

Objects
Specialty Group

Article: Structural Repair of Plaster Sculpture Using Polyvinyl Butyral Resin
Author(s): L. H. (Hugh) Shockey Jr.
Source: *Objects Specialty Group Postprints, Volume Twenty-Four, 2017*
Pages: 136–146
Editors: Emily Hamilton and Kari Dodson, with Tony Sigel Program Chair
ISSN (print version) 2169-379X
ISSN (online version) 2169-1290
© 2019 by American Institute for Conservation of Historic and Artistic Works
727 15th Street NW, Suite 500, Washington, DC 20005 (202) 452-9545
www.culturalheritage.org

Objects Specialty Group Postprints is published annually by the Objects Specialty Group (OSG) of the American Institute for Conservation (AIC). It is a conference proceedings volume consisting of papers presented in the OSG sessions at AIC Annual Meetings.

Under a licensing agreement, individual authors retain copyright to their work and extend publications rights to the American Institute for Conservation.

Unless otherwise noted, images are provided courtesy of the author, who has obtained permission to publish them here.

This article is published in the *Objects Specialty Group Postprints, Volume Twenty-Four, 2017*. It has been edited for clarity and content. The article was peer-reviewed by content area specialists and was revised based on this anonymous review. Responsibility for the methods and materials described herein, however, rests solely with the author(s), whose article should not be considered an official statement of the OSG or the AIC.

STRUCTURAL REPAIR OF PLASTER SCULPTURE USING POLYVINYL BUTYRAL RESIN

L. H. (HUGH) SHOCKEY JR.

This article will focus on the design and use of an adhesive system for the structural repair of plaster sculpture. The parameters influencing adhesive system design and the choice of polyvinyl butyral resins as a consolidant will be explored, including methods for dealing with prior adhesive repairs, the issue of plaster's structural strength, controlled reversibility, and planned stress relief. These topics will be illustrated through the presentation of a case study of the treatment and retreatment of a painted plaster sculpture over the course of 10 years. The information presented will be applicable to the treatments of conservators working with plaster in a variety of formats, including hollow cast, solid cast, modeled, and architectural applications.

KEYWORDS: Plaster, Calcium sulfate dihydrate, Sculpture, Adhesive, Polyvinyl butyral resin, Butvar, B-76, B-98

Calcium sulfate dihydrate, gypsum, plaster of Paris, or just plaster, all are names to describe a widely used material for the creation of art throughout history. Whether used as part of the modeling process for a sculpture rendered in a different final material or the primary constituent of a finished sculpture, it is a material frequently used by artists. My own experience with plaster—from "coloring" on a classmate's cast in grade school to any number of cast, carved, dripped, and molded "experiments" in a college studio class—gave me an understanding of its versatility and low cost, perfect for an artist's needs. As a conservator, I've learned much more about plaster as a material from its seeming solid durability to its incredible fragility and susceptibility to both surface and structural damage. Plaster also presents a number of treatment problems that haven't always had satisfying solutions. My own search for a better solution for structural repair began when confronted with the evidence of several previous repair campaigns to Ferdinand Pettrich's *Washington Resigning His Commission* of 1841, a faux-bronzed plaster in the collection of the Smithsonian American Art Museum (fig. 1).

My treatment of Pettrich's sculpture included mending the broken right hand with outstretched scroll. This was not the first time that the area had been damaged or treated—far from it, as evidence from the sculpture's conservation record would illustrate. The history of damage and repair dated far into the past, with numerous episodes of damage followed by repair. One of the better documented interventions from the late 1960s is described and illustrated as an extensive treatment, necessitated by damage done to the sculpture while on display, that included the remodeling of two fingers on the hand in addition to rejoining the scroll and finger portion with the upper hand at the palm (fig. 2). The file also contained documentation of additional repairs, always to the same break across the palm, with different adhesives over the course of 50 years. The record and the evidence in the break line indicated that, in addition to more reversible natural and synthetic adhesives, less easily reversible polyvinyl acetate emulsion and epoxy had been tried. Looking closely at the break faces, it was possible for me to see a variety of surface conditions related to the prior interventions (fig. 3). The conditions I observed included: areas where a prior adhesive remained adhered to one of the break faces that had a thin layer of plaster over the surface apparently pulled from the opposite face; areas where a mass of adhesive with a smooth glossy surface was well adhered to only one face, suggesting no actual contact with both break faces; and areas of gloss with filled-in surface topography that suggest the application of a resin and solvent mixture that may have been used to mend, consolidate, or seal the surface. In all, the surfaces before me could be described as heterogeneous in nature, no longer just plaster, but soft porous plaster with a menagerie of other materials scattered over its surface.

While contemplating the treatment of the sculpture, I had the good fortune of being invited to a workshop on adhesives jointly taught by Peter Sparks and Richard Wolbers (fig. 4) at the Winterthur



Fig. 1. Ferdinand Pettrich, *Washington Resigning His Commission*, ca. 1841, painted plaster, 86 × 48 1/2 × 36 3/8 in. (218.3 × 123.2 × 92.3 cm), Smithsonian American Art Museum, Gift of the Artist, XX35 (Courtesy of the Smithsonian American Art Museum)

Museum, Garden and Library in January 2006. It was during this workshop that I began to think of alternative paths to mend the damage to the Pettrich sculpture. The workshop provided a review and distillation of adhesive science, coupled with benchtop testing methods, and a decision-making framework to assist practicing conservators in thinking more strategically when making adhesive selections for what are often less than ideal adherend and adhesive variables.

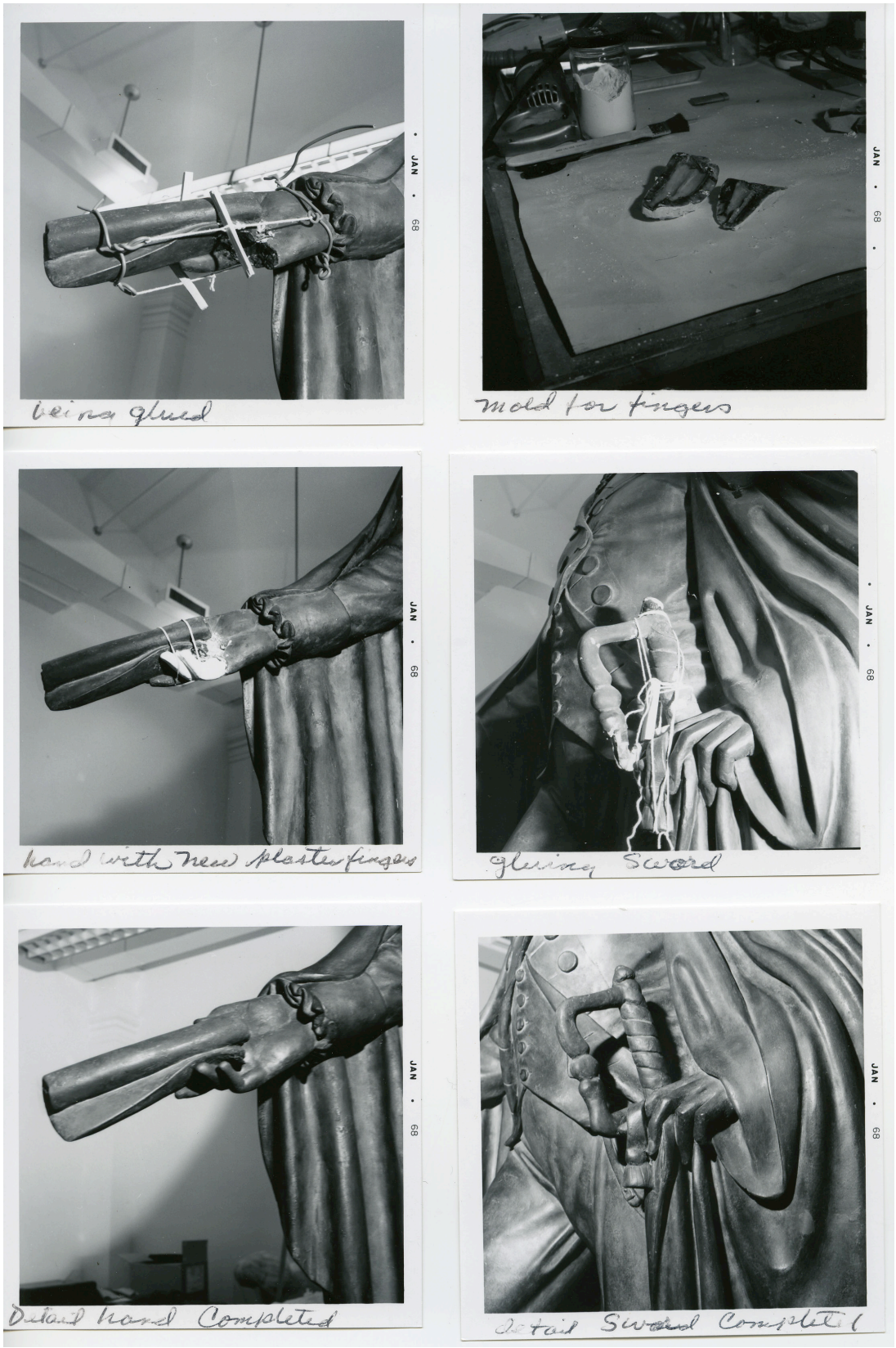


Fig. 2. Images from the conservation file for *Washington Resigning His Commission* showing the stages of treatment in 1968 (Courtesy of the Smithsonian American Art Museum)



Fig. 3. The break face of the scroll and finger fragment from *Washington Resigning His Commission* with a variety of adhesive residues and previous repairs

In addition to providing a review of adhesives used in conservation, the workshop helped me think more about what I am actually doing when I choose an adhesive—beyond being reversible, solvent compatible, and strong enough for the repair. I began to think more about the surface properties of the adherend, how it can be modified, and how its interface with the adhesive can be manipulated. How does this relate to the treatment of Pettrich's sculpture? The previously described menagerie of surface materials on the break faces presents a challenge to a single adhesive system because it requires the selected adhesive to match the surface energies of each material on the surface. Should the selected adhesive match the surface energies (attracted to versus repelled by) of a heterogeneous adherend (the face of a break with mixed

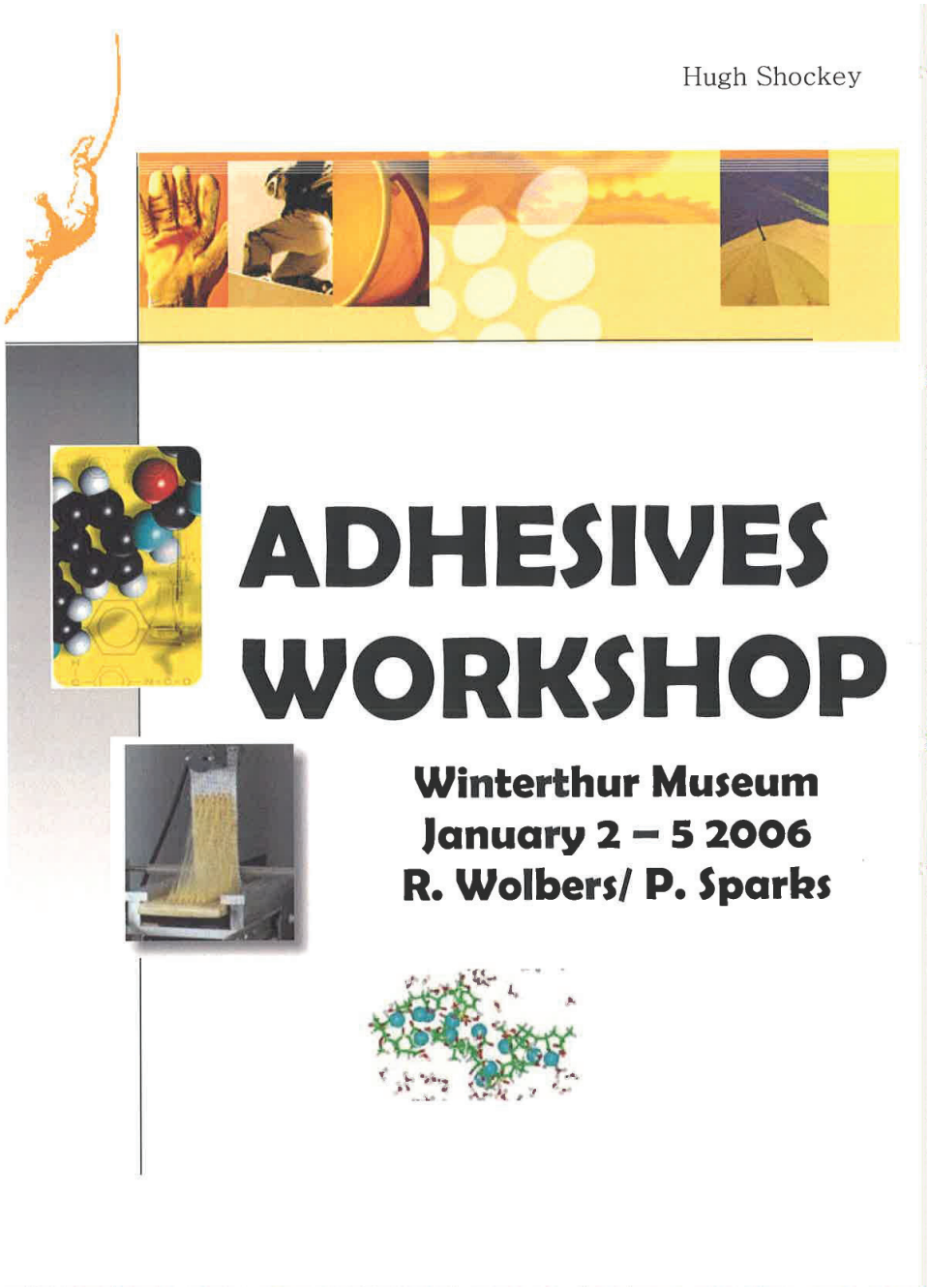


Fig. 4. Adhesive workshop notebook cover; the contents included articles and references on adhesive properties established through testing, adhesive science and theory, case studies on adhesive use, and evaluation methodology for use in treatment.

surface types), the bond energies between each of the materials of the surface are certain to be different (e.g., adhesive A will have a different affinity for surfaces 1, 2, and 3 if all surfaces are different materials chemically), resulting in areas of high and low bond strength. In the workshop, I learned that choosing a broadly compatible secondary coating for application to a heterogeneous surface can have the effect of creating a homogeneous adherend surface for the application of the mending adhesive, effectively establishing a new unified surface for mending. If theory holds, application of the mending adhesive to the newly established homogeneous surface will tend to bond with equal force across the break. It was

with this advantage in mind that I began to think more seriously about designing a multi-adhesive system rather than choosing a single-adhesive solution to solve the problem of the mend surface being a mixture of historic plaster and previously applied and absorbed adhesives.

Pursuant to the idea of a multi-adhesive system, I began to look at the properties of the Butvar series of polyvinyl butyrals (PVBs) that, as a family of resins, offers a broad range of variability in formulation and considerable control of their physical properties in solution. I was introduced to the adhesive potential of PVB resins, the Butvar line specifically, during the workshop. It was interesting for me to learn that PVBs have been considered for use in archaeological conservation since the 1960s (Kostrov and Sheinina 1961). While many other common conservation adhesives were discussed, PVBs stuck in my mind as an intriguing possibility for the repair of plaster sculpture due to its mechanical properties and solvent-influenced viscosity.

Of the Butvar formulations available, both B-98 and B-76 drew my attention as possibilities for designing an adhesive system for repair of the Pettrich sculpture. At first glance, both resins have a wide range of solvent solubility, which suggests that they have the ability to wet onto and bond with a variety of materials. As I began to consider the problem further and compare the technical specifications of the two resins, a potential solution to the problems of the Pettrich sculpture took shape. Taking into consideration the sculpture's long history of damage and repair cycles, I shifted my thinking from how to make the strongest repair possible to how to create a repair that will fail under excess stress in a controlled way. My thought was that, by designing an adhesive system that would fail under excess stress, it would help prevent additional damage to the plaster body by relieving the stress at the bond line rather than deeper in the plaster body. The challenge with plaster is that it has very little tensile or shear strength, well below the adhesive strength of most resins. In thinking back on the idea of establishing a homogeneous adherend surface, I wondered whether it was not possible to pick a resin that could penetrate the surface and create a cohesively strengthened break face—a break face that is strong and tough enough that a weaker resin's adhesive strength would fail before its cohesive strength would. To add to the challenge, I also wanted the system to be retreatable and solvent reversible according to best practices.

Butvar B-98's use in conservation for the consolidation of porous archaeological materials with limited structural strength has been documented in the literature several times and has included evaluation of its aging characteristics and reversibility (Spirydowicz et al. 2001; Simpson 2003). As a penetrative consolidant, Butvar B-98 offers the advantage of a strong resin that has very low viscosity depending on the solvent selected for a solution. It is these properties that make it a good resin to consider for strengthening the porous crystalline matrix of plaster. Anecdotal evidence from benchtop testing suggests that the introduction of Butvar B-98 into the plaster matrix alters its physical characteristics, making it a tougher, more resilient material. The perceived result in treatment applications is that a plaster substrate infused with Butvar B-98 becomes more durable when handled with less powdering and loss on the soft, friable surfaces associated with a break, including improved handling of small fragments.

Butvar B-76 has been mentioned sparingly in the conservation literature when compared with Butvar B-98 (Davidson 2004). As a higher molecular weight sibling of B-98, B-76 has interesting properties for consideration as an adhesive paired with B-98. While B-98 and B-76 are both PVBs, the distribution of their alcohol, acetate, and butyral species occurs in different proportions along the polymer chain (Eastman Chemical Company 2017). Review of the manufacturer's properties data indicates that B-76's molecular weight is nearly twice that of B-98, which is likely related to the increased butyral content. This higher percentage of the bulky butyral structure also has an effect on the rheology of solutions made from the polymer. Looking again at the data, B-76 has more than twice the viscosity of B-98 at the same concentration in the same solvent (Eastman Chemical Company 2017). What I found most interesting

in my review of the properties was the comparison of tensile strength between B-76 and B-98. The test results clearly indicate that B-76 has a much lower yield and break strength than B-98. Even more interesting is that the upper threshold of B-76's results just meet or slightly overlap with the lowest threshold of B-98's performance (Eastman Chemical Company 2017).

In addition to the way the physical testing results align, the results of solvent solubility testing show that, depending on the solvent chosen, it is possible to dissolve or at least partially solubilize B-76 while only swelling or having no effect on B-98 (Eastman Chemical Company 2017). When I examined these properties together, B-76 began to look very good as the mending resin for the adhesive system I was hoping to formulate. In review, B-76 is adhesively compatible with B-98. Thus, it should bond to the surface with uniform strength; it can be formulated to have a high, but spreadable, viscosity so that it will stay at the bond line rather than migrate into voids or the pores of the plaster; it has a lower tensile strength than B-98 such that, in theory, when excess stress is applied it should fail cohesively along the bond line when B-98 is just beginning to be stressed; and, finally, B-76's bond can be undermined more readily than B-98's in select solvents commonly used in conservation should it become necessary to reverse or reactivate the adhesive bond in the future.

Following my investigation and identification of the potential resins I hoped to use for mending Pettrich's sculpture, I began benchtop testing. During the tests I was keen to understand how B-98 and B-76 would perform together and to arrive at optimal concentrations for the repair to carry it out successfully. Mock-ups were made using USG Hydro-Stone (a type of gypsum cement made by United States Gypsum) and Plaster of Paris found in the Smithsonian American Art Museum lab's stock. Each material was mixed in water to a creamy consistency and cast into aluminum sample trays, giving finished cast discs approximately 1.75 in. (4.45 mm) in diameter and 0.375 in. (9.53 mm) thick. I then broke the samples in half across their diameter with a chisel and hammer. Fragments of unsuccessfully split samples were used to evaluate the application and absorption of B-98 into the plaster surfaces.

Knowing that I wanted a very-low-viscosity solution with as high a solids content as possible, I chose methanol, despite its toxicity, as the carrier solvent for B-98. The penetrative consolidation treatments in the literature most often describe the use of toluene and ethanol mixtures or ethanol alone. However, review of the manufacturer's data clearly shows that at the same percent solids, B-98's viscosity is significantly lower in methanol than in mixtures of ethanol and toluene or ethanol alone (Eastman Chemical Company 2017). I tested a number of concentrations on the plaster fragments and evaluated the surface for visible change and the presence of a film. Concentrations (all w/v) from 1% to 5% showed no perceptible change on the matte plaster surface, even on the very-low-porosity Hydro-Stone samples. Concentrations from 5% to 10% would begin to show film formation on the surface depending on the porosity of the sample, and concentrations above 10% formed a surface film quickly.

Having established some idea of how to deliver the penetrative consolidant and at what concentration, I moved to consider B-76 for the mending adhesive. In thinking about formulating the B-76 solution, I settled on ethanol as the solvent since the data indicated that it would create a workable viscosity for controlled application. I conducted simple benchtop testing on the strength of the B-76 bonded samples by clamping one-half of the broken sample to the work bench, with the break line parallel to the bench's edge, and then applied force with my hands and upper body to the other side. Two things became quickly apparent: concentrations (w/v) of B-76 below 10% are not suitable for structural repair of large plaster sculpture, and the improvement in bond performance between the samples with B-98 applied and those without was glaringly apparent. While B-76 would bond to the untreated plaster surface and could hold the

two halves of a sample together, it did not perform in a way that I would consider serviceable, as it took very little applied force to cause failure of the join. Further testing found that concentrations between 20% and 25% offered the best balance of strength and handling. Samples mended with concentrations of B-76 within that range, when applied to surfaces pretreated with B-98, were sturdy enough to handle with normal care but would yield and fail under excess force without significant damage along the bond line. Concentrations above 25% became very viscous and were bulky in the bond line.

When I considered the results of the testing anecdotally, it was clear that for my needs a multipart adhesive system performed better than a single adhesive alone. Given the substrate and the solvent used, a number of factors could be contributing to the results. Since the depth of penetration for the B-98 was not measured, it is difficult to claim to what extent the resin provides reinforcement of the plaster matrix. However, it is clear that pretreating the surface of the break face helped improve bonding with the mending adhesive. Having observed minimal damage to the break faces of the samples after causing failure of the adhesive bond suggests, to me, some degree of penetration and cohesive distribution in the pores of the plaster must occur. If not, I would otherwise expect to see large areas where the dried resin had pulled away from plaster completely or cleaved a thin layer of adjacent plaster from the surface.

In considering the performance of the B-76 resin as an adhesive, I was pleased to see that it behaved very much as predicted. The B-76 solution was compatible with the B-98 treated surfaces, helping the system achieve uniform bond strength. Its higher viscosity helped it remain on the surface of the break face, and its sufficient but not excessive strength demonstrated good yielding properties before causing damage to the surrounding area. Its poor performance bonding to untreated plaster surfaces may be due to the bulkier molecules' tendency to stay on the surface as well as the porous plaster substrate's ability to wick away solvent, starving the join and reducing the resin's ability to bond with the surface.

While benchtop testing confirmed the hypothesized performance, there are a number of alterations that I would incorporate into future sample preparation and evaluation. These include greater aeration of the sample mixture to reflect historical plaster densities and the addition of a visible light or UV visible marker to the solution to better gauge distribution across and into the substrate.

In practice, using the B-98 and B-76 adhesive system is no different than adhesive mending of the many other types of materials that an object conservator might encounter in a museum collection. It is critical to consider sequence and timing for the application of the resin solutions. As the penetrative solution, B-98 is applied to the surface of break faces first and allowed to set for 12 to 24 hours. Application of the solution is easily accomplished by flowing from a brush or hypodermic syringe fitted with a 20- to 28-gauge needle. The B-76 solution should be applied liberally to all pretreated break edges just prior to assembly and clamping since ethanol's evaporation rate from the film gives it a short open time. Delay in joining may cause an increase in viscosity of the solution, which can result in an overly thick bond line. Once assembled, the mends should stay clamped and unstressed for a minimum of 24 hours; longer is advisable. Removing clamps from a mend prior to complete setting of the B-76 resin will likely result in join opening or failure, as the resin does not reach full mechanical strength until set. Application of the B-76 solution is best done with a moderately stiff bristle brush and the surface should be liberally covered on all break faces such that some excess adhesive will ooze from the break line. The oozed excess can be removed using mechanical or solvent methods depending on the finished surface of the plaster.

For the treatment of Pettrich's sculpture, I undertook a more tailored approach, with intermediary steps. In an effort to get deep penetration into the already compromised plaster body of the sculpture, I saturated the plaster with methanol just prior to wicking a 5% (w/v) concentration of B-98 in methanol

onto the surface of the exposed plaster and around all areas of previous repair. After allowing the adhesive and solvent-saturated surface to dry, I followed by wicking and brushing a 10% (w/v) solution onto the surface to more strongly reinforce the plaster matrix at the break edge. This was followed by a brush application of 20% B-98 (w/v) overall, including over old repairs and a menagerie of adhesive deposits to establish a homogeneous break face. After the B-98 set, I applied a 10% (w/v) solution of B-76 in ethanol to the area of the break faces overall to ensure that the B-76 mending resin would bond well with the B-98 during assembly and clamping. Once the coating set and the parts were ready for assembly, I used a 25% (w/v) solution of B-76 in ethanol applied liberally by brush to the break faces to complete the mend. Excess adhesive was removed from the surrounding surfaces with mechanical and solvent methods as necessary. I clamped the mend with self-adhering silicone tape (fig. 5) and allowed it to set for two days, checking in frequently during the first few hours to ensure that there was no drift in alignment after clamping and to clean up any additional residues surrounding the break line. After the setting period, the clamping tape was removed to reveal a stable mend. The remainder of the overall treatment included compensation for loss of the plaster body and surface coating.

At this point, I believe that most articles on treatment come to a conclusion, but mine does not end just yet. Recalling my previous thoughts on designing a mend that would fail controllably if too much force was applied, there remains the question of how the theory holds up in practice. Well, no thanks to my own head's accidental collision with the outstretched scroll, I can report that the system performs beautifully! The force of the collision at the end of the scroll was enough to pop open the break line across the palm. It disrupted the soft fill material and acrylic emulsion paint film on the surface, but there was no visible loss or fragmentation of plaster along the break faces. This unfortunate good fortune also gave me the opportunity to assess the retreatability of the repair, which I found to be easily undertaken by removal of loose fill material and a new application of a B-76 solution to the break faces clamped as before. Losses along the break line were again filled and inpainted to match the surrounding area. The story of failure and retreatability does not stop at this incident. The sculpture was "damaged" at least



Fig. 5. The joint clamped for curing

twice more by inappropriate visitor interaction over the course of 10 years and each time successfully retreated.

Having now worked with Butvar B-98 and B-76 regularly over the last 10 years, I can offer a few tips for the new user. When using either B-98 or B-76 with fast-evaporating solvents such as methanol and ethanol, it is wise to have a neat solvent at hand to clean your chosen applicator regularly, as not doing so will likely result in the gumming up of your tool. If you are attempting to consolidate very friable or porous material with a low-resin concentration, a syringe often offers more control and continuous feed as an applicator without the problem of evaporative concentration change. Cleanup of thickly applied B-76 that oozes out of the break line is actually easier to remove in bulk if it is allowed to dry to the consistency of a thick-bodied caulk. Cleanup of oozed B-76 is also aided by a light application of chalk or talc to the areas around the break line if the surface is compatible, allowing for the removal of fine particulate from the surface. High concentration solutions of Butvar that appear thick when applied, generally dry down to thin, compact films—that thick bond line will shrink tight as the resin sets. As an adhesive and consolidant, Butvar does not reach full strength until its carrier solvent has completely evaporated from the film. When in doubt, wait to test the strength of the mend or remove the clamps. Both B-98 and B-76 are strongly reactive to water, and not in a beneficial way: contact with excess moisture can cause the resin to drop out of solution in opaque, ropey strands. If you experience problems with surface "whitening" of methanol solutions, confirm that your solvent has not absorbed atmospheric moisture.

In conclusion, I hope that I have provided an option for structurally mending plaster sculpture that the practicing conservator can use and a window into the method I followed for evaluating the manufacture's data to predict performance. I chose to highlight treatment of the sculpture that challenged me to think a little more broadly, but it is by no means the only plaster sculpture that I have used the adhesive system described in this article to mend. The combination of Butvar B-98 as a penetrative consolidant and B-76 as a mending adhesive has, in my opinion, proven successful for the structural repair of plaster. In my experience, it has proven to be adaptable in scale and provides serviceable strength. The anecdotal evidence in the treatment history of Ferdinand Pettrich's *Washington Resigning His Commission* suggests that the system may also offer support for alternative perspectives on how mends should perform. I think that confirming our understanding of the forces at work in the system by analytical means is worthwhile and lacks only the interested researcher with the necessary resources available. The data would be particularly useful if paired with statistical research into the characterization of plaster densities correlated to location and historical period. For the practicing conservator considering or attempting to use the system as described, I encourage you to conduct your own benchtop tests since—in the parlance of our time—your mileage may vary.

ACKNOWLEDGMENTS

Peter Sparks
Richard Wolbers

REFERENCES

Eastman Chemical Company. 2017. *Butvar Polyvinyl Resins: Properties and Use.* Kingsport, TN: Eastman Chemical Company.

Davidson, Amy. 2004. "Preparation of a Fossil Dinosaur." *Objects Specialty Group Postprints, Volume Ten, 2003.* Washington, DC: American Institute for Conservation of Historic and Artistic Works (AIC). 49–61.

Kostrov, P. I., and E. G. Sheinina. 1961. "Restoration of Monumental Painting on Loess Plaster Using Synthetic Resins." *Studies In Conservation* 6 (2-3): 90–106.

Simpson, Elizabeth. 2003. "The Conservation of the Wooden Objects from Gordion, Turkey: Methods for the Treatment of Dry Archaeological Wood." In *Art, Biology, and Conservation: Biodeterioration of Works of Art*, edited by Robert J. Koestler. New York: Metropolitan Museum of Art. 358–369.

Spirydowicz, Krysia E., Elizabeth Simpson, Robert A. Blanchette, Arno P. Schniewind, Mauray K. Toutloff, and Alison Murray. 2001. "Alvar and Butvar: The Use of Polyvinyl Acetal Resins for the Treatment of the Wooden Artifacts from Gordion, Turkey." *Journal of the American Institute for Conservation* 40 (1): 43–57.

FURTHER READING

Pizzi, A., and K. L. Mittal. 2003. *Handbook of Adhesive Technology*. Boca Raton, FL: CRC Press.

Skeist, Irving, ed. 1990. *Handbook of Adhesives*. New York: Springer.

SOURCES OF MATERIALS

Butvar B-76 and B-98
Talas
330 Morgan Ave.
Brooklyn, NY 11211

High-Temperature Self-Adhering Electrical Tape
McMaster-Carr
200 New Canton Way
Robbinsville, NJ 08691-2343

USG Hydro-Stone Gypsum Cement
United States Gypsum Company
Industrial Products Division
550 West Adams St.
Chicago, IL 60661

L. H. (HUGH) SHOCKEY JR. MS, AIC-PA is the head conservation and object conservator at the Saint Louis Art Museum. He was previously the objects conservator at the Lunder Conservation Center of the Smithsonian American Art Museum, where he performed treatment on electronic media and modern and contemporary works in addition to the vast variety of materials in the American Art collection. He is a graduate of the Winterthur/University of Delaware Program in Art Conservation and is past president of the Washington Conservation Guild. He has worked in the collections of the National Museum of American History, the National Museum of the American Indian, the National Park Service, the Los Angeles County Museum of Art, and Elvis Presley's Graceland. Address: One Fine Arts Dr. Saint Louis, MO 63110. E-mail: hugh.shockey@slam.org