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Retouching matt contemporary paint layers: a new approach using natural polymers

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Abstract: Different painting techniques, materials and application methods that characterise contemporary artworks, with predominantly matt surfaces and uniform tones, make retouching one of the most complicated conservation treatments, since sameness is the main target. The retouching intervention carried out at the Galleria Nazionale d'Arte Moderna e Contemporanea in Rome on *Tempi prospettici* (1969), an installation by the Italian artist Carlo Alfano, gave the opportunity to investigate a method to obtain different matt/glossy values through the use of natural polymers as binders. The binders chosen (different polysaccharides, cellulose derivatives and isinglass) were analysed, both individually and mixed, through colorimetric and glossometric measurements. The pigment-binder ratio and the addition of silica to get a modulation of the matt appearance of paint formulations were also evaluated. The comparison of the colorimetric values of painting samples and those of the original paint led to the identification of the best solution for the retouching of the artwork.

Keywords: retouching matt contemporary paintings, colorimetric measurements, carbon black, plastic laminate, natural binders, sturgeon glue, funori, silica

Reintegración de capas pictóricas contemporánea mate: un nuevo enfoque utilizando polímeros naturales

Resumen: Las diferentes técnicas de pintura, materiales y métodos de aplicación que caracterizan las obras de arte contemporáneas, con predominio de superficies mate y tonos uniformes, hacen de la reintegración cromática uno de los tratamientos de conservación más complicados, ya que la similitud es el objetivo principal. La intervención de reintegración realizada en Galleria Nazionale d'Arte Moderna e Contemporanea en Roma, en *Tempi prospettici* (1969), una instalación del artista italiano Carlo Alfano, dio la oportunidad de investigar un método para obtener diferentes valores mate / brillante a través de uso de polímeros naturales como aglutinantes. Los aglutinantes elegidos (diferentes polisacáridos, derivados de celulosa y pegamento de esturión) se analizaron, individualmente y mezclados, utilizando medidas colorimétricas y glosimétricas. La relación pigmento-aglutinante y la adición de sílice también se evaluaron para obtener la modulación de la apariencia mate de las formulaciones de pintura. La comparación de los valores colorimétricos de las muestras de pintura y los de la pintura original condujo a la identificación de la mejor solución para la reintegración de la obra de arte.

Palabras clave: reintegración en pinturas mate contemporáneas, medidas colorimétricas, negro de carbón, laminado plástico, aglutinantes naturales, pegamento de esturión, funori, sílice

Reintegrações de camadas pictóricas contemporâneas mate: uma nova abordagem usando polímeros naturais

Resumo: Diferentes técnicas de pintura, materiais e métodos de aplicação que caracterizam as obras de arte contemporâneas, com predominância das superfícies mates e tons uniformes, tornam a reintegração cromática um dos tratamentos de conservação mais complicados, já que a semelhança é o principal alvo. A intervenção de reintegração realizadas na Galleria Nazionale d'Arte Moderna e Contemporanea de Roma, em *Tempi prospettici* (1969), uma instalação do artista italiano Carlo Alfano, deu a oportunidade de investigar um método para obter diferentes valores mates / brilhantes através do uso de polímeros naturais como aglutinantes. Os aglutinantes escolhidos (diferentes polissacarídeos, derivados de celulose e cola de esturjão) foram analisados, individualmente e misturados, por meio de medidas colorimétricas e glossométricas. Foram também avaliadas a proporção pigmento-aglutinante e a adição de sílica para obter a modulação da aparência mate das formulações de tinta. A comparação dos valores colorimétricos das amostras de pintura e os da tinta original levou à identificação da melhor solução para a reintegração da obra de arte.

Palavras-chave: reintegração em pinturas contemporâneas mates, medidas colorimétricas, negro de fumo, laminado plástico, aglutinantes naturais, cola de esturjão, funori, sílica

Introduction

This work is the starting point of a wider research focused on the issue of retouching contemporary paintings characterised by matt surfaces and uniform tones. These characteristics make the aesthetic treatment of paint losses very complex because the main target is to achieve the same appearance of the original paint.

There are different matt levels, due to various factors: e.g., the characteristics of the medium used, the nature of the pigments, the absorbance of the substrate (preparation and/or support), the presence of additives in the paint formulation, the application method used.

The challenge of this ongoing research is to try to develop a gradation scale of matt/glossy mediums in which single adhesives or mixtures can provide conservators with a method to choose the most suitable products to undertake retouching. During this study, only natural polymers were evaluated in order to use water-soluble, non-toxic, easily reversible mediums and, most importantly, compatible with the previous consolidation treatment. For this reason, compatibility with Funori have been prioritised.

The intervention on *Tempi prospettici* (1969)

This research on natural polymer binders was prompted by the retouching intervention carried out at the Galleria Nazionale d'Arte Moderna e Contemporanea in Rome on *Tempi prospettici* (Perspective times), an installation made by the Italian artist Carlo Alfano in 1969. The artwork is composed by two polygonal formica panels, on which there are painted sign patterns and glued cylinders in transparent polymethylmethacrylate (PMMA) of various lengths protruding from the surface. The two panels have to be hung at the corner of two walls, thus creating an optical illusion. With *Tempi Prospettici* Alfano approached the kinetic

art playing with perception, which changes according to the visitor's point of view [Figure 1, left].

"Formica" is the trademark of a chipboard covered by a plastic laminate, which was registered in 1913 by the Italian manufacturing company of the same name. The laminate is composed by cellulose layers impregnated with phenolic and melamin resins and consolidated under heat and high pressure. On one of the formica panels of *Tempi prospettici* there is a squared area painted in black, which had adhesion and cohesion issues. This matt black paint is directly on the support of formica and is unvarnished. Two small samples of it were analysed through ATR-FTIR spectroscopy in order to characterise the nature of the binder and identify the main components used as pigments (Carnazza et al. 2019). The analysis highlighted the presence of nitrocellulose as binder and silica as matting agent. In the absence of any signals on the spectrum that refer to the presence of organic pigments and apatite (mineral that characterises bone black), it is very likely that the pigment present in the original paint is a carbon-based black. Therefore the use of carbon black is the most likely, even considering that it is commonly used in the industries for its tinctorial power. The matt appearance of the paint is not only due to the presence of silica in the formulation, but it is also a result of the technique used by the artist, who probably sprayed the nitrocellulose paint on the formica panel instead of using a brush. This consideration arose after different tests were made applying a matt black nitrocellulose paint currently on the market on formica panels: the brush produces compact and more polished-looking films than the matt and velvety black paint on Carlo Alfano's artwork. The application with a compressor, on the other hand, can generate different effects depending on the pressure and diameter of the nozzle: the use of a 4 atm compressor and 14 mm nozzle leads to obtain a paint layer certainly thinner and homogeneous than that obtained by brush, but still compact; a pressure between 2 and 3 atm and 10 mm nozzle allows to get a paint layer that looks similar to that of *Tempi prospettici*. It is therefore likely that the artist

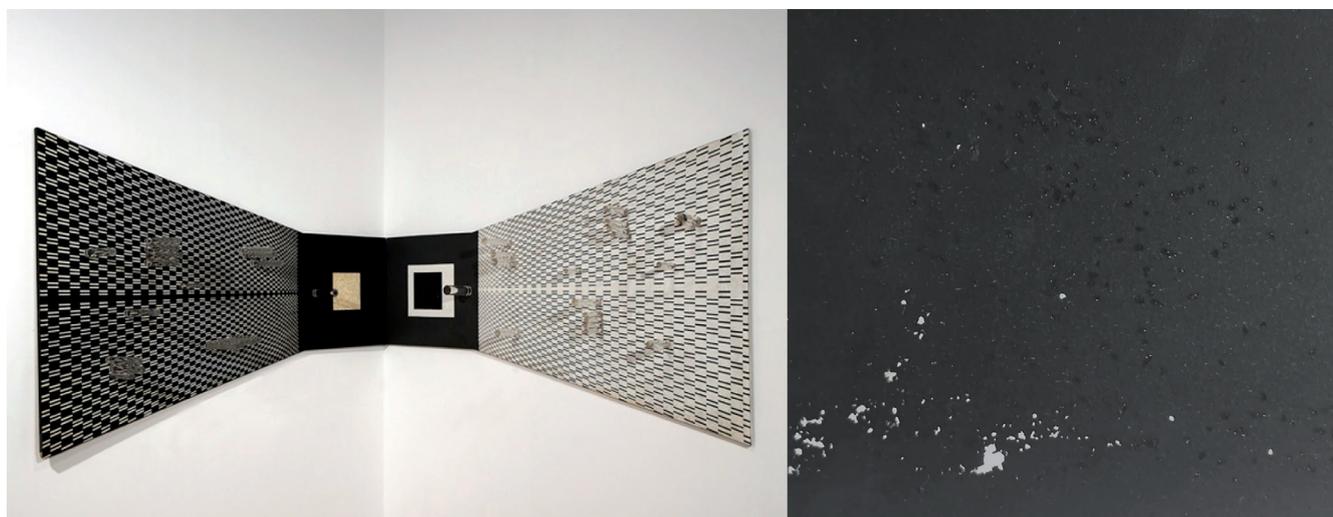


Figure 1.- Carlo Alfano, *Tempi Prospettici* (1969) – Courtesy: Galleria Nazionale d'Arte Moderna e Contemporanea of Rome (Italy); on the right, a detail of losses and previous retouching on the black area of one of the formica panels

applied the matt black nitrocellulose paint to the formica panel using an airbrush. Moreover, the degradation process led to the formation of microcracks spread all over the paint layer which increase the scattering effect.

During the conservation treatment, the consolidation of this matt black paint layer was obtained brushing two hands of Funori solution prepared in demineralised water at a concentration of 0.4% and heated to 35°C. Funori was chosen for its well-known property not to alter the matt appearance of treated surfaces. A colorimeter was used to monitorise all the optical changes occurred during the treatment; after the application of the Funori solution the colour saturation increased thanks to the microcracks reduction and the colorimetric values became more homogeneous. To verify the adhesive strenght of Funori in this specific paint-substrate system, a sample of painting with matt black nitrocellulose was prepared by applying the paint on a formica panel through a compressor, as to obtain a velvety-looking pictorial film, not firmly cohesive to the substrate. Sequently, three areas of the sample were treated with 0.4% Funori, applying respectively one, two and three hands of the solution. The scotch tape test showed a progressive decrease of dectached microfragments, confirming the adhesive strenght of the consolidant used (Carnazza *et al.* 2019).

Due to the presence of many losses on the Alfano's artwork which left uncovered the white surface of the formica, retouching was necessary to recover the evennes of the monochrome squared area. A previous retouching intervention was carried out in occasion of a recent exhibition loan and removed before our consolidation treatment. It was reported that it was made using 1% Funori solution and ivory black as pigment, but unfortunately the retouched areas appeared darker than the original paint depending on the angle of view and had also adhesion issues with the formica substrate [figure 1, detail on the right]. For these reasons the approach in this case-study was to use the same pigment of the original paint layer, that is carbon black, and to evaluate the more suitable medium to achieve the colorimetric values as similar as possible to the original matt black.

Experimental test on natural binders

The first part of the tests focused exclusively on the binders. A series of water-soluble, non-toxic, easily reversible and retractable mediums were evaluated. Finally it was decided to use only natural polymers for this study. The binders chosen are the following:

- **Funori**: a polysaccharide extracted from the Japanese *Gloiopeltis* seaweeds;
 - **Arabic gum**: a polysaccharide exudated by tapped branches of *Acacia* trees;
 - **Zin Shofu**[®]: gluten free wheat starch imported from Japan;
 - **Sturgeon glue (isinglass)**: a protein obtained from dried sturgeon bladders of the highest quality.
- Moreover, the following cellulose ethers (artificial cellulose derivatives) were tested:

- **Tylose**[®] **MH 300P**: methyl 2-hydroxyethyl cellulose – 150-450 mPa.s, 2% in H₂O (20°C);
- **Klucel**[®] **G and E**: two hydroxypropyl cellulose with different molecular weight – Klucel G: 150-400 mPa.s, 2% in H₂O (25°C), 370.000 u.; Klucel E: 300-600 mPa.s, 10% in H₂O (25°C), 80.000 u.

In total, seven binders were used for the experimental test. The percentage of preparation of the binders [figure 2] were defined according to the common use of these products for retouching, taking in consideration also the viscosity values when known (as in the case of cellulose ethers). Funori is usually used at 1% for retouching, but we decided to test a higher concentration of 2% to get more adhesive strenght. We decided to prepare Funori in both concentrations instead of getting the diluted solution by adding water to the 2% solution, because the 1% solution is more easily filterable, so it has less remnants of mucilage than the 2% solution. As for the consolidation, Funori solutions were prepared rinsing the dry seaweeds, leaving them in demineralised water for at least six hours, then heating the preparation in a water bath at about 75°C for 45 minutes and filtering it four times.

Binders were applied on two industrially prepared canvases. Concerning these first experimental tests, part of a wider and currently ongoing study on retouching and contemporary mediums, it was decided to use standard conditions of absorbance like a prepared canvas, instead of a not absorbent substrate like a formica panel without any preparation. The chosen binders were applied: 1) each one at the prepared concentration [as reported in the table in figure 2]; 2) with a dilution of 50% of the prepared concentration; 3) in mixtures of different parts (1:2, 1:1, 2:1) of each binder with all the others, using each one at the prepared concentration. In total, 74 samples of binders and their mixtures were brushed on the canvases.

A colorimetric analysis was carried out to measure the reflectance of dry layers of binders, subtracting the Specular Component Excluded (SCE) to the Specular Component Included (SCI). For the Δ SCI-SCE measurements a Minolta CM 2600d spettrocolorimeter was used (illuminant D65, observator 10°). The results obtained were as follows:

- 1)- Considering the individual binders at the prepared concentration, Funori (2%) and Klucel G have no reflectance values. Tylose has a very low reflectance value (< 0.01). Zin Shofu and sturgeon glue have reflectance values between 0.02 and 0.03. Klucel E is slightly more reflective than sturgeon glue. Arabic gum is the binder with the highest reflectance value (0.33).
- 2) - With a 50% dilution of the prepared concentration, all the binders become less reflectant. Funori is slightly absorbent. Klucel G has no reflectance value. Tylose, Zin Shofu and sturgeon glue have reflectance values lower than 0.01. Klucel E has a reflectance values slightly above 0.01. Arabic gum is still the binder with the highest reflectance value, but lower than 0.1 (0.06).

Binders	Concentration in dem. water
FUNORI	2% - 1%
ARABIC GUM	1:2 (20 gr in 40 ml +1 ml glycerol)
TYLOSE MH 300	2%
KLUCEL G	2%
KLUCEL E	10%
ZIN SHOFU	1:10
STURGEON GLUE	1:10



Figure 2.- On the left, table showing the percentage of preparation of the chosen binders in demineralised water. On the right, a picture related to the brushing of the different mediums and mixtures on industrial canvases.

3)- The mixtures with the highest reflectance values are the ones with Arabic gum (between 0.06 and 0.1). Only when mixed in a proportion 1:2 with Funori, Klucel G, Tylose and Zin Shofu, Arabic gum lowers its reflectance value between 0.03 and 0.04. The mixtures with the lower reflectance values are the ones with Funori and Klucel G (between 0 and 0.01), slightly higher in the case of Klucel G mixed in a proportion 1:2 with sturgeon glue and mixed with Tylose (< 0.02).

Taking gloss into account, the international standard ISO 2813:2014 specifies a method for determining the gloss of coating using 20°, 60° and 85° measurement angle. Therefore a glossmeter, that is a specific instrument which measures the specular reflection on surfaces, was also used to analyse the layers of binders and compare the results obtained to those of the colorimeter. It was used an ARW E 20/60/85 glossmeter, 0-200 GU, measuring area 55 x 10 mm. The reflection distribution changes depending on

the surfaces: a high gloss surface reflects the incident light beam almost completely at the complementary angle; a normal gloss surface reflects light in a small directed share and a diffuse one; an ideally matt surface reflects the incident light beam equally diffuse to all directions. Normally, the 20° measurement angle is indicated for gloss surfaces and the 85° measurement angle is indicated for matt surfaces. After measurements of binder samples were carried out with all the three measurement angles (20°, 60° and 85°), we identified in 60° the best representation angle for our samples: in fact, the measurements taken with the 60° angle better highlighted the differences in reflectance among the surfaces analysed.

Making a comparison between the glossmeter 60° curve and the ΔSCI-SCE curve [Figure 3], it was possible to notice almost the same pattern. This evaluation allowed us to consider the reliability of the values detected with the colorimeter in relation to the reflected component.

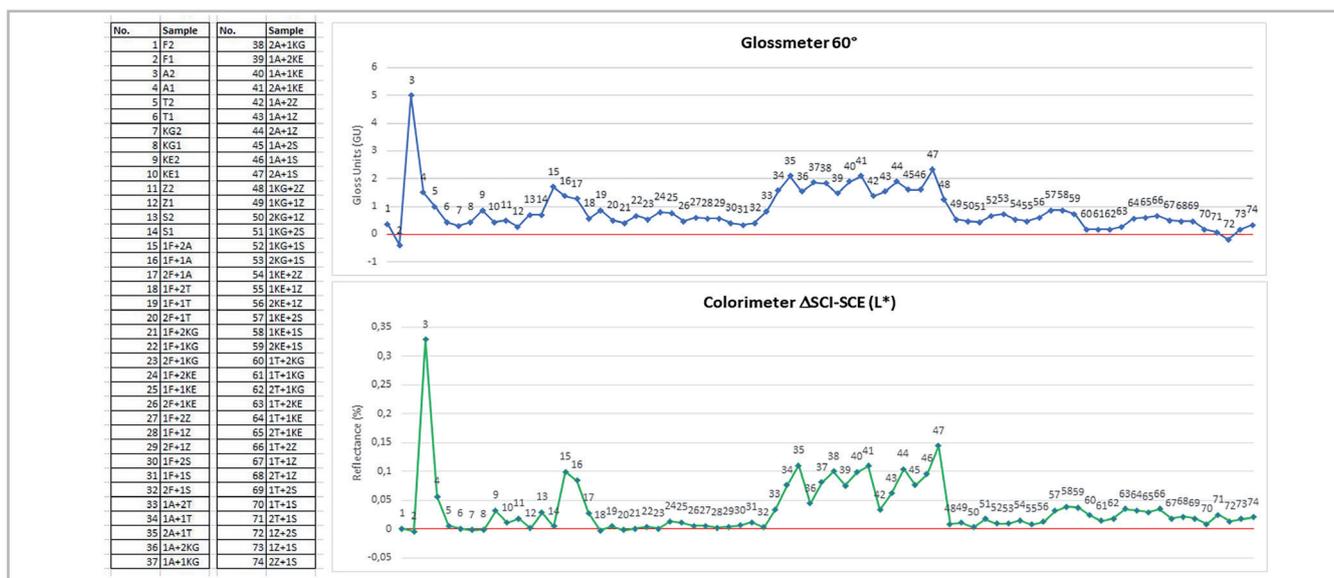


Figure 3.- Graphical comparison of reflectance measurement values detected with colorimeter and glossmeter. In the table on the left, it is reported the binder or mixture of binders used for each sample. F=Funori, A=Arabic gum, T=Tylose, KG=Klucel G, KE=Klucel E, Z=Zin Shofu, S=sturgeon glue. F2, A2, T2 etc. are the binders at the percentage of preparation, F1, A1, T1 etc. are the binders diluted at 50%. In the mixtures (samples 15 to 74) each binder was mixed at the prepared concentration with another binder, in ratio 1:2/1:1/2:1. For example, 1F+2A is a mixture of 1 part of Funori 2% and 2 parts of Arabic gum 1:2. The values reported in the graph are the result of correlation with the measured values on references (areas of prepared canvases left without binder layers).

Test of retouching paints

The second experimentation was aimed at identifying the right pigment-binder mixture to be used in the specific case-study, for the retouching of the matt black area present on Alfano's artwork. This part of the research was preceded by some considerations.

As in artistic paints, the main components in the formulation of retouching paints are the following three:

- **Pigments** are solid particles dispersed in the binder; their molecular weight, refractive index, density, and chemical composition have an impact on their wettability, on the needed amount of binder and on the appearance of the paint surface.
- **Binder** is a polymer forming a continuous film on the substrate surface; it must ensure good cohesion of the pigment particles and a good adhesion of the paint layer to the substrate. Different binders can have an impact on the appearance of the paint film, depending on the ability to wet pigment particles and the ratio of the volume of the pigment divided by the volume of both pigment and binder together (Pigment Volume Concentration, PVC).
- **Diluent (or thinner)** can be water or an organic solvent, it makes the paint a less viscous liquid that will spread evenly; important properties of the diluent are: the evaporation rate, the ability to dissolve the paint components, the potential toxicity. The binder and the diluent together can be called vehicle.

Finally additives, such as plasticizers, can also be added in paint formulations (e.g. glycerin in watercolours).

Spreadability is an important property of paints. It depends on: viscosity (due to the intrinsic medium's viscosity, the presence of a diluent, and to the nature, dimension and number of pigment particles), and surface tension, that is

the force that acts at the interface between different phases (solid-liquid-gas). The contact angle is related to the surface tension and measures the surface wettability. The tool for measuring the contact angle, according to the UNINORMAL 33/89, is composed of a light source, a zero-slope support for the sample, a syringe for the deposition of a drop of liquid and an image capture system.

In this phase of the research, we decided to measure the contact angle of the binders chosen in the first experimental test, as a preliminary analysis to the choice of the most suitable mediums for the retouching on the plastic laminate. The sessile drop technique was used dropping each binder on a formica panel and resulting images were processed with the ImageJ software. By measuring, it was found that sturgeon glue has the lower contact angle, followed by Klucel E. Both these binders have a contact angle lower than water.

In this specific case focused on the retouching of Carlo Alfano's *Tempi Prospettici*, there were also other elements to consider:

- The type of pigment: carbon black has very thin particles with a hydrophobic nature, extremely low wetting and dispersing characteristics; surfactants and proteins led to its dispersion in water (Tucker 1936);
- The type of vehicle: the binders chosen are all water-based, they are not toxic at all but the solutions prepared have a greater water content, especially in the case of Funori, Tylose and Klucel G (98%);
- The type of substrate: formica is a plastic laminate, so it is not absorbent and not easily wettable; paint films directly on formica can easily detach, especially if the cohesive force among pigment particles is greater than the adhesive force of the paint film at the support.

For the reasons above it was necessary to choose those binders with the lowest water content and the lowest contact angles, to ensure greater adhesion and cohesion strength. After several tests [figure 4], it was verified that it was not possible to use the solutions of Funori, Tylose and

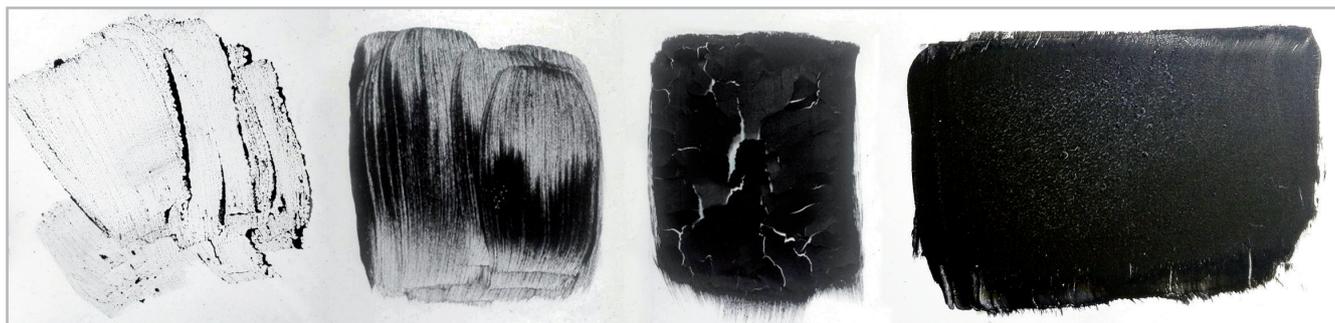


Figure 4.- Some photos of preliminary painting tests with carbon black mixed with some binders, at different pigment volume concentrations, made before choosing the appropriate binders for the second experimental part of the study. From the left: a sample made using Funori; a formulation made using 20% carbon black/ 80% Klucel G; a formulation made using 33% carbon black/ 67% Arabic gum (cracked and detached after drying); a sample containing more than 1% silica (that is the maximum percentage suggested to have a good paint layer). These tests were useful to exclude hygroscopic binders and to improve formulations for final samples, as in the case of that made using Arabic gum, which was then prepared with less pigment and more glycerin. The last photo is interesting because the type of microcracks formed after drying are very similar to the ones present on the original paint film, so it could be also possible that the degradation of Alfano's black paint layer was facilitated by the presence of silica in the impasto.

Klucel G in the paint formulations for the experimentation: their amount of water content is too high and the type of polymers are also highly hygroscopic, therefore inadequate to be used as mediums for paint to be applied on a plastic laminate and mixed with pigments hard to wet. Infact, formulations with these binders at different PVC turned out to be hardly spreadable on formica, not forming films. Also formulations with Zin Shofu had the same difficulties, as wheat starch is highly hygroscopic too. Then, the binders used for the formulation of retouching paints in this part of experimentation were three: Arabic gum 1:2, Klucel E 10% and sturgeon glue 1:10. They allowed to get well spreadable paints, when binded to carbon black, on a formica panel using a brush. Arabic gum was prepared with more glycerin to increase flexibility of obtained paint layers (2 ml for 20 gr of Arabic gum in 40 ml of demineralized water). Arabic gum was chosen for the lowest water content; Klucel E for the low molecular weight; and sturgeon glue for the lowest contact angle. The peptidic nature of sturgeon glue promised the best result of this binder in terms of dispersion of carbon black in water, but it is to consider that Arabic gum has peptide components (glycoproteins) as well.

Successively, many attempts were done to find the right pigment-binder ratio, in order to obtain coherent paint layers, not pulverulent and well adhered to the substrate. Critical Pigment Volume Contentration (CPVC) defines the optimal ratio of binder to pigment where the pigment is at its maximum loading and all the voids between the particles are completely filled with binder. It generally ranges between 30-60% (amount of pigments in the pictorial film). If the PVC is over the CPVC the paint film is more matt but increasingly fragile, because there are empty spaces among pigment particles, so it is a condition to avoid in the formulation of a retouching paint.

The CPVC of pigments in linseed oil is known. Linseed oil has small molecules which are able to wet pigments well. The average oil by weight to wet carbon black is 160 gr per 100 gr of pigment. To know the CPVC of carbon black in the water-based binders chosen for the experimentation it was necessary to make tests. It was important to consider the amount of the aqueous part of the binders tested, since it evaporates during the drying process of the pictorial film, as opposed to the case of oil medium where nothing evaporates away.

The pigment-binder ratio was defined after several tests: 25% carbon black/ 75% Arabic gum (1:3); 20% carbon black/ 80% Klucel E (1:4); 33% carbon black/ 67% sturgeon glue (1:2, more viscous); 25% carbon black/ 75% sturgeon glue (1:3, less viscous). These ratios were also kept in the corresponding mixtures of binders (e.g., 25% carbon black is binded by 75% of mixtures of Arabic gum with another binder). For the mixtures, Funori 2% and Zin Shofu 1:10 were chosen in consideration to their low reflectance values detected in the first part of the research; they were used also diluted (Funori 1% and Zin Shofu 1:20)

and in the maximum amount allowed considering the spreadability of the pictorial formulations obtained. Moreover, it was decided to test silica as matting agent in some formulations.

25 formulations were prepared, chosen according to their good spreadability on a formica panel. Each one was applied in two different ways: by brush, to obtain thinner films and to test the spreadability of formulations; using a flexible spatula, to avoid brushstrokes and obtain a more homogenous film. In total 50 samples of paint were applied. After they were dried, the colorimeter was used to verify variations of L^* (lightness) a^* (green-red) b^* (blue-yellow) values and find the best paint formulation for the retouching of the Alfano's artwork, considering also the SCI and SCE values.

Analysing the colour variations of samples at the different formulations, it can be attested that carbon black binded with Arabic gum has higher values in $L^* a^* b^*$ than carbon black binded with Klucel E and sturgeon glue, with the yellow component higher than the red one. Carbon black binded with 75% sturgeon glue gives an average value of lightness slightly lower than carbon black binded with 67% sturgeon glue. The addition of only 1 part of Funori or Zin Shofu doesn't lower the lightness of the formulations: in the case of 1-1.5 part of carbon black binded with 2 parts of sturgeon glue, L^* value rises slightly with the addition of 1 part of Funori 2% or Zin Shofu 1:10, while it remains almost unchanged with the addition of the same diluted binders (in the same proportions 1:2 with sturgeon glue). 1% silica always lower the lightness value of the formulations, less in the case of carbon black binded with Arabic gum, more in the case of carbon black binded with Klucel E.

The average values of the original paint of Alfano's artwork after the consolidation with Funori solution were $L^*22.1 a^*-0.1 b^*-0.7$ with a $\Delta SCI-SCE$ of 0.2. Considering the $L^* a^* b^*$ average values of Alfano's, the ΔE (total colour difference) of each painting sample was calculated and we identified in the mixture of 1-1.5 part of carbon black binded with 2 parts of sturgeon glue 1:10 and 1 part of Zin Shofu 1:20 the nearest values to those of Alfano's (both pigment-sturgeon glue ratios, 1:2 and 1:3) [figure 5, graph on the left]. Considering the only $\Delta SCI-SCE$, it was more difficult to find a single sample of reference, because more samples have a $\Delta SCI-SCE$ similar to that of Alfano's matt black paint. Samples with a higher $\Delta SCI-SCE$ were generally the ones applied by brush [figure 5, graph on the right]. A greater sheen of these samples was also visible to the naked eye, and is probably due to the method of application in which the paint is most flattened on the support. It is to consider that samples more similar to a real retouching are those applied using the spatula, since the application method in retouching is never brushstrokes on the surface but delicate brush touches. Testing a spray application in the experimentation would not make sense in relation to retouching because impractical, especially for small losses.

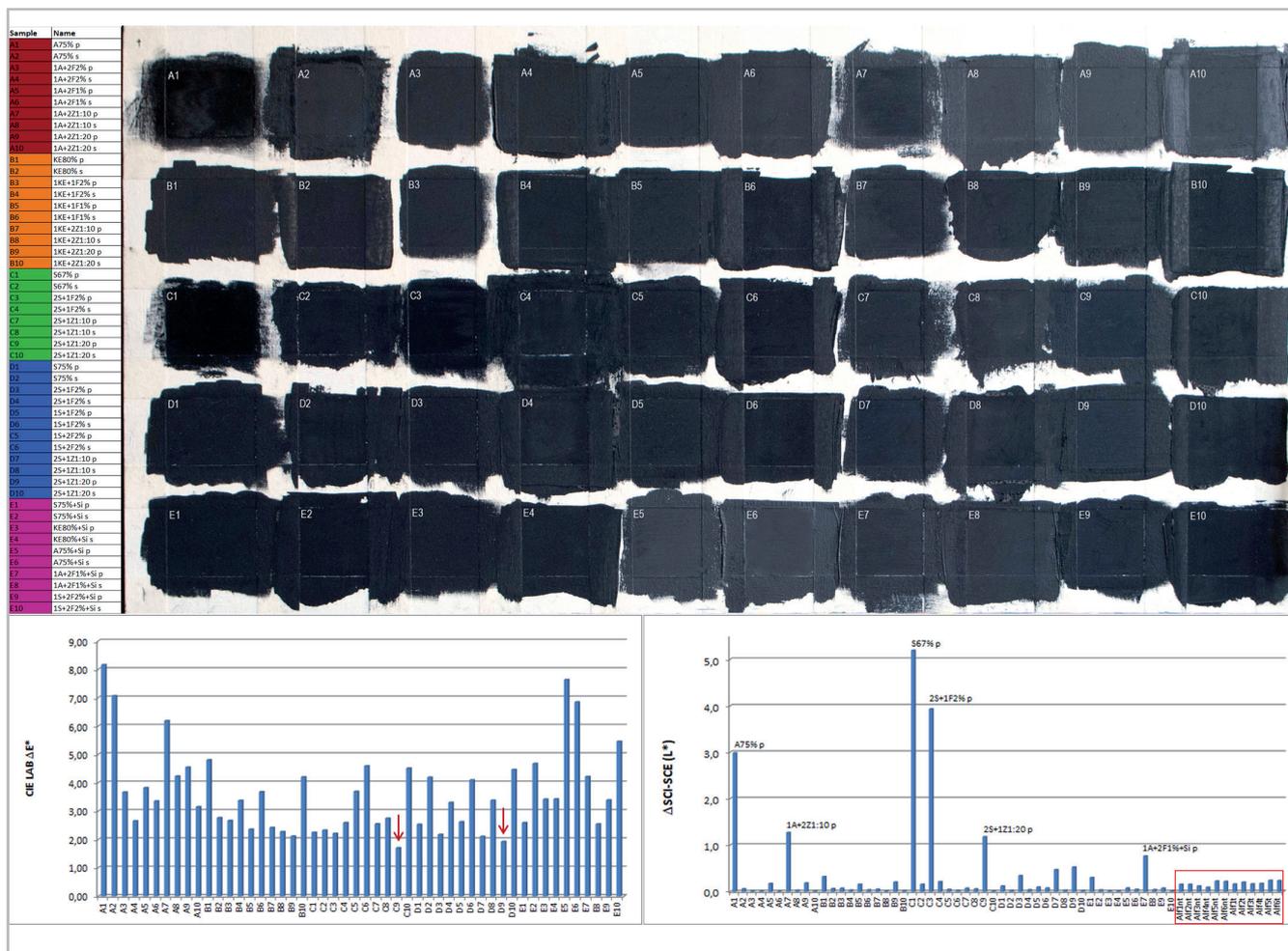


Figure 5.- The 50 paint samples applied on a formica panel for the second part of experimentation. In the table on the left, formulations used for each sample are reported. Odd samples are the ones applied by brush (p), the even ones are those applied using a spatula (s). There are 5 groups of samples (distinguished by colours in the table), each one is characterised by the concentration of medium indicated in the first two samples of the group. For example, sample A1 was made using 75% Arabic gum/carbon black applied by brush, sample A4 (1A+2F2% s) was made using a mix of 25% Arabic gum + 50% Funori 2%, for a total of 75% medium/carbon black, applied using a spatula. Below, on the left there is the graph related to colour differences between samples and the black area of Alfano’s artwork: the lowest ΔE values (so closer to Alfano’s) are C9 and D9, both correspond to the formulations of 1 part of sturgeon glue mixed with 2 parts of Zin Shofu 1:20, in different percentages of medium (C9 is 67% medium/carbon black, D9 is 75% medium/carbon black). Below, on the right there is the graph related to the ΔSCI-SCE values of all the paint samples and the black area of Alfano’s artwork, measurement points before the consolidation treatment (Alf1nt, Alf2nt etc.) and after the consolidation treatment (Alf1t, Alf2t etc.).

A general interpretation of the results was carried out by analysing the colour parameters through the analysis of the main components (PCA), so that the distances between the analysed variables could be observed simultaneously. Although not particularly suitable for the analysis of a few variables (in this case four), the PCA allows a clear interpretation of colour data, generally intuitable in other graphic forms. The matrix in particular was composed of the variables L*a*b* and ΔSCI-SCE for the black original paint of Alfano’s and the samples. To simplify the interpretation, the graph used was a biplot and contains both scores (scaled variables) and loadings (contribution of the original variables). The variables L* and b* describe well the fields used for comparison, as they deviate from the reference group (Alfano) especially

in relation to their variations. Samples with high ΔSCI-SCE and a* values are the outliers and correspond to applications by brush [figure 6].

As it is possible to see from the graphic representation of the main components, the ΔSCI-SCE values influence the result obtained by analysing the only ΔE. The group of points nearest to Alfano’s values (20, 30, 32, 36, 26, 40, 42, 50) corresponds mostly to sturgeon glue-based formulations (pigment-binder 1:3) applied using the spatula. No.30 and 40 have the same formulation of samples identified as the nearest to Alfano’s L*a*b* average values through the ΔE calculation. Point no.50 overlaps perfectly with one of the Alfano’s values before the consolidation treatment. Therefore, this analysis

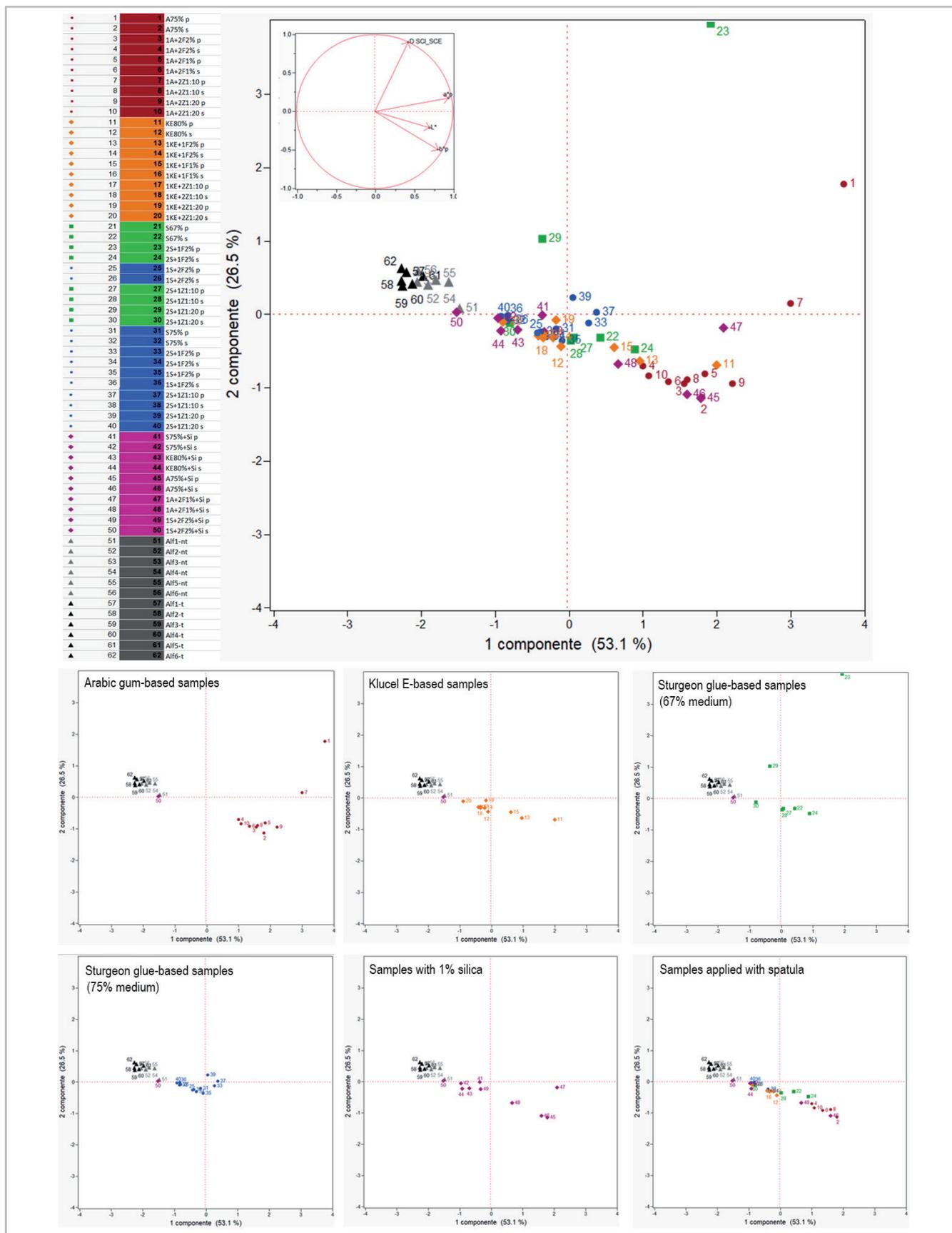


Figure 5.- PCA graphs. Above, in the table on the left there are the matches between sample numbers and symbols in the graphs. In the nearest group to Alfano, in addition to no. 50 (1S+2F2%+Si – pigment-binder ratio 1:3) there are 20 (1KE+2Z1:20), 26 (1S+2F2% – pigment-binder ratio 1:3), 30 (1S+2Z1:20 – pigment-binder ratio 1:2), 32 (S75%), 36 (1S+1F2% – pigment-binder ratio 1:3), 40 (2S+1Z1:20 – pigment-binder ratio 1:3), 42 (S75%+Si). All values correspond to the spatula application. 30 and 40 correspond to the formulations of C9 and D9 samples [see figure 5].

suggested that the best formulation for retouching of the artwork could be done with 1 part of carbon black binded with 1 part of sturgeon glue 1:10 and 2 parts of 2% Funori, with the addition of 1% silica.

Final considerations and conclusion

In relation to the individual binders considered in this study, the differences in terms of reflectance were highlighted. Funori, Klucel G and Tylose are the most matt binders, followed by Zin Shofu. The mixtures of Funori with the other binders (excluding those with Arabic gum) are the mattiest, as well as those of Klucel G and Tylose mixed with Zin Shofu and sturgeon glue. Mixtures of Zin Shofu and sturgeon glue are also matt. The addition of water and subsequent dilution leads to lower reflectance values. Obviously, when a retouching intervention is necessary, the binders have to be chosen in relation to the type of pigments with which they have to be mixed and the type of substrate on which the retouching has to be done (because both pigment and substrate involves different absorbent values).

This study was useful to show that results obtained analysing the Δ SCI-SCE of the layers of the tested binders with the colorimeter have similarities with those obtained with the glossmeter - 60° measurement angle. This means that the colorimeter can provide reliable data in relation to gloss values.

Finally, we demonstrated the usefulness of colorimeter as a response tool of the pictorial formulation to be used to get lightness and chromatic values as close as possible to those of the original paint film, thus respecting the requirement of sameness in the retouching of contemporary paintings characterised by matt surfaces and uniform tones.

References

CARNAZZA, P., FRANCONI, S. et al. (2019). "The consolidation of black matt synthetic and semi-synthetic paints in contemporary art. Experimentations, diagnostic analyses and observations." In *Proceedings of the VIII International Congress Colore&Conservazione*, Cesmar7, Venice (Italy) 25-26 Oct. 2018.

HACH (2016). "Measuring the specular reflection on surfaces (gloss measurement)" *Application Report No. 74*, <https://uk.hach.com/asset-get.download.jsa?id=51277653607>, [accessed 15/10/2019].

LALLI, C.G., KRON MORELLI, P. et al. (2016). Funori, natural adhesive for mural paintings and paper materials (in Italian), San Salvo: Linea Grafica editrice.

TATE-HARTE, A. et al. (2010). "Funori: a new medium for consolidation and retouching.", *The picture restorer*, 36: 13-14.

TUCKER C.W. (1936). Aqueous dispersion of carbon black. United States Patent 2046758.

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