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The Conservation Study of a Funeral Coat of Arms (*huvudbaner*) with a Focus on Cleaning and Consolidation

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——— The cleaning and consolidation of egg white tempera were evaluated to help conserve a polychrome sculpture, the funeral coat of arms of Pehr Stålhammar, dated 1701. This coat of arms was a wooden structure of carved pine and lime wood, grounded with a chalk and rabbit skin glue ground layer, and polychromed with egg white tempera in combination with smalt blue, lamp black, and red pigments.

Due to the difficulties of preserving the physical properties of egg white tempera, it was necessary to evaluate the consolidation effects in terms of color, gloss, and cohesion. Four consolidants were chosen: JunFunori, sturgeon glue, Aquazol 200, and Lascaux's Medium for Consolidation. Among these, Aquazol 200 and JunFunori performed more efficiently.

Another type of difficulty occurred during the conservation cleaning treatment process, especially with the blue paint, which is more fragile and has hydrophobic qualities. To conceive a safe cleaning method, various cleaning techniques and materials were tested with a microscope, scanning electron microscopy, and an artificial aging chamber. The investigation showed that the dry cleaning method and use of hydrogels could work together and target different tasks.

Keywords: water-sensitive, egg white tempera, hydrogels, consolidation, smalt blue, lamp black.

1.
Huvudbaner (funeral coat of arms) of Pehr Stålhammar before conservation treatments, photo by Rosberg, Pierre / Kalmar läns museum

Introduction

A *huvudbaner*, as it is known in Sweden, is a sculpted coat of arms marking a noble person's status at the time of their funeral. This one belonged to Pehr Stålhammar, a military officer born in Småland in 1613,[1] dated 1701 after his death [fig. 1]. The Kalmar Museum acquired the banner in 1935 from Carl Adam Stålhammar's estate.[2]

The object was in critically deteriorated condition and needed immediate conservation. The materials used for its construction were very fragile and made it challenging to preserve, especially the smalt blue and lamp black. This article aims to answer the following questions:

- What is an appropriate method to use for conservation cleaning treatment on a polychrome sculpture, and why?

- Which of the selected consolidation materials is more efficient on the consolidation of the polychrome sculpture?

The aim, therefore, is to determine the cleaning materials that are safe to apply on the hydrophilic egg white tempera paint and the consolidation materials that can perform more efficiently on the egg white tempera. It was specified upon examination that the unvarnished egg white tempera paint layers on the funeral coat of arms (KLM 014946) required special attention, particularly the areas with blue paint.

Analysis of the material

As a first step, the materials used in the coat of arms were investigated using Fourier transformed infrared spectroscopy (FTIR), X-ray fluorescence (XRF), and cross-sections of ultraviolet (UV) and infrared (IR), and it was found that:

The ground layer binding medium is rabbit skin glue, the filler in the ground layer is chalk, the paint layer binding medium is egg white, the black pigment is lamp black, and the blue pigment is smalt blue[3] [fig 2].

1 Lars-Olof Larsson, *På marsch mot evigheten: svensk stormakstid i släkten Stålhammars spegel* (Stockholm: Prisma, 2017).

2 "Digital Museum: Kalmar läns museum", *Begravningsvapen KLM 14946* (October 2020), https://digitaltmuseum.se/021027912771/begravningsvapen.

3 Angela Caira, *Evaluation of the effects of four consolidants on matte paint and their ageing* (master's thesis, Institutionen för kulturvård, Göteborg: Göteborgs Universitetet, 2021), 11–14.

2.
Diagram of a cross-section of the polychrome sculpture, illustration by Angela Caira, 2021

Review

The first stage in cleaning procedures is based on removing superficial dirt with dry cleaning methods. On this topic two studies were found which probed their results on water-sensitive and mechanically sensitive surfaces. The articles providing dry-cleaning evaluation were "Conservation of Contemporary Painting: A Comparative Study of the Effect of Dry Cleaning Techniques" by Golle[4] and "Dry Cleaning Approaches for Unvarnished Paint Surfaces" written by Daudin-Schotte, Bisschoff, Joosten, van Keulen, and van den Berg.[5]

After studying the qualities of the dry cleaning method, the next stage was to look at the aqueous materials. It was resolved to use rigid gels to avoid mechanical actions and proceed with safer steps in cleaning treatment. This aqueous approach was developed 30 years ago and is suitable for polychrome artifacts.[6] To avoid using water in its free liquidform, it is made viscous by adding a gelling agent and providing a more controlled application. Water is a physical solvent and tends in its pure form to create damage and undesirable effects on painting films.[7] The article "Rigid Gels and Enzyme Cleaning" refers to gel types like Klucel, xanthan gum, Carbopol, and Pemulen-TR2. Those gels prevent water release, but they have the significant disadvantage that they require the gelling residues to be rinsed.[8] Moreover, the authors of the article tested the most used gel, agar-agar, and

4 Karen Golle Cordova, "Conservation of Contemporary Painting: a Comparative Study of the Effect of Dry Cleaning Techniques", *Science and Arts*, no. 17 (2017).

5 Maude Daudin-Schotte, Madeleine Bisschoff, Ineke Joosten, Henk van Keulen, and Jan van den Berg, "Dry Cleaning Approaches for Unvarnished Paint Surfaces", in *New Insights into the Cleaning of Paintings: Proceedings from the Cleaning 2010 International Conference, Universidad Politecnica de Valencia and Museum Conservation Institute* (Washington DC: Smithsonian Institution, 2013), 209–219.

6 Paolo Cremonesi, "Rigid Gels and Enzyme Cleaning", in *New Insights into the Cleaning of Paintings: Proceedings from the Cleaning 2010 International Conference, Universidad Politecnica de Valencia and Museum Conservation Institute* (Washington DC: Smithsonian Institution, 2013), 179–183.

7 Ibid.

8 Ibid.

their analytical examination proved that this gel does not transfer residues onto the porous paint surface.[9]

This study selected different hydrogels, and half of them contained poly(vinyl alcohol) as a component. The properties of poly(vinyl alcohol) were studied as a hydrogel base in an article called: "Poly(vinyl alcohol)/poly(vinyl pyrrolidone) hydrogels for the cleaning of art." The research was focused on several aspects, such as viscoelastic properties, porosity, crystallinity, and the behavior of water inside the polymeric network in the gel liquid.[10] The examination to observe the residue issue was performed with FTIR. The polivinilpirrolidone (PVP) component was not found between the 1705 and 1641cm^{-1} range, and poly(vinyl alcohol) (PVA) can be found on the stretching (C-O), but no peaks indicating this material at 1664 cm^{-1} or 1904 cm^{-1} were detected.[11]

Speaking of poly(vinyl alcohol) in combination with poly(vinyl pyrrolidone), a Nanorestore gel® Peggy 5 and Nanorestore gel® 6 with a (PVA) component were created.[12] The research "Reviving WHAAM! a comparative evaluation of cleaning systems for the conservation treatment of Roy Lichtenstein's iconic painting" tested both Nanorestore gel® types on the water-sensitive surfaces by using them to remove soil and dust. The result showed that Nanorestore gel® Peggy 6 was a more successful treatment with the addition of triammonium citrate (TAC).[13] This result is particularly interesting because the physical hydrogel Nanorestore gel® 5 with the two components provides enhanced retention of liquid, which could provide a potentially better result. However, when evaluating dirt removal efficiency, Nanorestore gel® Peggy 6 achieved superiority.[14, 15]

9 Ibid.

10 Nicole Bonelli, Giovanna Poggi, David Chelazzi, Rodorico Giorgi, and Piero Baglioni, "Poly(vinyl alcohol)/poly(vinyl pyrrolidone) hydrogels for the cleaning of art", *Journal of Colloid and Interface Science*, vol. 536 (2019): 339–348.

11 Ibid.

12 Angelica Bartoletti, o. a. "Reviving WHAAM! a comparative evaluation of cleaning systems for the conservation treatment of Roy Lichtenstein's iconic painting", *Heritage Science*, no. 8, 9 (2020): 1–30.

13 Ibid.

14 Ibid.

15 The Nanorestore gel® Peggy 6 qualities were also mentioned in the article "Removing Ingrained Soiling from Medieval Lime-based Wall Paintings Using Nanorestore Gel® Peggy 6 in Combination with Aqueous Cleaning Liquids", *Studies in conservation*, vol. 65 (2020): 284–291, doi:org/10.1080/00393630.2020.1790890.

The investigation in this study proved a good cleaning efficiency with Peggy 6 hydrogel even when loading it with (TAC) or Apolar Coating (ApC).[16]

The gel structure and characteristics of Nanorestore gels® were described in the article "Innovative Method for the Cleaning of Water-Sensitive Artifacts: Synthesis and Application of Highly Retentive Chemical Hydrogel." This information clarified the difference between Nanorestore Gel Dry series and Peggy gels.

In-depth information about gels in conservation and their structure and qualities was collected from two books. The first book was *Solvent Gels for the Cleaning of Works of Art, The Residue Question*, written by Stulik, D., Miller, D., Khanjian, H., Carlson, J., Khandekar, N., Wolbers, R., and Petersen, W. C., published in 2004. The other was *Gels in the Conservation of Art*, edited by Lora V. Angelova, B. Ormsby, Joyce H. Townsend, and R. Wolbers in 2017. The second book includes surveys and overviews of the effects of different gels on various materials, which contributed to our work and understanding of gels' functional and structural aspects.

On the other hand, in the matter of consolidation of matte paint the main concerns have been the suitability characteristics of consolidants and their ageing properties and the evaluation of color stability. Other properties assessed include the performance of adhesives in strength, flexibility, and adhesion power, with the use of standard tensile testers[17] or standardized tape testing models.[18]

In the area of consolidation procedures, matte paint is mainly found in contemporary paint in various binding media, such as linseed oil[19] and acrylic paint,[20] and painted surfaces found in wall paintings[21] and

16 Kathrine Segel, et al., "Removing Ingrained Soiling from Medieval Lime-based Wall Paintings Using Nanorestore Gel® Peggy 6 in Combination with Aqueous Cleaning Liquids", *Studies in Conservation*, vol. 65, issue sup1 (2020): 284–291, doi:org/10.1080/00393630.2020.1790890.

17 David Horton-James, Sue Walston, and Steven Zounis, "Evaluation of the stability, appearance and performance of resins for the adhesion of flaking paint on ethnographic objects", *Studies in Conservation* 36, no. 4 (1991): 203–221.

18 Miloš Drdácký, and Zuzana Slížková, "In situ peeling tests for assessing the cohesion and consolidation characteristics of historic plaster and render surfaces", *Studies in Conservation*, vol. 60, issue 2 (2015): 121–130.

19 Bettina Ebert, B.W. Singer, and Nicky Grimaldi, "Aquazol as a consolidant for matte paint on Vietnamese paintings", *Journal of the Institute of Conservation*, vol. 35, no. 1 (2012): 62–76.

20 Rosario Llamas-Pacheco, and Demian Ramos San Pedro, "Colorimetric evaluation of three adhesives used in the consolidation of contemporary matte paint after artificial ageing", *Conservar Patrimonio*, no. 20 (2014): 11–21.

21 Karin Catenazzi, "Evaluation of the use of Funori for consolidation of powdery paint layers in wall paintings", *Studies in Conservation*, vol. 62, issue 2 (2017): 96–103.

ethnographic objects.[22] The authors highlight the fact that the paint is powdery in all cases, and the reason found is because of a high pigment volume concentration, not primarily because of the binder medium.

Methodology

The study in the first stage was focused on object-based conservation research where the materials and techniques used on the funeral coat of arms were a fundamental base for the analytical approach. A deductive method was used to map original materials and the object's technical structure. Following this process, several technical analyses were performed, because each method has its limitations. Therefore, several examinations were made to gain a sufficient result with a clear understanding of the structure.

To evaluate the cleaning material's action on the pigment smalt and the consolidation on the smalt and lamp black pigments, experimental analysis methods were implemented on artificially aged mockup samples.

Color Measurements

Measurement was performed on the original banner surface and the mock-up surfaces before and after cleaning treatment. The colorimeter tool used was the Konica Minolta CR-300 Chroma Meter, which measured the surface's reflective colors. The measurement area on the substrate surface was at Ø 8 mm, using diffusion illumination and a 0° viewing angle.[23] After that, it was sampled in triplicatefrom the sample surface spot. The data values were calculated for each sample and averaged E* with the deviation calculation in Microsoft Excel software.[24] In the end, CIE (1976) L*a*b* color difference was calculated for data analyses.[25]

22 David Horton-James, Sue Walston, and Steven Zounis, "Evaluation of the stability, appearance and performance of resins for the adhesion of flaking paint on ethnographic objects", *Studies in Conservation*, vol. 36, issue 4 (1991): 203–221.

23 *Chroma meter: Instruction manual* (Konica Minolta, 1991).

24 Angelica Bartoletti, et al., "Reviving WHAAM! a comparative evaluation of cleaning systems for the conservation treatment of Roy Lichtenstein's iconic painting", *Heritage Science*, no. 8, 9 (2020): 1–30.

25 Linda Owen, Rebecca Ploeger, and Alison Murray, "The effects of water exposure on surface characteristics of acrylic emulsion paints", *Journal of the Canadian Association for Conservation = Journal de l'Association Canadienne Pour La Conservation et La Restauration*, no. 29 (2004): 8–25.

Spectrophotometer Measurements

For this measurement, the Konica Minolta CM-26d was used. This tool offers precise accuracy for measuring color parameters. The spectrophotometer was horizontally aligned with the measurement area on Ø3mm. The color parameters were then calculated with an L*a*b value system on a CM-CT1 Configuration Tool software following the (ISO 7724/1) norm.

Optical Microscope examination

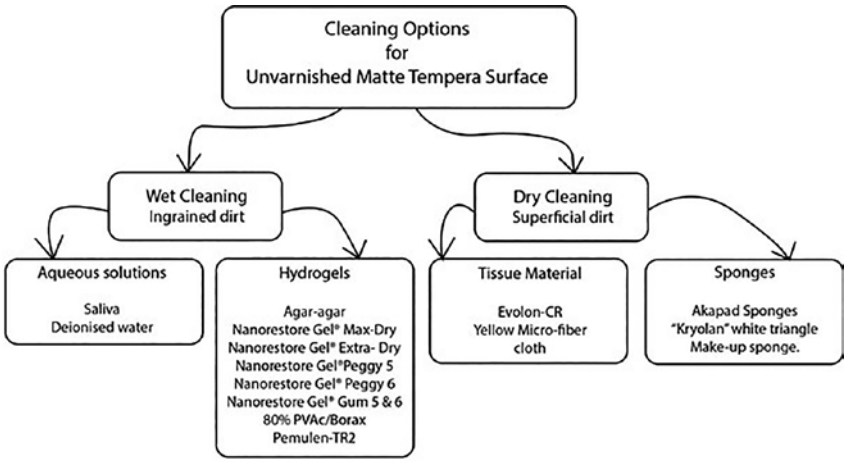
For the evaluation of the cleaning method, a Leica S9D optical microscope was used. With the 122 mm allowance of working distance, it was easy to manipulate the sample to see the gel surface condition after application on the substrate. The high magnification for up to 55x and 9:1 zoom helped review details to achieve an efficient process. This stage focused on evaluating the gelling agent's surface and the dry-cleaning methods to study the pigment pick-up or the residues left on the mockup surface.

Scanning electron microscopy (SEM) analyses

The SEM scan process was carried out on mockup sample surfaces to evaluate the cleaning gel residue on specific samples after cleaning. The instrument which was used was the Hitachi S-3400N with the settings at about 10kV, probe current 40 with emission on 100μA (Jourbert, 2017). The magnification varied from 40x up to 900x. The samples for the examination were covered with carbon.

Artificial aging

As the last stage for evaluating the gel residue effect, the selected samples are placed into the Atlas Xenotest 440, a highly versatile weathering instrument. The International Organization for Standards (ISO 16474-2) norm is suited for examining the paints and varnishes in indoor conditions (Standard 11266, 2014). The samples were placed in the machine for 120h, with radiant exposure on 12332 kJ/m^2, irradiance 50W/m^2, temperature 38°C, black standard temperature 65°C, and relative humidity 70%. Irradiance control was set at 300-400nm. With the help of xenon-arc light,



3.
The table of Cleaning Material Selection, illustration by Anastasiya Serdyukova, 2021

this condition reproduces the weathering condition indoors with daylight filtered through window glass.[26]

Cleaning System Selection

The figure below [fig. 3] represents the cleaning options that were selected for this thesis research. The process of selection was designed by studying the articles which dealt with water-sensitive paint materials. Each of the cleaning materials has its disadvantages and advantages, from which it will be easier to determine the possible applicable cleaning strategy system.

The requirements to select the suitable method from the presented range of materials were:

- To avoid any undue risks on the painting film surface. This can be in the form of swelling, pigment pick-up, watermarks, gloss change, or residue.

- The ability to minimize mechanical actions.

- The ease of use for achieving an efficient cleaning action.

The gels were selected to explore whether the removal of ingrained dirt can be safely achieved or not. The gel formulation was convenient

26 Felipe Sierra, "Accelerated Ageing", in *Encyclopedia of Gerontology*, 2nd ed. (2007).

to examine because it can reduce the pigment pick-up, watermarks, and swelling resulting from aqueous methods.

Nanorestore® gels are a novel material, and the Extra Dry (HWR) and Max Dry (MWR) versions are chemical hydrogels specially designed for water-sensitive materials. However, the Peggy 5 and 6 versions are physical hydrogels and have less liquid retention than Nanorestore® chemical hydrogels, and it was important to experiment with both types. The polysaccharide gel agar-agar was chosen because it is widely used in paper conservation and various other water-sensitive materials. The 80% PVA/Borax gel has an easy "peel off" action considered appropriate for our surface. For the comparative material, Pemulen-TR2 was used because it requires mechanical action and additional clearance steps for the residue.

Consolidation materials selection

The selection of the consolidants focused on the most frequently used and commented on adhesives for the consolidation of matte paint. Their application process was done equally on every mock-up by brushing the consolidant on Japanese paper after testing the application directly on the surface and on silk paper. The use of Japanese paper allows the consolidant to spread over the surface evenly and minimizes the risk of leaving tidelines.

- Lascaux's Medium for Consolidation: The concentration of the medium can be adjusted by the addition of distilled water according to the datasheet. During practical work on the object, the proportions 1:1 in deionized water and 1:2 in deionized water were used. In this present work, solutions of Lascaux's Medium for Consolidation at 100% were tested for following other conservators' results and 25% were tested for effectiveness in lower proportion, meaning a smaller ratio of solid polymers.

- Aquazol: This resin consolidant is used in a wide range of materials. It has been found to fail as a consolidant on very porous paintings and gilded areas, which explains how the solution at a maximum of 5% was so dilute that it just flowed through the material.[27] Other solutions previously tried included 2.5% Aquazol in water applied in three layers and then at 5%

27 Julie Arslanoglu, "Aquazol as used in conservation practice", *WAAC Newsletter* 26, no. 1 (2004): 10–15.

concentration to get maximum penetration.[28] Five percent Aquazol 200 in water was preferred to be tested here.

- Sturgeon glue: Since its preparation can vary in terms of purity, swelling process, and due to its natural origin, the composition is not standard. Preliminary testing on paper showed that 3% sturgeon glue did not add much gloss to the surface, and its adhesion was proven sufficient as indicated in published papers.

- JunFunori: JunFunori is recommended by the manufacturer to be used at 1% in deionized water. According to the manufacturer, more than 1.5% is not worth testing since its dissolution is not possible.[29] After the preliminary tests, the gloss and color of 0.25%, 0.5%, and 1% were very similar to the eye. Therefore, what changes principally may be the strength. One percent JunFunori was evaluated.

Results and discussion

Cleaning system evaluation with star diagrams

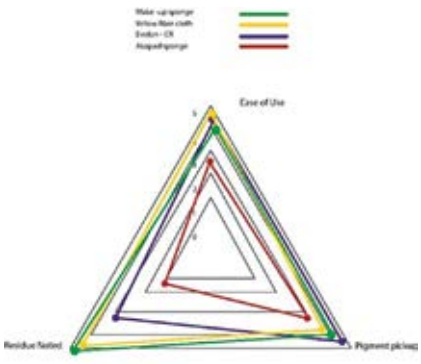
Triangle and polygon diagrams were made for a clear presentation of the micro images taken by the Leica Microscope S9D. This system for evaluation was created by the Cultural Agency of the Netherlands.[30] Various parameters were rated from 5 (most appropriate) to 1 (inadequate). The star diagrams provide a clear image of the gel parameters [figs. 4–7]. When the form aligns with the polygon shape, it means an adequately promising good result. The diagram's modification towards the triangle shape was created to adjust to the dry cleaning systems because cleaning parameters differ from dry cleaning and hydrogels options. This method allows us to evaluate and see a clear image of the gel and dry cleaning applications and how they interacted with the substrate.

28 Yuanyuan Zhang, Li Xuanhua, and Wei Bingqing, "Environment-Friendly Poly (2-ethyl-2-oxazoline) as an Innovative Consolidant for Ancient Wall Paintings", *Nanomaterials* 8, no. 9, 649 (2018): 1–13.

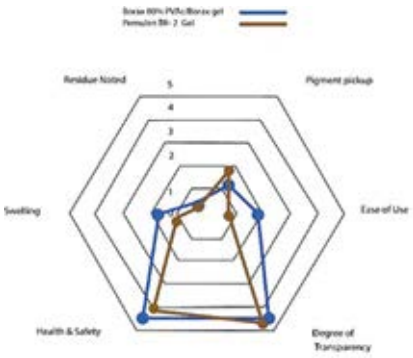
29 Lascaux, "JunFunori", webpage, accessed October 20, 2020, https://lascaux.ch/en/products/art-handling-and-restauro/starches-and-celluloses.

30 Karen Golle Cordova, "Conservation of Contemporary Painting: a Comparative Study of the Effect of Dry Cleaning Techniques", *Science and Arts*, no. 17 (2017).

4.
The star diagram with agar-agar gels, illustration by Anastasiya Serdyukova, 2021



5.
The triangle diagram with dry cleaning materials, illustration by Anastasiya Serdyukova, 2021



6.
The star diagram with xPVAc/Borax and Pemulen-TR2 gels, illustration by Anastasiya Serdyukova, 2021

7.
The star diagrams with Nanorestore gels, illustration by Anastasiya Serdyukova, 2021

The dry cleaning methods results

The dry cleaning materials are easy to use and prepare [fig. 8]. Moreover, their limited cleaning action in comparison to wet-cleaning methods has some advantages, in particular, when we consider ethical aspects. After testing the materials, it was proved that the Akapad sponge is not suitable for this purpose. The unvarnished egg white tempera required more delicate cleaning methods. During the test, the yellow micro-fiber

8.
The dry cleaning systems, photos by Anastasiya Serdyukova, 2021

cloth had a good result when we extracted the dirt from the surface with a minimal pigment pick-up. The Evolon-CR© had some issues when we tested it on mockup substrates. The material was leaving residues in the form of fiber threads. This happened to the sharp, potassium glass fragments in the smalt pigment, which scraped the filament fibers out. The yellow microfiber cloth remained stable at this specific point.

Nevertheless, the pigment smalt degrades over time, and on the original polychrome sculpture, the dry cleaning material Evolon-CR© might perform differently. The smalt pigment does not just change color during aging but its chemical and physical properties in the paint film also change. The scientific literature reports that the shrinking of glass can appear when a large number of alkaline components are leached.

The contraction of the glass can be at around 14wt% K_20.[31] This fact should be taken to account, and Evolon-CR© should not be stricken from the list. When the material was tested on the original pigment layer on the banner, it had a good result. The absorption of the dust and grime layer was high, and no damage was observed on the paint layer. Neither was pigment pick-up seen on the non-woven filament surface.

The wet-cleaning method results

The smalt pigment proved to be water-sensitive to mechanical wet cleaning with a cotton swab and saliva. Consequently, it was necessary to use a cleaning method that did not involve mechanical surface treatment and controlled the amount of water injected into the sensitive colors.

The Nanorestore Peggy gels 5 and 6, due to their chemical composition, had lower liquid retention than the HWR and MWR gels. Consequently, this led to a source of trouble in the form of an unacceptable amount of pigment pick-up. The common characteristic of all nanogels is that they are solid gels. This can eliminate mechanical movement and reduce the amount of moisture released on the painting's surface. The amount of water exposure to the painting layer is significantly reduced compared to agar-agar gel results.[32] Nanogels work in such a way that either contaminants are drawn directly into the gel or they can swell the dirt, and then the grime can be removed with a cotton swab. Moreover, the easy and straightforward method of peeling off the gel from the surface ensures that no detectable residues will be left on a substrate surface.

HWR and MWR Nanorestore gels® indeed showed exceptional results. However, the problem is that it is hard to extrapolate this research to the original work. Therefore, it is hard to state if these gels will work adequately with the integrated dirt on the banner from Kalmar Castle. The rigid gels may have weak adhesion to the surface due to their low viscosity, which may decrease their cleaning ability.

31 Marika Spring, Catherine Higgitt, and David Saunders, "Investigation of Pigment-Medium Interaction Processes in Oil Paint containing Degraded Smalt", *National Gallery Technical Bulletin*, no. 26 (2005): 56–70.

32 Piero Baglioni, David Chelazzi, and Giorgi Rodorico, N*anotechnologies in the Conservation of Cultural Heritage: A compendium of materials and techniques* (Netherlands: Springer, 2015).

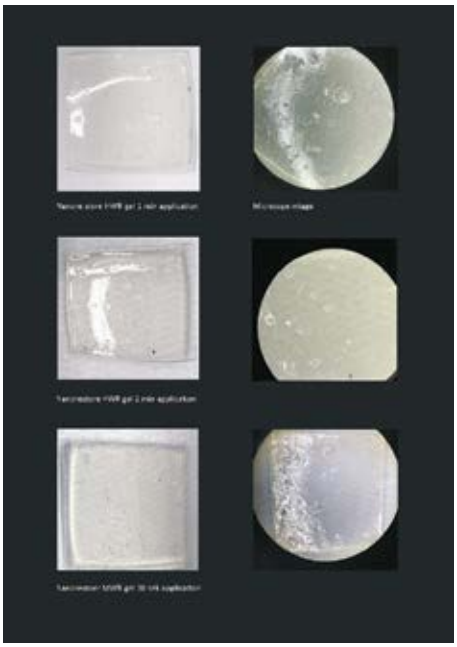
The situation with the agar-agar gels with different concentration percentages showed an even result, where some of the parameters increased and simultaneously others decreased. For example, the swelling issue occurred to a higher degree with a higher percentage even though it has eminent liquid retention. Overall, the application time was extended because, as soon as the percentage was elevated, it needed more time to perform a working cleaning action. The agar-agar gels with 2% (w/v) concentration were left on for 60 seconds.

On the other hand, the agar-agar with 10% concentration had to be left on the surface for up to 10 minutes. However, balance was achieved with the 6% agar-agar gel, which was left on for 60 seconds. It showed an acceptable result without any pigment pick-up when the time was increased up to 3 minutes. Some visible pigment pick-up was observed on the edges.

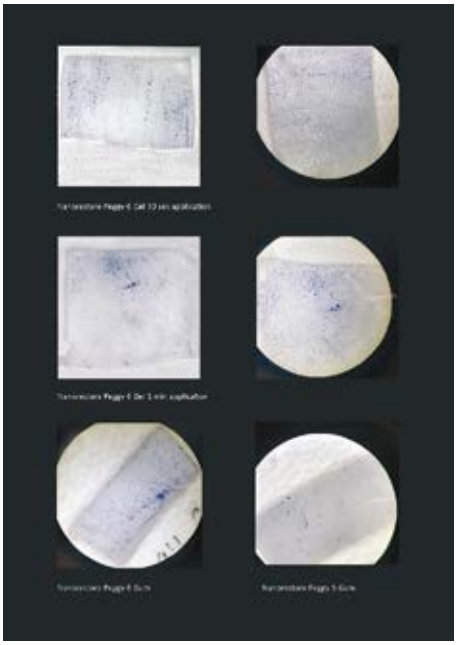
Among the various hydrogels applied on a substrate, the 80xPVAc/Borax gel and Pemulen-TR2 type were the biggest failures. The unacceptable result with major pigment pick-up and the difficult method of using it during the application confirmed that these gels are not appropriate for further analyses. The high viscosity of the gel caused a problem while removing the gel from the substrate. It became sticky and left significant visible residue on the surface, even after cleaning the excess with the cotton swab. The residue was noted with SEM image analyses.

Several problems appeared during the use of the borax gel. One of them was an uncontrollable application. Also, the preparation of borax was not easy. One of the problems was that the gel-like consistency while diluting the 80% PVAc with borax did not happen every time. Preparation failed multiple times before it was possible to master the preparation of the gelification process. It turned out to be a very time-consuming process with an unacceptable outcome.

The Pemulen-TR2, compared to borax, had a much more liquid consistency and was stickier. It was too sticky on the surface, which led to permeable action onto the surface of a substrate. Much residue occurred in the form of thick irregular layers [fig. 9].



9.
Nanorestore Gels® HWR and MWR, photos by Anastasiya Serdyukova, 2021



10.
Nanorestore gels® Peggy 6 and Peggy 5, photos by Anastasiya Serdyukova, 2021

Additionally, the Pemulen-TR2 gel is made with the addition of triethanolamine (TEA)which can also leave residues that can provoke future deleterious effects.[33] This happens due to the low vapor pressure of the amines such as TEA. That is why Pemulen-TR2 cannot be applied to water-sensitive materials, especially unvarnished ones. It can be more useful to apply to oil paintings with varnish problems since it contains three primary alcohol end groups that can work as a solvent agent[34] [fig. 10].

Evaluation of the consolidants

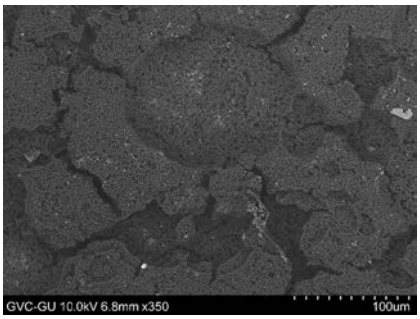
In the mock-ups consolidated with Aquazol 200, the results given for color measurements can be considered adequate for aging but have a yellowing and darkening effect on the paint. The cohesion test shows different effects on the smalt blue paint losing its cohesion power after artificial aging, while it is the opposite on the lamp black. Given the characteristics of the ageing of the black paint and how it changes to a more "wet effect," it is possible that the Aquazol 200 follows the pigment's movements while ageing and rearranges with it, helping to raise the paint cohesion.

The texture of the layer formed by Lascaux's MfC is a very flexible and "plastic" film which, in the case of untreated powdery paint, may not be suitable considering the residue cannot be removed without damaging the paint. The formation of a film can be observed by eye, and in the cohesion tape tests, the samples consolidated with this acrylic dispersion at 100% concentration had a firm cohesion. A significant difference can be seen in samples consolidated with the acrylic dispersion at 25% concentration in water, which seems to have penetrated the paint more deeply and possibly formed a consolidant film at a lower level between the pigment particles.

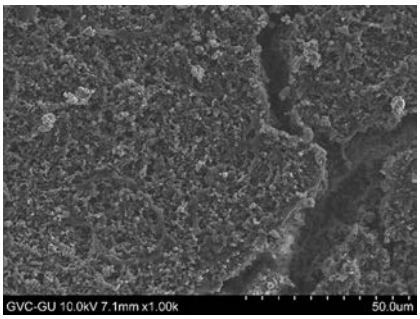
On the other hand, the natural and widely used consolidant sturgeon glue 3% concentration in water showed an increase in the gloss that may not be considered suitable for a matte paint surface. Other considerations regarding the use of sturgeon glue are its sustainability, being a by-product of the collection of sturgeons for the food industry and other

33 Burnstock, and Tom Learner, "Changes in the surface characteristics of artificially aged mastic varnishes after cleaning using alkaline reagents", *Studies in Conservation*, vol. 37, issue 3 (1992): 165–184.

34 Sofia Hennen, Francisco Mederos-Henry, Cécile de Boulard, María-Fernanda Espinosa, and Paolo Cremonesi, "The influence of organic and inorganic alkalis on the formulation and properties of Pemulen-TR2 gels", in *Gels in Conservation of Art* (London: Archetype Publications, 2017), 165–170.



11.
SEM of the mock-up 12d: lamp black + egg white consolidated with 1% JunFunori, unaged. 350x, image by Delia Rosel, 2021



12.
SEM of the mock-up 12c: lamp black + egg white consolidated with 1% JunFunori, artificially aged for 120 hours. 1000x, image by Delia Rosel, 2021

purposes that threaten several sturgeon species with extinction. Its advantages include its ability to be reapplied and the fact that its ageing properties can be studied from various case studies consolidated centuries ago.

JunFunori, as expected after literature research, has shown good properties for color and gloss, being one of the most suitable consolidants regarding visible characteristics [table 1]. On the other hand, the tape test has demonstrated that its power of cohesion between pigment particles is not very strong, which may be interesting for keeping a minimum change in the powdery paint and not "overloading" the surface with the consolidant. Its physical ageing properties can be observed in the SEM images [figs. 11, 12], where the consolidant appears not to have broken or reduced its bonds. The amount of the substance needed for the consolidation of the paint depending on its condition and thickness should be considered for its use, taking into consideration the economical aspect and the sustainability that this polysaccharide product can reach.

Table 1. Gloss measurements on the consolidated mock-ups before and after artificial ageing, and difference of gloss, table by Angela Caira, 2021.

Samples		**Gloss units before artificial ageing**	**Gloss units after 120 hours of artificial ageing**	**Calculated difference of gloss ΔG**
Smalt blue	No consolidant	0.2	0.3	0.1
	100% Lascaux's MfC	0.3	0.3	0
	25% Lascaux's MfC	0.3	0.3	0
	5% Aquazol 200	0.2	0.3	0.1
	3% sturgeon glue	0.3	0.5	0.2
	1% JunFunori	0.3	0.3	0
Lamp black	No consolidant	0.2	0.2	0
	100% Lascaux's MfC	6.8	6.8	0
	25% Lascaux's MfC	0.5	1.2	0.7
	5% Aquazol 200	0.3	0.5	0.2
	3% sturgeon glue	1.1	1.8	0.7
	1% JunFunori	0.3	0.2	0.1

Conclusion

If it's necessary to remove ingrained dirt and perform a partial cleaning treatment, Nanorestore Gel® HWR and MWR is recommended. The cleaning efficiency might be lower in HWR than MWR due to higher liquid retention and a more rigid composition, which might not allow close contact with the porous paint layer. Both of the dry hydrogels showed no changes to the surface after accelerated aging. Moreover, no residue was detected in SEM analyses.

This study has shown the changes that occurred in the consolidation of egg white tempera with smalt blue and lamp black in egg white medium in measurable ways that have contributed to a technical assessment.

In general, Aquazol 200 5% and JunFunori 1% in water solutions have proven to age with more suitable properties than the other two consolidants assessed.

In matters of color and gloss changes, JunFunori 1% has been the most efficient by showing the smallest differences when applied and after artificial ageing. However, the matter of its cost in the market must be considered when planning its use, followed by Aquazol 200 5%, which, although changing the lightness of the mock-ups, performed efficiently after artificial ageing. Lascaux's MfC 100% and 25% can be assessed in different application modes striving for different, more adequate outcomes, and sturgeon glue has showed less appropriate ageing properties.

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Santrauka

Laidotuvių herbo (*huvudbaner*) konservavimo tyrimas, daugiausia dėmesio skiriant valymui ir tvirtinimui

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Reikšminiai žodžiai: jautrus vandeniui, kiaušinio baltymo tempera, hidrogeliai, tvirtinimas, kobalto mėlyna, anglies juoda.

Pehro Stålhammaro laidotuvių herbui – XVIII a. polichromuotai skulptūrai – buvo reikalingas konservavimas. Šiame darbe analizuojamos herbą sudarančios medžiagos, tarp kurių, kaip paaiškėjo remiantis šaltiniais ir analizės metodais įvertinus objektą, yra tempera su kiaušinio baltymo rišikliu. Naudojant šią tapybos techniką, dažai būna jautrūs vandeniui, neskaidrūs ir birūs. Kadangi tokio tipo dažų fizines savybes išsaugoti yra sunku, buvo išbandyti ir įvertinti jų konservavimo procesai valymo ir sutvirtinimo požiūriu. Vertinti šie tvirtinimo metodai: tvirtinimo medžiaga *JunFunori*, eršketų klijai, *Aquazol 200* ir *Lascaux* tvirtinimo medžiaga dažniausiai naudojamomis proporcijomis vandens tirpaluose ant kobalto mėlynos ir anglies juodos spalvos dažų. Vertinimui pasirinkti valymo būdai buvo sausieji metodai ir hidrogelių naudojimas, daugiausia dėmesio skiriant kobalto mėlyniems dažams, kuriais buvo padengta didelė polichrominės tapybos sritis ir kurie kėlė didžiausių iššūkių. Norint patikrinti hipotetinius šių intervencijų rezultatus, apdoroti mėginiai buvo dirbtinai pasendinti. Rezultatuose atsispindi pradinė mėginių sudėtis pagal FTIR, spalva remiantis kolorimetrija ir blizgesys pagal blizgumo skalę. Vėliau šios savybės buvo išmatuotos dirbtinai pasendintuose mėginiuose. Aptariant rezultatus atskleidžiama, kad iš valymo priemonių ir metodų *Nanorestore Gel® HWR* ir *MWR* veikė efektyviau dėl didesnio skysčių susilaikymo ir tvirtesnės sudėties, o vertinant tvirtinimą, *Aquazol 200* 5 % ir *JunFunori* 1 % vandens tirpaluose sendami pasižymėjo geresnėmis savybėmis nei kitos vertintos proporcijos ir tvirtikliai.