017). It is now clear that all the additives were included in the formulation to render the paste more elastic and to retard its drying (Lavorini 2007; Laroche and Saccarello 1996), and that they also play a role in the aging of the paste (Ackroyd 1995).

That the original basic recipe contained little or no animal glue can be deduced from the color of the adhesive, which in the older linings is very light, although it should be darker because the type of flour used was less refined and therefore full of husks, and itself darker in color. Thus, the lightness of the adhesive must be related to the amount of animal glue present in the recipe. Orlandi, in the *Abecedario pittorico*, first published in 1704, proposes a flour-paste glue without the addition of animal glue (Orlandi 1753, 548). We know that the glue was added soon after; for example, Pietro Edwards, only fifty years later in Venice, suggests adding German glue, that is, strong ox glue (*colla forte*). Edwards also uses a starch-paste glue for his facings and for localized consolidation; and in his descriptions of works requiring restoration, he refers to patches that are poorly attached because of the inadequacy of the "paste made from gluten" (*gluttini*) (Tiozzo 2000, 152). The difference in terminology, which alludes to a material difference, continues over time up to the Forni manual, which still reports patches that are either "pasted or glued on" (Bonsanti and Ciatti 2004, ch. 3).

Ironing

At the very beginning of the use of lining systems, the pressure and heat applied were very light and gentle. But before long the initial massaging of the reverse was associated with heat.

In Orlandi, we learn that the canvases were left beneath a uniform weight provided by a heavy panel, but that the various thicknesses of the paint were nevertheless protected by layers of paper or even felt (Orlandi 1753, 548).

The introduction of heat, generally termed *stiratura* (ironing), is documented by Edwards, who describes an ingenious system in which heated sand was placed on the reverse of the lining. We have found residues of this sand, confirming the practice as recounted in the sources (Tranquilli 1996). This system ensures even pressure while at the same time adapting to the material nature and profiles of the paint layers without causing excessive flattening of the texture.

The reference to irons in relation to the *stiratura* is clearly made in L. Crespi's 1756 letter to F. Algarotti, in a passage in which he relates what seems to be a consolidation procedure from the reverse. In this passage, Crespi expressly refers to the irons used for starching; therefore, it really is the same irons used in laundering that are meant (Bottari 1822–25).

At this juncture during the lining procedure, after the ironing the original tacking edges were turned over the strainer (but often they were included in the front surface, thus slightly enlarging the dimensions of the picture) and then secured with nails or glue. The old method is easily distinguishable in that the sprigs used to stretch the lining canvas are visible under the painted canvas edges (see fig. 34.4).

The entire procedure described is observable in *Adoration of the Shepherds*, by Cesari (inventory 1120) (fig. 34.5). The work is part of the Torlonia bequest (one of the cores of the museum collection) and was acquired by the Torlonia from the Soderini family.

Figure 34.5 *Adoration of the Shepherds*, verso, showing a lining dating from the 18th century attributed to D. Michelini. Image: Barberini Corsini National Galleries, Rome / Gallerie Nazionali di arte antica (MiBACT)–Alberto Novelli

The Soderini were one of the main patrons of Marco Benefial, a painter who always worked with Domenico Michelini, who was the most important restorer in Rome in the first half of the eighteenth century.[12] We can therefore infer that Michelini also worked for the Soderini, and we can attribute this lining to him.

It is interesting to observe that in the eighteenth century there were famous "duo" collaborations between restorers and painters, in which the restorer could not paint at all and would carry out the lining, the filling, and sometimes the cleaning,[13] while the painter would retouch.[14] Such famous duos include D. Michelini and M. Benefial, and later G. Principe and P. Anesi or D. Corvi.[15] (See Cerasuolo's paper in these proceedings for more on this division of labor.)

Documents show the restorer Giovanni Principe, heir and son-in-law of Michelini, working in the same environment where Giovanni Torlonia conducted his business. Therefore, it is easy to imagine that they had business interests in common. However, many of the linings that have been preserved bear the Torlonia seal, which dates from the time when the inventory of the collection was drawn up, at the very beginning of the nineteenth century.

THE SEVENTEENTH CENTURY

To conclude our survey going back in time, the oldest dated lining in the Barberini Galleries dates to the middle of the seventeenth century. The presence of the seal on the strainer dates its assembly, and therefore the lining of the painting, to 1641–42. The strainer is of chestnut with shouldered bridle joints that are not blocked, and a fine, regularly woven, plain-weave lining canvas is in every way comparable to a contemporary canvas that has never been lined (fig. 34.6).

CONCLUSION

Among the paintings in our gallery are many works lined with wax resin, a system that was increasingly used during the 1960s, perhaps in pursuit of an ideal of modernity. If we compare two *pendants* by Benefial, one lined with the wax-resin system (inventory 1182) (fig. 34.7) and the other lined with glue paste (inventory 1183) (fig. 34.8), the difference demonstrates how the wax-resin system has a far greater impact on the perception of the painting. The different saturation of the colors caused the original link between the two paintings to be lost. Therefore, it is essential to consider all the effects of the conservation method used to preserve a painting.

Figure 34.6 Bolognese School, *Herodias*, 17th century. Oil on canvas, 64 × 49.5 cm (25 1/5 × 19 1/2 in.). The lining can be dated from the visible seal. Image: Barberini Corsini National Galleries, Rome / Gallerie Nazionali di arte antica (MiBACT)–Alberto Novelli

Figure 34.7 M. Benefial (Italian, 1684–1764), *Hercules and Omphale*, 1735–40. Oil on canvas, 218 × 135 cm (85 4/5 × 53 1/8 in.). Lined with the wax-resin system. Image: Barberini Corsini National Galleries, Rome / Gallerie Nazionali di arte antica (MiBACT)–Biblioteca Hertziana, Istituto Max Planck per la storia dell'arte/Enrico Fontolan

Figure 34.8 M. Benefial (Italian, 1684–1764), *Pyramus and Thisbe*, 1735–40. Oil on canvas, 218 × 135 cm (85 4/5 × 53 1/8 in.). Lined with the glue-paste system. Image: Barberini Corsini National Galleries, Rome / Gallerie Nazionali di arte antica (MiBACT)–Biblioteca Hertziana, Istituto Max Planck per la storia dell'arte/Enrico Fontolan

Seeking to implement a minimal structural intervention respectful of the aesthetic qualities of the works in our collection, our studio is focusing on developing thread-by-thread mending techniques for tears, as for Maratti's *Portrait of Cardinal Barberini* (inventory 5001), as well as on a program of preventive conservation. This is also what led us to study again the ancient lining systems with glue paste, which are still effective after centuries, sustainable from an environmental point of view, and an almost unique example of a completely reversible intervention, as for instance in the *bozzetto* for *Vision of Saint Romualdo* (fig. 34.9), by A. Sacchi (inventory 4632), which has been delined.

Figure 34.9 A. Sacchi (Italian, 1599–1661), *Vision of Saint Romualdo*, 17th century. Oil on canvas, 68 × 44 cm (26 3/4 × 17 3/4 in.). Delined. Image: Barberini Corsini National Galleries, Rome / Gallerie Nazionali di arte antica (MiBACT)–Biblioteca Hertziana, Istituto Max Planck per la storia dell'arte/ Enrico Fontolan

NOTES

1. For a concise history of the Roman museum system, see Nicita 2009 and Bernini 1997.
2. I am at present carrying out a full conservation survey of all the gallery's paintings, which will provide the actual number of "old" linings preserved.
3. Their fame made them the object of visits from important personalities. For example, De Brosse paid a visit in 1739–40 to a certain "Domenico," maybe the very same Michelini mentioned later in this paper, perhaps still hunting for curiosities and secrets. Goethe's visit to the restorer Andres in Naples on March 15, 1787, however, was undertaken in a completely different spirit. Goethe says he cannot describe the restorer's art; due to the difficulty of the task, he was unable to describe the happy solutions found by the restorer. (Andres worked in Rome for the Borghese, then went to Naples, invited by Hackert, and became restorer at court.)
4. This paper discusses only structural interventions. The aesthetic restoration of the painting surface has been carried out by other restorers—in some instances repeatedly.
5. The associated ironing is rather heavy handed, perhaps done with a roller, and it is not unusual to find the imprint of the canvas in the paint layers as a visual effect resulting from this process.
6. In the end, the Podio family did not undertake the restoration.
7. From documents in the archive, we know that in 1924 the strip in the lower section was exchanged for a wider one to repair a tear.
8. Ackroyd 1995 highlights rigidity as the aspect that enables the lining canvas to act as the new support.
9. Among the different glue-paste lining systems, in the Florentine system the painting is never left free; even when not stretched onto the stretcher, the canvas is always in a state of tension through the attachment of bands of paper glued at the edges. It is clear that this system aims at the control of canvas deformations differently (Lavorini 2007).
10. Pietro Edwards suggests canvases finer than the original ones. In the *Obblighi ed incombenze dell'Ispettore al ristauro generale dei pubblici quadri*, he writes, "Che non si ometta di foderare il quadro per evitare la spesa delle costose tele e che queste siano sempre di grana più fine della tela vecchia, perché essendo il contrario non legano bene" (Do not omit lining the painting in order to avoid the expense of a lining canvas, which must be finer, because if it is coarser the adhesion will be poor) (Tiozzo 2000, 122).
11. For example, Filippo Lauri, *Festone* (inventory 1934), or the *Landscape* by an anonymous artist (inventory 2232), both from the end of the seventeenth century.
12. There are many references to Michelini working for the most important Roman families; see, for example, Debenedetti 2004, 2005; Bodart 1970; Ghezzi 1744; letter from L. Crespi to Francesco Algarotti (Bottari 1822–25, 419); Nougaret and Leprince 1776, 66, 143; and Standring 1988, 608–26, particularly 621 and 624. For a more complete study, with all the biographical notes, see Marinetti 2007. All the works for the Pamphili are cited in De Marchi 2016. In the Palazzo della Cancelleria, Michelini worked with Ventura Lamberti, Benefial's teacher. For the Ruspoli family, he prepared the canvas for Trevisani to paint a Saint Francis. For the Giustiniani, he restored the first version of Caravaggio's *Saint Matthew.* For the Pellegrini church, he cleaned Reni's *Trinity* and repaired a panel painted by the Cavalier d'Arpino (*Madonna, Saint Francesco, and Saint Agostino*). For San Giovanni dei Fiorentini, he worked on Maratti's copy of the *Madonna and Saints.* The Albani family introduced him at the Savoy court. Poerson, director of the French Academy in Rome and president of the Academy of Saint Luke, tells of his restoration for the Odescalchi family, together with B. Luti. Finally, he worked also for the Corsini and the Soderini, being the most important restorer of his time in Rome.
13. "Signor Domenico Michelini raccomodatore di quadri, che abita in Campo Marzio, è nel suo mestiere bravissimo ma non sa dipingere, ma per ritirarli e ripulirli non ha l'eguale et anche è buonissimo huomo, et à un figliolo che si porta assai bene nel medesimo mestiere. Et io cavaliere Ghezzi ne ho lassata la memoria il 16 luglio 1744" (Domenico Michelini, paintings restorer, who lives in Campo Marzio, is excellent in his work but he cannot paint; but for the restretching and cleaning of a painting he has no equal. He is also a good man, and he has a son who is also very good in the same line of work. And I, Ghezzi, have left this testimony, July 16, 1744" (Ghezzi 1744, cited in Marinetti 2007, 34–35).
14. Edwards, in his set of guidelines, insists on this point in order to define a profession that was quite distinct, and in the process of evolving, emphasizing the mechanical and structural operations. He criticized those who believed that it was sufficient to know how to paint to become a restorer. Where the retouching involved more than simple losses and larger areas of painting were required, he looked for painters whose style was as near as possible to that of the original painting (Tiozzo 2000).
15. We know that important painters also worked as restorers, and we know the effectiveness of their structural interventions. For example, Ciro Ferri, a well-known painter who also worked in the art market and as a restorer, did both structural repairs (patches) and retouching (Marinetti 2007, 29–46, 179). Moreover, Bellori recounts a restoration by the young Maratti, in 1672, on Annibale Carracci's *Nativity* (originally in Loreto, now in the Louvre) (Ciatti 2009, 99; Conti 2003, 107). It should be noted that these were well-known painters, so this work was not simply a fallback for unknown artists in financial difficulties but reflects a desire to establish an autonomous profession, with its own specific subject matter, independent of the field of painting.

35

The Impact of a Major Flood on Relined and Transferred Paintings from the Musée Girodet in Montargis, France, and the Conservation That Followed

Dominique Martos-Levif, Scientist and Painting Conservator, in charge of the restoration paintings studios, Centre de Recherche et de Restauration des Musées de France, Paris, France
Ludovic Roudet, Private Conservator, Paris, France
Matthieu Gilles, Head of Painting Section, Centre de Recherche et de Restauration des Musées de France, Paris, France

In 2016, after the flooding of the temporary storage area of the Musée Girodet of Montargis, sixty-nine paintings were brought to the Centre de Recherche et de Restauration des Musées de France for restoration. The works showed various structural and aesthetic alterations due to their prolonged immersion. The aims of the interventions were to reestablish the cohesion of the multilayer system to ensure its conservation over time and to improve the presentation of the paintings. The restoration campaign of this corpus allowed the authors to study the behavior of works according to their age, including old alterations and earlier restorations, and notably the presence of old backing supports. Different types of structural restoration treatment (modern or traditional practices) were then chosen depending on the sensitivity and state of conservation of each painting. The methodological approach of the interventions is discussed through a case study of a work presenting a particular restoration problem, The Sacrifice of Abraham, *by a follower of Maertens De Vos.*

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INTRODUCTION

On May 31, 2016, the failure of a dam on the Loing canal, a tributary of the river Seine, completely flooded the temporary storage area of the Musée Girodet in Montargis, France.[1] As a result, 182 paintings, 450 sculptures, and 1,230 drawings were immersed in water for three days. After emergency conservation measures on-site, fifty-one paintings on canvas of importance or presenting complex conservation problems (or both) were brought to the Centre de Recherche et de Restauration des Musées de France (C2RMF) for conservation.[2] Among the fifty-one paintings, all painted oils (except one painted with gouache), four dated from the sixteenth century, eighteen from the seventeenth century, eight from the eighteenth century, and twenty-one from the nineteenth century.

Numerous alterations due to prolonged water immersion could be seen on the canvas supports and on the paint layers. The aim of the conservation interventions was to stop the degradation process of these paintings, to ensure their conservation over time, and to improve their visual presentation. Various structural operations were carried out, in particular relining with traditional, synthetic, or mixed techniques, while taking care to adapt the treatments to the specific problems of each artwork. Several teams of private conservators were selected by the collection managers of the Musée Girodet to work in the C2RMF workshops for two years. They were thus able to benefit from studio space, specific equipment, logistical means, and the assistance of the center's professionals, both curators and scientists.

This paper first presents a synthesis of the multidisciplinary study carried out on this corpus of immersed works based on archival study of the material history of the artworks, detailed condition reports, scientific imaging, and analysis. We will then review the different types of structural treatments carried out by conservators during this campaign, in particular relining with different adhesives and techniques. Finally, we will present one case study, the conservation of *The Sacrifice of Abraham* by a follower of Maertens De Vos.

BEHAVIOR OF A CORPUS OF ARTWORKS IMMERSED FOR SEVENTY-TWO HOURS

The behavior of paintings during and after immersion is linked to the physical and chemical properties of their constitutive materials and the painting technique, as well as the past intervention history of the artworks and their prior state of conservation. A canvas naturally oxidizes and becomes brittle over time, and storage conditions also affect aging, especially when artworks are stored under poor conditions. Examination of the fifty-one paintings showed that forty had already undergone conservation treatments prior to the flood, including major structural intervention on thirty-one of them, sometimes at the C2RMF. Two had been transferred; twenty-five had been lined with glue paste, one with wax resin, and two with synthetic adhesives; and one had been mounted on cardboard. In addition, many of the paintings that had not been entirely relined had reinforcing patches added to their back, and one of them had been strip-lined. Most of the paintings from the sixteenth and seventeenth centuries had been either transferred or lined using the traditional method with glue paste, while some from the eighteenth century had been lined with polyvinyl acetate (PVA) materials. Artworks from the nineteenth century had undergone fewer structural conservation interventions but were more often treated with a large number of patches on the back of the paintings. Table 35.1 summarizes the past structural interventions of the paintings.

Canvas is a hygroscopic material that swells in the presence of water and shrinks upon drying if it is not properly stretched on a frame (A. Roche 2003). Consequently, paintings that had too weak a frame or were not sufficiently stretched suffered particularly during the flood. In addition, twenty-eight out of thirty-one past linings peeled off partially or completely; only three linings of small-format paintings retained their mechanical properties. To limit the shrinkage of the canvases at the time of the rescue, conservators removed eighteen paintings from their stretchers and placed them on wooden boards. They also stapled a certain number of canvases to their stretchers. Nevertheless, many canvases were distorted during drying and some shrank at their edges or at tears. Indeed, tears were observed on thirty-five of the fifty-one paintings. Twenty paintings had old tears that had been treated in the past, and fifteen had new, more complex tears corresponding to traumas suffered during the flooding (fig. 35.1).

Figure 35.1 Anne-Louis Girodet-Trioson (French, 1767–1824), *The Death of Camille*, 1785. Oil on canvas, 113 × 146 cm (44 1/2 × 57 1/2 in.). Inv. 874.10. Conserved by D. Cherron and A. C. Hauduroy for structural treatments, and by C. Pasquali, A. Aurand, J. B. Bodiguel, N. Rinaldi, and D. Sorrentini for paint-layer interventions. Image: C2RMF, J. Requilé

The swelling and subsequent shrinking of the canvas during first immersion and then drying caused not only deformations to the canvas itself but also loss of adhesion, and sometimes powdering, of the preparation layer. The

Table 35.1

Number of paintings with previous structural interventions by century and treatment type

	16th century	17th century	18th century	19th century	Total
Transfer	1	1			**2**
Lining, glue paste	3	14	4	4	**25**
Lining, wax resin				1	**1**
Lining, synthetic adhesive			1	1	**2**
Marouflage on cardboard			1		**1**
Strip-lining		1			**1**
Reinforcing patch		1[a]	2	6[a]	**7**
Total structural interventions	**4**	**16**	**8**	**11**	**39**
Total paintings	**4**	**18**	**8**	**21**	**51**

a. One 17th-century and one 19th-century painting had both lining and reinforcing patches.

Table: Dominique Martos-Levif

canvas and the paint layers form a heterogeneous multilayer system. When the canvas swells, the paint layers separate from the support because their elasticity is limited. In addition, the physicochemical properties of some preparation layers can exacerbate the split between the support and the paint layers. Clay preparation layers may contain swelling clays and are often more sensitive to water than preparation layers made of calcium carbonate. Furthermore, lean preparation layers made with animal glue are more reactive than oil preparation layers. Most of the sixteenth- to eighteenth-century artworks' preparation layers contain clay (generally red, brown, or green in color; fig. 35.2). According to records, at least thirty-four out of the fifty-one paintings have shown adhesion problems between the paint layers and the support in the past, and thirty-one of these had already been reaffixed. On the paintings that had a clay ground layer, numerous consolidations were made during lining interventions, whereas the reaffixing was more localized on paints with calcium carbonate preparations (white in color in fig. 35.2).[3]

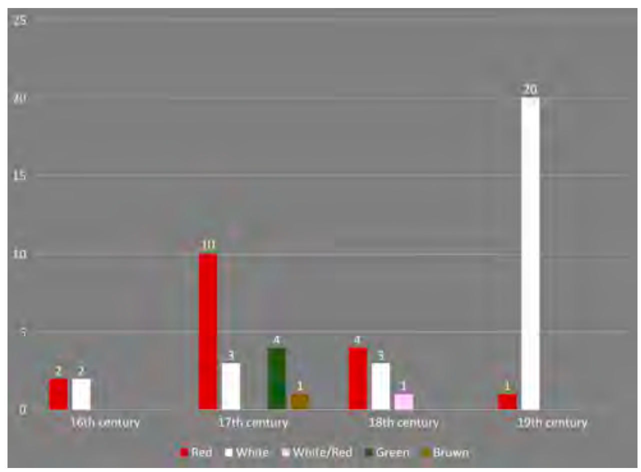

Figure 35.2 Number of paintings by color of preparation layer and century. Image: Dominique Martos-Levif

During drying, the shrinking of the canvas led to the failure of adhesion between paint layers and canvas and caused tenting: roof-shape lifting and loss of the paint layer. During the rescue, temporary protection papers (facing) were adhered to the paint layer of thirty-one paintings to limit the loss of paint. As an example, Francisco de Zurbarán's painting *Saint Jerome in the Desert* (fig. 35.3) suffered greatly during the flood.[4] This artwork, painted on a dark clay preparation, was lined at the end of the nineteenth century or at the beginning of the twentieth. In 1981, the paint layer was reaffixed. During its immersion in water, the materials used for reaffixing and for the lining lost their mechanical properties, and the canvas lining spontaneously peeled off. In this case, the clay nature of the ground layer did affect the level of degradation caused by immersion in water, especially loss of cohesion of the paint layer.

Figure 35.3 Francisco de Zurbarán (Spanish, 1598–1664), *Saint Jerome in the Desert*, 17th century. Oil on canvas, 174.5 × 123.2 cm (68 3/4 × 48 1/2 in.). Inv. 874.19. Raking-light photograph taken after local consolidation with sturgeon glue and removal of the temporary paper facing placed during the emergency operations. Note the flaking of paint from the tented areas. Image: C2RMF, P. Salinson

STRUCTURAL INTERVENTIONS

According to Cesare Brandi, matter is structure and aspect, and the aim of conservation is to stop the process of degradation of the artwork and to restore its structural unity to improve the perception of image and color (Brandi 2001, 34). Additionally, conservation treatments and products must be compatible with the original materials, stable, and as reversible as possible.

In 1974, the Greenwich Conference on Comparative Lining Techniques highlighted the risks incurred by paint layers when moisture, pressure, and heat are applied, particularly with regard to traditional glue-paste and wax-resin techniques (A. Roche 2003). Indeed, these treatments can crush the paint layers, especially the impasto, and can also induce blanching. More recently, new methods of lining with synthetic adhesives have been developed, while traditional methods have evolved to improve the control of the different parameters of the procedure.

The goal of the 2016–2017 interventions was to correct the deformations of the canvas, to reduce the lifting of paint layers, and to restore the cohesion of the multilayer system. Conservation protocols for all the paintings were established by taking into consideration the characteristics of each painting: the physicochemical properties of the original materials, the nature of the alterations, and past conservation treatments. Due to the fragility of the paintings, the conservators intervened very gradually. They alternated operations from the front, such as cleaning, and from the back of the artwork: reduction of deformations, consolidation, and relining, taking care to protect the paint layer with facings when it was necessary.

For all the paintings, the first intervention essentially consisted of locally consolidating the paint layer with sturgeon glue before removing the facings with Bollore paper and hide glue applied during the rescue. Securing the paint layer with new facings made it possible to remove the mud residue, the adhesive, the patches, and the deficient old linings. After the long work of reducing the fabric canvas deformations with controlled humidity and pressure, and stretching the paintings on temporary metallic stretchers or with paper strips on panel as necessary, the localized moisture input and the application of weights made it possible to relax the canvas and bring the edges of the tears closer together before consolidating them by linking them thread to thread.

Moisture was also essential to relax the canvas and to allow the paint layer to regain its place in the areas of roof-shape lifting. The conservators then applied facings, often in several layers, to restore the flatness of the paint layer. The supply of moisture and the level of pressure was controlled by using a variety of papers or gauzes with different properties of stretching upon wetting and of tension and shrinkage upon drying, as well as synthetic or natural adhesives at different concentrations (Delsaut and Durand 1989). Facings adhered to the paint layer with glue paste along with moderate heat and moisture were the most successful in flattening the roof-shape lifting back to the surface plane. However, this treatment was not systematic. Throughout the interventions, conservators also used a low-pressure vacuum table, in particular to restore the flatness of the paint layer and to simultaneously consolidate it.

Table 35.2
Number of paintings consolidated from the back by type of adhesive used and type of preparation layer

Preparation layer	Adhesive				
	Hide glue	**Sturgeon glue**	**Aquazol**	**Plexisol P550**	**Paraloid B72**
Red, brown, green	10	4	1	4	
White, white-red	5	3	1	10	3
Total paintings	**15**	**7**	**2**	**14**	**3**

Table: Dominique Martos-Levif

Another type of intervention was carried out to restore the cohesion of the different layers and the adhesion between the paint layers and the support. Most of the paintings were impregnated from the reverse of the canvas with different adhesives: Aquazol, hide glue, sturgeon glue, and acrylic resins: Beva 371, Plexisol P550, and Paraloid B72. A total of forty-one paintings were thus consolidated (table 35.2). Most of the paintings with a red clay–based preparation layer were consolidated with protein adhesives (animal glues) used in colloidal solutions. Because the clay-based preparations have a significant absorption capacity, this consolidation restores the cohesion within the preparation layer and the adhesion between the different layers. In contrast, white preparations form a more cohesive and rigid layer, so the addition of an aqueous adhesive is likely to accentuate the stresses between the preparation layer and the canvas—which, on more recent paintings, is often more reactive to water. For that reason, synthetic adhesives were used on most artworks with a white preparation layer.

To increase the mechanical properties of the original fabric and to stabilize it, thirty-six of the fifty-one paintings were relined. Of the thirty-one paintings that had been lined in the past, all but three had to be relined following the disaster. As mentioned, those paintings whose lining was kept are small format. One was previously lined with glue paste and the other two with vinyl glue, according to previous treatment documentation.

When the paint layers showed significant roof-shaped lifting, the traditional relining allowed restoration of the cohesion and the stability of the multilayer system due to the controlled provision of humidity and heat. The operation starts first with the protection of the paint surface with one or more layers of paper adhered with glue paste; then a gauze and a new transfer canvas are applied to the back of the original canvas with glue paste. After drying, the paint layer is returned to the surface plane using controlled ironing (heat and pressure).

Mixed treatments consist of applying a gauze with glue paste to the back of the original canvas, sometimes followed by other interlayers such as nonwoven polyester. The canvas is then lined with a synthetic adhesive: Beva 371 or Plextol B500. These treatments make it possible to obtain a good flattening of the paint layer while minimizing the quantity of moisture added during the relining. (The case study presented below explains in detail this new mixed treatment, which interweaves tradition and modernity.) Finally, moisture-sensitive paints and less-damaged nineteenth-century paintings were relined only with synthetic adhesives.

While in the past the majority of paintings were lined with glue paste (twenty-five out of thirty-one), the relining methods were diversified in the 2016–17 restorations. Out of thirty-six relined paintings, only sixteen were treated with traditional lining adhesives (glue paste), six with mixed adhesives, and fourteen with synthetic adhesives. Table 35.3 summarizes the types of structural interventions carried out in 2016–17 and compares them to past interventions.

CASE STUDY: *THE SACRIFICE OF ABRAHAM*

The Sacrifice of Abraham, attributed to a follower of Maertens de Vos (sixteenth century), was originally an oil painting on panel; it entered the collections of the Musée Girodet between 1853 and 1857. The museum’s archives indicate that, due to extensive flaking, it was transferred from panel onto canvas in 1960.

As a reminder, a transfer is the replacement of the original support of a painting by a new support. Transfer is no longer practiced today; our view on the artworks has changed, and we have set ourselves certain limits for ethical and philosophical reasons. But in the eighteenth century and for some time after, transfer was thought to

Table 35.3
Number of paintings that received the different types of structural interventions carried out in the past and in 2016–17 by painting production date

	16th century		**17th century**		**18th century**		**19th century**		**Total**	
	Number of interventions and when									
	Past	**2016–17**	**Past**	**2016–17**	**Past**	**2016–17**	**Past**	**2016–17**	**Past**	**2016–17**
Major structural intervention: transfer and lining										
Transfer	1		1						**2**	
Lining, glue paste	3		14	10	4	5	4	1	**25**	**16**
Lining, wax resin							1		**1**	
Lining, mixed				5				1		**6**
Lining, synthetic adhesive		4		2	1	1	1	7	**2**	**14**
Marouflage on cardboard					1				**1**	
Total major structural interventions	**4**	**4**	**15**	**17**	**6**	**6**	**6**	**9**	**31**	**36**
Minor or no structural intervention[a]										
Strip-lining			1	1[b]		1[b]		8[b]	**1**	**10**[b]
Reinforcing patches			1[c]	1[b]	2	1[b]	6[c]	5[b]	**7**	**7**[b]
Double canvas loose-lining				1[b]						**1**[b]
Past lining kept						1[d]		2[d]		**3**[d]
No structural intervention[a]			2			1	10	4	**12**	**5**
Total minor or no structural interventions			**3**	**1**	**2**	**2**	**15**	**12**	**20**	**15**
Total paintings	**4**		**18**		**8**		**21**		**51**	

a. For the purpose of this table, paintings consolidated from the back only are included in the "No structural intervention" category.

b. Some paintings simultaneously had strip-lining, reinforcing patches, and double canvas applied.

c. One 17th-century and one 19th-century painting had both lining and patches. These paintings are not included in the totals for "Minor or no structural intervention."

d. Paintings whose past lining were kept during the 2016–17 campaign and had no new structural intervention are included in the "No structural intervention" category in 2016–17.

Table: Dominique Martos-Levif

"bring back life" to paintings in poor condition, "saving" them from the ravages of time by giving them "eternal life" (Lépicié 1752, 43–44). Indeed, some restorers would be awarded the task of transferring the king's royal paintings to other supports (Emile-Mâle 1982, 225). There is a whole corpus of paintings previously transferred, on a part of which it may be necessary to intervene.

In May 2016, *The Sacrifice of Abraham* remained submerged for seventy-two hours, due to the disaster that occurred in the Musée Girodet storerooms after the flooding of the Loing river in the city of Montargis. The deep immersion of the painting caused a significant alteration of the support of the artwork: very pronounced roof-shape lifting of the paint layer (fig. 35.4), separation of the canvas, and—as we discovered later—powdering of the ground layer. The transfer as a whole was weakened, and thus a complete dismounting was necessary.

What was visually disturbing was that the painting appeared to still be on the wooden panel: the cracks, mainly horizontal, followed the grain of the former support and the joints between the former boards were visible, so that anyone facing the painting would have thought that it was still on a wooden panel.

The first step was some local consolidations with sturgeon glue, using the temporary protection papers glued during the emergency operations carried out in 2016 at the museum. These papers were delicately removed, as well as the crushed flakes that had been spread upside down all over the painting and which could not be put back in place.

Figure 35.4 Follower of Maertens De Vos (Flemish, 1532–1603), *The Sacrifice of Abraham*, 16th century. Oil on canvas (originally oil on panel), 82 × 113 cm (32 1/3 × 44 1/2 in.). Inv. 874.40. Detail, after disaster. The raking light highlights the numerous tented areas across the entire painting. Image: Ludovic Roudet

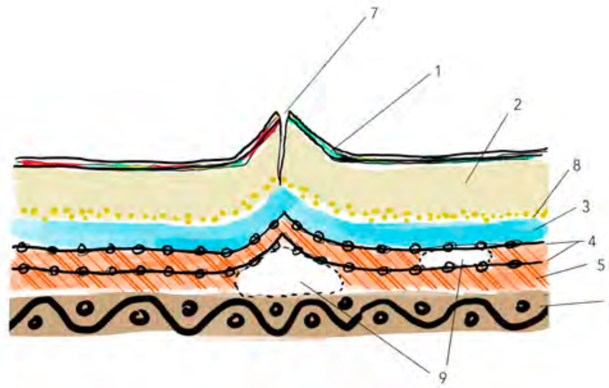

Figure 35.5 Stratigraphy of the transferred painting: (1) paint layer, (2) chalk ground layer, (3) polyvinyl acetate, (4) cotton gauzes, (5) glue paste, and (6) transfer canvas. Also shown is the damage the painting suffered from the disaster: (7) tenting, (8) surface powdering of the ground layer, and (9) air pockets. Image: Ludovic Roudet

A first layer of fine paper was applied to the paint layer with glue paste; after drying, this facing allowed the stretcher to be removed without risk. Then we used glue paste to add several other protective layers of facing paper and a cotton gauze onto the painting. As a reminder, glue paste is basically a baked glue made of wheat flour and rabbit-skin glue. This strong, reliable protection perfectly matched the damaged surface condition of the paint layer: dismounting a transfer is always a very delicate operation—one that requires a perfect facing, because once the transfer support is removed, the facing is the only way to secure the painting.

The painting was stretched on a working stretcher, and the transfer canvas was gradually dismounted by peeling, using controlled moisture, to loosen all stresses. The removal of the transfer canvas revealed two layers of cotton gauze. As we had suspected, it was indeed a transfer using the traditional “French-style” technique with glue paste.

The only difference from the traditional technique was that the cotton gauze directly in contact with the original ground was glued with PVA, instead of glue paste. The previous conservator must have thought that this would improve the bonding. The moisture used for the dismounting made the PVA layer swell, and it peeled off without much difficulty (fig. 35.5).

The dismounting revealed the thick, original chalk ground, which still showed signs of the veins of its former wooden support. The original ground layer was almost wholly preserved, a rare occurrence in the case of a transferred painting. However, its surface was very powdery: the slightest contact with the surface left a white residue on the fingers. If this powdering had obviously facilitated dismounting, as it stood, no further treatment was possible without consolidation of the ground layer—a difficult decision to make, since it would slightly change the nature of the original ground.

After a long discussion, we collectively chose to impregnate it with Plexisol P550 to enable the intervention to continue. We used the Plexisol at low concentration (5%), with volatile solvents, in order not to cause too much penetration of the consolidant into the ground, which would have been likely to optically modify the painting.

A thin cotton gauze was then glued with glue paste to the reverse side of the painting. It perfectly matched its imperfections. This new temporary support made it possible to replace the actual facing—which had been used to dismount the transfer—with a new one that was more flexible, made of two layers of paper. By releasing the painting from some of these constraints, we were able to start flattening the distortions. The deformations were reduced by using the intrinsic properties of the paper and the tensile strength of the glue paste, with the help of a low-pressure table. Gradually, through controlled moistening and drying, most of the deformations were reduced.

The facing was removed next to allow us to examine the condition of the surface of the painting. There were still some small roof-shape liftings, which were now noticeable due to the removal of the larger ones. These were reduced using local moistening and careful massage to transform small, narrow deformations into larger, more flexible ones. Then these larger deformations were flattened using a mini low-pressure table, as well as through the local use of paper and glue paste.

Once this surface condition was satisfactory, a new facing was applied with glue paste to the painting, in preparation for the adhesion to a new support. The gauze on the reverse was removed because the operations carried out so far on the deformations could have weakened its adhesion. It was replaced by two new thin cotton gauzes, adhered with glue paste.

There remained the issue of bonding the new transfer canvas itself. In the traditional French technique, the painting is adhered with glue paste to its new canvas, then ironed through the facing; this technique provides very good improvement of the surface condition and good flattening of the lifting paint. Nevertheless, it is a delicate procedure, one that requires a high degree of mastery. As the surface condition was now satisfactory, we considered that such an operation was not necessary.

From that point, we shifted to a synthetic type of bonding. We glued a nonwoven polyester fabric layer onto the cotton gauzes with diluted Plextol B500; this thin, fast-drying layer is meant to isolate the reverse from the greater amount of moisture used during the lining.

On another working strainer, we stretched a linen-polyester lining canvas, which combines the strength and tension of linen with inertia and the relative stability of polyester to moisture variations. It was adhered to the reverse of the painting using a mixture of equal parts Plextol B500 and Tylose MH-300 (methyl cellulose) at 6% (see fig. 35.6). After the lining, the protective facing layers were removed, and the painting was stretched on a new stretcher.

Figure 35.6 The stratigraphy of the transferred painting after treatment: (1) paint layer, (2) chalk ground layer, (3) consolidated part of the ground layer, (4) glue paste, (5) cotton gauzes, (6) nonwoven polyester layer, (7) Plextol B500, and (8) transfer canvas. Image: Ludovic Roudet

This restoration proved to be complex. We constantly had to balance the advantages and disadvantages of the several techniques available to us, and there was never a straightforward answer. The traditional French technique, using glue paste, did not ensure the consolidation of the ground layer nor a long-lasting bond, due to the ground's powdery surface. The traditional lining process would have involved sustained moistening of the stratigraphy, and this would have inevitably led to a reappearance of deformations, which ironing could not have effectively reduced, as the chalk priming reacts primarily to humidity and not to heat. The traditional technique would therefore have been a risk with no apparent benefit.

On the other hand, while synthetic materials offered the benefit of good consolidation and adhesion, they did not have the rigidity of glue paste, and they did not intrinsically contribute to the surface flattening. Moreover, they would have provided elasticity to a painting that did not have any elasticity and caused the appearance of new cracking on this painting, which is stiff by nature.

The painting is now consolidated and lined; the deformations and roof-shape lifting have been reduced and no longer impede its legibility. The structure keeps a certain stiffness, which respects the thick chalk ground layer (fig. 35.7). Moreover, the synthetic materials on the outer part of the painting somehow form a moisture barrier. It is therefore the deliberate combination of traditional and synthetic methods that made this balanced result possible.

Figure 35.7 *The Sacrifice of Abraham* after structural treatment. The painting is consolidated and lined, and the deformations and tenting have been reduced. Image: Ludovic Roudet

CONCLUSION

For almost three years, the collection managers of the Musée Girodet in Montargis and the painting department of the C2RMF monitored the conservation work carried out on the paintings damaged by the 2016 flood. The treatment choices were made collectively by the museum collection managers, the C2RMF staff, and the conservators during weekly visits organized in the studios, taking into consideration technical, scientific, and aesthetic issues.

The work carried out by the six teams of conservators enabled the fifty-one paintings hosted at the C2RMF to regain their physical integrity and their visual appearance so that they may be returned to the exhibition galleries of the Musée Girodet. The paintings conservators specializing in the canvas support worked in collaboration with the paintings conservators specializing in the paint layers, who were responsible for carrying out all cleaning and reintegration operations of the paint layers. It was important to work with several teams of conservators, each of which had distinct skills and practices. They were able to assess different and complex problems together.

During this campaign, knowledge of the painting techniques, material history, behavior and treatment of the immersed works has greatly improved. Out of a corpus of fifty-one paintings submerged for seventy-two hours, thirty-one of which had already undergone major structural interventions in the past, thirty-six were relined using traditional, synthetic, or mixed methods. The interventions carried out show that traditional and modern methods of relining are not opposed but complement each other.

It is also crucial that the knowledge of both traditional and modern methods be passed on so that the full range of treatments remain available to conservators in the future. The guiding principle was to find the best treatment for each painting in this very particular context, while considering the number of paintings that needed to treated at the same time.

NOTES

1. The town of Montargis is 100 kilometers south of Paris. In France, Montargis is known as the birthplace of the painter Anne-Louis Girodet-Trioson (1767–1824).
2. C2RMF is a French public institution whose mission is to implement, in conjunction with the curators in charge of collections, the policies of the Ministry of Culture in the areas of research, preventive conservation, and conservation of artworks from public French museums.
3. Statistics from artwork files compiled by S. Lemeux-Fraitot from conservation reports in the C2RMF and Musée Girodet archives.
4. This painting was conserved by L. Roudet and E. Joyerot for the structural interventions, and S. Deyrolle, B. Bedel de Buzareingues, and D. Dollé for the paint layers.

36

Remedial Conservation of Canvas Paintings: Issues and Challenges Due to Previous Treatments

Anil Dwivedi, Project Associate, Conservation, Indira Gandhi National Centre for the Arts, New Delhi
Achal Pandya, Head of Conservation, Indira Gandhi National Centre for the Arts, New Delhi

Remedial conservation aims to arrest the ongoing deterioration process of an art object, but it can create serious problems if it is not executed properly. This was noticed during a conservation project undertaken at a government museum in India's state of Rajasthan. This paper endeavors to discuss the issue and describe the challenges faced during the conservation work on the paintings.

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INTRODUCTION

In November 2017, the Government Museum of Rajasthan approached Indira Gandhi National Centre for the Arts (IGNCA) regarding the documentation and conservation of its collection in the Government Museum Alwar. This museum was established in 1940 in the city palace of Alwar and is spread over three halls. However, the collection is displayed in four galleries. The first gallery contains sculptures and inscriptions; the second gallery contains musical instruments, a natural history collection, and decorative items. The third gallery houses the unique collection of canvas paintings and manuscripts, and the fourth gallery is dedicated to arms and armor.

Alwar (a former principality) is a prominent city in the state of Rajasthan and is popularly known as the gateway to Rajasthan. The city is situated 160 kilometers southeast of New Delhi, the capital of India, and is part of the National Capital Region. In ancient times, this area was known as Matsya Mahajanpad; it is mentioned in the Buddhist text *Anguttar Nikaya* as being among sixteen *Mahajanpadas*. Bairath (present-day Viratnagar) was the capital of Matsya Desh (fig. 36.1).

The Alwar Museum is known for its unique, varied collection; it houses around fourteen thousand objects, including textiles, miniatures, rare books, canvas paintings, wooden objects, furniture, a natural history collection, metalwork, arms and armor, decorative art, and terracotta and stone objects. The collection also has twenty-six canvas paintings; twenty-four were on display at the time of our work, while two were kept in storage.

These paintings are excellent works made locally by artisans under the patronage of the Alwar maharajas. The founder of the kingdom didn't have time to concentrate on arts and crafts, but his successors gave patronage to

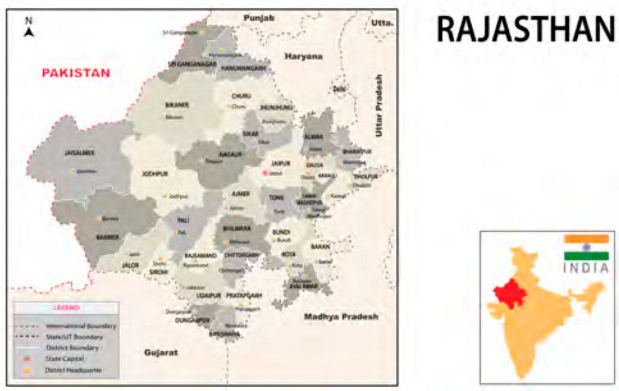

Figure 36.1 Map of Rajasthan showing Alwar. Image: Shutterstock

Dalchand, Baldev, and Saligram. Although Dalchand and Saligram came from Jaipur, they started the Alwar school of paintings in the eighteenth century. This school was developed from the Jaipur school of paintings and had a Mughal influence. Dalchand had worked in the Rajput style, and Baldev was expert in the Mughal school, so the amalgamation of these two styles gradually came to be known as the Alwar school of paintings.

Maharaja Viney Singh was the greatest art enthusiast in the Alwar royal family tree and was himself a painter, calligrapher, and binder. During his time, Aga Mirza Khan was also a great calligrapher. Similarly, Natha Khan Darvesh and Abdul Rehman were expert in making figures and designs at the borders of paintings. The paintings displayed at the Alwar Museum were made during the reign of Maharaja Singh (1815–57) and have great historical significance (fig. 36.2).

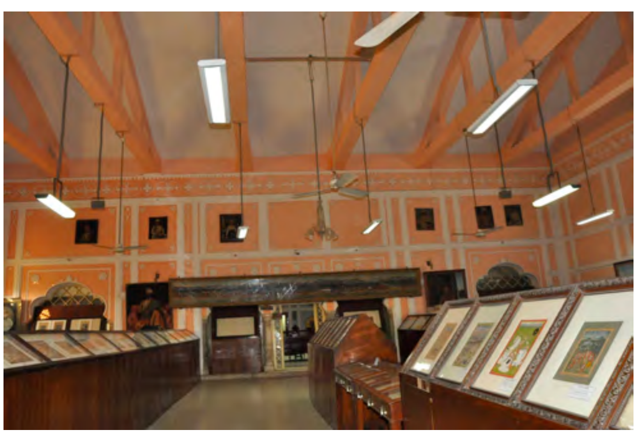

Figure 36.2 Paintings on display in the Government Museum, Alwar, prior to conservation. Image: IGNCA, New Delhi / Jitender Kumar Chauhan

The museum is located in what was once the Maharaja's palace, which was converted for the task. Three large halls on the upper floor are dedicated to the display of objects. The canvas paintings that are the subject of this paper are displayed in gallery 3. The building has had various problems that arose since it was repurposed into a museum. Weather extremes and the overall condition of the building did not provide a suitable environment for the collection. For example, broken glass in a large window let biological agents into the galleries, and the activity of those agents caused problems that were noticed on the paintings during the documentation. Gaps between the walls and paintings had provided habitat for bats and other pests, and as a result the paintings had suffered paint losses and the disintegration of canvas due to bat excreta and other biological activity. The museum also had problems with leaks, leading to dampness on walls. This resulted in fungal infestations on the paintings.

Overall, paintings were exposed to many agents of deterioration: climatic conditions, negligence, and poor storage, as well as previous interventions. It was determined that all the paintings had been treated in the past. Also, the materials and methodology used in the treatment showed that all the paintings had been conserved by a single person and within the same timeframe. However, no conservation records could be found from the host institution.

The following problems were noticed on the paintings:

- Bulging. The painting was lined without flattening. The unflattened area resulted in bulges, and this transferred to the paint layer.
- Impression on image layer. Patches, used for mending, are visible on the paint layer.
- Dark, yellowed varnish
- Cutting of fold over edge
- Overpaint or filling of losses spread over the image layer
- Pasting of original canvas onto the strainer/stretcher
- Presence of nails, thread, and other foreign material between the lining and original canvas
- Problems due to improper storage, including tears and paint losses

CONSERVATION PLAN

It is impossible to undertake a satisfactory and ethical treatment without a good conservation plan. Conservation planning requires a thorough understanding of material and technique, and of the causes of deterioration in order to ethically conserve the artworks. Our conservation plan included the following phases:

- **Documentation.** This is the method of understanding the cause of problems and determining the materials and techniques used in an artwork.
- **Deterioration.** It is necessary to determine the nature of any deterioration, its cause, and the extent of damage for remedial conservation.
- **Treatment/remedial conservation.** This is where satisfactory treatment is determined and applied based on the information derived from previous phases. In this phase, it is vital to keep in mind the principles of minimal intervention, compatibility, and reversibility.

Museum administration asked us to undertake the work only in the museum. We were assigned space in gallery 3, which was converted into a temporary in situ studio (fig. 36.3). This was an open studio where visitors were allowed to interact and ask questions about the ongoing activities. The museum collection is public property; therefore, it is the public's right to know what is happening to these collections. Keeping this in mind, we entertained any interested visitors.

Figure 36.3 The temporary lab where the conservation work took place. Image: IGNCA, New Delhi / Anil Dwivedi

In formulating our conservation plan, we carried out a thorough initial study to understand the reasons behind the problems and study the techniques and art historical aspects of the paintings. Examinations done with visible, raking, transmitted, and UV light sources were used to retrieve information from the objects. Overpainted areas (hidden beneath the surface) were revealed using UV light.

After the documentation phase, we could definitively state that all the paintings had been treated in the past. In principle, whatever material is being used for a given conservation treatment should be reversible and compatible with the artworks. This approach was not applied in previous treatments, which meant that these treatments become one of the causes of deterioration. Past treatments included cleaning, patch mending, lining, filling, inpainting, and varnishing.

After finishing our detailed study, we decided on the following steps for treating the paintings:

1. Removal of varnish
2. Removal of previous lining
3. Removal of extra adhesive from the back of the painting
4. Flattening to remove the bulges
5. Removal of patches. realignment of tears, and mending
6. Strip-lining or lining as needed on a case-by-case basis
7. Loose-lining
8. Filling and inpainting
9. Varnishing

PROBLEMS DUE TO PAST TREATMENTS AND THEIR SUBSEQUENT REMEDIES

Patch Mending

Patches were found in abundance on almost all the paintings. Three phases of patch mending were found: one on the original support, one on the lining canvas, and sometimes a third patch on the patch applied to the lining canvas. The material of the patch was cotton, but in some cases electrical tape or paper was also used for mending purposes (fig. 36.4), and these were applied without removing older patches. The mending itself caused problems in some paintings. The dimension of each patch was larger than the tear it addressed, and the density of cloth greater than that of the original canvas, causing these patches to be clearly visible on the image layer and leading to problems in the paint layer (fig. 36.5).

Figure 36.4 Verso showing a history of patches. Material used was typically cotton, but in some cases paper or electrical tape was employed. Image: IGNCA, New Delhi / Jitender Kumar Chauhan

Figure 36.5 Impression of patch on paint shown in raking light. Image: IGNCA, New Delhi / Achal Pandya

Our approach involved first carefully removing all the patches and cleaning off the adhesive properly, using acetone. This was easy, as the used adhesive had become brittle and lost adhesion. Then a thin film of Beva 371 was laid onto fine muslin cloth; after drying, this film was used for mending. Tears were aligned properly, and the film was applied with the help of heat and pressure. The thickness of the applied film was less than that of the original canvas, so this treatment should not create any problems in the future. If the mend shows some irregularity, it can easily be removed without damaging the original artwork.

Lining

All but three paintings were lined. Two kinds of glue (glue paste and wax resin) had been used as an adhesive for lining purposes. Necessary precautions had not been taken while lining the painting in the past, and, as a result, air was trapped between the original and lining canvases. This led to a separation of the lining canvas from the original and caused other structural problems, including local detachment, opening of the lining, and other surface problems.

Lining is a major intervention to an artwork. It may alter the appearance of the painting, for example, color change, flattening of impasto, and impregnation of the painting with the lining adhesive. These risks are the reasons that lining is considered a maximum intervention and should be practiced only as a last remedy.

The following problems were noticed in the previously lined paintings:

- Air pockets between original canvas and lining canvas
- Presence of foreign material between original canvas and lining canvas
- Lining executed without flattening of canvas

These issues led to delining, bulging, and loss of paint layer.

After removing the linings, we found that the original canvas was stable, although tears and holes were evident. Seeing the condition of the canvas, we decided not to line the majority of the paintings.

Because the paintings were at serious risk and all required structural treatment to stop the ongoing deterioration process, we began by removing them from their stretchers/strainers and then removing the lining canvas. At that point, we found that most of the original canvases were in sound condition, except for three in which the canvas had deteriorated and was no longer able to support the weight of the image layer.

The principle of minimal intervention was followed for the paintings in which the canvas was found in good condition. Most of these paintings did not have the fold-over edge; it is possible those edges had been removed to trim the paintings. Strip-lining was decided for these paintings where the canvas was in stable condition.

In some paintings, the original canvas was folded over the stretcher. We decided to reveal the folded canvas in these cases, increasing the size of the painting. However, the curator resisted this idea because it would create a discrepancy in museum documentation. We explained to the curator that for ethical reasons the original paint layer should be revealed. Finally, the new size was accepted by the museum, which justified its decision on the grounds that during the conservation treatment the original paint layer was revealed to have larger dimensions than those previously recorded.

As mentioned, three paintings needed to be lined, as the original canvases were not in good enough condition to hold the image layer. A lack of equipment made lining on-site difficult. Nonetheless, we lined the paintings on a makeshift suction table using vacuum pressure (fig. 36.6). The adhesive used for lining was Beva 371. Lining was carried out in a vacuum envelope, and the heat was applied using an iron.

Figure 36.6 Equipment setup for the lining of paintings using vacuum envelope. Image: IGNCA, New Delhi / Achal Pandya

CLEANING

Cleaning means removal of all the material that is adhered on the paint surface and whatever appears on the surface due to degradation. The details of the paintings had become obscured due to darkened varnish and dust and dirt accumulated on the surface. Changes to the color of the paintings also caused them to lose their three-dimensional effect. The paintings had dust and dirt, stains, paint splashes, and oxidized varnish on the surface. In addition, biological activity was noticed on the painting's surface as well as on the verso. Therefore, it was important to clean the surface both to reveal the image and to stop further decay of the artworks.

We considered a series of questions before starting the cleaning process. This exercise assures the integrity of the artwork and the ethical approach to cleaning the painting's surface.

- What is foreign material?
- Is it dirt?
- Is it damaging? If yes, what will be the extent of cleaning?
- Is cleaning necessary?
- Can the painting survive the cleaning process?
- What will be the effect of cleaning?
- What will be the object's appearance after cleaning?
- Will the stability of the object be affected?
- How can you clean the object?
- Is there a suitable treatment?
- How does the treatment work?
- Is the treatment safe for both the object and us?
- At what point should we stop?

After assessing these questions and their consequences, the cleaning was carried out. After discussion with the curator, it was decided to fully clean the paintings. The cleaning was done to address the dust and dirt and to remove yellowed/darkened varnish, overpaint, and other foreign material from the surface. Tests were carried out on small areas using solvents of increasing strength—starting with saliva and progressing through alcohol to ketones to a solution of aliphatic solvents and, finally, to a solution of aromatic solvents—to find a solvent that could remove the varnish and overpaint and other unwanted material from the surface without harming the original paint film. Once the solvent was determined, a cleaning safety margin test was carried out with the selected solvent to ensure it would not affect the stability of the colors present in the painting.

The aromatic solvents yielded fantastic results, but the same result was achieved with polar solvents by increasing the reaction time. Hence, the varnish removal was done using acetone and isopropyl alcohol (fig. 36.7).

Figure 36.7 Area showing varnish removel using acetone and isopropyl alcohol. Image: IGNCA, New Delhi / Jitender Kumar Chauhan

CONSOLIDATION

The term *consolidation* is used to describe the application of adhesion between loose layers of a painting that are separated from the ground. Generally, this is done to stabilize problems such as flaking, cupping, powdering, and blisters. Consolidation can be executed from the back (maximum intervention) or on the front, only to affected areas (local application). Preference was given to local consolidation in line with the principle of minimal intervention. Beva 371 was applied on affected areas using a small brush and later settled with a hot spatula (fig. 36.8).

Figure 36.8 Consolidation of paint using a hot spatula. Image: IGNCA, New Delhi / Achal Pandya

RESTRETCHING

After completion of the structural work, the paintings were restretched. A strip of Tyvek was added at the tacking margin to avoid direct contact between nails and the original support. Loose-lining (also with Tyvek) was provided to give extra strength to the original canvas. This was done from the back to protect the painting from moisture, dust, and dirt, and to prevent future biological activity behind the canvas. Except for the paintings that were restored to their earlier dimensions, the same stretchers/strainers were used for restretching the paintings after stabilization.

FILLING AND TEXTURING

It was necessary to reintegrate lacunae after restretching the paintings. It was important to fill the gaps to restore continuity and aesthetics in the image layer. Various methods are used for filling on canvas paintings. We used a traditional method of filling with a mixture of French chalk, kaolin, pigment, and PVA emulsion. This material was used to fill the lacunae using brush and spatula. Fills required texturing similar to the surrounding area. Inpainting without texturing does not match and looks out of place.

RETOUCHING

Retouching originally meant corrections or changes made by an artist as final adjustments to the artwork. Nowadays, retouching is sometimes considered to be synonymous with inpainting. To us, retouching means the last step of painting conservation—one that is required to please museum visitors and to accurately reflect the artist's original intentions. This is normally at least a two-step process. It is necessary to conserve the painting to stabilize it and stop the ongoing deterioration process, but a painting can survive without retouching for a longer time. However, ground color correction is required for aesthetic reasons to allow the painting to be appreciated.

The retouching was carried out using pigment and Paraloid B72 as a medium. Before any retouching was done, a layer of Paraloid B72 was applied to the fill areas to ensure the reversibility of the retouching.

CONCLUSION

After the remedial conservation, the paintings were well stabilized and could once again be appreciated by visitors. The colors that had been hidden by dark varnish are now visible. The ongoing structural problems of the paintings have been stabilized, and there are no longer unstable areas that will lead to further deterioration.

During this project, we also trained the museum staff, students, and conservation professionals of that region through workshops. The workshop titled Conservation and Documentation of Oil Paintings was conducted in collaboration with SRAL, in the Netherlands, under the leadership of Kate Seymour. The paintings conservation project was completed in eighteen months' time. In addition to the paintings, the museum got a new look through a complete renovation, and conservation of the entire collection was done as well, including documentation. The paintings we restored are now displayed in the same location and can be viewed in a far better state and appreciated anew (fig. 36.9).

Figure 36.9 Paintings displayed in the Government Museum, Alwar, after conservation. Image: IGNCA, New Delhi / Achal Pandya

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Low and Slow: The Role of Targeted Precision Heat Transfer and Innovative Flexible Mat Technology for New Methodologies in the Conservation of Paintings on Canvas

Nina Olsson, Paintings Conservator and Precision Mat Co-founder, Nina Olsson Art Conservation and Precision Mat, LLC, Portland, Oregon
Tomas Markevičius, Paintings Conservator, Doctoral Researcher, and Precision Mat Co-founder, University of Amsterdam and Precision Mat, LLC, Portland, Oregon

The paper discusses novel approaches and targeted structural treatments of paintings on canvas made possible by a precision temperature management methodology for mild heat transfer based on flexible mats. Flexible silicone mats and carbon nanotube–enabled IMAT prototypes and the associated mobile MAT and IMAT electronic temperature management consoles were designed specifically for the field to offer accuracy and mobility for new smart approaches to conserving paintings on canvas, setting new standards in precision, steadiness, uniformity, and control in mild heat transfer. The varied dimensions of mats and their thin, flexible profile, combined with accuracy in the low-energy range, allow conservators to formulate novel "low and slow" targeted treatments that exploit the effects of well-controlled, precision low-energy heat transfer over time on previously treated/lined paintings. Even more critically for unlined and extremely fragile modern or contemporary works, this methodology allows them to be treated without removing them from their stretchers or exposing them to unnecessary stress and the uncontrolled high-heat-transfer risks of the past.

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INTRODUCTION

Conservation treatment methodologies have historically exploited heat as an essential factor for the effective remediation of structural damage in paintings on canvas. However, past interventions were not without considerable risk, since heat was applied with rudimentary tools that provided quite limited control over the set temperature, steadiness of delivery, and uniformity of distribution over the treatment surface area, leading to highly undesirable results ranging from incomplete treatments to irreversible changes in surface morphology of the paint and ground layers.

During the 1974 Greenwich Conference on Comparative Lining Techniques, concerns over the effects of excessive heat during lining processes were raised, and this contributed to the overall conclusion that treatments should adhere to goals of minimal intervention and reversibility. The then-new "cold lining" methodologies were seen as an alternative to heat-driven methods with poorly managed or uncontrolled—and therefore damaging—temperature ranges, and the call for a moratorium on lining in 1975 was a result of the dissatisfaction with the status quo in treatment outcomes (Percival-Prescott 2003a). In response to those monitions, conservators have since sought to limit or eliminate the application of heat, humidity, and pressure (which they could not control well due to limited technical means) in order to minimize the harmful impact of structural treatments.

Precise and well-controlled heat, humidity, pressure, and associated time factors, however, do not have equally effective alternatives in structural treatments due to the inherent viscoelastic nature of painting materials: paint, ground, and canvas support. Without the option of exploiting the physical factors of heat, humidity, and pressure, treatment choices become extremely limited. Control over time, temperature, and humidity allows the manipulation of Young's modulus to temporarily plasticize the painting materials during the treatment and shift their physical properties toward the "safe zone" of viscoelastic dynamics, which is essential for both effective treatment and minimal risk.

This aspect has always been intuitively understood by practitioners, who continue to use hand irons and ad hoc heating setups such as hot-water bladders, heat guns, and similar tools designed for household use, despite their lack of precise, safe control of temperature and heat transfer. In fact, the real issue has not been the heat, moisture, or pressure but the extremely poor control over these physical factors, in particular fluctuating and excessively high temperatures, which exacerbate the effects of moisture and pressure, and which were the main source of stress on constituent painting materials in structural treatments in the past.

The 2019 Conserving Canvas symposium affirmed the field's paradigm shift away from lining to a broader consideration of multiple material and intangible authenticity aspects and targeted structural treatment of traditional and unlined modern and contemporary paintings, as well as the challenges of the expanding types of new media used in twentieth- and twenty-first-century paintings on canvas. Since Greenwich, the approach of minimal intervention has fully matured in the field as a principal guiding ethos, yet technological advancements in heat-transfer instrumentation and temperature-based methodology have lagged, leaving conservators without an essential temperature management technology to bridge theory and bench practice.

An innovative approach that aims to overcome this gap involves a new low-temperature-optimized treatment methodology that employs flexible low-energy silicone-clad heating mats and associated precision temperature-management technology. Research, experimentation, and treatments have been conducted by the authors using the low-energy heating mats since 2003, and the design features of the technology have evolved to permit conservators to precisely apply heat, in particular in a low temperature range—from ambient temperatures to those customarily used for adhesive activation (25°C–65°C)— for localized and targeted methodologies to allow for minimal treatments to address the expanding needs in the laboratory (Olsson and Markevičius 2017). In particular, gaining control over steady, accurate heat transfer in the low-energy and temperature range (21°C–40°C) over an extended time period is the essential novelty of the new "low and slow" approach, an option that was previously inaccessible due to technological limitations.

HEAT TRANSFER IN CONSERVATION OF PAINTINGS ON CANVAS: HISTORY, APPROACHES, AND LESSONS FROM THE PAST

The examination of paintings on canvas with prior lining treatments often involves identification of visual evidence of unwanted alterations that can be attributed to the effects of uncontrolled heat that exceeded the required or safe temperatures and were combined with equally uncontrolled and unsafe levels of humidity and wetting, all of which together caused irreversible changes in canvas and paint surface morphology.

The execution of traditional flour-paste or wax-resin linings requires elevated and sustained heat transfer. Historically, it was performed with thermally uncontrolled methods such as hot sand or water bags, flat irons, or self-heating box irons, which relied on the reliner to monitor and regulate the temperature by touch. The introduction of electric irons in the early twentieth century led to their adoption for relining treatments, and they continue to be among methods employed to the present day (Bomford 2003, 31). Most electric hand irons used by conservators today are not precision tools: they lack steadiness in heat transfer, as they are regulated by thermostatic on-off mechanisms that deliver only an average set temperature, which in actuality is a fluctuating series of over- and undershoots that trigger the on-off function. Variance as high as ±1°C has been observed on hand irons (fig. 37.1).

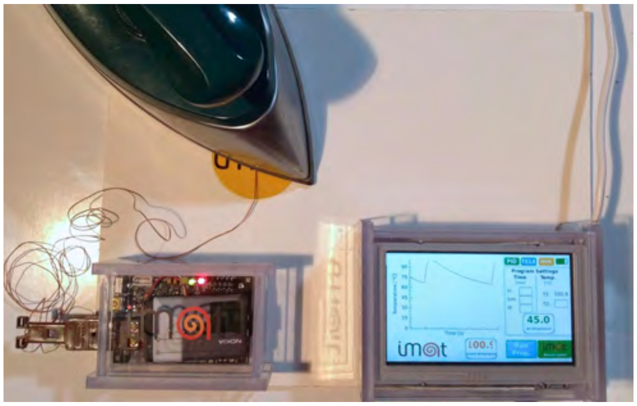

Figure 37.1 Heating pattern of widely used handheld irons, regulated by an on-off switch that delivers fluctuating heat in a 30°C range. Image: The IMAT Project, Università degli Studi, Firenze, EU FP&-ENV-NMP.2011.2.2-5

This lack of steadiness is even more problematic when the conservator attempts to heat a larger area with sweeping movement of the iron, which requires the set temperature to be considerably higher than the desired surface temperature. Furthermore, most hand irons are designed for household textiles and therefore have operational parameters between 120°C and 180°C, far above the safe, low-energy range needed for painting materials. Other temperature controls, such as rheostats, measure energy output and are not corrected by local temperature readings, so the actual surface temperature is unknown.

The primacy of lining as the most significant structural remediation method motivated conservators in the mid- to late twentieth century to develop custom-fabricated hot tables to address the difficulties of heating a larger surface area than possible with a hand iron. The earliest of these were guided by the desire to improve impregnation at 65°C or higher when performing the prevailing method of wax-resin lining (Ruhemann 1953, 73; Plenderleith 1956, 169; Bomford 2003; Rees Jones, Cummings, and Hedley 2003; Berger and Zeliger 2003, v–ix; Ackroyd 2002; Falvey 2008). Refinements were made to the design of multipurpose heating tables from the 1980s on, to be used in combination with thermoplastic synthetic adhesives for linings that are activated at 65°C. Nonetheless, many heating tables lack uniformity in heat transfer over the table surface area, which is easily identified by thermal imaging cameras, and users come to know the idiosyncratic hot and cold spots present on their device (Olsson and Markevičius 2010).

From the 1970s to the 1990s, various low-pressure envelope methods were combined with infrared lamps for heat transfer (Hedley, Hackney, and Cummings 2003)—or even heat guns—with the inevitable obstacles to accuracy and control, although these methods also aimed to achieve the customary 65°C heat activation temperatures for synthetic thermoplastic consolidating and lining adhesives. These large, costly devices do not resonate with the fundamental shift in conservation methodology to prioritize targeted, minimally invasive treatments, today performed by conservators rather than specialized reliners. The application of heat transfer expanded to localized remedial treatments, such as tear mending, consolidation, stabilization of cracked and lifted paint, and reduction of diverse deformations and planar distortions. In the absence of alternatives, these treatments are performed with spatulas and tacking and hand irons (Olsson and Markevičius 2010).

PAINTINGS ON CANVAS AS VISCOELASTIC SYSTEMS: THE ROLE OF TEMPERATURE

The risks and beneficial effects of heat transfer in conservation treatments must be assessed within a comprehensive understanding of the nature of paintings and painting as physical systems. This understanding is crucial to evaluating paintings' materials, condition, potential response to treatment, and long-term sustainability and stability of the intervention—and to formulating treatment protocols. In 1991, Mecklenburg published experimental data indicating that artists paints are viscoelastic systems (Mecklenburg and Tumosa 1991b). The viscoelastic behavior of paintings has been investigated in the context of their cleaning and mechanical properties (Hedley and Odlyha 1989; Michalski 1991; Hagan et al. 2007; Hagan 2017; Phenix 2011), and the effects of temperature and humidity have been investigated in the contexts of art transportation and preventive conservation. However, the effects of temperature and viscoelastic behavior have been investigated less in the context of structural treatments of paintings on canvas. These aspects were addressed by Berger and others (Russell and Berger 1982; Berger and Russell 1984, 1986, 1988; Goddard 1989; Olsson and Markevičius 2010, 2017; Markevičius et al. 2013, 2017).

Once fully dry, paint films behave as elastic, viscoelastic, or viscoplastic materials, depending on the chemical nature of their components. With aging variations in the pigments used, oil films acquire a greater degree of cross-linking and stiffness, with a corresponding rise in glass transition temperature (Tg) from ambient temperature (0°C–50°C) to as high as 75°C–100°C for paints containing lead white (Phenix 2011). Glass transition temperatures of acrylic, alkyd, and oil primers were found to be in the range of 21°C–44°C (Hagan et al. 2007).

In structural conservation treatments of paintings on canvas, the constituent viscoelastic materials, such as paint films, may suffer structural failure caused by the rapid application of force while in a stiff, glassy state. However, it is possible to shift from a strain causing failure to one avoiding failure by temporarily rendering the viscoelastic material more plastic (enabling it to adapt to the required rate of deformation) in various ways: by adding moisture or other agent that acts as a plasticizer or increasing the amount of energy in the system, that is, raising the temperature. The relationship of stress and strain (Young's modulus) is influenced by plasticizers, such as water (humidity treatments) and thermal energy (expressed in temperature). By tailoring the introduction of thermal energy to the required rate of deformation of the material during treatment, the stiffness of the system may be temporarily reduced, allowing planar distortions to be manipulated in the more malleable state. Optimal control of heat energy transfer is therefore paramount, as beneficial heat effects cannot be safely exploited without the precision instrumentation.

TARGETED PRECISION HEAT-TRANSFER TREATMENT METHODOLOGY USING NANOTUBE-ENABLED AND OTHER CONDUCTIVE FLEXIBLE MATS

Development and Functionality of a Flexible Mat System

As previously discussed, the heat-transfer instrumentation used historically and currently available lacks accuracy in the low-temperature range, as well as steadiness and uniformity, and this deficit limits options and treatment approaches. The surface areas of heat-transfer instruments are limited to the small size of spatula heads, tacking irons, hand irons, and extra-large heating tables, with no alternatives in between.

In response to the omissions and gaps in currently available instrumentation, a precision heat-transfer technology in the form of flexible silicone-clad heating mats and associated temperature control consoles was developed specifically for art conservation applications. The mats provide the conservator with novel control in the low-energy range (ambient to 40°C) making prolonged heat transfer possible and allowing implementation of a low-and-slow approach that permits conservators to gain control over the heat transfer and innovate safe, nuanced treatments of both lined and unlined paintings. The mats are designed to deliver heat at the temperatures slightly above those customarily used to activate thermoplastic adhesives (to 70°C) and they provide access the low-energy range below 40°C, which was previously inaccessible.

For the novel treatment methodology, heating mat systems were designed to provide an accurate, versatile, mobile low-energy heat-transfer technology. All are based on three key components: the heating mat, the thermocouple (TC), and the temperature control console (fig. 37.2). The heating mat is the thermal output surface. The mats are laminates composed of resistive elements embedded within an exterior cladding of vulcanized silicone. In 2010, the authors first proposed using carbon nanotubes (CNTs) for precision low-energy heat transfer (Markevičius et al. 2011). The resulting heating mats are very flexible, with a nontack surface and thin profile that can be inserted between the wood strainer and canvas verso for treatment of a painting in situ on the stretcher.

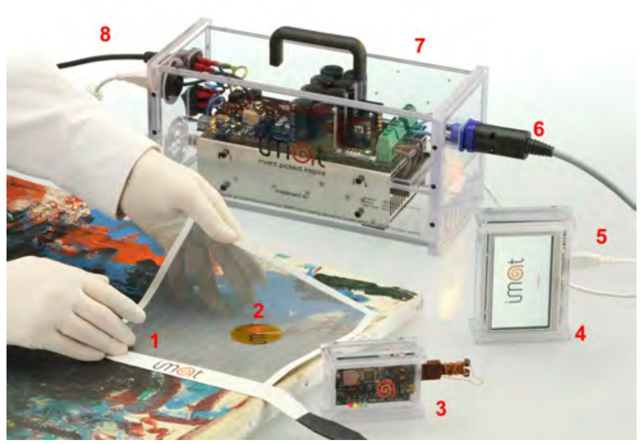

Figure 37.2 IMAT system with (1) flexible heating mat, (2) thermal sensor, (3) wireless Bluetooth thermocouple relay, (4) touch-control screen, (5, 6) connecting cables, (7) temperature control console, and (8) power input. Image: The IMAT Project, Università degli Studi, Firenze, EU FP&-ENV-NMP.2011.2.2-5

The thermocouple is the sensor used to measure the actual temperature at its tip, which provides feedback to the temperature controller. The TC (type T) is made of two metallic wires that conduct heat, copper, and constantan (nickel-copper alloy), which are joined at one end. The type

T thermocouple has a sensitivity of 43 μV/°C and is accurate to 0.5°C. It was selected for its temperature range, high degree of reliability, and accuracy. The TC is positioned in direct contact with the heating mat surface, or it can be placed strategically on any surface as needed.

The control console is a unit composed of a PID (proportional-integral-derivative) temperature controller, which employs a control loop mechanism to continuously calculate an error value as the difference between the desired setpoint temperature and a measured process variable and applies a correction based on proportional, integral, and derivative terms. Depending on the PID controller, the temperature feedback loop may be corrected between four and forty times per second, resulting in ultrasteady heating patterns (fig. 37.3).

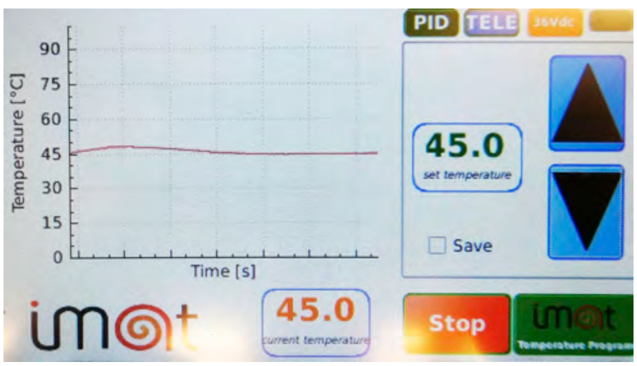

Figure 37.3 IMAT technology touch-control screen showing the extremely steady heating pattern of the PID temperature controller and high-response carbon nanotube heating mats (compare to fig. 37.1). Image: The IMAT Project, Università degli Studi, Firenze, EU FP&-ENV-NMP.2011.2.2-5

First Practical Applications

The first prototype heater was adopted from existing industrial technology in 2003 and manufactured for use in the lining treatment of two large-format New Deal murals by Howard S. Sewell in Oregon City, Oregon. The silicone heating mat was made with wound copper and fiberglass resistance wire elements plotted in a dense linear pattern at 1/4-inch intervals. It was custom made to accommodate the height of the murals. The relining process also employed a Dartek vacuum envelope with two outflowing points connected to a Gast vacuum pump. The mural sections were bonded with a Beva interleaf to the backing by heating them in sections, positioning the thermocouple between the heating mat and the backing surface. The portability of the mat allowed all of the work to be conducted on site (Olsson and Markevičius 2010).

IMAT: Innovation Using Carbon Nanotubes

In 2010, the authors first proposed using carbon nanotubes for precision heat transfer in art conservation (Markevičius et al. 2011). From 2011 to 2014, the European Commission's IMAT Project (Intelligent Mobile Multipurpose Accurate Thermo-Electrical Device[1]), coordinated by the University of Florence, considerably refined the design of flexible heating laminates for art conservation. The IMAT mats were created with innovative e-textiles woven with integrated yarns coated with CNTs, as heating elements. Various prototypes were developed, including a transparent mat and a breathable version that allowed for permeability when humidity was used during treatment. The significant advantages of using CNTs lie in their ultra-low mass and extremely high electrical and thermal conductivity, which allows rapid thermal response (essential for accuracy) and safe, ultra-low voltage (36V). The project's final deliverable was proof-of-concept IMAT prototypes, which continue to be used for diverse conservation and research projects. As of this writing, the project is awaiting further investment for upscaling and production for use in bench practice (as shown in fig. 37.2).

INTERIM MAT SYSTEM: MOBILE ACCURATE TEMPERATURE MANAGEMENT

In order to advance research and treatment methodologies of precision heat transfer, available wound wire technology has also been employed in the design of a series of silicone heating mats and associated consoles for conservation use. The first MAT system for cultural heritage applications was commercialized in 2022.[2] Operational parameters and design features have been further adapted to prioritize performance in the low-energy range, increase portability, and function with standard domestic power input. The standardized mat dimensions range from 2 × 5 inches (5 × 13 cm) to 25 × 30 inches (64 × 76 cm), with a maximum size of 30 × 40 inches (76 × 102 cm; 230V only), and the units function at 120V for North American use or 230V for EU use; larger-than-standard mats require more powerful consoles and a power input of 240V or higher.

FROM PRECISION HEAT TRANSFER TO NEW LOW-AND-SLOW TARGETED TREATMENT METHODOLOGY

Overview: The Use of Time, Temperature, and Moisture to Manipulate Failure Criteria and Remain within the "Safe Zone"

In practice, remedial treatment to reduce planar distortions, such as cupped paint and surface deformations of the paint, ground, and canvas layers, may be conducted by exploiting their viscoelastic properties with controlled increase in temperature to cause the paint film to transition from a glassy state to a pliable state, when pressure may be applied safely and effectively. The transition temperature may be reduced by introduction of a temporary plasticizer, such as humidity or heat energy. Accuracy is critical for safe and effective heat treatment in order to maintain a steady set temperature for the duration of treatment within the Tg range and achieve the transition to a compliant state while avoiding undesirable overheating of the paint surface. Thick or aged films may require a longer period of heat transfer to achieve even warming throughout the entire painting stratigraphy. With aging and given variations from the effects of pigments, oil films acquire a higher degree of cross-linking and stiffness with a corresponding rise in Tg from ambient temperature (0°C–50°C) to as high as 75°C–100°C for paints containing lead white (Phenix 2011). Therefore, in many instances the ideal operational temperature will be in the low or ambient temperature range, and in some cases even a small viscoelastic response can be significant.

Integration into Existing Treatment Methods and Development of New Treatments: Case Studies

The case studies described below illustrate the application of the mats with mild heat transfer for minimal structural and lining treatments of diverse paintings conducted over a seventeen-year span (2003–20). The operational parameters and practical advantages offered by the new warming nanotechnology and targeted approaches taken in each particular treatment show the broad versatility of the new method and how easily it could be tailored to the specific needs of each case, opening new opportunities for art conservators to refine their treatments within the margins of minimal intervention and risk.

Case Study 1: Stabilizing Cracks, Addressing Planar Distortions, and Strip-Lining

Our first example is John E. Stuart's *Mt. St. Helens from a Hill Back of Portland* (1885).[3] Planar distortions from cracks and severe cupping had formed in extremely brittle paint and ground layers, and the tacking edges were degraded at the return edge. The scope of structural treatment was to stabilize cracks, reduce or eliminate planar distortions, and reinforce the tacking edges with a strip-lining. Lascaux P550 (20% in naphtha) was introduced into the cracks from the recto in an area with particularly unstable paint and ground cracks. Following full evaporation of the solvent, localized humidification with a small chamber preceded application of localized mild heat transfer at 30ºC for forty minutes, which produced a pliable state, allowing mild pressure to be used for consolidation (fig. 37.4).

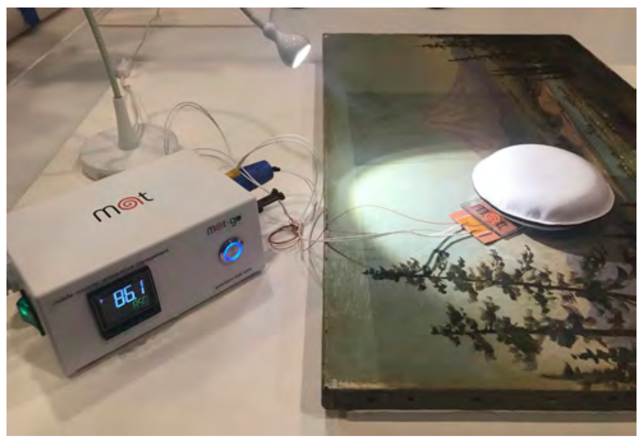

Figure 37.4 Localized low-and-slow heat transfer treatment of the painting at 30°C for consolidation and remediation of cupping and planar distortions. Image: Oregon Historical Society Museum 75-1.72

Once unstable areas were treated, the painting was removed from the stretcher for a general structural treatment. The same P550 resin was applied to the reverse and allowed to dry. The verso was then lightly humidified for thirty minutes using a moistened blotter with an interleaf of Polartec microporous membrane. A custom-cut platform of museum board and 1/2-inch foam core was created to support the fragile tacking edges. The painting was then placed in a low-pressure envelope and warmed to 40°C for forty minutes (fig. 37.5). The museum board was replaced after twenty minutes to capture introduced moisture. Finally, strip-lining supports of crepeline were prepared with Beva film prior to bonding them to the tacking edges using an angled support to prevent flattening of the fold edge during adhesion.

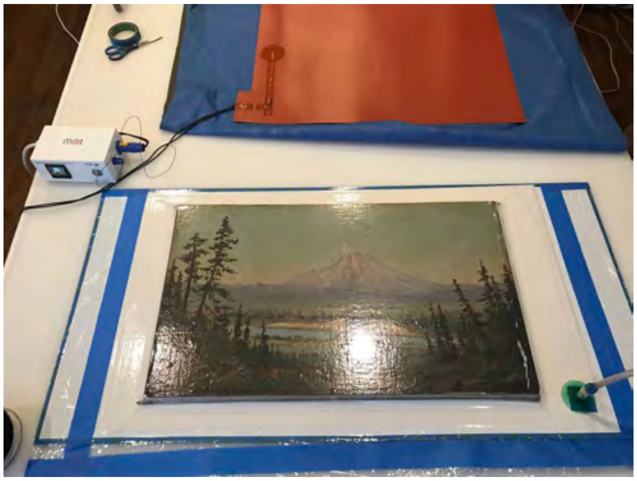

Figure 37.5 Subsequent general treatment of the painting using a low-pressure vacuum envelope and mild heat transfer while supported by a custom platform to protect fragile tacking edges. Image: Oregon Historical Society Museum 75-1.72

Case Study 2: Sustainable Treatment of Paintings with Glue-Paste Linings

André Bouys's *A Woman Knitting* (ca. 1700)[4] had been flour-paste lined in a prior treatment dating to the late nineteenth century, and that lining was still stable and well adhered. However, the recto had several areas of lifted, cupped, and curled paint caused by animal-glue residues from the facing, probably dating to the relining treatment.

The recto was humidified through a microporous Polartec membrane with a moist blotter. Subsequently, mild heat of 36°C was applied to the recto for forty minutes. Once the paint layers had transitioned to a compliant state, the cupped and curled paint was brought into plane with a heated spatula. Once planarity had been regained, the animal-glue residues were removed from the paint layer.

Case Study 3: Targeted Remedial Treatment of Indentations and Tears

Clifford Gleason's *Still Life in Whites* (1939)[5] had several indentations and canvas tears, including one large complex H-shape tear. The scope of treatment was to perform remedial treatment while the painting remained on the stretcher. Prior to thread-by-thread mending, the flap edges were temporarily joined with tape bridges. Localized humidification of the verso was followed by mild heat transfer at 40°C for twenty minutes; this was also done at dent sites and in buckled corners. Following the tear repair, humidification and mild heat transfer were again used to achieve planarity of the tear site (fig. 37.6).

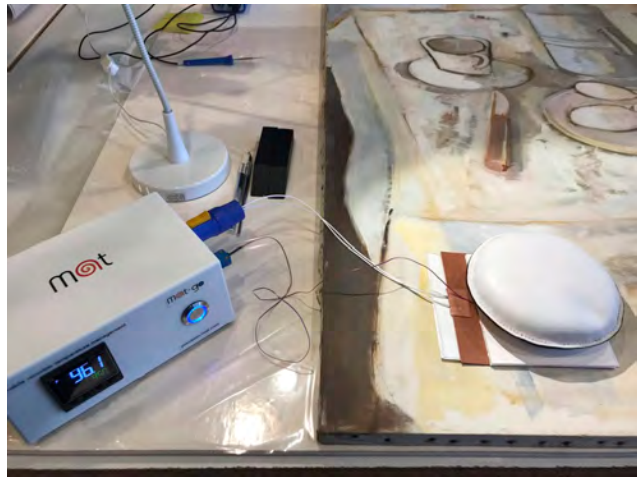

Figure 37.6 Mild heat transfer used in localized repair of a large H-shape tear and treatment of multiple planar canvas distortions of the painting while on its stretcher. Image: Collection of the Hallie Ford Museum of Art, Willamette University, Gift of the Maurice Hudkins Collection in memory of C. Ronald Hudkins and Betty-mae Hartung Hudkins, 2005.019.027

Case Study 4: Targeted Remedial Treatment of Wax-Resin Lined Works

Wax-resin adhesive was widely used for structural treatments until the 1974 Greenwich conference and continued after. When paintings with this treatment history require consolidation or treatment of planar deformations, intervention is problematic without an accurate mild heat source, due to the thermal sensitivity and melting behavior of crystalline waxes where the safe treatment temperature range is just above room temperature (~20°C) and the critical upper limit is 40°C or lower. The lack of adequate low-temperature devices has led to invasive treatments to reverse the wax-resin linings.

Testing of mild heat transfer on wax-treated paintings is nascent and has been limited to simulated treatments (Markevičius et al. 2017). The preliminary results indicate that gradual mild heat transfer over an extended period of time allows safe and efficient treatment of deformations and dents and reactivation of wax-based adhesives.

Case Study 5: Targeted Remedial Treatment of Beva-Lined Paintings

Robert Motherwell's *Open No.16 in Ultramarine with Charcoal Line* (1968)[6] was damaged during transport, leaving a 13-centimeter concave dent in the center of the composition and two areas of surface distortions in the lower corners. The work had been previously cold-lined with Beva Gel onto cotton canvas.

A thin profile mat was introduced between the wood stretcher and the canvas verso and heated to 40°C for ten minutes to soften the lining adhesive and relax the canvas and paint layers in a safe range for acrylic paint, for this particular artwork. Based on practical experience, temperatures below 40°C appear to be relatively safe, but this is not always the case. The range is specific to both the material and treatment and needs to be assessed together with other factors, such as applied pressure, physicochemical characteristics of specific paint, and amount of moisture used, which acts as a temporary plasticizer in a complex viscoelastic system (Hagan et al. 2015).

Once softened and smoothed, the deformation sites were cooled between two heat sink plates held in place for thirty seconds from either side. The same procedure was used to smooth the large concave dent in the center (Markevičius et al. 2017).

Case Study 6: Sustainable Lining Using Diverse Adaptive Lining Systems

Since 2003, flexible mats have been used in numerous lining treatments: in combination with low-pressure vacuum envelopes for the lining of a seventeenth-century painting by Orazio Gentileschi (Olsson and Markevičius 2017) (fig. 37.7), a series of six paintings by Kenneth Hudson (Markevičius et al. 2017), and in the 2010 loomed treatment of Veronese's Petrobelli altarpiece at the National Gallery of Canada (Olsson and Markevičius 2010).

Figure 37.7 Relining treatment of the painting using a low-pressure envelope and IMAT heating mat to achieve the thermoplastic activation temperature of Beva adhesive section by section. Image: Nasjonalmuseet, Oslo, Norway

Silicone mats can be made in large dimensions and conveniently rolled and stored while not in use. Alternatively, if the work is contained within a vacuum envelope during treatment, heat may be applied in sections and easily integrated into traditional and innovative lining treatments.

CONCLUSIONS

In the aftermath of the 1974 Greenwich conference, and especially since the 1990s, conservators have wrestled with the question of if, when, and how to undertake structural remediation of paintings on canvas, often preferring postponement rather than treatments employing heat and humidity despite the real conservation needs of paintings in their care. After all, conservators are tasked with designing thoughtful treatments that effectively resolve the problem at hand without repeating the errors of the past. It goes without saying that in this pursuit, the creation of new conservation materials and sophisticated instrumentation is of fundamental importance.

Ongoing studies provide a new understanding of the viscoelastic properties of constituent polymer materials in paintings on canvas, and identify behavioral changes caused by external forces such as time, heat, and humidity and how these factors may be exploited to shift aged and brittle materials into physical states that allow safe remedial treatment. This new knowledge can be applied by conservators to improve safety and effectiveness of structural treatment outcomes with the proposed methodology using MAT and IMAT heat-transfer technology for low temperature ranges (25°C–40°C) and up to those customarily used for thermoplastic adhesive activation (65°).

The new methodology represents a radical shift from low-tech, poorly controlled heating methods to an approach where the heat transfer is targeted, safe, and commensurate with the desired result. While traditional tools such as hand irons threaten to overheat the paint surface and operate at temperatures higher than is safe, the MAT's precision and even heat diffusion over large areas allows for a novel low-and-slow approach—the use of safe, low temperatures over an extended period of time, tailored to each specific treatment—and provides the means for conservators to address conditions previously considered untreatable.

Beyond temperature control, novel access to sophisticated microporous membranes that enable better control when humidification is used as a plasticizing agent provides conservators with alternatives to help formulate new structural treatment methodologies of paintings on canvas and more—within the margins of minimal intervention and risk—while achieving the maximum result.

The variety of case studies shows the broad spectrum of application for mild heat-transfer technology in structural treatment and beyond, from the use of mild heat over an extended period to treat planar and surface distortions (the low-and-slow approach) to safe treatment of works previously treated with natural and synthetic crystalline waxes to the utility of the thin, flexible profile to reach between canvas and stretcher bars for treatments that conserve the original mounting and structural integrity of the piece. The compact dimensions and portability of the MAT device allow the conservator to easily work in the laboratory or conduct state-of-the-art treatments in the field, advancing best practices in art conservation and treatment of artworks.

It is the authors' hope that further study will provide a better understanding of how to exploit the beneficial effects of low-energy heat transfer applied to structural treatment, while the introduction of precision heating mats and the low-and-slow approach developed and advocated by the authors, as well as numerous collaborators and colleagues who contributed to this research, will make future treatments on canvas more efficient, sustainable, and safer.

NOTES

1. Call ID 283110.
2. Precision Mat, LLC, Portland, Oregon. http://www.precision-mat.com.
3. Oil on canvas, 45.7 × 76.2 cm. Oregon Historical Society Museum 75-1.72.
4. Oil on canvas, 90.8 × 71.4 cm. Gift of the Podemski family in memory of their parents and grandparents, Max and Anna Podemski. Portland Art Museum, Portland, Oregon, 2017.60.1.
5. Oil on canvas, 93.9 × 73.7 cm. Collection of the Hallie Ford Museum of Art, Willamette University, Gift of the Maurice Hudkins Collection in memory of C. Ronald Hudkins and Betty-Mae Hartung Hudkins, 2005.019.027.
6. Acrylic on canvas, 252.7 × 473.7 cm. Previously Dedalus Foundation collection.

VII

Conserving Modern and Contemporary Art

38

The Structural Treatment of Modern and Contemporary Canvas Paintings: Changing Approaches and Considerations

Mary H. Gridley, Partner, Art Conservation Solutions LLC, New York

Changing priorities about the structural treatment of modern and contemporary paintings on canvas mirror the general trend in conservation toward localized or minimal interventions and reflect the lack of consensus among stakeholders—including the artists themselves—about an acceptable degree of aging in these recently made works. Surface perfection rarely coexists with age-related authenticity. While the use of unconventional materials or techniques in an artwork can complicate treatment, some commonly used modern artists materials, such as acrylic paints and grounds, can be exploited for our benefit during treatment. The unique demands of these paintings and our struggle to find suitable and successful treatments for them have generated a welcome increase in scientific research into modern materials as well as specialized training for emerging conservators.

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INTRODUCTION

As a conservator in private practice in New York who specializes in recently created artworks, I have spent a great deal of the last twenty-five years performing structural repairs on canvas paintings, absorbing and adapting to the ever-evolving techniques and goals of these treatments.

Modern and contemporary art is loosely defined as anything made in the last 75 to 125 years, a span that embraces many different styles and "schools." But for practical purposes, in paintings conservation we think of it as starting with the Abstract Expressionist era, in the 1950s, when artists' use of nontraditional materials and painting methods dramatically increased. Paintings created with non-artist-grade supports or paint, with unusual media such as chewing gum or molasses, or those with Minimalist surfaces that readily show every damage can be difficult to treat. Monochromatic paintings, a perennial lure for modern artists, in which the subtleties of the surface are paramount, can be particularly challenging.

Works that are intended to be displayed unframed, unglazed, and unvarnished are vulnerable to damage from handling, travel, and installation. Hence, while conservators of these works are rarely faced with failing fabric supports or extreme cupping, they are confronted with impact cracks, tears, and deformations, some of which may be exacerbated by poor materials or inadequate structural supports.

While monochromatic or unconventional surfaces may be challenging to maintain during a structural treatment, some of the other material components of these works are more resilient and less degraded than those found in older, more traditional paintings, greatly improving the odds for successful treatment. Cotton duck, widely used by American artists for the last seventy years, behaves differently than linen. The common use of acrylic gesso and sizing, which retain malleability and are quite responsive to moisture, temperature, and solvents, provide layers that can be exploited in the flattening of cracks and cupping.

Over the last six decades in both private practice and institutional conservation labs, the structural treatment of twentieth- and twenty-first-century canvas paintings has mirrored that of older paintings, moving away from lining as localized solutions became more popular. Conservators have promoted the embrace of minimal intervention, as well as respect for authentic and historical elements and meanings of the artwork, to private collectors, dealers, and artists. *Authenticity* in this context describes a number of qualities of an artwork other than its outward face. Tangible examples include normally unseen elements, such as stretchers, inscriptions, old tacking holes, studio handling marks, labels, and provenance. More intangible and subjective aspects are age-related patination or historical associations independent of the imagery. The relative value of all these types of authenticity varies widely by time and place and is a reflection of the concerns of the larger culture.

Actual treatments I have carried out are often a compromise between returning the surface of a work close to its original, unblemished state and acknowledging or embracing its evidence of authenticity and age. Many of these works have never been treated, so the treatment methods and materials employed must have an eye to future ramifications.

The rising popularity of contemporary art has greatly impacted the conservation world. There is a fast-growing body of research into modern materials and artists' techniques. The proliferation of smaller institutions devoted to contemporary art collections feeds the demand for materials and technical research, as well as for care and treatment of this type of painting, and has spurred more specialized training in conservation degree programs. Graduates have spread out across the globe to staff institutions and the private studios devoted solely to treatment and care of these works.

CHANGING CONSERVATION PRIORITIES

In the private sector, the goal of most treatments is to make an artwork exhibitable—and, depending on the stakeholders, salable. For modern and contemporary paintings, which are still transitioning from brand new to antique, this can mean different things for different artists, for different genres, and for different owners: there is no unilateral agreement on what levels of damage are considered acceptable for display. While there is an obvious desire for a legible surface that clearly demonstrates the artist's aesthetic intent, there are also varying notions about whether and how to value signs of age or history. Institutions tend to tolerate more evidence of age than the private sector, where these artworks have not only an aesthetic and historic value but also perhaps a significant financial one.

Treatment choices not only depend on what is possible but also can be driven by what is deemed most important for a given artwork by a given collector. If an owner is anxious to obliterate any signs of damage or aging, no cracks are left untreated. Another may want only the eye-catching, prominently placed impact cracks treated, but not those at the turnover edges, and for a third, a moderately cracked and aged paint film is an appropriate expression of the age and history of the object itself. Contemporary artists themselves have strong opinions about what degree of damage is acceptable in their work. In my experience, if asked, they generally say they want it to look "perfect" and are often willing to repair or remake it themselves if it cannot be successfully conserved—an outcome that can open up Pandora's box. Decisions about how much to treat and what to prioritize are not specific to modern and contemporary art, of course, but have been more open for discussion as the conservation field has evolved from the scattered and relatively isolated group of artist/restorers of old to the degree-trained conservators of today.

What the art world now thinks of as "blue chip" contemporary art was initially collected and promoted by small groups of enthusiasts and was not widely sought after. It was not of very high value compared to works of Cubism or Impressionism or the old masters, for example. Only a few conservators—all of them apprentice-trained or self-taught—performed treatment exclusively on these works. In New York, Daniel Goldreyer, Orrin Riley, Jean Volkmer, and Margaret Watherston all wrestled with the unique demands of modern and contemporary paintings, adapting old techniques or inventing new ones.[1] Their clients were often the artists themselves, which allowed for collaboration and experimentation. Their work was influential and sometimes controversial. The apprentice system was alive and well during this period, and many of my colleagues today trained with one or more of these individuals.

Naturally enough, those conservators used the tried-and-true structural repair techniques that succeeded on older paintings. They also enthusiastically embraced the new equipment, lining adhesives, and supports adopted and developed in the 1950s, 1960s, and 1970s, many of which were introduced at the 1974 Conference on Comparative Lining Techniques in Greenwich. These included Gustav Berger's Beva 371 adhesive (and the subsequent film form), flocked polyvinyl acetate (PVA) adhesive, nap-bond adhesives, fiberglass solid and fabric supports, polyester sailcloth fabric, stiff Mylar interleaves, and low-pressure hot tables. I have seen examples of most of these lining types on paintings that have come through the studio. Some have been very successful, some less so, but their application to modern and contemporary paintings is problematic for some collectors and dealers: there is a perception that a lined contemporary painting is somehow lesser. This could be a genuine aesthetic problem, for example, weave interference or other subtle alterations to the surface created by pressure or heat during the lining process.

More often, it is the verso that is the problem. Paintings lined using heavy Mylar are a case in point. Even if the lining has successfully brought the cracks or tears into plane, the very shiny plastic appearance of the Mylar on the verso is an inescapable reminder that a painting has had fairly extensive conservation treatment. Localized repair of structural damage, while often much more labor intensive and therefore more expensive than a global treatment like lining, satisfies two criteria I think are important: retreatability and a light touch, both of which leave the door open to better future solutions for these young paintings.

The search for better methods and materials for structural treatments in the years leading up to Greenwich was an acknowledgment that lining treatments corrected some types of damage but could also create new ones. After Greenwich, this realization slowly manifested as an ethical dilemma: Was lining too aggressive? *Should* the many individual issues a lining could resolve—flaking, distortions, cupping, tears, weakening fabric—be dealt with all at once? Or would it be better to deal with them separately and perhaps delay a lining treatment? What began in Greenwich as an exciting, hopeful exchange of new research and techniques on improvements in the structural treatment of canvas paintings was flipped on its head by the realization that perhaps it was not the *method* of lining, but the *act* of lining that needed to be reevaluated (Percival-Prescott 2003b). Subsequently, a period of reflection set in, and many conservators began to pull away from global treatments, opting for more localized, targeted treatments instead.

The ascendancy of "minimal intervention," as this approach came to be called, had a substantial effect on the continued prevalence of lining. When I was a graduate student at the Courtauld Institute of Art between 1988 and 1991, structural conservation of canvas paintings in London (and perhaps elsewhere) was at a crossroads. Although students were instructed in both structural and cosmetic treatments, there was a separation between the two in the real world at the time—an acknowledgment that only specialized knowledge and experience could confer mastery in one or the other. There were still private studios in London where pictures were sent to be lined, and the National Gallery of London maintained a separate studio and conservation staff that dealt only with structural work. The ample research into better methods, materials, and equipment in the 1970s and 1980s spurred many conservation studios to procure the new equipment needed to offer lining treatments to their clientele. But the equal and opposite move away from global interventions meant these tables were used less and less, until in many studios they became simply flat surfaces on which to do other kinds of work (Hedley and Villers 1993; Stoner 1994). In the first studio where I worked when I returned to New York in 1994, the lining table was used only for moisture and flattening treatments. I have not worked with a lining table since, using instead a portable suction platen or steel weights when flattening was necessary.

This shift toward separate and/or staggered treatments has become deeply embedded in the current conservation culture, and we have passed that philosophy on to a wider public. Conservation as a whole has a much higher profile today thanks to targeted exhibitions, public-facing conservation labs in museums, and treatments carried out in public galleries. One change I have observed over the last few decades is that our more sophisticated clients actually notice past structural treatments and have opinions about them, which is a testament to how much more mainstream conservation and discussion of condition has become. This is in stark contrast to what George Stout, one of the founders of science- and museum-based conservation in America, described as the "contempt for concern about condition" prevalent in his early years in the field (Stoner 2005). Historically, the importance of an artwork was confined to its surface imagery and art historical importance; whether the painting had had conservation treatment—even treatment that radically altered the surface—was not considered relevant.

TREATMENTS ON MODERN AND CONTEMPORARY PAINTINGS

Lining and Patching

Given the practical and existential difficulties of lining, it is not surprising that some examples of early linings of modern and contemporary paintings that have passed through our studio provide cautionary tales. This is particularly true for Minimalist paintings, which have the infuriating characteristics (to the conservator, at least) of being the most in need of structural intervention when cracks appear and having the least tolerance for any intervention. Given the extremely subtle nature of the aesthetics of these paintings, some examples of early linings we have seen exhibit changes to the paint film that we are anxious to avoid repeating, such as locking cracks in place with thick layers of adhesives and auxiliary supports, thus prohibiting access to the reverse. One previously treated, multipanel Minimalist painting I worked on had numerous impact cracks on all five canvases. Two of the panels were unlined while the other three had been lined with thickly flocked PVA. While the cracks in the unlined elements were improved with local flattening treatments to the reverse, the PVA on the other three could not be safely removed, so the cracks could not be retreated.

Although I have seen old linings—of all varieties—that have worked well and remain sturdy, this is not always the case. A great deal of the success relies on the experience of the practitioner. Glue-paste linings in particular seem to require a vast amount of particularized knowledge and skill. On a Minimalist painting, they can be wonderfully successful, but they can also result in weave interference due to lining pressure and small distortions caused by uneven adhesive application or inherent faults in the canvas weave.

Wax-resin and Beva linings are less stiff and unyielding, but that can create problems as well, such as spotty delamination between the original and lining canvases due either to an initial, uneven heat application or to eventual degradation of the adhesive (figs. 38.1, 38.2). The inherent flexibility of these adhesives—so useful in other contexts—is often no match for the paint film's strong need to equilibrate forces around existing cracks, leading to their reappearance over the long term. I have seen wax-resin linings change the gloss of a surface or darken with time, throwing off the balance of light and dark in the composition.

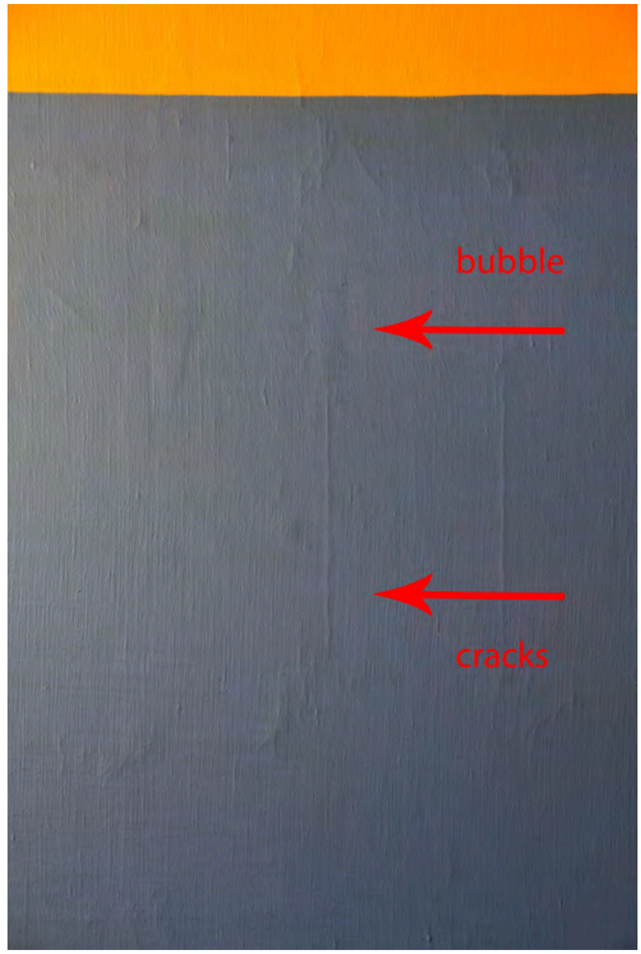

Figure 38.1 Detail of a 1959 Minimalist oil painting lined with Beva. Note the delamination of the cracks for which it was originally treated, as well as bubbles caused by local adhesive failure. Photographed in 2013. Image: Mary H. Gridley

The use of a very stiff lining material or interlayer, such as heavy Mylar, has proved successful in some cases, but in others such interventions only locked the partially flattened cracks in place. The same can be said for thickly flocked PVA adhesives, as noted above. Their stiffness overwhelmed the lining fabrics, and they cannot be reversed without a great deal of mechanical force or solvent (Rabin 1976). Local treatments with patches have resulted in unsightly bulges over time, caused by the shrinking of adhesives combined with realignment of forces between those canvas fibers that are held in place by adhesives and those that are not (fig. 38.3).

Figure 38.2 Detail of a 1956–58 oil painting lined with wax resin. The cupping has reappeared. Photographed in 2016. Image: Mary H. Gridley

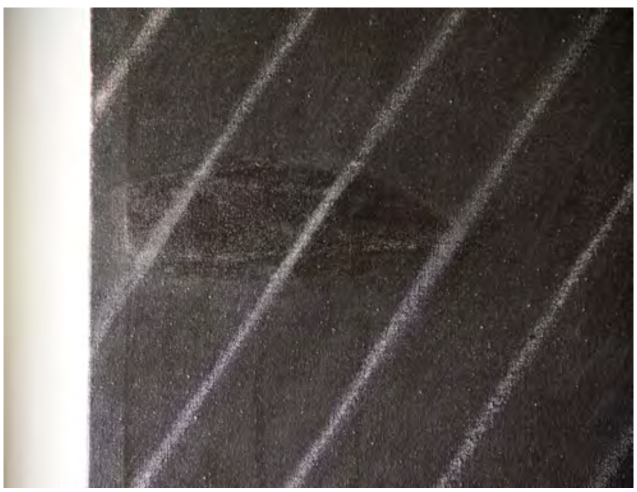

Figure 38.3 Detail of a 1959 oil painting showing the bulge caused by an old patch to mend a horizontal tear. Photographed in 2012. Image: Mary H. Gridley

For paintings meant to be displayed without frames or with only modest strip frames, the bulk added by any kind of lining fabric and adhesive can compromise the crispness of a painting's edges by forcing some of the unpainted tacking edge onto the face of the painting. Many of these treatments are difficult or impossible to reverse, and often lead to devaluation, both aesthetic and financial. Even past treatments sanctioned by the artist are subject to scrutiny. What was once acceptable, maybe even cutting edge, is now often viewed as undesirable in modern and contemporary paintings.

Local Treatment and Preventive Conservation

The most common structural damage we see in our studio is impact-related cracking of the paint film. This type of cracking often takes the form of concentric circles or feather-like shapes, resulting from accidental knocks to the face or the reverse. They also appear as straight lines directly on top of the edges of stretcher lips, rails, and crossbars, caused by repeated contact with the sub-support, or as smaller systems along the crossbars where people have distended the back of the canvas while grabbing the bars in transit.

While aesthetically disturbing, these impact damages do not always pose an actual threat to the overall stability of the painting. Successful flattening of such damage has always depended on softening or reforming both the paint and ground layers while simultaneously stiffening the canvas layer. Doing this successfully through localized treatment is possible, but the history and literature on treating cracks without resorting to lining is scant and the conclusions often discouraging. Moisture, solvent, heat, and pressure have been explored in various combinations (Gridley 2017). Experiments have been carried out in which the reverse of the canvas is treated in various ways to equilibrate the distortion caused on the face by local breaks in tension (Hough and Michalski 1999; Dimond and Young 2003; Hough and Michalski in this volume), but there are practical challenges, and local treatments are not always less time-consuming than global interventions.

Treating numerous similar damages one by one can be both labor intensive and expensive. However, there are collectors for whom an "untouched" or minimally treated artwork commands a premium, so there is value in underwriting the cost and time such treatments consume. This attitude has allowed our studio to develop expertise in carrying out such treatments. Treatment of impact cracks is often the first structural intervention in a modern or contemporary painting's life, and it is very important to acknowledge that better future treatments may be possible only if we tread lightly now.

As noted earlier, the current and widely adopted approach to structural repair of modern and contemporary paintings is one where a desire for local or minimal intervention meets a growing respect for authenticity. For example, there is perceived value in an unlined painting, with its original wooden auxiliary support and the verso of the canvas available for viewing. For eyes now accustomed to localized treatment of cracks or thread-by-thread tear mends, linings can appear heavy-handed. The occasional request to remove old linings without replacing them does not always occur because the lining has failed. More often, the lining itself is viewed as an undesirable condition of the painting. The many types of values embraced by stakeholders—unblemished surface, stable condition, age-appropriate damage, retention of hidden original or authentic components, unease with evidence of past conservation—are often contradictory, if not actually mutually exclusive, and present thorny ethical dilemmas when discussing treatment.

While minimal intervention and authenticity often complement each other in a treatment, that is not always the case. Removing a lining to reveal the original verso is not a minor treatment. Unstretching a painting to replace or modify an original subsupport that is inadequate or actively damaging the painting is not without risk and may end with an unsatisfactory compromise (fig. 38.4).

a

b

Figure 38.4 (a) Artist-made strainer from 1970 composed of wood, plywood, and particle board, 180.3 x 287 cm (71 x 113 in.). (b) The same strainer, modified in 2018. The effort to keep the original components and achieve adequate structural integrity resulted in a strange hybrid support. Images: Mary H. Gridley

An important strategy for mitigating against the return of old cracks or the creation of new ones involves preventive conservation. The installation of backing boards and handles prevents knocks from the reverse or edges being gripped during transport and installation. More complex interventions include stretcher bar linings or loose-linings for individual paintings. Where appropriate, framing and glazing are good protection, as are wrapping and crating to prevent contact with the face of the painting. Preventive conservation, while perhaps not understood by galleries or collectors to be a whole subspecialty of our profession, is something of which they are very aware. Proper storage, professional shipping, and environmental controls are not just institutional priorities; they have worked their way into the mindsets of commercial galleries, private collectors, and art handling and storage facilities.

MODERN MATERIALS

Successful local treatment relies to some extent on the material integrity of the painting itself. If the canvas still has adequate strength and the paint films remain relatively coherent and well adhered to the support, minimal intervention can both solve the current problem and leave the door open to future treatments. While some artists have incorporated unpredictable and problematic non-art materials into their works, generally the increased use of synthetic polymer-based materials and cotton supports in modern and contemporary paintings has advantages in problem-solving localized treatments.

Perhaps the most significant material difference between older and newer paintings is the widespread use of acrylic grounds and synthetic sizing. I would estimate that 90% or more of the post-1965 paintings I have examined, regardless of the type of support fabric or paint medium, are painted on acrylic grounds. The fast-drying, nontoxic qualities of acrylic grounds and sizing are very appealing to painters. In a nod to both this and to conservation research, one American manufacturer, Gamblin Colors, has even discontinued sales of rabbit-skin glue sizing and its proprietary traditional gesso (which also contained rabbit-skin glue). In doing so, Gamblin cited scientific research by the Smithsonian Conservation Lab that deemed these materials to perform poorly on canvas paintings over the long term due to the high reactivity of the glue and fabric to changes in RH. The more brittle paint layer(s) do not swell and contract as easily, and this incompatible elasticity can result in cracking or delamination of the paint (Gamblin n.d.).

In the past two decades, significant analysis and research has been done on acrylics. Much of it has centered on the various paint components and additives, as well as their aging properties, and what that means for cleaning,[2] but from a structural repair perspective, acrylic has some unique features. Its continued sensitivity to moisture, heat, and commonly used solvents such as alcohols and ketones makes it an ideal candidate for reforming (Zumbühl et al. 2007). When the acrylic is confined to the ground and size layer, with other media in the image layers, there are additional opportunities to manipulate its properties, allowing less interference with the paint and canvas layers.

Since World War II, when imported linen was hard to come by, cotton duck has been widely used in the United States, and to a lesser degree elsewhere. It became popular due to availability of large bolt sizes and comparatively low cost. It is unclear what the widespread use of cotton supports will bring us in terms of future structural problems, but in my experience they seem to suffer less embrittlement than linen during aging, even though the shorter and fluffier fibers are harder to work with individually, as required in a thread-by-thread tear mending. Linen, still widely used globally, retains its strength and resiliency for decades, allowing conservators to delay lining or other major structural interventions. Ongoing research into the materials and structure of aging contemporary primed canvases remains necessary to guide us in the future (see Carter et al. in this volume).

CONCLUSION

Structural treatment of modern and contemporary canvas paintings presents both technical and aesthetic challenges. In the private sector, treatments are judged not only by improved aesthetics or stability but sometimes also by how readily detectable a treatment may be to a future observer. While the various stakeholders—collectors, artists, and conservators—all wish for a work to be exhibitable, their definitions of that may not be identical, and furthermore are bound to change as the artworks and their components naturally age and new treatments evolve. The struggle to achieve a near-perfect surface while exercising restraint in intervention continues to drive innovations in treatment. The field has come a long way in the last seventy-five years: refined technical abilities, in-depth materials analysis, and a shared philosophical framework have allowed us to bring a more nuanced understanding to our work.

NOTES

1. Daniel Goldreyer was in private practice, active from approximately 1950 to 1995. Orrin Riley was at the Guggenheim Museum and in private practice from about 1960 to 1986. Jean Volkmer was at the Museum of Modern Art ca. 1958 to 1983. Margaret Watherston was at the Whitney Museum of American Art and in private practice from around 1965 to 2005.
2. For a foundational overview of modern paints, see Learner 2004. For a brief summary of cleaning research, see Ormsby and Learner 2016.

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Wax-Resin Extraction Traction on a Late Georges Braque Still Life

Desirae Dijkema, Assistant Paintings Conservator, The Menil Collection, Houston, Texas
Bradford Epley, Chief Conservator, The Menil Collection, Houston, Texas

In 2018, the Conservation Department of the Menil Collection performed a novel wax-resin extraction treatment utilizing Evolon CR on Pitcher, Candlestick, and Black Fish *(1943) by Georges Braque. The treatment was preceded by extensive wax-resin extraction trials; multiple methods of extraction were tested, focusing on the variable contributions of heat, suction, solvent selection, and the capillary action of an Evolon CR substrate. Based upon optimized parameters determined in the preliminary trials, the wax-resin extraction treatment on the painting was performed on a suction table, utilizing xylenes-saturated Evolon CR against the back of the canvas, ShellSol OMS–saturated Evolon CR against the face, and two cycles of suction and heat. Visually, the canvas regained weave distinction and a variety of surface that is inherent to the way that paint conforms to fabric. Spectrophotometry readings taken before and after wax extraction show a perceivable lightening of the ground. After treatment, the weight of the canvas had decreased by 14%.*

◆ ◆ ◆

INTRODUCTION

"Why subject it to this rack-like torture? . . . Restorers are amazing. They have transformed my guitar into a tambourine." So said Georges Braque to John Richardson after viewing one of his still lifes that had been wax-resin lined. He completed the sentiment with a tap of his brush on the painting's taut surface (Richardson 2004, 533).

In 2016, the Conservation Department at the Menil Collection began a long-anticipated cleaning of Georges Braque's 1943 painting *Pitcher, Candlestick, and Black Fish* (*Vase et poisson noir*). The painting had been treated in 1961 by Caroline Keck, receiving a "superficial cleaning," wax-resin lining, and a poly butyl methacrylate varnish.[1] The motivation for lining was largely preventative. In a letter in the painting's file, Keck explains that "the result of the rolling and its mishandling has caused cracks to develop, some easily seen with the eye in the yellow area, others developing definitely in the structure but visible under magnification only at this stage . . . this is an important moment to treat the painting, to prevent any serious damage and even loss of surface as these cracks go further."[2] The painting was likely rolled twice in 1940, when Braque traveled to the south of France and then back to Paris at the beginning of World War II (Danchev 2006).

That Braque sought variation in his final surfaces is effectively demonstrated by Favero, Mysak, and Khandekar in their technical study of twenty-one of his paintings from 1928 to 1944. Braque achieved a variety of textural effects by mixing sand, fine gravel, and quartz into his grounds or using combs and sculptors' tools to scrape through wet paint (Favero, Mysak, and Khandekar 2013). He created more delicate variations of surface by mixing varnish or beeswax into the paint or by selectively varnishing certain passages. Richardson describes Braque's practice of applying a varnish to certain passages, sometimes according to a viewer's expectations of an object's reflectance (as in his paintings of the 1920s and 1930s, where shiny objects such as a glass vase received a glossy finish while matte objects such as a lemon received nothing), or sometimes in deliberately playful ways that go against a viewer's expectations by rendering inherently shiny objects matte (Richardson 2004, 533).

In *Pitcher*, the cleaning revealed that Braque manipulated the final surface sheen with two black paints—one that is velvety matte and one that is glossy—to establish subtle contrasts across the surface.[3] For instance, a fish featured in the foreground is almost entirely painted in matte black paint except for two small reveals around its eye and gills where Braque left underlying glossy paint in reserve, creating a shiny iris and gleaming gill line (fig. 39.1).

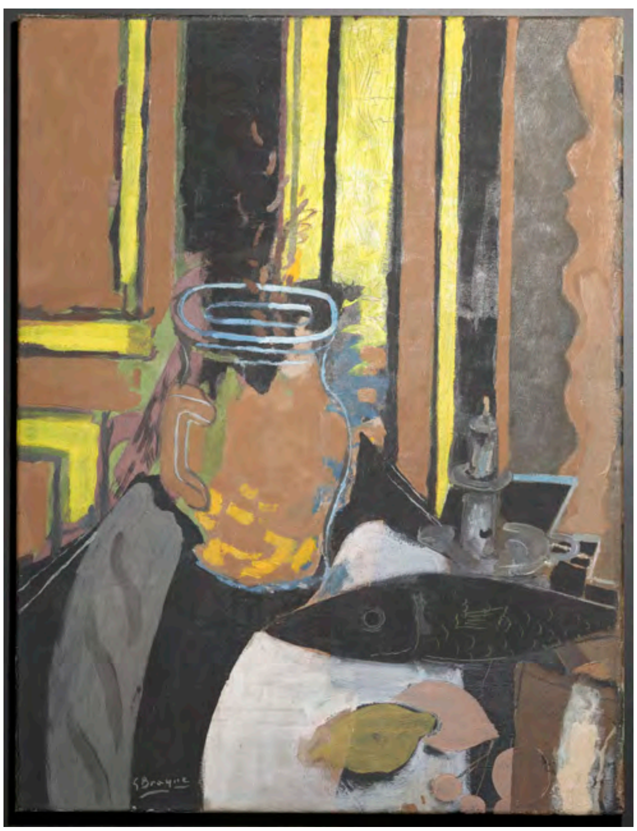

Figure 39.1 Georges Braque (French, 1882–1963), *Pitcher, Candlestick, and Black Fish* (*Vase et poisson noir*), 1943. Oil on canvas, 64.8 × 49.5 cm (25 1/2 × 19 1/2 in.). During treatment (after cleaning and lining removal, before wax-resin extraction), under specular illumination. The Menil Collection, Houston. Image: © Artists Rights Society (ARS), New York / ADAGP, Paris / Photo: Adam Neese

In addition to creating variable gloss and matteness, Braque manipulated the texture of *Pitcher*'s surface. Fine sgraffito marks outline the lemons, and medium to wide gouges create detail in the background, indicating that Braque used a variety of tools to establish a variable surface with tactile characteristics. In certain passages, grooves unite with precise paint application, merging the textural and the visual: two gouges extend upward from a cherry in the foreground, revealing dark underlying paint and beginning its stem; after approximately 1 centimeter, a fine stroke of brown paint fills them in and completes the stem's length.

At some unknown date prior to Keck's 1961 treatment, the painting had also received a bleached shellac coating.[4] Though it is unclear who applied the shellac coating, two reasons make it highly unlikely to have been Braque: his dislike of overall varnishes for their unifying effect on sheen, and the areas of retouching underneath the shellac layer that were discovered during the cleaning. These had been incorrectly applied to grooves in the paint that were misinterpreted as abrasions; there are multiple examples of similar, nonretouched grooves throughout the composition. During the lining process, the shellac had softened and deformed from exposure to heat and pressure, resulting in a tangled network of ridges and valleys that imparted an artificial texture across the surface. Visible under magnification and to the naked eye, the compromised shellac scattered light and hindered legibility of subtle brushstrokes and sgraffiti.

Given Braque's practices regarding his differentiated paint surfaces, the rationale for the 2016 cleaning was twofold: to reduce the compromised shellac and to restore the surface's original, varied sheen and texture by removing the varnish layers and their unifying gloss. The decision to pursue a lining reversal and wax-resin extraction was motivated in part by the possibility of enhancing reflective and textural gains revealed by the cleaning, as well as by the artist's aforementioned dislike of what he perceived as an artificial planarity and stiffness imposed by linings.

TREATMENT TRIALS

The wax-resin extraction on the painting was preceded by forty-eight test trials performed on strips of the lining canvas, which was removed from the painting mechanically by peeling it back at a low angle. Examination of the canvas fibers after removal of the lining revealed that they were in good condition and had not been shaved prior to lining. Of the trials, the first twenty-eight were more exploratory in nature, while the final twenty were more controlled, as the most important treatment parameters emerged. The lining canvas strips were subjected to different conditions exploring multiple variables, including solvent location in relation to the bulk of the wax-resin mixture (whether the solvent was introduced from the back or from both front and back), the type of solvent, the solvent delivery system (brush-applied, gelled, or by fabric), the wicking layers (number of layers, type of material used, and frequency of change-out during treatment), the temperature, and the use of suction. Initially, gels were used as a solvent delivery system, after the methods published by Bettina Landgrebe and Gunnar Heydenreich (Landgrebe 1988; Heydenreich 1994). However, relatively early on it became clear that Evolon CR could deliver solvent as effectively as a gel, while minimizing preparation and simultaneously acting as a means for absorption.

A general setup of the trials from the Willard suction table surface upward was as follows: heat and/or suction provided by a vacuum hot table, one to three wicking layers (Evolon CR, paper towels, or linen), an "acting" solvent layer (sheet of Evolon CR or gel containing a solvent with a high chemical affinity for the wax resin), the lining canvas strip faceup,[5] and in some trials a low-polarity "superficial" solvent applied by brush or Evolon CR to the face. Evolon CR is a nonwoven textile composed of polyester and polyamide microfilaments that can absorb up to four times its weight in water and slightly more than that in hydrocarbon solvents.[6] The acting solvent layer is meant to promote dissolution of the wax resin, while the superficial solvent encourages movement of deeply impregnated wax resin out of the lining canvas and into the wicking layers below.

Exploring a few trials in detail illustrates some key takeaways that ultimately informed the treatment parameters on the painting. The time-consuming nature of the trials made it difficult to do extensive investigations of all variables. Trials included here offer empirical findings and observations. Moving forward, performing a greater number of trials per single variable will be necessary in order to form conclusions that are statistically relevant.

Efficacy of wax-resin removal was evaluated based on the appearance and feel of the lining canvas strips and their percentage of weight loss after treatment. In order to establish the maximum amount of wax resin that could be extracted, small coupons of lining canvas were individually weighed, and then each was immersed in one of the range of solvents being considered for use (xylenes, ShellSol Odorless Mineral Spirits [OMS], hexamethyldisiloxane, and octamethylcyclotetrasiloxane) for approximately forty-eight hours, after which it was removed from the solvent, allowed to dry, and reweighed. This demonstrated that the maximum amount of wax resin that could be extracted was around 30% of the weight of the coupon. The most successful solvents, xylenes and ShellSol OMS, resulted in 31% and 32%, respectively.

Trials that involved application of solvent to the face resulted in the supplest canvas feel and the best final appearance—clarity of weave, saturation, evenness of wax-resin removal—with comparable results regarding weight-loss percentage. In a set of eight trials, four involving superficial solvents and four without, all of those involving superficial solvents resulted in the supplest canvas feel and most improved clarity of canvas weave. While it was clear that the application of solvent to the face would not necessarily result in a higher percentage of weight loss (taken as a measure of efficacy of wax-resin removal), the visual and tactile characteristics were deemed more improved in the lining canvases that had received superficial solvent than in those that had not.

Using xylenes as the acting solvent consistently dissolved more wax-resin mixture than did ShellSol OMS. Trials with xylenes in the acting solvent layer resulted in good clarity of weave with no visible wax-resin residue, a supple canvas feel, and higher weight-loss percentages. Trials with ShellSol OMS in the acting solvent layer resulted in visible wax-resin residues, lower weight-loss percentages, and a blanched final appearance, likely resulting from incomplete dissolution of residual wax resin.

Halfway through the trials, it became clear that the downward draw of the wax-resin mixture into the Evolon CR via capillary pressure was significantly stronger than any contribution from the downward draw of air by the suction table. In trials with and without suction, both trials resulted in good clarity of canvas weave, no visible wax-resin residue, a supple canvas feel, and comparable losses in weight. However, it was important to use the suction table anyway, for two reasons: as a means of ensuring close conformity between the lining canvas strip and the Evolon CR, and as a means to evacuate solvents and avoid a solvent-package effect. In trials without suction, droplets of solvent were visible pooling on the underside of the Dartek covering the stack, which we deemed a nonviable method for the eventual treatment of the painting.

Consistently more wax resin was extracted when the trials involved heat. The strong capillary effect of the Evolon CR raised the possibility that extraction utilizing the solvent might be possible at room temperature. Trials performed at approximately room temperature resulted in a slightly improved clarity of canvas weave on the back of the strip, but an increased obfuscation of weave and darkening on the front. The canvas remained stiff after treatment and underwent minimal weight loss.

Using a larger volume of acting solvent results in a higher percentage of weight loss in the lining canvas strip. In a set of four trials—two involving an acting solvent layer of twice the weight of the Evolon CR and two involving three times the weight of the Evolon CR—trials involving the larger volume of solvent resulted in the highest percentage of weight loss.

When it came time to design the treatment methodology for the painting, several parameters had become clear from the trials. A low-polarity superficial solvent, xylenes as the acting solvent, suction for solvent evaporation and conformity, and heat would result in the highest percentage of weight loss and the best final feel and appearance of the canvas. In spite of the success of trials involving higher volumes of solvent, we decided to load the Evolon CR with twice its weight in solvent (rather than three times), because of the relatively finer weave of the painting's canvas.[7] Other parameters were less certain, such as whether to change out the wicking layer once or twice, and whether one or two rounds of extraction should be performed. Ultimately, we decided to change out the wicking layer once in order to minimize handling and to determine whether a second round was necessary after seeing the results of the first round.

TREATMENT

Broadly speaking, the treatment involved applying Evolon CR that had been saturated with ShellSol OMS to the face and Evolon CR that had been saturated with xylenes to the back while placing the entire stack under heat and suction. As in the trials, the volume of solvent in the Evolon CR was determined by weight. In order to load the Evolon CR with solvent, a sheet of the material was weighed, rolled, and folded and placed in a clean, empty metal paint container. Double its weight in solvent was added, and the container was sealed and left overnight. The painting was weighed before and after treatment by placing it on a rigid board and subtracting the weight of the board alone from the weight of the two together. Spectrophotometric measurements were taken before and after treatment.

The treatment occurred in two rounds, each comprising three stages. For all rounds, the Evolon CR was applied as single sheets cut larger than the size of the painting.

In the first stage:

- A cross section of the material stack from the Willard table upward is as follows: Hollytex to prevent adhesion to the lining table; a dry sheet of Evolon CR as a wicking layer; Evolon CR saturated with twice its weight in xylenes (the equivalent of 100 mL); the painting faceup; and Dartek.
- The table temperature was set to cycle between 39°C and 51°C, though the temperature at the painting's surface consistently registered 2°C–3°C lower when checked with an infrared thermometer.
- With suction set to 2 mbar, the painting was left in this stack configuration for 15 minutes.

During the second stage:

- The Dartek was temporarily removed, Evolon CR with twice its weight in ShellSol OMS (the equivalent of 120 mL), was placed over the front, and the Dartek was replaced.
- The table temperature's cycle remained the same (39°C–51°C), and the painting's surface continued to measure 2°C–3°C lower.
- The suction was increased to 7 mbar, and then the painting was left for twenty minutes.
- After twenty minutes, the wicking Evolon CR was replaced with a new, dry sheet, the Dartek was put back in place, and the stack was left for another twenty minutes.

During the last stage:

- The Dartek and Evolon CR on the face were removed.
- The heat was turned off, but the suction was left at 7 mbar.
- The painting was left to cool for thirty to fifty minutes while light suction encouraged solvent evaporation

Wax-resin residues were clearly visible on the back of the canvas after the first round, so all three stages were repeated for a second round.

TREATMENT RESULTS AND DISCUSSION

When considering the treatment results, there are a variety of aspects to consider, including the aesthetics of the pictorial layer, the planarity of the support, the appearance of the back of the canvas, the percentage of weight loss,

Figure 39.2 *Pitcher, Candlestick, and Black Fish* after treatment, under specular illumination. The Menil Collection, Houston. Image: © Artists Rights Society (ARS), New York / ADAGP, Paris / Photo: Adam Neese

Figure 39.3 *Pitcher, Candlestick, and Black Fish* after treatment, under raking illumination. The Menil Collection, Houston. Image: © Artists Rights Society (ARS), New York / ADAGP, Paris / Photo: Adam Neese

and color change. The wax-resin extraction resulted in relatively subtle changes to the pictorial layer. The colors in the face of the painting were not significantly altered, but there was a clearly perceptible lightening of the ground visible on the tacking margins. The painting does not have areas of exposed ground within the design, as do many of Braque's pictures, so the impact of this brightening upon the overall color harmony of the composition is less noticeable than it would be if the ground was a defining element. There was no perceivable change to the painting's varying sheens of matte and glossy black paints (fig. 39.2; compare to fig. 39.1).

The planarity of the canvas is now visibly more congruent with the age of the paint layer, as it no longer has the rigid tautness it did before. Six horizontal cracks spanning the painting's width are more prominent, resulting in subtle planar distortions that are visible in the final stretching (fig. 39.3). These cracks likely relate to when it was rolled during Braque's evacuation from Paris at the outset of World War II; their return makes visible an aspect of the painting's history that was previously masked by the lining's flatness. In addition to evidencing history, this return of dimensionality restores a relationship between paint and support that is more in keeping with Braque's governing thoughts about the artistic process. Favero et al. have eloquently summarized these using an example described by the artist: "For Braque, color was inextricably bound to material and texture: 'Dip two white cloths, but of different material, into the same dye; their color will be different'" (Favero, Mysak, and Khandekar 2013, 99).[8] Restoring the pliancy of the linen that had formerly been restricted by the wax resin creates an interaction between color and support that was previously absent.

In addition to an improved clarity of weave, a number of previously invisible marks became apparent on the back of the canvas after the saturating effect of the wax resin was removed (figs. 39.4, 39.5). There are areas where the ground has seeped through the canvas (fig. 39.6), and several dark marks, some of which follow contours of an underlying figural composition.

Figure 39.4 *Pitcher, Candlestick, and Black Fish* during treatment, back of painting before wax extraction with interleaf intact, under available illumination. The Menil Collection, Houston. Image: © Artists Rights Society (ARS), New York / ADAGP, Paris / Photo: Desirae Dijkema

Figure 39.6 *Pitcher, Candlestick, and Black Fish* during treatment, back of painting after wax extraction, detail. Notice the ground seeping through the canvas in the lower center. Light areas of blanched wax residue that correspond with cracks on the front are seen in the cross-shape form to the right of center and the elliptical shape near the center of the left edge. The Menil Collection, Houston. Image: © Artists Rights Society (ARS), New York / ADAGP, Paris / Photo: Adam Neese

Figure 39.5 *Pitcher, Candlestick, and Black Fish* during treatment, back of painting after wax extraction, under normal illumination. The Menil Collection, Houston. Image: © Artists Rights Society (ARS), New York / ADAGP, Paris / Photo: Adam Neese

Several areas of lighter canvas appeared on the back, including six horizontal lines corresponding with cracks on the front, in addition to a few larger forms, coinciding with areas of thin paint application. It seems likely that these and other intermittent light areas are areas of blanched wax or wax resin left in the canvas interstices. Some of these light areas have fine white deposits; Fourier transform infrared (FTIR) analysis of a sample from one deposit closely matches the reference spectra for wax.[9] Current analysis is inconclusive regarding the presence of a resin such as dammar, Ketone Resin N, or Zonarez B-85, which were common components in the Kecks' wax-resin mixtures.[10] Analysis of the white deposits with gas-chromatography mass-spectrometry is forthcoming. UV photos taken of the back of the canvas after extraction show a faint fluorescence in these areas, suggesting the presence of wax or wax-resin residues (fig. 39.7). The blanching may be related to the higher evaporation rate of solvents at an air interface, such as a comparatively open pathway of a crack versus a solid paint film (Hansen 1970).

Figure 39.7 *Pitcher, Candlestick, and Black Fish* during treatment, back of painting after wax extraction and edge-lining, UV-induced visible fluorescence. The Menil Collection, Houston. Image: © Artists Rights Society (ARS), New York / ADAGP, Paris / Photo: Adam Neese

UV photos were taken of all eight Evolon CR sheets used during treatment as a way of visualizing the wax resin's location after extraction. The sheets on the face showed almost no wax-resin absorption, save for residues on the tacking margins and turnover edges. The acting solvent layers show an even distribution of wax resin, as do the dry wicking layers placed underneath for the first half of the treatment rounds. The wicking layer that was placed underneath the acting solvent layer for the second half of the treatment rounds shows an uneven distribution and minimal absorption of wax resin. Comparison with the front of the painting indicates that the distribution of wax resin in the wicking layer corresponds to cracks and thin paint layers. As mentioned, the pattern of UV-fluorescent and blanched material suggests that these areas retained wax throughout each treatment round. It seems likely the wax resin was not removed entirely because a higher solvent evaporation rate inhibited sustained dissolution.

The weight of the canvas decreased by 14%, a percentage significantly lower than the weight changes that were achieved during the most successful trials, which were consistently over 30%.[11] The percentage difference between the trials and the painting does not necessarily mean less wax resin was removed, however, because—when compared to the lining canvas strips—the wax resin contributed less to the weight of the painting due to the paint and ground layers.

Spectrophotometry measurements were taken from fifteen locations in total: three from the ground on the tacking margins and twelve from areas within the face of the painting. The measurements of the ground on the tacking margins confirmed quantitatively what is apparent visually: the color of the ground became lighter and warmer.[12] The ΔE_{76} of an average of three measurements taken from the ground is 4.12 ± 0.41, the L* increased by 3.71 ± 0.37 toward white, the a* increased by 0.537 ± 0.12 toward red, and the b* increased by 1.71 ± 0.20 toward yellow. It is likely that the reduction in wax resin increased scattering, resulting in a brighter color (Rees Jones 1991).

Following the wax-resin extraction, the tacking margins received an edge-lining with linen and Beva 371 film. During restretching, some consolidation was necessary along the turnover edges, and it was possible to use sturgeon glue, indicating the possibility of treatment with aqueous methods. The painting will receive a rigid backing board and will be reframed and glazed.

MOVING FORWARD

There are several avenues that deserve further research. The time at which the wicking layer is changed out should be reconsidered. The wicking layer that was in place for the *first* half of each treatment round appears to have absorbed an amount of wax resin that is comparable to the xylenes-saturated sheet. The wicking layer that was in place for the *second* half of each round appears to have absorbed the least amount of wax resin. Perhaps the xylenes-saturated sheet above the wicking layer became too saturated with wax resin by this point in the treatment to allow further absorption below it. Or perhaps there was not enough solvent in the system to encourage movement of the wax resin into the Evolon CR. Understanding the timeline of wax-resin absorption better could help to bring about more efficient future treatments.

Exactly what was extracted needs to be identified. Does what was removed correspond with the components of the wax-resin mixture? Have certain materials been preferentially removed? Are there differences between the composition of the material present on the Evolon CR on the back and that on the front? Analysis is pending on extractions from the Evolon CR sheets used during treatment.

It is worth exploring whether there are alternative hydrocarbon solvents that would be equally effective. As evidenced by the solvent-immersion test, ShellSol OMS actually extracted a similar amount of wax resin by weight to xylenes (32% compared to 31%). Clearly, it had an affinity for the wax-resin mixture, but it takes longer to work. Solvents with similar properties should be explored, perhaps ShellSol D38.

Weight loss per surface area should be measured instead of weight change percentages, as Gunnar Heydenreich did in his 1994 wax-resin extraction treatment (Heydenreich 1994, 25). This will more easily allow for comparison of wax-resin loss across samples of varying weights and sizes. The impact of a higher solvent volume on the amount of wax resin extracted should be explored with more trials. Perhaps using a higher volume with a shorter treatment duration could optimize the amount of wax resin extracted while minimizing solvent and heat exposure.

We need to better understand what is causing the blanching around cracks and areas of thin paint. Is it related to incomplete wax-resin removal, a higher rate of solvent evaporation, or a combination?

CONCLUSION

Wax-resin linings have a mixed legacy—they partially address physics at the expense of certain aesthetics. Qualities like saturation and color harmony are sacrificed for a planarity free from distortions that can impair legibility. Though wax-resin impregnation has been shown to improve tensile properties (Hedley 1975) and increase protection against changes in humidity for short exposure times (Young and Ackroyd 2001), it has also been shown to increase contraction forces resulting from long exposures to high humidity (Andersen et al. 2014).

Its impact on color change is similarly contradictory. Wax-resin linings affect color saturation to varying degrees, dependent upon the presence of sizing, pigment type, medium type, layer thickness, and hiding power (Nieder, Hendricks, and Burnstock 2011, 98; Froment 2019, 439). Bomford and Staniforth have demonstrated that wax-resin impregnation has a significant impact on the color of canvas of varying weights as well as grounds of differing compositions, particularly those that are underbound, but whether such a change is visible in the painting is dependent on the degree to which the canvas or ground plays a visible role in the composition (Bomford and Staniforth 1981). Though recent studies have indicated that certain artists chose to have their paintings lined very early in a painting's life or even during the painting process (Hackney 2004b), it is clear from Richardson's writings that Braque preferred a surface in which the variable qualities of stretched canvas are visible.

A treatment such as this one is not undertaken lightly. In terms of solvent amounts and their potential effects on paint films, the treatment is not dissimilar to the process of cleaning. Above all, the words of the artist offer direction. Without its lining, *Pitcher, Candlestick, and Black Fish* presents a planarity that is more congruent with its age and honors its history. Furthermore, reduction of the wax-resin adhesive allows physical response to environmental fluctuations. Perhaps most importantly, it restores the relationship of the canvas's materiality and paint layers to one more in keeping with Braque's artistic practice. When considering Braque's statements about the interconnectedness of those two elements at the start of treatment, the question became: Why continue to subject it to this rack-like torture?

ACKNOWLEDGMENTS

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APPENDIX A: MATERIALS AND SUPPLIERS

DMF-0.65, hexamethyldisiloxane, a linear silicone solvent (not to be confused with dimethylformamide) that is completely volatile. Average viscosity 0.65 cst at 25°C. Shepard Bros., Inc. http://www.shepardbros.com

CSF-4 octamethylcyclotetrasiloxane, cyclic silicone solvent that is completely volatile at flash point: 59°C, Shepard Bros., Inc. http://www.shepardbros.com

Dartek F-101, cast nylon film (nylon 6,6). Distributor: TALAS. http://www.talasonline.com

Digital Bench Toploading Balance (for lining canvas strips): APX-153, Apex Series Balances, Denver Instrument, discontinued

Digital bench scale (for painting): CPWplus 35, Adam Equipment. https://www.globalindustrial.com/p/adam-bench-weighing-scale-75lb

Evolon CR, nonwoven fabric composed of polyester and nylon microfilaments, Deffner and Johann. https://deffner-johann.de/en/evolonr-cr-on-roll-102-cm-x-10-m.html

Hollytex, made from acid-free, fine, nonwoven, spun-bonded 100% polyester. Distributor: TALAS. http://www.talasonline.com

Infrared thermometer: Etekcity Lasergrip 774 Noncontact Digital Laser / Temperature Gun.

ShellSol Odorless Mineral Spirits, distributed by Conservation Support Systems, Santa Barbara. https://conservationsupportsystems.com/main

Sigma Aldrich Xylenes, ≥98.5% xylenes, ethylbenzene basis. https://www.sigmaaldrich.com/US/en/product/sigald/247642

Spectrophotometer: Konica Minolta CM 700d, 8 mm aperture, SCI (specular component included) / SCE (specular component excluded). https://sensing.konicaminolta.us/us/products/cm-700d-spectrophotometer/

APPENDIX B: TRIAL PROCEDURE

All trials involved the following procedure with adjustments for specific variables:

- The material stacks were covered with Dartek and cycled between 50ºC and 63ºC for 70 minutes at two to seven mbar suction.
- Halfway through, the wicking layer was replaced with a new, dry sheet of Evolon CR.
- The entire process was repeated for a second round.
- The weight of the lining canvas strip was measured before and after rounds 1 and 2, and percentage weight loss was calculated by dividing the difference of a lining canvas strip's weight from before round 1 and after round 2 by the initial weight of the lining canvas strip and then multiplying by 100. (Lining canvas strips were allowed to desaturate through evaporation for at least two days before weight measurements after round 2.)
- Evolon CR was loaded with solvent by weight: first the weight of the Evolon CR sheet was measured, then multiplied by two or three to determine the solvent weight. Solvent was added dropwise to the Evolon CR and sealed in a glass jar for two to twenty-four hours before the beginning of a trial.

NOTES

1. It is assumed that "superficial cleaning" refers to dirt removal. Keck's treatment report says the painting was varnished but does not say with what. At the time they were treating *Pitcher*, the Kecks were also treating a Picasso from the de Menils, which *is* documented as receiving a poly butyl methacrylate lining in the same treatment report as Braque's *Pitcher* (Caroline Keck, letter in the conservation file, March 13, 1961). Sample T 703 s14 taken from a scraping in the varnish atop a yellow band in the background near the top center exhibited a spectrum that, through spectral subtraction, indicated that a butyl methacrylate–containing species could be present. Attenuated total reflectance (ATR) Fourier transform infrared (FTIR) spectra were collected by C. E. Rogge using a Lumos FTIR microscope equipped with a motorized germanium ATR crystal with a 100 µm tip (Bruker). The spectra are an average of 64 scans at 4 c^{-1} spectral resolution, and an ATR correction was automatically applied by the Opus 7.0 instrument control and data collection software.
2. Caroline Keck, letter to Mrs. de Menil in the conservation file, February 9, 1961.
3. The painting was surface cleaned with saliva, the poly butyl methacrylate coating was removed with ShellSol A100 and cotton swabs, and the bleached shellac coating was removed with a sequential application of isopropanol and 2,2,4 trimethyl pentane (iso-octane) applied with cotton swabs or a brush while working underneath the microscope.
4. FTIR data taken by C. E. Rogge, using the same instrumental parameters as described in note 1 above. Photographs of the varnished painting taken under UV illumination showed a coating with a blue-green fluorescence, rather than the characteristic orange fluorescence typically associated with shellac. Chemical bleaching destroys the compounds responsible for the orange fluorescence. See Sutherland 2010.
5. The face was defined as the side that had the least amount of wax resin.
6. Evolon CR belongs to a line of fabrics made by Freudenberg that have a wide variety of uses, including anti-mite bedding, cleaning cloths, sound absorption, and sun protection. Evolon CR was developed by Deffner & Johann, a conservation materials and tools supplier in Germany, in discussion with the manufacturer specifically for use in conservation. It is PVC-free and produced without solvents or binders. See "Evolon CR," Deffner & Johann, accessed June 26, 2010, https://deffner-johann.de/en/evolonr-cr-on-roll-102-cm-x-10-m.html. Freudenberg Performance Materials, "Key Benefits of Evolon Technology," https://evolon.freudenberg-pm.com/evolon_technology/key-benefits, accessed April 12, 2022.
7. Other variables considered include the introduction of the superficial solvent as free solvent brushed over the surface or introduced by means of saturated Evolon CR; both produced similarly successful results. In practice, the saturated Evolon sheets proved a more reliable way of delivering a known amount of solvent uniformly across the surface and eliminating the variable pressure and delivery volumes associated with brush application. It should be noted, however, that the use of Evolon CR prevents observation of the paint surface during treatment.

8. Favero et al. translated Braque as quoted in an interview with Dora Vallier, “Braque: La Peinture et nous: Propos de l’artiste recueillis par Dora Vallier,” *Cahiers d’art*, no. 1 (1954): 16–22.

9. FTIR data were collected by C. E. Rogge on June 23, 2020, with the same instrumental parameters given in note 1 above.

10. Corina Rogge, FTIR spectroscopy results, June 23, 2020: “The background absorbance in the 1100-900 c^{-1} range is higher in this portion of the sample suggesting additional materials are present, but the low amounts, weak signal and lack of characteristic peaks preclude identification.”

11. Percentage of weight loss was calculated by dividing the difference of the painting’s weight before and after treatment by its weight before treatment and multiplying by 100.

12. Only the results from the measurements on the tacking margins are included here, as three measurements were taken, which permits calculation of standard deviation. The difference perceptible to the human eye has been a subject of debate in the literature since the 1980s. Some authors suggest that one CIELAB unit (1ΔE*) corresponds to the smallest difference that is perceivable to the naked eye, while other authors suggest it is between one and two units, and others above two. For purposes of comparison with other research, a ΔE* of 1 was defined as the perceptible limit in this paper. See Froment 2019, 140.

40

Local Treatments of Cupped Cracks in Contemporary Paintings and Their Appearance after Twenty-One Years

Mary Piper Hough, Head of Paintings Conservation, Library and Archives Canada, Ottawa
Stefan W. Michalski, Heritage Conservation Scientist (retired), Canadian Conservation Institute, Ottawa

Single cracks in contemporary paintings on canvas can be disfiguring due to cupping. In 1999, the authors published a study of fourteen different methods for local treatment of such cracks, applied to slack paintings (Hough and Michalski 1999). Model paintings were created to simulate contemporary paintings of oil paint on acrylic ground on cotton duck fabric. Nine cracks, each 15 cm (6 in.) long, were created in each of nine paintings. Profiles of the treated cracks were monitored over a period ranging from five minutes to seventy days. Only three of the treatments gave good results at seventy days. The results were consistent with the known viscoelastic properties of the materials used. A year later, three paintings were keyed out in order to study the taut condition, where cupping is driven by stress alignment rather than curl, and to study the tendency of the repairs to surface. In 2018–19, the samples were reexamined. Surfacing had become pronounced in many but not all of the samples that had been keyed out: one treatment still looked good. In this paper, the mechanisms causing cupping and surfacing are modeled and the predictions compared to the experimental results.

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INTRODUCTION

Single cracks or localized cracks in contemporary paintings on canvas can be disfiguring due to cupping. A local treatment, if successful, has the advantage of avoiding risks that a whole painting treatment presents to the remainder of the painting. Although cupping may be removed temporarily by moisture, solvent vapors, and/or heat, maintaining flatness may require reinforcements, which in turn may surface.[1] In 1999, we published a study of fourteen different methods for local treatments of such cracks in slack paintings (Hough and Michalski 1999). Here, we will discuss the appearance of these treatments in paintings twenty-one years later, with and without keying out (i.e., with both taut and slack conditions).

MECHANICAL MODELING

Curl and Stress Alignment

During curing, paint layers (which are “fatter” layers) attempt to shrink more than ground layers (which are “lean”). If a crack forms and if the painting is slack, this differential shrinkage curls the painting at the crack, as shown in figure 40.1a.

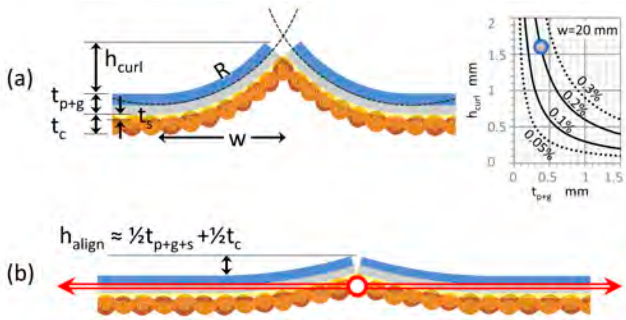

Figure 40.1 (a) Curl, caused by greater shrinkage in the paint (blue) than in the ground (gray). Inset graph for curl height for various differential shrinkages and a width of 20 mm, assuming no restraint by the size of the canvas (slack). (b) Stress alignment (red line) in a taut painting. The canvas hinge (red circle in center) aligns with the stress that is centered in the intact size, ground and paint adjacent. (R) radius, (h) height, (t) thickness, (w) width. Subscripts: (p) paint, (g) ground, (s) size, (c) canvas. Image: © Mary Piper Hough and Stefan W. Michalski

By combining equations from geometry with Timoshenko's equation for curvature of a two-layer laminate (Timoshenko 1925), we can derive the height of the curl in the paint-ground laminate.[2] Height depends on the difference in shrinkages, the thickness of the laminate (in this case, paint and ground), and the width (w) of the region that is free to curl. The inset graph in figure 40.1 shows cupping height (y-axis) for various laminate thicknesses (x-axis), for paintings where the paint layers are equal to, or not more than a few times thicker than, the ground, and are not especially soft compared to the ground.[3] Plots are shown for a range of differential shrinkages, with 0.2% as a difference we can expect for an oil paint on a lean ground, whether oil or acrylic.[4] The blue circle marks the predicted curl for the model paintings in this study. Much larger shrinkages due to severe aging or solvent leaching will drive much larger curl.

The size layer is not considered in this model for curl (equations for a three-layer system are beyond the scope of this paper). However, one can expect shrinkage of the size layer to counteract shrinkage of the paint layer, especially at low humidities, but in Hough's measurements of curl in the experimental samples (see "Profile Measurement" below), curl definitely increased with lower RH (Hough 2000, fig. 11),[5] showing that shrinkage of the paint layer dominated shrinkage of the size layer. We can qualify this simple two-layer model for curl, paint-ground, as an estimate of the maximum expected curl.

Where the painting is cracked, the canvas acts as a hinge (fig. 40.1b). Curl is then limited by the surrounding area of the painting plus any overall tension. If the painting is keyed out, the canvas hinge and the cupping are pulled toward flatness, but this flattening reaches a limit when the canvas hinge aligns with the center of the tension located in the size, ground, and paint layers of the uncracked regions.[6] Cupping cannot be flattened beyond this limit no matter how much tension is applied. This flattening limit h_{align} is equal to at least half the combined thickness of canvas, size, and ground (for low-stiffness paint) and at most half the combined thickness of canvas, size, ground, and paint (for high-stiffness paints). In figure 40.1b, the simplest situation has been assumed, where the red line is in the middle of the size-ground-paint laminate.

Surfacing Mechanisms

If a reinforcement is added to the verso and if the painting has zero tension, then the result shown in figure 40.2a is plausible. In a painting with some tension (driven by keying out, gravity, or low humidity), the reinforcement will surface with a profile somewhere between the two extremes: a ridge if the reinforcement behaves like a chain (fig. 40.2b), or a plateau if the reinforcement behaves like a plate (fig. 40.2c). Additional distortions may be superimposed if there is differential swelling or shrinkage driven by heat, plasticizer, solvents, moisture, or an adhesive.

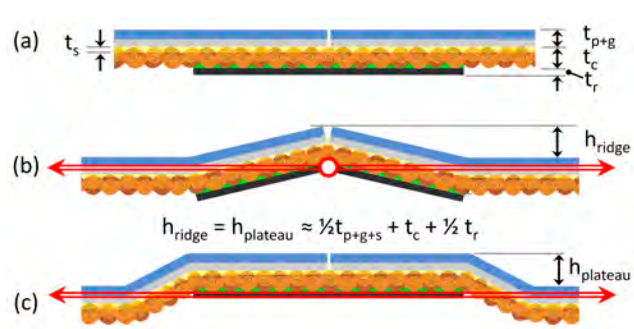

Figure 40.2 The three conformations of a locally reinforced crack when under tension. (a) The desired state, when paint and reinforcement are completely inflexible (plate-like). (b) Ridge surfacing, due to stress alignment of a flexible reinforcement (chain-like) with a flexible painting (chain-like). (c) Plateau surfacing, due to stress alignment of a rigid reinforcement (plate-like) with a flexible painting (chain-like). Subscripts: (p) paint; (g) ground; (s) size; (c) canvas; (r) reinforcement. Image: © Mary Piper Hough and Stefan W. Michalski

The deformations shown in figures 40.1 and 40.2 are not static; they can only be measured and understood within the framework of viscoelastic mechanics; that is, one must consider time. Large elastic deformations of paints can be accomplished in as little as seconds when high temperature and plasticizer are used, whereas at room temperature, large elastic movements take months or years. On the one hand, trying to bend a paint film quickly at room temperature will fracture it; on the other hand, successfully flattened paint can recover the memory of its old deformation over the course of months and years. (For a theoretical background, see papers in these proceedings by Hagan and by Daly-Hartin, Michalski, and Hagan.)

To maintain flatness over the years, a reinforcement must stress relax much more slowly than the paint layers. This suggests that one should select either inorganic materials (metal, glass) or highly cross-linked, filled polymers.

Butt Joints

Theoretically, the ideal solution to cupping at a crack would be to repair the crack itself—to make a butt joint. It is, unfortunately, extremely difficult in practice to make a butt joint that is continuous, reliable, and invisible.

EXPERIMENTS

The aims of the study were as follows:

- Make cracked model paintings that exhibit significant cupping
- Subject the cracks to local treatments, orthodox and novel, that attempt to flatten cupping and restrain its reappearance
- Document the cupping heights of the cracks as a function of time
- Determine which treatments, if any, are visually acceptable
- Apply the models of viscoelastic mechanics to the interpretation of the results

Preparation of Model Paintings

The model paintings follow a technique often used by artists from 1950s onward: oil paint on acrylic ground on cotton duck fabric. One or more localized disfiguring cracks have often been observed in such paintings. Nine paintings were prepared on commercial stretchers, 61 × 168 cm (24 × 66 in.), in landscape orientation. Two wide, vertical crossbars were rigidly attached to the top and bottom stretcher bars, so that tension could be released in the horizontal axis without disturbing the vertical axis. The corners of the stretcher were expanded 6 mm in each direction prior to application of the canvas, to permit slackening when needed.

After stretching the cotton duck, the perimeter was masked to create a 7.6 cm (3 in.) border of uncoated fabric. This flexible border reduced tension in the painted area, simulating the large slack paintings that were the focus of the study. The cotton was coated with three layers of acrylic ground, followed by six layers of lead white/zinc white oil paint. The total thickness of the ground roughly equaled the thickness of the paint. All layers were monitored by weight to ensure uniform application.

Cracking and Heat Aging of Model Paintings

To create multiple uniform cracks, a guillotine-like apparatus was made. The apparatus and painting were kept in a cold room at −5°C (±2°C) to ensure brittle, glassy behavior during impact. The painting was placed facedown over a narrow trench, and the dull blade was dropped. The amount of indentation was limited by an adjustable stop to avoid plastic deformation. Nine 15 cm (6 in.) cracks were created in each painting, parallel to the short dimension and spaced evenly along the long dimension. Fairly consistent, clean fractures with very little distortion of the canvas were obtained.

The paintings were keyed in to slacken them in the direction perpendicular to the cracks to facilitate curl. They were then heat aged for nineteen days at 41°C to speed any curing and relaxation processes prior to treatment (fig. 40.3).

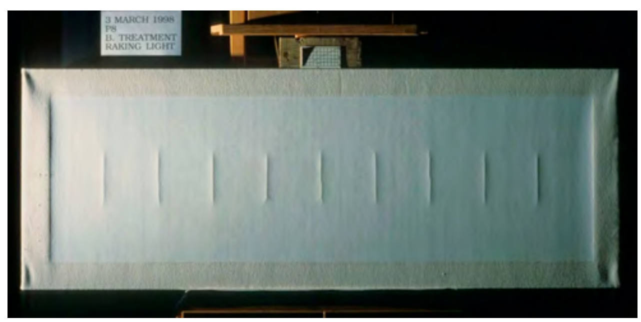

Figure 40.3 Raking-light image taken before treatment of one of the model paintings. Each of the nine cracks was slackened in the direction perpendicular to the cracks to facilitate curl. The raking light used in this photograph at the beginning of the testing was less extreme and less sharp than that used in subsequent figures. Image: © Mary Piper Hough and Stefan W. Michalski

Experimental Treatments

Of the fourteen local treatments tested, one included moisture and heat alone with no reinforcement; others included various sizing or adhesive methods, and eight were variations on the application of thin reinforcing strips adhered across the crack verso. Two implausible treatments using rigid plates applied to the crack verso were tested to establish baseline “flatness” data. Some treatments were derived from those in use at the time in the local treatment of cupped cracks or of tears; others were experimental designs. Variation in the resulting degree of stiffness was a main reason for choosing a treatment to see its ability to hold the cupping flat. Important also were the application from the verso, especially for paintings with sensitive surfaces, and the ease of removability of the added reinforcement. The treatments varied in the location of the added element, the adhesive, the reinforcement, or both, some of which have consequences for surfacing.

During treatment, the painting was placed facedown, and each crack was held flat for about thirty hours using a purpose-built suction table. For most treatments (2–11), the reinforcement was applied to the crack verso while the crack was held flat under suction. Eight simple suction tables were made to allow multiple treatments to be performed in one day, since pressure needed to be maintained for drying or curing.

All the strips of material used in treatments 4–11 were fabricated so that their thickness was the same (0.50 mm ± 0.05 mm). This thickness was fixed by the stainless-steel strips of treatment 4 (0.48 mm). Width varied between 0.64 mm (stainless-steel strips) and 2 mm. Various casting and molding techniques were employed, and a micrometer was used to check thicknesses. Strips 8 and 9 (wet treatments) were molded in situ, with steel strips present as thickness gauges. All strip treatments were applied across the crack verso and were spaced at 3.2 mm (1/8 in.) intervals, with alternating lengths of 25.4 mm and 12.7 mm (1 in., 1/2 in.), except treatment 8. Verso images of some treatments are shown in figure 40.4.

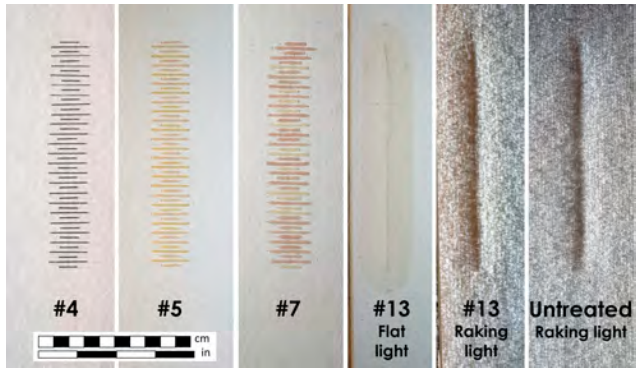

Figure 40.4 Verso images of four treated cracks showing strips (treatments 4, 5, 7) and size (treatment 13). Raking-light images show cupping of canvas for 13 and an untreated crack. Image: © Mary Piper Hough and Stefan W. Michalski

Details of each treatment are as follows:

1. Moisture, heat, and flattening; no reinforcement. Moisture was applied to the crack area at recto using damp, felted Gore-Tex for twenty-four hours, followed by suction from recto and heat from verso.
2. Acrylic plate, 3.2 mm thick, applied to the canvas over a wide area with five-minute epoxy. This was a benchmark reinforcement for experimental purposes, not a suggested treatment for paintings.
3. Epoxy/aluminum foil plate, 50 mm wide, attached with two layers of Beva 371 film.[7] This was an exploratory treatment designed to test the behavior of very thin aluminum composites and continuous patches.
4. Individual stainless-steel strips (0.48 mm × 0.64 mm orthodontic “wire” with rectangular cross-section); attached with two layers of Beva 371 film.
5. Strips made of Epoweld 3672 epoxy filled with full-length glass filaments (50 µm diameter), oven-heated to improve curing of the epoxy; attached with two layers of Beva 371 film.
6. Strips made of polyester threads coated with epoxy (Epoweld 3672), oven-heated; attached with two layers of Beva 371 film.
7. Strips made of polyester threads coated with epoxy (Epoweld 3672), allowed to cure at room temperature; attached with two layers of Beva 371 film.

8. Strips made of polyester threads coated with epoxy (Epoweld 3672), applied wet to the crack verso. Four variations on thread length and spacing were tried.

9. Strips made of polyester thread coated with PVA (Jade 403), applied wet.

10. Beva 371 size (1:1 naphtha) applied to verso of the crack area, 12.7 mm on each side of the crack, and dried for two days. A hot aluminum plate was applied, and the area was left to cool. Strips from treatment 6 were attached with two layers of Beva 371 film.

11. Acryloid B-72 size (20% in xylene) applied to verso of crack area, 12.7 mm on each side of the crack, and dried for two days. A hot aluminum plate was applied, and the area was left to cool. Strips from treatment 6 were attached with two layers of Beva 371 film.

12. Beva 371 size (1:1 naphtha) applied to verso of crack area, 12.7 mm on each side of the crack, and dried for two days. A hot aluminum plate was applied, and the area was left to cool. No reinforcement.

13. Acryloid B-72 size (20% in xylene) applied to verso of crack area, 12.7 mm on each side of the crack, and dried for two days. A hot aluminum plate was applied, and the area was left to cool. No reinforcement.

14. Epoxy (EPO-TEK 301) flowed into the crack from the recto to adhere the two fracture faces in a butt joint. Unlike in treatments 1–13, suction was applied from the verso by a Mitka suction table with the painting faceup. Then a hard, flat weight was applied over the crack area for twenty-four hours.

Profile Measurement

In the first phase of the study, the profiles of each crack were scanned using a mechanical scanner developed for this project. The scanner provided a profile of a 20.5 cm (8 in.) line perpendicular to the center of the crack, with a sensitivity of about 1μm in height. Unfortunately, over the years the scanner had been discarded, so for the height measurements at twenty-one years, we used calibrated raking-light photographs. Calibration was made using a 0.6 mm leaf from a feeler gauge, held firmly below each crack by magnets behind the painting.

For further information on the experimental methods and materials, and initial results for the slack painting condition, please refer to our article (Hough and Michalski 1999) or Hough's thesis (Hough 2000).

Taut Painting Condition

A year after the first stage of the project ended, three paintings that contained at least one of almost all the treatments were keyed out in order to study the taut condition where cupping is driven by stress alignment rather than curl, and to study the tendency of the repairs to surface. To ensure reproducible movement, a central crossbar was added to the long dimension, with adjustable turnbuckles that controlled tension perpendicular to the cracks (fig. 40.5). The arrangement of the nine cracks in a row ensured that even if carefully calibrated keying out did not yield exactly the same tension across all paintings, at least within each painting, samples would be subject to equal tension and could be compared directly and reliably.

Figure 40.5 Verso of a model painting that was keyed out. Vertical crossbars were present on all paintings. The horizontal crossbar with turnbuckle expansion bolts at each end was added to paintings that were keyed out. Sliding metal guides at each end prevented twisting of the vertical stretcher bars. Image: © Mary Piper Hough and Stefan W. Michalski

RESULTS

Results for each treatment are summarized in table 40.1 and presented visually in figures 40.6 and 40.7. Cupping heights over time for all treatments are plotted in figure 40.8. Here, only the highlights are noted, with further detail provided in the Discussion section.

Table 40.1
Summary of treatment results

Treatment					Results: Visual appearance of crack in raking light (time after treatment)			
	No.	**Size**	**Reinforcement**	**Adhesive**	**Painting slack (70 days)**	**Painting slack (21 years)**	**Painting taut (21 years)**	**Images (21 years)**
Moisture and heat	1	Moisture, heat + flattening alone. No size, no reinforcement, no adhesive			Initially 1/2 height; in a few days, approached before-treatment height with more gradual slope; at 2 months, original steeper slope reappeared: crack profile narrowed + aperture opened	Crack has the appearance of an untreated crack	Crack has the appearance of an untreated crack; cupping height lower than in slack painting	Fig. 40.7
Plates, for reference	2	—	Acrylic, 3.2 mm	Epoxy	Crack appeared flat; plate perimeter surfaced	Same as 70 days after treatment	NA—not keyed out	Fig. 40.7
	3	—	Epoxy/ aluminum foil, 0.3 mm	Beva 371 film	Crack appeared flat; plate perimeter surfaced	Crack has slightly raised; surfacing still present	NA—not keyed out	Fig. 40.7
Strips	4	—	Stainless-steel strips	Beva 371 film	Crack slightly raised	Crack raised slightly higher; no surfacing	Same as for slack painting	Figs. 40.4, 40.6, 40.7
	5	—	Epoxy/glass filaments; heat cured	Beva 371 film	Crack slightly raised	Crack still appears slightly raised; no surfacing	Crack remains slightly raised; however, now with surfacing due to bending of strips; gradual slope	Figs. 40.4, 40.7
	6	—	Epoxy/ polyester threads; heat cured	Beva 371 film	Crack slightly to moderately raised; epoxy heat curing appears significant in stiffening compared to treatment 7	Crack is moderately raised; no surfacing	Crack appears moderately to fully raised; surfacing is present	Fig. 40.7
	7	—	Epoxy/ polyester threads; room cured	Beva 371 film	Crack moderately raised	Crack is moderately raised, height higher; no surfacing	NA—not keyed out	Fig. 40.4
	8	—	Epoxy/ polyester threads; room cured	Threads applied wet	Crack slightly raised; epoxy flowed intermittently into crack for greater height control, resulting in stitched appearance	Crack moderately to fully raised; stitched appearance; no surfacing	Cupping height is lower than in slack painting; stitched appearance; surfacing is present	Figs. 40.6, 40.7
	9	—	Jade 403/ polyester threads	Threads applied wet	Initially 1/2 height; in a few days, approached before-treatment height with gradual slope; at 70 days, original steeper slope reappeared	Crack has appearance of an untreated crack; no surfacing	NA—not keyed out	Fig. 40.7
Size + strips	10	Beva 371, heat	Epoxy/ polyester threads; heat cured	Beva 371 film	Crack was slightly raised; slight moating in sized area	Crack is slightly to moderately raised; strong	Crack approaches appearance of untreated; keying out removed appearance	Figs. 40.6, 40.7

Treatment					Results: Visual appearance of crack in raking light (time after treatment)			
	No.	**Size**	**Reinforcement**	**Adhesive**	**Painting slack (70 days)**	**Painting slack (21 years)**	**Painting taut (21 years)**	**Images (21 years)**
						moating, no surfacing	of moating; surfacing present	
	11	B-72, heat	Epoxy/ polyester threads; heat cured	Beva 371 film	Crack appeared moderately raised; strong moating in sized area	Crack is slightly to moderately raised; severe moating, no surfacing	Crack approaches appearance of untreated; slight moating is visible; surfacing present	Fig. 40.7
Size alone	12	Beva 371, heat	—	—	Crack appeared slightly to moderately raised; sized area was moderately moated	Crack has appearance of untreated; slight moating is visible: no surfacing	Cupping height is lower than in slack painting; moating not apparent; no surfacing	Fig. 40.7
	13	B-72, heat	—	—	Crack appeared to be half of before-treatment height; sized area was severely moated	Crack has appearance of untreated; strong moating is visible; no surfacing	Cupping height is lower than in slack painting; moating is minimized; no surfacing	Fig. 40.7
Butt joint	14	—	—	Epoxy butt joint	Crack appeared moderately raised	Crack appears moderately raised; no surfacing	Crack appears moderately raised; no surfacing	Figs. 40.6, 40.7

Table: Mary Piper Hough and Stefan W. Michalski

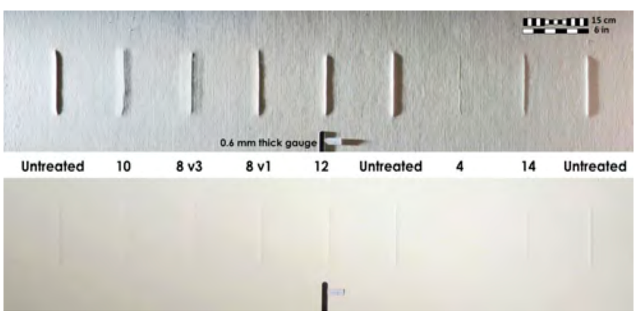

Figure 40.6 Two photographs of a painting that contains a sample of treatment 4, the most successful of those tested, taken 21 years after treatment and 20 years after keying out. Top: raking light 1:40 from the left. Bottom: 30-degree lighting from the left. Image: © Mary Piper Hough and Stefan W. Michalski

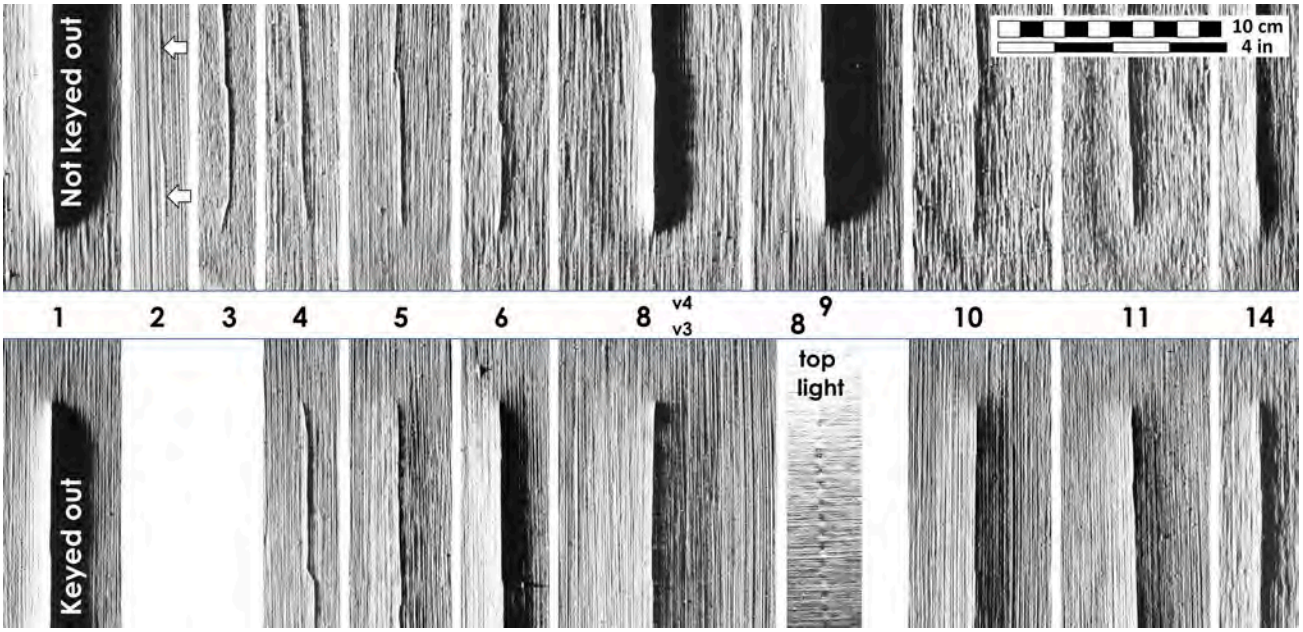

Figure 40.7 Raking-light close-ups of individual treated cracks after 21 years. Top row: samples in slack paintings. Bottom row: the same treatments in taut paintings (keyed out 20 years ago). For clarity, the images have been changed to grayscale and their contrast increased. Image: © Mary Piper Hough and Stefan W. Michalski

During the early monitoring of the cracked model paintings, prior to any treatment, cupping increased after the tension was released, exceeding the painting's half thickness, thus confirming curl as the dominant driving force (Hough and Michalski 1999, fig. 7).

After the first seventy days, before any keying out, only three of the treatments (4, 5, 6) were successful in terms of visual appearance—rigid enough to hold the cupping down and insubstantial enough not to create new distortions.

After twenty-one years of being slack, only 4 and 5 remained visually acceptable, and no surfacing was present (see fig. 40.7, top row).

After twenty years of being taut (keyed out), many treatments showed pronounced ridge surfacing (see fig. 40.7, bottom row). Only 4 was successful: it held the cupping almost flat but did not provoke plateau surfacing. One of the treatment 4 samples is shown in figure 40.6, alongside other treatments as well as untreated cracks within a single painting.

For treatment 8, the epoxy was allowed to set up for a period before the suction was turned on. Despite this time allowance, the suction pulled the epoxy into the crack face, partially closing the crack and holding it flat intermittently—resulting in a partial (inadvertent) butt joint. This is visible when raking light comes from above, as in figure 40.7, bottom row: the crack has a stitched appearance and a comb-like shadow.

The cupping in the untreated cracks reached heights of ~0.7 mm in the slack paintings. In the keyed-out paintings, the cupping reached only ~0.51 mm, less than in the slack paintings, as expected (see fig. 40.1). On the verso, the canvas has followed the curling paint layers. No delamination was noticed in any of the samples.

DISCUSSION

Final States of Treatments after Twenty-One Years

In terms of the predictions of curl (see fig. 40.1a), given the ~0.38 mm thickness of paint and ground for the model painting, assuming a region for unrestrained curl about 20 mm wide on each side of the cracks, and assuming the shrinkage differential between oil paint and acrylic ground of 0.2% estimated earlier, the result places the blue circle in the inset graph in figure 40.1, predicting a cupping height of ~1.6 mm. The average cupping height of untreated cracks in slack paintings, 0.68 mm, is less than half of this estimate, implying either that the estimate of shrinkage is too high or, more likely, that the canvas hinge (and perhaps the size) is restraining curl.

In terms of the predictions of stress alignment without reinforcements (see fig. 40.1b), given the thickness of the paint and ground, ~0.38 mm, and the canvas thickness of ~0.76 mm, then by the equation in figure 40.1b, we expect untreated, heat/moisture-treated, or size-treated cracks to have cupping height of ~0.57 mm. Untreated cracks in taut paintings (three samples) reached 0.51 ± 0.02 mm. If we estimate that half the ground sank into the canvas weave, then the prediction falls to ~0.52 mm, as observed. The cupping of heat/moisture treatment (1) reached 0.45 mm, 12% lower than untreated cracks, while size treatments (12, 13) reached 0.35 mm, 31% lower.

Keying out created ridge-shaped surfacing in all treatments that used reinforcements, except treatment 4, the steel; that is, all polymer reinforcements and the glass bundles embedded in a polymer bent at the crack, thus creating a ridge, as shown in figure 40.2b. Keying out generated consistent ridging heights: worsening treatments that did well when slack (except treatment 4), and improving treatments that had maximum curl when slack.

Both the ridge surfacing caused by reinforcements under tension and the moating[8] caused by size treatments were precisely aligned with their location on the back of the canvas. There was no complex extension of visible deformation beyond the boundaries of the verso treatment.

In terms of the predictions of surfacing of reinforcements (see figs. 40.2b, 40.2c), given the thickness of all reinforcements of 0.50 ± 0.05 mm and the paint, ground, and canvas thicknesses specified earlier, we expect the height of surfacing to be ~1.2 mm (only ridge surfacing was observed). Heights for reinforced treatments using polymers (6, 8) ranged between 0.35 mm and 0.30 mm, respectively (see fig. 40.8, graph on right, top). The glass fiber reinforcement (5), while successful in a slack painting, surfaced as much as the polymer reinforcements when taut: 0.35 mm. None of the ridge surfacing of reinforcements reached the prediction of stress alignment; all remained at or below 0.45 mm, about a third of our prediction. This suggests that the treatments, although visually unacceptable, had functioned to some extent as intended. From another perspective, it is suggested that the tension applied by the keying out was not severe enough to achieve maximum surfacing.

Only one mystery remained: since the stainless-steel strips, treatment 4, did not bend at the crack, why did they not surface as a plateau instead? The simplest answer is that the amount of tension we provided by keying out was not enough to bend the paint and ground into the S shape required at each edge of the surfacing plateau of figure 40.2c. This is consistent with the conclusion that the tension in the keyed-out paintings, while enough to drive some ridge surfacing of polymer reinforcements, was not enough to drive the maximum predicted. In other words, the keyed-out paintings were tight enough to cause ridge surfacing of flexible reinforcements, but not sufficient to cause noticeable plateau surfacing. Unfortunately, the raking-light measurement method did not show small, gradual profile changes that more sensitive scanning might have detected. Perhaps our expectations of plateau surfacing were biased by observation of old patches that employed generous amounts of glue. These generate huge forces during low humidity, independently of keying out, and are much thicker than the reinforcements we used.

Viscoelastic Response over Time

In the graph on left in figure 40.8, we can follow the viscoelastic behavior of the treatments that were never keyed out, starting at five minutes after they were released from the suction table up to twenty-one years later. This type of graph—the logarithm of an elastic measurement versus the logarithm of time (a log-log plot)—is conventional in viscoelastic studies of polymers, because it can be placed in the context of master curves, as described elsewhere in these proceedings by Daly Hartin et al. and by Hagan. The heavy gray line at the top of the graph on left in figure 40.8 shows the slope of the master curve for stress relaxation of oil paintings measured by Daly Hartin et al. for the range of five minutes to one hundred years, which was 1/13, that is, 1 log unit in height for each 13 log units of time.[9] The overall slope of the treatments that failed (and allowed the cupping to return) is similar to this slope. Even sized samples with a rapid increase in cupping in the first few hours followed by a striking decrease that lasted several months (treatments 10, 11, 12, 13), did return over the years to an overall slope of ~1/13, if one simply considers the first and last data points.

Treatment 1 (heat and moisture) also shows a small wobble in its plot, though not as pronounced as that of the sizes. This plateau between a few days and a few months led us to believe in our 1999 paper that this was a final plateau, but over the last twenty-one years it has returned to its initial rate of climb and reaches just short of completely untreated cracks.

The spread in the five-minute data points shows the diminishing springback of cupping immediately[10] after the suction pressure was released. As expected, heat and moisture without reinforcement (treatment 1) has the

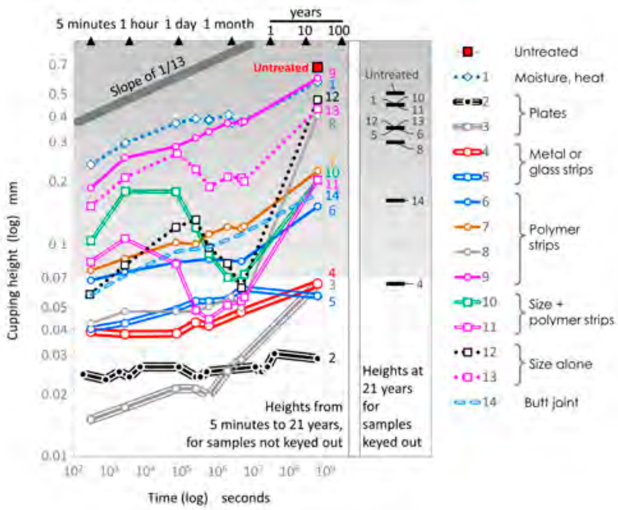

Figure 40.8 Cupping height from five minutes to 21 years. Graph on left shows growth over time for treatments in slack paintings. Graph on right shows single data points for treatments in taut paintings that were keyed out 20 years ago. Gray region indicates heights that are noticeable under normal 30-degree lighting. Image: © Mary Piper Hough and Stefan W. Michalski

largest springback, about one-third of the twenty-one-year cupping; by the first month, the second third recovers. Treatment 9 behaves similarly—demonstrating that a non-cross-linked polymer with a low glass transition temperature, such as the PVA (Jade 403), offers negligible resistance. The benefits, if any, of such treatments are transitory. Remaining five-minute data points are in the expected order of increasing stiffness and less springback: polymer, then glass, then metal.

Since glass fibers (treatment 5) do not relax, the epoxy matrix binding them must have relaxed by shearing between filaments.

The difference between treatments 6 and 7 shows the benefits of heat-curing the epoxy to decrease its relaxation.

The butt joint (treatment 14), although not perfect in adhesion, kept the cupping at around a quarter of untreated heights throughout the duration, while climbing at the master slope of ~1/13.

The benchmark plate treatment (2), which within experimental error can be considered a flat line, demonstrated that it is possible to hold the cupping completely flat with a thermoset adhesive that soaks into the canvas and is cemented to a thick, rigid plate. It also established that the suction table could hold the cupping flat to within 0.025 mm on all treatments prior to release of the suction. The thin aluminum foil treatment (3) did not appear to bend either, but it did allow small cupping to emerge over the twenty-one years, as did treatments 4 and 5. All three showed very slow climbs toward a similar, nondisturbing height at twenty-one years. These cuppings are extremely low and narrow, and although the canvas could easily be seen to follow the large deformations of unsuccessful treatments, it was not possible to determine if the back of the canvas had followed exactly these very small deformations. A cupping height of 0.06 mm is only 8% of the thickness of the canvas (0.76 mm), so a slight bulging of the canvas threads would be enough to allow this curl of paint, and even if Beva entered the threads, as a thermoplastic it could certainly flow over the decades, allowing the canvas to bulge.

CONCLUSIONS

Our conclusions fall into two categories: those that have practical ramifications and those that are more theoretical.

Practical Conclusions

- The application of a local adhesive in solvent (naphtha or xylenes) as a size (treatments 10–13) results in distortions (moating) that do not completely disappear.
- Surfacing of local reinforcements is driven by tension in the painting. Ridge surfacing of flexible reinforcements occurs at lower tension than plateau surfacing of rigid reinforcements (assuming paintings with similar structure to our model painting, or those with even thicker paints or grounds).
- Keeping the first two conclusions in mind, good results are possible if the reinforcement, such as metal, does not stress relax; if it is thin, such as very thin stainless-steel strips (treatment 4); if it is spaced and feathered; and finally, if the painting is under only moderate tension.
- The neatest theoretical solution to both cupping and surfacing would be to adhere the fracture faces in a butt joint. Treatment 14 showed moderately good control of cupping. This treatment may eventually fail, but at least it will never surface. For this reason alone, more study of this option is warranted.
- Data on samples before treatment showed that low RH substantially increases curl (Hough 2000). Low RH also drives overall tension in a painting. Therefore, low RH will drive curl in slack paintings and surfacing in taut paintings.

- Careful lighting can reduce the visibility of cupping.

Theoretical Conclusions

- The slow return of cupping over time is the result of viscoelastic phenomena that are consistent with the master curves for paintings presented by other authors in these proceedings.
- In taut paintings, cupping of untreated cracks or treatments not using reinforcements was consistent with the model predictions for stress alignment.
- In taut paintings, ridge surfacing of reinforced paintings was less than the maximum predicted, indicating that all reinforcements resisted bending to some degree at the level of tension used.

NOTES

1. *Surfacing* refers to the development at the surface of a painting of a deformation that corresponds to the shape of a local repair applied to the verso of the painting, such as a patch.
2. Timoshenko derived the curvature of any two-layer laminate with differential shrinkage. If the differential shrinkage is ($\varepsilon_1 - \varepsilon_2$), m is the ratio of the two thicknesses, n is the ratio of the two moduli of elasticity, and t is the laminate thickness, then radius of curvature is R=(t*(3*(1+m)^2+(1+m*n)*(m^2+1/(m*n))))/(6*($\varepsilon_1 - \varepsilon_2$)*(1+m)^2). The height h of the arc over a base of w and curvature R is h=R-(R^2-w^2). See https://www.mathopenref.com/sagitta.html.
3. Given initial values of m=n=1 (see note 2) a plot of h stays within 25% of initial value despite changes in thickness ratio, n, by a factor of 3, or changes in elasticity ratio, m, by a factor of 7. Heavy impasto, or paints known to be soft, such as poor driers, will need the full equation, rather than the inset graph in figure 40.1.
4. Curing shrinkage of linseed oil was suggested as a contributor to paint failure as early as 1929 (Clark and Tschentke 1929). Pure medium with driers, cured in the dark, shrank 1%–1.6% by volume, so 0.3%–0.5% in length. A paint of 35% pigment volume concentration (PVC) would experience ~65% of pure oil values, so ~0.2–0.3%. A ground at critical PVC would shrink negligibly in comparison. Browne reported dimensional change for films of linseed oil paints after they were released from the casting substrate and exposed to cycles of high RH (Browne 1955). Michalski plotted the nonrecoverable shrinkage from Browne's data: ~0.3% for an oil paint of 30% PVC, consistent with Clark and Tschentke (Michalski 1991, n25).
5. Since the RH in the room where cupping was measured varied gradually over the course of the study, all cupping heights prior to treatment were plotted versus RH in order to derive a correction factor to normalize results to 50% RH. The factor was 2.1% height increase per 1% RH drop, for example, 21% height increase when RH is reduced from 50% to 40% RH (slack paintings).
6. The stress-alignment concept was introduced to our field in an unpublished report by Marion Mecklenburg. His original term was "force realignment" (Mecklenburg 1982).
7. The original formulation of Beva was used in all experiments.
8. Moating is the development of a depression resembling a moat in a treated area of the painting, in this case, a depression encircling the crack.
9. The slope of the stress relaxation is actually negative 1/13, the mirror image of the +1/13 of creeping of cupping.
10. There is no "immediate" time zero in viscoelasticity; the springback would have occurred during several milliseconds as the suction pressure decreased, and with the correct tools one could have measured cupping heights growing from those milliseconds forward to our first data point at five minutes. Milliseconds would enter the glassy plateau shown by Daly Hartin et al. for millisecond events.

VIII

Posters

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Waxing Historical: Preliminary Insights into Wax-Resin Lining Practices at the Brooklyn Museum

Lauren Bradley, Associate Paintings Conservator, Brooklyn Museum, New York
Josh Summer, Louise B. and J. Harwood Cochrane Assistant Conservator of Paintings, Virginia Museum of Fine Arts, Richmond

This short article compiles preliminary findings from an ongoing survey of wax-resin lining treatments performed at Brooklyn Museum (BkM) from 1936 through 1985. BkM's Conservation Department was established in 1934 with the hire of Sheldon Keck and is among the oldest in the United States. BkM holds both the paintings and the associated conservation records for a wide range of canvases treated by Keck, his wife, Caroline, and their protégés; researching this collection has the potential to reveal much about the broader twentieth-century lining movement in the United States. It is estimated that 20%–25% of the canvas paintings in BkM's collection have been wax-resin lined. Lining trends identified within the collection, reasons for lining, and adhesive recipes used at BkM are discussed. Initial survey results challenged some of the authors' preconceptions about historical lining practices at the museum. At the time of publication, nearly half of the conservation files had been evaluated.

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INTRODUCTION

Motivated by an interest in past treatment techniques and a desire to put current Brooklyn Museum (BkM) projects into a historical context, BkM conservators are endeavoring to build an internal database of wax-resin linings through a comprehensive survey of the paintings collection. Using both the conservation records and the paintings themselves, the project aims to reconstruct the history of wax-resin lining practices at BkM. The authors seek not only to identify trends in lining application but also to evaluate the decision-making process behind individual treatments and to assess how they have aged. Because lining materials and techniques have implications for collection care, another goal is to develop a framework that will enable the adhesive recipe to be characterized if only the conservator or date of execution is known, aiding in the establishment of markers for paintings that may warrant condition monitoring. This poster presents an overview of the project and considers preliminary findings from the ongoing survey.

HISTORY

Founded in 1934 with the hire of Sheldon Keck as restorer, the BkM Conservation Department is among the oldest in the United States and was the first established within a New York City institution. The department, which has continuously employed a paintings conservator, holds documentation for a wide range of canvases treated by Keck, his wife, Caroline, who was also an accomplished conservator, and their successors. Researching the BkM conservation records together with the associated paintings has the potential to reveal a great deal about both the approaches to wax-resin lining at the museum and the broader twentieth-century lining movement in the United States.

Documentation has been integral to conservation practice at BkM since the department's beginning. Although reports have become more nuanced over time, many early records were abbreviated, rarely elaborating on the treatment rationale or describing the materials and techniques in a way that would allow the processes to be reproduced. Often reports were unsigned, recipe components were not itemized or quantified, and procedures were summarized using undefined terms (such as "the Dutch method" for lining preparations). With a few notable exceptions, this lack of detail presents challenges in understanding the relationship between current condition issues and previous treatments.

Archival research has provided valuable insights into BkM treatment methods absent in the documentation. In 1954 and 1962, Sheldon and Caroline produced two films for a general audience, both of which illustrate the complex operation of performing a wax-resin lining. The earlier film features a lining executed with a hand iron (fig. 41.1) (Keck and Keck 1954), and in the later one, conservators demonstrate the use of a vacuum hot table (fig. 41.2) (Keck and Keck 1962). In both films, the narration illuminates the reasoning behind each action and material selected. The filmed processes are remarkably consistent with physical evidence of lining observed on many paintings in the collection, such as paper residues on the tacking margins or brush marks and fingerprints on the versos of paintings lined by hand.

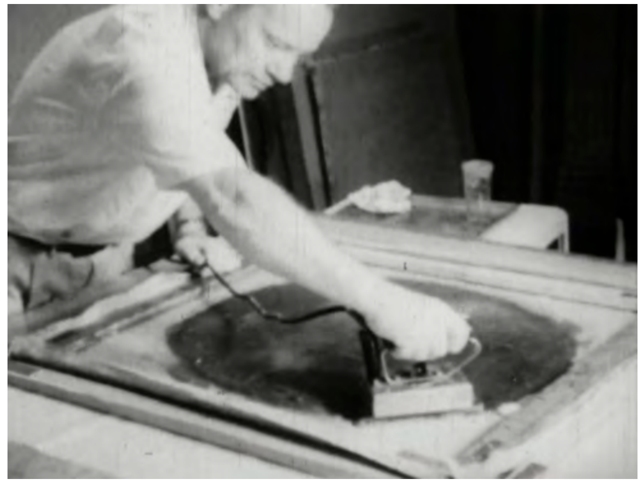

Figure 41.1 Sheldon Keck using a hand iron to infuse a lining canvas with wax-resin adhesive. Film still from Keck and Keck 1954. Image: © Brooklyn Museum / Brooklyn Museum Archives, Audiovisual Collection

Figure 41.2 BkM conservators performing a wax-resin lining on a vacuum hot table. Film still from Keck and Keck 1962. Image: © Brooklyn Museum / Audiovisual collection, Brooklyn Museum Archives

METHODOLOGY

BkM conservation records are kept as paper files and digital assets on The Museum System (TMS) database. The survey to identify wax-resin lined paintings began in 2018 and has advanced according to the paper folder organization system, progressing alphabetically by artist's surname. An Excel spreadsheet was developed to track progress and standardize information gleaned from the records. At the time of publication, over half of the approximately two thousand painting conservation files had been evaluated, around 80% of which pertain to paintings on canvas. The findings presented here derive from the initial sample set of paintings by artists who have surnames starting with *A* through *M.*

PRELIMINARY FINDINGS

Wax-resin linings were performed at BkM over a nearly fifty-year period from 1936 through the mid-1980s, encompassing the rise and fall of the technique's popularity in the United States. Based on the records reviewed to date, the authors hypothesize that 20%–25% of the canvas paintings in the BkM collection are wax-resin lined. The earliest linings were primarily done on paintings that had been in the collection for decades. The institution, with roots dating back to 1823, had been collecting paintings for nearly a hundred years before employing a conservator. In his first years on the job, Keck may have encountered a backlog of paintings in unstable condition that he judged to be in need of lining. The data appear to suggest that, starting in the 1940s, many paintings were lined as they were acquired. This trend is consistent with the developing role of the conservator within the museum. Annual reports from 1938 onward emphasize the practice of examining all artwork considered for acquisition “to make sure of their good condition and authenticity” (Brooklyn Museum 1940, 23).

Most of the paintings wax-resin lined at BkM were between 50 and 125 years old at the time of lining (fig. 41.3), including paintings from the early nineteenth century through the 1930s. Few paintings predating the nineteenth century were lined at BkM, which likely reflects the strength of BkM collection holdings in certain areas.

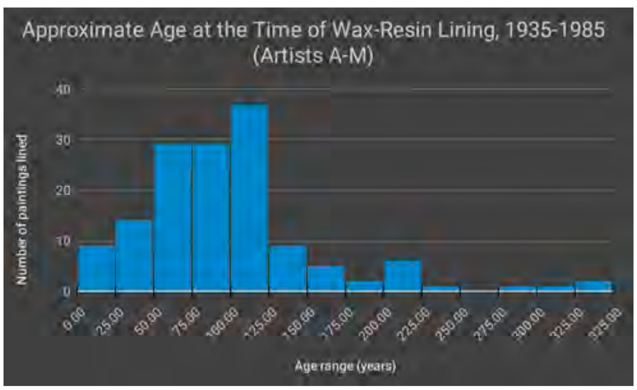

Figure 41.3 Bar graph summarizing the age of paintings when lined with wax resin at BkM (1935–85). Image: Brooklyn Museum Conservation Department

Fluctuations in the number of linings performed each year may correspond with significant events (fig. 41.4). Keck performed the first wax-resin lining on record at BkM in 1936, two years after he was hired.[1] This initial delay may relate to setting up a new laboratory rather than a concerted effort on his part. In 1943, Keck left to serve in World War II as one of the Monuments Men in the U.S. Army’s Monuments, Fine Arts, and Archives Program (Monuments Men Foundation n.d.). Few paintings were lined until Caroline assumed his museum duties and resumed the practice.

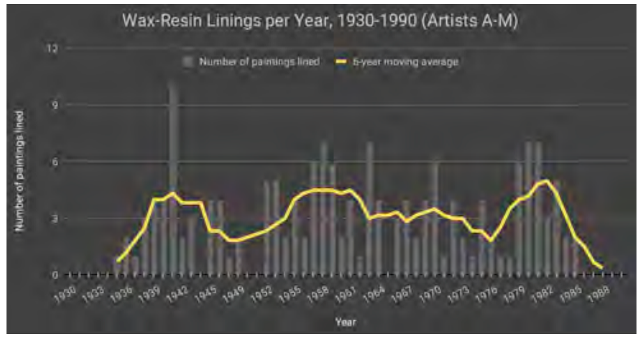

Figure 41.4 Graph illustrating the number of wax-resin linings performed at BkM by year (1930–90). The gray histogram represents real data gathered to date (approximately half of the paintings conservation files); the yellow line is a six-year moving average highlighting broader trends. Image: Brooklyn Museum Conservation Department

Some variations in lining frequency may be linked to new technology, such as the vacuum hot table acquired in 1961, and/or staffing changes that occurred in the department over the decades. The apparent increase in numbers observed in the late 1970s and early 1980s warrants further investigation, considering the critical attitudes against lining that developed in the field of conservation at this time.

The most common motivations given for lining include a “cupped” or “cracked” paint film; a “dry,” “brittle,” or “slack” canvas; and the failure of an old glue-paste lining. Significantly, not all paintings called to the laboratory were lined as a matter of course; many underwent less-invasive treatments or were left untouched. This was sometimes attributed to lack of time, but also occurred if it was determined that no intervention was required, particularly in cases where a stable lining was already present.

There were significant periods when adhesive components were not listed each time a lining was performed (fig. 41.5). The earliest reports, dated 1936–40, reliably include the same formula of 60 parts beeswax, 35 parts dammar resin, and 5 parts Canada balsam. In 1941, the terms *wax resin* and *wax* were used alone, without specifying components. Reports from 1942–44 contain a similar recipe to the earlier one, with slightly different proportions: 65 parts beeswax, 30 parts dammar resin, and 5 parts Canada balsam. The term *wax resin* predominates again from 1945 to 1946, and from 1961 onward. These trends indicate that generic language was common once the same formula had been used for a while, with little variation.

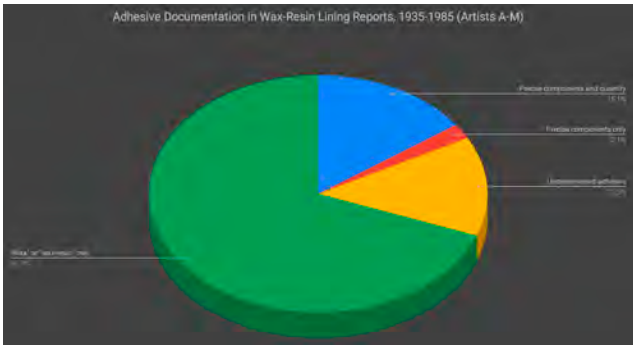

Figure 41.5 Pie chart comparing adhesive recipe detail contained in BkM reports (1935–85). Image: Brooklyn Museum Conservation Department

Starting in 1949, Multiwax W-835 was added to some wax-resin mixtures, marking the beginning of an experimental period with different materials, which included microcrystalline wax, gum elemi, and turpentine. On occasion, current or former trainees lined paintings at BkM using distinctive recipes. In the early 1950s, Louis Pomerantz treated at least one painting as a student volunteer using 6 parts beeswax, 6 parts Multiwax W-835, 6 parts dammar resin, and 1 part Canada balsam.[2] In 1971–72, BkM contracted Bernard Rabin, who used an adhesive made from 3 pounds unbleached beeswax, 5.5 pounds Multiwax W-445, 1 1/2 pounds Piccolyte S-85, and 2 pounds dammar resin.[3] References to “Bernard Rabin’s wax-resin mixture” appear in later reports, suggesting his 1971–72 formula was reused.[4]

The majority (approximately 80%) of the linings assessed to date remain stable and have not required later treatment to address adhesion failure or other structural issues. Some exhibit local delamination along the tacking margins or around the perimeter of the picture plane. Surface residues, likely wax-resin and/or facing adhesives, have been found on many paintings, suggesting inadequate clearance was common.

CONCLUSIONS AND FUTURE STEPS

Preliminary findings challenged preconceptions about historical BkM lining practices. Prior to starting this project, the authors assumed a majority of canvas paintings at BkM were wax-resin lined and that paintings routinely underwent lining treatments as a preventive measure regardless of their condition. The survey has revealed what seems to be a more discerning and varied approach. Decisions over whether or not to line a painting appear to have been carefully weighed, even if the rationale was not described.

Upon completion of the survey, the influence of BkM collecting and exhibition practices on lining treatments will be evaluated. Further consideration will be given to age at the time of lining to determine if the treatment approach differed between newer paintings and those that had been through the restoration cycle many times. Data regarding the replacement or reuse of auxiliary supports and the method of canvas attachment are also being gathered with the intent to link individual conservators with idiosyncratic techniques.

The authors hope to inspire similar studies of wax-resin lined paintings in other collections, creating the potential to trace the exchange of lining materials and techniques across laboratories.

ACKNOWLEDGMENTS

We wish to thank the many people who contributed to this project, including Maribel Vitagliani, Scott Aaronson, Lisa Bruno, Jessica Ford, Terri O’Hara, Elaine Miller, Ellen Nigro, Victoria Schussler, and Molly Seegers, in addition to acknowledging the Getty Foundation and the Andrew W. Mellon Foundation for funding support.

NOTES

1. The date of the earliest lining encountered in the records thus far is 1936.
2. Treatment report for Bertram Hartmen, *Trinity Church and Wall Street* (30.1109), February 26, 1952, Brooklyn Museum Conservation Department Records, Brooklyn, New York.
3. Treatment report for Cuzco School, *The Legend of Santa Sophronia* (48.206.88), 1971 and 1972, Brooklyn Museum Conservation Department Records, Brooklyn, New York.
4. Treatment report for William Hart, *Near Hurley, Ulster County, New York* (15.333), August 1972, Brooklyn Museum Conservation Department Records, Brooklyn, New York.

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The Greenwich Conference on Comparative Lining Techniques, April 23, 24, and 25, 1974: Three Days That Changed Conservation

Joyce Hill Stoner, Director of the Preservation Studies Doctoral Program, University of Delaware/Winterthur Museum, Garden & Library

The 1974 Greenwich conference participants reviewed both past and current techniques of lining paintings with adhesives such as flour paste, animal glue, wax resin, Beva 371, and Plextol B500, using hand irons, hot tables, vacuum pressure, low-pressure suction tables, and vacuum envelopes. They also discussed declaring a moratorium on lining.

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INTRODUCTION

In 2017, in the article that provided the subtitle for this paper, David Bomford wrote the following with 20/20 hindsight:

> The [1974] Greenwich Lining Conference had two profound and contradictory effects, one immediate and practical, the other philosophical and slow-burning. The first was to open the eyes of many of those present to the advances in the technology of lining, including machinery and materials . . . The second effect was to set in motion something quite different—a debate that questioned the whole basis of lining. Westby Percival-Prescott's keynote "The Lining Cycle" conjured up a graphic picture of the spiral of repeated treatment, deterioration, and re-treatment in which canvas paintings become trapped once they are lined for the first time. (Bomford 2017, 5)

This paper presents vignettes related to this landmark conference, accompanied by quotes from interviews from the Foundation for Advancement in Conservation (FAIC) Oral History File.

GREENWICH: RECORDED THOUGHTS FROM THE PARTICIPANTS

Westby Percival-Prescott (1923–2005) (fig. 42.1) was a major force in bringing about the reexamination of traditional structural treatments. Delegates from twenty-four countries were present at the conference he organized at Greenwich, London, in 1974. From 1975 to 1978 Percival-Prescott served as coordinator of the Lining and Stretchers Working Group of the International Council of Museums – Committee for Conservation (ICOM-CC); the group's name changed to Structural Restoration of Canvas Paintings in 1978, at which point Percival-Prescott became co-coordinator with Pierre Boissonnas.

Figure 42.1 Westby Percival-Prescott, who organized the Greenwich conference, photographed at IIC 1982, Washington, DC. Image: Joyce Hill Stoner, PhD, Director, Preservation Studies Doctoral Program, University of Delaware

In 1975, Percival-Prescott reported that the lectures and/or demonstrations at Greenwich fell into three main categories (Percival-Prescott 1975). The first was traditional hand-linings: Russian sturgeon glue; Italian flour paste and animal glue; British "compo" glue; Belgian and Polish natural beeswax and resin; and National Gallery, London hand-lining. The second was hot-table linings: Swiss Lascaux synthetic wax on fiberglass fabric, vacuum hot tables, and Beva. The third category was dubbed "new alternatives" and included Courtauld vacuum envelopes using wax resin; Berger vacuum envelopes using the verso of the painting as the top of the envelope; Mehra's prototype cold-vacuum lining table and Plextol B500; and how to prevent the need for lining at all.

In the United States, we quickly heard about a "moratorium on lining." As Gillian Lewis told me:

> A call for a moratorium was made by Westby at the closing address at the end of the Greenwich conference. There was a show of hands—mostly in favor. It took us all by surprise and appeared impromptu, but in fact he had been pondering it for some years and had talked informally to several people about it. I think he kept quiet about it until the conference itself had taken place, as he anticipated that some contributors might not be so open in their descriptions of techniques had they known this could be the outcome.[1]

Suddenly, as a professor of paintings conservation in the 1970s, I had to be ready to teach many more lining techniques than I had learned in the 1960s. At Greenwich, Gerry Hedley (1949–1990), Stephen Hackney, and Alan Cummings delivered "Lining in a Vacuum Envelope with a Traversing Infrared Heat Source," and Cummings and Hedley delivered "Surface Texture Changes in Vacuum Lining: Experiments with Raw Canvas." Alan Cummings described the experience in his FAIC interview:

> We became a kind of three musketeers: myself, Gerry Hedley, and Stephen Hackney. We were all at Courtauld at the same time. Our particular interest was in the structural treatment of canvas paintings in lining. I did my final-year research project at Courtauld on texture changing and vacuum lining of paintings. We gave the papers at the lining conference in 1974. I think that whole conference was quite significant, including the colorful character Gustav Berger, the birth of Beva, and Vishwa Mehra. All of the debates about vacuum lining versus other kinds of lining. Yeah, it was a very significant period.[2]

Stephen Hackney talked about the vacuum-envelope experiment in his FAIC interview:

> Professor [Stephen] Rees Jones had originally given me a project, essentially to rebuild and get the old hot table working again and to give the department the capability of doing wax-linings. It started as a technical challenge with machinery, no budget, and cramped conditions. Gerry Hedley then joined me and brought his mechanical engineering talents, and we started doing some radical work, deconstructing the whole process of wax-lining, especially the use of vacuum. Westby, Gillian, and Ronald Chittenden [all from the Greenwich Maritime Museum] came to visit us more than once.[3]

In 1993, Hackney wrote about Hedley's contributions (fig. 42.2):

> It was clear that there was little fundamental understanding of the properties of materials used in paintings and their conservation. The complex structure of an old stretched canvas painting had not been considered from an engineering standpoint. As a consequence, at the Greenwich lining conference some very strong contradictory opinions were expressed. It was Gerry's gift that he could quickly analyze an argument and identify its premises, frequently enabling him to resolve a dispute or misunderstanding (Hackney 1993, 4).

Figure 42.2 Gerry Hedley demonstrating a vacuum envelope at Winterthur / University of Delaware, 1981. Image: Joyce Hill Stoner, PhD, Director, Preservation Studies Doctoral Program, University of Delaware

Turning to the contributions from the Italian delegation, Andrea Rothe (1936–2018) (fig. 42.3) had translated and delivered in English the paper by Umberto Baldini and Sergio Taiti, "Italian Lining Techniques: Lining with *Pasta* Adhesive (and Other Methods) at the Fortezza da Basso, Florence." He gave me the history in his FAIC interview.

Figure 42.3 Andrea Rothe (right) with Umberto Baldini and Ornella Casazza at the J. Paul Getty Museum, 1985. Image: Joyce Hill Stoner, PhD, Director, Preservation Studies Doctoral Program, University of Delaware

> I had been doing only *pasta* linings. A little wax-lining every now and then. In 1974, I gave the talk [on Italian lining], and I answered questions. I got so carried away I fell off the stage and fell into the people sitting on the first row. I didn't fall very far. It wasn't a high stage, but it was sort of embarrassing. After that, everybody knew me as the guy who had fallen off the stage . . . It was a very useful conference. From what I've seen afterwards, no other conferences really had the quality of that lining conference. There was a lot going on: Mehra with his technique, Gustav with his wife—she kept giving him instructions. John Brealey says he met me in Greenwich.[4]

John Brealey (1925–2002) chaired a panel at Greenwich and mounted a photographic display of his treatments of the nine huge (nine-foot-square) paintings on canvas by Mantegna in Hampton Court, a series known as the Triumphs of Caesar. Commissioned in 1484, they were "very thinly painted, on fine linen, with practically no ground . . . like gouache."[5] They were overpainted in oil in the eighteenth century and again with oil by Roger Fry in the nineteenth, and then wax-lined in the 1930s by Stanley Kennedy-North (1887–1942), who used 15-pound irons that created "welts" in the paintings. In interviews and lectures, Brealey told our students about removing a "ton" of wax.[6] His treatments took more than nine years. Brealey spoke against wax-lining in his interviews and celebrated unlined paintings in his lectures. For a time, Brealey supported

Robert Fieux's research and Fabri-Sil lining (more on this below).

Beva 371 (Berger's ethylene vinyl acetate) was first formulated in 1970 and presented at the Congress of the International Institute for Conservation of Historic and Artistic Works in Lisbon in 1972. Two years later, Gustav Berger (1920–2006) presented demonstrations, a film, and four papers at Greenwich: "Effects of Consolidation Measures on Fibrous Materials," "Wax Impregnation of Cellulose: An Irreversible Process," "Lining of a Torn Painting with BEVA 371," and "Some Effects of Impregnating Adhesives on Paint Film." Only a decade later, in 1984, Gerry Hedley received ninety-three replies to his international questionnaire on lining, and Beva 371 was found to be the most widely used lining adhesive (Hedley and Villers 1984).

In his 1995 FAIC interview, Berger noted:

> The movement against lining is foolish. I have shown, through my experiments and lining demonstrations, that I can line butterflies. For if you can line a butterfly, then really I don't think you would damage a painting when you line it. So paintings can be lined without damaging them. You only have to know how, and to do it properly, and have the right materials.[7]

Berger had the verso of the butterfly collage on canvas serve as the top of the vacuum envelope. In 1976, he told me, "There is another little thing that I developed . . . that you can use the painting itself as a membrane and reline it without any pressure from the top."[8] During the opening session in Greenwich, *The Guitar*, a freshly painted collage, oil, and mixed media work on primed canvas by Raphael Berger, with high impasto and preserved butterfly specimens, was lined in a public demonstration. The lining left the high impasto and the butterflies intact (Berger and Russell 2000, 35).

New terminology and key personalities emerged at Greenwich. Caroline Villers noted that Berger coined the term *weave interference* (Villers 2003a, v), while Percival-Prescott had invented the portmanteau *shrinkle* to describe what happens when moisture causes the canvas to shrink and the paint to wrinkle. I was among the many audience members over the following years who were treated to conference talks featuring Gustav Berger at the podium while his wife, Mira, moved up and down the aisles passing out squares of Kleenex tissue "lined" with other squares of Kleenex using Beva 371 (with no resultant staining). Mira would sometimes call out instructions from the back of the auditorium: "No, no, Gustav—wrong slide!" (fig. 42.4).

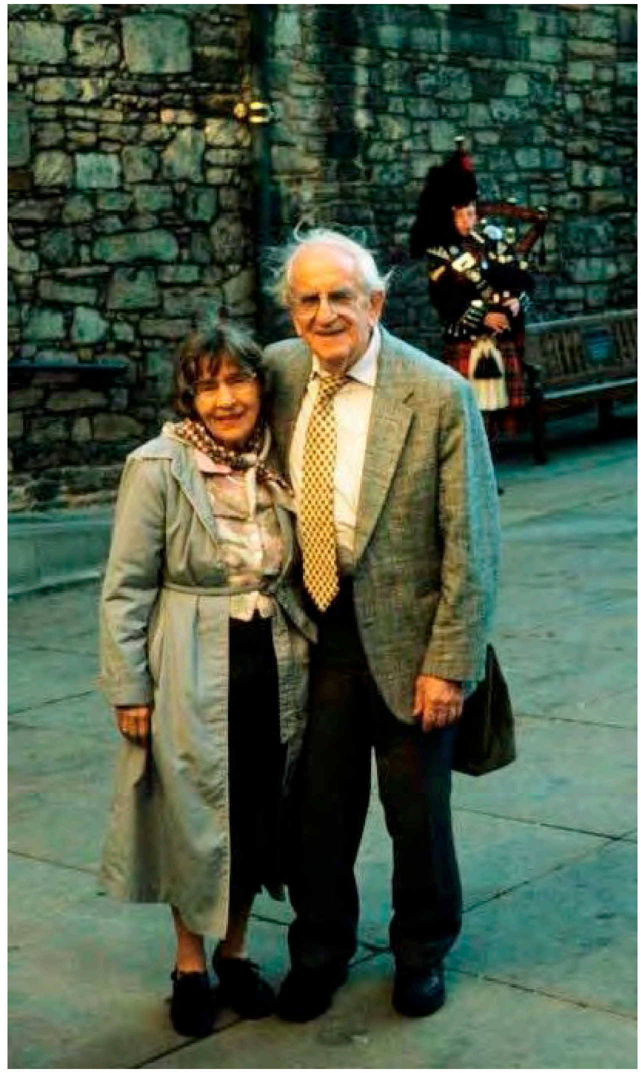

Figure 42.4 Mira and Gustav Berger at ICOM-CC, Edinburgh, 1996. Image: Joyce Hill Stoner, PhD, Director, Preservation Studies Doctoral Program, University of Delaware

At ICOM-CC's 1972 triennial meeting, in Madrid, Vishwa Raj Mehra (b. 1931) had presented a radical review of lining methodology, in which he began to argue for a more graduated approach to structural treatment and to question assumptions about the cohesive strength required of lining adhesives and the tensile forces in the painting composite. Percival-Prescott wrote in 2003:

> The atmosphere in the Greenwich Conference will never be forgotten and led to many substantial developments. . . . One of the greatest of these was Vishwa Mehra's low-pressure cold table; this invention took its place in lining history and was to be copied extensively throughout the world, including for use with paper and textile conservation. Mehra had brought a prototype lining table, transported specially

to the conference in order to demonstrate lining with Plextol B500 cold-setting adhesive and woven polypropylene fabric. (Percival-Prescott 2003a, ix)

Robert Fieux (1919–1991) (fig. 42.5) presented a paper at Greenwich reporting on a meeting in Cooperstown, New York, in summer 1973, hosted by Sheldon and Caroline Keck, comparing wax resin, glue paste, Beva, and polyvinyl acetate. Fieux gave papers in Ottawa in 1976 and at ICOM-CC 1978, in Zagreb, titled "Electrostatic Cling as a Pressure Source in Lining of Paintings." He invented Fabri-Sil linings: silicone adhesive on Teflon-coated fiberglass fabric, which required only gentle hand pressure for attachment. This seemingly gentle technique was adopted at New York's Metropolitan Museum of Art and at the Museum of Fine Arts, Boston, for a time but was later abandoned.

Figure 42.5 Robert Fieux (left) demonstrating electrostatic hold, Winterthur, 1977. Image: Joyce Hill Stoner, PhD, Director, Preservation Studies Doctoral Program, University of Delaware

ACKNOWLEDGMENTS

I am grateful to the twenty-first-century Getty project Conserving Canvas (nicknamed Greenwich 2.0) for reconsidering the historical techniques of *pasta* and wax-linings in addition to presenting newer ideas that have since been introduced, and to all the contributors to the FAIC Oral History Project.

NOTES

1. Gillian Lewis, National Maritime Museum, Greenwich, email correspondence with the author, August 1, 2019.
2. Alan Cummings, FAIC interview by Alison Richmond, Winterthur Museum and Libraries, October 1, 2009.
3. Stephen Hackney, FAIC interview by Kari Rayner, July 15, 2016.
4. Andrea Rothe, FAIC interview by the author, July 9, 1985.
5. John Brealey, FAIC interview by the author, January 1, 1976.
6. Brealey interview; lectures to students in the Winterthur / University of Delaware Program in Art Conservation, 1980–88.
7. Gustav A. Berger, FAIC interview by Jean D. Portell, August 3, 1995.
8. Gustav A. Berger, FAIC interview by the author, September 20, 1976.

43

A Roman Technique of Open-Weave Canvas Lining

Emma Kimmel, Graduate Student, Conservation Center of the Institute of Fine Arts, New York University

During treatment of Francesco Bassano's Adoration of the Shepherds *(Arkansas Arts Center), the painting was found to have been lined to a very open-weave canvas using glue-paste adhesive. Further research revealed this to be an Italian lining technique, likely applied before the painting's acquisition by the Kress Foundation in the 1930s. This poster explores the differences between Florentine and Roman lining techniques, proposing that the lining applied to the Bassano is Roman. It also provides an overview of the Roman lining method and ultimately identifies the type of canvas used on the Bassano.*

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INTRODUCTION

In the fall of 2018, the Arkansas Arts Center's *Adoration of the Shepherds*, attributed to Francesco Bassano (fig. 43.1), was brought to New York University's Conservation Center for treatment. The painting is part of the dispersed Kress Collection and had not been studied since 1932, when it was restored by then-conservator of the Kress Collection, Stephen Pichetto.[1] During treatment at the Conservation Center, it was revealed that the painting had been lined with a very open-weave canvas (fig. 43.2). This was an unusual discovery, as canvas paintings treated by the Kress Foundation during this period were often lined after acquisition with tightly woven canvases.[2] Additionally, there were no notes in the Kress Foundation Archive that discussed the addition of a lining. So where was it applied?

Figure 43.1 Attributed to Francesco Bassano (Italian, 1549–1592), *Adoration of the Shepherds*, ca. 1580. Oil on canvas, 94.8 × 132.7 cm (37 1/3 × 52 1/4 in.). After treatment. Little Rock, Arkansas Arts Center, Gift of the Samuel H. Kress Foundation, 1934.001. Image: Emma Kimmel

The lining has several characteristics that point to an Italian method of canvas lining. Although the original canvas has a fine weave, approximately 30 × 30 threads per inch, the lining has a very open, plain weave with approximately 16 × 16 threads per inch. The canvas is composed of threads with irregular widths (fig. 43.3), and the lining overall was adhered with a thin layer of glue-

Figure 43.2 Verso of *Adoration of the Shepherds* before treatment; note the visibly open-weave lining. Image: Emma Kimmel

Figure 43.3 Detail of the lining of *Adoration of the Shepherds* with a swatch of linen from the Conservation Center paintings studio for comparison. Image: Emma Kimmel

paste adhesive. Clues from the painting's provenance were quite limited, leading back only to the dealer who sold it to the Kress Foundation in 1930; this was Florentine dealer Count Alessandro Contini-Bonacossi, who supplied many paintings to Samuel H. Kress (Shapley 1973). It is therefore likely the lining was applied in Italy before the painting was sold, though it is unknown where it might have been done, or by whom.

ROMAN VERSUS FLORENTINE LINING CANVASES

In Italy, there are two traditional glue-paste lining methods: Florentine and Roman. This distinction originates from the work of two nineteenth-century Italian restorers, Count Giovanni Secco-Suardo and Ulisse Forni. The glue-paste recipe and lining techniques advocated by Secco-Suardo informed the Florentine technique, whereas Forni's became the basis for the Roman technique (Forni 1866; Reifsnyder 1995, 77–78).[3] A characteristic difference often cited between these approaches is the glue-paste recipes;[4] however, there is also a large variation in the types of lining canvas chosen. While both methods generally employ plain weave hemp and/or flax-based canvases, their weave densities differ greatly.

Typically, the Florentine method uses a tighter weave similar to that of the original canvas, though slightly more robust, to support the painting (Reifsnyder 1995, 79).[5] This type of canvas is chosen to provide a more rigid support and minimize weave interference (Baldini and Taiti 2003, 116). The Roman technique, in contrast, uses an open weave. There are two main types of this open-weave canvas: the more open *tela patta*, at 10–15 threads per inch, and the slightly more dense *tela pattina*, at 20–25 threads per inch. Selection of either the *tela patta* or *tela pattina* largely depends on the size of the painting, the structure of the original canvas, and the painting's condition (Laroche and Saccarello 1996, 13). Generally, this type of canvas allows for a lighter, more flexible support after lining; however, the overall flexibility is also highly dependent on the glue-paste recipe (Lavorini 2007).[6]

BRIEF OVERVIEW OF THE TRADITIONAL ROMAN LINING PROCESS

The following outlines the steps of the Roman lining process.

1. The painting is prepared for lining by applying an overall facing, removing it from its support, cleaning the reverse of the canvas, mending tears, and applying any canvas inserts.
2. Diluted *colletta* (glue) is applied to the back of the original canvas to consolidate preparatory layers before the lining procedure.
    - The *colletta* is often composed of hide glue, water, white vinegar, molasses, and oxgall, and sometimes a small amount of fungicide.
    - For moisture-sensitive paintings, a synthetic adhesive or mastic resin can be substituted for this step.

3. The lining canvas is soaked in water for at least twelve hours and then left to dry before being stretched onto a wood or metal working frame.

4. A thin layer of *colla di pasta*, or *colla pasta* (glue paste), is spread onto the back of the painting. The lining canvas is placed on the back of the painting and massaged from the reverse, pushing from the center outward to remove excess glue. This process is sometimes repeated from the front of the painting until only a thin layer of glue remains.

    - The *colla pasta* is often composed of wheat flour, water, undiluted or dry *colletta*, and Venice turpentine. A fungicide and/or alum is also sometimes added.

    - Although excess glue is extracted, it is important that the lining canvas be fully impregnated with the glue paste for an adequate bond with the original canvas.

5. After drying for several hours in an upright position, the painting is then ironed from the front through waxed paper until the surface is dry to the touch. Normally the iron weighs 3–7 kg and is heated to 45°C–60°C.

6. The painting is left to dry fully for at least a day before removing the facing. After several days, the painting can then be stretched onto its final support.[7]

The Roman method has several advantages, primarily a lower overall weight after lining, a thin layer of glue, and the flexibility of the open-weave canvases. It does have limitations, however, and would not be suitable for highly damaged or sensitive works. The heat, moisture, and pressure of traditional glue-paste lining processes are also not appropriate for many paintings and require a very skilled practitioner for proper implementation.

CONCLUSIONS

After investigation into the various types of traditional Italian lining canvases, it was determined that *Adoration of the Shepherds* was lined with a Roman *tela patta* canvas. The exact techniques and recipes used for its application remain unknown, though Italian scholarship provides an overview of the salient differences between the Florentine and Roman methodologies that may have been employed. Traditional glue-paste linings are now considered inappropriate for many works, yet almost ninety years later this Roman lining remains unobtrusive and flexible. During treatment, it was decided to retain the lining due to its excellent state of preservation. There are many favorable aspects of the Roman lining process, and further experimentation using open-weave canvases with alternative adhesives and/or application methods could make this traditional technique less intensive while still providing a light, flexible support.

ACKNOWLEDGMENTS

The author would like to thank the following for their guidance and expertise: Dianne Dwyer Modestini, Michele Marincola, Margaret Holben Ellis, Hannelore Roemich, Paolo Roma, Kevin Martin, Shan Kuang, and Kristin Holder. She would also like to thank the Samuel H. Kress Foundation for its continued support throughout her studies, and the Arkansas Arts Center for the study of its wonderful painting.

NOTES

1. Art Collection Data Sheet K-105. Samuel H. Kress Foundation Archive, New York, New York. For more information on Stephen Pichetto and the conservation practices of the Kress Collection from this period, see Hoenigswald 2006, 31–41.
2. Dianne Dwyer Modestini, in discussion with the author, fall 2018.
3. See also Laroche and Saccarello 1996, 11–12. The Florentine technique has been used and taught by Opificio delle Pietre Dure, in Florence; the Roman technique, at the Instituto Centrale di Restauro, in Rome.
4. See Laroche and Saccarello 1996, Lavorini 2007, and Reifsnyder 1995 for detailed descriptions of various glue-paste recipes.
5. This type of canvas can be called *olona* and is typically closer to 30 threads per inch; see Laroche and Saccarello 1996, 17.
6. See also Reifsnyder's comments on the flexibility of the recipes she tested, citing the Roman glue paste as being more rigid after lining (Reifsnyder 1995, 81).
7. This description reflects the practices of the Instituto Centrale de Restauro, in Rome, from the early 1980s, as described in Laroche and Saccarello 1996, 12–15. See also Forni's description of nineteenth-century approaches (Forni 1866, 116–20).

44

A Method for Remounting Lined Paintings Using Beva 371 Film

Elizabeth Court, Chief Conservator of Paintings (retired), Balboa Art Conservation Center, San Diego, California
Alexis Miller, Head Conservator of Paintings, Balboa Art Conservation Center, San Diego, California
Bianca García, Assistant Conservator of Paintings, Balboa Art Conservation Center, San Diego, California

This poster describes the evolution and current technique of the procedure employed in remounting lined paintings at the Balboa Art Conservation Center (BACC). BACC has been performing structural treatments, including the lining of canvases, since its establishment in 1975. As lining practices have changed and evolved over the years, so have the approaches to reattachment and retensioning of paintings on stretchers at BACC. Starting with the technique of wax-lining and the attachment of lining canvases and original tacking edges to the stretcher using adhesive all around the edges, the center has moved to a system of reattaching lined canvases to their stretchers using Beva since the early 1980s. The adhesive provides more even, constant tension all around the edges, as opposed to the individual points of stress that occur when using the traditional method of restretching and attachment with tacks or staples only. The BACC method also minimizes any stress on the original canvas by attaching and tensioning the lining canvas before the original tacking margins are gently folded back and secured into place.

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INTRODUCTION

The Balboa Art Conservation Center (BACC) has been performing structural treatments on canvas paintings, including linings, since its establishment in 1975. When Beva 371 replaced wax resin as the most frequently used lining adhesive starting in the early 1980s, it was first used in much the same way that wax had been: the adhesive was applied to the edges of the lining fabric and used to adhere the edges of the lining and the original tacking edges to the stretcher. However, material and handling differences between wax resin and Beva 371 presented problems from the start. Beva 371 does not allow the original tacking edges to slide over the lining as it is bent around the stretcher, as wax does when heated, leading to stress on the tacking edges. A facedown remounting procedure that evolved and has been used at BACC since approximately 1985 addresses these issues, creates even tension around all sides of the painting (eliminating anchor points created by tacks or staples), and protects the original tacking margins from stress and splitting.

PREPARATION STEPS

Certain tasks precede the lining itself.

- Any tears in the original tacking edges or splitting along the turnover edges are mended or reinforced before lining, for example with Japanese tissue.
- In preparing the lining fabric, the adhesive is applied to the lining precisely within the picture area, preferably approximately 1/16 inch smaller on all sides; it does not extend onto where the tacking edges will lie. The adhesive used for lining has no bearing on this remounting technique.
- The placement of the lined painting on the stretcher is determined and marked before proceeding. This can be accomplished with strategic pinpricks from the front connected with lines drawn on the reverse of the lining. The lining fabric is then precreased along these lines.
- The lining fabric is cut at the corners so that it does not impede keying or expanding the stretcher.

THE PROCESS

Lining is a six-step process.

1. Prepare the stretcher by adhering Beva 371 film cut to the depth of the stretcher. There should be adhesive around the perimeter of the stretcher (fig. 44.1).

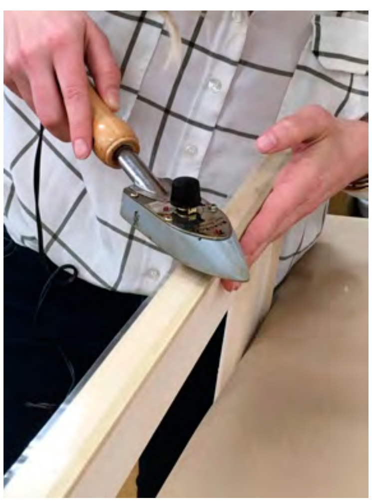

Figure 44.1 Step 1: Prepare the stretcher with Beva 371 film. Image: Balboa Art Conservation Center / Bianca García

2. The lined painting is placed facedown on a flat surface. The lining canvas is precreased at the fold-over edge (fig. 44.2) to help guide the conservator in the placement of the stretcher and to avoid the effect commonly known as TV screening (named for the slightly rounded cathode-ray tube displays on older televisions). The stretcher is put in place and adjusted as needed to accommodate the size of the painting.

Figure 44.2 Step 2: Crease the lining fabric at the fold-over edge. Image: Balboa Art Conservation Center / Bianca García

3. The tacking margins of the lining canvas are secured to the stretcher with pushpins on the back of the stretcher (fig. 44.3). There should be no excessive pulling or tensioning of the lining fabric; the goal is simply to hold the canvas in place.

Figure 44.3 Step 3: Align the stretcher with the painting, following the crease lines, and use pushpins to secure the lining fabric to the stretcher. Image: Balboa Art Conservation Center / Bianca García

4. Using a tacking iron, heat the tacking margins of the lining to activate the Beva 371 film and secure the painting to the stretcher (fig. 44.4). The fabric is pulled taut with hand strength, working around the four sides and making sure that the lining fabric has properly adhered to the stretcher.

Figure 44.4 Step 4: Use a tacking iron to activate the Beva 371 film and secure the lining fabric to the sides of the stretcher. Image: Balboa Art Conservation Center / Bianca García

5. At this point, the stretcher can be gently expanded to properly tension the painting. The original tacking margins of the painting will stick out (fig. 44.5).

Figure 44.5 Step 5: Gently expand the stretcher to provide adequate tension to the lined painting. The original tacking margins are still unsecured at this stage. Image: Balboa Art Conservation Center / Bianca García

6. The original tacking margins can now be folded down and secured with the preferred method, for example, tacks or staples (fig. 44.6).

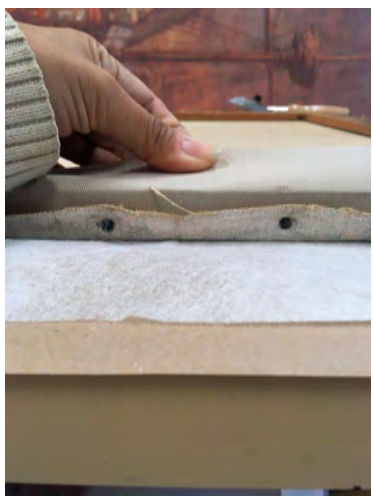

Figure 44.6 Step 6: Fold down the original tacking margins and secure with tacks, staples, or any preferred method. Image: Balboa Art Conservation Center / Bianca García

ADVANTAGES OF THE SYSTEM

The BACC system has a number of advantages.

- The plane of the painting is established by laying it facedown on a flat surface. The conservator is not applying force (unevenly) to pull it flat. Canvas pliers or excessive pulling is not required.
- Attachment of the lining canvas to the entire edges of the stretcher with Beva 371 film provides even tension when the stretcher is opened out, as opposed to individual points of stress when using tacks or staples.
- Beva 371 has good shear strength and will not slip when the lining canvas is tensioned.
- The stress of proper tensioning of the lined painting on the stretcher is carried primarily by the lining canvas, while the original canvas—and especially the fragile tacking edges—is not pulled.
- After they are gently folded down, the tacking margins need not be adhered to the lining overall, making reversal of the lining in the future, if needed, easier and less stressful to the original canvas.

45

On Color Change in Seventeenth-Century Netherlandish Paintings after Wax-Resin Lining

Emilie Froment, Lecturer, University of Amsterdam

Wax-resin lining is known to alter colors in paintings. To date, however, only a few research studies have investigated the conditions under which the alteration may occur and the extent of the change. This research focuses on color change in ground layers of seventeenth-century Netherlandish paintings. Central to the research methodology are visual examination and color measurements of reconstructions based on material evidence from paintings and documentary research relevant to the period. The procedure used for the wax-resin treatment is also designed based on historical evidence. The research results revealed that the composition of the ground, the layer thickness, and the hiding power of the ground are influential in the degree of change.

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INTRODUCTION

Wax-resin lining was invented in the Netherlands in the first half of the nineteenth century. Until the 1970s, it was considered an overall cure for structural alterations in canvas paintings and therefore was used extensively by conservators in the Netherlands and abroad. The technique, however, proved to have detrimental effects on paintings' material and physical characteristics, including color changes. Although today the use of wax-resin lining is almost extinct, most paintings preserved in the Netherlands received this treatment in the past.

This research examines the impact of wax-resin lining on the color of ground layers in seventeenth-century Netherlandish paintings on canvas (Froment 2019). In these works, the ground is often left visible and used as a middle tone. Therefore, any color change of the ground would significantly alter the overall aesthetic of the painting. Furthermore, color change is considered a sign of the modification of the painting's materials, which is relevant for the future conservation of these works. The results of the research aim to support the work of conservation professionals in identifying color change due to lining, thus preventing misinterpretation of the works and enabling an adaptation of conservation strategies.

HYPOTHESIS

Material evidence found in four paintings by Jacob Jordaens (1593–1678) in the Royal Palace Amsterdam provided the basis for the research hypothesis (fig. 45.1).[1]

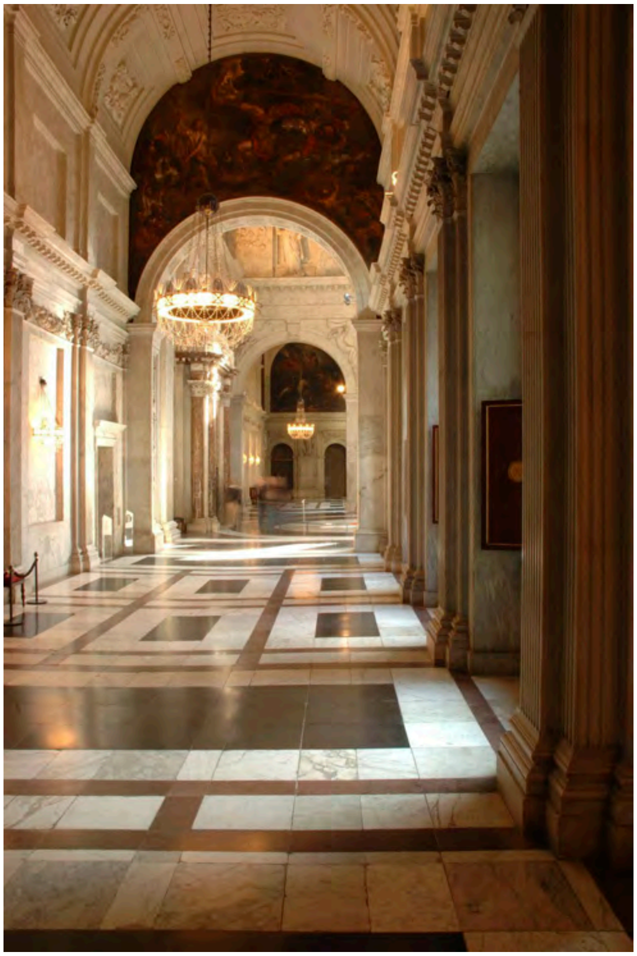

Figure 45.1 Royal Palace Amsterdam, South Gallery. Above the arch: Jacob Jordaens (Flemish, 1593–1678), *David and Goliath*, 1664. Oil on canvas, 550 × 550 cm. Image: J. Schlomoff

Figure 45.2 Jacob Jordaens, *David and Goliath*, 1664, detail, approximately 250 × 120 cm (98 2/5 × 47 1/4 in.). Image: Emilie Froment

Figure 45.3 Jacob Jordaens (Flemish, 1593–1678), *Peace between the Romans and the Batavians*, 1661. Oil on canvas, detail, approximately 80 × 50 cm (31 1/2 × 50 5/8 in.). Image: Emilie Froment

Technical examination revealed that though the paintings were in different states of condition, they had aged in identical environments and received similar restoration treatments, including wax-resin linings in 1963 (van Eikema Hommes and Froment 2011). Differing degrees of darkness were particularly striking (figs. 45.2, 45.3).

Analysis of cross sections from each of the paintings highlighted the use of different ground types that varied in both the number of layers and material composition as well as the type of binding medium. The correlation between material evidence and documentary sources that report color change in paintings after wax-resin lining supported the hypothesis that the visual consequence of wax-resin linings in seventeenth-century Netherlandish paintings is related to the original preparation technique.

EXPERIMENTAL CONDITIONS

Central to the research was the study of visual phenomena observed on naturally aged ground reconstructions.

The Reconstructions

The materials and techniques used for the reconstructions were based on material evidence from paintings selected for their relevance to the research. These included works by Jordaens in the Royal Palace Amsterdam as well as paintings by Gerard van Honthorst (1592–1656) and Theodor van Thulden (1606–1678) created for the Oranjezaal, a painted ballroom in the Huis ten Bosch, a royal palace just outside of The Hague. *The Night Watch*, 1642, by Rembrandt (1606/7–1669), was also considered.

Technical study of the grounds of these paintings identified three types of single ground and four types of double ground, with colors of either off-white, beige, red, brown, or gray. Mineral composition was analyzed with a scanning electron microscope with energy dispersive X-ray. Binding media were investigated using gas chromatography–mass spectrometry (GC-MS) and Fourier transform infrared spectroscopy (FTIR). Ground recipes found in documentary sources from the period and results of technical research from other paintings were also incorporated (Stols-Witlox 2017).

Thirty-two different ground types were reconstructed. Each of them was applied in a single layer on linen canvas previously sized with gelled animal glue. The mineral components used for the grounds were chalk, lead white, raw umber, yellow iron oxide, red iron oxide, tile red, charcoal black, quartz, and ball clay. Each type was used both independently and in mixtures of various ratios. Two types of binding media were used: linseed oil and animal glue.

Ground's Hiding Power

As the color of linen canvas darkens dramatically after wax-resin impregnation, the degree to which a ground layer hides the underlying canvas was hypothesized to be a key parameter for color change in paintings after wax-resin treatment. To investigate the influence of grounds' hiding power, a pilot study was conducted, consisting of the systematic application of each ground type in different thicknesses onto opacity charts. These applications were subjected to color measurements in order to determine the degree of hiding power of each group type at a specific thickness.

Wax-Resin Lining

Research into wax-resin lining methods used by conservators in the Netherlands supported the choice for the lining of the reconstructions. The procedure simplified historical practices in order to minimize variables. Essentially, it included the impregnation of reconstructions with a wax-resin mixture composed of 10 parts beeswax to 3 parts colophony (weight/weight). The adhesive was applied warm on the reverse of the reconstructions and melted into them using a hot handheld iron.

Analytical Techniques

Color measurements were recorded with a CM-2600d Konica Minolta spectrophotometer in the CIELAB color space. The 1976 formula was used to measure color difference (ΔE^*) and evaluate the degree of hiding power. Furthermore, cross sections from the reconstructions were analyzed using light microscopy, providing further insight into the effects of ground layer thickness.

RESULTS

General Trends

Result showed that wax-resin impregnation caused color change in nineteen of the thirty-two ground types tested.

Comparative color measurements revealed that the extent of change was influenced by the type of binding medium and both the type and proportion of mineral components. Ground layer thickness was also influential; in general, the thinner the ground, the more significant the color change. Furthermore, the pilot study showed that the extent of color change was related to the degree of hiding power of the ground; all oil-bound grounds that changed color were measured as poorly hiding.

Comparative color measurements showed that nearly all reconstructions that underwent color change became darker and cooler (L^*, a^*, and b^* values decreased). An exception to this was the ground composed of chalk in animal glue, which changed predominately to a more yellow hue.

Grounds Composed of One Type of Mineral

An experiment investigated the influence of pigment type and binding medium on the degree of color change. For this purpose, reconstructed grounds contained a single pigment type bound in either oil or glue.

After impregnation, each glue-bound reconstruction changed color significantly, with differences ranging from 12.21 to 22.09 ΔE^* units.

For the oil-bound grounds, those composed of either ball clay or chalk measured the most altered after treatment, by 3.26 and 5.4 ΔE^* units, respectively. The grounds composed of either red iron oxide, yellow iron oxide, raw umber, or charcoal black did not undergo change, and the ground containing lead white changed only when thinly applied, by 1.5 ΔE^*.

In general, color measurements showed that glue-bound grounds changed more significantly than oil-bound, thus highlighting the influence of binding medium. It was assumed that voids inherently present in glue-bound grounds filled with wax resin, resulting in modification of refractive index and surface texture, thus causing color change. In contrast with the behavior of glue-bound grounds, the impregnation of wax-resin adhesive into the oil-bound grounds was never observed during the wax-resin treatment. For these reconstructions, color change was believed to be caused by the degree of hiding power of the ground. This assumption was supported by the pilot study, which showed that grounds containing either chalk or ball clay had poor hiding power.

After impregnation, the glue-bound ground composed of chalk and the oil-bound grounds composed of chalk, lead white, and ball clay developed a typical “abraded look” (fig. 45.4).

Figure 45.4 Ground reconstruction composed of chalk in animal glue before (left) and after (right) wax-resin impregnation. Detail, approximately 9 × 5 cm (3 1/2 × 2 in.). The canvas weave became visible after impregnation. Image: J. Schlomoff

Color measurements of these grounds reported significant differences in hiding power as a result of layer thickness. As thickness varies considerably due to the inherent irregular texture of canvas supports, the color change of these grounds was more significant on the highest points of the canvas weave, resulting in local darkening (fig. 45.5).

Figure 45.5 Cross section (microphotograph in bright field) of an oil-bound ground reconstruction composed of a 4:1 ratio of lead white to chalk. The sample is taken from an area where the canvas weave was visible after wax-resin impregnation. The ground exhibits a layer thickness of 59–276 μm, depending on the texture of the canvas. Image: J. Schlomoff

Also key is the tonal value of the grounds that contrasted significantly with the darkened support.

Chalk-Containing Oil-Bound Grounds

Another experiment examined the influence of the proportion of chalk on color change in reconstructed oil-bound grounds containing yellow iron oxide and/or raw umber as well as lead white with and without raw umber. Variables of the experiment included pigment ratio and layer thickness. In general, the color measurements showed that the higher the concentration of chalk, the more significant the change. Furthermore, the thinner the layer, the more visible the color change. However, the extent of the change was dependent on the type of pigment with which the chalk was mixed.

For example, the ground composed of lead white with 50% chalk changed by 5.91 ΔE* units, while the ground composed of lead white with 80% chalk changed more markedly, from 6.9 to 8.27 ΔE* units, depending on thickness. The influence of chalk was further shown when comparing these results to the reconstruction composed of lead white in oil, which changed only by 1.5 ΔE* units when thinly applied. Color measurements also showed that the inclusion of 10% raw umber to the grounds composed of lead white and chalk prevented color change, as no difference was measured when the proportions of chalk were 45% and 70%. In these latter instances, a thinner application did not cause color change.

The influence of chalk on color change was also measured in reconstructed grounds composed of chalk combined with yellow iron oxide and/or raw umber. Grounds composed of 98% chalk combined with either yellow iron oxide or 1:1 yellow iron oxide and raw umber changed color more noticeably when thinly applied.

By correlating experimental results from the reconstructions with results of the pilot study, it was found that an increased proportion of chalk reduced the hiding power of nearly all grounds. Furthermore, the study revealed that grounds composed of 98% chalk combined with either yellow iron oxide or 1:1 yellow iron oxide and raw umber, as well as the ground composed of 80% chalk with lead white, hid the opacity charts to varying degrees that were dependent on thickness. Ground types composed of chalk combined with raw umber and lead white remained opaque regardless of thickness. Results for grounds composed of chalk with yellow iron oxide were not conclusive.

Oil-Bound Grounds Containing Quartz

After 1642, canvas paintings by Rembrandt are frequently primed with a quartz containing ground. Results of technical analysis revealed that this ground consists mainly of clay minerals, with a high proportion of quartz sand in linseed oil (Groen 2005). Research suggests that the composition of quartz ground varies among paintings, with the variables including the type of clay minerals and the proportion of trace elements such as chalk, iron oxide, and carbon black. An experiment in this study examined the influence of the clay-to-quartz ratio, as well as the effect of adding of yellow iron oxide on the extent of color change.

Each quartz-containing oil-bound ground showed substantial color change following impregnation (fig. 45.6). The change was among the most significant of all oil-bound grounds tested, with differences ranging from 4.23 to 6.80 ΔE* units. Trends indicated that the higher the ratio of quartz to clay, the greater the change. Although the inclusion of 3% yellow iron oxide tended to reduce this effect, color change remained significant. Finally, each of the quartz-containing grounds tested changed color to a similar extent regardless of thickness.

Figure 45.6 Oil-bound ground reconstruction composed of clay and quartz in a ratio of 4.2:0.8. The left part is not impregnated with wax resin, while the right part is. Note the striking color difference. The upper and lower edges are bare canvas. Image: Emilie Froment

This series of grounds proved to have the poorest hiding power of all grounds tested (fig. 45.7). This condition was most pronounced in samples where the ground was applied thickly, while most other grounds examined in this study were opaque under those conditions. Furthermore, the pilot study indicated that the higher the concentration of quartz, the poorer the hiding power, supporting the influence of hiding power on the color change of the reconstructions.

Figure 45.7 Oil-bound ground reconstruction composed of clay and quartz in a ratio of 4.2:0.8, applied onto an opacity chart at a wet thickness of 200 μm. The test revealed the poor hiding power of the ground. Image: J. Schlomoff

CONCLUSION

The study of visual phenomena observed on historically informed reconstructions was central to this research. The reconstructions are a simplification of the material and physical complexities usually found in historical paintings. This approach proved to be beneficial, since it allowed clarity of conditions and understanding of the extent to which wax-resin linings may have changed the color of paintings. It also permitted the identification of physical phenomena resulting from lining treatment.

NOTES

1. The paintings by Jordaens in the Royal Palace Amsterdam are *Peace between the Romans and the Batavians*, 1661–62; *A Roman Camp under Attack by Night*, 1661–62; *Samson Defeats the Philistines*, 1661; and *David and Goliath*, 1664–66.

46

Historical Canvases Deciphered: Five Case Studies

Helena Loermans, Lab O, Odemira, Portugal

Textiles with a woven pattern were used as painters' canvases by Spanish and Italian artists in the sixteenth and seventeenth centuries. In this poster, textiles that have been hidden for centuries between paint and lining canvas come to life in handwoven reconstructions. The research and reconstruction of canvases contributes to the understanding of technical painting and art history and brings attention to an understudied aspect of textile production during the period that an artwork was created. Canvas reconstruction enables new research and may provide insight into why old masters used these supports, as well as how and when these textiles were made.

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INTRODUCTION

Textiles with a woven pattern were used as painters' canvases by Spanish and Italian artists in the sixteenth and seventeenth centuries. But art historians and paintings conservators have focused on the painted layers rather than on the underlying fabric.

In this poster, textiles that have been hidden for centuries between paint and lining canvas come to life in handwoven reconstructions of the support canvas of five paintings by El Greco (fig. 46.1), Titian (fig. 46.2), Caravaggio (fig. 46.3), and Velázquez (figs. 46.4, 46.5). The support canvas used by the great masters is shown in each of the figures.

MATERIAL AND METHODS

Close examinations enabled Lab O to analyze the weave structure of the patterned textile canvas. Using software developed for computer-aided handlooms, Lab O then developed a weave draft for the reproduction of these linen textiles.

A weave draft of the El Greco canvas had already been published (de los Rios y Rojas and Socorro 1977). Four high-resolution X-ray images, provided by the museums that hold the paintings, were deciphered to find the pattern of these textiles.

After consulting the first published book on weaving (Ziegler 1677) and a modern facsimile, translation, and study (Hilts, Ziegler, and Lumscher 1990), a weave draft was generated for each textile using software developed to interface with computer-aided handlooms.

All reconstructions were then woven in linen on a dobby loom.

THE PROJECT GOAL

Lab O, a laboratory for handwoven canvas located in Odemira, Portugal, was founded to deepen the technical and practical knowledge of historical canvases and to promote their analysis, authentication, and conservation. The work at Lab O connects craft, entrepreneurship, technology, science, and art history.

The research and reconstruction of canvases contributes to the understanding of technical painting and art history and brings attention to an understudied aspect of textile production during the period that an artwork was created. Canvas reconstruction enables new research and may provide insight into why old masters used these supports, as well as how and when these textiles were made.

El Greco

Figure 46.1 El Greco (Greek, 1541–1614), *The Burial of the Count of Orgaz*, 1586. Oil on canvas, 480 × 360 cm (189 × 141 3/4 in.). (a) Piece of original canvas showing weave pattern. (b) Weave draft (de los Rios y Rojas and Socorro 1977). (c) Computer-generated weave draft. (d) Handwoven reconstruction of the canvas. Images: (a and b) de los Rios y Rojas and Socorro 1977, (c) Lab O, (d) Lab O / João Mariano

Titian

Figure 46.2 Titian (Italian, ca. 1488–1576), *The Vendramin Family*, 1540–45. Oil on canvas, 206 × 288.5 cm (81 1/8 × 113 5/8 in.). (a) Detail of Gabriel's left hand before cleaning and after retouching. (b) Handmade drawing of the pattern. (c) Computer-generated weave draft. (d) Handwoven reconstruction of the canvas. Images: (a) National Gallery London, (b and c) Lab O, (d) Lab O / João Mariano

Caravaggio

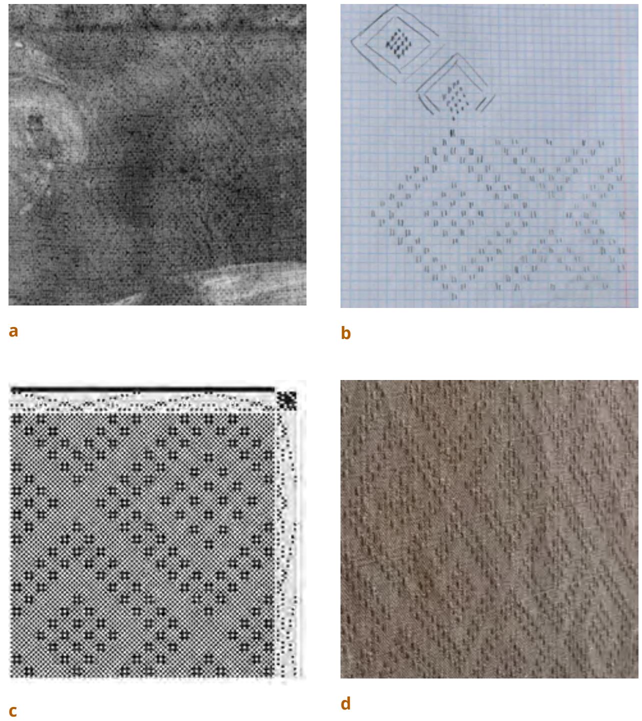
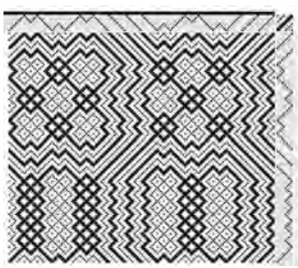


Figure 46.3 Caravaggio (Italian, 1571–1610), *The Crucifixion of Saint Andrew*, 1606–7. Oil on canvas, 202.5 × 152.7 cm (79 3/4 × 60 1/8 in.). (a) Radiograph. (b) Handmade drawing of the pattern. (c) Computer-generated weave draft. (d) Handwoven reconstruction of the canvas. Images: (a) Cleveland Museum of Art, (b and c) Lab O, (d) Lab O / João Mariano

Velázquez

a

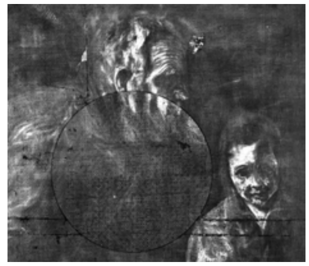
b



c

d

Figure 46.4 Diego Velázquez (Spanish, 1599–1660), *Supper at Emmaus*, 1622–23. Oil on canvas, 123.2 × 132.7 cm (48 1/2 × 52 1/4 in.). (a) Radiograph. (b) Handmade drawing of the pattern. (c) Computer-generated weave draft. (d) Handwoven reconstruction of the canvas. Images: (a) Metropolitan Museum of Art, (b and c) Lab O, (d) Lab O / João Mariano



a

b

c

d

Figure 46.5 Diego Velázquez (Spanish, 1599–1660), *Education of the Virgin*, 1617–18. Oil on canvas, 168 × 136 cm (66 1/8 × 53 1/2 in.). (a) Radiograph. (b) Handmade drawing of the pattern. (c) Computer-generated weave draft. (d) Handwoven reconstruction of the canvas. Images: (a) Yale University Art Gallery, (b and c) Lab O, (d) Lab O / João Mariano

47

A System to Keep Paintings on Canvas at a Constant Tension during Conservation Treatment

Luigi Orata, Painting Restorer, private practice, Florence, and Professor of Structural Conservation Treatment, Academies of Fine Arts, Bologna; Brera, Milan; and Naples

This paper focuses on the issue of tension variation on canvas paintings during conservation treatment. The solution proposed has been developed through the observation of several cases encountered during many years of professional activity. It aims at keeping the painting in a constant tension during structural conservation phases, thus minimizing potential damage to the canvas.

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INTRODUCTION

When a painting on canvas is removed from its stretcher, it usually undergoes a tension variation. In most cases, it will be restretched, using added tacking edges, on a temporary stretcher for structural treatment (e.g., consolidation of the paint and ground layers or for lining). During this operation, the painting is put under tension and stretched. When the work is finished, the canvas is detached again (another contraction) to be definitively stretched on the final stretcher (another stretching). These repeated movements cause mechanical stresses in the painting that affect its different layers, that is, the canvas as well as ground and paint layers, and these can result in real structural microtraumas.

The problem has previously been highlighted, for instance, by V. R. Mehra and Sergio Taiti.[1] Both restorers, despite coming from different restoration traditions and schools of thought, dedicated particular attention to the study of a method for maintaining constant tension during the treatment of a painting, specifically so as to avoid problems created by relaxation and contraction of the canvas. Mehra set up a well-known system with three stretchers in which, after the painting is removed from its stretcher, it is immediately tensioned on an interim stretcher by means of a nonwoven fabric. After the consolidation phase (or after lining, in the final phase), the system obtained is dismantled and the painting is remounted on the definitive stretcher. A possible solution, shared during his lessons, consisted of remounting the painting from the interim stretcher to a larger, definitive stretcher. The latter is positioned on the back, and the canvas is secured directly from the front, along the original edges, with metal staples. Naturally, Mehra was aware that this practice was not always feasible, especially in the presence of an original stretcher or dimensional restrictions (e.g., due to a frame or reinstallation in an architectural niche).

In parallel, Taiti, well aware of the stresses and movements occurring in a painting undergoing consolidation with animal glue in an aqueous solution (following the traditional techniques of Florentine glue-paste lining), figured out how to mount the painting on a larger interim stretcher. He employed strips of kraft paper, later replaced by polyester canvas as the use of different materials evolved, and thus maintained tension until the eventual lining. He was also developing ideas on the final step, although, unfortunately, these were never brought to fruition due to his premature death.

The sensitivity of approach demonstrated by these two important figures for numerous aspects of restoration was greatly influential as it spurred the desire to continue delving into what is a delicate and often undervalued subject.

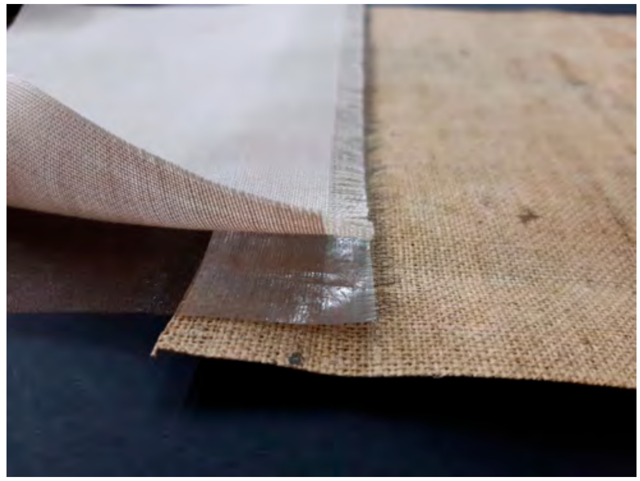

Figure 47.1 Detail of the double-strip lining used in the tension variation system for canvas paintings. From the bottom: original canvas, frayed Origam, Beva 371 film, and frayed Trevira, positioned in a staggered manner. Image: Luigi Orata

A VERSATILE SYSTEM

My experience in the field of structural conservation of canvas paintings has allowed me to test and use a system[2] to mitigate the problem of variation in tension of canvases undergoing restoration, with significant results. This innovation aims to maintain the painting under a constant tension during all of the phases of treatment and to transfer the degree of tension that is initially established for the temporary stretcher to the definitive one, thereby avoiding the potentially damaging “accordion” effect.

The system is extremely versatile in that it is applicable to paintings undergoing either only consolidation or a full lining, and hinges on the use of specially designed perimeter strips. Each strip is composed of two polyester canvas layers: the first, a lightweight polyester that comes in contact with the original painting (Origam 254, 18 g/m^2), and the second, a heavier polyester (Trevira C.S. Ispra, 130 g/m^2). Each is frayed[3] for about 10 mm along the longer edge. The individual strips, thus prepared, are then paired in a staggered manner, longitudinally, with Beva 371 film between them. They are then inserted in a vacuum envelope, and the adhesive is reactivated by heating it to 80°C, a measure aimed at ensuring a particularly solid bond[4] (fig. 47.1).

Once the painting is detached from the original stretcher, and after the back has been cleaned, it is possible to apply these double strips to the back of the original canvas (inside the fold-over marks from the original stretcher at a distance suited to the specific painting) with pressure (best if generated with vacuum suction for a better and more even bond) and heat, but only up to the minimal temperature for Beva reactivation (65°C), to provide for better reversibility. This means the double strip adheres to the original canvas less aggressively, while the bond between the two strips is stronger.

Afterward, the original canvas is stretched on the temporary stretcher using the plane of the table to provide support for the canvas as the double-layer perimeter strips are secured to the temporary stretcher (fig. 47.2). Following structural conservation treatment, the temporary stretcher and canvas are again laid facedown on a flat surface. The definitive stretcher is then positioned on the back, within the width of the temporary stretcher, aligned with the fold-over marks on the original canvas. The first of the two layers of the added tacking margin (the heavier, outside one) is cut free from the temporary stretcher and fixed to the definitive one with steel staples, thus preventing the canvas from contracting (figs. 47.3, 47.4). Only after having secured the entire perimeter is the second layer of the strip cut free from the working stretcher and fixed to the definitive one (fig. 47.5).

This sequence avoids variations in tension as, during the shift to the final stretcher, a bond is always maintained with the temporary stretcher. The initial tension is constant and can be transferred to the definitive stretcher.

For further study, the system could be tested on different models while carrying out measurements in order to give some scientific weight to the method described. This would provide numerical values and objective data to support the use of this simple technical innovation.

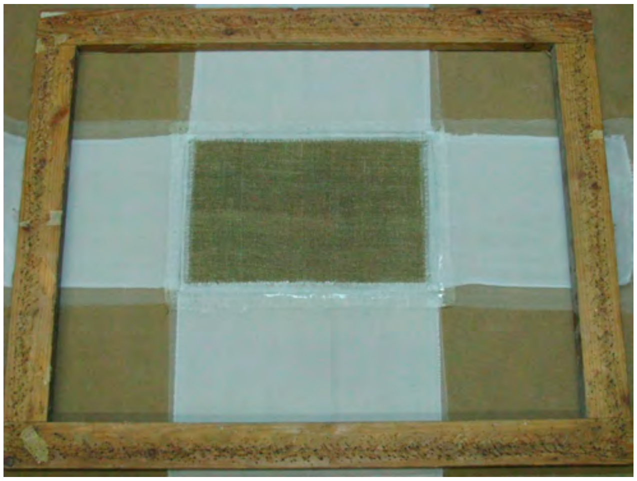

Figure 47.2 The double-strip lining is stretched and secured on the temporary stretcher. Image: Luigi Orata

Figure 47.4 Detail showing attachment of the first layer to the definitive stretcher. Image: Luigi Orata

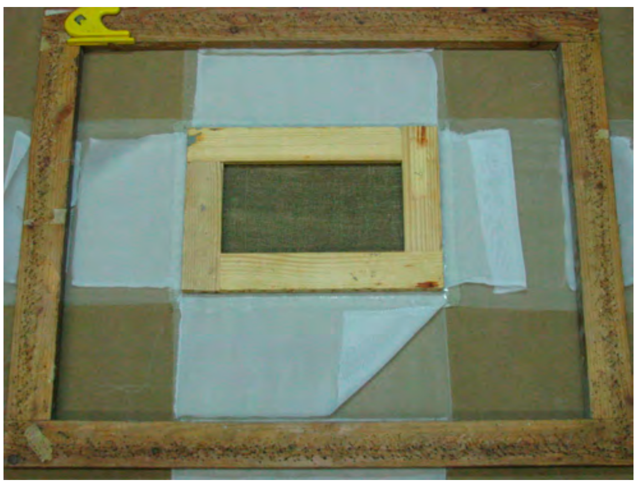

Figure 47.3 After structural conservation, the definitive stretcher is placed down. The first layer of the double-strip lining is cut free from the temporary lining and secured to the definitive stretcher while the second layer is still under tension. Image: Luigi Orata

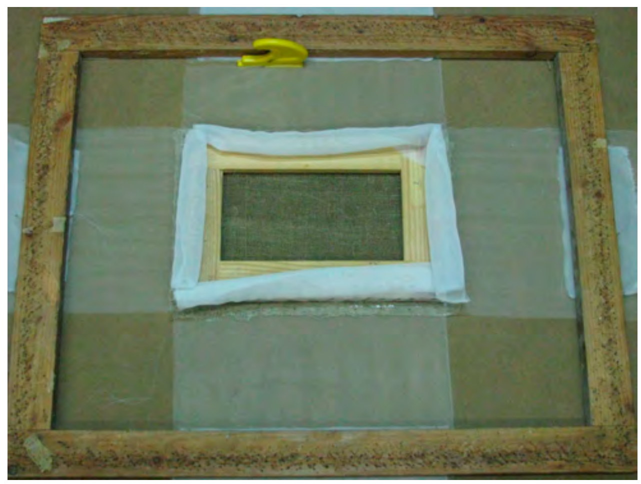

Figure 47.5 When the first layer of the double-strip lining is completely secured, the second layer is cut free and attached to the definitive stretcher. Image: Luigi Orata

NOTES

1. Sergio Taiti was head restorer of the structural conservation of canvas paintings at the Opificio delle Pietre Dure (OPD) from the 1940s to 1987, the year of his death.
2. The first use of this system was in 2002 on the painting that was the subject of my diploma thesis: Bartolomeo Bimbi, *Le zucche dei monaci di Monteoliveto*, 1714, oil on canvas, 202 × 144 cm.
3. The aim of the fraying is to lessen the abruptness of the differential created by the thermal-hygrometric exchange between the front and back of the original canvas.
4. Alternatively, different adhesives, canvases, or adhesion methods can be used, taking into consideration the adhesive strength that is optimal with respect to the characteristics of the painting.

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Removing Beeswax Residues from the Structure of the Canvas with AEROSIL

Marina Voronina, Conservator, Department of Scientific Conservation of Oil Paintings, State Research Institute for Restoration (GOSNIIR), Moscow
Ekaterina Morozova, Conservation Scientist, Laboratory of Physical and Chemical Research, State Research Institute for Restoration (GOSNIIR), Moscow
Maria Churakova, Head, Department of Scientific Conservation of Oil Paintings, State Research Institute for Restoration (GOSNIIR), Moscow

The paper presents the results of the case study in which a solvent paste based on fumed silica (AEROSIL) was applied to remove beeswax from a canvas structure. The restored object was a portrait painted by Russian artist Fyodor Rokotov. The painting had a large tear that had been previously fixed with beeswax, and ground losses had also been filled with beeswax and had oil overpaints. The removal of beeswax residues using AEROSIL paste enabled thread-by-thread tear mending using polyvinyl butyral adhesive, as well as the use of water-based glue to consolidate the paint layer. Lining the original canvas was avoided as a result of these treatments.

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INTRODUCTION

The application of wax and wax-resin materials was a common practice in conservation and restoration in Russia from the nineteenth century until the last quarter of the twentieth century. Due to their high stability and availability, these materials were used for a wide range of operations: lining, strip-lining, tear mending, and consolidation of ground and paint layer. Wax-resin lining began to be used in Russia from the mid-twentieth century (Gorin and Tcherkasova 1977, 113).

The main reasons for using wax and wax-resin compositions for consolidation were interlayer cleavage, flaking of the paint layer from oil ground, previous restoration with wax resin, deterioration of paintings caused by mildew or heat, and the like (Gorin and Tcherkasova 1977, 110). Nonetheless, the authors of Russian manuals on restoration mentioned the negative consequences of using wax-resin adhesives that had been observed. For example, *The Restoration of Easel Oil Paintings* states, “Wax-resin composition has a number of negative properties for lining. Impregnating porous chalk grounds, it changes the general tone of the painting towards darkening, especially in the light areas of the picture. During lining the wax-resin composition impregnates the author’s canvas and practically cannot be removed from the picture. It destroys the hygroscopic properties of the canvas, which are necessary for correcting canvas deformations, the picture loses its elasticity, becomes firm and heavy” (Gorin and Tcherkasova 1977, 129).

After the negative effects of wax and wax-resin impregnation of canvas paintings were scientifically proven and presented by Gustav Berger and Harold Zeliger in 1975, the application of these materials by Russian conservators came to be limited, primarily performed only for the consolidation of murals made in oil technique (Fedoseeva 1999, 24–36).

One of the foremost problems mentioned by Berger and Zeliger is the difficulty of removal of wax and wax resin from the structure of canvas (Berger and Zeliger 1975). Wax treatment limits the use of other restoration materials, particularly water-based ones, for conservation. In this regard, diverse methods of wax/wax-resin extraction have been developed and suggested. The most widely adopted method is the use of a heated spatula and filter paper for absorption of melting wax. The main disadvantage of such a procedure is that, during heating, wax is only partly absorbed by the paper and penetrates deeper in the structure of canvas fibers.

Another popular method of wax removal is mineral spirit compresses. After being subjected to the solvent, wax softens and can be easily taken away—but only from the surface of the canvas. In 1988, Landgrebe suggested using solvent pastes based on hydroxypropyl cellulose (Klucel M) and solvent mixtures (Nicolaus 1999, 95).

To achieve more complete removal of wax-resin adhesives, any such treatment should be done on a low-pressure table. However, not every conservation studio is equipped with one. Thus, searching for a material that can effectively absorb wax and wax-resin residues from the structure of canvas paintings without special equipment is a focus area.

A NEW PROCESS FOR WAX REMOVAL

In 2004, at the State Research Institute for Restoration (GOSNIIR), in Moscow, Vilena Kireeva and Maria Churakova developed a procedure of removing oil-resin stains from the canvas structure with pyrogenic silicon dioxide (trade name AEROSIL) (Kireeva and Churakova 2013). This procedure was first applied during the restoration of the painting *Adoration of the Magi* by the eighteenth-century German artist Johann Knechtel (Churakova 2005). Previously, the same substance had been successfully used to clean old, dried oil from a parchment in the Department of Conservation of Medieval Manuscripts at GOSNIIR.[1]

This poster presents the results of the case study of applying an AEROSIL and mineral spirit mixture to remove beeswax from a canvas.

MATERIALS

AEROSIL is a trade name of a line of fumed silica (SiO_2) products produced by the German chemical company Evonik Industries. It is a pure, very fine powder with a specific surface area of 50 ^{2}/g or more. AEROSIL is synthesized during flame hydrolysis (T >1000°C) of silicon tetrachloride ($SiCl_4$) by the following reaction:

$$SiCl_4 + 2H_2 + O_2 = SiO_2 + 4HCl$$

The adsorption properties of AEROSIL are determined by silanol (SiOH) and siloxane (SiOSi) functional groups presented on its surface (Evonik n.d.; Zhuravlev 2000).

For beeswax removal, purified mineral spirit (Maimeri) was used as a solvent. AEROSIL and mineral spirit were mixed in a ratio of 1 mg to 10 ml (respectively), until the mixture formed a transparent, gel-like substance.

Procedure Outline

Kireeva and Churakova offered two ways of working with the paste. In the first, the paste is spread on the stain that needs to be removed and is covered with cellophane film to prevent solvent evaporation (in their work, ethanol was used). For better absorption, the paste is applied in a thick layer using a metal spatula or palette knife and left for ten to fifteen minutes. In the case study described by the authors, the paste was colored by the removed resin (Kireeva and Churakova 2013). After the specified time, the cellophane film is removed to allow the solvent to evaporate. The solvent is considered to have evaporated from the paste when the latter loses its transparency. The dried paste, with the absorbed material, is then cleaned from the surface of the canvas with scalpel, bristle brush, and vacuum cleaner. These operations should be repeated until the maximum possible stain removal has occurred.

The second method employs heat to accelerate the absorption process. This option works more effectively in the case of thicker and uneven stains. The paste is applied on the treated area, covered with fluoroplastic film, and ironed with a heated spatula at a temperature of 40°C–50°C for around three to five minutes. After the heating procedure, the fluoroplastic film is removed and the paste is left on the treated area surface until the solvent evaporates. As in the first method, the solvent is considered evaporated when the paste loses its transparency and becomes whitish or colored with the resin. Cleaning the residues of the paste from the surface of the canvas is done as described in the first method. If necessary, the procedure can be repeated.

CASE STUDY: *PORTRAIT OF F. N. SINYAVINA* BY F. S. ROKOTOV

In Russia, a large number of paintings that have previously been treated with beeswax currently require conservation. One of these works was the *Portrait of F. N. Sinyavina* painted by the great Russian artist Fyodor Rokotov (1735/1736–1808) and held in the State Historical Museum.

The canvas of the painting had a large tear that had been fixed with beeswax, and losses of ground and paint layer had been filled with beeswax and then overpainted in oil (figs. 48.1, 48.2). Over time, the wax had lost its adhesive strength, which resulted in the detachment of the tear edges and the formation of the strains in the canvas near the tear. The original paint layer was covered with surface dirt, overpaint, wax drops, and uneven and darkened varnish. The painting was stretched on a stretcher of a smaller size than the original, with the paint layer wrapped over the sides.

Figure 48.1 Fyodor S. Rokotov (Russian, 1735/1736–1808), *Portrait of F. N. Sinyavina*, 18th century. Oil on canvas, 74 × 58 cm (29 1/8 × 22 5/6 in.). Moscow, State Historical Museum. Detail of the painting before conservation. Image: Department of Scientific Conservation of Oil Paintings, State Research Institute for Restoration (GOSNIIR) / Photo: Anton Mikhailov

Figure 48.2 Reverse side of the painting, showing the tear area before conservation. Image: Department of Scientific Conservation of Oil Paintings, State Research Institute for Restoration (GOSNIIR) / Photo: Anton Mikhailov

As mentioned above, wax treatment limits the use of restoration materials other than synthetic or natural wax. To avoid repeated restoration of the painting using wax-based compositions, the beeswax needed to be removed from the canvas structure, and the AEROSIL-based paste was applied for this purpose.

Removal of beeswax from the canvas was done using the first method described in “Procedure Outline” above. (It is worthwhile to note that during wax absorption the change in the paste color was not observed.) After the mineral spirit evaporated, the surface layer of the paste with absorbed beeswax was removed with a scalpel (fig. 48.3), followed by the use of a bristle brush and vacuum cleaner for more complete cleaning.

Figure 48.3 Removing AEROSIL paste with absorbed beeswax from the surface of the canvas. Image: Department of Scientific Conservation of Oil Paintings, State Research Institute for Restoration (GOSNIIR) / Marina Voronina

This procedure allowed 5% sturgeon glue to be used to consolidate the paint layer and ground. The tear was then

a

b

Figure 48.4 The tear area after removal of beeswax and overpaint followed by thread-by-thread mending with a 5% solution of polyvinyl butyral. (a) Front of painting. (b) Reverse of painting, showing threads from canvas edges added for reinforcement. Images: Department of Scientific Conservation of Oil Paintings, State Research Institute for Restoration (GOSNIIR) / Photo: Anton Mikhailov

mended thread-by-thread with a 5% solution of polyvinyl butyral (PVB) in isopropanol (with a high degree of purity) (fig. 48.4). On the reverse, the tear area was reinforced with additional threads taken from the canvas edges to further secure the area during stretching on a new stretcher.

After the elimination of canvas deformations, losses to the ground were filled. Surface cleaning was done using a solution of one part of purified ox bile and four parts distilled water. After applying the mixture, the treated area was rinsed with distilled water. A mixture of ethanol and pinene (1:2) was used to thin the darkened varnish.

After strip-lining, the painting was stretched on a new stretcher of appropriate size for the picture; this also helps to control canvas tension. Retouching the paint losses was performed, and the surface of the painting was covered with protective varnish based on dammar resin. Labels with inscriptions from the old stretcher were transferred onto acid-free cardboard and fixed to the central bar of the new stretcher.

CONCLUSIONS

We presented the results of the case study on the application of a solvent paste based on fumed silica (AEROSIL) to remove beeswax from the canvas structure of a portrait painted by Russian artist Fyodor Rokotov. The painting had a large tear that had been previously fixed with beeswax, and ground losses had also been filled with beeswax and had oil overpaints. The removal of beeswax residues using AEROSIL paste enabled thread-by-thread tear mending using polyvinyl butyral adhesive and as well as the use of water-based glue to consolidate the paint layer. As a result of these treatments, lining the original canvas was avoided.

The suggested solvent paste based on AEROSIL proved to be an effective material for absorbing both beeswax and oil-resin stains from the structure of the canvas. It enables removal of these materials from local treated areas of paintings without any special equipment. Moreover, it allows the use of water-based glues for further treatments in the future.

NOTES

1. Personal communication between Vilena Kireeva, senior researcher at the Laboratory of Physical and Chemical Research, GOSNIIR, and Maria Churakova, head of the Department of Scientific Conservation of Oil Paintings, GOSNIIR, 2003.

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Analysis of Evolon CR as a Poulticing Agent for Wax-Resin Lining Adhesives: Py-GCMS, BET, and SEM Analyses of Used Evolon CR Tissues

Julianna Ly, Assistant Conservator of Paintings, Cleveland Museum of Art
Chun Liu, Scientist, Janssen Pharmaceutical Companies of Johnson & Johnson, Titusville, New Jersey
Jing Qu, Research Scientist, University of Delaware Advanced Materials Characterization Laboratory, Newark, Delaware
Gerald Poirier, Director, University of Delaware Advanced Materials Characterization Laboratory, Newark, Delaware
Matthew Cushman, Winterthur/University of Delaware Program in Art Conservation, Newark, Delaware

Evolon CR, an absorbent fabric composed of polyester and polyamide microfilaments, is currently used in conservation for the purpose of reducing and removing overpaint and varnish from paintings. This study explores its use as a poulticing agent for the reduction of wax from wax-resin lining treatments. Experiments involving different methods of using the tissue, as well as analyses of the tissue after use employing various analytical methods, indicate that it is most effective when used as a single sheet of solvent-wetted tissue. While the tissue can be used more than once, its ability to poultice wax-resin significantly decreases after first use. Finally, the most important role in influencing the efficacy of poulticing is the solvent choice.

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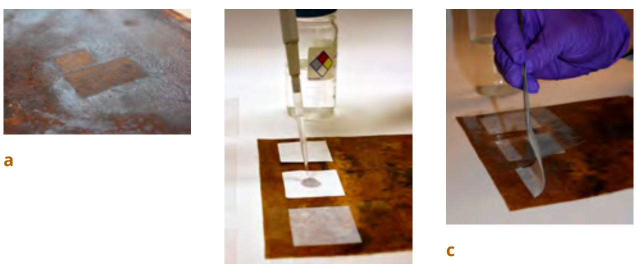
INTRODUCTION

Despite the successful use of Evolon CR (a nonwoven tissue made of a polyester and polyamide blend)[1] in removing overpaint and varnish (Ribits 2017), little research has been done on its ability to poultice wax-resin mixtures. Confronted with two wax-resin lined paintings that required relining, the authors sought a method that would achieve a homogeneous surface topography and remove residual wax-resin mixtures on the verso. The successful reduction of wax-resin mixtures (fig. 49.1a) prompted further research into the efficacy of this method and into the constituent materials poulticed into and onto the Evolon CR tissue. The goals of this study were to better understand the chemical and physical properties of Evolon

CR and to evaluate the tissue's efficacy at reducing wax-resin mixtures in an effort to improve and expand its practical use in conservation.

EXPERIMENTAL DESIGN

Fragments of twentieth-century paintings, previously wax-lined by students using a 2:1 microcrystalline wax to Piccolyte resin, were used for this study. Following the removal of the old lining with heat, the adhesive mixture on the verso of the canvases was reduced using the following procedure (unless otherwise noted): Evolon CR squares measuring 2 inches (each weighing 0.18 g ± 0.001 g) were placed onto the verso of the painting and then wetted with 1 mL of petroleum benzine, delivered by Eppendorf 1000 uL pipette. They were then covered with Mylar and left for varying lengths of dwell time before being removed (figs. 49.1b, 49.1c).



a b c

Figure 49.1 (a) Initial test areas with Evolon CR tissue and solvent on the verso of a painting following wax-lining reversal. (b) Applying 1 mL of solvent to Evolon CR tissue. (c) Removal of Evolon CR after prescribed dwell time. Images: Julianna Ly

Four experiments were conducted to evaluate solvent dwell time on the surface, the potential to reuse the tissue, different application methods, and the solvent delivered with Evolon CR.

All tissues were manipulated with gloves to prevent transfer of oils or dirt from hands in the event this would impact weight gain or pyrolysis–gas chromatography–mass spectrometry (Py-GCMS) analysis, and all were allowed to off-gas overnight.

Quantitative analyses included calculating the weight and porosity changes between unused and used tissues. The weight of the tissue was measured before and after each use for all four experiments on a scale accurate to 0.0001g. Porosity change analyses were conducted using Brunauer-Emmett-Teller (BET) theory. Qualitative tests included scanning electron microscopy–energy dispersive X-ray spectroscopy (SEM-EDS) with back-scattered electron (BSE) imaging, and analysis of poulticed organic materials with Py-GCMS. All experiments and analyses were conducted in 2019 at Winterthur Museum Scientific Research and Analytical Laboratory (SRAL) and the University of Delaware Advanced Materials Characterization Laboratory (UDAMCL).

DWELL TIME

Experiment 1, Dwell Time, assessed the efficacy of Evolon CR left on the surface and under Mylar for one, five,[2] and fifteen minutes. Time points were selected to explore practical and extreme scenarios.

SINGLE- VERSUS DOUBLE-LAYER APPLICATION

Experiment 2, Single- versus Double-Layer Application, assessed the difference between applying a single square of Evolon CR versus a two-layer system (a single wetted square under a dry square covered with Mylar). This method was investigated to determine whether layering a dry tissue over a solvent-soaked Evolon CR tissue could increase the poulticing ability of the material. Both the Single-Layer and Double-Layer experiments were run in triplicate with a five-minute dwell time.

ITERATIVE USE

Experiment 3, Iterative Use, assessed the effects of reusing the same Evolon CR tissue up to three times. The experiment aimed to explore the capacity of the material for reuse and the subsequent changes in efficacy.

SOLVENT STUDIES

Experiment 4, Solvent Studies, assessed the effect of using different ratios of acetone and petroleum benzine and how the solvent selection influenced the materials poulticed and retained in the tissue. Ratios of 10% and 50% acetone in petroleum benzine were compared to neat acetone and petroleum benzine alone.[3]

ANALYTICAL METHODS

SEM-EDS

SEM-EDS was used to analyze the Iterative Use experiments to visualize morphology changes within the tissue structure after repeated uses. Samples were examined using a Zeiss EVO MA15 SEM with LaB6 source at an accelerating voltage of 20 kV for the electron beam. Each of the runs was imaged at 25×, 50×, 137×, and 302×. SEM-EDS was conducted by Dr. Judy Rudolph, a volunteer conservation scientist at SRAL.

BET

Porosity measurements of the tissue were conducted for the Iterative Use experiments to assess the effects of iterative tissue use compared to a control. Porosity measurements were done on a Micromeritrics BET analyzer (Micromeritics ASAP 2020). The pore-size detection limit was 10 nanometers. BET was conducted by Dr. Jing Qu, research scientist, and Gerald Poirier, director of UDAMCL.

Py-GCMS

Py-GCMS was used to analyze the Solvent Studies experiment to characterize low-molecular-weight solvent-extractable materials poulticed from the surface. Samples were analyzed using a Frontier Lab Multi-Shot Pyrolyzer (EGA/PY-3030D), a double-shot pyrolysis system interfaced to an Agilent 7820A gas chromatograph equipped with a 5975 mass selective detector (MSD). GC-MS analysis was conducted by Dr. Chris Petersen, a volunteer conservation scientist and affiliated associate professor at SRAL.

RESULTS AND DISCUSSION

The first three experiments aimed to understand the practical features of Evolon CR, while experiment 4, Solvent Studies, was designed to understand whether the amide and ester functional groups within the tissue influence the material poulticed.

DWELL TIME

Differences in the amount of material poulticed nearly doubles when the tissue is left to dwell for five minutes compared to one minute (fig. 49.2). However, an extra ten-minute dwell only yielded an additional 11% increase in poulticed material. These results support that poulticing capacity decreases as the tissue approaches its saturation point. The fifteen-minute time point, representing an extreme scenario, was tested to understand the length of time it would take for the tissue to approach saturation. In practice, the ideal dwell time should be tested for each particular case.

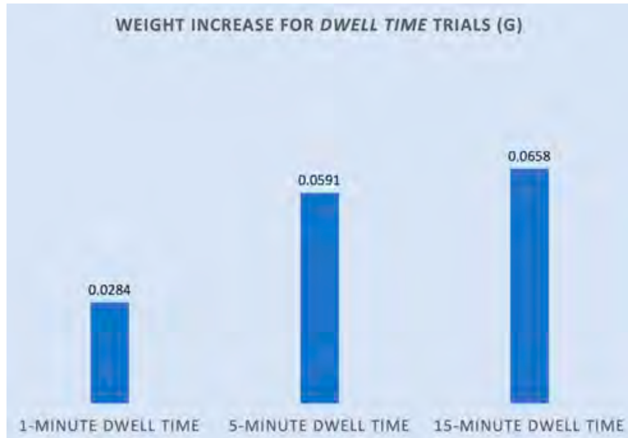


Figure 49.2 Amount (in grams) of the wax-resin mixture poulticed into each tissue after 1-, 5-, and 15-minute dwell times. Image: Julianna Ly

SINGLE- VERSUS DOUBLE-LAYER APPLICATION

The use of a two-layer application proved less effective at poulticing material into the tissue compared to using a single sheet of Evolon CR (table 49.1). Wetted single-layer tissues consistently poulticed more material compared to both wetted tissues only and the combined wet and dry tissues from the Double Layer experiment. A possible explanation is that the dry tissue wicks solvent out of the wet tissue, reducing the amount of solvent delivered to the wax-resin mixture.

ITERATIVE USE

In addition to assessing the efficacy of wax-resin poulticing through weight gain, this series also used SEM-EDS and BET to gather information regarding physical changes. Each use of the Evolon CR tissue resulted in increased material sorption, albeit with decreased amounts for each iteration (fig. 49.3). This trend can be explained using a similar rationale as the decreased weight gain when using excessively long dwell times: as the tissue approaches saturation, its poulticing capacity decreases.

Table 49.1
Weight increases for Single versus Double Layer Application trials

Single-Layer experiment (5-minute dwell time)		**Double-Layer experiment (5-minute dwell time)**						
Trial 1	**55.0 mg**	Trial 1	Wetted	36.0 mg	Dry	8.7 mg	Combined	**44.8 mg**
Trial 2	**59.6 mg**	Trial 2	Wetted	42.5 mg	Dry	8.6 mg	Combined	**51.1 mg**
Trial 3	**62.6 mg**	Trial 3	Wetted	39.5 mg	Dry	10.2 mg	Combined	**49.7 mg**

Table: Julianna Ly

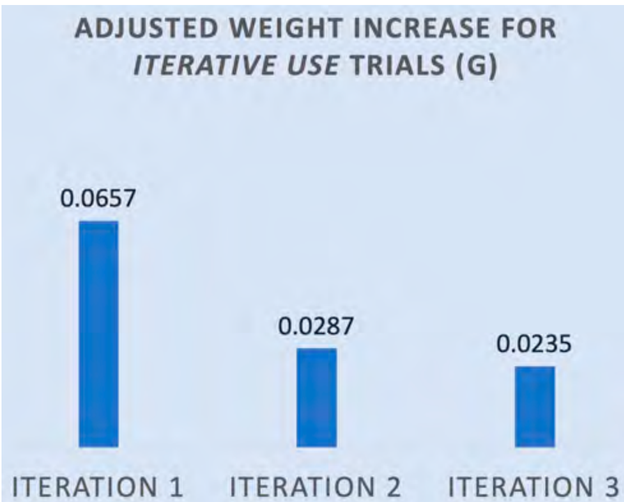
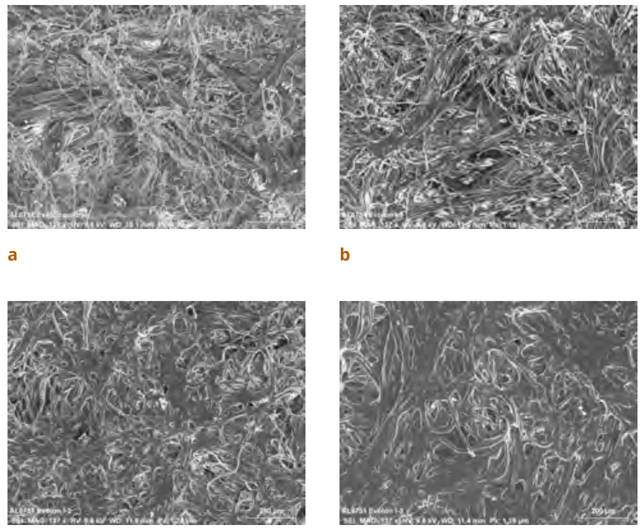


Figure 49.3 Weight increase (in grams) after each iterative use. Image: Julianna Ly



a b c d

Figure 49.4 SEM BSE images of unused tissue: (a) control, (b) after iteration 1, (c) after iteration 2, (d) after iteration 3. (Surface morphology changes visualized in SEM BSE images captured at 137× by Dr. Judy Rudolph, volunteer conservation scientist, SRAL, Winterthur Museum. Images: Julianna Ly

SEM images (fig. 49.4) visualized morphology changes on the surface. With each use, the individual fibers become increasingly less distinct, presumably as the wax resin coats and fills the pores. The loss of definition with each use could be attributed to redistribution of the wax resin already poulticed into the tissue upon re-exposure to solvent, the continued filling of tissue interstices with freshly solubilized/softened wax resin, or a combination of both.

BET analysis yielded a surprising result (fig. 49.5). An increase in measured surface area was observed after the first use, from 0.0982 ^{2}/g (unused control) to 0.4315 ^{2}/g (after single use). Contrary to the weight-gain data and SEM images, both of which confirmed that the tissue had picked up wax resin, BET suggested the porosity increased. However, after the first iteration, BET data trended as expected: with each iterative use, the measured surface area decreased as more wax resin was poulticed into the tissue.

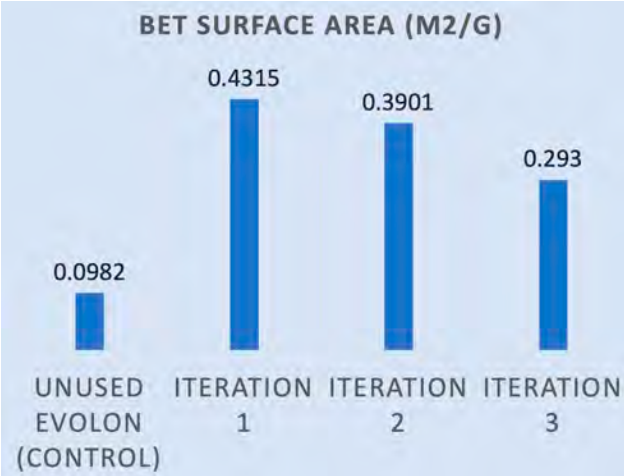


Figure 49.5 Increase in surface area (^{2}/g) analyzed through BET. Image: Julianna Ly

While this publication was in preparation, further analysis of the BET data revealed an anomaly. After further discussion with external scientific colleagues, our preliminary data suggest that BET might not be the ideal instrument for analyzing porosity in Evolon CR due to the relatively low porosity of the fibrous tissue compared with materials BET is typically used to analyze. Further research is needed to develop a quantitative method for measuring porosity changes in Evolon CR before and after use.

SOLVENT STUDIES

The 1:9 mixture of acetone and petroleum benzine gave the largest weight increase, followed by neat petroleum benzine (fig. 49.6a). These results demonstrate a clear relationship between the choice of solvent and amount of poulticed material. The 1:9 mixture likely performed best due to acetone's ability to solubilize resinous components in the wax-resin mixture. As expected, neat acetone resulted in negligible weight gain given its chemical incompatibility with nonpolar, aliphatic compounds. Importantly, this latter result also suggests that the chemical groups making up the Evolon CR (the polyamide and polyester fibers) have minimal effects in poulticing wax resin. The efficacy of poulticing appears to come primarily from solvent choice. Py-GCMS analysis (fig. 49.6b) of the poulticed material showed the characteristic Gaussian distribution of hydrocarbon peaks from the wax component. As expected, the wax-based hydrocarbon peaks increased in intensity as the ratio of petroleum benzine to acetone increased.

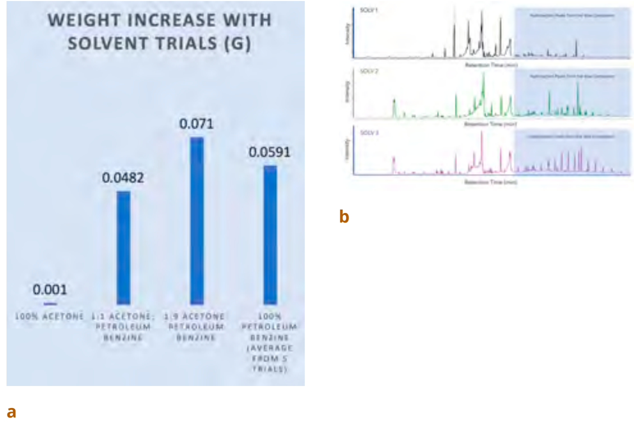


Figure 49.6 (a) Weight increases (in grams) for each tissue exposed to the solvents or mixtures tested. (b) Py-GCMS analysis of the three solvents: solvent 1 is 100% acetone, solvent 2 is 1:1 acetone and petroleum benzine, and solvent 3 is 1:9 acetone and petroleum benzine. (Py-GCMS analysis conducted by Dr. Chris Petersen, volunteer conservation scientist and affiliated associate professor, SRAL, Winterthur Museum.) Images: Julianna Ly

In summary, the results from all experiments indicate that Evolon CR is an effective material for reducing wax resin; however, the tissue alone never resulted in complete removal of the adhesive.

EVOLON CR IN PRACTICE

Much still remains to be understood about practical uses of Evolon CR, yet results from these experiments indicate that, under our testing conditions, it was less effective to use two layers compared to a single sheet of solvent-wetted tissue. Additionally, while Evolon CR can be used more than once, its ability to poultice wax resin significantly decreases after its first use. Finally, our results indicate solvent choice plays an important role in poulticing, and that this role, at least for the removal of wax resin, is stronger than that resulting from the chemical composition of the Evolon CR fibers. Our studies did not use controlled loading of Evolon CR, a recently developed parameter of application where the tissue is loaded with only a fraction of its maximum solvent capacity instead of full saturation (Tauber et al. 2018).

FUTURE DIRECTIONS

While most research on Evolon CR has centered around its use in varnish and overpaint reduction and removal, more study is needed to maximize the efficacy of Evolon CR at poulticing wax-resin lining mixtures. This can include testing aromatic/aliphatic solvent mixtures in differing ratios to most effectively target the wax-resin mixture.

To better understand whether solvents play a role in increasing the porous network of Evolon CR through a rearrangement of the microfilament bundles or if another physical or chemical interaction is at work, continued analysis on solvent-exposed Evolon CR is needed. These experiments should also be conducted on other common poulticing materials used in the field, including Tek Wipe and cotton blotting paper, for comparison.

NOTES

1. See https://evolon.freudenberg-pm.com/evolon_technology/technology.
2. Data for the five-minute time point are the average of the triplicate run from the Single-Layer experiment in the Single- versus Double-Layer Application portion of the study. Note that the data for the one-minute and fifteen-minute time points are single runs (not an average).
3. Data for neat petroleum benzine solvent are the average of the triplicate run from the Single-Layer experiment in the Single- versus Double-Layer Application portion of the study. Note that the data for the neat acetone, 1:9 acetone to petroleum benzine, and 1:1 acetone to petroleum benzine solvents are single runs (not an average of a triplicate run).

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Various Recipes of Wax Resin for Lining Used in Japan and How the Recipe Affects Removal

Saki Kunikata, PhD Candidate, Conservation and Restoration, Department of Conservation, Graduate School of Fine Arts, Tokyo University of the Arts
Takayasu Kijima, Emeritus Professor, Conservation and Restoration, Department of Conservation, Graduate School of Fine Arts, Tokyo University of the Arts
Masahiko Tsukada, Professor, Conservation Science, Department of Conservation, Graduate School of Fine Arts, Tokyo University of the Arts

Wax-resin linings were introduced to Japan at the end of the 1960s and subsequently were applied to many oil paintings. However, due to their disadvantages, they fell out of use in Japan around 2000. Now, some linings applied decades ago need further treatments, and we needed to understand their material properties in order to appropriately conserve them. This research began with compiling the disseminations of wax resin for lining into Japan, which were derived from the most common recipe used at that time. On that basis, various recipes of wax resin were reconstructed and removal experiments performed. It was revealed that the formulation, amount, and types of resin used in wax resins influenced how the mixtures could be removed. The fact that not all components of wax resin are always removed and, moreover, not uniformly removed, calls for great care in the future treatments of oil paintings lined with wax resin in the past.

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INTRODUCTION

Japanese conservation of oil paintings began to take shape at the end of the 1960s, when Japanese conservators and conservation scientists who had studied the conservation of oil paintings abroad returned to Japan. Wax-resin linings composed a major part of the techniques they brought into Japan. From then on, this lining method was applied frequently in Japan, where the climate is humid year round. However, as the disadvantages—such as darkening and the difficulty of retreatment—gradually became clearer, the use of wax resin for lining declined, eventually falling out of use in Japan around 2000. Since then, information about its use had not been published in detail, and the recipes were often handled much like trade secrets in Japan. Now the linings, which were applied decades ago, are partly detaching from some paintings, which now need further treatments.

This poster sheds light on how Japanese conservators restored oil paintings using wax resin as lining adhesives in the past, focusing on their various recipes through research done by conducting personal interviews and related bibliographic surveys. As the adhesives are reconstructed and the removal experiments performed, we should gain a better understanding of their material properties in order to choose or propose appropriate ways to conserve paintings treated this way in the past.

WAX-RESIN RECIPES FOR LINING USED IN JAPAN

As a first step, interviews on the composition of wax resin and the ways in which it was applied were conducted with conservators who had treated oil paintings in the 1970s and 1980s in Japan using this method. In particular, the authors interviewed conservators who had been involved with the War Record Paintings Conservation project, which was an enterprise of national importance at that time (National Museum of Modern Art, Tokyo 1977). These conservators made significant contributions to the establishment of Japanese oil paintings conservation.

Figure 50.1 shows various recipes of wax resin obtained through the interviews and the related bibliographic surveys. Wax-resin linings were introduced to Japan via two different routes: from Belgium's Institut Royal du Patrimoine Artistique (Royal Institute for Cultural Heritage [KIK-IRPA]) and from the United States' New York University (NYU).[1] Most of the recipes used in Japan originated from Georges Messens's recipe, used at KIK-IRPA. Tsuneyuki Morita and Mitsuhiko Kuroe studied under Messens (Kuroe 1969, 1975),[2] and they brought his recipe and method to Japan in the late 1960s.

Morita and Kuroe said that it was difficult to get gum elemi at that time in Japan, so they had to find a substitute. One chose colophony because it strengthens the adhesive property and has excellent compatibility with beeswax. The other chose microcrystalline wax—the first synthetic material introduced for wax-resin lining in Japan. It appears that the mainstream wax-resin recipe in Japan then became 7 parts beeswax, 2 or 3 parts dammar resin, and 1 part microcrystalline wax. Most conservators continued to use wax resin for lining over the next two decades, but the modification of the lining adhesive recipe had already been completed in the 1970s. There were few who used ready-made wax resin, although it was available.

EXPERIMENTAL REMOVAL OF WAX-RESIN ADHESIVE

Based on the recipes shown in figure 50.1, six formulas of the lining adhesives were prepared for the experiments. As the test pieces, 10 cm square pieces of linen canvas faced with Japanese Tengujo paper on one side were prepared.

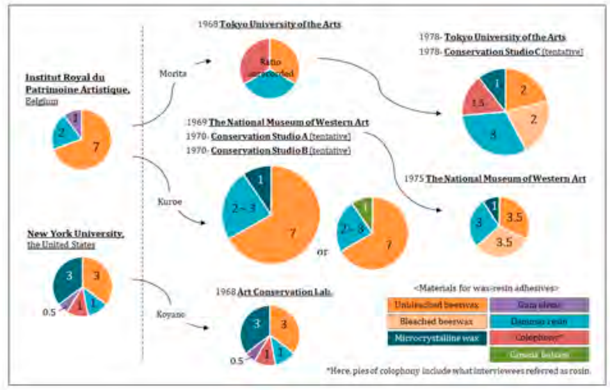

Figure 50.1 Various recipes of wax resin for lining used in Japan. Wax-resin linings were brought into Japan at the end of the 1960s, and the recipe of the lining adhesive had already been modified by the 1970s. (Note: colophony was referred to in interviews as "rosin.") Sources: Institut Royal du Patrimoine Artistique: Messens 2003; New York University: Keck 1965; 1968 Tokyo University of the Arts: Utada and Morita 1968; Art Conservation Lab: Koyano 1968; 1969 National Museum of Western Art: Kuroe 1969; 1970 Conservation Studios A and B: interviews by author, 2018; 1975 National Museum of Western Art: Kuroe 1975; 1978 Tokyo University of the Arts: documents in the Tokyo University lab archives; 1978 Conservation Studio C: interviews by authors, 2018. Image: Saki Kunikata

They were impregnated with the recipes shown in table 50.1 from the fabric side and labeled A through F. On the reverse (uncovered) side, a 1 ml drop of mineral spirit was applied. The drop was covered with blotting paper, and a glass plate and weight were placed on top for thirty seconds. This operation was repeated fifteen times for each piece. After the solvent evaporated completely, the weight loss was measured and the removal amount and rate (percentage) of each sample were compared.

Ten test pieces were prepared for each adhesive (A–F), and half of them were subjected to artificial aging. The heat aging was carried out in an Espec LHU-113 Benchtop Temperature/Humidity Chamber at 55°C and 45% RH for three months. This aging condition was used by Gustav Berger in 1972 to test adhesives used in the consolidation of paintings. According to the reference, the heat aging at 55°C could keep the objects below the melting point (and possible critical deterioration point) of resins (Berger 1972b). The mean value of the removal rate for each recipe was calculated as follows:

$$\frac{\text{sample weight after adhesive impregnation} - \text{sample weight after adhesive removal}}{\text{sample weight after adhesive impregnation} - \text{sample weight before adhesive impregnation}}$$

The results are shown in figure 50.2.

Table 50.1
Wax-resin recipes used in experiments

Sample	Wax	Quantity (part)	Resin	Quantity (part)	Other	Quantity (part)
A	Unbleached beeswax	7	Dammar resin	2	Microcrystalline wax	1
B	Unbleached beeswax	7	Dammar resin	4	Microcrystalline wax	1
C	Unbleached beeswax	7	Dammar resin	2	Gum elemi	1
D	Unbleached beeswax	7	Dammar resin	2	Colophony	1
E	Unbleached beeswax	7	Dammar resin	2	Canada balsam	1
F	Unbleached beeswax	All	—	—	—	—

Table: Saki Kunikata

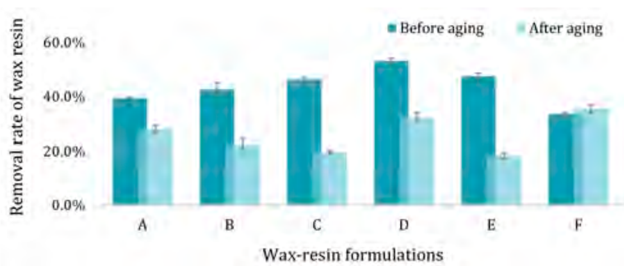

Figure 50.2 Removal rate of wax resin by weight. Image: Saki Kunikata

Before the artificial aging, it was revealed that the larger the amount of resin in the mixture, the higher the removal rate of wax-resin adhesive. In particular, wax resin D, containing colophony, was removed effectively.

After the artificial aging, the removal rate of wax resin decreased for all the samples except F, which contained no resin. Comparing the samples in terms of the amount of resin, the removal rate of B after aging, with the doubled dammar resin, became smaller than that of A, whereas the opposite results were obtained before aging. It was also revealed that it became difficult to remove C and E, which contained more resins than A; more than 80% of the impregnated wax resin by weight remained on the pieces after removal. As for F, its removal rate didn't change much after aging. Accordingly, a rough tendency could be summarized as follows: the greater the amount of resin in the wax-resin adhesive, the higher the removal rate of wax resin before aging. Conversely, the more resin there was in the recipe, the less the removal rate would be after aging.

For the next step, what was left on the test pieces after removal was investigated by Fourier transform infrared (FTIR) spectroscopy. The FTIR spectra of wax-resin residues both before and after the removal were measured by using a Bruker Alpha FTIR spectrometer with attenuated total reflectance (ATR) mode. To compare each spectrum, we focused on the range of wave numbers from 1800 to 1600 cm^{-1}. Beeswax has its highest peak at about 1736 cm^{-1}, and resins have peaks at around 1700 cm^{-1}. The spectra of all the components are shown in figure 50.3, and the spectra of mixtures (A–E) are shown in figure 50.4.

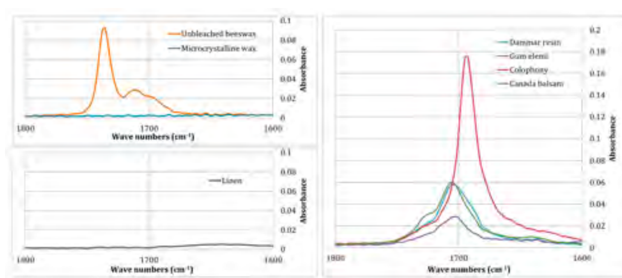

Figure 50.3 Materials for wax-resin adhesive: FTIR spectrum measurements of test samples (1800 cm^{-1} to 1600 cm^{-1}). Image: Saki Kunikata

As the spectrum of wax resin A before aging shows, its peak intensity became weaker at about 1735 c^{-1} and a little stronger at about 1710 c^{-1} by the removal. This implies that the spectrum gradually grows more similar to that of a resin than to that of beeswax. These changes of spectra were common in almost all the mixtures (A–E). These results suggest that beeswax tends to be removed better than resins. The spectra after aging showed changes by the removal similar to those observed before aging.

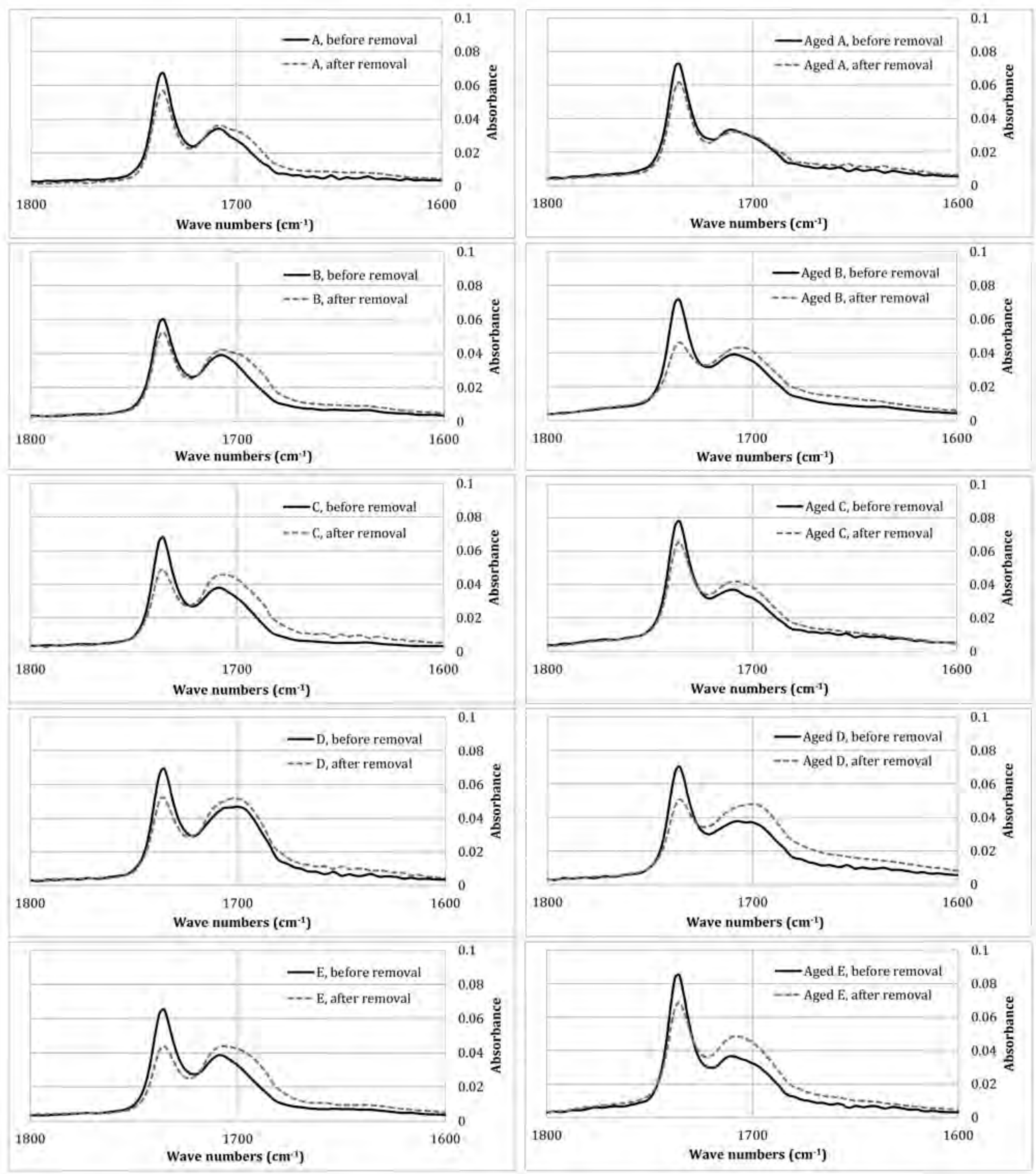

Figure 50.4 FTIR spectrum measurements of wax-resin samples A–E (1800 cm^{-1} to 1600 cm^{-1}). Image: Saki Kunikata

DISCUSSION OF EXPERIMENTAL RESULTS

Through the experiments, it was revealed that the removal rate of wax resin with the method tested varied for each formulation and for the amount and kinds of resins, influenced whether the mixtures could be easily removed. The measurement results of FTIR spectra suggested that the proportions of resins in the residual wax resin on test pieces could increase compared to spectra from before the removal operations. We speculate that resins in the mixtures became oxidized by artificial aging, and the oxidized resins made it difficult to remove the entire mixtures, leaving resin behind on the canvases.

It should be noted that the results reported here were achieved under a specific situation—one method of removal with one solvent—but similar results probably would be achieved using heat for the removal. Melting tests of the Netherlands' MolArt project (Molecular Aspects of Ageing in Painted Works of Art, 1995–99) showed that only wax was melted out from an aged wax-resin mixture when heating at a certain temperature.[3] Aged resins need much higher temperatures and cannot be removed without risk to the paintings. We also need to bear in mind that the remaining resins in the canvas, when not accompanied by wax, can make the paintings even more brittle after the removal operations whether solvents or heat is used for removal.

CONCLUSION

This poster discussed the introduction of the wax-resin lining method to Japan and how it expanded throughout the country with small modifications. The most common recipes used at that time were deduced. It is likely the recipe we would encounter most often when treating oil paintings lined with wax resin in Japan.

Various recipes of wax-resin adhesive were reconstructed, and some comparisons were made to clarify how various recipes of wax resin behave on removal. The experimental results demonstrated some trends: which recipes of wax-resin adhesive—and which of their components—tend to remain on linen canvas.

In Japan, little study has been done to reconsider old linings of canvas paintings, but it is high time that the findings are well documented and disseminated for present and future generations. We intend to continue research on this matter and hope it will guide conservators and allied professionals to think about how to treat oil paintings lined with wax resin.

SOURCE OF MATERIALS FOR WAX RESIN

The following materials were obtained from the same source used by the interviewees or are materials currently available in Japan:

Dammar resin: Holbein Works Ltd., Japan

Gum elemi: Talas, United States

Colophony: Hayashi Chemical LLC, Japan (marketed as Rosin)

Canada balsam: Showa Chemical Industry Co. Ltd., Japan

Beeswax: Yamada Bee Company, Inc., Japan

Microcrystalline wax: Victory White Wax, Baker Hughes, United States

NOTES

1. Masako Koyano, personal communication. Koyano, who studied at NYU's Institute of Fine Arts, related that people there used the recipe devised by Caroline and Sheldon Keck. The Kecks founded the Conservation Center at the institute, and Sheldon Keck was its director from 1960 to 1965 (Ken Johnson, "Caroline K. Keck, Art Conservator, Dies at 99," *New York Times,* January 15, 2008).
2. Tsuneyuki Morita, interview by the authors, January 29, 2018. Mitsuhiko Kuroe's connection to KIK-IRPA was also referred to in this interview.
3. Mireille te Marvelde, email message to the authors, February 8, 2020.

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An Insight into the Limits and Possibilities of the Biological, Chemical, and Mechanical Performance of Glue-Paste Lined Paintings

Laura Fuster-López, Professor, Instituto Universitario de Restauración del Patrimonio, Universitat Politècnica de València, Spain
Cecil Krarup Andersen, Associate Professor and Head of Paintings Conservation, Royal Danish Academy of Fine Arts, Schools of Architecture, Design and Conservation, School of Conservation, Copenhagen
Nicolas Bouillon, Chemist, Centre Interdisciplinaire de Conservation et de Restauration du Patrimoine (CICRP), Marseille, France
Fabien Fohrer, Entomologist, Centre Interdisciplinaire de Conservation et de Restauration du Patrimoine (CICRP), Marseille, France
Matteo Rossi-Doria, Painting Conservator, C.B.C. Conservazione Beni Culturali
Mikkel Scharff, Professor, Royal Danish Academy of Fine Arts, Schools of Architecture, Design and Conservation, School of Conservation, Copenhagen
Kate Seymour, Professor, Stichting Restauratie Atelier, Maastricht, the Netherlands
Ángel Vicente-Escuder, Professor, Instituto de Tecnología de los Materiales, Universitat Politècnica de València, Spain
Dolores Julia Yusà-Marco, Associate Professor, Instituto Universitario de Restauración del Patrimonio, Universitat Politècnica de València, Spain
Sofía Vicente-Palomino, Associate Professor, Instituto Universitario de Restauración del Patrimonio, Universitat Politècnica de València, Spain

Glue paste has been the most widely used lining adhesive in the Southern European tradition. This research was devoted to studying the mechanical performance and failure mechanisms of mock-up linings made with selected simplified glue-paste recipes when subjected to changing environments as a function of the materials and application techniques used. For this purpose, different qualities of wheat and rye flours were tested, mixed with selected animal glues in different proportions. The elimination of additives from the recipes studied provided coherence and clearer evaluation of results. Two representative lining canvases were selected, and linings were carried

out following the Italian tradition. The lined mock-ups were subjected to RH cycles, and the impact on the mechanical, chemical, and biological properties of the lined paintings was reported, with special attention given to the effects of the degree of milling, the cereal protein content of the flours, and the weave density of the lining fabrics.

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INTRODUCTION

A variety of materials have been used in glue-paste linings throughout history, and this lining type is found on a significant number of the paintings in collections worldwide. Recipes varied from country to country and epoch to epoch. Cereal flours and animal glues were usually the main ingredients, either because they were readily available or simply owing to tradition. A variety of different additives (molasses, vinegar, Venetian turpentine, garlic, etc.) were commonly included in recipes, aiming to enhance performance or to prevent mold growth (Hackney et al. 2012; Macarrón, Calvo, and Gil 2016).

Glue-paste linings can be long-lasting, but they can also lead to further degradation. It has remained unclear why some of these linings fail while others remain well preserved. In the last twenty-five years, there has been a significant interest in understanding the performance and aging of glue-paste linings. Some studies have analyzed the role of each component and given some insight into the bond performance of the adhesive mixture (Ackroyd 1995, 1996; Young and Ackroyd 2001; Young, Hibberd, and Ackroyd 2002). The research presented here shows how varying the dominant ingredients of the glue-paste recipe influences the mechanical performance (bond strength, stiffness, etc.) and degradation processes (biodeterioration) of lined canvas paintings. The impact of cyclic RH on the biological and physical stability of the laminate structure is also reported.

THE ROLE OF GLUES AND FLOURS IN THE MECHANICAL PERFORMANCE OF GLUE-PASTE LININGS

Glues and flours are the two main components of glue-paste adhesives. Their complex structure, properties, and stability suggested a need to prioritize the research aimed at understanding their behavior and interaction before considering the role of the different additives cited in treatises and recipe books.

The study of protein glues in the conservation field has attracted some attention in recent years. Obtained from the skin and bones of animals through different preparations and purification treatments, their chemical, physical, and mechanical properties are largely influenced by the chemical structure of the protein and its denaturation process. Protein glues generally have high cohesive strength and stiffness in comparison to synthetic adhesives, as previous research has shown (Mecklenburg 1982; Andersen and Fuster-López 2019).

The molecular weight (size and length of the chains of the protein), the content of the helix structures formed during renaturation, and the type of intra- and intermolecular bonds in the protein as a function of the proline and hydroxyproline content determine the cohesive strength and the viscosity of the glue solution (Schellmann 2007). The stiffness of gelatin leads to the classification into different Bloom grades, which are also an indication of mechanical properties (Melià Angulo, Fuster-López, and Vicente Escuder 2017). Hide glues are also responsive to humidity fluctuations, developing high internal stresses if restrained and subjected to desiccation and losing all strength and undergoing biodeterioration above 70% RH (Mecklenburg 1982). Together, these characteristics mean that animal glues play a major role in the behavior and long-term performance of glue-paste adhesives.

The second main component in glue pastes is flours, in which starch, proteins, and lipids are the most relevant components. Starch has functional properties such as solubility, water-holding capacity, swelling power, viscosity, and consistency, all of which largely depend on the amylose-amylopectin ratio as well as on the size of their granules as a function of the botanical origin and nature of the starch. The protein content also plays a major physicochemical role in the rheological behavior of the adhesive mixture (García Castillo 2016).

BIOLOGICAL, CHEMICAL, AND MECHANICAL PERFORMANCE OF GLUE-PASTE LININGS

After preliminary research dedicated to the study of several protein glues with different Bloom grades and some flours with different protein content, mock-ups with eight different combinations of materials were prepared (fig. 51.1). For this purpose, one cowhide glue, one rye flour, and three wheat flours were selected (table 51.1). Two different fabrics were used as lining support, and a commercial primed linen canvas with a ground layer of titanium white/zinc oxide bound in oil was used to simulate a canvas painting. Glue-paste mixtures were tested according to the ratio shown in table 51.2. Peel and tensile tests were run in order to record the adhesion and cohesion forces at different RH conditions for unaged and aged samples. Biodeterioration and insect infestation tests were also carried out (Fuster-López et al. 2017).

Figure 51.1 Matteo Rossi-Doria and Nicolas Bouillon at Universitat Politècnica de València preparing the mock-ups. Images: Courtesy of the research team

Table 51.1
Materials tested

Fabrics

Type	Light microscopy	
	10×	**25×**
Open-weave washed linen fabric: 9 × 9 threads/cm^2 (CTS 2297)		
Close-weave washed linen fabric: 15 × 15 threads/cm^2 (CTS 1111)		

Glue

Type	Brand	Form	Bloom grade	Viscosity
Hide glue	Kremer 63010	Pellets	240–250	80 mPA

Flours

Type	Brand	Protein content (%)	Wet gluten (%)	Amylose-amylopectin ratio
Fine-milled Candeal white wheat, Type 45	El Corte Inglés	10–11	21.5	0.45
Fine-milled Manitoba white wheat, Type 55	Finestra sul Cielo	14	27.3	0.44
Rough-milled semiwhole wheat, Type 80	Minoterie DOM	10–11	24.8	0.35
Rough-milled semiwhole rye, Type 70	Minoterie DOM	7	—	0.35

Table: Courtesy of the research team

Table 51.2
Glue-paste mixtures

Glue-paste mixture (ratio 1:6)		Lining fabric	Mock-up painting: primed canvas	Unaged samples	Aged samples
Glue	**Flour**				
63010 Kremer	Wheat Manitoba Type 55	Open-weave linen canvas: 9 × 9 threads/cm^2 (CTS 2297)	Primed linen canvas, titanium white/zinc oxide bound in oil as ground layer (Claessens, Belgium)	WM-O-U	WM-O-A
	Wheat Type 45			WT55-O-U	WT55-O-A
	Wheat Type 80			WT80-O-U	WT80-O-A
	Rye Type 70			Rye-O-U	Rye-O-A
	Wheat Manitoba Type 55	Close-weave linen canvas: 15 × 15 threads/cm^2 (CTS 1111)		WM-C-U	WM-C-A
	Wheat Type 45			WT55-C-U	WT55-C-A
	Wheat Type 80			WT80-C-U	WT80-C-A
	Rye Type 70			Rye-C-U	Rye-C-A

Note: O = open, C = closed, A = aged, U = unaged.
Table: Courtesy of the research team

Results (table 51.3) evidenced the influence of lining materials and adhesive formulations on the mechanical properties and the tendency toward biodeterioration. Peel tests showed an average peel force of 6.52 N/cm in close-weave canvases and 4.98 N/cm in open-weave ones. In general, aging significantly increased (by 10%–27%) the force needed to peel off the close-weave lining fabrics in all cases, except for those where Type 45 wheat flour (WT45) had been used. Conversely, the average peel force decreased (by 32%–39%) in linings made of open-weave canvases except for those where WT45 was used. Results also showed that the type of flour and the degree of milling, as well as the density of the lining canvas, strongly influence the mechanical and dimensional stability of glue-paste linings and determine the failure risk of the paint layers. This approach to the possible influence of weave tightness on crack formations has been recently witnessed in a study of four paintings by Pablo Picasso (Fuster-López et al. 2020).

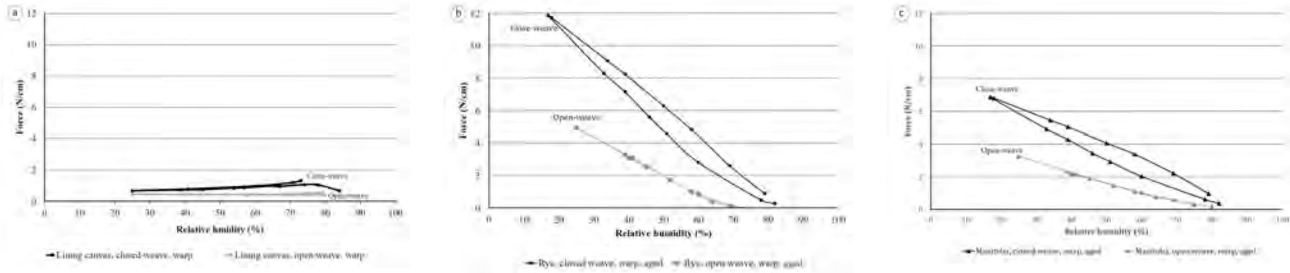
Table 51.3
Adhesion peel tests

Samples tested in weft direction		Lining canvas	Average peel force (50–250 mm) (N/cm)	Standard deviation (N/cm)	Minimum force (N/cm)	Maximum force (N/cm)
Unaged samples	Rye Type 70	Close weave	5.46	0.90	3.63	8.02
	Wheat Type 80		6.42	1.06	4.04	9.46
	Wheat Type 45		5.44	1.92	2.04	9.63
	Wheat Manitoba Type 55		7.41	1.50	3.76	13.35
	Rye Type 70	Open weave	7.40	1.86	4.00	11.69
	Wheat Type 80		8.40	1.72	4.96	12.94
	Wheat Type 45		2.26	0.39	1.67	4.17
	Wheat Manitoba Type 55		5.05	0.83	3.18	7.62
Aged samples	Rye Type 70	Close weave	6.80	1.02	4.89	10.14
	Wheat Type 80		6.91	1.06	4.79	10.20
	Wheat Type 45		4.31	1.20	2.39	8.24
	Wheat Manitoba Type 55		9.43	1.27	6.74	15.34
	Rye Type 70	Open weave	5.29	1.47	3.00	11.34
	Wheat Type 80		5.67	1.06	3.44	8.62
	Wheat Type 45		2.38	0.33	1.78	3.46
	Wheat Manitoba Type 55		3.40	0.42	2.68	5.08

Note: Tested using ASTM D1876-01 standard; T-type specimens in Shimadzu universal testing machine, 1 kN load cell.

Table: Courtesy of the research team

Figure 51.2 shows the restraint tests of different lining fabrics and glue-paste linings. While the force development in the restrained raw canvases when subjected to different RH was similar for both canvas densities tested, significant differences can be observed when the same textile is used as lining fabric in combination with the different glue-paste formulations. For example, adhesive mixtures containing rye Type 70 (7% protein content) develop twice the force when used in combination with close-weave fabrics than when used with open-weave fabrics over a wide range of RH conditions (fig. 51.2b). These values drop to half for both open- and close-weave fabrics when Type 55 (Manitoba) wheat flour is used (fig. 51.2c). In addition, it was observed that among all the combinations tested, closely woven canvases and semiwhole flour–based recipes induce the highest contraction forces in restrained samples, leading to significant risk of cracking and delamination (fig. 51.3).



a

b

c

Figure 51.2 Restraint tests of different lining fabrics and glue-paste linings. (a) Force development of open- and close-weave lining canvases (alone) when subjected to different RH. (b) Force development of rye T70, linings as a function of the weave geometry of the lining canvas when subjected to different RH. (c) Force development of Manitoba wheat T55, linings as a function of the weave geometry of the lining canvas when subjected to different RH. Images: Courtesy of the research team

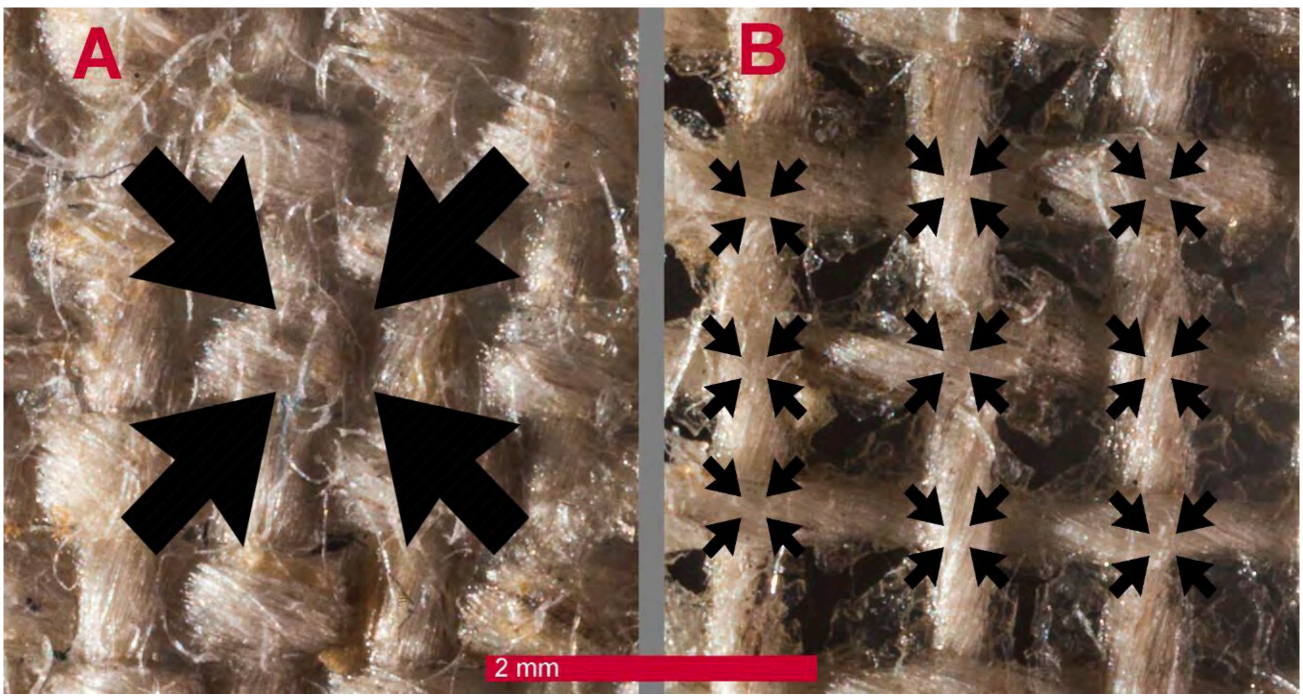
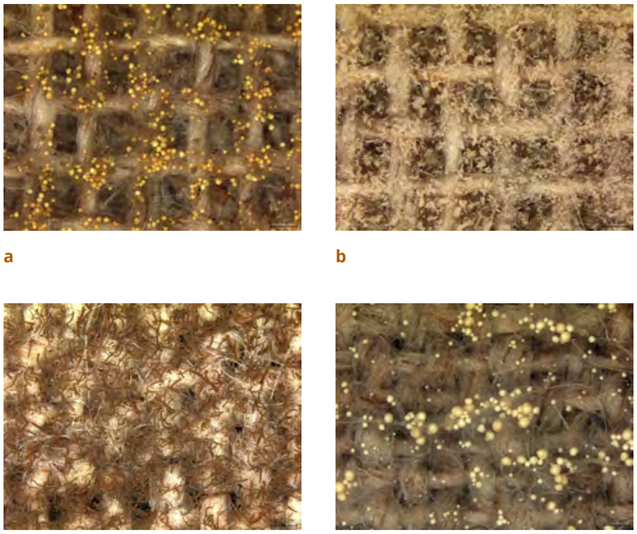


Figure 51.3 Detail of the two canvases with glue-paste applied. (a) Tight weave: a continuous glue-paste film. (b) Open weave: fractured glue-paste film. Images: Courtesy of the research team

Results evidenced that biodegradation is governed by the flour milling and flour-glue ratio, and by the nature of the starch and protein when the flour-glue ratio is kept constant. Mold growth and pest infestation tests evidenced that glue-paste linings containing semiwhole flours are more sensitive to RH than those made from fine-milled white flours—meaning a greater tendency toward biodeterioration at high RH. Again, the weave geometry of the lining canvas influences the results (fig. 51.4). Close-weave and open-weave canvases are both affected by biodeterioration; open weave-canvases seem to be more prone to contamination by mold but slightly less vulnerable to degradation by insects. Concerning mold, the second layer of glue paste applied from the reverse after the laying on of the lining canvas can act as a better hydrophilic substrate for mold growth. A possible explanation for less infestation is that *Stegobium paniceum* is a lucifugous insect, so the exposure to light caused by open-weave interstices can disrupt the act of laying eggs.



a b c d

Figure 51.4 Detail of microbiological study. Binocular examination of contaminated samples at the end of the test (25× magnification), showing spores and mycelium of mold species that have contaminated the samples. (a) Rye T70, open-weave fabric. (b) Wheat T80, close-weave fabric. (c) and (d) TK. Image: Courtesy of the research team

The need to agree on objective parameters that allow the comparison of the different variables considered when studying materials for a given treatment has been suggested by Cecil Krarup Andersen in this publication. Such parameters could help conservators make informed decisions based on the mid- to long-term vulnerability of the materials used. Figure 51.5 shows different star diagrams corresponding to the eight glue-paste linings studied. Values of 1 to 5 are given for each risk factor, with 1 being low risk and 5 high risk. This means that numeric values measured for each factor (Fuster-López et al. 2017) are normalized to fit this scale.

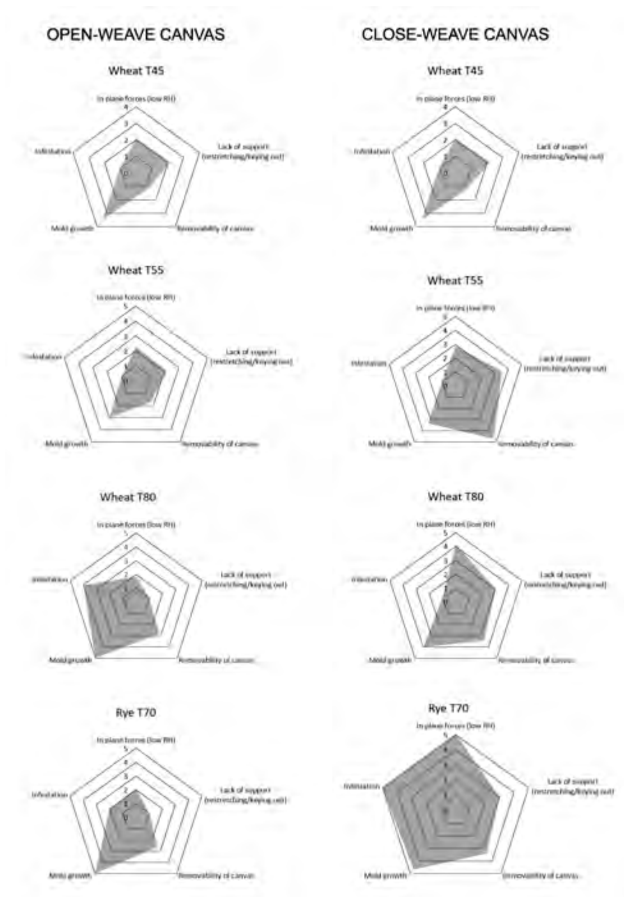


Figure 51.5 Star diagrams representing the risks for glue-paste linings as a function of the flour used. Considering that the five parameters tested are RH-related, the smaller the area covered, the less vulnerable the glue-paste lining is to RH; in other words, larger gray areas suggest the need for more restrictive environmental conditions to ensure the stability of the lined painting. Image: Courtesy of the research team

The aspects considered are as follows:

- Buildup of in-plane forces with low RH—higher numbers correspond to higher forces.
- Lack of support offered by the lining when restretching or keying out—higher numbers correspond to lower stiffness/less support.
- Removability of canvas—higher numbers correspond to greater force required for removal.
- Mold growth—higher numbers correspond to greater tendency for mold growth.
- Pest infestation—higher numbers correspond to greater tendency for pest infestation.

As they depict a risk scale, these star diagrams can be considered either a representation of the stability of each formulation or evidence of their vulnerability.

CONCLUSIONS

In this research, several lining-adhesive formulations made of glues and flours were tested. Results evidenced that the choice of materials has a strong impact in the vulnerability of the lined painting in the mid- to long term, which could explain the different conditions of glue-paste linings typically present. It was shown that the weave geometry of fabrics influences the adhesion, dimensional response, and vulnerability to pest infestation of the lined paintings. As a rule, open-weave lining canvases seem to exhibit less mechanical degradation than closer-woven ones. In addition, keeping the glue-to-paste ratio constant made it possible to observe that the type of flour also contributes to the dimensional response and the tendency toward pest infestation and mold growth in glue-paste linings. Rye-based formulations were shown to be the most vulnerable ones—those that require the most restrictive environmental conditions for their long-term stability.

ACKNOWLEDGMENTS

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The Structural Treatment of Titian's *Rape of Europa*: Extending the Life of a Two-Hundred-Year-Old Glue-Paste Lining

Courtney Books, Paintings Conservator, Saint Louis Art Museum, Missouri
Corrine Long, Associate Paintings Conservator, Gianfranco Pocobene Studio
Gianfranco Pocobene, Chief Paintings and Research Conservator, Isabella Stewart Gardner Museum, Boston

In preparation for a multivenue loan and the rigors of transatlantic travel, Titian's Rape of Europa *underwent a structural treatment in 2018. Remarkably, the painting retains what appears to be a late-eighteenth-century glue-paste lining. While the painted surface was stable, it was observed that sections of the lining canvas had detached along the edges of the cropped original canvas support and that the painting was also extremely loose on its strainer. Although the notion of relining was considered, it was decided to preserve the old glue-paste lining. The strainer, dating from the time of the lining procedure, was in poor structural condition, exhibiting severe bowing of the cross members, extremely weak corner joints, and woodworm damage. As these condition problems precluded the original strainer's reuse, a new modified stretcher system, incorporating lightweight, rigid panel inserts and a loose-lining fabric, was employed to support the painting.*

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INTRODUCTION

The Rape of Europa (1560–62) is one of six canvases from Titian's seminal Poesie paintings, commissioned by Philip II of Spain.[1] Inspired by Ovid's *Metamorphoses*, the mythological painting depicts the moment of Europa's abduction by Jupiter, who took the form of a bull and carried her off to Crete. Where and how Philip II displayed the Poesie series in Madrid remains unclear, but by 1707 *Europa* was in the collection of Philippe II, Duke of Orléans, in Paris. In 1793, *Europa* was transported to England, where it remained in the collection of the Earl of Darnley until Isabella Stewart Gardner purchased it in 1896, on the advice of Bernard Berenson. For more than 120 years, it has been on permanent display in the Isabella Stewart Gardner Museum's Titian Room. In 2020–21, the Poesie paintings were reunited for the first time in over four hundred years for the international exhibition *Titian: Love, Desire, Death*, with exhibitions at the National Gallery, London; Museo Nacional del Prado, Madrid; and the Isabella Stewart Gardner Museum, Boston.

When the exhibition was first proposed, concerns about the condition of the *Rape of Europa* were raised, as it had never previously been loaned. An examination by Andrea

Rothe in 1989 indicated that while the painting was well preserved and stable, with regard to the lining, “under no circumstance should the painting travel in its present state.”[2] At the curator’s request, a preliminary examination of the canvas was conducted in 2017 to consider the viability of loaning the picture. While several condition issues were discovered, it was determined that with appropriate structural intervention, the painting could be stabilized and reinforced for travel. In 2018, the museum’s commitment to participate in the historic exhibition compelled a thorough assessment of *Europa*’s structural and aesthetic condition, and it was concluded that the painting required treatment. Three distinct but interrelated phases of work composed the project:

1. Comprehensive technical and analytical research to determine Titian’s techniques and materials, and to ensure the appropriate treatment procedures (see the appendix for a description of the analysis)
2. A minimally invasive structural treatment to support the canvas for travel to Europe and ensure long-term preservation
3. Cleaning and aesthetic restoration to remove discolored coatings and to realize selective retouching of abraded paint layers

This essay focuses on the structural treatment of the *Rape of Europa* in preparation for the exhibition. Once the physical concerns were identified, a structural support system, which sought to impart no change to Titian’s canvas, was devised.

MATERIAL COMPOSITION

The large-scale (71 3/4 × 80 1/2 inch [182.2 cm × 204.5 cm]) painting is executed in oil paint on linen canvas. The original support is a sixteenth-century herringbone canvas constructed from two pieces of fabric sewn together with a slightly curved, vertical seam 95 cm from the left edge. The original canvas is lined onto a secondary support with a protein-based adhesive. The auxiliary canvas comprises two pieces of herringbone-weave linen sewn together with a vertical seam 89.5 cm from the left edge; it was likely manufactured before the mid-nineteenth century, when fabrics were fabricated on a handloom and typically did not exceed a meter in width. It is therefore presumed that the lining likely occurred in the late eighteenth or early nineteenth century. Hot, heavy irons would have been used to bond the canvases, which accentuated the seam and the weave.

The painting was stretched over a lightweight, six-member softwood strainer with metal tacks along the tacking margins. Two cross members reinforced the strainer and hand-forged nails secured the corner lap joints. The nonoriginal strainer is likely contemporary with the glue-lining procedure.

The preparatory layer consists of an exceptionally thin gesso (calcium sulfate) ground. Titian then applied oil-bound pigments in mostly thin, energetic brushstrokes and used varied techniques of dry scumbles and binder-rich glazes. Surface coatings were a thin layer of aged, natural resin varnish intermeshed with proteinaceous lining-adhesive residues.

CONDITION CONCERNS

The condition of the painting’s support system generated considerable concern. Structurally, the weakened strainer was inadequate: the cross members had developed a prominent outward bow on the reverse, the strainer members were brittle from woodworm damage, and the lap joints were weak and loose. The adhesion between the lining fabric and the original canvas was also questionable. There were instances of adhesion failure between the original and lining canvases, which resulted in small separations along the edges. Furthermore, tearing of the lining at the tacking sites contributed to looseness of the canvas support. The assortment and severity of condition issues prompted an initial consideration of relining. Despite some occurrences of delamination at the lining’s edges, however, gentle probing between the canvases with a microspatula proved the bond strength of the adhesive to be fully adequate. Further investigation with raking light and sounding with fingernails confirmed adhesion away from the edges.

STRUCTURAL TREATMENT AND METHODOLOGY

Several objectives guided the structural treatment of Titian’s *Europa*. The overarching principle was to use materials congruent with the historical materials present, both original and belonging to previous interventions. Treatments deemed more aggressive, such as subjecting the canvas to lining removal and potential stress to paint layers, were to be avoided. Furthermore, the treatment needed to impart adequate resistance to vibrational/mechanical stress (i.e., rigid support), while simultaneously avoiding immobilization of the paint and canvas structure.

The structural treatment was executed in two stages: the first involved stabilization of the original canvas and lining canvas and reinforcement of the lining support; the second comprised the restretching of the painting and implementation of a blind-panel stretcher and loose-lining fabric support.

The first stage included re-adhering the detached areas of lining fabric, removing the canvas from the unstable strainer, and adjusting the seam allowance of the loose-lining so that it would not impart an impression onto the painted surface. The second stage involved constructing a blind-panel stretcher and installing the loose-lining. The custom blind-panel design would replace the structurally weak strainer and add stability and resistance to mechanical stresses by providing additional support (fig. 52.1). Complete restriction of the painted canvas was avoided by using the loose-lining technique to provide a gentle nap bond. Preventive measures were also taken by reducing excessive tensioning during restretching to ensure the picture plane remained unaltered. Following structural treatment, comprehensive technical analyses were executed, and continued conservation work, such as varnish removal, retouching, and revarnishing, was performed.

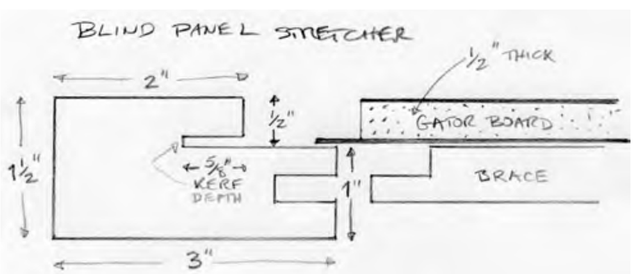

Figure 52.1 Diagram illustrating insert joint between the custom-fabricated stretcher and incised Gator Board panel insert. Image: Isabella Stewart Gardner Museum / Photo: Gianfranco Pocobene

STRUCTURAL TREATMENT

Part 1: Treatment of the Lining Support

The painting, laid facedown on a smooth table surface, was separated from the strainer by removing the metal nails. The bottom turnover edge had become a dirt pocket that was heavily caked with soil, insect casings, straw, and debris. The reverse was vacuumed using a HEPA filter and soft brushes, followed by overall surface cleaning with latex sponges.

To prevent distortions from imprinting to the pictorial face, textural aberrations in the historical lining fabric were reduced. This included minor slubs and embedded debris, as well as leveling of the 1/2-inch-wide seam allowance of the lining canvas using a scalpel. Minor gaps between the two lining canvases were reinforced to prevent separation of the seam. Linen fibers, flocked for compacting power, were saturated with an adhesive paste of rabbit-skin glue, wheat-starch paste, and Klucel G (6:4:1) and applied along the entire seam. The flock reinforcements were weighted under blotters for ten minutes and then ironed with mild heat and pressure until the seam was smooth and dry.

Strips of Belgian linen were prepared for strip-lining with Beva film (fig. 52.2). To stiffen and prevent distortion of the turnover edge, 1 1/2-inch strips of polyester sailcloth were adhered to the inner side of the strip-lining with Beva 371 film aligned with the tacking margin.

Figure 52.2 Preparation of lining canvas with strip-lining reinforcements prior to restretching. Titian (Italian, ca. 1488–1576), *Rape of Europa*, 1560–62. Oil on canvas, 179.8 × 202.4 cm (70 3/4 × 79 5/8 in.). Boston, Isabella Stewart Gardner Museum. Image: Isabella Stewart Gardner Museum / Photo: Gianfranco Pocobene

With the painting facedown, the 4-inch buckle at the upper left corner and a few small areas along the border juncture of original canvas and lining canvas were re-adhered. The same glue-paste-Klucel adhesive mixture used to reinforce the seam allowance was fed into the delamination pockets (humidified with atomized water) with brush and microspatula, then set down with gentle heat applied with a tacking iron through Remay cloth and blotters and weighted until dry.

Part 2: Blind-Panel Stretcher + Loose-Lining Hybrid Treatment

The new stretcher, reinforced with four cross braces (two horizontal, two vertical), was custom fabricated by Upper Canada Stretchers to receive interlocking blind-panel inserts to create a flush, rigid surface for the painting's pictorial plane (fig. 52.3). Along the inner surface of each 3-inch stretcher bar, a 1-inch-wide × 1/2-inch-deep recess was cut into the wood, along with a 5/8-inch-deep kerf that followed flush along this recess (fig. 52.4). This would allow for the panel inserts to interlock tightly within the stretcher bar system, ensuring a level, immobile support.

Figure 52.3 View of the complete blind-panel stretcher system, verso, during alignment of canvases over loose-lining and stretcher. Image: Isabella Stewart Gardner Museum / Photo: Gianfranco Pocobene

Figure 52.4 Corner detail, installation of Gator Board panel inserted into stretcher bar (custom fabricated by Upper Canada Stretchers). Image: Isabella Stewart Gardner Museum / Photo: Gianfranco Pocobene

The blind-panel inserts, constructed from three sections of Gator Board, were cut to fit in the stretcher recess and prepared with acrylic gesso medium to prevent migration of any degradation by-products. Then 1/2 × 1/2 inch sections of laminate surface and foam were cut away from the outer borders of each panel, leaving the bottom skin of the board protruding to lock into the kerf cut of the stretcher bar (see fig. 52.4). After the insert panels were locked into place, each panel was secured to the cross members with wood screws, and each screw location was covered with a thin patch of polyester fabric adhered with Beva film.

Belgian linen was stretched over the blind-panel stretcher and attached with staples secured along the turnover edges followed by securing the strip-lining edges with pushpins to align the painting (see fig. 52.3). The painting was stretched over the loose-lining and attached with staples secured to the strip-lining fabric. This was accomplished with the painting faceup, supported by sawhorses, and executed by two people working in tandem (fig. 52.5). The rigid support prevented sagging of the original canvas because it was fully supported and in plane while it was being stretched in the horizontal position. Therefore, only minimal tensioning of the painting was needed, as the strip-lined edges were attached to the stretcher. In addition, the loose-lining provided some cushioned support between the old lining canvas and the rigid blind-panel stretcher support. The rigid panel inserts also serve as a kind of inherent protection system typically provided by backing boards.

Figure 52.5 Restretching of the original canvas of the *Rape of Europa* and historical lining fabric: attachment to the loose-lining and blind-panel stretcher with staples and tandem tensioning. Image: Isabella Stewart Gardner Museum / Photo: Gianfranco Pocobene

REFLECTIONS

The decision to conserve the auxiliary and fabric supports of Titian's *Europa* was not a capricious one: the ethics of less or no treatment versus a thorough structural treatment were weighed and evaluated. At the time of treatment, the framing and display conditions for the exhibition were unknown. In London, the painting was rehoused in a well-designed, period-reproduction frame crafted at the National Gallery, which included nonreflective glazing. In hindsight, would the treatment applied still be deemed necessary? Ultimately, the stress of travel, despite the most secure packing or framing conditions and materials, would have placed the painting and historical, degraded wood strainer at risk. The implementation of a new stretcher and rigid support system fully prepared the structure for safe travel and future security at the Isabella Stewart Gardner Museum.

Fortuitously, the stabilizing intervention of the support greatly facilitated safe and more accurate technical analysis, especially macro X-ray fluorescence spectroscopy (MA-XRF) scanning research that clarified the approach to cleaning and visual reintegration of the picture preceding its reunion with the rest of the Poesie paintings.

ACKNOWLEDGMENTS

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APPENDIX: ANALYTICAL TECHNIQUES USED

High-resolution imaging was carried out in visible, UV, and infrared wavelengths. X-radiographs taken in 1980 were digitized and stitched together, allowing for a detailed examination of the painting's structure. MA-XRF cross-section analysis and scanning electron microscopy–energy dispersive X-ray spectroscopy (SEM-EDS) were used to determine the structure and elemental composition of pigments. Collaborators on the analytical work include Courtney Books, Jessica Chloros, Richard Newman, Gianfranco Pocobene, and Aaron Shugar.

NOTES

1. The other paintings in the series are *Danae* (1553–54), Wellington Collection, Apsley House, London; *Venus and Adonis* (1553–54), Museo Nacional del Prado; *Diana and Actaeon* (1559) and *Diana and Callisto* (1559), National Gallery, London, and National Galleries of Scotland; and *Perseus and Andromeda* (1554–56), Wallace Collection, London.
2. Andrea Rothe, examination notes, December 9, 1989, Paintings Conservation Treatment Files, Isabella Stewart Gardner Museum.

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Relining *The Menagerie van Prince Willem V*

Carlota Barbosa, Paintings Conservator and Freelance Paintings Conservator, Portugal
Leonora Burton, Paintings Conservator and Freelance Paintings Conservator, United Kingdom
Kristin Rattke, Paintings Conservator and Freelance Paintings Conservator, Germany
Kate Seymour, Head of Education, SRAL, Maastricht, the Netherlands
Eva Tammekivi, Paintings Conservator and Freelance Paintings Conservator, Estonia
Jos van Och, Senior Conservator (retired), SRAL, Maastricht, the Netherlands

The treatment of five large-scale paintings by Dutch artist Aart Schouman (1710–1792) from the series The Menagerie van Prince Willem V is discussed. The paintings are part of the collection of Palace Huis ten Bosch, The Hague. They were rediscovered in the 1970s and subsequently wax-resin lined. Display environments over forty years caused structural deformations to develop. The current treatment consisted of the removal of this wax-resin lining, tear mending, and the application of an innovative cold-lining support with an integrated glass-fiber interleaf.

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HISTORICAL BACKGROUND

The Menagerie van Prince Willem V series consists of five large-scale paintings by Dutch artist Aart Schouman (1710–1792) (fig. 53.1). Prince Willem V van Oranje-Nassau (1748–1806) commissioned the series for his private chambers in the Stadhouderlijk Kwartier, The Hague. The continuous landscapes depict Prince Willem's private collection of exotic animals. Transferred to Palace Huis ten Bosch at an unknown date, they languished, rolled up and folded in the attic until their rediscovery in 1975.[1] That same year, the paintings were restored by Nico van Bohemen Sr. and team, then installed in the palace.

Unfortunately, little documentation of the 1975 treatment remains, but luckily one of the restorers, Nico van Bohemen Jr., was available to be interviewed as part of the current project and was happy to answer our questions.[2] He had treated the paintings under the supervision of his father, Nico van Bohemen Sr., who was a successful self-taught restorer in The Hague. Van Bohemen Jr. recalled that the Schouman paintings were wax-resin lined using a mixture of raw, yellow beeswax and powdered resin and were lined on a vacuum hot table facedown on top of a sheet of Melinex.

As the paintings were larger than the table, they had to be lined in sections. The middle section was ironed by hand. The wax-resin adhesive was warmed and brushed onto the reverse of the original canvas and onto the lining canvas.[3] The content of the wax-resin adhesive was confirmed. Fourier-transform infrared spectroscopy–attenuated total reflectance (FTIR-ATR) analysis carried out in 2015 by Ana

Figure 53.1 Aart Schouman (Dutch, 1710–1792), *Birds I*, in the Menagerie van Prince Willem V series, 1786. Oil on canvas, 312 × 260.5 cm (122 5/6 × 102 1/2 in.). Collection of the Royal House of the Netherlands. Picture taken before treatment. Image: SRAL

Pereira indicated the presence of beeswax and natural resins, most likely elemi and colophony.

2015–16 TREATMENT

By 2015, planar distortions in the supports and the degradation of the restoration materials applied in the 1970s dictated that retreatment was required. The structural stability and aesthetic appearance of the paintings had been greatly impacted. Two types of planar deformation were present: bulges caused by the weight of the lining and creep due to the temperature sensitive adhesive, as well as slight lifting along the fold lines, caused by insufficient adhesion.

That same year, the Palace Huis ten Bosch underwent extensive renovation and Schouman's paintings were sent to Stichting Restauratie Atelier Limburg (SRAL) for treatment. Considering the paintings' size and their display in a historic building without environmental controls, the decision to reline was crucial to improve stability and flexibility and to prevent long-term deformations from recurring. Recent research shows that wax-resin lined paintings are heat and moisture sensitive (Andersen et al. 2014). A cold-lining system practiced at SRAL using an acrylic dispersion was chosen, as it would avoid the use of heat, moisture, and excessive pressure during lining.[4] This system also allowed the needs of each individual painting within the series to be accommodated.[5]

The acrylic dispersion lining adhesive was rolled rather than sprayed onto the lining support. This also facilitated the use of a glass-fiber interleaf material, which added stiffness to the lining system while minimizing the addition of weight. This lining system is approximately 570 g lighter per square meter than the 1975 wax-resin lining. In addition, a weaker application of adhesive was used between the glass-fiber interleaf and the original canvas—compared to that between the interleaf and lining fabric—to facilitate future reversibility, if necessary.[6]

Lining Adhesive

The lining adhesive consisted of 70% Dispersion K 360 (pH neutralized with ammonium hydroxide) and 30% Plextol D540, thickened with Rohagit SD 15, all v/v. Plextol acrylic dispersion products have been used for lining since the 1970s, and extensive research has established their aging properties (Down et al. 1996; Witte, Florquin, and Goessens-Landrie 1984; Mehra 1984). However, these products are subject to market influences; thus, since the product formulations and availability have changed, the reported results may no longer be valid for products mentioned in this essay.[7]

Dispersion K360 is too soft, sticky, and flexible to make a satisfying lining adhesive alone. Combining it with Plextol D540, which has a higher molecular weight and an accordingly higher glass transition (Tg) temperature, achieves the desired stiffness of the lining adhesive. The ratio of the two acrylic dispersions is 70:30 (v:v). Adding an emulsifier, Rohagit SD 15 (also a polymethacrylic acid), increased the viscosity of the mixture, thus improving application properties and preventing impregnation of the lining adhesive into the original canvas and the lining fabric during the reactivation process. The pH of the adhesive mixture was raised to 7 using ammonium hydroxide (NH_4OH).

Interleaf Fabric

Glass-fiber fabric was selected for its high tensile strength, dimensional stability, low moisture absorption, and high resistance to solvents and chemicals, all of which contribute to its great durability (A. Boissonnas 1961). It is also lightweight and provides extra strength without introducing additional tension, weight, or thickness to the new lining system (P. Boissonnas 2003). Glass-fiber fabrics use bundles of monofilament glass threads to create the weave. This woven textile does not have a nap, and a nap cannot be created without disrupting the weave draft. The lining-adhesive mixture, therefore, is best applied by rolling it onto the stretched fabric. This produces an even, textured surface, promoting adhesion. The moisture content is then allowed to evaporate. The dried adhesive produces a soft and elastic film, which encases the interleaf material and is stiff enough to prevent creep formation (Seymour and van Och 2005, 99). This fabric is available in widths of up to 90 cm; bands of the prepared material were used.

Lining Fabric

A spun-yarn polyester fabric was considered a good lining fabric due to its availability in a wide loom width, its low crease potential, dimensional stability, and high abrasion-resistance properties (Young and Jardine 2012, 251). Trevira CS was selected due to its built-in flame resistance. The Trevira CS fabric has a modified polyester molecule, which means it is permanently flame retardant, which is an important feature considering the paintings' unconditioned, historic-home environment.[8] To ensure sufficient bonding with the impregnated glass-fiber interleaf, a solution of 20% Plextol D540 and 20% Dispersion K360, diluted with 60% distilled water, was brushed onto the stretched fabric.

Lining Table

A stiff, solid support was desired during the lining process to assist in mitigating the planar distortions present in original support. As a conventional low-pressure table would have been too small, a makeshift adaptive lining table was constructed (fig. 53.2). The lining table described is an adaptation of the low-pressure envelope used in the mist-lining process (see Seymour, Strombek, and Van Och in this volume). Vinyl flooring was laid on the wooden floor, creating a firm, smooth surface with sufficient cushioning for any painted impasto areas. This was covered with a thick HDPE plastic sheet. This sheet extended beyond the vinyl and was stretched and secured taut to the floor with tape to prevent movement during lining. This sheet was punctured with holes to ensure that the painting, placed facedown, and lining canvas conform to the vinyl substrate during lining. This provided the required resistance during lining to apply pressure to high points, such as the raised edges of the folds of the original canvas. This plastic sheet provides the lower side of the lining table. A piece of open-weave cotton cheesecloth was placed over this plastic sheet to increase airflow within the lining envelope.

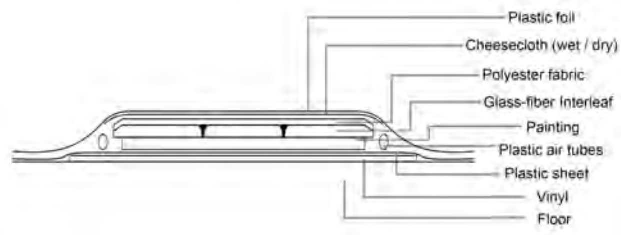

Figure 53.2 Cross-section of the construction of the lining system used for *Birds I*, *Birds II*, *Mammals*, and *Deer*. Image: Leonora Burton

Lengths of plastic PVC tubing were connected together using 90-degree elbows to create a peripheral ring slightly smaller than the plastic sheeting described above. A T-splitter was included on one side, which connected to a motor (a vacuum cleaner). Small holes were drilled into the inner side of the pipes to facilitate air extraction from within the lining envelope. The pipes were shrouded with an open-weave fabric (cheesecloth) to prevent the upper plastic from closing off these holes. The lining envelope was completed using a single piece of (green) lightweight polyethylene plastic, which was placed on top, sealing the system. A motor controlled with an inverter[9] was used to draw air through the tubing, maintaining an even, low air pressure. The holes punched into the lower plastic sheet ensured that the upper, more flexible lightweight HDPE plastic conformed to the surface topography of the vinyl and the material within the envelope.

RELINING

To begin the relining, the lightweight HDPE plastic sheeet throughout was rolled back; the painting was placed facedown on the lining table; the stretcher, old lining fabric, and adhesive were removed; and holes and tears in the canvas were secured. The tears were mainly butt-joined using Beva 371 film as the adhesive. Bridging glass-fiber strips were applied over the tear for additional support and adhered using Beva 371.

Bands of glass-fiber interleaf were laid onto the painting's reverse, slightly overlapping one another (fig. 53.3). The lining fabric was then rolled out on top of the interleaf, and the lightweight HDPE plastic sheet was repositioned (fig. 53.4). Before relining proceeded, a dry run ensured that the air would be evacuated quickly and evenly, and any irregularity in the structure was evaluated using raking light.

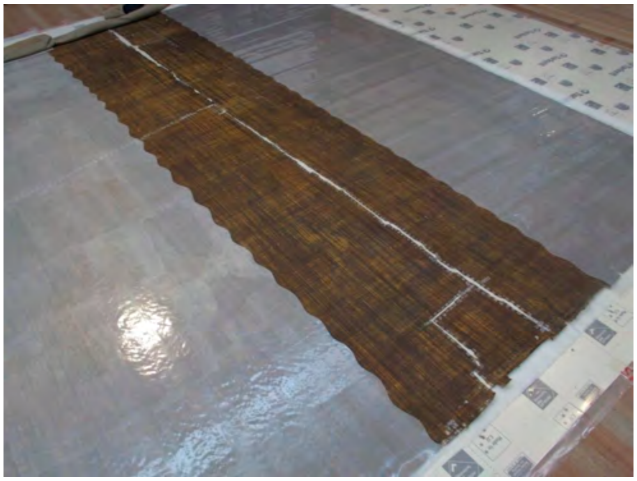

Figure 53.3 Placing strips of glass-fiber fabric interleaf on the reverse of the painting. The overlapping edges were cut wavy to avoid straight lines. Image: SRAL

Figure 53.4 Placing the lining fabric on top of the glass-fiber fabric interleaf. Image: SRAL

The activation of the adhesive bonding the lining canvas to the interleaf and the interleaf to the original support was done in situ. The dry adhesive was reactivated using solvent vapors: xylene and ethanol (30:70). Cheesecloth was chosen as a carrier for the vapors due to its ability to absorb polar solvents easily. The solvent delivery cloth measured slightly larger than the surface area of the applied adhesive. The cloth was rolled into a tight bundle and wrapped with cling film (Saran wrap). A precalculated amount of solvent was then injected (75–80 ml per m^2), and the roll was clamped for several hours to guarantee an even distribution of the solvents within the roll. At that point, the roll was unwrapped and placed quickly (to reduce evaporation loss) on top of the prepositioned, lining canvas. A string was attached to each corner of the solvent delivery cloth before the cloth was folded, rolled, and wrapped to help speed distribution over the reverse.

To ensure the tightest possible contact between lining fabric and cheesecloth, the lightweight HDPE plastic sheet was repositioned and the motor activated (50 mbar). After approximately twenty minutes, the motor was deactivated and the cheesecloth replaced with a heavy woolen fabric to absorb any excess solvent vapors present within the envelope, thus accelerating the bonding process. The package was then re-covered with the lightweight HDPE plastic sheet, and the motor was reactivated (110 mbar) (fig. 53.5). After about two hours, the motor was switched off and the upper lightweight HDPE plastic sheet was removed to allow the remaining solvent vapors to evaporate.[10]

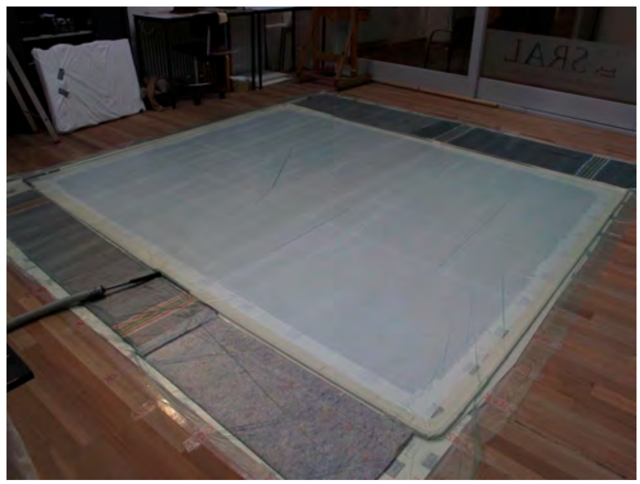

Figure 53.5 During relining. Image: SRAL

CONCLUSION

The treatment was designed to be both lasting and reversible. Relining with an acrylic adhesive mixture and glass-fiber interleaf provided a lighter, more rigid alternative to traditional lining systems and excluded the use of heat, moisture, or excess pressure. Developing this kind of treatment was possible by building on the experience of other large-scale lining projects undertaken at SRAL and can be used as a paradigm for the treatment of similar paintings (Schlotter 2009).

ACKNOWLEDGMENTS

The complex lining system described in this text was developed by author Jos van Och. It is an adaptation of the mist-lining system. The cold-lining system using acrylic

dispersions and a glass-fiber interleaf was first used for a large-scale ceiling painting from Huys Amerongen, Utrecht, in 2009, and further evolved for this particular series of paintings. The unique approach to solving structural problems presented by wax-resin-lined legacy paintings is the outcome of van Och's thirty-year expertise in treating canvas paintings. This experience was shared by the co-authors who were fellows at SRAL for the duration of this project. The mist-lining system is sill practiced today, though van Och is retired, and is discussed elsewhere in this publication (see particularly "Demystifying Mist-Lining," paper 9).

The authors thank Ana Pereira for the FTIR-ATR analysis, Ilona Jaaranen and Bascha Stabik for helping with practical work, and Nico van Bohemen Jr. for the interview.

NOTES

1. This is probably the only set of Schouman's wall hangings still remaining in the Netherlands (Bol 1991, 9).
2. Interview with Nico van Bohemen Jr., November 28, 2015, Stichting Restauratie Atelier Limburg (SRAL) archives, unpublished audio file. For transcription, see Barbosa et al. 2015.
3. For treatment steps other than the lining interventions, see Barbosa et al. 2015.
4. The cold-lining practiced was developed under Jos van Och's expertise and is inspired by the mist-lining system. The mist-lining system is reported elsewhere in this volume; see Seymour, Strombek, and van Och.
5. For a detailed description, see Seymour and van Och 2005.
6. For treatment steps other than lining, see Barbosa et al. 2015.
7. For example, Plextol D360 is no longer available; it has been replaced by Dispersion K360. Plextol D540 was discontinued after this project was completed.
8. See https://www.trevira.de/en/trevira-cs/how-trevira-cs-works.
9. Fuji FVR 022 K7S-7EX electric inverter. This instrument allowed the team to measure the pressure within the lining envelope.
10. Three paintings (*Birds I, Birds II,* and *Mammals*) were lined with the technique described. The remaining two (*Rodents* and *Deer*) are much smaller, so the lining technique was adapted accordingly. The materials used were the same. For a detailed description, see Barbosa et al. 2015.

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Evaluating Structural Treatment Options for an Untensioned Oil Painting on Canvas

Marie-Hélène Nadeau, Conservator, Paintings and Polychrome Surfaces, Fine Arts, Canadian Conservation Institute, Ottawa

A painting (ca. 1910) attributed to Tom Thomson was brought to the Canadian Conservation Institute (CCI) for treatment to address the instability of the cupped paint film and quilting of the unrestrained canvas. The aim of the treatment was to address condition issues with as minimal intervention as possible. Although complete removal of the quilting was not considered possible or desirable, a methodology for reduction of these deformations was devised. The canvas was exposed to repeated and increasing levels of controlled humidification and to flattening treatments on the vacuum hot table under low pressure and warming. After strip-lining, the painting was installed in a "Dutch stretcher" with turnbuckle joins for even and constant tensioning of the canvas during treatment. The cupping and cracking paint layer was consolidated as the deformations relaxed. In place of a lining, a sheet of Plexiglas was secured to the face of a newly constructed stretcher. This insert supports the canvas, acts as a buffer against rapid humidity changes, and allows for visibility of the verso.

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INTRODUCTION

A small, unstretched oil-on-canvas painting (ca. 1910), attributed to Tom Thomson (1877–1917), arrived at the Canadian Conservation Institute (CCI) in 2016 for treatment (fig. 54.1). The paint and ground layers were cracked and cupped and showed losses, and the unrestrained cotton canvas was heavily quilted. It was clear that the painting, which measures 33.1 cm high × 40.6 cm wide, had been cropped from a larger composition, given the lack of tacking margins, its frayed edges, and the absence of any tension garland. As this work is attributed to an important Canadian artist, the owner was understandably interested in stabilizing the painting and making it accessible for display, loans, and research as an example of the artist's early work.

CONDITION

According to the description provided by the gallery, prior to its acquisition the unstretched painting had been rolled (pre-1970), then laid flat in the early 1970s by its owner at the time.

The paint and ground layers were cracked from being rolled, and the cracking was exacerbated by the thickness of the paint layer(s) and by the brittleness of paint and ground. The cotton fabric support was a tight-weave, lightweight, untensioned canvas, extremely responsive to humidity fluctuations. The canvas, especially in areas where the paint was heavily applied, had developed local

Figure 54.1 Work attributed to Tom Thomson (Canadian, 1877–1917), *Untitled*, ca. 1910. Oil on canvas, 33.1 × 40.6 cm (13 × 16 in.). Collection of the Kitchener-Waterloo Art Gallery, gift of Mr. and Mrs. David Young, 1995.030.001. Before treatment, small facing tissues visible. Image: © Government of Canada, Canadian Conservation Institute

bulges from the tension exerted by the paint layers. Where the paint is cracked, tension had been released, so bulging often begins between and around areas of cracking in the paint and ground. Analyses had identified zinc fatty-acid salts (zinc soaps) in a beige paint layer applied as a primer above the ground. Microfissures had formed and may be associated with the cracking of the paint and the delamination between the priming and ground layer (Helwig et al. 2014).

TREATMENT CONSIDERATIONS

The objectives of the treatment were as follows: to relax the cupping of paint and ground layers, to consolidate cracks and areas of delamination and, in tandem, to relax and bring back into plane some of the most prominent canvas deformations. We were especially concerned about maintaining the integrity of the work of art, with as little introduction of new materials as possible and avoiding any materials that might obscure the original support. Despite those aims, the work needed, at the least, the addition of tacking margins to allow it to be secured onto a new auxiliary support.

METHODOLOGY OF STRUCTURAL TREATMENT

Concerns related to cracking, cupping, and delamination of paint and ground layers were addressed through local as well as overall infused consolidation, followed by exposure of the painting to repeated and increasing levels of controlled humidification. Cycles of exposure to humidification were combined with relaxing-flattening treatments on the vacuum hot table under low pressure and warm temperature.

Preparation for Relaxation Treatment

Paper facings were put in place over areas of fragile paint using rabbit-skin glue (RSG) and distilled water (3% w/v).

Prior to the application of strip-lining, a 2.0 cm band of long-fiber, wet-strength paper was adhered to the recto perimeters of the work with 5% (w/v) Aquazol 200 in isopropanol. This was done in order to protect the cut paint and ground layers at the edges of the canvas.

Strips of a thin, nonwoven polyester (Hollytex) were adhered to the outer edges of the painting verso with Beva 371 film (2.5 mil). The Hollytex extended 2.0 cm into the perimeters, corresponding to the area that had been faced on the recto. Additional Hollytex extended beyond the perimeter by approximately 5.0 cm to prepare for the next steps. The painting was then turned faceup, and strips of a woven acrylic fabric (Sunbrella) were adhered with Beva 371 film (2.5 mil) to the extensions of Hollytex. A few millimeters of the Sunbrella was frayed and butt-joined to the edges of the canvas perimeter. This strip-lining allows a very thin layer of Hollytex to connect the painting to the heavier, stiffer Sunbrella, which provides the new tacking margins for the painting.

The work was then installed into a working stretcher. Given the instability of the paint layers, it was determined that an impregnating consolidation through the canvas verso would further secure the ground and paint layers, especially through the relaxation and flattening processes. To ensure good penetration into and through the canvas, Beva 371 was diluted (1:1 toluene and mineral spirits) and applied by brush onto the verso.

Local consolidation was carried out on the face of the painting, where cracks, cupping and lifting paint were particularly unstable. RSG (7% w/v in distilled water) was applied with a small brush in several applications. An overall facing (low wet-strength "L" tissue secured with 7% RSG w/v in distilled water) was applied to the entire face of

Table 54.1
Relaxation of cupping and quilting—treatment steps

Humidification methods	Ambient lab conditions (cycles 1–4, 12)	• 50% RH at 23°C • Sometimes followed by direct moisture application through light misting of reverse osmosis (RO) water of verso • In cycle 12, RO water applied to cracks at verso of canvas with a small brush
	Humidity box: painting in working stretcher suspended above damp blotters. Small box fans ensured circulation of air (cycles 5–8, 13)	• RH from 60% to 70% • 1–5 hours • Sometimes followed by light misting of verso with RO water • In cycle 13, misting done with a super humidifier for greater humidification on recto and verso
	ESPEC environmental chamber (cycles 9–11)	• 60% to 65% RH • 20°C • 4–5 days
Flattening/ relaxing on the vacuum hot table	After each humidification process described above, the painting was placed on the vacuum hot table under 1/2 "Hg pressure for 45 minutes at a temperature of 45°C–54°C; then cooled and held flat under weights for 24 hours.	

Table: Marie-Hélène Nadeau

the painting to prevent any paint loss during the flattening treatments. The glue would allow the after-treatment removal of the facing to be done with water, which was safe to conduct due to the Beva 371 impregnation.

Relaxation of Cupping and Quilting

Plastic recovery of planar distortions in paint, ground, and canvas is the result of a combination of moisture, heat, pressure, and tension. Humidification increases elasticity in the paint and ground and allows movement in the canvas; the heat assists in softening paint and ground layers, and the pressure allows the new, flatter configuration to set into place as heat and moisture levels return to ambient conditions and the painting remains under tension.

The work was exposed to cycles, each consisting of a humidification followed, without delay, by gentle warming and flattening on the vacuum hot table (table 54.1). After each cycle, the tension of the working stretcher was adjusted by slightly expanding the turnbuckle joints at the corners. This provided a gentle, consistent tension during the treatment, with a slight increase in tension between cycles.

In total, thirteen cycles of relaxation treatment were executed. Significant structural changes were observed from cycles 1 to 5. After cycle 7, diminishing results were noted, despite other approaches being adopted (see table 54.1). At the thirteenth round of flattening, the gains obtained appeared to have plateaued, and the relaxation-flattening phase was brought to completion (figs. 54.2, 54.3). It is hoped that lasting results were achieved with this gradual approach to relaxation using moisture, heat, pressure, and tension. These factors allow for movement in the paint and canvas layers without increased stress and the potential for further damage to occur during treatment.

Various methods for moisture uptake were tried, including beginning with misting and placement of the tensioned painting in proximity to dampened blotters, and later placing the painting in a controlled environment (ESPEC environmental chamber) for four to five days at between 60% and 65% RH (see table 54.1). We were interested to see if the presence of Beva 371 in the canvas would prevent the fibers from responding to humidity. As we presumed, this did not appear to be the case, but likely the response was slowed by the presence of this adhesive. After each humidification, the tensioned painting was allowed to warm up on the vacuum hot table to between 45°C and 50°C under low pressure for forty-five minutes, after which the painting was left to cool under weights for twenty-four hours to allow any change to the paint, ground, and canvas to plastically set.

Figure 54.2 Verso of painting before cycles of relaxation treatments, taken in raking light. Image: © Government of Canada, Canadian Conservation Institute

Figure 54.3 Verso after 13th relaxation treatment, taken in raking light. Image: © Government of Canada, Canadian Conservation Institute

Given that significant changes were noted mostly between cycles 1 and 5, where the painting was at 50% RH and moisture was applied by light misting on the verso, it would appear that the paint and ground were sufficiently softened by a sudden uptake of moisture to allow for important movement in these layers. Exposure to water vapor plus direct contact from misting also effectively softened the paint and ground layers (cycles 5–8). Additional softening by exposure of the painting to longer periods of uptake of moisture using the ESPEC chamber did not produce significant results.

Insertion of Rigid Support

A new turnbuckle stretcher provided an auxiliary support for the painting. The dimensions are slightly larger than those of the painting to ease the turnover of the newly fabricated tacking edges, and to ensure that the maximum amount of painting is visible within the window of the frame. To give additional support to the painting when stretched, a sheet of 1/8 inch (approximately 0.3 cm) clear Plexiglas (polymethyl methacrylate) was cut to exactly fit the stretcher.

The Plexiglas was secured to the face of the stretcher by means of countersunk screws. The predrilled screw holes were made larger than the screw shaft, thus allowing for some lateral movement of the Plexiglas if any small alterations are required to the stretcher. The Plexiglas edges and corners were rounded to reduce wear of the strip-lining fabric at the turnover. The screw holes were backfilled with microcrystalline wax (Multiwax W-445 Microcrystalline Wax) and covered with a lightweight Japanese tissue.

The rigid sheet will stabilize the auxiliary support structure, permit the retention of an original auxiliary support, prevent stretcher bar cracks, remove stress load on the canvas, and protect against rapid humidity changes. It also prevents deposits of dust and access by pollutants from the verso and reduces vibration to the painting during handling and transit. Depending on the material chosen, it may allow for visibility of the verso. Other materials can be used for this purpose, such as a chemically stable foam board.

A narrow, L-shape inner basswood frame was designed to protect the outer edges of the painting and to cover the exposed Sunbrella margins around the face of the painting. The frame also acts as a spacer between the paint surface and the glazing layer in the final framing and allows for safe handling of the painting either before it is placed in the outer decorative frame or upon removal from this frame (fig. 54.4).

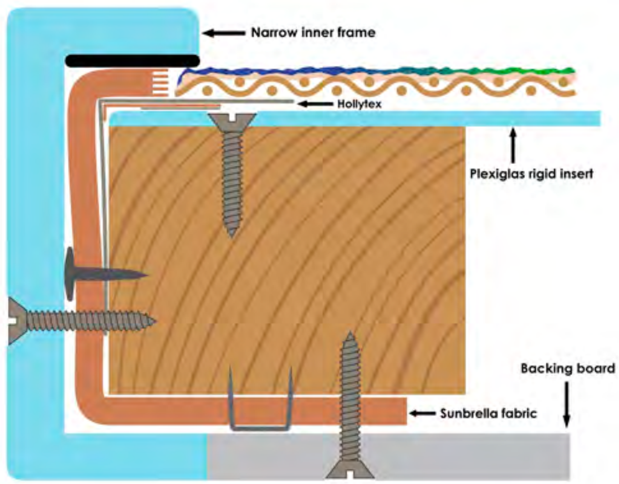

Figure 54.4 Diagram of the final stretching of the strip-lined painting. Image: © Government of Canada, Canadian Conservation Institute

REFLECTIONS

The combination of repeated applications of humidification, low heat, and low pressure while maintaining tensioning was successful in reducing the quilting and gave satisfactory results from both an aesthetic and structural point of view. Given that complete flattening was never anticipated and that the canvas still had physical integrity, minimal intervention, combined with support from a rigid insert on the stretcher, was deemed to be the best treatment choice. It is also anticipated that this painting will be displayed in climate-controlled environments, which will reduce future movement in paint and ground layers as well as in the canvas and ensure that the new planar configuration will remain. This project demonstrates the success of minimal intervention for maximum benefit in the case of a structurally compromised painting on canvas.

ACKNOWLEDGMENTS

I would like to thank Wendy Baker, CCI senior conservator, Paintings and Polychrome Surfaces, for her mentorship during the execution of the treatment and her invaluable help in reviewing this article. I also want to acknowledge Paul Bégin, senior conservation scientist (retired), for his help with the ESPEC chamber, and the CCI former and current staff who carried out analyses and photodocumentation: Dominique Duguay, Eric J. Henderson, Germain Wiseman, Jason Anema, Kate Helwig, and Mylène Choquette. I am also very grateful to preparatory technicians Richard Lane and Denis Larouche.

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Conservation and Restoration of *The Crucifixion*, an Eighteenth-Century Canvas Painting: Challenges of the Large-Scale Lining, Complicated Tear Repair, and Verification of the Authorship

Katarzyna Dobrzańska, Jan Matejko Academy of Fine Arts, Kraków, Poland
Magdalena Lentowicz, Jan Matejko Academy of Fine Arts, Kraków, Poland

This paper describes the conservation treatment performed on a large-scale eighteenth-century canvas painting from the collection of the Museum of John Paul II Catholic University of Lublin, Poland. The conservation and accompanying research was executed at Jan Matejko Academy of Fine Arts, Kraków. The former altar painting, depicting the crucifixion based on the composition Coup de Lance *by Peter Paul Rubens, had been subjected to numerous unprofessional repair attempts, resulting in its extremely poor and fragile condition. The large scale of the object influenced the decisions made during the conservation process. The damages were fully addressed during an extended, multistep treatment, which included removal of the overpainting, repair of canvas tears, relining, and reconstruction of the incomplete composition. Additionally, research into the authorship of the painting, which was attributed to Polish painter Jan Bogumił Plersch (1732–1817) was conducted in an attempt to verify the historical sources.*

BACKGROUND

The painting titled *The Crucifixion* originates from the neoclassical parish church of Saint Mary Magdalene in Serniki, a village in eastern Poland. Construction of the church, designed by architect Jakub Fontana, was funded by Eustachy Potocki (1720–68), a Polish magnate (Gombin 2009, 123). Formerly a main altar painting, *The Crucifixion* was attributed by local tradition to Jan Bogumił Plersch (1732–1817), one of the most important Polish painters active during the rule of Stanisław August Poniatowski (1732–1798), the last king of Poland (Król-Kaczorowska 1981). The painting depicts Christ on the cross with figures surrounding him and was modeled after the composition *Coup de Lance*, which was painted in 1620 for the Convent of the Friars Minor in Antwerp by Peter Paul Rubens. Rubens's composition was reproduced in a popular graphic print by Boetius à Bolswert. The print itself was based not on the painting but on a later drawing prepared in Rubens's studio (Art Institute of Chicago n.d.).[1] This print appears to have served as a direct inspiration for the author of the Serniki painting.

The Crucifixion was painted with oil paint on a primed linen canvas that was sewn together from two main and four additional smaller pieces. It was once mounted on a traditional wooden stretcher, which no longer existed at the time of the conservation. Due to the painting's rapidly declining condition, numerous damaging alterations, and extensive overpaintings done throughout its history (fig. 55.1), the painting was removed from permanent display in the main altar during the second half of the twentieth century (Brykowski 1975, 239). It was then kept in a storage room, where it was subjected to further decay, awaiting future conservation treatment.

As the project of conserving and restoring *The Crucifixion* exceeded the capabilities of a small parish, in 2014 the painting was handed over to the collection of the Museum of John Paul II Catholic University of Lublin. It then became the subject of a joint master's thesis executed at the Faculty of Conservation and Restoration of Works of Art at the Jan Matejko Academy of Fine Arts, Kraków, from 2015 to 2017 (Dobrzańska and Lentowicz 2017).

CONDITION AND TREATMENT GOALS

The condition of the painting, which spent many years in the attic of a church, can be described as extremely poor (fig. 55.2). Many unprofessional conservation attempts contributed to the dismal state of the artwork. The original support was lined to a linen canvas with a starch-based adhesive. The lining was almost completely detached from the painting. Underneath the lining, an attempt at strip-lining was discovered; it had been done using a very coarse canvas and with a thick layer of rigid gluten glue and chalk gesso serving as an adhesive.

There were also numerous stratified fabric patches (fig. 55.3, top) attached with beeswax to the back of the original canvas, which was also almost entirely covered with a black impregnating substance (most probably various oil paints and bitumen) (see fig. 55.2). In addition, the canvas support was torn in many places, and its parts were roughly sewn together with twine, pierced through the front of the painting and all its layers (see fig. 55.3, bottom). The original paint and ground layers had poor adhesion to the canvas support, which resulted in many losses. The painting had been overpainted several times

Figure 55.1 Attributed to Jan Bogumił Plersch (Polish, 1732–1817), *The Crucifixion*, ca. 1750–1800. Oil on canvas. Muzeum Katolickiego Uniwersytetu Lubelskiego Jana Pawła II (Museum of John Paul II Catholic University of Lublin). The condition of the painting before conservation. Image: Muzeum Katolickiego Uniwersytetu Lubelskiego Jana Pawła II

with thick layers of oil paint. The whole structure was rigid yet fragile, and seriously deformed.

The main goal of the conservation was to remove all harmful transformations. This was essential in order to recover the original painting. It should be noted that none of the alterations carried any historic or artistic value. The major overpainting was done around 1945–46. After that, due to the painting's poor condition, it was displayed only occasionally. All of the other repairs could only be

Figure 55.2 *The Crucifixion*, back of the canvas support before conservation. Image: Muzeum Katolickiego Uniwersytetu Lubelskiego Jana Pawła II

Figure 55.3 *The Crucifixion*, back of the canvas support before conservation, detail. Image: Muzeum Katolickiego Uniwersytetu Lubelskiego Jana Pawła II

interpreted as rather makeshift attempts at stabilizing the painting's structure, and they undoubtedly were not executed by a professional.

TREATMENT PLAN

The treatment plan called for the removal of the old lining and patches, cleaning of the back of the canvas, consolidation of the paint layer, flattening of deformations, removal of overpainting, and filling and reintegration of losses. Due to the condition of the painting and the severity of the damages, each step took several weeks or months to complete.

The stage of addressing the consequences of the structural damage of the canvas support proved to be a particularly challenging part of the process, as the integrity of the material was almost completely lost. The most serious tear ran diagonally; it measured 2 meters in total and was amateurishly sewn together with twine (see fig. 55.3, bottom). When the twine weakly holding the torn parts of the canvas was removed, it became clear that it was impossible to reassemble the pieces correctly without causing a great deformation. The diagonal tear reached about two-thirds the height of the whole painting, creating two almost separate "branches" of canvas, which became unevenly distorted after being subjected to changes in humidity: the gap between the parts reached 2.5 cm. Despite this, the mutual edge of the torn parts was still identifiable.

It would have been possible to maintain the existing arrangement by adhering the torn pieces together with the addition of the necessary inlay. However, the consequent distortion of the composition would have been so significant that this option was not pursued.

TREATMENT STEPS

To gradually change the structure of the canvas support without causing stress to the already fragile paint layer, it was very gently subjected to higher humidity levels. The problematic areas of the canvas were moistened with blotters and relaxed, which enabled structural corrections. Single linen threads were temporarily adhered with Vinavil NPC to the edges of the torn parts to form a loose bridging, and the structure was secured with locally placed weights. The whole procedure was repeated several times, with the temporary bridging "braces" being reapplied in order to form a tighter join (Rouba 2000, 65). With such a large-scale tear, it was impossible to reconstruct the course of the original weave pattern completely by using a thread-by-thread approach. Nonetheless, the final results were still satisfactory; the remaining gap was not larger than 4 mm. The torn parts of the canvas were glued together with Vinavil NPC, matching their mutual edge, and this procedure did not cause any structural deformations. Only small inlays were inserted in places where the tear edge was destroyed and not possible to reweave. The repaired tears were secured from the back with Beva Tex.

The next challenging step of the structural conservation of the canvas support was to apply a new lining in order to stabilize and secure the original canvas, which could no longer withstand its own weight. It was decided to make it a fully reversible lining using high-quality linen canvas and 65 μm Beva 371 film. Because of the dimensions of the painting, the process was carried out in phases. The adhesive film was placed on the lining canvas impregnated earlier with a solution of Vinavil NPC. The lining canvas was placed on the back of the painting and ironed with hand irons to create the initial bond.

The whole structure was then transferred to a heated suction table, where the lining was performed in three stages. As the size of the object was much larger than the dimensions of the suction table, it was treated in three separate sections with the remaining length of the painting secured on a roller. A modified version of a vacuum envelope was used during this process. The painting was placed facedown, as the original canvas support was sewn from parts with protruding stitches. In this way, the danger of deepening distortions trailing the course of stitches was minimized. The whole process in its essence did not differ from a standard lining procedure. However, the dimensions of the painting required that additional thought be put into the handling of the object. The stability of the painting was ensured by mounting it on a specially designed constant tension metal stretcher. The stretcher was designed and made by Henryk Arendarski, using a patented construction method.[2]

It was decided that the conservation of *The Crucifixion* should be finalized with a complete and reversible reconstruction of the composition executed on the basis of the graphic print by Boetius à Bolswert. Without retouching, the overwhelming number of losses made the composition almost illegible to a viewer (fig. 55.4). Although this process could not be described as one strictly following the rule of minimal intervention, we believe it was the only chance for *The Crucifixion* to regain its aesthetic value (fig. 55.5). As the painting will become part of a museum collection, thorough information about the conservation process will be provided with its exhibition.

Figure 55.4 *The Crucifixion*, face of the painting during conservation: filling in losses to the ground. Image: Muzeum Katolickiego Uniwersytetu Lubelskiego Jana Pawła II

VERIFICATION OF AUTHORSHIP

Research concerning the verification of authorship was conducted simultaneously with the conservation process. Because of the poor condition of the original paint layer (see fig. 55.4), it was almost impossible to perform a comparative, formal, or stylistic analysis with any other of Plersch's paintings. No archival documents concerning the creation of the painting have survived, nor have any signatures or inscriptions been found. Extensive research and field studies were conducted, together with a comparative analysis of samples obtained from other paintings by Plersch done using scanning electron microscopy–energy dispersive X-ray analysis (SEM-EDX). Chemical and physical examinations indicate that the ground composition in *The Crucifixion* is similar to another painting originating from the same church: *The Visitation of the Blessed Virgin Mary*, painted and signed by Plersch in 1760. Although the study remained inconclusive, it has

Figure 55.5 *The Crucifixion* during conservation: retouching. Image: Muzeum Katolickiego Uniwersytetu Lubelskiego Jana Pawła II

allowed formation of a hypothesis for further investigation, which is being performed by Katarzyna Dobrzańska as part of her postgraduate research at the Doctoral School of Jan Matejko Academy of Fine Arts, Kraków.

CONCLUSION

The conservation of large-scale paintings comes with unique challenges. Many logistical matters require consideration, such as the handling of the object, the configuration of the workspace, and accessibility to certain areas of the artwork. Even basic treatments and procedures when performed on a large-scale object are unusually prolonged. Every aspect of addressing the consequences of structural damages to the canvas support required additional preparation. The conservation and restoration treatment of *The Crucifixion* was a challenging process; however, it laid the foundation for future research. The structural conservation of the canvas support, performed by two students at the beginning of their careers, was a valuable experience and an inspiration for future development.

NOTES

1. See https://www.artic.edu/artworks/181067/the-crucifixion-coup-de-lance.
2. See http://arendarski.com.pl/.

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An Approach to Conservation Treatment Options for Double-Sided Painted Canvases with Ritual Functions

Filip Adrian Petcu, Director, Regional Center of Research and Expertise in Restoration and Conservation of Cultural Heritage, Faculty of Arts and Design, West University of Timișoara, Romania

The poster summarizes the morphology and function of two dozen double-sided processional painted flags and epitaphs on fabric and discusses the technical context of their current material degradation, studied in conjunction with their storage condition and cultic, itinerant purpose in eighteenth- and nineteenth-century Byzantine Orthodox ecclesiastic ritual. Such objects need to preserve their cultic function after conservation. The examples of processional artifacts discussed belong to various distinctive collections in Romania and will be analyzed to characterize the properties of their technique and materials. This analysis will further affect discussions on decision-making regarding treatment options, tools, materials, and useful techniques to consolidate both the delicate pictorial surface of the majority of double-sided painted cultic objects and their flexible, and sometimes very fragile, canvas supports.

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INTRODUCTION

The paper describes a theoretical and practical approach to the remedial conservation of double-sided canvas paintings, cultic flags, and epitaphs on fabric with ritual functions, dating from the eighteenth and nineteenth centuries in Romania. Double-sided painted flags and banners call back to an ancient archetype, the Constantinian *labarum,* a semantic reconversion of the Roman *vexillum*—the flag of the Roman cavalry—to a symbol of Christianity. Painted cloth artifacts are known from Egyptian antiquity through the medieval period in Europe,[1] with the *gonfalone*, the heraldic flags of the Renaissance and beyond to banners of ‘professional guilds in Europe. Asian *thangka* paintings are another example.

Double-sided painted textiles have been used since ancient times in the Orthodox Church during processions, ecclesiastic feasts, and litanies. The identity of double-sided painted canvases with ritual function marks a particular chapter of challenges for paintings conservators, starting from the cultural perspective and extending to the very specific technical aspects that define such complex objects, defined typologically as paintings on canvas or as painted textiles (Pollak 2003).

The conservation of such painted banners has rarely been addressed in the literature yet is a subject of interest to conservators of liturgical objects. The *Bibliography of Romanian Vexilology* (Mureșan and L-Șt. Szemkovics 2018) mentions sixty-nine titles referring to conservation aspects

Table 56.1
ATR-FTIR results of the analysis of canvas thread samples from 16 banners and 1 interstitial canvas

Materials added to fibers of banner and epitaph fabric						
Sample banners/epitaphs	**Proteic compound**	**Lipids**	**Kaolin**	**Gypsum**	**Calcium carbonate**	**Calcium oxalate**
2	+					
3	(+)	+	+			
4	(+)	+	+			
5	+	+				
6	+	+				
7	+	+				+
8	(+)	+	(+)			
9	+					
10	+					+
12	+			+		+
14	+	+			+	
15	+					
16	+				+	
17	+					
22	+					

Note: FTIR was done by Cristina Carșote.
Table: Cristina Carșote and Filip A. Petcu

of flags and banners; however, most of the references address textile artifacts and embroideries, rather than painted banners. The Getty Conservation Institute's online database AATA Online[2] reveals ninety-eight results over a broad search on the topic. In this study, the technical examination of twenty-five of these banners is used to inform research into consolidant choices for the treatment of these objects.

CONTEXT

This study addresses eighteenth- and nineteenth-century processional ecclesiastic objects painted on canvas supports, double-sided painted banners called *prapori,* and painted epitaphs, originating from wooden churches (fig. 56.1). The majority of these objects are stored in the collection of the Orthodox Archdiocese of Timișoara, in the Metropolis of Banat.

Figure 56.1 Studied banners, epitaphs, and interstitial canvas from a painted wooden church (22 of 25). See table 56.3 for details of each piece studied. Images: Filip A. Petcu

In the Christian ecclesiastic space, double-sided painted banners are always stored vertically, hanging from a pole in the narthex or the nave of the church. Banners are mounted on a special designed T-shape suspension pole, which is associated with the holy cross; this pole functionally supports a second horizontal wooden pole, called a *drug,* on which the painted fabric is draped. The wooden poles are attached to the structure of the rows of standing pews along the north and south perimeter aisles of the architectural space, except for once a year, when they are carried in processions. The display as a function of the scenography inherent to the specific moment of the ecclesiastic year induces significant stresses to the canvas due, basically, to the action of gravity and the weight of the canvas itself, leading to deformation and other mechanical damage.

By comparison, painted epitaphs are generally laid horizontally on flat surfaces, which protects the canvas from many of the mechanical stresses to which banners are subjected. In both cases, however, the integrity of the painted image, the religious icon, is related to the liturgical presence of the depicted subjects and has to be considered essentially as an argument during strategies for a conservation planning.

MATERIALS AND TECHNIQUE

Twenty-five different painted liturgical textiles were studied; they are constructed of a variety of materials (see fig. 56.1). The horizontal wooden top poles are occasionally polychromed and have profiled bulbs mounted on their ends. The textile supports are either a single piece of plain-weave linen or hemp or composed of two different pieces of the same fabric, sewn together along the vertical axis of the banner. In addition, there may be a variety of ornamental accessories such as lappets, fringes, tassels, textile ribbons, and braids. Generally, in the case of the banners, the canvas surface is entirely covered with paint. In rare cases in the epitaphs, the fabric is only partly painted. Metal leaf is used for gilding halos and the painted frames that structure the composition.

In most examples, with rare exceptions, the canvas supports carry a sizing and/or a ground layer of different thickness and layer structure all over the canvas surface. However, sometimes the ground only covers the rectangle corresponding to the central image of the composition and not the lappets of banners. The layering of paint strata is simple, thinly applied on heterogeneous ground layers,[3] using the pigments available at the time, which provided a generally matte surface finish.

Strips of material sewn all around on three of four margins of the banners' perimeter were used as structural reinforcements to protect the regular perforated edges of the fabric; this indicates that the canvas was prestretched. Occasionally, the perimeters are decorated with patterned ribbon or, rarely, fringes of wool. Some of the painted banners carry dyed wool tassels mounted on carved wooden elements that hang from the lappets,[4] the rectangular, triangular, or rounded bottom panels descending from the banners.

Epitaphs (and, less often, banners) are painted on satin-weave dyed textiles, and the pattern of the textile is included as an element of texture in relationship with the painted surface of the composition. The painting media are proteinaceous and/or lipidic (table 56.1) and may be associated with similar binder and pigments used to decorate wooden churches of the same period, where primed canvas strips are commonly used to secure the joints between neighboring wooden panels.

DEGRADATION

The itinerant purpose of painted banners and epitaphs for ecclesiastic display, as well as their technique and constitutive shape, are factors that contribute to their degradation. Mechanical stress and strain develop unevenly within the textile support in conjunction with the horizontal upper suspension pole of banners and their inherent lack of a strainer. The structural presence of heavy lappets cut out from the larger fabric surface also contributes to these stresses. The objects are used outdoors and exposed to severe weather conditions and UV radiation. Inside churches, they are exposed to environmental conditions such as air currents, high fluctuations of ambient parameters, and occasionally direct contact with water. They are also exposed to fatty components and soot from oil lamps, candles, and censers. Handling during rituals, inappropriate storage, transportation, and routine maintenance can all lead to mechanical damage. Biological damage can be caused by birds, bats, and moths and other insects. Technical issues inherent to the paintings' manufacture include rigid layering, critical or high pigment volume concentration (PVc), chemical alterations due to pigment-media interaction, unstable pigments or dyes, embrittlement of the paintings' strata, loss of adhesion or cohesion due to failure of the binding media within the layers, and other technical issues regarding the painting technique, such as structural losses, tears in the fabric, and biochemical degradation of canvas threads.

INSTRUMENTAL ANALYSIS

Digital photography and portable handheld digital microscopy with UV, visible, and infrared spectra illumination were used to document the objects. A consistent number of microsamples were collected for technical examination purposes, generating large quantities of data that are still being studied.

The samples were observed with light microscopy under high magnification with a Zeiss Axio Imager A1m and Olympus BX51 microscopes, and some samples were analyzed using scanning electron microscopy–energy dispersive X-ray analysis (SEM-EDX)[5] to provide more in-depth information on the surface of the samples and the presence of various specific elements in different strata. Three banners were inspected using a noninvasive portable X-ray fluorescence (XRF) spectrometer.[6] More insight into the samples' crystalline nature came to light using X-ray powder diffraction (XRD) examination. The identity of some pigments and media was confirmed by analysis of the samples using micro-Raman spectroscopy,[7] an Olympus BX-51 microscope, and attenuated total reflectance–Fourier transform infrared spectroscopy (ATR-FTIR).[8] Canvas threads were investigated with ATR-FTIR using a portable Alpha spectrometer from Bruker Optics equipped with an ALPHA Platinum ATR module. Spectra were recorded in the 4000–650 cm^{-1} spectral range with a 4 cm^{-1} resolution, using thirty-two scans (fig. 56.2; see table 56.2). The data from samples of the referred objects were compared with measurements taken on a sample of painted canvas, cloth glued over the face of the joint, from a painted wooden church from Curtea, dated 1806, to confirm that painters of wooden churches used similar materials—canvas and ground layer composition—to paint banners.

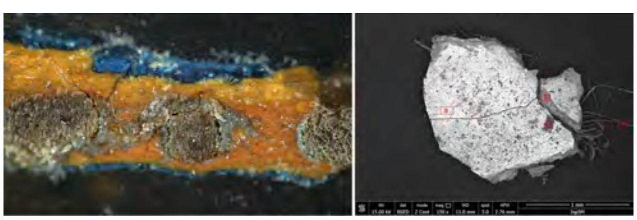

Figure 56.2 (a) Cross section from mounted sample of banner 25. (b) SEM-EDX image of gilded sample of banner 8. Images: (a) Filip A. Petcu; (b) Oana Buriac

CONSOLIDATION TESTS

In preparation for future interventions in cases where the degraded canvas carries a heavy load of paint strata on both sides, consolidation tests were performed on canvas, ground, and/or paint layers. Different formulated products were assessed to stabilize flaking paint, improve the strength of the layers and their adhesion to the substrate, and structurally reinforce the weakened canvas. Testing was performed on a surviving fragment of a banner and on a damaged area of a second banner that presented severe craquelure, deformation of the detached paint layers in the interface support ground, cleavage of paint layer from ground, and displaced flakes of paint stratigraphy (table 56.3).

Research on previous consolidation campaigns with similar objects reveal the use of protein glues and carboxymethyl cellulose (Dumitran and Rustoiu 2007, 30). Beva 371b formulations were previously used (Petcu 2017), but some of the ingredients may raise concerns for conservators. Water-based consolidation systems and adhesives prone to severe shrinkage, as protein glues are, were not considered here due to the fragility of the untensioned canvas and paint as well as the presence of metal soaps.[9] Potential cross-linking materials were also excluded from the list.

The properties of the chosen materials were researched with recommendations from the available literature,[10] and further mixtures were selected, including particular additives. The eleven formulas chosen included polyethyloxazoline (PEOX) solutions, including Aquazol 200 and 500; polyvinyl alcohol (Mowiol 4-88), acrylic solutions such as Degalan P 550 and Paraloid B72, nonionic cellulose ethers such as MC and MHEC, and Celluforce NCC cellullose nanocrystals (Bridarolli et al. 2018b) (see table 56.2). Aquazol was selected given its versatility, nontoxicity, minimal interaction with the constituent materials of paintings, and good reversibility (Bosetti 2012). To enhance the diffusion of the consolidant and its efficiency, surface cleaning and prewetting were carried out selectively.

Considering the dry environment of current storage, Aquazol 500—stronger than Aquazol 200 (Mecklenburg, Fuster-López, and Ottolini 2012, 21) but with lower penetration (Arslanoglu and Tallent 2003)—was used instead of protein glues, assuring optimum penetration, plasticization, and the necessary workability to reattach the flakes. The addition of 1% Celluforce NCC helped improve the interlayer adhesion and grip while simultaneously reinforcing the degraded canvas. Culminal 2000, a methyl cellulose derivative, was added to impart gelled consistency to the adhesive, decreasing the RH responsiveness (Arslanoglu 2004) and better performance in filling gaps between shrunken ground and canvas threads. Repeated applications by brush and syringe and

Table 56.2
Adhesive and consolidant formulas tested on double-sided painted banners and epitaphs dating from the 18th and 19th centuries

Compounds for adhesive/consolidant solutions	Solution (% or w/w)	Solvent 1/w for 100 g	Solvent 2/w for 100 g	Prewetting of the surface prior to application	Re-adhesion of loose paint flakes	Impregnation, stabilization of decohesive paint	Electric conductivity
Celluforce NCC CNC	1%	DIW 99	—	Yes, DIW:IMS (1:1)	—	√	174 μS/cm
PVOH: Mowiol 4-88	10%	DIW 90	—	Yes, DIW:IMS (1:1)	√	√	—
Aquazol 200	10%	Isopropanol 90	—	Yes; DIW:IMS (1:1)	√	√	—
Aquazol 200	5%	Isopropanol 47.5	Naphtha 47.5	No	—	√	—
Plexisol P550 (30%)	5%	—	Naphtha 95	No	—	√	—
Paraloid B72 5% BAC + Aquazol 200 10% IP	9:1	Butyl acetate 95	IP 90	No	—	√	—
Methocel A4M	2%	DIW 98	—	Yes; DIW:IMS (1:1)	—	√	198 μS/cm
Culminal 2000	3%	DIW 48.5	IP 48.5	Yes, nonpolar solvent for surface sealing	√	—	79 μS/cm
Aquazol 500: Culminal 2000	1:1 w/w	Isopropanol 56.25	DIWater 32.25	Yes, nonpolar solvent for surface sealing	√	—	—
Aquazol 500	20%	Isopropanol 64	DIWater 16	Yes, DIW:IMS (1:1)	√	—	—
Aquazol 500 + Celluforce NCC CNC*	1:1 w/w	Isopropanol 40	DIWater 72	Yes, DIW:IMS (1:1)	√	√	—

*1 part by weight of Aquazol 500 (20%) solution in 4:1 of isopropanol to deionized water, plus 1 part by weight nanocellulose (1%) in deionized water.
Abbreviations: BAC = butyl acetate; CNC = cellulose nanocrystals; DIW = deionized water; IMS = industrial methylated spirits; IP = isopropanol
Table: Filip A. Petcu

cold mechanical pressure using a silicon tool and the heated spatula proved useful in achieving satisfactory adhesion and a stabilization of canvas and paint on both sides of the banner (fig. 56.3).

Figure 56.3 Adhesive application on banner 1. Images: Filip A. Petcu

Over time, however, the impact of the weight of the lappets on the overall mechanical behavior of the canvas might further require local reinforcement with an adhesive that provides an additional bonding capacity to the paint layers before further necessary structural interventions can be carried out on the support. Polyamide welding powder was preferred for structural repairs on the heavy lappets, yet interventions were postponed due to a need for immediate stabilization of the flaking. Previous research has shown that Beva 371 presents good bonding properties[11] and that the cohesive properties remain fairly stable over a wide range of humidity. This is significantly interesting considering that these artworks are usually stored in uncontrolled environments. Being a thermoplastic adhesive, Beva 371 should also stay flexible in the long term.

ACKNOWLEDGMENTS

This study would not have been possible without the expertise, goodwill, and active participation of Nicoleta Ploșnea (Mitropolia Banatului), Petru Negrea and Oana

Table 56.3
Painted double-sided banners and epitaphs in the study

No.	Location*	Face A	Face B	Dimensions	Lappets/ streamers	Date/ provenance	Canvas weave count per (cm^2)	Horizontal wooden suspension pole (*drug*)
1	**MBT**	Dormition of the Theotokos with 5 Seraphs	Theophany (Baptism) of Jesus Christ + 1 Saint, 3 Seraphs	109 × 91.5 cm	3, oval, seraphs	19th century	15 × 13	Lost
2	**MBT**	The Virgin Mary as Empress of the Heavenly Hosts with Jesus Christ Child, Star, Triangle. Medallion with St. H. Nicholas of Myra, 5 Cherubs	Holy Archangels Michael and Gabriel, sun and moon, medallion with St. Paraskeve of the Balkans, 5 Cherubs	157 × 130 cm Canvas: 114 cm	3, oval, cherubs	1848 Poeni, Timiș county	14 × 18	Profiled (3 bulbs), painted red
3	**MBT**	Pentecost, flanked by the 2 Archangels. Lappets: Saint Emperors Constantine and Helen; central lappet detached (Ascension of the Lord Jesus), Nativity of the Theotokos	Coronation of the Virgin Mary with medallions of Saint Ap. Peter and Paul, 2 floral ornaments, lappets: 3 Evanghelists,	144 × 107 cm	3, oval; central lappet broken	1876 Poeni, Timiș county	14 × 16	Lost
4	**MBT**	Coronation of the Virgin Mary, flanked by Archangels. Lappets: Seraph, St. M. George, St. M. Dimitrios, Seraph	Theophany-Baptism of Jesus Christ, flanked by the Mother of God with Christ Child and St. Paraskeve of the Balkans, on the lappets: St. H. Nicholas of Myra, St. H. John Chrisostomos (St. H. Basil the Great), St. H. Gregory Bogoslov.	142 × 108 cm	4, not distinguishable; one lappet lost	1812 Poeni, Timiș county	15 × 15	Lost
5	**MBT**	Apostles Peter and Paul, 2 Seraphs, 2 Cherubs. Lappets: 3 Seraphs	Coronation of the Virgin Mary, 4 Seraphs, on the lappets: 3 Seraphs	93 × 89 cm Canvas: 75 cm	3, oval, seraphs	1881 (Crivina de Sus, Timiș county)	12 × 12	Profiled, 3 bulbs
6	**MBT**	Mother of God flanked by 4 seraphs. Lappets: 3 seraphim	Nativity of the Virgin Mary, flanked by 4 seraphs	90 × 90 cm Canvas: 77 cm	3, oval, seraphs; central lappet missing	1882 Crivina de Sus, /Timiș	13 × 13	Profiled, 3 bulbs
7	**MBT**	Theophany-Baptism of Jesus Christ. Left: Virgin Mary with Christ Child. Right: St. Paraskeve of the Balkans. Lappets: St. Apostle Paul, St. Gregory Bogoslov (St. Basil the Great), St. John Chrisostomos	Coronation of the Theotokos, flanked by 2 archangels	137 × 107 cm	4, rectangular shape lappets; 1 missing	1867 Poeni, Timiș county	8 × 10	Lost
8	**MBT**	Mother of God with Jesus Christ Child and Cherub	Holy Trinity, with medallion and inscription	73 × 73 cm Canvas: 54 cm	Pennant has the shape of a chalice	1848 Hezeriș, Timiș county	14 × 14	Profiled, masterful fixing system of the canvas

No.	Location[*]	Face A	Face B	Dimensions	Lappets/ streamers	Date/ provenance	Canvas weave count per (cm^2)	Horizontal wooden suspension pole (*drug*)
								to the wooden pole
9	**MBT**	Pentecost	Saint M. George	56 × 43 cm	—		20 × 27	Lost
10	**MBT**	Theophany, Baptism of Jesus Christ	Archangel Michael. Lappets: St. Paraskeve of the Balkans, St. Nicholas of Myra, St. Demetrios	132 × 102 cm Canvas: 92 cm	3, rectangular shape, saints	1777 Zolt, Timiș county	13 × 8	Wooden pole
12	**MBT**	Theophany, Baptism of Jesus Christ	Theotokos with Christ Child, Saint Apostle Peter	140 × 100 cm	4, rectangular shape, cherubs and seraphim	1779	10 × 13	Wooden pole (new, improvised)
13	**MBT**	Resurrection of Jesus Christ	Nativity of Jesus Christ	99 × 75 cm	3, oval shape	1875, Clopodia, Timiș county	—	Lost
14	**MBT**	Epitaph	Burial of Jesus Christ	75.5 × 62cm	—	1848, Nerău	16 × 17	—
15	**MBT**	Epitaph	Burial of Jesus Christ	70.5 × 55.5 cm	—	1824, Govojdia, Timiș county	14 × 15	—
16	**MBT**	Epitaph with scenes and symbols from the cycle of the Passions of Christ	Burial of Jesus Christ	120 × 87 cm	—	—	—	—
17	**MBT**	Theophany, Baptism of Jesus Christ	Dormition of the Theotokos	111 × 88 cm	—	—	—	Lost
18	**MBT**	The Holy Trinity	The Annunciation	56 × 51 cm	—	Jupânești, Timiș county	12 × 11	Lost
19	**Private**	Saint M. George	The Annunciation	63 × 53 cm	—	Cubleșu, Sălaj	11 × 11	Lost
20	**MBT**	Theophany, The Baptism of Jesus Christ	Virgin Mary Theotokos(?)	75 × 59 cm	—	Jupânești, Timiș county	12 × 11	Lost
21	**Private**	Theophany, The Baptism of Jesus Christ	Saint M. Tryphon and St. Paraskeve of the Balkans	108 × 85 cm	7, triangular shape	1848 Socu, Gorj county Authors: George, Kostandin, Kostandin	11 × 13	Original shape of the wooden pole to which the textile is sewn around with a rope
22	**MBT**	Interstitial canvas from wooden church St Paraskeve of Curtea	Photographic detail from the scenes of the Parables of Jesus Christ.	—	—	1806 Curtea, Timiș county	—	—
22	**Private**	The Holy Trinity	Nativity of Lord Jesus Christ	—	—	Cubleșu, Sălaj county	—	Fragment
23	**MArT**	Theophany, Baptism of Jesus Christ, Saints Evangelists John and	Saint Archangel Michael, Saint Evangelists Mark,	—	5, rectangular shape	18th–19th century	—	Profiled wooden pole

No.	Location*	Face A	Face B	Dimensions	Lappets/ streamers	Date/ provenance	Canvas weave count per (cm^2)	Horizontal wooden suspension pole (*drug*)
		Luke, Saints Bishops Basil, Gregory, John	Saint M. Theodore Tiron, Saint M. Nestor					
24	**MBT**	The burial of Jesus Christ on the Great Friday (with cherubs)	Apostles Peter and Paul (with cherubs)	—	3 lappets; central lappet lost	ca. 1882, Crivina de Sus, Timiș county	—	Only surviving wooden pole with 1 bulb, with painted canvas / Fragment from a deteriorated banner cut off and stolen from its pole
25	**MBT**	Theotokos with Jesus Christ Child	The Holy Trinity	79 × 56 cm Canvas: 65 cm	The pennant has the shape of a chalice; lappet missing	Pogănești, Timiș county	—	Profiled fixing system of the canvas to the wooden pole

Abbreviations: MBT = Museum of the Orthodox Archdiocese of Timișoara; MArT= Timișoara Museum of Art; Private = private collection. This table details the banners and epitaphs in the study shown in fig. 56.1.

Table: Filip A. Petcu

Buriac (Universitatea Politehnica Timișoara, Institutul de Cercetări pentru Energii Regenerabile: XRF, SEM-EDX), Marinela Miclău and Melinda Vajda (Institutul Național de Cercetare – Dezvoltare pentru Electrochimie și Materie Condensată: XRD), Zoltan Szabadai and Andrei Racu (Laboratorul de Energii Regenerabile – Fotovoltaic: micro-Raman, UV-VIS spectrometry), Cristina Carșote (Muzeul Național de Istorie al României: FTIR), Ksynia Marko (National Trust), and James Black (International Academic Projects).

NOTES

1. For *tüchlein* paintings, scenic backcloths, and theatrical cloths, see Villers 2000 and Costaras and Young 2000.
2. https://aata.getty.edu.
3. As described by Cennino Cennini, *The Book of the Art,* and by Dionysius of Fourna, *Hermeneia.*
4. Sometimes called *streamers* (Hourihane 2013, 514).
5. Quanta Feg-250 equipped with an EDAX Apollo silicon drift detector, 15 kV.
6. ThermoFisher Scientific Niton XL3t GOLDD+.
7. Argon Laser Stellar-Pro Select 150 with adjustable emission at 514 nm.
8. Andor Shamrock 500i Detector with iDus 420 CCD spectroscopy camera and a Bruker Vertex 70 FT-IR spectrometer.
9. The introduction of water can lead to formation of metal soaps inside of paint layers. See van Loon, Noble, and Burnstock 2021.
10. Adding 10% Aquazol 200 to Paraloid B72 improves qualities of B72 in acetone (Wolbers 2008, 115).
11. The adhesive and cohesive properties of Beva 371 are assessed in depth compared to other conservation products (Mecklenburg, Fuster-López, and Ottolini 2012).

57

The Challenges of Treating and Displaying Two-Sided Oil Paintings

Elena Iurovetskaia, Conservator, Department of Scientific Conservation of Oil Paintings, State Research Institute for Restoration (GOSNIIR), Moscow
Anastasia Yurovetskaya, Research Fellow, Department of Scientific Conservation of Oil Paintings, State Research Institute for Restoration (GOSNIIR), Moscow
Maria Churakova, Head, Department of Scientific Conservation of Oil Paintings, State Research Institute for Restoration (GOSNIIR), Moscow
Artyom Romanov, Conservator, Department of Scientific Conservation of Oil Paintings, State Research Institute for Restoration (GOSNIIR), Moscow

In this paper, conservators from GOSNIIR offer several techniques for displaying and treating two-sided paintings without giving preference to one as the main side. They have adapted a method of tear mending for the process of strip-lining. The edging margins of the painting are connected to the new canvas strips thread-by-thread with polyvinyl butyral in isopropanol. Its strong, elastic film allows application of gentle pressure to stretch the painting on a special frame. The joint can be strengthened by stitching. For restretching, a manually controlled system is offered consisting of two frames: an inner extensile one, to which the painting is attached, and an outer frame with rigidly fixed edges with screws that move forward and backward toward the bushings and change the tension by pulling and pushing the inner frame. The techniques are discussed using case studies as examples.

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INTRODUCTION

A shift from nineteenth-century academic painting to the modern approach of the twentieth century changed not only painting technique but also the attitude toward the whole structure of the picture. In order to save materials, artists would more often create their works on old canvases, disregarding sketches or studies in oil on the other side. Sometimes even finished oil paintings would become a support for a new artwork. Over the course of time, the problem of displaying and treating such two-sided paintings became evident to curators and conservators.

STRIP-LINING

The task of restretching such pictures without giving preference to one "principal" side is a serious challenge. Even if the artist had a certain intent about which side should be presented, nowadays we often selfishly want both sides to be accessible to the public and researchers. Conservators at the State Research Institute for Restoration (GOSNIIR), in Moscow, adapted a method of tear mending for the strip-lining process in order to avoid overlaps, especially for pictures that have images of the same size on both sides. A common method of tear

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Figure 57.1 Vladimir Tatlin (Russian, 1885–1953), *Still-Life with Melon and Apples/Green Leaves in a Jar*, 1912. Oil on canvas, 77 × 67 cm (30 1/3 × 26 3/8 in.). Moscow, Russian State Archives of Literature and Art. (a) Fragment before treatment. (b) Fragment after the tear was fixed with PVB solution and reinforced with stitching. Images: Russian State Archives of Literature and Art

mending in Russia developed in 1978 treats tears and cuts of the textile painting supports with a 5% solution of polyvinyl butyral (PVB) in ethanol or isopropanol. Saturated threads are woven together, and after drying are fixed by hot spatula (Surovov and Yashkina 1979).

PVB has been widely used in conservation practice in Russia since the 1950s (Rumyantsev 1953), especially for treating murals, ceramics, and fabric painting supports. Its glass transition temperature is approximately 60°C–70°C. "PVB films are resistant to light and heat-sealable at temperatures above 120°C. . . . PVB films are noted for their biostable and abrasion resistance properties as well as for good colourfastness against ultra-violet light, low static generation, and low water absorption" (Sannikova 2018, 106).

For the issue of two-sided paintings, conservators from GOSNIIR offered this technique to attach new canvas strips thread-by-thread to the original supports of the pictures (Yashkina and Churakova 2013). PVB is a polymer with strong, elastic films and stable properties (Sannikova 2018), and when used for such type of strip-lining it allows the painting to be stretched on a special frame by applying gentle pressure. The joint can also be slightly reinforced by applying some linen fibers mixed with the adhesive or by stitching (fig. 57.1). This method can be especially useful for cases in which the paintings do not have any original margins.

STRETCHERS

According to modern conservation standards, new stretchers must be extensible, and in the case of double-sided pictures, systems with wedges, screws, and springs all may be suitable. But if conservators do not wish to give preference to one side of the picture, a system must be developed that results in a situation where the painting does not have a verso. The stretching should be performed using the same standards as for an ordinary, one-sided picture: the tension should be evenly distributed along the perimeter and in the corners to keep the painting in plane for optimal viewing and display (Zaycev 1977). But now we also have a goal to prevent stretcher bars from obscuring the paint layer on both sides of the artwork, eliminating the need for crossbars. Following are technical details for an example of a two-sided picture that underwent structural treatment in our studio at GOSNIIR.

Case Study: Andrey Vasnetsov's New Village

New Village, by Andrey Vasnetsov (1924–2009), had been kept unstretched in the storage of Abramtsevo museum-reserve for a few decades. Each side of the canvas was painted with a finished landscape, oriented in a different direction. One of these paintings is also approximately 10 centimeters larger than the other (fig. 57.2). The painting was brought to our institution for research and restoration. Conservators consolidated the matte paint layer with copolymer of polyvinyl acetate with ethylene (Fedoseeva et al. 2016, 88). Then strip-lining was performed. In this particular case, we didn't have to attach new linen margins thread-by-thread because one of the

Figure 57.2 Andrey Vasnetsov (Russian, 1924–2009), *New Village*, 1950–1960s. Oil on canvas; obverse side is 79 × 99.5 cm (31 1/8 × 39 1/6 in.); reverse side, 89 × 99 cm (35 × 39 in.). Moscow region, Museum-reserve "Abramtsevo." Obverse side before conservation. Note the visible difference in size. Image: Museum-reserve "Abramtsevo"

paintings was slightly smaller, so there was enough space to do a traditional variant with an overlap. After these operations, the painting had to be stretched.

Conservator Artyom Romanov developed a system for doing so that was influenced by a constant tension system suggested by Barry B. Bauman of the Chicago Conservation Center. In 1982, Bauman designed a device for stretching and framing a double-sided painting that had an adjustable spring mechanism to ensure continuous canvas tension (Bauman 1982). In our case, the museum and conservators decided to make the system manually controllable (fig. 57.3). The stretcher for *New Village* consisted, in fact, of two frames. The inner, extensile one, to which the painting was attached, had furniture bushings around the perimeter on its side ends. The outer frame, with rigidly fixed edges, had tension screws that moved forward and backward toward the bushings and changed the tension by pulling and pushing the inner frame (Romanov 2013). Instead of springs and wall grips, the screws went directly into the furniture bushings. The number of tension screws may vary depending on the size of the picture and the condition of canvas. In this particular case, a linen sackcloth with a weaving density of about 8 by 8 threads per square centimeter was used as the painting support. For the smaller stretcher, Romanov installed bushing in threes on the long sides and in pairs on the shorter ones.

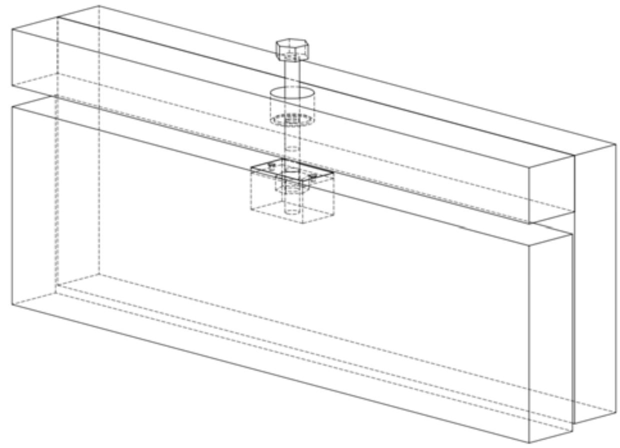

Figure 57.3 Schematic of screw mechanism installed by Artyom Romanov for tensioning Vasnetsov's two-sided painting *New Village*. Image: GOSNIIR

For display, the structural features of the stretchers should be hidden in order not to distract attention from the painting. Decorative elements on the two sides can be made in distinct styles to match a particular image. Moreover, if the images on the different sides of the painting are presented in different sizes or even formats, the outer frame can be designed to compensate for the difference, as in the case of the Vasnetsov picture (fig. 57.4). The inner frame, which carried the original support, was created based on the measurements of the bigger painting, making it possible to cover the areas of blank canvas on the smaller side with decorative elements.

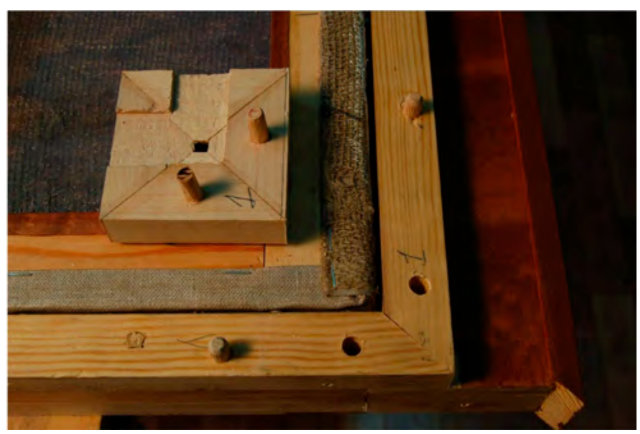

Figure 57.4 *New Village*, process of installing decorative elements of the frame. Image: GOSNIIR

Case study: Diego Rivera's Glorious Victory

Another interesting example was designing a stretcher for a large-scale (260 × 450 cm) painting titled *Glorious Victory*, by Diego Rivera (1886–1957), from the Pushkin Museum, in Moscow. The picture is actually one-sided, but there is an unfinished art piece on the reverse, which was shown in the exhibition *Viva la Vida: Frida Kahlo and Diego Rivera* at Moscow Manege in 2018. The size of the painting and the intention to arrange a two-sided view led to the decision to present it on a stand with an integrated exhibition frame.

The screw stretching system was hidden inside the frame, which was attached to the wood-decorated metal post. As the temperature and humidity conditions were not very stable, the curators were worried that strains could appear on the picture. The oak panels of the frame had holes on the sides that allowed access to the screw elements, and these let the conservators easily change the tension without deinstallation of the whole structure.

CONCLUSION

For decades, the problem of presenting both recto and verso of two-sided paintings was troubling to the artistic and scientific communities. Nowadays, modern restoration provides conservators with a wide variety of opportunities for treating such objects without sacrificing a part of the whole (Runeberg 2019). The major step of accepting the challenge has been taken up in the past; today our aim is to improve and modernize conservation techniques to make our work more effective. The projects presented in this paper contribute to the discussion about conservation and presentation of double-sided paintings.

58

Is Lining Inevitable? Tear Repair of a Seventeenth-Century Canvas on Its Original Strainer

Matthew Hayes, Director, Pietro Edwards Society for Art Conservation, New York

This short paper describes the treatment of Madonna and Child with the Young St. John the Baptist and Two Angels, *a painting attributed to the anonymous "Pittore di Pontignano" and dated about 1650. The canvas, which preserves its original stretching and strainer, recently suffered injury resulting in a 104 centimeter tear. Conservation treatment, developed in discussion with the picture's owners, was designed to mend the damage yet preserve the artifactual character of the work. Thread-by-thread tear repair was undertaken to rejoin the broken fabric, with some local reinforcement added to reinforce the brittle fibers. Deformations and old varnish in the canvas were both reduced. A modified "stretcher bar lining" and backing board were mounted to the strainer to protect the primary support. The approach questions the necessity of lining and emphasizes the importance and interest in preserving a painting as an object as well as an image.*

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INTRODUCTION

The thread-by-thread method of repairing torn paintings, developed by conservator Winfried Heiber and described in his 1996 article on the subject, is widely known and implemented, especially in the German-speaking world (Heiber 1996, 2003; Heiber et al. 2012). While to some degree a familiar technique in U.S. museums, it remains underused in private practice—at least in New York, where lining is still a common treatment for damaged canvases. In my own experience speaking to colleagues, thread-by-thread tear repair can be seen as tedious or untenably time-consuming; for clients it remains an unfamiliar remedy, one met with curiosity. This brief article hence does not present a novel solution but is rather an attempt to encourage a known procedure while presenting it in combination with additional measures—varnish removal from an old canvas and the construction of an insert lining—designed to enhance its results.

THE CASE

Madonna and Child with the Young St. John the Baptist and Two Angels (ca. 1650), attributed to the anonymous "Pittore di Pontignano" (fig. 58.1), had suffered mechanical damage resulting in a tear some 104 centimeters long.

The painting is unlined and stretched on what appears to be its original strainer, with parts of its first stretching intact (fig. 58.2). The strainer is constructed of a medium-density hardwood, perhaps walnut, with shouldered bridle joins at the corners, each secured with a single wooden peg.[1] The medium-weight, plain-weave canvas had originally been attached with flat iron nails, driven partway

Figure 58.1 Attributed to the "Pittore di Pontignano," *Madonna and Child with the Young St. John the Baptist and Two Angels*, ca. 1650. Oil on canvas, 128 × 93.5 × 3 cm (50 2/5 × 36 5/6 × 1 1/6 in.). Private collection. Image: Matthew Hayes

into the strainer and bent down over the narrow tacking edges. Some of these edges had later been reinforced and secured with modern tacks, as well as with additional wooden strips on three sides. The tacking margins appeared secure and were lent support by the cushioned rabbet of the picture's frame. The canvas itself was not under tension and had a slight overall undulation, rendered less noticeable by the marked texture of the paint film. The painting, apparently executed in oil, had been restored multiple times in the past, including fairly recently.

My suggestion that local tear repair could mend the damage while avoiding lining—and so maintain the valued "object nature" of the artwork—met with a positive response from the owners. Old canvas repairs, notably two patches on the reverse, were not addressed.

Figure 58.2 Upper edge of the strainer, showing the original stretching. Image: Matthew Hayes

TEAR REPAIR AND REINFORCEMENT

Loose paint along the tear was first secured with 5% sturgeon glue.

The tear was then repaired using the thread-by-thread method (fig. 58.3). Working under a binocular microscope, broken threads were realigned and rejoined using a 1:1 mixture of 20% sturgeon glue and 10% wheat-starch paste. I used a Weller WD1M soldering station with a micro soldering iron to cure the adhesive mixture. This tool has the benefit of digital temperature control, and exchangeable tips in various precise shapes are available.[2]

Because the overlap of the torn fibers was not great in some areas—many canvas threads were essentially butt-joined—the tear was reinforced. Using the same glue-paste adhesive, linen threads were attached to the canvas reverse to bridge the tear (fig. 58.4). The spacing of the bridging threads was guided organically by the overlap, and hence stability, of the repaired original fibers. Their length was varied from 0.5 to 2 cm to broaden the area of reinforcement, avoid creating a single line of tension, and attenuate the added material. The introduction of a second adhesive system to attach the bridging threads was considered: polyvinyl acetate emulsions, Beva 371, Paraloid B72 resin, and polyamide welding powder were all potential candidates and might have introduced greater resistance to moisture; however, the easy reversibility of the sturgeon-glue mixture proved more alluring to this conservator.

After securing the tear, humidification of the canvas with drying under weight was performed to reduce deformations. Because the canvas is not under tension, the possibility exists that, although the canvas matrix now appears quite cohesive, future tenting of the support at the tear could occur. It is hoped that the secondary supporting measures discussed below will mitigate this. Additional steps to keep the tear flat, such as the

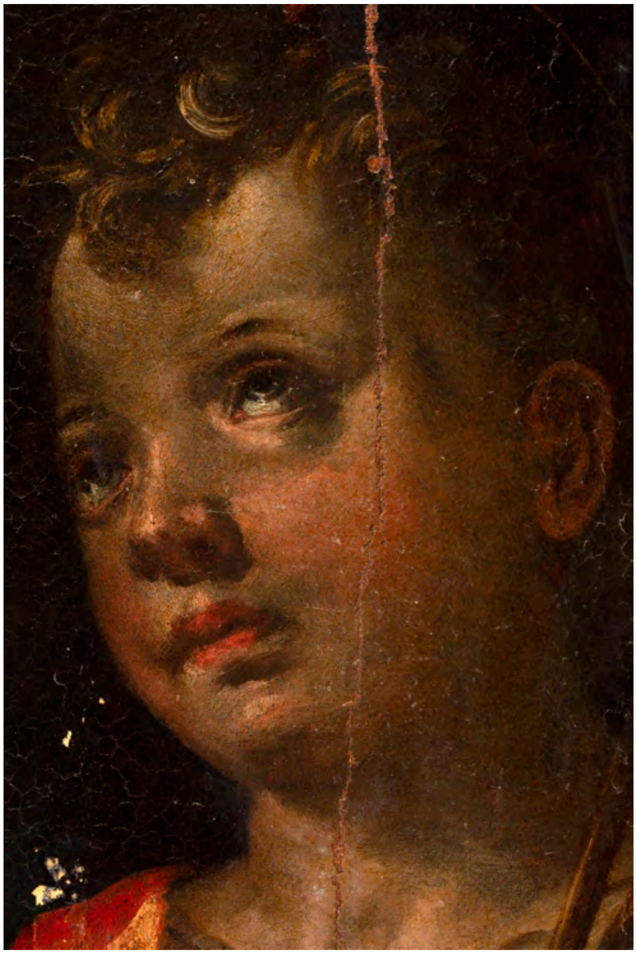

Figure 58.3 Detail of the repaired tear from the front. Image: Matthew Hayes

Figure 58.4 Detail of the repaired tear from the reverse, reinforced with bridging linen threads. Image: Matthew Hayes

attachment of bridging wires or pins, remain a future treatment option should this prove necessary.

CLEANING OF THE CANVAS

The canvas support had discolored to a ruddy brown and was traced with a dark network of lines mirroring the craquelure of the paint, likely where later varnishes and perhaps consolidants had seeped through from the front. That the canvas was quite brittle appeared to be partly due to its impregnation with these old resins. Reducing the quantity of this oxidized material thus seemed desirable. After normal surface cleaning with brushes and a vacuum, and some testing, the varnish in the canvas was reduced using poultices of ethanol-saturated Evolon CR, a nonwoven microfilament textile made from 70% polyester and 30% polyamide. Pressed onto the reverse, the Evolon drew discolored matter out of the canvas, which was afterward considerably more flexible as well as lighter in color. That the textile support was initially so stiff and brittle was thus due not solely to its own degradation but also, considerably, to the degradation of the varnish it had absorbed.

ATTACHING AN INSERT LINING AND BACKING BOARD

Although the tear was closed and appeared secure after several weeks of observation, the entire object remained fragile. To lend additional support and stability to the canvas, a type of insert lining was constructed.

For this, a basswood frame was built with an L-shape profile that could rest within an inner lip of the primary strainer; as on a modern stretcher, the edges of the new frame facing the canvas were slightly beveled. Unbleached cotton muslin was then stretched over this frame, secured at its outer edges with staples. The insert lining was fixed to the inner edges of the strainer using six screws, with the stretched muslin placed just behind and barely touching the canvas. An acid-free backing board was attached to the wooden frame of the insert (fig. 58.5). The construction is designed to support the canvas and cushion its movement, provide an environmental buffer for the canvas reverse, and protect from further mechanical damage. It is easily reversible, leaving only the small holes from the attaching screws. The construction is similar to the so-called vibration protectors (*Schwingungsschutze*) I observed while an intern at the Kunsthistorisches Museum, in Vienna.

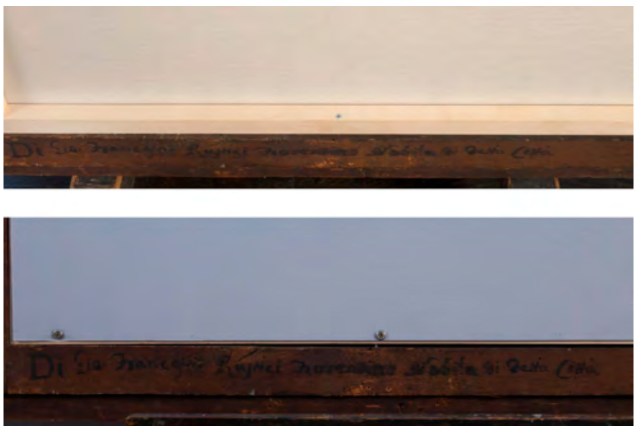

Figure 58.5 The insert lining, a wooden frame stretched with muslin, secured to the strainer (top) and with a backing board attached (bottom). Image: Matthew Hayes

FILLING, RETOUCHING, AND VARNISH

Though unrelated to the structural concerns of this volume, the aesthetic treatment of the picture deserves mention. This work was done traditionally. Losses along the tear and throughout the painting were filled with a putty of Champagne chalk and 7% sturgeon glue. The losses were textured with this gesso to match the surface of the surrounding paint. Some additional texturing was added to the surface using Golden Heavy Gel Gloss, a thick, transparent acrylic medium. Initial retouching of the losses was done with gouache, with subsequent inpainting carried out using dry pigments bound in polyvinyl acetate resin (Mowilith 20).

The painting appeared to have been treated not long in the past. Due to its easy solubility in aliphatic hydrocarbons, the uppermost varnish was suspected to be Regalrez 1094. This, interestingly, had become extremely uneven, raising questions about the practical aging of this popular material. A thin spray of 5% mastic varnish in turpentine was applied to unify the surface gloss.

CONCLUSION

For this work by an anonymous seventeenth-century artist, the artifactual nature of the painting is part of its value, both historical and financial. That I was awarded this commission with a proposal to preserve these features, rather than unstretching the canvas and lining it on a modern stretcher, offers a potent indication that perceptions of lining have shifted considerably since the 1974 Greenwich conference—not just among conservators but also for an art-buying public. The object remains fragile, but this is all the more reason that it should be handled carefully. Secondary, reversible means are available to support such weak canvases. The painting can always be lined in the future should this be judged necessary, and repairing the tear prior to lining would have been required in any case.

While the scope of this damage is perhaps atypical within my practice, I frequently use the thread-by-thread method of tear repair. Even for freelance conservators for whom project times can be particularly limited, it offers a viable and elegant treatment option.

SOURCES AND MATERIALS

Blick Art Materials, New York: Golden Heavy Gel Gloss; Schmincke Horadam gouache.

Kremer Pigments, New York: Champagne chalk, mastic resin, polyvinyl acetate resin (Mowilith 20), sturgeon glue, wheat-starch paste (Jin Shofu).

Talas, New York: Evolon CR, Heritage Archival Corrugated Board.

NOTES

1. Wood identification was not performed.
2. Newer models of this tool are available, for instance the Weller WX series workstations with a Pico soldering iron WXPP; see https://weller-tools.com.

59

Magnetic Systems as an Alternative to Traditional Methods for the Conservation-Restoration of Painted Canvas Supports: A Proposal of Minimal Intervention Protocols

Emanuel Sterp Moga, PhD Researcher, Department of Painting and Conservation-Restoration, Faculty of Fine Arts, Complutense University of Madrid, Spain
Alicia Sánchez Ortiz, Professor, Department of Painting and Conservation-Restoration, Faculty of Fine Arts, Complutense University of Madrid, Spain

This research shows the application of neodymium magnets in the conservation/restoration of paint on canvas, establishing minimal intervention as the main criterion. In an innovative way and with the aim of respecting the authenticity of the original, a new tool has been designed consisting of an internal auxiliary frame equipped with a magnetic system (IAFMS). Its use contributes to facilitating and improving the operation during some procedures, such as thread-by-thread sutures, textile intarsia, and thread-bridge reinforcement.

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BACKGROUND

During the past decades, the criterion of minimal intervention has acquired great importance and continues to guide the actions of conservative practitioners aiming to keep open options for retreatment (Appelbaum 1987). In the specific field of painted canvas supports, progress has been constant as a result of the search for new operational methodologies that continue to provide better responses to the problem of deterioration. Neodymium magnets have a wide field of application in the assembly of objects in permanent and temporary exhibitions, especially graphic works, textiles, and decorative arts collections (Spicer 2019), but specific applications for pictorial works are still scarce (Bestetti 2005; Rella and Saccani 2006, 17–19; Sterp Moga and Sánchez Ortiz 2019) .

An internal auxiliary frame equipped with a magnetic system (IAFMS) has been developed by the authors to assist the conservator in maintaining tension during conservation procedures involving thread-by-thread suture for tear mending, textile intarsia, and reinforcement with thread bridges. The frame is equipped with a magnetic system on the inner and outer edges, consisting of different magnets embedded flush with each edge and a U-shape iron gutter, adequately protected (fig. 59.1). The

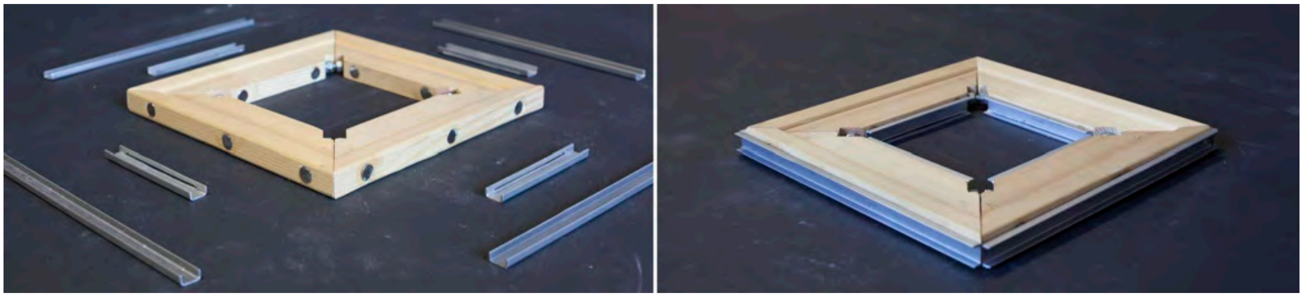

Figure 59.1 Internal auxiliary frame with magnetic system (IAFMS). Image: Emanuel Sterp Moga

magnets holding the gutter allow the gutter to be raised and lowered to bring the threads closer to the surface of the damaged canvas. Different magnets are housed in the gutter; these act as a clamp and allow the textile material (the necessary threads with the warp and weft) to be held according to the needs of the tear, gap, or break in the textile support. In addition, the system allows the application of a minimum tension by means of the tensioners composed of stainless-steel dowels and threaded rods and nuts placed in the four corners of the frame. In short, the IAFMS allows the tension of the threads to be maintained and exactly positioned during treatment, thus facilitating the adhesion of the suture. At the end of the procedure, the frame and the excess threads are removed from the treated area.

MATERIALS AND METHODS

Tension Value Studies

The continuous environmental changes to which paintings on canvas are subjected are one of the main agents of deterioration, as the constituent materials respond in very different ways. As a result of mechanical stress and the release of this stress, the canvas becomes loose and deformed, with the consequent appearance of folds and other deformations.

In 1950, Roberto Carità carried out the first studies on the quantification of the mechanical tension forces and made the first prototype of a frame with springs (Carità 1955). Gustav Berger and William Russell carried out experimental tests showing that canvases are capable of withstanding a maximum tension of 100 N/m when exposed to environmental conditions of 21°C and 60% RH (Berger and Russell 2000).

In more recent research, Antonio Iaccarino Idelson has analyzed what could be the most suitable tension parameters for paintings on canvas mounted on frames modified with a spring system. According to the results, the tensions should be between 1.5 N/cm and 2.6 N/cm, with some cases being acceptable up to 3.4 N/cm (Iaccarino Idelson 2009).

Thread Tension Tests

Different threads were selected for testing, both synthetic and natural: Lipari, 260 g/m^2; Ispra, 130 g/m^2; cotton, 320 g/m^2; and linen 2297, 170 g/m^2. A selection of block-shape neodymium magnets with a protective nickel coating (NiCuNi), of varying dimensions and grades (magnetization), were also tested: 8 × 8 × 4 mm (N45), 10 × 10 × 3 mm (N42), 25 × 6 × 2 mm (45SH), and 20 × 10 × 2 mm (N45). Each thread was stretched between two magnets by means of a high-quality digital balance for forty-eight hours.

Elaboration of the Models

Three samples of each of four types of models were made: (A) Lipari synthetic fabric, 260 g/m^2, and a preparation of Talens acrylic gesso; (B) Lipari synthetic fabric, 130 g/m^2, and a preparation of plaster (calcium sulfate) and rabbit-skin glue; (C) cotton fabric, 320 g/m^2, and a preparation of plaster, chalk, and PVA latex; and (D) linen 2297, 170 g/m^2, and industrial preparation with vinyl resin (Modostuc). Different damages were inflicted on the samples. They were subjected to different cycles of artificial aging by means of UV from sixteen Ultra Vitalux lamps (300 W/230 V), at a temperature of 50°C and RH of 20%–25%, for 700 hours. The aging protocol followed the ISO 4892-2 standard.

Tension Measurement

The tears caused by artificial aging were treated using two methods: first, without tensioning the new threads, and second, by subjecting them to slight tension using the

a b c

Figure 59.2 (a) Thread-by-thread suture. (b) Textile intarsia. (c) Reinforcement with thread bridges. Image: Emanuel Sterp Moga

IAFMS tool. Measurements were taken before and after the operation to see which method was more effective using a HT-6510N tension meter. The models were also subjected to RH oscillations between 50% and 80%.

Creation of the Frame and Selection of the Magnets

The IAFMS measures 25 × 25 × 2 cm and is made of laminated spruce. The four corners of the frame are cut at 45 degrees and consist of a tensioning mechanism composed of stainless-steel pins, threaded rods, and nuts.

To carry out the local treatments on the support—thread-by-thread suture, textile intarsia, and thread-bridge reinforcement—IAFMS has a magnetic system located on the edges of the slats. It is composed of an iron chute with an anti-rust coating and has three magnets on the outer edges and two on the inner edges. The system acts as a clamp holding the warp and weft threads according to the needs of the damage to be treated (see fig. 59.1). The new threads are held to the mechanism with the different axial magnets mentioned above.

Textile Microsurgery

Yarns extracted from the textile used for each model were used. They were laid by both the traditional method and by IAFMS (fig. 59.2). The adhesive selected for the sutures and the textile intarsia was 10% starch paste and 20% sturgeon glue; a small drop was deposited with a brush on each thread to be sutured. In the case of the reinforcement bridges, the threads were impregnated with Plextol B500. Each new thread was aligned and placed in its exact position and kept taut at a value of 1 N/cm as the adhesive was reactivated with a thermal spatula.

RESULTS AND DISCUSSION

Measurement of Wire Tension and Tension of Painting Canvas

The results obtained are shown in table 59.1. The N45 magnets measuring 20 × 10 × 2 mm were selected for their dimensional characteristics, which better adapt to the magnetic system of the frame. These magnets have approximately 20.6 N in direct contact with each other, and when used to tension the thread, they produce a maximum tension of 2.64 N. As shown in table 59.2, after the intervention with the neodymium magnets on the models, a tension of between 2.8 and 3.5 N/cm was achieved. This tension was kept constant after twenty-four hours of having been subjected to RH oscillations. Therefore, this is an adequate tension for the desired conditions during conservation of paintings.

Thread-by-Thread Suture

When the traditional thread-mending method was used, the tension values remained between 0.1 and 0.3 N/cm. After the model was subjected to fluctuations in RH, the treated area experienced a general detensioning. The tension applied to the new yarns with IAFMS allowed us to achieved better results while providing adequate tension (2.5–3.5 N/cm) in the area of the treated textile support. During the RH oscillation tests, the tension values were maintained in this range, so the intervention was considered adequate for the intended purpose.

Textile Intarsia

With nontensioned thread, tension values are between 0.3 and 0.5 N/cm. When the models were subjected to fluctuations in RH, the area being worked on relaxed. During the process of laying the threads, if the threads are

Table 59.1
Variables of the tension of different threads by means of several types of magnets

Type of canvas	Magnet grade	Size (mm)	Clamping force (N)*	Maximum operating temperature (°C)	Initial force (kG)	Force after 24 hours (kG)	N
Lipari (synthetic) 260 g/m²	N45	8 × 8 × 4	14.7	80	0.200	0.200	1.96
	N42	10 × 10 × 3	16.7	80	0.390	0.390	3.82
	45SH	25 × 6 × 2	16.7	150	0.310	0.310	3.03
	N45	20 × 10 × 2	20.6	80	0.270	0.270	2.64
Ispra (synthetic) 130 g/m²	N45	8 × 8 × 4	14.7	80	0.255	0.255	2.49
	N42	10 × 10 × 3	16.7	80	0.390	0.390	3.82
	45SH	25 × 6 × 2	16.7	150	0.310	0.310	3.03
	N45	20 × 10 × 2	20.6	80	0.235	0.235	2.30
Cotton (natural) 320 g/m²	N45	8 × 8 × 4	14.7	80	0.200	0.200	1.96
	N42	10 × 10 × 3	16.7	80	0.360	0.360	3.52
	45SH	25 × 6 × 2	16.7	150	0.340	0.340	3.33
	N45	20 × 10 × 2	20.6	80	0.315	0.315	3.08
Flax 2297 (natural) 170 g/m²	N45	8 × 8 × 4	14.7	80	0.235	0.235	2.30
	N42	10 × 10 × 3	16.7	80	0.330	0.330	3.23
	45SH	25 × 6 × 2	16.7	150	0.235	0.235	2.30
	N45	20 × 10 × 2	20.6	80	0.290	0.290	2.84

*The approximate maximum force between two magnets when they are in direct contact.

Table: Emanuel Sterp Moga

Table 59.2
Tension measurements of traditional and magnet interventions, before and after RH oscillations

	Tension before intervention (N/cm)	Tension after traditional intervention (N/cm)	Tension of traditional intervention after RH oscillations* (N/cm)	Tension after intervention with N45[†] magnets (N/cm)	Tension of intervention with N45 magnets[†] after RH oscillations* (N/cm)
Model A: Lipari synthetic fabric (260 g/m²) and a preparation of Talens acrylic gesso					
Thread-by-thread suture	0.1	0.8	0.5	3.0	2.9
Textile intarsia	0.0	1.0	0.7	2.8	2.6
Thread-bridge reinforcements	0.2	0.7	0.5	3.2	3.0
Model B: Lipari synthetic fabric (130 g/m²) and a preparation of plaster (calcium sulfate) and rabbit-skin glue					
Thread-by-thread suture	0.1	1.1	0.6	3.1	3.0
Textile intarsia	0.0	0.9	0.4	3.0	2.8
Thread-bridge reinforcements	0.0	0.8	0.5	2.9	2.8
Model C: Cotton fabric (320 g/m²) and a preparation of plaster, chalk, and PVA latex					
Thread-by-thread suture	0.1	0.9	0.6	3.3	3.1
Textile intarsia	0.2	1.0	0.6	3.5	3.3
Thread-bridge reinforcements	0.1	0.7	0.4	3.1	2.9
Model D: Linen 2297 (170 g/m²) and industrial preparation with vinyl resin (Modostuc)					
Thread-by-thread suture	0.1	0.6	0.3	2.9	2.8
Textile intarsia	0.0	0.8	0.4	2.8	2.6
Thread-bridge reinforcements	0.0	0.7	0.4	3.1	2.9

*RH was varied from 50% to 80%
[†]20 × 10 × 2 mm
Table: Emanuel Sterp Moga

held in place at a tension of 1 N/cm, the treated area has a tension of 2.5–3.5 N/cm, and the whole remains stable.

Thread-Bridge Reinforcements

Without adding tension, the treatment carried out with the new threads did not achieve good results. The model showed a tension of 0.5–0.8 N/cm—a value insufficient to guarantee the stability of the textile support. When using IAFMS, the yarns are kept at a tension of 1.5 N/cm and the tension is 2.8–3.4 N/cm. These values remained stable.

REAL-WORLD APPLICATIONS

Two anonymous works were chosen to test the IAFMS tool in practice. Both works showed a generalized weakening of the fibers of the support due to oxidation and to the existence of various tears in the fabric as a result of adverse exposure and storage conditions.

Case Study 1

The first painting was an eighteenth-century representation of the Virgin and Child rendered in oil on linen, measuring 104 x 76 cm. The textile support has a plain weave and a traditional preparation of plaster and glue.

The adhesive was chosen for suturing thread by thread: 10% starch paste and 20% sturgeon glue in water (1:1). Natural linen threads 2297, 170 g/m², were used and maintained at a tension of 1 N/cm thanks to the IAFMS (fig. 59.3). At the end of the operation, the textile support showed a tension of 3.2 N/cm in the treated area. For the reinforcement bridges, the same natural linen threads were used, but impregnated with Plextol B500. The tension applied with Q-20-10-02-N magnets and the IAFMS was 1.5 N/cm. Once the treatment was finished, the treated area maintained a tension value of 3.0 N/cm.

Case Study 2

The second work was an oil painting on cotton cloth, dating from the twentieth century, whose motif is a still life. It is supported with a taffeta ligament, is industrially prepared, and measures 98 × 48.5 cm.

Cotton fabric threads, 320 g/m² (fig. 59.4), were used, along with 10% starch paste and 20% sturgeon glue in water (1:1) as adhesive for the textile intarsia. Because a water-based adhesive was used, small dots were applied to the ends of each thread. The tension of the new threads was 1 N/cm, and after the operation was completed, the treated area had a tension of 3.5 N/cm.

Figure 59.3 Performing the thread-by-thread suture using the IAFMS. Image: Emanuel Sterp Moga

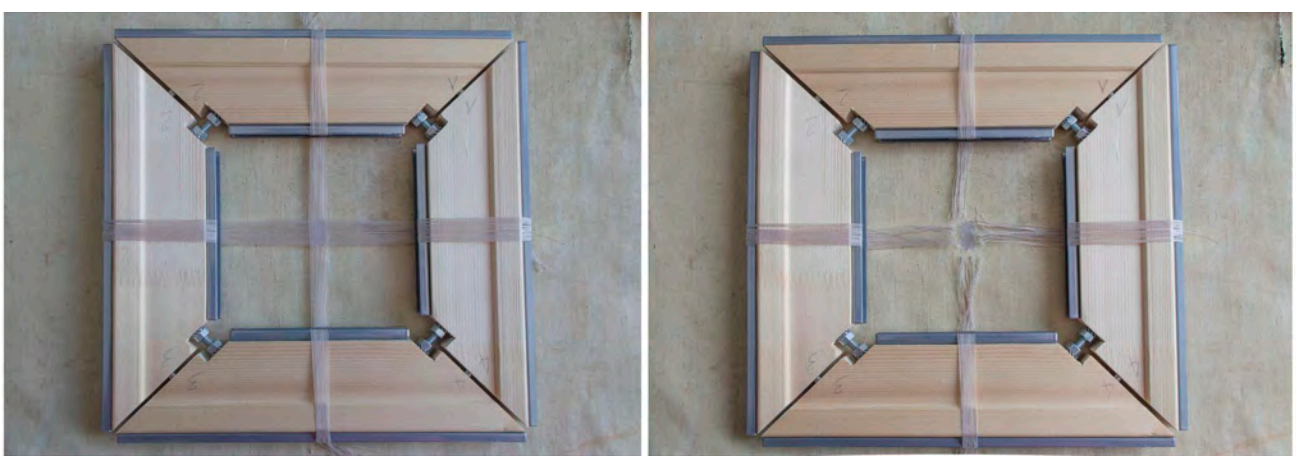

Figure 59.4 Realization of the textile intarsia by means of the IAFMS. Image: Emanuel Sterp Moga

CONCLUSIONS

Experimental tests demonstrate the validity of using neodymium magnets as an alternative to traditional procedures in the conservation of painted fabric supports. The magnetic IAFMS allows one to make treatments of sutures thread-by-thread or using textile intarsia, or thread-bridge reinforcement, minimizing the manipulation of the work and with it the risks. It is important to remember that the method of assembly of the magnetic system, the holding and tension force, and the size and weight of the magnets are factors that must be evaluated by the restorer. This method is simple, low-cost, effective, reversible, and respectful of the original work of art.

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Structural Conservation Issues with European Easel Paintings Housed in High-Humidity Regions Such as Mumbai, India

Omkar Kadu, Assistant Curator of Conservation, Chhatrapati Shivaji Maharaj Vastu Sangrahalaya, Mumbai

The Sword of Damocles, *by French artist Antoine Dubost, is a jewel of the European painting collection of the Chhatrapati Shivaji Maharaj Vastu Sangrahalaya (CSMVS), in Mumbai. Since its acquisition, the painting, which was previously glue-paste lined, gradually deteriorated: the lined support became rigid and inflexible, the paint layer became extremely brittle, and the varnish layer darkened. Furthermore, displayed in the coastal city of Mumbai, the painting has been exposed to high levels of RH and warm temperatures, which often result in recurring incidences of fungal growth. For the restoration, CSMVS collaborated with the Courtauld Institute of Art. Experts from the Courtauld and the National Museum, London, and art historians from the United Kingdom were consulted to develop a best-practice structural conservation plan for this painting that would take into account the environmental conditions prevalent in Mumbai. Conservation treatment was jointly executed by conservators from the Courtauld and CSMVS.*

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INTRODUCTION

The European paintings collection of the Chhatrapati Shivaji Maharaj Vastu Sangrahalaya (CSMVS), in Mumbai—one of India's premier history and art museums—holds nearly 240 European oil paintings. Paintings in the collection date from as early as the sixteenth century and include artworks from British, Italian, French, Dutch, Flemish, and German schools. Sir Ratan Tata and Sir Dorabji Tata, the pioneer industrialists of India, bequeathed these paintings to CSMVS. Most of these works were shifted to CSMVS from the donors' residences in London and Mumbai in 1922 and 1933.

Mumbai is located on India's western coast, on the Arabian Sea. The coastal nature of the city results in a moderately warm and fluctuating temperature with high levels of humidity. Due to the coastal location of the museum, the paintings have been exposed to high levels of RH and warm temperatures, which have often resulted in recurring dimensional changes of paintings and incidences of fungal growth. Many galleries located in the museum's east wing are equipped with high-precision climate control systems. The galleries in the museum's main building do not yet have such control systems installed, and this includes the European paintings galleries and their associated storage area.

Many paintings had undergone structural conservation treatment prior to their transfer to CSMVS. This paper is an attempt to present comparative case studies of two paintings. These works had undergone structural conservation treatments about a hundred years ago using two different lining adhesives and techniques. The alterations and the changes observed on the paintings over the years with respect to the varying temperature and high humidity climate of Mumbai form the basis of this research.

THE COLLECTION AND ITS CONDITION

About 30 percent of the museum's European painting collection has been displayed in two galleries named after the Tata brothers. The majority of the collection is housed in the European painting storage. Many have survived well for the last hundred years in the fluctuating temperature and high-humidity environment of the city. Few works show common signs of structural and visual deterioration, such as bulging, sagging of support, craquelure, and alteration of pigments due to aging; however, some paintings, especially works on panel supports, have been affected by insect attack in the past, while others show signs of paint losses and other physical damages over a period of time. Natural resin varnishes, commonly used in many of the paintings, have darkened over time. It was observed that the paintings were previously lined with either wax-resin or glue-paste adhesive before they were acquired by the museum. In this comparative case study, one painting previously lined with a glue paste and another with wax-resin adhesive are discussed, along with a brief description of their conservation status and challenges faced when re-treating the paintings.

CASE STUDY 1: *THE SWORD OF DAMOCLES*

Brief History of the Painting

The Sword of Damocles is an early nineteenth-century Neoclassical painting by French artist Antoine Dubost (fig. 60.1). This valuable piece of artwork was bequeathed to the museum by Sir Ratan Tata in 1921. The name of the artist was at that time unknown and remained a mystery for several decades. In 2004, art historian Richard Spear of the University of Maryland came to study the European paintings collection at CSMVS. Based on his expertise on the subject, Spear suspected that the painting was the work of Dubost. This suspicion was reaffirmed two years later, when the artist's hidden signature was discovered during conservation efforts.

Figure 60.1 Antoine Dubost (French, 1769–1825), *The Sword of Damocles*, 1804. Oil on canvas, 228 × 258 cm (89 3/4 × 101 3/5 in.). Chhatrapati Shivaji Maharaj Vastu Sangrahalaya collection, Acc. No. 22.4544. After treatment. Image: © Chhatrapati Shivaji Maharaj Vastu Sangrahalaya (CSMVS)

Condition and Conservation Status

The painting previously formed part of the interiors of Sir Ratan Tata's York House, in Richmond (London). The painting had been lined using a glue-based adhesive before it was bequeathed to the museum. Over the years the painting gradually started showing signs of deterioration. The support had become very rigid, stiff, and inflexible, and the paint layer was extremely brittle. Due to exposure to the high levels of humidity and warm temperatures of Mumbai, there were also recurring incidences of fungal growth. Fungus had not only attacked the back of the painting but also contributed to the separation of the various strata of the canvas and the ground and paint layers. The old varnish layer had darkened with time as well, necessitating its removal and replacement.

Conservation History at CSMVS

In the 1980s, CSMVS staff noticed that the edges of the cracks of the paint layer appeared raised and that paint layers had begun to flake off in a few areas. They decided to consolidate the paint layer using wax. The flaking paint layers were first faced with wax and tissue, then a layer of wax was applied from the back of the painting. Heat was applied from the back, which flattened the raised edges of the craquelure. The facing was then removed, and the painting was put back on display.

In 2004, Dr. Kalpana Desai, then the director of CSMVS, was instrumental in setting up a conservation lab within the museum premises and initiating a conservation project on the *Sword of Damocles*, supported by the Sir Dorabji Tata Trust. It was under her leadership that a team of conservation experts from New York, Abraham Joel and Barbara Bertieri, was invited to examine the painting and prepare an initial treatment plan. The darkened varnish was removed along with any overpaint. This was a particularly important step, as it revealed the artist's signature on the footstool in the bottom half of the painting. The flaking paint layer was then consolidated, and antifungal treatment was carried out using absolute alcohol (ethanol) applied to the verso. The painting was then faced with gelatin and Japanese tissue pending the next phase of the project.

Several years later, in 2011, the final treatment plan was developed under the leadership of Director General Sabyasachi Mukherjee; Anupam Sah, head of Art Conservation, Research, and Training; and Dilip Ranade, senior curator of the European Painting Collection. The museum collaborated with the Courtauld Institute of Art and experts Dr. Aviva Burnstock, head of the Department of Conservation and Technology; Paul Ackroyd, senior conservator at the National Gallery, London; and Dr. Satish Padiyar, an art historian specializing in paintings of the Neoclassical period. A conservation team was assembled, led by Harriet Pearson and Mark Coombs, postgraduate students at the Courtauld specializing in conservation of easel paintings, and CSMVS conservator Omkar Kadu. A support team from the museum assisted in executing the treatment plan.

Technical Examination and Documentation

The painting was extensively documented and examined under visible light, UV radiation, and infrared reflectography (IR). The pigments were identified using scanning electron microscopy–energy dispersive X-ray analysis (SEM-EDX), and cross sections of samples taken from the painting were examined under a compound microscope. The examination using IR revealed pentimenti that showed changes to the positions of the hands and the sword itself. This helped in understanding not only the artist's painting process but also what happened to the painting once it left the artist's studio (for more on this, see Spear 2006). Examination of the cross section and SEM-EDX of the underside of the ground (fig. 60.2) revealed that the fungus had infested not only the surface but also the lining fabric, glue layer, and original canvas support. It was thus important to remove the old lining and reline the painting.

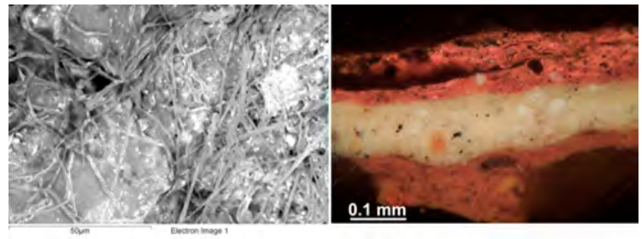

Figure 60.2 Left: Backscatter SEM image of fungal infestation of size layer at 1123× magnification and 20 keV. Right: Mounted cross section showing fungal infestation leading to delamination between canvas and ground layer. Images: © Chhatrapati Shivaji Maharaj Vastu Sangrahalaya (CSMVS)

Conservation Treatment

The fragile paint layer was faced using Beva 371 film and tissue to protect it during further conservation treatment; this replaced the temporary gelatin facing, which was removed before the technical study. The painting was then placed facedown and the old lining and glue layer removed mechanically by shaving it off the support. This process was painstakingly difficult due to the strong, rigid glue, which could not be dissolved or softened by any solvent. Tears were then mended and losses in the support filled.

A number of lining techniques were considered, while keeping in mind the local climate and the exhibition conditions under which the painting would be displayed. Glue-paste lining was eliminated due to the responsivity of the material to fluctuating RH and its propensity to fungal growth. Wax-resin lining was rejected because of its penetrative nature and, potentially, the excessive amount of material required to create a bond.

Beva 371 gel was used to reline the painting. The relative ease of application, its reversibility, and its potential to create a barrier against moisture (as suggested by the invited experts) made Beva 371 an apt choice for relining. Trevor Cumine, a specialist in the lining of oil paintings from the U.K., was specially invited to lead the lining process. Beva 371 was applied on the lining cloth and the back of the painting. A vacuum envelope was then created around the painting, and controlled, uniform heat was applied. Once the lining was complete, it was observed that the painting had become more flexible and the paint layer stable. The painting was then stretched and varnished, and paint losses were filled and retouched (figs.

60.3, 60.4). Finally, the painting was reframed, and it is currently on display.

Figure 60.3 Top left: Consolidation of paint layer with Plextol B500 through a window of the 2004 glue facing. The facing here is the old facing given in 2006. Top right: Reconstruction of paint flakes on net. Bottom left: Facing with lens tissue and Beva 371. Bottom right: Removal of old lining cloth. Images: © Chhatrapati Shivaji Maharaj Vastu Sangrahalaya (CSMVS)

Figure 60.4 Top left: Local tear repair on verso using polyamide welding powder. Top right: Decrimping of new lining cloth. Bottom left: Lining. Bottom right: Removal of wax and dammar mixture, applied to further consolidation, from recto. Images: © Chhatrapati Shivaji Maharaj Vastu Sangrahalaya (CSMVS)

Results

This project successfully conserved the painting and fostered global relationships with experts and institutes who consulted on the project. Some new innovations were formulated by the author to tackle difficult situations. For example, syringes with extended capillary tubes were used to inject consolidants where air pockets had formed between the support, ground, and paint layer. Manually inflated airbags were placed underneath the support. The air pressure introduced in the airbags helped to push the canvas toward the ground and paint layer. This ensured secure adhesion between the three layers of the painting without applying pressure directly on the paint layer from the top. Delaminated flakes were assembled using a net prepared with exceptionally fine monofilament threads.

The skill sets of both Indian and visiting conservators were widened. Both groups learned from their accumulated expertise how to further develop and adapt techniques and methodologies to their needs.

CASE STUDY 2: *PORTRAIT OF HENRY PHILIP HOPE*

The early nineteenth-century *Portrait of Henry Philip Hope*, showing the subject in Ottoman costume, was painted by British artist Sir Thomas Lawrence and completed by Martin Archer Shee. This valuable piece of artwork was bequeathed to the museum by Sir Ratan Tata in 1921.

Condition and Conservation Status

At the time of its acquisition, this painting had already been lined with wax resin. The lined support was flexible but had started detaching at various places. Air pockets were observed from the front, and the painting had sagged considerably. Although most of the paint layer was in good condition, active flaking was noticed at the bottom area of the painting, where the sagging was most prominent. The old varnish layer had darkened and was not uniform.

Conservation Treatment

A detailed condition report was produced and a treatment plan devised in 2012. During this time, the painting was extensively documented and examined. The artist's materials and process, as well as the painting's current condition, were used to design the treatment plan.

The paint flakes were first consolidated and the darkened varnish removed. The fragile paint surfaces were faced locally using methyl cellulose. The painting was then placed facedown and the old lining and wax-resin layer removed using a combination of mechanical and solvent-based methods. When the old lining was being removed, it was found that the wax application was not uniform. The adhesive was soft and easy to remove. Once previous old patches had been removed, the painting was ready for lining.

Given the positive results of using Beva 371 for the *Sword of Damocles*, it was decided to follow the same process meticulously. The painting was hand-lined with Beva 371. The painting was then restretched, local facings removed, and paint losses filled, and the painting was varnished, retouched, and framed for display (fig. 60.5).

Figure 60.5 Sir Thomas Lawrence (British, 1769–1830), *Portrait of Henry Philip Hope*, ca. early 19th century. Oil on canvas, 261 × 155 cm (102 3/4 × 61 in.). CSMVS collection, Acc. No. 22.4614. Left: Before treatment. Right: After treatment. Images: © Chhatrapati Shivaji Maharaj Vastu Sangrahalaya (CSMVS)

CONCLUSION

The experience gained from both these projects was stimulating. The deteriorations resulting from the different lining techniques used in the paintings' respective pasts were diverse. These experiences encouraged the author to observe and monitor the behavior of other paintings in the collection. Damages were mapped in the collection more closely and with a new perspective. It was observed that paintings lined using glue-paste adhesives undergo regular dimensional changes with changing seasons, whereas others show different problems, and paintings on panel have altogether distinct structural conservation issues. This understanding raises further questions with respect to conservation interventions at CSMVS: Should conservators follow the often recommended policy of wait, watch, and monitor, and treat only those paintings that have begun to show signs of deterioration? Or should paintings be conserved using materials and techniques more suitable to Mumbai weather before any future damage occurs?

Based on our local environment, we should strive for a balance and adapt both new techniques and traditional old methods that have stood the test of time. Through various national and international collaborations, CSMVS has taken the initiative to take experts' opinions on these issues and draw a conservation plan to safeguard our collection.

61

Termite Attack in a Humid Climate: How to Deal with Damaged Canvases; The Conservation of *The Delhi Durbar (1903)*, a Case Study

Dibakar Karmakar, Restoration Assistant, Victoria Memorial Hall, Kolkata
Baishakhi Mallick, Restoration Assistant, Victoria Memorial Hall, Kolkata

This case study discusses the extent of damage caused by termite attack on a large, iconic oil painting: The Delhi Durbar (1903), *by Roderick Dempster MacKenzie (1865–1941), from the collection of Victoria Memorial Hall, Kolkata. The monumental work (340 × 544 cm) is painted on a single piece of linen canvas. It had suffered structural damage in the past that was treated by adding strip-linings, patches, and local repairs for tears. These older, local repairs were failing; furthermore, termite damage was also present along one vertical stretcher member. The tropical climatic zone of Kolkata places artworks at high risk of biodeterioration. It is impossible to fully prevent the development of termite colonies inside century-old buildings like Victoria Memorial Hall. The large scale of the painting and its condition presented a considerable conservation challenge. This poster presents, step by step, how the conservation team repaired the damaged canvas with minimum interference.*

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INTRODUCTION

Victoria Memorial Hall, in Kolkata, India, holds a vast collection of important historical artifacts and documents from the British Colonial period (eighteenth and nineteenth centuries) and houses one of the largest collections of Western oil paintings in India. One of the museum's major galleries is the Royal Gallery, which displays the large-scale painting *The State Entry into Delhi by Lord and Lady Curzon, Delhi Durbar (1903)* by Roderick Dempster MacKenzie (1865–1941) (fig. 61.1). The conservation of this painting is of paramount importance to the museum and its staff.

Figure 61.1 Roderick Dempster MacKenzie (British American, 1865–1941), *The State Entry into Delhi by Lord and Lady Curzon, Delhi Durbar (1903)*, ca. 1904–6. Oil on canvas, 340 × 544 cm (133 7/8 × 214 1/6 in.). After completion of structural treatment and necessary reintegration from front side. Image: Victoria Memorial Hall, Kolkata, India

A long-standing collaboration between experts in the structural conservation of paintings and the museum's conservation department has been ongoing since the 1990s. The Calcutta Tercentenary Trust project (1990–2002) allowed a team of British, European, and American visiting conservators to instruct Indian colleagues in current lining practices applicable to Kolkata's climate. More recent training of members of the conservation team of the museum through the Indian Conservation Fellowship Program has paved the way for a more updated approach. These international collaborations and supports allowed the museum conservation team to devise a treatment plan suitable for this large-scale canvas painting.

HISTORICAL BACKGROUND OF *DELHI DURBAR (1903)*

The term *durbar* was used in Mughal India to refer to a meeting of the ruler's court or council; it was adopted by the British to refer to a ceremonial gathering that demonstrated loyalty to the crown.[1] The painting that is the subject of the case study depicts the second such occasion; a previous Durbar was held in 1877 to proclaim Queen Victoria empress of India. Following Victoria's death in 1901, the 1903 Durbar marked the declaration of Edward VII and Queen Alexandra as emperor and empress of India. Though the royal couple did not attend the ceremony, they were represented by Edward's brother, the Duke of Connaught, seen riding on the second elephant in the scene.

The viceroy, Lord Curzon, commissioned British American artist Roderick MacKenzie (1865–1941) to paint the ceremonial procession. Lord Curzon is depicted seated on the elephant leading the procession in the painting. The entire event culminated in a grand coronation ball attended only by the highest-ranking guests and overseen by Lord Curzon and the stunning Lady Curzon in her glittering jewels and regal peacock gown.

After this first painting, MacKenzie subsequently painted the same scene on a slightly smaller scale. The latter painting is now in the collection of the Bristol Museum and Art Gallery, in England.

CONSERVATION OF *DELHI DURBAR (1903)*

In 2016, during a survey of the museum's holdings, it was discovered that the magnificent and historically important painting *Delhi Durbar (1903)* (the second-largest painting in the museum's collection at 340 × 544 cm), had developed a termite channel vertically on the back between the stretcher and canvas. The high humidity of a tropical climatic zone like Kolkata places artworks at high risk of biodeterioration. It is impossible to fully prevent the development of a termite colony inside a century-old building like Victoria Memorial Hall, particularly as it is surrounded by fifty-seven acres of gardens. Despite regular monitoring and our other efforts, we could not prevent termite attacks on our precious collections.

Nonetheless, this type of loss was an eye opener, and action was taken immediately to eliminate the living elements, followed by necessary conservation treatment. The assignment to conserve such a historically important painting was both an honor and a challenge. As conservators, we were grateful for the opportunity.

CONDITION

The condition of the painting from the front side was generally good. There was termite damage in a few particular places on the front where the termite channel had developed from the back; a few holes were visible and loose dust had accumulated on the surface of the paint layer. It is relevant to mention here that the painting had been treated just a decade earlier to remove the altered varnish layer and for necessary conservation.

When we took up the assignment, we noticed that the actual problem lay at a location beyond our reach unless the painting were to be removed from its stretcher, as the termite channel had reached the top of the painting in between the painting and the stretcher crossbar. Assessment of the extent of the damage due to termite attack was impossible without removing the obstruction of the stretcher. Accordingly, after surface cleaning and application of facing on the areas of loss, a decision was made to lay the painting on the floor to remove the stretcher.

As this is the second-largest painting in Victoria Memorial's collection, handling and transportation requires proper planning. To lessen the huge gravitational force on the canvas, which is basically attached to the stretcher by rusted nails, specialized and professional handling was needed. The painting was first covered with Tyvek and cotton tape. Thereafter, a bed was prepared on the floor of the Royal Gallery, ensuring a flat, safe surface. The plan was then discussed again with everyone involved. Finally, the action of moving the painting started, and it was successfully laid on the prepared bed.

FINDINGS AND OBSERVATIONS

After removing the tape and Tyvek, removal of the stretcher was initiated. Within a couple of days, the stretcher had been removed and separated from the painting. The extent of damage could be observed from the back side (fig. 61.2). One positive about the stretcher was that hardwood had been used to construct it; this prevented the termites from chewing into the wood, so only a mud channel had developed on the stretcher surface (fig. 61.3). But due to the organic nature of the canvas, the termites had eaten away the canvas cloth up to the ground layer, where the channel developed.

Figure 61.2 Examination of the painting after removal of stretcher from back. Image: Victoria Memorial Hall, Kolkata, India

It was also noticed that at the time of previous conservation activity, extra unpainted edge areas had been removed and original painted portions were used as fold-over edges and nailed through to attach the canvas to the stretcher. Therefore, the exact dimensions of the painting at the time of execution are unknown.

The remains of a very old lining canvas were found under the stretcher bars. No adhesive was noted that would have attached this canvas to the reverse of the original; it could be peeled off without effort. This full, additional lining

Figure 61.3 Damage due to termite attack to back side of stretcher bar. Image: Victoria Memorial Hall, Kolkata, India

might have been removed sometime in the past. It was cut at the intersection of the stretcher, leaving the remains behind. This was evidence that the stretcher had not been removed during the past treatment, of which there is no documented evidence.

Numerous patches (also undocumented) had been applied to the reverse of the canvas to provide support for tears and holes. These were attached using an animal glue as a binder, and the glue had degraded, resulting in a weak bond. The evidence of these past treatments indicated that the termite attack had occurred in the more distant past.

TREATMENT

Once the condition was assessed, a treatment proposal was prepared that included strip-lining. For preparation of the strip-lining, requisite conservation steps that included flattening the edges of the canvas, removing the old patches, and manual cleaning of the surface of the canvas were undertaken. In order to clean the canvas, at the outset dusting and cleaning was done with a vacuum cleaner. Gently rubbing ground eraser powder on the reverse of the original canvas delivered a good result in removing the dirt from the back.

Manual cleaning with scalpels was also done to remove the old patches and their residual dry adhesive (fig. 61.4). It was decided not to remove the vertical patches in one go, as it was observed that they held the original canvas together. The termite damage had eaten away at the original support, effectively splitting the canvas into two almost independent sections. Had the vertical patches been removed all at once, it could have made it difficult or impossible to exactly align the two halves of the painting. Therefore, the patches around the perimeter of the support were removed first, leaving the central ones intact. The strip-lining of Beva 371 and sailcloth was then applied to the perimeter.

Figure 61.4 Manual cleaning of the muddy termite channels. Image: Victoria Memorial Hall, Kolkata, India

An experiment of overlapping the sailcloth on every corner was conducted, where cloth from both sides was merged in order to maintain equal thickness and tension in each corner. This prevented problems when restretching the canvas to its stretcher. Once the perimeter was stabilized with the strip-lining, the old patches in the center of the support could be removed. In this way, the potential alignment problem was avoided, and the damage to the center could be addressed. The old patches could be removed manually very easily. Manual cleaning of dried adhesives revealed areas where removal had been carried out in the past.

In some places where termites had ingested the canvas fiber entirely, a layer of splintered cotton wool fiber with Beva 371 binder and thin synthetic cloth was applied to maintain an equal level with nearby areas. The termite-damaged area was repaired sufficiently by applying two larger vertical patches and four smaller ones. The same adhesive and patch material was used for all support additions. After completion of all additions, the whole strip-lining was executed successfully (fig. 61.5).

The second phase of conservation started with necessary cleaning and repairing of the stretcher by removing the nails, followed by applying a loose-lining and then restretching the painting. In line with our decision to apply the loose-lining, a market survey was carried out to find a wide, starch-free cloth. Ultimately, a cloth fitting our requirements was found at Burra Bazar Cotton Street, in Kolkata. One vertical seam was necessary to get the

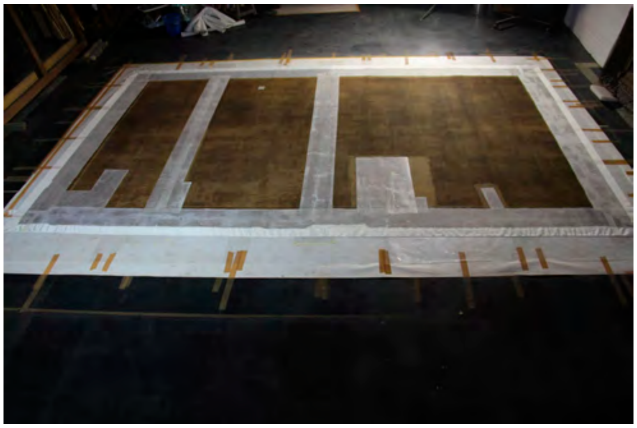

Figure 61.5 After completion of strip-lining with Beva 371 and sailcloth. Image: Victoria Memorial Hall, Kolkata, India

required dimension, and then the loose-lining was completed.

Following the loose-lining, the original canvas was restretched. To protect the edges of the painted area of fold-over edges, a strip of acid-free cardboard the same width as the stretcher was placed as a buffer between the tacks and the paint surface before executing the nailing. This buffer material will help to keep the outer frame from abrading the original painted portion at the fold-over edge. The back side of the painting was also given a Tyvek cover to avoid further accumulation of dust and dirt.

After the painting was put against the wall, a few interferences that occurred during the structural repair due to loss of the old filler were refilled successfully. The conservation of the painting was completed with required reintegration and varnish matching locally (see fig. 61.1).

CONCLUSION

The foremost priority of attending to the structural repair of the painting *Delhi Durbar (1903)* was to make it stable. We have successfully resolved that issue. The assignment was very special to us, as the infrastructure actually required for handling such a magnificent painting was not available, but we successfully overcame those issues with our limited resources and practical experience. In the meantime, the Royal Gallery of Victoria Memorial Hall has been renovated and reopened to the public after two decades. We are happy to see *Delhi Durbar (1903)* on display again at the Royal Gallery.

ACKNOWLEDGMENTS

We are thankful to our secretary and curator for the opportunity to perform the conservation and for giving the utmost priority to this job and providing all manner of help on an urgent basis. We were honored to be able to present our case study at the Conserving Canvas symposium in 2019. A very special thanks to Yale University and the Getty Foundation for extending their support to us to attend the symposium.

NOTES

1. See https://www.britannica.com/topic/durbar.

62

Investigating Commercially Primed Contemporary Artist Canvases

Anne Carter, Paintings Conservator, Queensland Art Gallery | Gallery of Modern Art, Brisbane, Australia
Lynn Chua, Conservation Scientist, Heritage Conservation Centre, National Heritage Board, Singapore
Filzah Mohd Amir, Assistant Conservator, Heritage Conservation Centre, National Heritage Board, Singapore
Ruby Awburn, Independent Conservator, Australia
Gillian Osmond, Paintings Conservator, Queensland Art Gallery | Gallery of Modern Art, Brisbane, Australia
Joey Ng, Lab Assistant, National University of Singapore

Contemporary painters often choose commercially primed canvases as their painting support; however, manufacturers provide little technical information about the materials used in their production. The authors were prompted to learn more about these materials' manufacture after observing unexpected responses to established conservation treatments. Canvas fiber, priming binder, pigments, and fillers used in fifty-three commercially primed canvases purchased from Australian and Singaporean suppliers were analyzed. The materials detected show variations in canvas types and priming formulations that suggest reasons for unusual conservation treatment characteristics.

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INTRODUCTION

Commercially primed artists canvases are common supports for contemporary painters. Such canvases are convenient and often affordable; however, the product information available for both artists and conservators to inform purchase choice or likely aging characteristics is limited. This paper reports on the material analysis of fifty-three commercially primed artists canvases purchased from Australian and Singaporean suppliers in 2018–19.

Research was prompted by observations that some contemporary paintings exhibit unusual responses to conservation treatment that are potentially attributable to their commercially primed canvas support. Observations include stretchiness, the priming's ability to tolerate heat above 45°C (sometimes as high as 80°C), unpredictable response to humidification, priming discoloration, and delamination of subsequently applied oil paint. Commercially primed canvases from seventeen applicable collection paintings dating from 1990 to 2018 were also analyzed; however, those results are presented here only where they help to inform the discussion.

BACKGROUND

Historical studies of commercially primed canvases document the frequent use of lead white, chalk, protein, and oil in single or double priming layers on cotton or linen canvas supports (Ravaud et al. 2014; Hackney 2020; Townsend et al. 2008). Today, these priming layers are commonly substituted with synthetic alternatives, with acrylics being the most commonly encountered. For example, Ormsby et al. studied priming layers of fifty-two paintings from the Tate collection dated 1963–2008 and identified 60% of priming layers as acrylic emulsion, 27% as oil based, and 10% as alkyd, with 3% “other” (Ormsby et al. 2008). The prevalence of synthetic fiber use in contemporary canvas supports is also a question to be investigated.

To inform canvas sample selection for this current study, thirty-seven Australian and Singaporean painters were surveyed about their canvas choices, revealing that most painters routinely purchased commercially primed canvases—selecting their canvas by trial and error, availability, working qualities, and price point (Osmond et al. 2018). Commercially primed canvases are usually produced as type U: universal (synthetic emulsion), suitable for both water- and oil-based paint; or type O: suitable for oil paint. However, many artists were unaware of the priming type and did not vary their canvas selection according to paint medium.

METHODOLOGY AND RESULTS

Fifty-three commercially primed artists canvases were collected from art stores in Australia and Singapore, representing nineteen brands manufactured in Europe, China, Australia, the United States, India, and Mexico: Artfix, Claessens, Belle Arti, Fredrix, Winsor and Newton, Caravaggio, Sydney Canvas Company, Art Spectrum, Clairefontaine, Mont Marte, National Art Materials, Jasart, Overjoyed, Pebeo, Semco, Francheville, Phoenix, Talens, and Colorpro. Samples cover various price points, and forty-nine samples were identified as having synthetic polymer priming and oil-based priming.

Canvas fiber, priming binder, and pigments/fillers were primarily analyzed using optical microscopy, attenuated total reflectance–Fourier transform infrared spectroscopy (ATR-FTIR), pyrolysis–gas chromatography–mass spectrometry (Py-GCMS), and X-ray fluorescence spectroscopy (XRF); some were analyzed with Raman spectroscopy and scanning electron microscopy–energy dispersive X-ray spectroscopy (SEM-EDS). In addition, uniaxial tensile strength testing and heat testing were undertaken.

A summary of results is presented below. More detailed analysis for each sample is found as supplementary data (Carter et al. 2020).

Priming Stratigraphy

Cross sections were prepared, and four priming layer stratigraphies were identified in visible light. Thirty-two percent of samples contained single priming layers, often with irregular thickness. Others appeared as double layers in three stratigraphies: equal layer thickness, with the bottom layer sometimes irregular in thickness and usually opaque (30%); thin layer over thick, with the bottom layer often irregular in thickness (19%); thick layer over thin, with the bottom layer sometimes transparent or opaque and continuous or noncontinuous (19%). The multiple priming layers specified by suppliers were not always discernible.

BINDER

The top surface of priming layers was characterized using ATR-FTIR (table 62.1, fig. 62.1) (Osmond et al. 2018). At this surface layer, forty-nine of the fifty-three canvas samples contained synthetic polymer binders and four samples contained oil priming. Styrenated-acrylic predominated as a binder, followed by acrylic and acrylic–polyvinyl acetate (PVAc) binders. No alkyd binders were found.

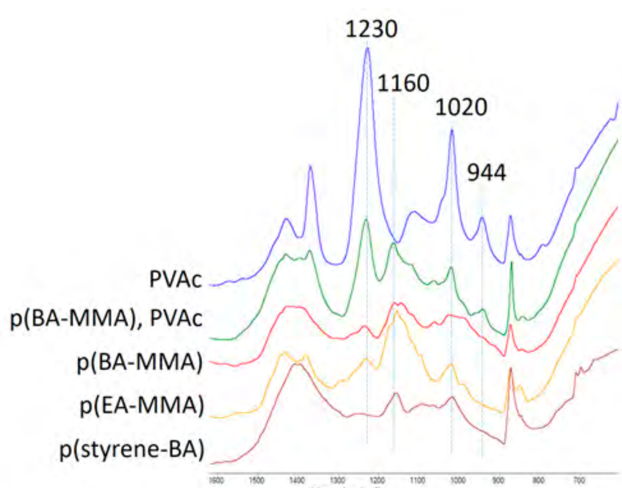

Figure 62.1 ATR-FTIR fingerprint region for priming highlighting key acrylic-PVAc peaks. Image: Queensland Art Gallery, Gallery of Modern Art, Australia, and Heritage Conservation Centre (National Heritage Board), Singapore

Table 62.1
Summary of results of analyses of 53 commercially primed canvases using ATR-FTIR and optical microscopy

Binder	%	Pigments and fillers	%	Fiber type	%	Weave	%
Acrylic-styrene	41.4	Chalk, titanium dioxide (TiO_2)	43.7	Cotton	58.5	Plain (1 × 1)	58.2
Acrylic	20.9	Chalk, TiO_2, talc	20	Linen	32	Half basket (1 × 2)	36.4
Acrylic-PVAc	11.3	Chalk	9.6	PET	5.7	Full basket (2 × 2)	5.4
Acrylic-PVAc-styrene	9.4	Chalk, TiO_2, barium sulfate ($BaSO_4$)	3.6	PET-cotton	3.8		
PVAc	7.5	Gypsum	3.6				
Oil	7.5	TiO_2, kaolinite	3.6				
PVAc-styrene	2.0	Other	15.9				

Py-GCMS provided further details of synthetic polymer binder constituents, including verification of the use of seven different acrylic monomers. Within the group of styrenated-acrylics, styrene n-butyl acrylate (BA) predominated (37%), and within the group of “pure” acrylics, only ethyl acrylate–methyl methacrylate (EA-MMA) and BA-MMA were found, with a slightly higher occurrence of EA-MMA. One EA-MMA priming showed significant amounts of diethylene glycol dibenzoate plasticizer. Within the group of PVAc-acrylic binders, some were copolymerized with vinyl versatate (VeoVa). Surfactants such as polyethylene oxide (PEO) (Scalarone and Chiantore 2004) were not observed with ATR-FTIR.

Priming layer combinations varied (fig. 62.2). Double priming layers included acrylic over styrenated acrylic (see fig. 62.2b), acrylic over acrylic-PVAc (see fig. 62.2c), and oil over styrenated acrylic (fig. 62.2d).

Variations were observed between ATR-FTIR and Py-GCMS data, including a significantly higher incidence of PVAc detected with Py-GCMS. This was found to correlate with the presence of PVAc in lower priming layers not captured by the surface-only ATR-FTIR. Thin surface layers were sometimes difficult to separate from other, similarly colored layers for Py-GCMS analysis (fig. 62.2d) (Osmond et al. 2018).

In total, thirty-four different copolymer binder combinations in the upper layer were found in the surface layer of the forty-nine synthetic-primed samples—indicating a wide variety of formulations and subsequent properties. The history of synthetic emulsion binders and copolymer properties is well documented, including in conservation literature (Scalarone and Chiantore 2004;

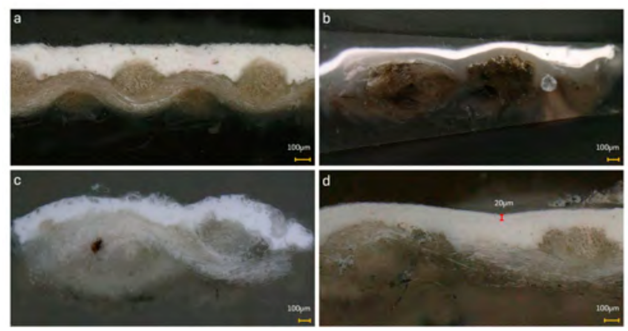

Figure 62.2 Cross sections viewed in visible light. (a) Artfix polyester canvas with single priming layer of PVAc (VeoVa)–acrylic (BA-MMA)–styrene with titanium white, chalk, and talc. (b) Caravaggio linen canvas with double priming layers; top: acrylic (EA-EHA-EMA-MMA) with titanium white (no chalk); bottom: styrenated acrylic (EA-MMA) with kaolinite. (c) Sydney Canvas Company cotton canvas with single priming layer of acrylic (BA-MMA)–PVAc with chalk and titanium white. (d) Phoenix cotton canvas with double priming layers. Surface: styrenated acrylic (ATR-FTIR). All: BA-MA-MMA-styrene-PVAc (Py-GCMS). Images: Queensland Art Gallery, Gallery of Modern Art, Australia, and Heritage Conservation Centre (National Heritage Board), Singapore

Learner 2004; Croll 2007; Standeven 2011), which describes how copolymers are formulated to provide optimal coating properties. For example, adding monomers that have a higher glass transition temperature (Tg), such as styrene (or MMA), to a “soft” acrylic monomer such as n-butyl acrylate results in a stiffer and possibly more heat-tolerant priming, depending on the monomer ratio (table 62.2).

PIGMENTS AND FILLERS

Fourteen different pigment and filler combinations were identified. The most frequent combinations are detailed in table 62.1. Two-thirds of synthetic primings were

Table 62.2
Glass transition temperatures (Tg) of common monomers and copolymers used in coatings

"Soft" monomers	Tg (°C)	"Hard" monomers	Tg (°C)	Copolymers	Tg (°C)
n-Butyl acrylate (BA)	−43	Styrene (sty)	107	*p*(BA-sty) (20:80) (40:60) (60:40) (80:20)	 74 41 13 −16
Ethyl acrylate (EA)	−8	Methyl methacrylate (MMA)	105	*p*(EA-MMA) (20:80) (40:60) (60:40) (80:20)	 81 50 24 5

Source: Penzel, Rieger, and Schneider 1997

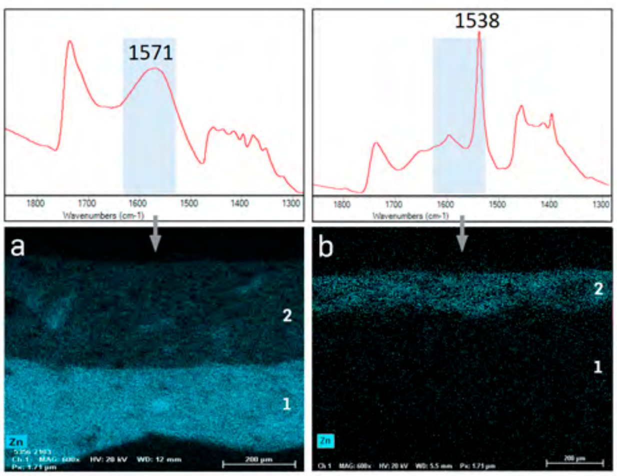

Figure 62.3 Cross-sectional SEM-EDX elemental distribution of zinc and corresponding ATR-FTIR spectra with highlighted metal carboxylate band from surfaces of (a) Claessens oil-primed linen, and (b) Artfix oil-primed linen. Images: Queensland Art Gallery, Gallery of Modern Art, Australia, and Heritage Conservation Centre (National Heritage Board), Singapore

composed of titanium dioxide and chalk; some also contained talc. Nine percent of samples contained chalk only. Pigmentation of layers also varied within samples; for example, titanium white was sometimes found only in the top of double-layered priming (see fig. 62.2b).

Oil Priming and Zinc Soaps

The four oil-primed samples were double primed. Three were oil over acrylic or acrylic-PVAc, and one contained two oil layers. Barium sulfate, titanium white, and calcium carbonate were found in oil primings. Additionally, zinc was detected in three of the oil-primed samples, and zinc soaps (amorphous and/or crystalline) were detected at the surface of these samples.

Amorphous zinc carboxylates (broad band centered 1571 cm^{-1}) were found at the top surface of the double oil priming where zinc oxide was present only in the underlayer. This suggests in situ formation of zinc soaps and migration from the lower layer to the surface (fig. 62.3a).

Crystalline zinc soaps (1538 cm^{-1}) were detected at the surface of two oil-primed canvases with acrylic-PVAc underlayers. The oil priming contained no zinc oxide, and thus zinc stearate was likely a constituent in the priming formulation (see fig. 62.3b). These results are important, as zinc soaps at the surface of oil-primed canvases may pose a risk to subsequent oil-paint adhesion (Osmond 2019).

CANVAS

Fiber analysis showed good correlation with the information provided by manufacturers. Cotton was the most prevalent fiber, followed by linen. Polyethylene terephthalate (PET) and PET-cotton blends were less common (see table 62.1).

Three weave patterns were identified: plain weave (1 × 1), half basket (2 × 1), and full basket (2 × 2) (see table 62.1). Cotton was typically found as half basket, while linen, PET, and PET-cotton blends were mostly plain weave. Twenty-five percent of cotton samples had a thread count of 10 × 30 threads/cm^2; otherwise, thread counts varied.

Uniaxial tensile strength testing of canvas samples indicated that the type or number of priming layers did not significantly affect tensile strength. The force at maximum for cotton and PET-cotton (56–258 N) was generally lower than for linen and PET (191–514 N) regardless of priming layers. The modulus of elasticity of the samples varied, generally showing a lower modulus of elasticity in the warp direction than the weft, aligning with research by others (Young and Jardine 2012).

HEAT TESTS

Response of the priming layer to heat was tested. Most samples were visually affected after holding a spatula heated to 80°C against the surface for one minute; however, there was no obvious visual effect in 19% of samples—that is, no flattening, burnishing, softening, or tackiness. No obvious correlation was found between heat response and binder or pigmentation type to inform conservation practice.

CONCLUSIONS

The synthetic emulsion primings found in this study reflect commercial development over the past seventy years. However, where industry has broadly transitioned from PVAc and PVAc-acrylic copolymers to acrylics and styrenated acrylics (Schwartz and Kossmann 1998), PVAc remains a common constituent in commercially primed artist canvases.

Styrene was found in 64% of priming surface layers—most frequently with acrylic but also combined with PVAc. Styrenated acrylics were also found as underlayers for both oil and acrylic layers. The prevalence of styrenated acrylics indicates a trend of increased use since 2008 (Ormsby et al. 2008).

Styrenated acrylic emulsions are generally used in more economical paints, as styrene monomers are cheaper than acrylics. However, styrenated acrylics can also produce high-end paints, depending on the performance required.[1] Importantly, styrene is not stable when exposed to UV radiation (Standeven 2011). It can become yellow and may "chalk" and crack if sufficient UV exposure occurs. When covered with another paint layer, styrenated acrylic is considered stable.[2] Thus, a general recommendation from this research is for artists to avoid leaving commercial priming layers (which may contain styrene) exposed to possible UV degradation.

In regard to oil-primed canvases, surface zinc carboxylates were identified. They present the risk of delamination of subsequently applied oil paint.

Of the fifty-three commercially primed canvases, none showed identical formulations of binder and pigment/filler except for some of the same brand. This finding implies that there is no standard formulation for commercially primed canvases, nor necessarily consistency within brands—the same product from different suppliers was not always identical, suggesting inconsistent production. Thus, priming-layer properties are difficult to identify from supplier information.

Cotton canvas predominated, primarily in half-basket weave. Synthetic canvases were not common; however, they showed the greatest tensile strength. Correlations between observations from artwork treatments and those works' commercially primed canvas type were unclear. However, within the small number of paintings analyzed (seventeen), artworks on half-basket weave cotton canvas with chalk-dominated priming were the main contenders for unusual treatment observations.

ACKNOWLEDGMENTS

The project was carried out as part of the memorandum of understanding between Queensland Art Gallery | Gallery of Modern Art (QAGOMA), Australia, and the Heritage Conservation Centre (National Heritage Board), Singapore. This research is supported by the QAGOMA Foundation and the QAGOMA Centre for Contemporary Art Conservation.

EXPERIMENTAL EQUIPMENT AND CONDITIONS

ATR-FTIR: Thermo Scientific Nicolet iN10 microscope with DTGS room-temperature detector coupled to an iZ10 diamond ATR bench accessory; 16 scans over 4000–400 cm^{-1} range, 4 cm^{-1} resolution.

Py-GCMS: Shimadzu GCMS QP2020 combined with a Frontier PY3030D pyrolizer unit with autosampler AOC-20i. Pyrolysis conditions: 600°C for 0.2 minutes. Gas chromatography conditions: 40°C for 5 minutes, ramped to 300°C at 10°C/min., hold 5 minutes. Oil-containing samples were derivatized with 3 μl of 25% tetramethylammonium hydroxide (TMAH) in methanol. Mass spectrometry conditions: Electronic index (EI) mode (70 eV), scan range: 50–600 m/z.

Uniaxial testing: 500N Zwick/Roell with 10 mm sample width and gauge length, and speed of 100 mm/min. at 55 ±5% RH and 22 ±3°C. Samples were tested in warp and weft with a tensile load of 500 N, measuring [Fmax/N] and t [Emod/GPa].

XRF: Bruker T 5i with Rh excitation anode, silicon drift PIN diode detector, no vacuum, Geo-Exploration mode calibration, spot size 8 mm.

Raman spectroscopy: Renishaw Raman spectroscopy instrument coupled to a confocal microscope. Laser of excitation: 785 nm.

SEM-EDX: Hitachi SU5000 scanning electron microscope coupled to a Bruker EDX system in partial pressure of 50 Pa. Voltage of 20 kV was applied, and EDS mapping of cross sections was collected over 5 minutes.

NOTES

1. Scott Olufson, manager, Coatings Technical Support, Dispersions BASF Australia Ltd, email communication, September 17, 2018.
2. Olufson, email.

63

Stabilization Processing of Canvas Paintings Damaged by Tsunami: Consideration of Blotter Washing to Acrylic Paintings on Cotton Canvas

Yuko Tsuchiya, Painting Conservator, Tokyo University of the Arts
Eriko Hoshi, Conservation Scientist, Joshibi University of Art and Design, Tokyo
Hiroshi Haze, Painting Conservator, Haze Painting Studio, Tokyo
Marie Moto, Paper Conservator, Japan Conservation Project
Nobuyuki Kamba, Conservation Scientist, Tokyo National Museum

A large number of cultural properties were damaged in the March 2011 tsunami that devastated Japan's Tohoku region. A problem arises when we are faced with removing salt matter from paintings: salts absorb moisture from the atmosphere, and that moisture can promote deformation of the support. The Tokyo National Museum began in 2011 to research methods for removal of salt matter from paintings on canvas. Through a number of experiments, methods of desalination were developed for acrylic paintings on cotton canvas. In one method, the canvas was temporarily removed from its original wooden frame, edge-lined with polyester cloth, and stretched on a temporary frame. Water was sprayed on the reverse and moisture absorbed with blotting paper. Experiments that followed confirmed that the amount of moisture and the period of immersion influenced the removal of remaining salts. Using techniques from paper conservation, moistened blotting paper was used as a compress, and water containing dissolved salts was removed as quickly as possible using polymer sheets. This process was repeated several times for desalination. As a result, it was possible to control the contraction of the canvas to about 0.3%, and the chloride concentration was reduced to about what is contained in tap water in Tokyo.

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BACKGROUND

A large number of cultural properties were damaged in the March 2011 tsunami, an unprecedented natural disaster that devastated Japan's Tohoku region (fig. 63.1). The process of conserving these properties has lasted nine years and remains ongoing to this day. At that time, I (Tsuchiya) was working at the Conservation and Preservation Department of Tokyo National Museum, and I was put in charge of looking into how to desalinate canvas paintings as part of the second stage of the rescue process. Specifically, I was entrusted with the task of restoring fifty-three canvas paintings from Rikuzentakata City Museum. These paintings were wrapped in plastic coverings at the time of the disaster (fig. 63.2). After the tsunami, they absorbed large volumes of grime and moisture and were kept in this moist state. As a result,

Figure 63.1 Photo showing the tsunami that attacked Tohoku in March 2011. Image: Jiji Press/AFP via Getty Images

Figure 63.2 Canvas paintings just after the first rescue. Image: © *The Japanese Times*

mold grew across the surfaces, and there was a considerable amount of paint flaking.

As a first step in the rescue process, remedial treatment was undertaken to remove the surface grime and mold and to fumigate the paintings (Ito 2014). However, it was impossible to remove the embedded grime and salt without using water, so those were left untreated during this stage. Chloride compounds left on the canvases after the tsunami ionized, and a certain amount of moisture was needed to remove them. Given the assumption that canvas shrinkage is a major factor impacting the status of the paints, the question arose as to how much shrinkage was tolerable. Based on research already carried out overseas, the shrinkage rate was set at within 0.5% (Mecklenburg 2007a, 2007b), and the research team set a goal of minimizing the damage to the paint layer by minimizing the shrinkage as much as possible.

After carrying out several experiments, our research focused on acrylic paintings painted on cotton canvases. We made several attempts to clean these paintings using water. In the end, we decided to adopt a desalination method that used the blotting technique when removing salt from the acrylic paintings (Tsuchiya et al. 2017). We essentially achieved our target with regard to the amount of chlorine remaining after treatment (Tsuchiya 2018).

DESALINATION PROCESS

The desalination work to remove the embedded grime and salt from the canvases could not be undertaken with any solvent besides water. However, there was a danger that water might cause the canvas to shrink or the surface paints to peel off. We focused on the conservation state of fifteen large acrylic paintings among those canvas paintings damaged by the tsunami.

Hardly any of the wooden frames were warped, even with the larger paintings, while the canvases had only minimal shrinkage and there was no paint flaking. As a result, it was reasoned that shrinkage could probably be kept to a minimum even if water was applied to these canvases. We prepared a life-size mock-up of a large acrylic painting, stretched it over an actual stretcher, and applied water. Hardly any shrinkage was observed (Tsuchiya et al. 2014).

Based on this, we undertook a desalination trial using the absolute minimum amount of moisture. We first tried a treatment method using gel sheets. Gel sheets with a 1.5% concentration and a 7:2:1 ratio of carrageenan (a seaweed-based emulsifying agent), xanthan gum, and locust bean gum were chosen for their ease of use and suitability for the syneresis process. A 16 × 11 × 2 cm sheet was pressed against the rear side of the canvas and left for about thirty minutes before being replaced with a new sheet. This process was carried out twice. However, the chlorine (CI) values of the canvas (rear side) remained at 50%–80% of the initial values (Tsuchiya et al. 2015). This was because the gel sheets alone did not have sufficient moisture to remove the salt and other material that had seeped into the canvas fiber.

We next examined the blotter-washing technique used in paper conservation. After several experiments, we reached the conclusion that this method could be used to desalinate the acrylic paintings among the canvas paintings in Rikuzentakata City Museum’s collection, so we carried out the conservation work accordingly.

PREPARING A CALIBRATION CURVE FOR THE COTTON CLOTH USED FOR THE CANVAS

The residual chlorine CI values were measured using X-ray fluorescence spectroscopy (XRF). The obtained values were in centipoise (cP), so a calibration curve was prepared to convert these into parts-per-million (ppm) values. As the affected acrylic painting canvas was on cotton, we prepared a cotton cloth for our trials. We also prepared CI water solutions of 1, 10, 50, 100, 200, 300, 500, 700, 1000, 10,000, 35,000, and 100,000 ppm. These were applied to pieces of the cotton cloth and then dried. These were set as reference standards and measured using XRF. We targeted a figure of 33 ppm (the CI value of drinking water in Tokyo) for the residual CI density on the post-treatment canvas (fig. 63.3).

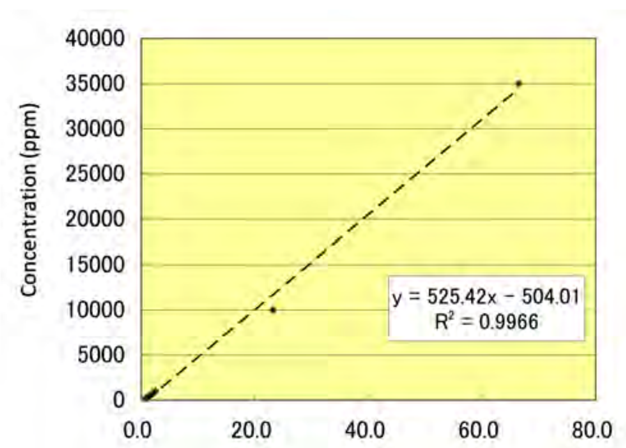

Figure 63.3 XRF calibration curve of chloride (CI) levels in the cotton cloth. Image: Research team

THE DESALINATION WORK

The target work was an acrylic painting by Masayoshi Nameki. The canvas had already been removed from the original stretcher. Polyester strips were attached to the edges of the canvas (strip-lining), and the canvas was remounted on a larger stretcher. The size of the canvas was recorded before applying water, then the desalination process was carried out as follows:

1. Water mixed with ethyl alcohol was sprayed onto the back of the canvas to apply moisture to the entire surface (fig. 63.4).

Figure 63.4 Water mixed with ethyl alcohol was sprayed onto the back of the canvas to apply moisture to the entire surface. Image: Research team

2. The entire surface was covered with dampened blotting paper and left for eight minutes (fig. 63.5).

Figure 63.5 The entire surface was covered with dampened blotting paper and left for 8 minutes. Image: Research team

3. A highly absorbent resin sheet was placed over the blotting paper for two minutes to soak up the grime and salt absorbed by the blotting paper.
4. The blotting paper and resin sheet were removed and steps 1–3 were repeated five or six times. After the first application, the water that was sprayed on did not contain alcohol.
5. A thin paper sheet was placed against the surface and sprayed with water. This process was carried out twice to remove the absorbed grime and salt.

6. The salinity concentration levels of the chloride test paper were measured each time (fig. 63.6, table 63.1).

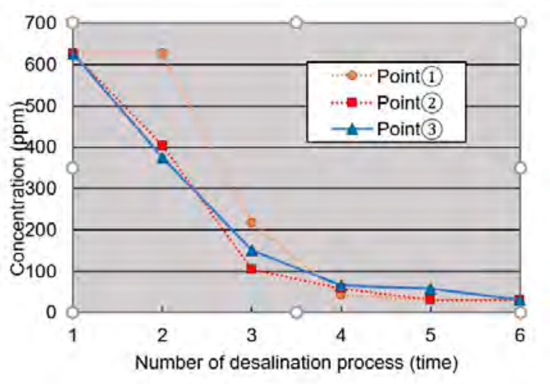

Figure 63.6 Salinity concentration levels of the chloride test paper were measured after each application of water (see table 63.1). Image: Research team

Table 63.1
Cl concentration of a blotting paper after it was used for desalination process of *Prologue: "Thinking in a Black Field"* (right side)

Measurement points (ppm)	1st	2nd	3rd	4th	5th	6th
Point 1	>627	>627	217	43	<30	<30
Point 2	>627	404	104	58	<30	<30
Point 3	>627	376	151	66	58	<30

7. Canvas shrinkage was recorded directly after each application of water, after the desalination process was totally finished, and the following day, when the canvas had dried.

CONCLUSION AND FUTURE ISSUES

The blotting method can be used to remove residual salt from acrylic paintings painted thinly on cotton-fiber canvases. The shrinkage rate of the canvas can be kept to within 0.5% of the total surface by maintaining the painting under tension during the treatment (tables 63.2, 63.3).

Researchers outside of Japan have been aware of the dangers of using excess moisture when cleaning paintings since the 1980s. In particular, there has been considerable debate about problems involving acrylic paints (a relatively new painting material), such as the swelling of resins due to the impact of various additives (Jablonski et al. 2003; Tumosa and Mecklenburg 2004; Ormsby and Learner 2009; Doménech-Carbó et al. 2013; Toriumi 2018; Hackney 2020). Additive agents in acrylic paints tend to rise to the surface of paints, so these paintings probably lost these additives as a result of the tsunami. Furthermore, a water-based treatment was also used during the desalination process. In light of these factors, going forward we will need to ascertain the damage to the paints by carrying out experiments while preparing specimens.

Acrylic paints are a new painting material, so we still have a lot to learn with regard to the deterioration process. While searching for a way to remove grime without damaging the paint layer, we need to constantly carry out post-treatment observations and the like to check for any problems with the method we adopted.

Further research will be needed to determine the extent to which this method can be applied to oil paintings on linen canvases.

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Table 63.2

Change and rate of change in dimensions of *Prologue "Thinking in a Black Field"* (right side)

	Process	Condition	Date of work	Short-side length (weft) (mm)	Expansion and contraction (mm)	Rate of change (%)*	Long-side length (warp) (mm)	Expansion and contraction (mm)	Rate of change (%)
Before treatments		Dry	5/29	1817			2272		
Mounting onto a temporary frame	After moving from wood frame	Dry	5/29	1810	−7	0.4	2263	−9	0.4
	After temporary mounting	Dry	5/30	1817	+7	0.4	2269	+6	0.3
Desalination work	Before the work	Dry	7/12	1819	+2	0.1	2273	+4	0.2
	After the work†	Wet	7/12	1798	−19	1.2	2263	−10	0.4
	1 day after	Dry	7/13	1815	+17	0.9	2270	+7	0.3
	2 days after	Dry	7/14	1815	0	0.0	2270	0	0
	2 weeks after	Dry	7/26	1818	+3	0.2	2270	0	0

*Rate of change in dimension before treatments.

†1 hour after drying by exchanging blotting paper three times.

Table 63.3
Change and rate of change in dimensions of *Prologue "Thinking in a Black Field"* (left side)

	Process	Condition	Date of Work	Short-side length (weft) (mm)	Expansion and contraction (mm)	Rate of change (%)*	Long-side length (warp) (mm)	Expansion and Contraction (mm)	Rate of change (%)
Before treatments		Dry	5/29	1818			2272		
Mounting onto a temporary frame	After moving from wood frame	Dry	5/31	1810	−8	0.4	2263	−8	0.4
	After temporary mounting	Dry	5/31	1817	+7	0.4	2269	+5	0.2
Desalination work	Before the work	Dry	7/13	1819	+2	0.1	2273	+2	0.1
	During the work	Wet	7/13	1803	−16	0.9	2265	−7	0.3
	Immediately after the work	Wet	7/13	1799	−	0.2	2265	0	0
	After the work	Wet	7/13	1799	0	0	2265	0	0
	After the work	Wet	7/13	1798	−1	0.1	2264	−1	0
	1 day after	Dry	7/14	1819	+21	1.2	2273	+9	0.4
	2 weeks after	Dry	7/26	1818	−1	0.1	2273	0	0

*Rate of change in dimension before treatments.

Glossary

This glossary is based on the *Handbook of Terms Used in the Lining of Paintings*, selected and edited by Westby Percival-Prescott and Gillian Lewis for the Conference on Comparative Lining Techniques, Greenwich, London, 1974, and reprinted in *Lining Paintings: Papers from the Greenwich Conference on Comparative Lining Techniques* (Villers 2003b). The main contributors to the *Handbook* were David Bomford, Alan Cummings, Gerry Hedley, Gillian Lewis, Joyce Plesters, and Westby Percival-Prescott.

In this revised and expanded version, the editors, Cynthia Schwarz, Jim Coddington, and Ian McClure, have reviewed the terms used in the 1974 version, removing those no longer current and adding terms not current in 1974, taking notice of terms used in the papers included in this publication.

◆ ◆ ◆

abrasion
Damaged area of paint, resulting from the scraping, rubbing down, or grinding away of the upper paint layers. A combination of an iron that is too hot plus careless application of pressure during hand lining will easily produce this form of damage, and frequently the excess heat, unevenly maintained in local areas, will succeed in softening, scorching, and burning the paint surface so that it adheres to any protective layers of paper and is subsequently removed with these facing layers after the lining is completed. On a smaller scale, an overheated spatula used for fixing down flaking paint will have a similar effect. Often seen as a regular pattern mirroring the canvas. See also *weave emphasis*.

absorption
(1) The concentration or retention of a substance within the porosity of another material (compare adsorption). (2) Optical light and radiant heat are absorbed by matter in varying degrees, leading to increase in temperature.

acrylic resins
Synthetic resins of a general formula where R1 and R2 are alkyl groups, or H. R1 is commonly CH_3, which gives methyl methacrylate, ethyl methacrylate, and butyl methacrylate where *Ri* = CH_3, C_2H5, C_3H7 etc. Some have a distinct tendency to cross-link, while for others there is no recorded tendency to do so. Solubility also varies widely. Examples of acrylic resins in conservation are polymethyl methacrylate, methylacrylate/ethyl methacrylate copolymer, and various other resins and emulsions.

acrylic sheet
Polymethyl methacrylate sheet. Available as a clear, transparent plastic in a range of thicknesses. It finds use as a backing board or a rigid support for marouflage, where its transparency is sometimes desirable. Also used for glazing, particularly if a nonreflective coating is applied.

adherend
A body secured to another body by an adhesive.

adhesion
Sticking of one surface to another, the result of forces of attraction between molecules, among other factors.

adhesive
A material that binds other materials together by forces of molecular attraction, chemical bonds, or interlocking action at the interfaces.

adhesive failure
See *bond strength*.

adhesive strength
See *bond strength*.

adsorption
The concentration or retention of a substance on the surface of a material. See also *absorption*.

aging test (accelerated)
To test the possible deterioration of materials with time they may be exposed to more extreme conditions of heat, light, air, and others than normally encountered, in order to age them artificially.

air conductor
For lining processes under vacuum pressure. Extraction of air present between the canvases. The working support and the upper membrane is usually facilitated by (1) strips of open-weave fabric, felt, webbing, corrugated paper, and other materials placed around the edges of the object and leading from it to the extraction points; by (2) similar strips actually fitted permanently in the edges; or by (3) channels built into the hot tab around the edge of the lining area See also *hessian* and *vacuum hot table*.

aluminum sheet
Aluminum alloy sheet used as a rigid support or in composite supports for marouflage, also used as a surface material for hot tables. It is available in a variety of types of differing alloy composition and surface properties and in a range of thicknesses.

animal glues (bone and hide)
Glues that are prepared from collagen, the principal constituent of skin, bone, and sinew, by treatment with acids or hot water to yield a soluble product. There are two main types of animal glues: those obtained from the hides and those made from the bones (most commonly of sheep and cattle). Hide glues are stronger than bone glues. Animal glues give viscous aqueous solutions that set first by gelation on cooling and then by loss of water. They swell and

lose strength in humid conditions. Common additives are humectants and plasticizers to offset embrittlement on aging, and fungicides to deter mold growth. See also *fish glue*.

backing, backboards, backing boards
Protection applied to the reverse of a painting and/or picture frame to prevent mechanical and atmospheric damage to picture fabrics.

balsam
A general term for the resinous exudate from trees of the order Coniferae. The balsams are soft semiliquids containing essential oil, terpenes, and resinous bodies. Distillation yields turpentine and the residue, resin or colophony. Common balsams are Venice turpentine, Strasbourg turpentine, and Canada balsam. Venice turpentine particularly finds use as a plasticizer and tackifier in both wax-resin and traditional aqueous adhesives such as Italian pasta. See also *oleoresin*.

batting
A layer between the backing board and the back of the canvas in back boards, also referred to as backing boards. Can be made from a variety of fibers.

beeswax
A secretion from honeybees from which the honeycomb is built. Natural beeswax is a yellowish-brown solid with a granular fracture, brittle when cold, plastic when warmed, and melting between 65°C and 68°C. It contains varying proportions of hydrocarbons, esters, free acids and other compounds, depending on where it was produced. Color and texture vary with origin. Bleaching is usually affected by (a) simple purifying and de-colorizing with charcoal or Fuller's earth (or similar bleaching earth) or boiling with water; (b) via oxidation by exposure to air or by treatment with oxidizing agents, such as ozone, chlorine, permanganate, potassium dichromate. Use of strong oxidizing agents (e.g., dichromates or chlorine) produces a more brittle and crystalline product. Beeswaxes are widely used in hotmelt wax-resin lining and facing adhesives because of their stability, inertness, and relative impermeability to moisture.

benzine
See *mineral spirits*.

Beva 371
Adhesive developed by Gustav Berger in the 1970s as a replacement for wax resin. A mixture of synthetic resins and waxes. The recipe has been modified over time, resulting in different thicknesses, properties, melting points, and performance. Available as both a gel and a film.

biodegradation
The breakdown of organic matter by microorganisms, such as bacteria and fungi.

blanket (heating)
A rubber sheet with embedded electric heating elements. Used (usually in conjunction with a metal plate) as a versatile extension of the hot-table method. Successfully used to reline outsize paintings, section by section.

blind stretcher
See *panel back stretcher*.

blister
A small, raised area of paint indicating cleavage of paint and/or ground layers either from each other or from the support.

Bloom strength
Bloom strength testing measures the strength of a gel or gelatin at a specified temperature. The test determines the weight in grams needed by a specified plunger (normally with a diameter of 1/2 inch) to depress the surface of the gel by 4 mm without breaking it. Also called *Bloom number*.

bobbinet
A fabric invented by John Heathcote in 1806. The warp threads are wound around the weft threads, producing a characteristic hexagonal mesh pattern, which is very strong and dimensionally stable. Widely used in fashion to support and shape garments, it has been used in conservation to support damaged large-scale fabrics, such as panoramas. Traditionally made from silk threads, currently a wide variety of threads—natural, synthetic, and metal—are used for numerous purposes.

bond strength
The force required to break an adhesive assembly. Three types of failure may occur, either separately or in combination: (1) Failure at the interface between the adhesive and adherend, called adhesive failure. The ability to resist adhesive failure is termed the *adhesive strength*. (2) Failure within the adhesive layer. This is called cohesive failure (of the adhesive), and occurs, for example, when wax-resin-impregnated canvases are separated. The ability of an adhesive to resist such failure is the cohesive strength (of the adhesive). (3) Failure of one or other of the adherents. This occurs when the strength of one of the adherends is less than either the adhesive strength or cohesive strength of the adhesive. Bond strength varies according to how the load is applied and is expressed accordingly: tensile strength, peel strength, cleavage strength, impact strength, sheer strength, and so forth.

bone glue
See *animal glues (bone and hide)*.

buckling
The appearance of waves or bulges in a canvas that has slackened on its stretcher. See also *cockling* and *corner draws*.

bulge
Irregular distortion, wrinkling, and swelling of stretched fabric support caused by uneven dimensional change or accidental pressure against the canvas.

burlap
A coarse loose woven canvas. Often made from jute fibers, its texture is favored as a painting support by some artists.

butt joint
A joint where the ends of the material are joined without any overlap.

cami-lining
A technique for adding support to an unlined canvas. It is done by attaching fabric, usually polyester for its stability, to the reverse of the stretcher using staples along the reverse of the outside members and feeding the fabric under the stretcher cross members to create a tensioned structure in which the lining is in contact or near contact with the original at only one point in the middle of the canvas. Also called *stretcher bar lining*.

canvas
A generic term for the fabric support for a painting and for the finished painting itself. Natural fibers were traditionally used, but use of synthetic fibers also occurs, either on their own or in combination with natural fibers.

canvas pliers
Pliers or pincers with wide corrugated jaws used in stretching canvas over a stretcher or strainer. A projection below one jaw acts as a fulcrum for levering against the back of the stretcher. Also called *stretching pliers.*

casein
A strong proteinaceous compound obtained from skimmed milk that forms an insoluble adhesive on mixing with an alkali (usually calcium hydroxide [lime water] to give calcium caseinate) or with formalin. Prepared casein glues are available that have only to be mixed with water. A very strong adhesive, casein has been used for centuries, particularly for wood, and was occasionally employed in the past for transferring paintings and as a pigment binder.

cellulose
A complex polysaccharide carbohydrate consisting of parallel unbranched chains of glucose units. It is the structural and principal tissue forming the walls or skeletons of plants. Cotton fibers and delignified wood are the most important raw materials for preparation of cellulose derivatives, such as cellulose acetate, cellulose nitrate, and methyl and ethyl cellulose. The chief

component of fabric fibers of vegetable origin, cellulose is hygroscopic, subject to oxidation, is decomposed by acid action, and acts as a culture for bacteria and fungi. Sodium carboxymethyl cellulose (SCMC) is an important derivative, a stable nonyellowing water-soluble compound used as a general-purpose adhesive in paper and textile conservation. It is also used as a thickener for other water-soluble adhesives.

ceresin
A white waxy substance but not a true wax. Like paraffin wax, ceresin is a mixture of high-melting-point hydrocarbons. It differs from paraffin wax in being plastic and noncrystalline in character. It is soluble in alcohol, benzene, and other solvents and has a melting point of 65°C–80°C.

cheesecloth
Cheesecloth, also referred to as butter muslin, is a thin, loosely woven cloth with fine mesh (traditionally used for wrapping butter), useful for straining impurities from adhesive mixtures (e.g., lumps or twigs out of natural resins), prior to their application for lining. Traditionally used in transfers as a support layer for the detached paint layer before reattachment to a new support. See also *muslin*.

chemisorption
Distinct from absorption and adsorption, chemisorption creates a chemical bond formed in the material. As a result, the liquid or gas taken up cannot be expelled by moderate heat.

cleavage
Separation between paint layers, paint and ground layers, or ground and support. Cleavage occurs where adhesion between layers has deteriorated and may often be found where a heavy glue layer has been placed between support and ground. Common treatment takes the form of local or total infusion with an appropriate adhesive; sometimes this involves lining or relining and full impregnation with the lining mixture.

clippings
Small pieces cut from full animal skins as waste and used in the preparation of animal glues, particularly parchment glue.

cockling
A ripple or wrinkle distortion occurring in lining and original canvases, usually during hand lining, when the canvas reacts severely to localized heat, expanding or contracting unevenly. The adhesive may then lock in this distortion. See also *buckling*.

cohesion
Force holding a solid or liquid together owing to attraction between the molecules.

cohesive failure
See *bond strength*.

cold flow
Commonly confused with creep but is in fact plastic deformation without the action of external forces.

colletta
Italian term, strictly meaning rabbit-skin glue but often used to mean that glue plus several other additives, together forming a thin, animal-glue composition. Used as a consolidant to the reverse of canvas paintings prior to lining with *pasta,* as a facing adhesive, for fixing flaking paint, and so forth.

colloid
A state of subdivision of matter that consists either of single, large molecules (proteins, organic polymers, etc.) or of aggregates of smaller molecules (colloidal gold, sulfur, etc.). There are eight recognized classes of colloids: solid sols (solid in solid), such as alloys; suspensions (solid in liquid), such as paint; smokes (solid in gas); gels (liquid in solid), such as glue gel and fruit jelly; emulsions (liquid in liquid), such as milk; fogs (liquid in gas), such as clouds or visible steam: solid foams (gas in solid), such as sponge rubber or pumice; foams (gas in liquid), such as soap lather. The colloidal particles are called the disperse phase and the surrounding medium, the continuous or external phase.

colophony
The residue that remains after turpentine has been distilled off from a species of the *Pinus* family. It is soft resin with a melting point of 100°C–130°C and is soluble in a variety of organic solvents. In the past, was sometimes used in wax-resin lining adhesives to improve the flow properties of the melt and as a plasticizer. Also called *rosin*.

compression
Decrease in dimension of a body or material by application of external inward-directed forces.

compression hold
A type of surface deformation associated with impregnation lining systems (particularly hot-melt adhesive) using vacuum hold in conditions where the paint structure can be deformed by this pressure and set in that deformed configuration on chilling. The degree of compression hold that will be distributed throughout the lining complex is directly related to the amount of vacuum pressure and degree of impregnation employed. The use of an unimpregnated interleaf between painting and support can reduce compression hold distortion. See also *nap bond lining*.

complex weaves
A repeating weave pattern that is other than plain, basket, or twill weave, such as herringbone, or weaves with repeating patterns such as the *mantelillo* canvases used in seventeenth-century Spain.

consistency
The viscosity or fluidity of a liquid or paste.

consolidant
An adhesive used in consolidation. A few examples used in the conservation of paintings are fish and animal glues, synthetic resins, and resin emulsions. See also *consolidation*.

consolidation
The use of an adhesive (consolidant) to re-adhere detached layers in a painting structure or to add cohesion to the layer.

constant tension stretcher
A stretcher that is constructed to be able to move in concert with expansion and contraction of the painting it supports.

contact lining
Contact lining is a low-pressure lining process where the adhesive adhering the lining canvas to the original is applied to the lining canvas only, and occasionally a thin layer is applied to the original canvas without impregnation. The bond is achieved without any penetration of the adhesive into the structure of the original canvas.

contraction
Decrease in dimension of an object or material resulting from internal structural changes rather than external compressive forces.

convection crackle
In a paint surface, a type of age crackle that predominates in areas affected by barriers (e.g., stretcher bars) or bottlenecks (e.g., behind keys) impeding the flow of air at the reverse of the painting. The buildup and consequent absorption by the canvas of moisture at these points induces differential local dimensional change and stress. The crackle will often be less or absent in the areas of the barriers themselves, where a more stable microclimate is maintained. See also *stretcher bar marks* and *convection patterns*.

convection patterns
Dust deposits visible on a wall on which a painting has been hanging. The restricted conditions for circulation, which seldom allow an unrestrained passage to warm, moisture-bearing air currents, cause dust patterns to accumulate. These can show detailed images of the stretcher, frame, canvas,

keys, labels, and other components of the picture, even though it is not in contact with the wall. These patterns may take twenty years or so to form but can clearly indicate wide variations within the microclimate, direction of air flow, and the like behind the picture.

cooling iron

A large, heavy, unheated iron used in manual thermoplastic-adhesive lining processes to rapidly cool a surface where heat setting adhesives have been introduced, to quickly set the adhesive. The iron is bulky to assist in pressing together the cooling canvases and adhesive and also to draw away heat as quickly as possible.

copolymer

A polymer that results from the joining of two or more different types of monomer molecules.

corner draws

A series of undulations in the canvas radiating from a corner of the stretched canvas. These can be caused by the canvas at the corners becoming detached from excessive tensioning, from distortions in the stretcher construction (for example, protruding tenons), or by the canvas becoming slack on the stretcher or strainer. See also *buckling* and *cockling*.

cotton

The seed hair of the cotton plant. Long, fine fibers make fine yarns, while short, coarse fibers make coarser yarns, the four main types ranging from coarse to fine are Indian, American, Egyptian, and Sea Island, but there is considerable variation within each type. The breaking strength of cotton increases with increased RH, and is good when wet, but the fibers are nearly pure cellulose and thus are readily affected by acids and oxidizing agents, have low resistance to mold attack, and react rapidly to RH change. Once degraded their wet strength will be lower than the dry strength. However, in hot, dry climates they exhibit good resistance to breakdown. Cotton came into wider use as a paint support in the middle of the twentieth century when it provided large quantities of cheap ready-made artists' canvas, but it developed a reputation for impermanence. Consequently, its use as a lining fabric is not common.

cotton duck

A heavy, plain-woven cotton fabric.

crackle

Breaks in the paint layers, or paint and ground layers, forming a network over the surface of a painting, occurring in two main forms: (1) Drying cracks (vehicular) caused by failure of the film to withstand its own contraction during drying or by the artist's incorrect use of paint. (2) Age cracks (mechanical) caused by strain from movement of the support. This second type of crackle is one of the first stages in mechanical breakdown of the complex structure of a painting, but it requires treatment only when it begins to form buckling or flaking.

creep

Plastic deformation (see elasticity) of materials under stress at room temperature. In lined pictures, *creep* refers to the gradual extension of a lining canvas impregnated with adhesive after the painting has been replaced on its stretcher. Over a period of time, this results in sagging of the painting under its own new total weight. Contrast with *cold flow*.

cross linking

The joining of long-chain polymer molecules by lateral chemical bonds. Through cross linking, a collection of effectively one-dimensional molecules becomes a two- or three-dimensional network. This has the effect of making the polymer insoluble in normal solvents. Materials susceptible to cross linking should be avoided in conservation, where reversibility is desirable.

cupping

Islands of aged paint, bounded by cracks, with upward curving edges forming saucer shapes; these often draw a less stiff canvas support with them. They are induced by slight shrinkage of the canvas support or by chemical contraction of the upper stratum of the paint and/or differential contraction of the paint and varnish films, which prevents the cracked paint from lying completely flat. Frequently, excess pressure and heat are used in an attempt to reduce cupping during the lining process, which can result in the tops of the cracks being crushed and the paint surface abraded.

curing

The irreversible hardening of a synthetic resin by action of heat, a chemical catalyst, or other means.

cusping

Tacking marks, visible in the original canvas as a regular scalloping of the threads at the perimeter of the painting. The peaks of the scallops indicate the original tack points (and therefore the overall dimensions) on a painting that has been lined subsequently. They are clearly visible on radiographs. Also called *stress garlands* or *scalloping*.

dammar

A pale yellow, brittle natural resin, completely soluble in aromatic hydrocarbons and turpentine to give light-colored solutions. It melts at 100°C–115°C and is used as a varnish, in facing mixtures and in wax-resin lining materials.

denaturation

The process of modifying the molecular structure of a protein. Denaturation involves the breaking of many of the weak linkages, or bonds (e.g., hydrogen bonds), within a protein that are responsible for the highly ordered structure of the protein in its natural state. Denatured proteins have a looser, more random structure. Denaturation can be brought about in various ways, for example by heating or by treatment with alkali, acid, urea, or detergents.

delamination

The failure of adhesion between layers of a painting, often manifested by dimensional change or loss of paint. Delamination is a mode of failure where a material fractures into layers. Surface coatings such as paints and films can delaminate from the coated substrate.

dextrin

A generic name for the degradation products of starch produced by heating in the presence or absence of hydrolytic agents, used commercially as a thickening agent. There are a number of types of dextrin, usually comprising a mixture of soluble starch, true dextrin, and sugar (maltose and dextrose). They yield syrupy aqueous solutions with moderate adhesive properties.

dibutyl phthalate

A plasticizer that has been used in wax resin and synthetic-resin adhesives. It is an organic solvent with a high boiling point (340°C) that is immiscible with water and has insect-repellent properties. In time, its high vapor pressure causes it to gradually leave the film.

distensibility

The capability of being lengthened or extended in any direction.

double boiler

A device based on the principle of the water bath for heating materials to the boiling temperature of water without danger of burning. An inner saucepan holds the material and fits into a larger pan containing boiling water. Also called bain-marie.

double lining

In large pictures, a single lining may not be strong enough to support the weight of the original canvas and paint. In such cases a second lining may be carried out on the back of the first, and both lining canvases are fastened to the stretcher. Double lining may also be used to support seams or tears of any length. Sometimes, different adhesives are used for the two linings—first an aqueous (glue-paste) adhesive and then a wax-resin adhesive. See also *interleaf*.

dry mounting
An idea developed from a method for mounting photographs. The original canvas and lining canvas are bonded together with a thin layer of thermoplastic material (such as polyvinyl acetate) under the action of heat and pressure; a vacuum hot table may be used. Suitable where only strengthening of the original canvas is required—cleavage and cupping of the paint layer would be treated separately.

ductility
The ability of a material to undergo plastic deformation by tension.

durability
The capacity of a material to remain unchanged under normal conditions.

Dutch method
A term sometimes used for the wax-lining process. After the beginning of the eighteenth century in The Netherlands, the traditional glue-paste lining adhesives were gradually abandoned in favor of wax or wax-resin lining adhesives. In France in the mid- eighteenth century, the Comte de Caylushad succeeded in impregnating a painting with wax from the back in front of a fire. Charles Wilson Peale (1741–1827), an American artist, used wax-resin mixtures to impregnate his own paintings in the 1780s. See also *wax-resin adhesives*.

dynamic mechanical analysis (DMA)
A technique used to study and characterize materials. It is most useful for studying the viscoelastic behavior of polymers. The temperature of the sample or the frequency of the stress are often varied, leading to variations in the complex modulus. This approach can be used to locate the glass transition temperature of the material.

elasticity
The property that enables a stretched or compressed body or material to return to its original shape and size when the forces acting on it are removed. The three stages a stretched material can experience are (1) elastic deformation, in which the material returns to its original size when the stress is removed; (2) plastic deformation, in which the material is irreversibly stretched and does not return to its original size; and (3) breaking point. (1) and (2) can happen simultaneously in some materials, notably canvases.

elemi
A term covering a number of oleoresins. The best known is Manila elemi, a soft, yellow resin that is soluble in a variety of solvents other than mineral spirit. It is a common constituent of wax-resin lining adhesives, its purpose being to provide tack.

Eltoline tissue
A fine, long-fibered paper tissue used as an alternative to the more expensive mulberry paper tissue as an interleaf or facing material. Eltoline is the trade name of a range of high-quality papers available in several grades.

embrittlement
Loss of flexibility by a material. The increasing inability of, for example, a resin film to be bent without cracking. Plasticizers are introduced to reduce embrittlement.

emulsion
An emulsion consists of drops of one liquid dispersed in another liquid, in which it is immiscible. Generally, a third component, the emulsifying agent, is incorporated to stabilize the emulsion and prevent coalescence of the drops. Both water-in-oil and oil-in-water emulsions can be prepared. See also *colloid*.

emulsion (or dispersion) glues
The well-known "emulsion-glues" are in fact not true emulsions but dispersions of solid globules of adhesive polymer in an aqueous matrix. Commercial emulsions may contain various additives unsuitable for use on paintings and have an unsatisfactory pH. Emulsion glues are commonly used as low-hold, nap-bond lining adhesives.

enzyme
A catalytic substance produced by living cells that has a specific action in causing the decomposition or synthesis of compounds into new ones. Occasionally enzymes are used for the removal of old lining adhesives.

epoxy resins
Epoxy adhesives comprise a liquid or a fusible solid containing epoxide groups and a curing agent containing functional groups with which the epoxide groups combine to form a cross-linked polymer. The curing is an irreversible reaction that results in a thermoset resin with only slight shrinkage. A wide range of properties can be obtained by the use of different resin-hardener adhesive systems. Epoxy resins such as Araldite are used in preparing honeycombed auxiliary supports. Because of their irreversible nature they are not used directly as lining adhesives, but occasionally they can be employed for joining tears prior to lining. Trade name: Araldite (Huntsman Corporation).

ethylene vinyl acetate copolymers
See *vinyl resins*.

examination techniques
Basic information concerning the characteristics and deformation present in any painting intended for lining is obtainable from examination by the following means: (1) raking light (reveals buckling, bulging, cupping, cleavage, flaking, shrinkage, heat and pressure distortion, etc.); (2) transmitted light (reveals structure of original canvas ground and paint distribution, losses and tears, joins and patches); (3) reflected light (reveals planar distortions, surface texture). Photographs made in raking light are a valuable means of recording changes before and after lining. Radiography is used to reveal canvas weave type (especially for lined paintings where the original canvas may not be readily visible), losses in each layer, original stretching marks, joins, and distribution of paint ground layers.

expansion
Increase in dimension of an object or material due to internal structural changes rather than as a result of an applied mechanical stress.

Fabri-Sil
A Teflon-impregnated glass cloth coated on one side with a silicone-based pressure sensitive adhesive. It is supplied with a protective release layer on the adhesive side. The threads are anisotropic. The fabric has 13 threads per centimeter in the warp direction and 8 threads per centimeter in the weft.

facing
A process whereby an adaptable material (very often a thin tissue such as Eltoline tissue, mulberry paper, sulfite paper, fine silk, very thin cartridge paper) is glued to the face of picture to protect the paint layer during lining or other mechanical manipulation of the support. A chosen facing adhesive is applied either directly through the facing fabric onto the paint surface or separately to the tissue, which is then carefully applied to the paint to avoid wrinkling. In major support treatment, such as transfer, composite facings may be necessary, using different types of material and adhesive in successive layers. See also *facing patterns*.

facing adhesives
These adhesives (often mixtures) prepared for use in facing paintings or on other materials must be readily reversible. They include hot melts, resin solutions or emulsions, and water-soluble glues.

facing patterns
Markings left on the surface of a painting by the facing material during or after the lining. May be caused by excessive heat softening the final paint layers, or by the facing mix having an affinity for a soft paint surface (e.g., a natural wax-resin facing adhesive for a final resinous glaze), or by excessive pressure imprinting the edges, joins, or wrinkles in the facing material into the paint texture.

feathering
In strip-lining and patching canvas pictures, the piece of canvas used for the repair should not have a hard edge, which could show through as a ridge on

the front of the picture. Thus, some threads along each side are removed, leaving only perpendicular strands at the edges. This creates a soft frayed or feathered transition, similar to a slight chamfer. The edge is sometimes not straight to further diminish the risk of it showing through.

fiber
See *textile fiber*.

Fieux lining
A lining system developed by Robert Fieux. It used a silicone-based adhesive preapplied to a synthetic fabric as the lining fabric. Lining was achieved by attaching the painting to the lining fabric using electrostatic hold to create a light pressure. See also *Fabri-Sil*.

filler
(1) An inert material added to an adhesive (or paint) to modify it, usually to improve its strength, flow, or other properties. Whiting or precipitated chalk, gypsum, and titanium dioxide are commonly used as fillers, for instance as a component in wax-resin lining mixtures. (2) *Filler,* or *gap-filler,* also refers to an adhesive material (i.e., putty) used to fill losses in a paint or ground film.

fish glue
Proteinaceous glue prepared from the heads, bones, and skins of fish, marketed in liquid form or in readily soluble cakes or sheets. Fish glue has weaker setting powers than mammalian glue, lower molecular weight, and different amino acid composition. Commercial glues generally contain preservatives and essential oils. Trade name: Seccotine. See also *sturgeon glue*.

fixative
A term usually applied to a dilute solution of a resin or adhesive that is sprayed onto chalk drawings or pastels. In the context of lining, a fixative is an adhesive solution or dispersion, or a hot melt, applied to the front of the painting in the treatment of cleavage flaking, blistering, and the like. Low viscosity and good wetting properties are usually required to allow good penetration beneath the flaking paint.

flaking
The breaking away or detachment of one or all paint and ground layers from the support in either small particles or larger areas. Flaking is an extreme stage of blistering, buckling, cleavage, and crackling. See also *blister*, *buckling*, *cleavage*, and *crackle*.

flocking
A method of spraying adhesives onto canvas that produces strands of adhesive in a fiber-like texture. The back of the canvas can conform to more thickly applied flocked adhesive layers.

flax
Plant from whose fibers linen is made. These fibers are fairly long, having a compound structure, and the twists in the yarn is usually fewer per unit length than that of cotton yarns because of the greater length. With time, continuous adjustment to changes of moisture content in the air can cause these compound fibers of the woven linen to fall apart and become so weak that the twist of the yarns and the crossing of the yarns in the fabric can no longer hold them in place. Some aged flax fibers have been known to develop a twist like a cotton fiber. Canada is currently the world's largest flax producer, and the very fine linens are made in Belgium, Ireland, and Scotland.

flexibility
An inexact concept referring to the degree to which a material may be bent or stretched.

flour paste
An adhesive differing from starch paste in working properties, in that flour contains gluten, a proteinaceous material, as well as starch. Different flour pastes also differ in working properties. Wheat, rye, rice, and linseed flours are those commonly chosen. Flour pastes are widely used in the Italian *pasta* lining adhesives, which are mixtures of animal glue, flour paste, Venice turpentine, and various other materials. The purpose of the flour paste is to act as a filler in the mixture, having lower contracting forces than animal glue and giving a higher solid-to-liquid ratio; it also provides "slip" and aids spreading. Can be susceptible to mold and insect attack.

formalin
A 40% aqueous solution of formaldehyde used as a disinfectant. Used very dilute, it hardens, embrittles, and renders insoluble gelatin and animal glues in general, egg tempera, and casein.

fungicide
A substance that destroys fungi and mold and prevents their growth. Commonly added to aqueous lining adhesives containing natural carbohydrate and protein materials that support mold, including compo, *pasta,* fish glues, and cellulose derivatives such as sodium carboxymethyl cellulose (SCMC). Names for fungicides used by restorers are topane, thymol, Formalin (formaldehyde), and sodium fluoride.

fungistat
A substance capable of preventing the growth of fungi, molds, and the like.

gacha
A traditional Spanish glue paste adhesive comprising animal glue, flour, and additives, similar to traditional Italian *pasta* recipes.

garlanding
See *cusping*.

gel
A jelly-like colloidal substance composed of a liquid and a solid. The solid phase forms a network of macromolecules and the liquid phase is distributed through it, for example, gelatin and water. See also *colloid*.

gelatin
The purest of the adhesives obtained from animal hide and bone. See also *animal glues (bone and hide)*.

gesso
The word is Italian for gypsum. Gesso is a pale, creamy white priming composed of burnt gypsum (plaster of Paris) mixed with glue. Two kinds of gesso grounds were used by early Italian painters: (1) *gesso grosso,* a mixture of plaster and glue size, which was applied direct to the painting support (usually panel), and (2) *gesso sottile,* a finer crystalline gypsum (slaked plaster of Paris) mixed with glue size, which could be used as a final surface over *gesso grosso* but also as a priming for canvas. *Gesso* has come to have a wider meaning today, which now includes grounds made from chalk (whiting) or another inert white pigment, bound with acrylic emulsions, glue size, parchment size, calfskin glue, rabbit-skin glue, or isinglass. Modified gesso is also common, in which the addition of white lead bound with flour paste and drying oil is used to produce "gesso" grounds more suited to oil techniques.

glass fiber woven fabric
Blown or drawn glass that has been made into fibers when molten and subsequently woven. The fibers are usually lubricated to assist weaving (if a nondrying oil is used as the lubricant, it can reduce the bond strength of some lining adhesives). The resulting fabric may be obtained in a variety of weaves, weights, and textures, with the yarn locked or unlocked. As an inorganic fabric, it is inert and offers resistance to agents of organic decay, molds, and so forth. It provides a degree of permanence plus an even, smooth surface texture that cannot be matched by natural-fiber woven fabrics. Probably first used as a lining support in London in 1952, it initially found fairly wide use in conservation, especially to produce transparent linings in combination with hot-melt adhesives, but is rarely used today because the fabric is difficult and hazardous to handle.

glass transition temperature
The glass-to-liquid transition, or glass transition, is the gradual and reversible transition in amorphous materials (or in amorphous regions within semicrystalline materials) from a hard and relatively brittle "glassy" state into a viscous or rubbery state as the temperature is increased. The glass-transition

temperature (T_g) of a material characterizes the range of temperatures over which this glass transition occurs. It is always lower than the melting temperature (T_m) of the crystalline state of the material, if it has one.

glassine paper
A transparent, glazed wrapping paper.

glaze
A layer of transparent or semitransparent paint through which the light passing to the surface beneath is reflected back such that the color of the glaze modifies that of the lighter underlying color. Essentially, a glaze uses transparent pigment—one with a low refractive index, such as lake, ultramarine, copper resinate, Prussian blue. Because of the higher vehicle-pigment ratio and the often resinous content, glazes can be affected by any excessive heat and pressure during lining; sometimes they will retain the imprint of facing paper fibers or joins in the facing material.

glue paste
An adhesive for lining made from flour and animal glue, with various additions to improve plasticity and fungicides to prevent mold. Recipes vary from conservator to conservator, often reflecting wider regional variations, such as Italian *pasta* and Spanish *gacha*.

glycerin/glycerol
A syrupy hygroscopic liquid used as a plasticizer and humectant for aqueous adhesives such as animal glue.

ground
A paint-like composition, usually containing inert fillers, earth colors, white or red lead, and driers. Ground is traditionally applied with a grounding knife in several layers over isolating layers of glue size. Used for filling the open weave of a canvas and for mechanical purposes, such as bonding subsequent paint layers to the support and supplying the necessary color base, uniform texture, and degree of absorbency. Also called *preparation*. See also *priming*.

gum elemi
See *elemi*.

hand-lining
A general term for adhering a lining canvas to an original canvas using devices controlled by hand, such as hand irons and rollers, with or without a vacuum system.

hardboard
A sheet material made by compressing wood pulp (often spruce) to which a thermosetting resin is added. The resin accounts for the dark color of hardboard, its relative resistance to water, and its strength and stability. Available in several grades. Trade name: Masonite.

heat-seal adhesives
Heat-activated adhesives generally consisting of two or more resins. One of these has a high softening point and high molecular weight and gives cohesive strength to the adhesive. Another may have a lower softening (or melting) point and lower molecular weight. At a given elevated temperature, the low-molecular-weight resin fuses and dissolves the high-molecular-weight resin, yielding a viscous solution. With application of pressure and after cooling the solution solidifies to form the adhesive bond. Bond strength may vary according to the temperature to which the assembly is raised. Individual resins with a sufficiently low softening point can be used alone as heat-seal adhesives. Other components such as waxes may be added to increase tack or flow during bond formation and to adjust the heat-seal temperature. The adhesives are generally applied in solution. They differ in this respect and in their viscosity from hot melt adhesives such as wax-resin. Examples of heat-seal adhesives used in lining are Beva 371 and PVA formulations. See also *dry mounting*.

heat sources
Depending on type of adhesive and method of lining required to effect impregnation and/or adhesion, the heat source may take the form of: (1) actual contact with the painting, or lining surfaces, passing by thermal conduction from irons, spatulas, heated rubber blankets, hot tables, and similar devices into the lining materials, or (2) radiant heat, derived from infrared lamps or heaters, hot air blowers, photographic light bulbs, or electric heating elements held at a distance from the lining area. Heat may be applied locally or over the whole area; usually the former will involve heat for a shorter time while the latter produces overall greater heat and often a much lengthier process. The heat may be applied from one or both sides alternately or simultaneously, depending on technique. With overall heating methods, such as hot tables, insulating layers (such as Melinex) may be employed to cut down heat loss to the surrounding air, thus enabling optimum temperatures for the lining process to be reached more quickly and in a controllable manner.

Heiber glue
A 1:1 mixture of sturgeon glue and wheat starch paste used by Winfried Heiber.

Heiber mend
A mend to a tear in canvas that reweaves the original structure of the canvas and attaches the original threads together using a strong glue. Pioneered by Winfried Heiber. Also called *thread-by-thread tear mending*.

hemp
Plant producing bast fibers from the stem that has been used for centuries to make rope, sailcloth, yarns, and textiles. Rarely found in painting canvases, and then probably chiefly in the nineteenth and twentieth centuries—although this is uncertain, as it is difficult to distinguish aged hemp and flax fibers from one another.

herringbone
See *complex weaves*.

hessian
Strong coarse cloth of hemp or jute. Chiefly finds a use in lining on the vacuum table, where strips of hessian webbing are used as breathers to draw out the air from the picture area and toward the vacuum ports.

honey
Produced by the eight species of honeybee, which are native to Asia, Europe and Africa, but are now globally distributed. Composed of the sugars dextrose and levulose, and other compounds, with variable amounts of water. It retains moisture and hence is used as a humectant and tackifier in aqueous lining adhesives—an important component of Russian sturgeon-glue lining adhesive.

honeycomb paper
A resin-impregnated paper structure that folds out into an array of hexagonal cells, like a honeycomb. It is available in a range of cell depths and cell densities. It is used in the preparation of composite supports for marouflage, glued between "veneers" of hardboard, Sundeala, or aluminum sheet, and provides rigidity with minimal increase in weight.

hot-melt adhesives
An adhesive that is solid at room temperature, on heating melts to a mobile liquid, and resolidifies on cooling to form the adhesive bond. The advantages of hot melts (such as the well-known wax-resin lining adhesives) are their low viscosity, and hence ready flow, and good penetration during bond formation. The 100% solids factor means there is no shrinkage problem due to loss of solvent. See also *thermoplastic*.

hot table
Widely used for lining pictures, a hot table consists of a large, polished (usually metal) tabletop with facilities for extremely uniform heating and cooling. Early versions of the tabletop were made of slate, plate glass, marble, and the like. See also *vacuum hot table*.

humectant
A substance that absorbs or retains water, such as glycerol or honey. Humectants are commonly added to aqueous adhesives of the carbohydrate or protein types to plasticize the glue film and to reduce brittleness.

humidity
The amount of water vapor present in the air. Can be stated as the absolute humidity, which is the mass of water present in a cubic meter of air, but usually quoted as the relative humidity (RH): the ratio of the mass of water vapor per unit volume of the air to the mass of water vapor per unit volume of saturated air at the same temperature, which is expressed as a percentage and measured with a hygrometer.

hygroscopic
Used to describe a substance that will readily absorb moisture from the air.

impasto
A thick, often opaque area of paint, applied with a brush or palette knife, which stands up above the surface to which it has been applied. (Can also be thin, low relief, with highly defined brushstrokes.) Successive heavy linings have reduced the relief of many impastos, thus drastically altering the effect of spontaneity in the handling of the paint. Also called *pastosity.* See also *moating*.

impregnation
The complete permeation of a porous material, such as lining canvas and paint layers, by an adhesive or consolidant, often under the action of heat and pressure.

infilling
The filling, with a compound, of holes and worn areas in the back of the original canvas prior to lining or relining. If this is not done, pressure applied during lining may cause the surface of the picture to form hollows in these thinner areas. Fabric of the same weight, cut to fit, is often used in addition to various filling compounds. *Infilling* also refers to the filling and texturing of losses on the front of the picture prior to retouching.

infrared heater
Groups of infrared (IR) bulbs or IR elements mounted within a metal frame, often suspended above a hot table. Useful for maintaining areas of a picture at an elevated temperature during lining and blister-laying processes. Precisely calibrated hot-air sources are more often used today.

insert
Pieces of canvas (sometimes fragments of other paintings with matching texture) are set into large losses in a painting during lining. See also *infilling*.

interleaf
A material introduced between the original and lining canvases intended either to give greater rigidity to the lining support (and hence prevent the reappearance of plane distortions and tears after lining) or to suppress weave interference between the fabrics. Mulberry or Eltoline tissue, paper, muslin, net, fine silk, and nonwoven polyester synthetic fabrics are used.

irons
Hot irons used in lining often have a large surface area, even heat spread, and a reliable thermostat. Precisely temperature-regulated irons designed for painting conservation are commercially available. See also *cooling iron* and *tacking iron*.

isinglass
Very pure fish gelatin made from the swim bladders of certain fish, especially sturgeon. See also *fish glue* and *sturgeon glue*.

isolating layer
(1) A sheet of nonstick material used in most stages of lining to prevent the painting from sticking to surfaces in contact with it. Commonly used materials are Melinex or (Mylar), silicone-coated Melinex/Mylar, and silicone paper. (2) In inpainting, the layer of varnish or other film that is applied to isolate the inpainting from the paint surface.

Japanese tissue
Fine, strong long-fibered paper made by hand in Japan from fibers of the paper mulberry tree and other trees and plants. In lining it is used as an interleaf or facing material. It is also widely used as a backing support for works on paper.

jute
A plant producing bast fibers, suitable for matting and sackcloth, that have poor durability; jute fabric is therefore less commonly found as a support for a painting. However, its coarse texture and slubs have been preferred by some modern and contemporary artists.

key
Thin, triangular piece of wood tapped into the corner of a stretcher. The key forces the stretcher members apart, thus tightening the canvas. Also called *wedge*.

kraft paper
Brown wrapping paper (also available as a gummed tape). In certain lining processes kraft paper is glued to the edges of the painting and to a surrounding loom or stretcher that is several inches larger than the actual painting. The paper follows a hysteresis cycle when moistened and allowed to dry. The overall contraction on drying places the painting in tension, allowing it to be worked on and treated. It should be noted that tensioning by this means is uncontrolled. Waxed kraft paper was often used in wax-resin lining in the past, but it is no longer widely available.

lacuna
Area of loss, a cavity, where one, some, or all layers of the painting have flaked away.

latex
A milky juice from the *Hevea brasiliensis* tree that is used to make natural rubber.

latex rubber sheet
The flexible membrane stretched over the vacuum hot table to seal the surface was typically made of rubber in the past. It has now been largely superseded by polyvinyl chloride (PVC), polyethylene, Melinex, or Mylar sheeting.

linen
Textile made from the bast fiber of the flax plant. As with cotton canvases, when wet the undegraded linen fabric can have an increased breaking strength of up to 30%. The reverse is true for degraded canvases that have undergone the damaging effects of chemicals, heat, and light; then their wet strength will be less than their dry strength. Linen has been the most common painting support for centuries, and is still the most commonly chosen lining fabric, although synthetic fabrics or mixtures of linen and synthetic fibers are increasingly used. See also *canvas*.

lining
The adhering of a fabric (traditionally a fine linen canvas) or solid support to the reverse side of a painting where the support has degraded to provide insufficient structural support. The purpose may be to counteract structural weakness in the original canvas itself and/or to secure cleavage between the paint, ground, and canvas layers. Past practice also used the adhesive chosen in the lining procedure to impregnate the canvas and the ground and paint layers from the reverse. Currently, consolidation and stabilization of the ground and paint layers would be a separate process, with the lining providing support. Several techniques are used employing a range of adhesives and supports. See also *hand-lining*, *mist-lining*, *contact lining*, and *Fieux lining*.

lithographic paper
A strong, thin, absorbent, adaptable cartridge paper that is used as a facing to “prestretch” a painting prior to lining.

locked weave
(1) In lining, the lining canvas on its loom can be impregnated with adhesive. When the adhesive is set and the lining canvas is cut from the loom it

maintains its stretched condition because the adhesive has locked the weave of the material. (2) A particular weave type of glass fiber fabric. (3) Describes herringbone, twill, and similar types of woven fabrics.

loom
Stout wooden or metal frame, larger than the picture to be lined, over which the lining canvas is stretched. Some designs have tensioning systems. See also *working stretcher*.

loose-lining
A layer of fabric, which might be also sized and painted, that is in contact with but not adhered to the reverse of a canvas or lining. It provides extra support and also buffers against environmental fluctuations of relative humidity and temperature. Original loose linings have been found on eighteenth-century paintings and the practice was common in nineteenth-century England, when commercial artists' colormen would supply stretched canvases with two layers of primed canvas; the layer on the reverse would have the primed face exposed. Paintings prepared in this manner have proved to be exceptionally well preserved. Adding a "tooth" to the loose lining by raising the fibers can improve the support it provides. See also *cami-lining*.

low tack
Used to describe adhesives of low cohesive strength that should be essentially stable, with resistance to creep, providing an adhesive hold that can be peeled apart.

lumps
Foreign particles in the support fabric, the lining adhesive, or on the release layers in between. With the application of heat and pressure, these produce lumps in the painted surface owing to the enlargement of the area covering the original fault.

malleability
The ability of a material to undergo plastic deformation by compression.

marouflage
The sticking of a canvas picture to a rigid support. Originally used to describe murals on canvas attached to a wall with white lead in oil as the adhesive, but now encompassing a wide range of supports and adhesives. See also *hardboard*.

mastic
A pale yellow, brittle, natural resin from the mastic tree (*Pistacia lentiscus*) that is soluble in a number of solvents, including the aromatic hydrocarbons, but not in mineral spirits. It melts at about 95°C and has been used in facing mixtures and wax-resin lining adhesives. More widely used as a natural resin varnish, but prone to yellowing.

Melinex
See *Mylar*.

melting point
The temperature (for a given pressure) at which the solid phase of a substance changes to the liquid phase. Usually quoted as measured at standard atmospheric pressure: 760 mm Hg.

membrane
The flexible sheet material that lies over or on either side of the painting, thereby enabling a vacuum to be created by means of a vacuum pump. The properties desirable in a membrane material are that it should be nonporous, thin and flexible enough to accommodate textures such as impasto, and have no texture of its own. Melinex/Mylar (polyethylene terephthalate), high-density polyethylene, and polyvinyl chloride sheeting are the most common membrane materials. Coatings with release materials such as silicon can reduce unwanted adhesion.

microclimate
A set of conditions that differ from the dominant or surrounding climate. Sometimes can be manifested in differing crack patterns, due to local differences in temperature and relative humidity (RH), along the stretcher bar area of a painting. Microclimates can be actively managed by controlling RH and temperature within an enclosure, to protect from differing conditions outside the enclosure. Microclimates can be passive, relying on insulation and hygroscopic materials within the enclosure, or active, where stable conditions are produced by specialist equipment.

microcrystalline wax
Wax derived from the heavy residual lubricating oil fraction of crude oil after the removal of paraffin wax. Its microcrystalline structure gives it a plasticity not possessed by the paraffin waxes, and it is further characterized by its high melting point, viscosity, flexibility at low temperatures, and high adhesion and cohesion. Available in a range of hardnesses. Used as a component of wax-resin lining mixtures and as an additive to some synthetic resin adhesives. Trade names: Cosmolloid, Multiwax, Victory White.

microorganism
Any minute organism visible only through a microscope, such as a bacterium.

mineral spirits
A solvent in painting conservation that is a mixture of petroleum hydrocarbons obtained from fractional distillation of petroleum. Boiling range is 150°C–210°C. Several grades are available. Mineral spirits was a common solvent for wax-resin facing adhesives and is regularly used for the removal of the residues of hot-melt adhesives after lining or impregnation. Also called *white spirit.*

miscibility
The property whereby certain liquids will mix together in all proportions to form a homogeneous mixture, for example, alcohol and water."

mist-lining
A process that employs adhesive sprayed exclusively onto the lining canvas. As practiced by Jos van Och and at SRAL in Maastricht, it is a complete and carefully calibrated procedure using precisely measured solvent to activate the adhesive within a vacuum envelope. The principle of the method was developed by Phenix and Hedley at the Courtauld Institute in the 1970s and by Mehra independently.

moating
Any raised portion or particle of paint (e.g., impasto) or any loose particle introduced between the paint surface and the pressure source of the lining process (particularly in any face-down lining technique), can be pressed down level with the rest of the paint surface, creating a small hollow all around it, like a moat around a castle—hence the term. This is distinct from flattening impasto, which is caused by a combination of pressure and heat softening the paint.

modulus of elasticity
Measures the tensile stiffness of a solid material, quantifying the relationship between tensile stress σ and axial strain ε.

moisture barrier
A layer with water vapor impermeability. Often applied as the last stage of treatment to the back of a glue-paste relining. Also applied to the reverse and edges of paintings to protect them from changes in atmospheric humidity. A layer of card or paper, or a rigid panel attached to the back of the stretcher can act in the same way. See also *backing, backboards, backing boards*.

monomer
A single molecule of a chemical compound that by repeated combination with others forms a polymer.

mulberry paper
A general heading for the strong, pure, long-fibered papers made by hand from the paper mulberry tree. They are available in a variety of weights and find use as interleaves or facing materials in lining. See also *Japanese tissue*.

muslin
A thin, loosely woven, plain-weave cotton fabric. Used for straining impurities from adhesives and varnishes and traditionally as an interleaf. See also *cheesecloth*.

Mylar
Trade name for polyethylene terephthalate sheet. It is available in very thin films due to its high strength and in a range of thicker grades. It is highly resistant to solvents, light, and heat. It is used in lining as a general-purpose protective and nonstick isolating material—particularly when supplied with a silicone coating—and as a membrane in vacuum lining. It has also been used as a lining support for some synthetic adhesives. It has a low propagation tear strength and cannot therefore be tacked or stapled. Melinex is a similar product.

nap bond lining
A lining system in which impregnating the original canvas with lining adhesive is avoided. The adhesive is applied to the lining support fabric or an interleaf, not to the original canvas, providing a uniform hold at the nap surface. See also *contact lining*.

nap
The raised smooth-cut, short fibers on the surface of some woven textiles. Also referred to as pile.

newton
The newton (N) is a unit of force. It is defined as 1 $kg{\cdot}m/s^2$, the force that gives a mass of 1 kilogram an acceleration of 1 meter per second per second.

nylon
Originally a trade name for a brand of a polyamide fabric. Now a generic term. Soluble nylon is also used as a term for polyamide welding powder. See also *polyamide fabric*.

oleoresin
(1) A natural combination of resinous substances and essential oils occurring in or exuding from plants. It is usually a soft semiliquid in which the resin is in solution in the essential oil. Four subgroups are classified: the varnish group, derived chiefly from plants of the Anarcardiaceae family; the copaiba group, sweet-smelling resins similar to the balsams; the turpentine group, from Coniferae soft resins; and the elemi group, which are soft resins containing above 10% ethereal oil. Among the oleoresins most common in pictorial painting are Venice turpentine and copaiba, both used in the older practice of picture restoration and in the compounding of some surface films.
(2) Occasionally used to mean a mixture of drying oil and resin (e.g., sandarac) which, according to literary sources were used from early times as constituents of glazes, but the use of oleoresin balsams in painting media is rarely mentioned before the mid-eighteenth century. See also *balsam*.

oxgall
The bile obtained from the gall bladders of oxen. Ropey, mucous transparent liquid of greenish brown color and complex composition. Used as a wetting agent, for example where it is necessary to increase the penetration of an aqueous adhesive.

padded backing
A layer, most commonly polyester wadding, usually attached to a backing board, which cushions the canvas layer of a painting. Often used to reduce the flexing of unlined or large paintings during transport.

panel back stretcher
A painting stretcher that has rigid panels inserted into the stretcher bars and completely covers the reverse of the painting. The panels can be set close to the reverse of the painting to provide some structural support. Widely used in the nineteenth century, panel back stretchers significantly reduce degradation of the canvas, even when non-acid-free materials such as wood are used.

paraffin wax
Mixtures of saturated aliphatic hydrocarbons obtained in the distillation of petroleum and available in grades melting in various ranges, such as 48°C–50°C, 50°C–52°C, up to 75°C. Hardness, density, and lack of crystallinity increase with increased melting point. They are white or bluish white translucent materials, soluble in nonpolar and weakly polar solvents, and have a tendency to become brittle. They have been used in wax-resin lining adhesives, often as a minor constituent to adjust the melting point of the mixture.

pasta
The term applied to a lining adhesive widely used in Italy. The principal components are flour paste (approximately 60% by volume), animal glue (about 20%), and Venice turpentine (20%). Other additives include disinfectants, linseed flour, and honey or molasses.

pastosity
See *impasto*.

patching
A canvas with a tear or hole that otherwise does not need lining may be patched on the reverse side using a feathered piece of fine canvas and normal lining adhesive. However, this is not good practice as it very often distorts the canvas in the region of the patch. See also *thread-by-thread tear mending*.

pavimenteuse
A type of ground/canvas structure common in Italy in the seventeenth century. It was made by spreading a thick paste ground with a knife into an open weave canvas. Over time, a regular crackle system of tiny cubes in the paint surface develops, which is easily accentuated by lining pressure or may be detached by careless treatment. Also called *pavementing.*

peel test
The resistance to peeling apart of original and lining canvases, typically employed to assess a variety of lining adhesives. A strip of canvas of given width is attached for a definite part of its length to a fixed vertical plate. The free end is bent down through 180 degrees (in the same direction as the fixed end) and weighted until the test strip peels away from the plate.

permeability
(1) The property of a material that allows the passage of another substance.
(2) Yielding passage to fluids, penetrable.

petroleum spirit
See *mineral spirits*.

pH
Measure of the acidity or alkalinity of a solution. Defined as pH = log10(1/ [H+]) (where H+ is the hydrogen ion concentration) and expressed on a continuous scale from 0–14: pH= 7 represents neutrality; 6–1 is increasingly acid, and 8–14 is increasingly alkaline. Can be determined by electrometric measurement or by use of colored indicators.

pigment-vehicle ratio
In artists oil paint the proportion of pigment to vehicle varies widely, between dense, low absorbent pigments (e.g., white lead requires 8% W/W vehicle) to more absorbent earth colors (e.g., raw sienna requires 35% vehicle; lakes, 55%) to the highly absorbent pigments (e.g., lamp black, 85%–100% vehicle; asphaltum, 150% vehicle). Paints with a high proportion of pigment to vehicle (usually the lighter parts of the picture) are more stable to heat and pressure than those paints with a higher vehicle content (found in the darker areas), which often show more signs of deformation (wrinkling, imprinting, flattening, cupping). See also *absorption*.

plasticizer
A substance added to a resin or adhesive film to increase or retain flexibility. Usually a nonvolatile or only slightly volatile liquid, which is retained in the film when the volatile solvents have evaporated.

plasticity
A material exhibits plasticity when it undergoes permanent deformation under the influence of applied stress. Substances that can be shaped or molded by heat, pressure, or both, are said to be plastic. See also *elasticity*.

platen
See *suction plate*.

polyamide fabric
A textile woven from fibers made from a group of synthetic polymers available under trade names (e.g., nylon). These fabrics have with differing properties according to spinning processes and aftertreatment, but commonly they have low moisture absorption, are quick drying, soften at 180°C, and tend to stretch, which can be partially irreversible. The latter makes these fabrics generally unsuitable as lining or patching supports. Occasionally used as a facing material.

polyamide welding powder
A resin in powder form distributed by Lascaux. It melts at approximately 100° C. Used to mend tears.

polycyclohexanone resins
Synthetic resins composed of chains of cyclohexanone and methylcyclohexanone units (or similar units with slight modifications). Average chain length is several units. The polycyclohexanones have similar visual and handling properties to the natural resins dammar and mastic but superior stability. They have thus found use as alternative resins in varnishes. They are all soluble in mineral spirits, are very brittle, and soften at 80°C–90°C. Trade names: AW2, M52. MS2A, MS2B, MS3, Ketone-N (MS2A is no longer commercially available and has been replaced with MS3. The cost of MS3 makes this resin an unlikely component of adhesives; its use is confined to varnishing paintings).

polyester fabrics
Woven textiles from fibers made from another group of synthetic polymers variously manufactured. Generally, their properties include extremely low water absorption (even when immersed), no swelling and thus quick drying, and stable to heating up to 130°C. The fibers extend less than those of polyamide fibers (nylon), and when processed on the cotton spinning system, the extensibility is about the same as cotton and linen. The light resistance is better than for polyamide fibers. Polyester fabrics are used fairly widely in textile conservation and are increasingly used as a component of lining fabrics. A common type is polyester sailcloth. Trade names: Cerex, Dacron, Hollytex, Kodel, Tergal, Terital, Terylene.

polymer
The majority of polymers are organic long-chain molecules. Combination of two or more molecules of the same compound results in formation of a new compound that has the same atoms in the same ratios but greater molecular weight. Thus, polymers are formed by the repeated joining, end to end, of single molecules called monomers. For example, the monomer ethylene gives rise to the polymer polyethylene. Polymers can be both naturally occurring (e.g., cellulose) or manufactured (e.g., synthetic resins, nylon). See also *copolymer* and *terpolymer*.

polyolefins
Purely aliphatic hydrocarbon polymers such as polyethylene and polypropylene. Fabrics woven from their fibers are finding increasing use in structural treatments, including facing, temporary supports, and storage.

polypropylene fabric
See *polyolefins*.

polyvinyl acetal/butyral/formal
See *vinyl resins*.

polyvinyl acetate
See *vinyl resins*.

polyvinyl alcohol
See *vinyl resins*.

pressure sources for lining
(1) Various sources of positive pressure have been used in lining procedures, ranging from early heated tailors' irons (mobile sources of local pressure), the modern vacuum hot table, and other pressure systems, such as vacuum envelopes and air vortices in low-pressure systems. Other systems include weighting with flexible water containers or sandbags over the entire surface of the lining composite. Flexible synthetic sheets can be used as adaptable pressure sources over paintings. Rollers (covered with foam, nylon, rubber, felt) can also provide auxiliary mobile pressure sources. The heated spatula, though light, can bring high-pressure loads to bear on local areas. Cooling irons of between 6 and 30 pounds are commonly used in both glue- and wax-resin lining methods to maintain contact between the canvases as the lining adhesive is cooling and setting. (2) Positive pressure exerted during lining will be complemented by an equal amount of inverse pressure, the source of which usually takes the form of a flat, hard surface, such as a terrazzo floor, marble slab, composite board table, or hot table. Soft materials are often used as buffers between the painting and the pressure sources. Sandboxes, sawdust beds, and, more recently, silicone rubber molds have all been used to accommodate the relief of the painting within an overall firm support. A tensioned lining canvas during the lining process can also act as an inverse pressure source, the degree of flexibility being determined by the tautness. Other efforts to overcome the flatness characteristic of many of these inverse sources has led to the development of balanced pressure forms. See also *vacuum envelope*.

prestretching
(1) Where the canvas to be lined has shrunk (indicated by cupping or buckling of the paint layer), or has been distorted by a previous lining adhesive, stretching and flattening of the original canvas to accommodate the full size of the paint layers is often carried out as a separate procedure before the lining process. Methods are various, usually involving the presence of moisture and/or heat, and can be achieved by edge attachment and local retensioning over a considerable period. It is important to remove inhibiting material (old lining canvases, adhesive, etc.). (2) Preparing a linen lining canvas by moistening after it has been stretched on a loom. The increased tension as it dries removes local variations in the weave. Adjustments to the stretching are usually needed after this process.

priming
Layer following the ground layer, providing a modified color base and/or textured surface on which to paint. Today, *priming* and *primer,* meaning a preparation coating for canvas, are synonymous with ground.

putty
A material prepared for filling losses in a paint-ground film prior to inpainting. Puttying can be carried out before or after lining and can be applied from the front or the back of the painting. Putties generally consist of an inert filler (whiting, kaolin, titanium dioxide, and/or other pigments) dispersed in an adhesive to give a liquid or paste that is brushed, dropped, or pressed into losses; after setting it is modeled to match the texture of surrounding areas. Inserting putty into losses before lining reduces the risk of the original canvas being pushed to the surface in these areas during the lining process. The adhesive may be a synthetic resin solution or emulsion, wax or wax resin, or a natural glue such as gelatin, and it may contain a variety of additives (e.g., stand oil). The properties important in a filler are ease of handling and modeling, minimal shrinkage on setting, ease of removal from surrounding paint, flexibility, and retention of color with age.

rabbit-skin glue
An animal glue traditionally prepared from the skins of rabbits. However, *rabbit skin* is now generally used to describe the properties of the glue, including rapid solubility and lower bond strength, and these glues are made from other sources.

raking light
When an intense point-source lamp (incorporating a heat filter) is positioned with the beam at an acute angle across the surface of the painting any relief or deformation is accentuated and can be easily observed or photographed. The physical state of the painting can thus be studied before, during, and after lining.

reflectance transformation imaging (RTI)
A technique that measures texture and relief of a surface from all angles, imaged on a computer, where a number of images with light sources in different positions are combined. Changes to distortions on a painting's surface can be visualized in precise detail.

refractive index (RI)
The RI of a medium is the ratio of the velocity of light in free space to that in the medium. Mathematically expressed as the sine of the angle of incidence divided by the sine of the angle of refraction, when light is traveling from a vacuum (or, as an approximation, air) into the medium. The importance of RI for paint films and lining techniques lies in the fact that the relative transparency or opacity of a paint film depends in part on the difference between the RI of the pigment and that of the suspending medium. A pigment with a high RI (such as titanium dioxide or vermilion) in oil will give an opaque film. Similarly, a pigment of comparatively low RI (such as whiting) will appear opaque in an aqueous medium and transparent in a medium of comparatively higher RI (such as oil). The increasing RI of oil with age increases the transparency of particular oil-pigment mixtures, producing the well-known phenomenon of pentimenti. In lining techniques, it is important not to saturate a low RI ground with a relining adhesive of similar RI because it would reduce the opacity of the ground and lead to a general darkening in tone.

relative humidity (RH)
See *humidity*.

relining
The lining of a canvas painting that has been lined before. Involves removal of the old lining canvas and adhesive and mounting on a new lining canvas with new adhesive.

resins, natural
Amorphous organic compounds of complex composition that are secreted or excreted by certain plants. Generally insoluble in water and soluble in organic solvents.

resins, synthetic
Substances with resinous properties produced by chemical synthesis. This was a term originally applied to a group of synthetic substances whose properties resembled those of the natural resins but is now applied more generally to the whole range of synthetic materials produced by polymerization. They can be classified in a variety of ways, most importantly as thermosetting or thermoplastic, by chemical constitution and structure, and by degree of polymerization and extent of cross linking. They are widely used in conservation in adhesives, consolidants, surface coatings, paint media, fibers/fabrics, nonwoven fabrics, films, and rigid supports.

retreatability
See *reversibility*.

reversibility
A theoretical basic criterion for conservation. A process or material applied to an art object should be completely reversible or removable by means that do not endanger that object. In practice, few treatments are totally reversible, so ensuring the object can be retreated safely is the more realistic goal.

reweaving
Filling a tear or a lacuna in canvas by recreating the weave in the area of damage by realigning and rejoining broken threads or weaving a similar section to fill a loss by joining and extending threads.

rheology
The study of the deformation and flow of materials.

rigidity
The resistance of a body to twisting and bending.

roller
Heavy iron heated rollers were in use at the end of the eighteenth century for reducing surface distortions during lining. Heavy floor layers rollers have been known to be used for lining ceiling paintings until recently. Today, small hand rollers—of some fairly soft material—may be used in lining (especially on a vacuum hot table) to assist in the expulsion of air trapped between the original and lining canvases. A soft foam rubber roller can be used in glue-paste lining, or a nylon flock roller may be used to apply adhesive in the required amount for a wax-resin lining.

rosin
See *colophony*.

RTI
See *reflectance transformation imaging (RTI)*.

sailcloth
A general term for a strong, plain-weave cloth used for boat sails. Sailcloth can be made from cotton, linen, jute, hemp, nylon, aramid, or polyester, but polyester is most common in painting conservation. Sailcloth has also been used as a support for paintings.

sand bed
Historically used in lining pictures with impasto. The painting is treated face down on a tray of fine sand, which, while providing a firm support, is sufficiently fluid to adopt the conformation of the paint surface.

sawdust box
Similar in principle to a sand bed, used as a bedding for lining pictures of high impasto.

scalloping
See *cusping*.

secant modulus
Using a stress-strain graph, one of the ways to calculate the modulus of elasticity of a material.

selvage
The continuous border formed by the weft threads returning at the edge of the warp of a woven textile. Also known as *selvedge*.

shear test
Used for testing shear properties of lining adhesives. Two strips of canvas of a given width are overlapped for a certain proportion of their length and joined with the adhesive. The free end of one strip is fixed, and the free end of the other is increasingly weighted until failure of the adhesive occurs. The results are expressed as shear strength and are given in the units of MPa or pounds per square inch (psi). The most common measurement obtained from a shear test is the shear strength, which is the maximum load a material can withstand in a direction parallel to the face of the material, as opposed to perpendicular to its surface. The shear strength is calculated by dividing the force required to shear the specimen by the area of the sheared edge. Creep can be measured by a similar procedure, but it is measured under constant load.

shellac
A yellowish-reddish brittle natural resin obtained from the lac insect, mainly in India. It melts between 77°C and 82°C and is soluble in alcohols.

shrinkage
Reduction in size that occurs naturally in the presence of moisture with some canvases; it is thus a major cause of blistering and cleavage of a hardened paint layer. Before lining a painting with an aqueous adhesive (and before treating bulges and distortions in the canvas with moisture) tests are made to check the response of the original canvas to water, and allowance is made for

the escape of the moisture during the lining process and during any subsequent drying time that may be necessary.

shrinker
A painting that is suspected to or does demonstrate shrinkage when moisture is applied to correct distortion.

silicone paper
Paper impregnated with a silicone resin that finds general use as a release material or nonstick isolating layer where paintings are being treated with adhesives.

silk
The natural product of certain moths that is processed to produce a lustrous, highly absorbent fiber that can be readily impregnated or wetted with water. Can be heated to 110°C but decomposes at 170°C. Apparently rarely used as a paint support in Europe, but commonly employed as such for many centuries in Asia.

size
In its broadest sense, *size* means any material used to seal a porous surface. The term is frequently applied to gelatin or the pure forms of glue. Raw canvas is normally sized before application of the ground or priming.

spatula
Literally, a large blade, usually of flexible steel. In conservation, may refer to a small electrically heated iron, often with a variety of shaped heads, used for applying heat to a localized area on a painting or other art object (e.g., in the laying of flaking paint).

starch glues
Chemically, starch is a polymer of glucose. It has two constituents: amylose and amylopectin. For the preparation of starch glues, the starch from rice, wheat, corn, or arrowroot is commonly employed. When mixed with water and heated the starch gelatinizes and forms a viscous paste, which is a solution of amylose thickened by jelly-like amylopectin. Because adhesive films encourage mold growth and become brittle with age, humectants and fungicides are common additives. Soluble starch can be prepared from starch by treating it with acid or using various other methods. It dissolves to give a clear solution in hot water and can be used as an alternative size to gelatin.

strain
The deformation of a material from stress. It is unitless and is shown as simply a ratio of the change in length to the original length.

strainer
A rigid wooden framework over which canvas paintings may be fastened. Unlike a stretcher it has fixed corners and so cannot be expanded to tighten the canvas.

stress
Stress is a physical quantity. The term is closely associated with *internal force.* It is the measure of average amount of force exerted per unit area over a material.

stress-strain curve
In materials science, a stress-strain curve can be used to interpret data such as the Young's modulus and the tensile strength of a material.

stretcher
A wooden frame over which canvas paintings are stretched. The corners are jointed but not fixed, so by driving in wedges or other mechanical means the stretcher can be expanded and the canvas tightened. Various stretchers have been devised using springs, rollers, and other devices with the aim of maintaining a constant tension on the painting. See also *constant tension stretcher*.

stretcher bar lining
See *cami-lining*.

stretcher bar marks
The appearance on the paint surface of the form of the stretcher bars as cracks or ridges that follow the inner edges of the stretcher bars or both sides of stretcher cross bars. The area between these marks and the outer edge of the canvas generally has areas of relatively uncracked or uncupped paint in a picture where the surface exhibits crackle. Indicative of the protective properties of any form of free, independent backing material behind the canvas; here the bars limit canvas movement by partially isolating the canvas from changes in the external climate and by guarding against accidental mechanical pressure or damage.

stretching
Associated with several stages of the lining process. (1) The stretching of the lining canvas onto the working stretcher prior to lining. (2) The stretching of the original picture canvas before and during lining to eliminate deformations. (3) The mounting of the lined picture on the stretcher and subsequent tapping out with wedges. See also *prestretching*.

strip-lining
Where a picture as a whole does not need lining, but the edges of a canvas painting are not strong enough to be tacked to a stretcher, strip-lining is carried out. Strips of canvas, a few inches wide and feathered on the inside edges, are lined onto the four edges of the picture; these strips are used to attach the painting to its stretcher.

sturgeon glue
Collagen glue made from the swim bladders of the sturgeon; known as *isinglass* in its purest form. Low melting point, plus high initial tack and oily spreading consistency, have led to its unique place as an adhesive in Russian lining methods, where it is used in combination with honey.

suction plate
A small plate with a perforated surface that when connected to a vacuum source can be used on the verso of a painting for a variety of uses, from humidification and flattening to consolidation. Also called a *platen.*

suction table
Refers to tables developed in the late 1970s and 1980s for lining that continue to be in use today. Suction is applied through perforations in the top of the table. Some suction tables can simultaneously provide heat or humidity to the painting.

support
Rigid or flexible substance on which a picture is made or painted.

supports for lining
Size, weight, evenness of weave, tensile strength, and expected endurance are all factors governing the choice of a lining support. Linen canvas has served in the past, mainly suiting glue-paste adhesives, having a typical life span of 80–100 years; it has also been used with wax-resin and synthetic-resin adhesives. Woven glass fiber fabric, offering evenness of weave, greater rigidity, and absence of creep, became common in the 1970s and 1980s, but have limited use today. Aluminum sheet or honeycomb sandwich panels have also been used as supporting materials (usually incorporating an interleaf between the original canvas and the backing panel). Woven polyester fabrics are often used and offer a limitless range of properties.

surface texture, changes in
The original surface of a painting is affected by the weave textures of the fabric; the texture layers, such as brush marks, impasto, and crackle; and structure of the paint, ground, and/or varnish. Lining procedures may cause marked changes of various types in surface texture. See also *pressure sources for lining*, *lumps*, and *weave emphasis*.

surfactant
Material added to a liquid that alters its surface tension and hence its spreading and wetting properties. Also called *surface-active agent* (SAA). See also *wetting agent*.

tabby
A weave type or binding system based on a unit of two warp threads and two weft threads.

tack
Tackiness or stickiness of an adhesive or varnish layer.

tacking iron
A small, lightweight iron, usually electrically heated. Often used when attaching adhesive tissue to an object. Can be used for lining by hand.

tensile strength
Ability of a material to withstand stretching forces. See also *elasticity*.

terpolymer
A particular type of copolymer in which the polymer molecule is made up of three specific monomers.

textile fiber
Fiber (either natural or synthetic) that can be spun, woven, or otherwise interlaced with other fibers as yarn to make fabric, as distinct from paper fibers, brush, and mat fibers.

texture loss
The creation of a flatter surface texture as a result of the lining process, for example in paintings lined face down on a rigid surface. See also *impasto*.

thermoplastic
Capable of being softened and made to flow by heat (and pressure). The term is commonly applied to artificial resins and plastics that are resoftened by heating. See also *hot-melt adhesives*.

thread-by-thread tear mending
A method of repairing tears in a canvas support, by realigning and rejoining individual threads broken by the tear, or adding fibers of similar weight if portions of threads are missing, then reweaving the torn section together. Broken threads are usually butt-jointed with a sturgeon glue/starch paste adhesive. Often tension is introduced to close the tear if it has opened (see *Trekker* entry), although tears are often repaired before any planar distortions are addressed. The method was developed by Winfried Heiber in the early 2000s and has been widely adopted.

time-temperature superposition
A principle used to determine temperature-dependent mechanical properties of viscoelastic materials using a reference temperature.

transfer
Removal of the support from the reverse of the paint and ground layers and subsequent mounting of these on a new support. Historically carried out when the condition of the canvas or panel has deteriorated so much that it cannot be further consolidated. In some cases, the ground is removed where it is in bad condition and a new ground is applied to the reverse of the paint film. This method was practiced widely in France from the middle of the eighteenth century, when many panel paintings were transferred to canvas, but was in use much earlier in Italy.

Trekker/Trecker
Introduced into use by Winfried Heiber, a device usually clamped onto the bars of a working stretcher with attached tensionable lines used to draw tears together before and during mending.

turpentine
A term originally applied to the balsams or oleoresins but now commonly used for the volatile liquid obtained from their distillation. The distillate is a mixture of various closely related hydrocarbons known as terpenes. When freshly distilled and pure it is a clear volatile liquid (boiling point 150°C–180°C) with characteristic odor. Widely used as a thinner or solvent for varnishes and adhesives.

twill
A weave type or binding system based on a unit of three or more warp threads and three or more weft threads. Canvases woven in the various kinds of twill (zigzag or chevron, herringbone, diamond) have frequently been used as paint supports by artists; use of twills as lining supports is rare.

twist
To obtain a continuous strand of fibers suitable for weaving, it must be twisted. The twist is the number of turns per unit of length; the product of this twisting is yarn. See also *yarn*.

vacuum
A pressure that is less than the surrounding atmospheric pressure. Essentially it is a difference in pressure, or differential, that can be used to do work.

vacuum envelope
The system has since been applied to the lining of canvas paintings. An envelope of plastic sheeting encloses both the painting and lining support, which are thus held together under vacuum pressure during the lining process. An external heat source and vacuum extraction points may also be incorporated. The method aims to minimize changes in surface texture by allowing the lining canvas and lining surface to conform to the reverse texture of the painting, rather than pressing it through to the paint surface. In this way lining pressure can be balanced, although the degree of tensioning of the lining canvas will affect this. The system allows full observation of both sides of the lining sandwich throughout the process, and rapid heating and cooling. First tested in 1964 in New York for the treatment of paint cleavage on panel paintings.

vacuum hot table
A hot table equipped with a membrane and vacuum pump that utilizes atmospheric pressure to hold the painting and relining canvas in close contact during the lining process. Air is withdrawn by breathers laid around the painting and through ports let into the table surface. A hot table was developed by Stephen Rees Jones at the Courtauld Institute in 1948 and the use of a vacuum to introduce pressure was added soon after.

vacuum pump
A mechanical device for withdrawing air to create a partial vacuum. Pressure is measured by a gauge calibrated in inches or millimeters of mercury. Readings should, strictly speaking, vary from 760 mm Hg (no vacuum) to 0 mm Hg (total vacuum), but they are often quoted in the reverse way as the apparent external pressure on the system.

Venice turpentine
The balsam obtained from the European larch, once widely used as a plasticizer and tackifier in lining adhesives.

vinyl resins
Thermoplastic synthetic polymers of the general formula (–CH=CH2). Four types of vinyl resins have found use in conservation as adhesives are (1) Ethylene vinyl acetate copolymers: synthetic resins in which the polymer chains contain both ethylene and vinyl acetate monomer units. They are available in a variety of grades of differing molecular weight and vinyl acetate content; these factors govern the strength and solubility properties of the resin. They are generally soluble in less polar solvents than polyvinyl acetate—in aliphatic hydrocarbons or mixtures of aliphatic and aromatic hydrocarbons—and are also available as emulsions. Grades with a vinyl acetate content greater than 25% have been found to exhibit cross linking in aging tests. They are used in solvent-applied heat-seal adhesives. (2) Polyvinyl acetate (PVA) synthetic resin is available in a range of grades of increasing degree of polymerization. Properties include stable to light; no evidence of cross linking; some tendency to swell in water; soluble in aromatic hydrocarbons, ketones, esters, and lower alcohols, but insoluble in aliphatic hydrocarbons. Viscosity of solutions, mechanical strength, and softening point (60°C– 200°C) increase with increasing degree of polymerization. PVA has been widely used as an adhesive in conservation in solvent types, heat-seal adhesives, and the well-known emulsion glues. Unlike wax-resin and other

adhesives, its low refractive index means it does not appreciably stain porous substrates. (3) Polyvinyl alcohol, a water-soluble synthetic resin. It has good light stability and retains solubility after drying. Weak solutions, but not films, tend to deteriorate and lose cohesion. The degree of hydrolysis and polymerization govern ease of solution and film strength, the latter being also dependent on humidity. Polyvinyl alcohol is a possible component of aqueous lining adhesives but is more often used for paper and textiles and is a common stabilizer for PVA emulsions. (4) Polyvinyl acetals (especially polyvinyl formal and polyvinyl butyral). Thermoplastic synthetic polymers obtained from polyvinyl alcohols by partial reaction with formaldehyde, acetaldehyde, and butyraldehyde respectively. They are available in various grades depending on degree of polymerization and polyvinyl alcohol content. They have good stability to light and form tough films varying from rubbery (the butyrals) to hard (the formals). The acetals and butyrals are soluble in aromatic hydrocarbons, alcohols, and acetone. The formals have limited solubility.

viscoelastic
Viscoelasticity is the property of materials that exhibit both viscous and elastic characteristics when undergoing deformation. Synthetic polymers, wood, and human tissue, as well as metals at high temperature, display significant viscoelastic effects.

viscosity
(1) The frictional forces within a fluid influencing its rate of flow. (2) The resistance to relative motion inside a liquid or gas. The coefficient of viscosity is a measure of the difference in flow between two adjacent layers of moving fluid.

warp
Parallel threads, stretched lengthwise on loom before a fabric is woven. The weft threads cross through the sheet of warp threads. The selvage runs parallel to the warp threads. See also *weave*.

warping, of canvas or stretcher
Crooked state produced by uneven expansion or contraction.

waxes
A term often applied to organic, solid, nongreasy, hydrophobic substances that melt at fairly low temperatures. The waxes, such as beeswax, are composed chiefly of esters of fatty acids with higher alcohols, together with free alcohols, acids, and hydrocarbons. The waxes of mineral origin consist of mainly higher paraffin hydrocarbons and include paraffin waxes, microcrystalline waxes, and ceresin. The perceived moisture impermeability and stability of waxes led to their widespread use in the treatment of paintings.

wax-resin adhesives
Hot-melt adhesives once widely used in lining, most commonly composed of beeswax with up to 40% natural or synthetic resin and other additives such as paraffin wax, gum elemi, and/or Venice turpentine.

wax-resin lining
A lining procedure using wax-resin adhesive. When heated, wax-resin flows readily and penetrates porous materials. It has some resistance to moisture. The technique was commonly used in Holland from the mid-nineteenth century and linings from this time survive in good condition. It was widely used up to the 1970s when adhesives were developed to address the serious drawbacks of the procedure, such as its overall penetration when heated into the canvas and paint structure, its capacity to darken porous substrates by saturation and to make some paint films more soluble to solvents.

weave
(1) To make a fabric by interlacing threads or yarn. (2) The binding system of crossing, interlaced warp and weft threads, characterized by overall design and type of weaving unit: tabby, twill, satin, or variations of these three. See also *warp* and *weft*.

weave emphasis
Accentuation of the weave texture of a fabric. Usually a result of lining under vacuum pressure, caused by the exertion of one-sided pressure against the flat, rigid surface of the lining table. The effect can occur in both lining and painting canvases and may combine to a greater or lesser extent. The paint suffers vertical distortion, adopting the accentuated texture of the underlying fabrics.

weave interference patterns
Wave patterns caused by the superimposition of the weave of the original canvas and the new weave of the lining canvas. These effects may be reduced or eliminated by placing a suitable interleaf or surfacing veil between the canvases, by using canvases of dissimilar weave, or reducing the pressure used in lining.

wedge
See *key*.

weft
The crossing threads that are woven into a sheet of warp threads to form a continuous fabric. The compactness of the fabric will be determined by the number of warp and weft threads per measured unit (thread count), by the fineness of the yarns, and the weave type. See also *warp*.

wet strength tissue
A thin, nonwoven plant fiber tissue that retains cohesive strength when wet. Often used in facing applications.

wetting agent
A particular type of surfactant that increases spreading of a liquid (usually water) in contact with a solid. Detergents are an example, and act by lowering the surface tension of the water.

whipstitch
A sewing stitch that joins two pieces of fabric by spiraling around both pieces' edges.

white spirit
See *mineral spirits*.

working stretcher
A stretcher or strainer used during the conservation treatment phase for keeping the canvas under tension. Sometimes used during lining, where the lining canvas may also be attached to a working stretcher.

wrinkling
A pattern of small creases on the paint surface on a macro scale can be caused by the use of too much heat during lining. It may occur locally or totally.

xylene
Dimethylbenzene, an aromatic hydrocarbon with solvent properties.

yarn
A continuous strand of textile fibers made by spinning or twisting or otherwise binding. It is characterized by twist, direction of twist, and fineness. The fineness is measured in terms of mass per unit length (the unit is denier) and is the most common system today for measuring all kinds of yarns, filaments, and fibers.

yield point
The point on a stress-strain curve when a material loses elasticity and becomes plastic.

Young's modulus
Quantifies the relationship between tensile stress σ (force per unit area) and axial strain ε (proportional deformation) in the linear elastic region of a material.

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