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# CONTACT LENSES ON THE CHROMATIC REINTEGRATION PROCESS OF THE EYEBALLS OF A WOOD SCULPTURE

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## ABSTRACT

Chromatic reintegration aims to decrease deterioration evidences in the artwork and retrieve the visual interpretation of its iconographic shapes and contents.
This case study will focus on the chromatic reintegration process of the eyeballs of a wood sculpture representing Saint Teotónio. Instead of applying colour over the eyeballs, it was decided to make thin lenses that could be placed directly on the surface.
Experiments were carried out with different resins, on one centimetre in diameter moulds. The resins tested were Paraloid B72; PVA Inpainting Medium (Gustav Berger's Berger's O.F.); Mowilith DS 5/2; Aquazol 200; Plextol B500 and the monomer 2-ethyl hexyl acrylate (2 EHA).
The selected resin was the monomer 2 EHA, which was then tested in a mixture with acrylic paint to achieve an accurate colour representation of the iris and pupil of the eye.

**Keywords:** Conservation of wood sculpture; eyeballs; lenses; chromatic reintegration; monomer 2-ethyl hexyl acrylate.

## 1. INTRODUCTION

One of the essential features of the chromatic reintegration of wooden sculpture and other artworks is to be discrete. The main goal of this intervention was to recover the “sight" of the sculpture without interfering with the interpretation of the original, maintaining its devotional function.

One of the most challenging restoration processes is reconstructing the eyes of a sculpture. Some changes in the Saint Teotónio expression can occur when no previous visual information exists. The reconstruction poses several ethical and practical questions. Since this sculpture is a holy object, the discussion on overcoming these challenges was widely debated. It was decided to create something that could be easily removed, functioning as a contact-lens, and avoiding the direct application of the colour in the reconstructed eyeball. This decision would also fulfil other criteria such as some properties of the original material- since the original eyeballs would have been made of glass.The current ones were created, in a prior intervention, using an epoxy resin; the application of an opaque layer of paint could lead to a much different optical result from

**Figure 1 –** The front side of Saint Teotónio sculpture and head with epoxy resin reconstruction of the eyeball in a prior intervention.


**Figure 2** – Detail of the backside of the 18th century sculpture, made of chestnut wood wearing episcopal robes.

the original, caused by a distinct interaction between the light and this new material (Figure 1).

There are artificial acrylic eyes for sculptures for sale in sizes 18 mm to 75 mm. The retina is sold in many colours such as Black, Brown, Light Blue, Dark Blue and Green. But no publications on the production of artificial eyes in conservation and restoration were found.

As context, it is important to mention that the object is a full-size 18th century chestnut wood sculpture, depicting Saint Teotónio, wearing episcopal robes (Figure 2). Two polychrome techniques had been used: oil for the flesh tones and tempera for the clothes and the pedestal.

The edgings of the clothes are decorated with gold leaf and the lower part of the robe with vegetal and geometrical shapes, made with an estofado technique. The base is decorated with a marble effect (Figure 3).

The sculpture had already been subject to volumetric reconstructions when we started the project. The eyeballs were reconstructed with an epoxy resin, white and opaque. It was decided to preserve the previous intervention in order to avoid damages to the original material, particularly in the eyelid, and to think of a solution to finish the treatment. So, we aimed to reintegrate the small losses and to accomplish a truthful


**Figure 3** – Detail of the pedestal. It is possible to see the estofado technique and the marble effect of the base.

colour representation of the iris and pupil of the eye (Figure 4).

## 2. VALUE QUESTIONS

Analyzing an object in the 21st century does not necessarily depend on predetermined values. It cannot be confined to historical-artistic characterizations only, since each case varies substantially. Also, the sense of conservation and restoration, or preservation, has been

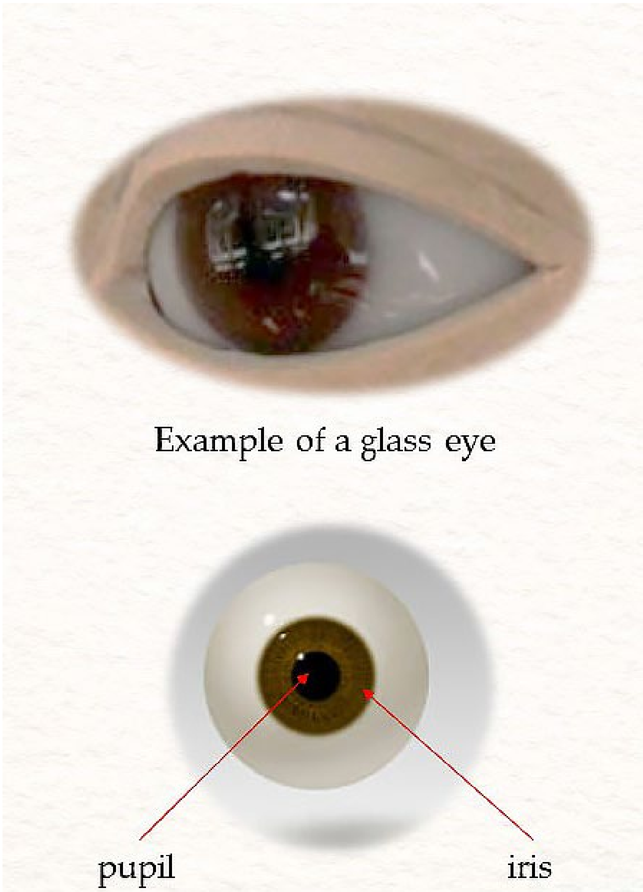



**Figure 4** – Example of a glass eye. Identification of the pupil and iris.

extended, considering the material and immaterial features of the object.
For the process of chromatic reintegration, the history and the marks of time are two things to have in mind.

The main goal is to return the object to a state close to its creation. The mentioned objectives are contradictory since to bring the work closer to what it would be in creation, it is necessary to eliminate certain marks of time. For this reason, it is essential to reflect on the need for reintegration and where and how an aesthetic procedure should be done. It is necessary at this stage to choose the most appropriate intervention for the object and take responsibility for this decision. As indicated by Ashley-Smith «the restoration treatments can produce (...) changes in their value [of the objects] » [1].

Considering the different values that an artwork can assume, it is considered that two of them, related to each other, can help in the decision-making process: the patrimonial function and the symbolic character of the object at the time of the intervention. The function can be subdivided into two categories: spiritual contemplation, associated with rite, symbolism, and iconography, and the material function, related to the creation of the work, *techné*.

In the first situation, when the losses interfere with the iconographic reading and the spirituality or the ritual of a community, the reconstruction of the work is considered so that it can fulfil its function. Reintegration is performed with formal and chromatic references and/or photographic or graphic documentation. In the second case, the decision depends on several actors and therefore may vary between non-intervention, minimal intervention, or integral reintegration (mimetic or differentiated).

The Saint Teotónio sculpture is a holy object. So, the aesthetic component of the artwork was taken into consideration. Devotion to an eyeless image is a difficult thing to do.

To accomplish both the criteria of recognition and retractability of the intervention, without changing the appearance of the face of the sculpture, the main idea was to create something that could be easily removed, and that could reassemble to a pupil and iris made of glass.

A contact lens seems to be the solution to achieve these criteria, avoiding the direct application of the colour in the reconstructed eyeball and providing similarity with the original material.

## 3. MATERIALS AND METHODS

### a. Mould Making

As A. Riley [2] wrote, "mould design is an important part of the development process when considering the production of a new moulding". To select the material for the mould, some considerations were taken:

- Successful removal of the casting from the mould is a critical factor to have in mind. The selected material for the mould should be flexible, and the side walls must ensure that the casting can be removed. The moulding must also be flexible enough and the undercut sufficiently small to pop or blow it off without damaging the casting material.

- The mould should have a circular shape with 1 cm in diameter to fit in the centre of the eyeball of Saint Teotónio;

- The mould should have approx. 1,3 mm of thickness. The lenses will be put in the eyeball through a magnet with 0,1 mm thick and with an area of 4,0 $mm^2$.

- The shape of the mould should be easy to replicate countless times without imperfections, in order to help with the experiment.

After taking these accounts into consideration, the siliconized paper from the silicone furniture crash pads seemed a good solution (Figure 5). More explanations will be given in the results topic.

**Figure 5** – Silicone furniture crash pads

#### b. Synthetic Resins

As mentioned, the application of an opaque layer of paint over the epoxy resin eyeballs would conduct to a much different optical result from the original glass eyeballs, caused by a distinct interaction between the light and this new material.

It was decided to compensate this lost of gloss using a material that could imitate the pupil and iris and reduce the impact of the changes in the light reflection.

The first experiments were carried out with five different resins available in the Conservation and Restoration Laboratory at the Instituto Politécnico de Tomar:

1. Paraloid B72 + Isopropanol (20% w/v);
2. PVA Inpainting Medium (Gustav Berger's O.F.) + ethyl alcohol (20% v/v);
3. Aquazol 200 + water (20% w/v);
4. Mowilith DS 5/2 (pure);
5. Plextol B500 (pure).

Paraloid B72 (Rohm and Haas) is a well-known and studied acrylic resin which has been and still is extensively used in the conservation field. It is a copolymer of ethyl methacrylate and methyl acrylate in a ratio of 70:30 [3], and it has a high molecular weight. According to Koob [4], its earliest use on glass is unknown but probably dates to the late 1970s and has been tested as a filling material for losses in ceramics and glass since then [4, 5]. For this case study, Paraloid B72 was prepared with 20% weight/volume of B72 dissolved in 2-propanol (i.e. 20g of B72 to 100ml 2-propanol) and allowed to dry up to l5 minutes.

PVA Inpainting Medium (Gustav Berger'sBerger's O.F.), is a concentrated retouching medium based on polyvinyl acetate (PVA), which can produce a very solid and transparent film [6]. The medium was diluted in ethyl alcohol (i.e. 20ml of PVA to 80ml ethyl alcohol) and allowed to dry up to 15 minutes.

Aquazol 200 (AQ 200) is formed by poly(2-ethyl-2-oxazoline) which have good resistance to ageing and high reversibility. It can be used both as an adhesive and consolidant of paint layers. It’s completely soluble in water, as well as polar solvents. It can replace water-based adhesives like animal gelatin, acrylic and polyvinyl acetate emulsions [7]. The resin was prepared with 20% weight/volume of Aquazol dissolved in demineralized water (i.e. 20g of AQ200 to 100ml water) and allowed to dry up to l5 minutes.

Mowilith DS 5/2 is a copolymer of vinyl acetate dibutyl maleate, which can be used as paint binders, coatings, and adhesives in conservation. As Mowilith DMC2 and Mowilith SDM5, the Mowilith DS 5/2 also ended up being discontinued. Like the manufacturing company Hoechst in 2009, Celanese (which included Hoechst) also decided to end the production of this soft polymer, widely used in conservation and restoration. CTS replaced Mowilith with a different polymer from a chemical point of view (ethylene vinyl acetate instead of a dibutyl maleate-vinyl acetate copolymer) called Eva Art [8]. But for this experience, it was used Mowilith DS 5/2, available in the lab, not diluted and allowed to dry up to l5 minutes.

Plextol B500 is an aqueous dispersion of a non-ionic stabilized thermoplastic acrylic polymer. It has excellent resistance against frost and high chemical stability. It is free from solvents and plasticizers and forms a clear, slightly tacky film. Plextol B500 has a density of 1.07 g/cm3 and an average particle size of 0.15 microns [9]. Plextol B 500 is most used in film-forming applications and as an adhesive for canvas lining and consolidation treatment of special plasters and was used not diluted.

The unsatisfying results, especially with elasticity, made the team search for another option. The chosen material for continuing the experiment was the monomer 2-ethyl hexyl acrylate (2-EHA), available on the market by Liquitex as a pouring medium for acrylics. At the time, this monomer was being used by one of the authors to get a solid and flawless body of very elastic paint.

The 2-ethyl hexyl acrylate (Dow) is not a well-known monomer in the conservation field. It's an acrylate monomer with the molecular formula of $CH_2 = CHCOOC_8H_{17}$, in the form of a transparent liquid.

2-EHA is one of the most used soft monomers/plasticizer materials for surface coatings, pouring medium, film, tapes, and for Pressure-Sensitive Adhesives (PSAs) [10] because of the low Tg (-54 and -70 ºC, respectively) [11] and low water solubility (0.15 g/100 $cm^3$ and 0.04 g/100 cm3 at 25ºC) [12]. It has good resistance to visible light and UV light.

The monomer 2-EHA is not soluble in water but is readily miscible with other organic solvents, such as alcohols and ethers. It has a characteristic acrylic odour and is readily polymerized with monomer molecules to create polymer chains. Reacts with oxidizing agents such as alkalis and polymerizes with heat application. It can be dosed through drops, has good dispersion, a higher tendency to generate gel [13] and low toxicity.

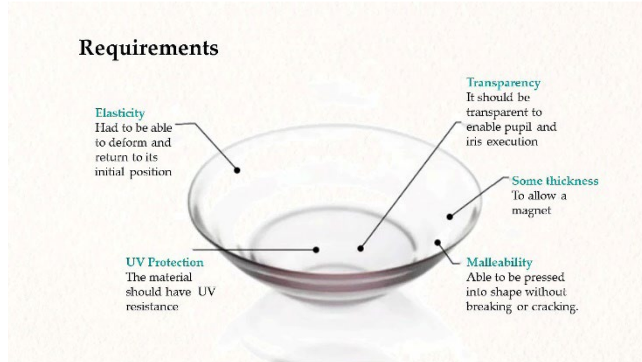



**Figure 6** – Requirements for the “lenses”.

In conclusion, this monomer respects the requirements of elasticity, transparency, thickness, malleability, and UV resistance designed for the “lenses” (Figure 6).

### c. Paints

Experiments with paints were performed to reach the intended hues for the iris and the pupil representation. Black was the selected hue. The intention was to attain a dark saturated pupil and an unsaturated, dark iris.

Were selected three brands of acrylic paints available in the lab:

- Vallejo Acrylic Artist Colour
- Winsor & Newton Galeria
- Liquitex Heavy Body

Vallejo Acrylic Artist Colour pigments are dispersed in a 100% acrylic polymer dispersion, with no addition of fillers or matting agents. The colours have a thick and pasty consistency, drying with a minimal colour alteration. The film is flexible and resistant. According to manufacturers [14], the colour is water-resistant, non-yellowing, and UV resistant.

The paints Liquitex Heavy Body have a minimal wet-to-dry shift. According to the information disclosure by manufacturers [15] forms a flexible, durable, non-yellowing, UV-resistant and water-resistant film when dry.

Winsor & Newton Galeria are fluid colours with a lower concentration of pigments, but, according to the manufacturers [16], with good coverage, opacity, and permanence with a smooth, satin finish.

### d. Application with magnets

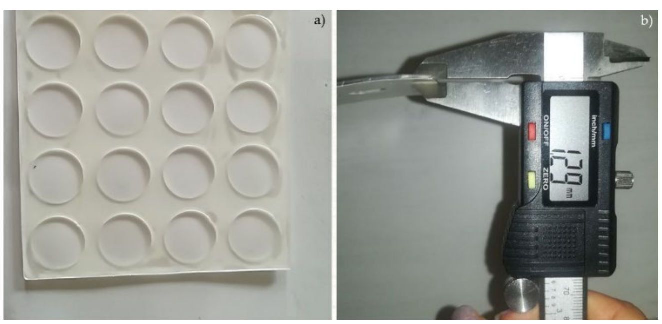
Along with the main goal of finding a solution that could reassemble the vitreous quality of the original eyes, it was also an aim to create a system that could be easily removed, if necessary. To achieve this, two 0,1 mm thick magnets, with an area of 4,0 mm$^2$, were applied in each eyeball and in the back of each lens (back of the pupil).

## 4. RESULTS

### a. Mould Making

The 3M siliconized paper was used as a mould without the silicone crash pads. With these "moulds" we could accomplish the requirements:

- circular shape with 10 mm of diameter;
- 1,29 mm of thickness (Figure 7);
- Flexible;
- side walls that will minimize the damage of the material of the casting;
- can be replicated countless times.



**Figures 7 –** a) The siliconized paper without the silicone crash pads; b) measurement of the siliconized paper with a pachymeter.

### b. Synthetic Resins

The first experiments were taken with the five different resins: Paraloid B72, PVA Inpainting Medium (Gustav Berger'sBerger's O.F.), Aquazol 200 Plextol B500 and Mowilith DS 5/2 at room temperature (approx. 18º C).

The evaluation of the behaviour of the resins was performed through observation and visual comparisons of optical, mechanical, and physical properties. One sample of each resin was prepared. Five factors were evaluated: drying time, elasticity, malleability, transparency, and thickness. Some of these parameters are related to each other in terms of thickness, elasticity, and plasticity. The result was intended to be a thin material, 1,3 mm thick, with enough flexibility to be shaped as a lens, and with enough elasticity to be safely removed from the mould, without risk of deformation.

The resin with the best results was Paraloid B72 (Table 1) because PB72 dried fast, had good elasticity, very good malleability, became utterly transparent and was possible to achieve a thin thickness.

**Table 1 –** Results of the visual comparisons between the five resins.

| | DRY TIME | ELASTICITY | MALLEABILITY | TRANSPARENCY | THIN THICKNESS |
|---|---|---|---|---|---|
| Paraloid B72 + Isopropanol | +++ Dries fast | ++ Good | +++ Very good | +++ Completely transparent | ++ Good |
| PVA + Gustav Berger | ++ Average | ++ Good | ++ Good | +++ Completely transparent | ++ Good |
| Mowilith Ds 5/2 | + Very slow | ++ Good | +++ Very good | ++ Transparent slightly yellow | + Bad |
| Aquazol 200 + $H_2O$ | ++ Average | + Bad | + Gets stuck in the mold | + Yellow opaque | + Bad |
| Plexol B500 | + Very slow | ++ Good | ++ Good | ++ Transparent slightly bluish | + Bad |

But the good results of PB72 were not enough. Some problems were experienced related to: bubbles; adjustment of the resin to the mould and deformation of the lenses when taking them out of the mould.

The elasticity was good but not excellent. The resin did not return precisely to its initial position.

The search for better results led to a second experiment with the monomer 2-ethyl hexyl acrylate (2EHA). It was then possible to overcome the bubbles' shape and deformation problems.

After selecting 2 EHA, it was necessary to define the accurate thickness of the lens. The first tests were made by applying one drop into the mould directly from the package. This material was very fluid and had a good dispersion. For these reasons, it was possible to use a tool such as a wooden stick or a small spatula to help

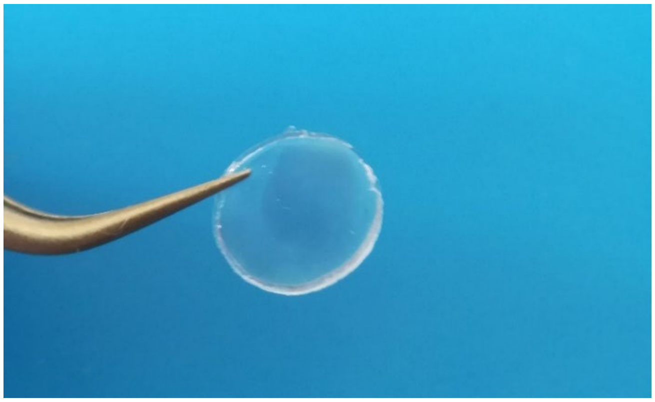


**Figure 8 –** First 2-ethyl hexyl acrylate lens.

the monomer flow into the mould. Due to the remarkable capacity of fluidity, 2 EHA adjusted precisely to the shape of the mould. To achieve the right thickness with some curve, were necessary six drops, c. 0,3 ml (Figure 8).

The lenses could be easily removed, but some minor deformation occurred when removing the lens from its mould, but the elasticity and malleability allows some corrections.

### c. Paints

The monomer 2 EHA was tested with the three previous mentioned brands of acrylic paint:

- Vallejo Acrylic Artist Colour
- Winsor & Newton Galeria
- Liquitex Heavy Body

Before starting the mixing, a question was imposed? How to achieve a pupil and an iris? Mixing the acrylic paint with the monomer did not seem to be the right way. The result would be a black "lens", without differentiation between pupil and iris. For this reason, it was attempted to apply the acrylic paint in the centre of the 2 EHA monomer after the beginning of the drying process to control the pupil's colour slightly and distinguish it from the iris.

As the tones of black vary, the undertones of three blacks were also compared before starting (Table 2):

**Table 2 –** Comparison of undertones of three blacks.

| Colour | Undertone |
|---|---|
| Lamp Black (PBk7) | A black with a bluish tint, producing a variety of cool blue-greys |
| Ivory Black (PBk9) | Black colour with brown undertones |
| Mars Black (PBk11) | A dense black colour with a brown undertone |

Lamp Black (PBK 7) is a semi-opaque to opaque, intense black with a high tinting strength. It often has a cool undertone, bluish-grey when mixed with white. It is an amorphous carbon from soot.

Ivory black (PBk 9) tends to be semi-opaque to semi-transparent, and it is usually lower in tinting strength. Often has a yellow or brown undertone, which can be seen in glazes and tints with white. Ivory Black was originally made by carbonizing ivory. Now, any black paint containing the pigment number PBk 9 is produced from animal bones, which is to bear in mind if the purpose is to avoid animal products.

Mars black or iron oxide black is different to all the previously mentioned black pigments because it is not carbon-based. This characteristic was one of the motives to choose this pigment. The two others were:

- warm in undertone, which gives a more realistic appearance for the pupil and iris;
- high tinting strength could help the achievement of a strong colour for the pupil.

The Mars family of pigments were developed in the 20$^{th}$ century as alternatives to natural earth pigments. This family includes Mars Yellow and Mars Violet, all synthetic iron oxides. Mars Black (PBk 11), along with Lamp Black (PBK 7) and Carbon Black (PBk 6), is one of the opaquest of the black pigments. It is often warm in an undertone, ordinarily brown, with high tinting strength and has good coverage.

After several tests, the resin that allowed better results was Vallejo, for not dispersing/emulsifying instantaneously in the monomer. It was possible to better control the distinction between pupil and iris,

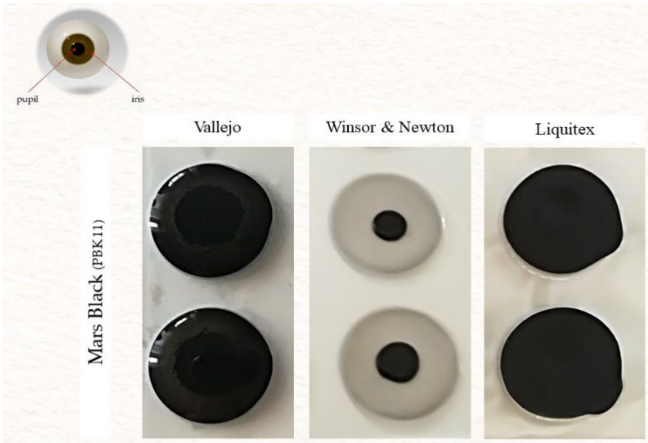



**Figure 9** – Testing three brands of acrylic paints: Vallejo, Winsor & Newton and Liquitex.

although it was necessary to accomplish several samples to have a similar pair. One in each group of five samples was chosen.

The acrylic paint from Liquitex, because it was of the same brand as the monomer in use, was instantly mixed with it, and for that reason, the pupil diameter could not be controlled. Winsor & newton's acrylic paint wasn't appropriately dispersed (Figure 9).

After the decision making about Vallejo Acrylic Artist Colour, the different blacks were tested, and the undertone was established (Figure 10).

After selecting the suitable materials and proportions, the main challenge was obtaining at least one pair of lenses with a similar paint distribution in the iris and a similar pupil diameter. After several tests, it was defined that the best way to get these results was to start by placing the 2 EHA in the mould cavity, followed by the paint applied with a wooden stick while the monomer is liquid. Are necessary six drops of 2 EHA (approx. 0,3 ml) and just a small quantity of paint (Figure 11). To put the colour right over the centre of the monomer is essential to use the stick perfectly perpendicular to the surface. The inclination of the wood stick promotes deformation of the pupil diameter that may become irregular.

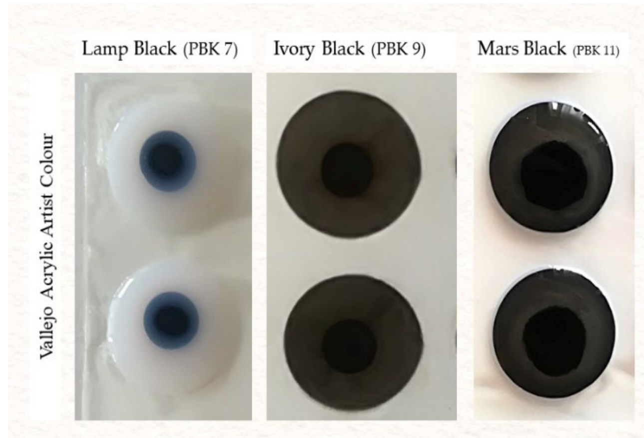



**Figure 10** – Testing the three blacks of Vallejo Acrylic Artist Colour. The best result was achieved with Mars Black.

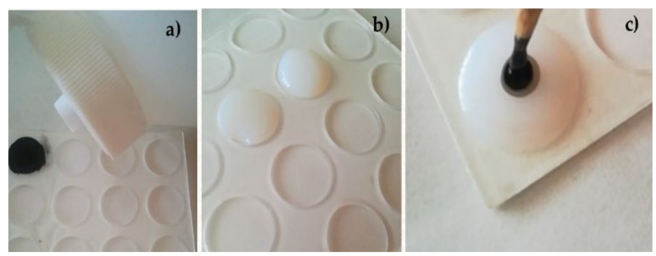



**Figure 11** – Methodology: a) placing the 2 EHA directed from the package; b) appearance of the monomer; c) applying the colour with a wood stick.

## d. Chromatic Reintegration and application of the lenses on the eyeball

### Chromatic Reintegration of the losses in the face

The treatment started with the chromatic reintegration of the filling materials in the face of the sculpture. Professional Watercolours of Winsor & Newton brand were applied layer over layer until they imitated the appearance of the original colour of the face as closely as possible. The technical name for this method is referred to as "imitative" or "mimetic" retouching because it aims to reconstruct the missing parts of the image and resemble the original colour. The colours applied were: Ultramarine Blue (PB 29); Yellow Ochre (PY 42); Indian Red (PR 101); Burnt Umber (PBr7); Raw Umber (PBR 7), and Titanium White (PW 6).

- It was used a pinkish tone, made with titanium white (PW 6), earth colours and Indian red (PR 101) for the flesh colour. In some areas it was also added a small portion of the blue colour (PB 29);
- For the hair, a mix of yellow ochre (PY 42), ultramarine blue (PB 29) and Indian red (PR 101), plus burnt umber (PBR 7).
- About the application: first, overpaint and then glazes.

**Application of the lenses**

Along with the primary goal of finding a solution that could reassemble the vitreous quality of the original eyes, it was also an aim to create a system that could be easily removed, if necessary. To achieve this, two 1,0 mm thick magnets, with an area of 4,0 mm$^2$, were applied in each eyeball and in the back of each lens (back of the pupil). For the lenses not to be separated from the surface of the eyeball, due to the increase of thickness from the magnets, it was necessary to carve the surface. In this way, it was possible to keep the correct conformation of the lenses, with no gaps between the surfaces. The magnets were glued using a polyvinyl acetate adhesive (Figure 12, 13).

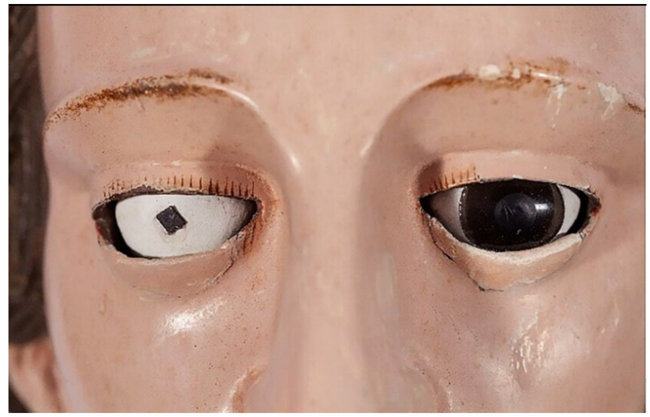


**Figure 12 –** Application of the lenses using a magnet.

**Figure 13 –** Final result.

## 5. CONCLUSION

Of the six tested materials, the one that gave the best results was the monomer 2-ethyl hexyl acrylate. With 2 EHA and a two-layer application system made of pure monomer and acrylic paint, it was possible to reach the three important properties initially defined, such as a flexibility, elasticity, and transparency. Although distinguishable from a glass eyeball, the result shows similarities in terms of the optical features and light interaction, mainly due to the depth achieved using a transparent and glossy material.

It is essential to point out that the evaluation of the behaviour of the resins was only qualitative, performed by visual comparisons of optical, mechanical, and physical properties. Other methodology can be applied to achieve other results.

These “lenses” obtained with 2 EHA can also be moulded into the desired shape and easily removed from the mould with minimal deformation.

This study is an ongoing project; many other tests are necessary to improve the surface, which can be more convex (bulging outwards from the lens), concave (depressed into the lens), or planar (flat) depending on the primary goal.

The result is a wood sculpture with a removable iris and pupil. The method applied can accomplish the ground principles of conservation and restoration, such as recognition, removability, and minimal intervention.

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