DEPARTMENT OF CONSERVATION AND RESTORATION

ȘTEFAN CĂTĂLIN ANTONESCU

Bachelor's Degree in Conservation and Restoration

TREATMENT OF AN 18TH-CENTURY OIL PAINTING BEATA LUDOVICA ALBERTONA FROM PALÁCIO NACIONAL DE MAFRA

MASTER IN CONSERVATION AND RESTORATION

NOVA University of Lisbon

September, 2025

NOVA SCHOOL OF
SCIENCE & TECHNOLOGY

DEPARTAMENT OF CONSERVATION AND RESTORATION

TREATMENT OF AN 18TH-CENTURY OIL PAINTING BEATA LUDOVICA ALBERTONA FROM PALÁCIO NACIONAL DE MAFRA

ȘTEFAN CĂTĂLIN ANTONESCU

Bachelor's Degree in Conservation and Restoration

Adviser: Joana Devesa
Senior Technician, Restorer in the Department of Ancient Easel Paintings, Laboratório José de Figueiredo

Co-adviser: Prof. Dr. Sara Sobral Babo
Auxiliary Professor, NOVA School of Science and Technology

Examination Committee:

Chair: Prof. Dr. Joana Lia Ferreira
Auxiliary Professor, NOVA School of Science and Technology

Rapporteur: Dr. Kate Seymour
Directory Board at ICOM-CC, Netherlands

MASTER IN CONSERVATION AND RESTORATION

NOVA University of Lisbon
September, 2025

Treatment of an 18th-Century Oil Painting Beata Ludovica Albertona from Palácio Nacional De Mafra

This document was created with Microsoft Word text processor and the NOVAthesis Word template.

ACKNOWLEDGMENTS

I would like to express my appreciation to my supervisor, Joana Devesa, for her invaluable guidance throughout the course of this research. I am grateful for the opportunity to work and learn under her supervision. Her expertise, insightful discussions and constant support were fundamental in shaping both this thesis and my personal and professional growth. I am equally thankful to my co-supervisor, Sara Babo, for her patience, understanding and constructive feedback throughout my academic studies and the research of this work.

This research would not have been possible without the support of Dr. Rui Borges, Director of Laboratório José de Figueiredo, which hosted my internship and provided access to essential resources. I thank all staff of the laboratory, who welcomed me with warmth and created such a motivating environment, especially Débora Sarmento, Elsa Murta, Maria João Furtado, Michele Portela, and Tiago Dias. I am especially grateful to Diana Conde and Vanessa Antunes from the Paintings Department for their valuable suggestions regarding my treatment intervention, to Ana Catarina Pinheiro for the biological analysis of the fungi infestation, to Ana Margarida Cardoso for her guidance in the tear-mending dynamometer empirical tests, and to Luís Bravo for his studio photography.

My gratitude extends to Dr. Sergio Gorjão, Director of Palácio Nacional de Mafra for providing important historical insights and allowing me to visit the Palace, as well as the Palace staff who accompanied my visit and shared their knowledge of its history and heritage.

To my friends and colleagues, Rita Mouta, Luís Visser and Andreia Silva, I am thankful for their companionship, for making my academic experience lighter and more enjoyable, and for accepting me as an international student.

To my dear friend and partner in crime, Alexandra Ioaneș, I am profoundly indebted for sharing with me this beautiful experience of moving and living in a different country. The moments we spent together were priceless, and I feel forever fortunate to have her wonderful soul by my side throughout all the good, the bad, and the ugly times.

Above all, I dedicate my deepest gratitude to my mom, dad, brother, grandmother, my cat Pietà, and all relatives who supported, encouraged, and had an unwavering belief in me. This accomplishment would not have been possible without them. Their love and sacrifice radiated across countries and was felt every day of my being, sustaining me through all the challenges encountered both in my personal or academic life.

Abstract

This thesis presents the study and treatment of *Beata Ludovica Albertona*, an 18th-century oil painting from Palácio Nacional de Mafra, Portugal. The project was carried out during an internship at the Laboratório José de Figueiredo between September 2024 and July 2025.

The painting belongs to a set of 13 paintings depicting the Devotional Saints of the Third Order of Saint Francis, all measuring 136 × 98 cm, with the exception of the painting under study. *Beata Ludovica Albertona* exhibited significant structural instability, including compromised strainer and tacking margins, two small tears, and delamination between the paint layers and the canvas, manifested through craquelure, flaking, cupping, and paint losses. The legibility of the composition was further obscured by surface dirt, an oxidized and yellowed varnish, and fungal infestation in the lower half of the canvas. Evidence of re-dimensioning was also identified, as paint layers were observed along the upper and lower tacking margins, and the lower edge presented evident signs of having been previously cut.

Based on prior historical research, the diagnosis assessment and a literature review, a treatment proposal was formulated. This included consolidation, application of a facing, cleaning the back, flattening of the paint layers, strip-lining, surface cleaning, varnish removal, tear mending, and infilling of losses. Although the treatment was not completed during the internship, the subsequent steps defined were the filling of the re-dimensioned lower section, chromatic reintegration, and the application of a final varnish layer. Particular emphasis throughout the intervention was placed on addressing the structural deterioration of the painting. The findings of the literature review on structural treatments, particularly consolidation, tear repair, and strip-lining, were combined with empirical tests of various adhesives and methods, to provide the rationale for selecting materials that ensured both effective stabilization and future retreatability.

Keywords: 18th-century oil painting; Structural treatments; Empirical testing; Conservation and Restoration intervention; retreatability.

Resumo

Esta dissertação apresenta o estudo e o tratamento da *Beata Ludovica Albertona*, uma pintura a óleo do século XVIII do Palácio Nacional de Mafra, Portugal. O projeto foi desenvolvido durante o estágio no Laboratório José de Figueiredo, entre setembro de 2024 e julho de 2025.

A obra integra um conjunto de 13 pinturas que representam os Santos Devocionais da Ordem Terceira de São Francisco, todas com dimensões de 136 × 98 cm, à exceção da pintura em estudo. A *Beata Ludovica Albertona* apresentava instabilidade estrutural significativa, incluindo grade e margens de fixação comprometidas, dois pequenos rasgões e delaminação entre as camadas pictóricas e a tela, manifestada através de craquelê, destacamentos, *cupping* e lacunas. A leitura da composição encontrava-se ainda comprometida por sujidade superficial, um verniz oxidado e amarelado, e infestação fúngica na metade inferior. Foram também identificados indícios de redimensionamento, dado que se observaram camadas pictóricas nas margens superior e inferior, estando a margem inferior recortada.

Com base na investigação histórica preliminar, na revisão bibliográfica sobre técnicas e materiais de conservação e no diagnóstico efetuado, foi formulada uma proposta de intervenção. A intervenção incluiu consolidação, aplicação de *facing*, limpeza do verso, planificação das camadas de pintura, *strip-lining*, limpeza superficial, remoção de verniz, reparação dos rasgões e reintegração das lacunas. Apesar de o tratamento não ter sido concluído durante o estágio, os passos seguintes incluem o preenchimento da faixa inferior redimensionada, a reintegração cromática e a aplicação de uma camada final de verniz. Ao longo de toda a intervenção, foi atribuída particular relevância à resolução da degradação estrutural da pintura. Os resultados da revisão bibliográfica sobre tratamentos estruturais, em especial a consolidação, a reparação de rasgões e o *strip-lining*, foram combinados com a experimentação empírica de diversos adesivos e métodos, permitindo fundamentar a escolha de materiais que assegurassem simultaneamente a estabilização eficaz da obra e a possibilidade de futuros retratamentos.

Palavas chave: Pintura a óleo; século XVIII; Tratamentos estruturais; Testes empíricos; Intervenção de Conservação e Restauração; Retratabilidade.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACRONYMS

DCR	Department of Conservation and Restoration
EVA	Ethylene vinyl acetate
FCT-NOVA	NOVA School of Science and Technology
HPC	Hydroxypropyl cellulose
LJF	Laboratório José de Figueiredo
MC	Methylcellulose
MFFT	Minimum Film Formation Temperature
MW	Molecular Weight
OM	Optical Microscopy
PNM	Palácio Nacional de Mafra
PVA	Polyvinyl acetate
RH	Relative humidity
RSG	Rabbit skin glue
SG	Sturgeon glue
TAC	Triammonium citrate
T_d	Temperature of denaturation
TEA	Triethanolamine
T_g	Glass transition temperature
UV	Ultraviolet
WS	Wheat Starch

1

INTRODUCTION

This thesis results from an internship at Laboratório José de Figueiredo (LJF), Department of Ancient Easel Paintings, carried out from September 2024 to July 2025, as part of the master's degree in Conservation and Restoration at FCT-NOVA, Lisbon. The research reflected on the integration of theoretical knowledge and practical applications. This combination enabled the advancement of technical expertise and a deeper understanding of the materials and methodologies involved in the conservation and restoration of easel paintings, particularly on the structural treatment of oil on canvas paintings.

The primary objective of this project was to conduct a complete treatment of an 18th-century oil painting on canvas, *Beata Ludovica Albertona*, of an unknown artist, from Palácio Nacional de Mafra (PNM), Portugal. The painting was received at LJF on June 3, 2024, in a deteriorated condition, necessitating extensive intervention to restore both its structural stability and aesthetic integrity.

The initial phase of the study focused on an overview of the painting's historical background, materials, and techniques. A detailed diagnosis of its state of conservation was conducted to assess the various forms of degradation and structural instabilities. The examination of the painting is presented in the first chapter, highlighting specific challenges in structural treatments. Given the painting's poor state of conservation and the absence of documentation of prior studies or interventions, this served as the basis and focus of the theoretical chapters and the formulation of an appropriate treatment proposal.

The second phase was subdivided into two sections: the theoretical research and the treatment intervention of the painting under study. The theoretical chapter focuses on structural treatments, which were later performed in the intervention. The objectives of the treatment intervention were established following Conservation and Restoration protocols (E.C.C.O., 2003), considering ethical considerations inherent in the field, such as retreatability.

The theoretical and intervention sections were structured into sub-chapters, each dedicated to a specific phase of the treatment, building upon knowledge acquired in the previous chapters and informed by continuous observation and research. The decision-making process was preceded by a bibliographic review, which guided the formulation of an appropriate treatment proposal that was then tailored to the painting's specific needs through empirical tests. The analysis of these empirical tests, considering both their possibilities and limitations, allowed for the selection of the most suitable materials and techniques for each treatment stage. Each stage of the process was guided by thorough observation. The initial photographic documentation of the painting was carried out by Luís Bravo in the laboratory's studio under visible, transmitted, and ultraviolet (UV) light. This was complemented by direct visual examination using optivisors, a UV lamp, and a Dino-Lite© Digital Microscope (AM4113T) to support the decision-making process. Additionally, micro-samples were collected, prepared as cross-sections, and analyzed under OM (see Appendix F.1 for the equipment) at the DCR of FCT-NOVA, enabling a characterization of the painting's stratigraphy. The appendices include photographic documentation, mappings, description of the empirical tests conducted throughout the process, and supplementary information. This information provides further insight into various subjects explored during the internship.

2

THE PAINTING *BEATA LUDOVICA ALBERTONA*

The existing information on the historical context of the painting was limited. To gain a clearer understanding of the painting's origin, particularly its religious theme and chronology of its past locations, the available public documentation (RAIZ, 2025) was consulted to make a more informed decision on the treatment intervention. Alongside the research, the Director of PNM, Dr. Sérgio Gorjão, was contacted via email to provide further insight into the painting. Following a subsequent visit to the Palace, it was possible to reconstruct a preliminary overview of the painting's historical background.

2.1 GENERAL DESCRIPTION

Beata Ludovica Albertona is an 18th-century oil painting on canvas, measuring, before treatment, 128.5 cm in length, 98.5 cm in width, and 2.7 cm in thickness (excluding the frame). It belongs to PNM, with the inventory no. PNM 2. The work is unsigned and not attributed to a specific artist. The painting portrays Blessed Ludovica Albertoni as indicated by the inscription "*B ‣ LUD ‣ CA ▾ ALBERT[...]NIA*" at the middle-top edge of the composition (Figure 2.1). The central figure, wearing a dark tunic, is depicted standing on clouds with her arms open, suggesting a gesture of adoration, gazing towards the upper right corner. At the top right of the painting, it appears that four cherubs are shown among the clouds, while a yellow beam of light illuminates the figure. On the left side of the composition, from what can be perceived as a window, a landscape featuring a sky and trees are visible in the background. To the right, a red altar is present, covered with a white cloth, on which a crucifix and two altar candles are placed.

Figure 2.1: Normal light before treatment, photograph of the front of the painting *Beata Ludovica Albertona*. @LJF Luís Bravo, 2024.

As noted by Puglisi (1992), Lloyd (2010), and Lark (2020), Ludovica Albertoni was born into Roman nobility in 1473 and demonstrated a deep devotion to faith from an early age. Her spiritual commitment intensified following the death of her husband in 1506, after which she became a member of the Third Order of Saint Francis. From that point forward, Ludovica's life became one of profound religious dedication, marked by acts of charity, constant prayer, and penance (Puglisi, 1992; Avery, 1997). She continued this path until her death in 1533, where she was buried in her husband's Altieri family Chapel, located in San Francesco a Ripa, in the Trastevere district of Rome (Lloyd, 2010). As Puglisi (1992) stated, it was not the ecstasies and miraculous phenomena, such as levitation, that primarily drew the admiration of the public, but rather her consistent acts of compassion and care for the poor. Over time, this admiration evolved into a popular devotional cult centered around her tomb. This widespread veneration culminated in her beatification in 1671 by Pope Clement X.

2.2 DEVOTIONAL ICONOGRAPHY OF THE THIRD ORDER OF SAINT FRANCIS

According to Dr. Sergio Gorjão (personal communication, October 17, 2024), the painting under study belongs to an iconographic group comprising 13 paintings, all centered on the theme of Devotional Saints of the Third Order of Saint Francis (see Appendix B for the complete list of paintings). Dr. Sergio Gorjão stated that, historically, this collection was even more extensive, as one of the paintings is currently in the possession of the Brotherhood of the Holy Sacrament of Mafra (Irmandade do Santíssimo Sacramento de Mafra), suggesting the group may have been separated over time. Dr. Sergio Gorjão expressed that in the mid-20th-century, Ayres de Carvalho, then conservator at PNM, proposed that these paintings were likely commissioned as a unified set during the 18th-century by King João V, intended to adorn the chapels of the covenant. Additionally, during the 19th-century, the paintings assumed a decorative role within the palace, displayed across two rooms on the ground floor near the North Entrance, and by the mid-20th-century, the series was removed from public view and transferred to storage rooms (see Appendix C for the history and timeline of the painting under study).

Because of the consistent thematic and physical characteristics shared across the works, it is reasonable to consider these paintings as a group. A comparative analysis of their inventory records, dimensions, and iconographic themes appears to reveal a likelihood amongst the paintings. Such similarity include their date of production and location. Those appear to be consistent to the early 18th-century, likely around 1730, and located in Italy, possibly Rome. Despite the shared attributes, the majority of paintings' authorship remains uncertain, as none bear a signature[1].

Thematically, the paintings comprising the series dedicated to the Devotional Saints of the Third Order of Saint Francis share notable visual and symbolic elements. Among the most consistent features are the coarse woolen tunics and knotted ropes worn around the waist, distinctive attributes traditionally associated with Saint Francis, which are depicted on each figure in the group, except for the painting *São José e o Menino Jesus* (Saint Joseph and Baby Jesus), inventory no. PNM 16.

In terms of physical characteristics, the paintings appear to have originally shared uniform dimensions, approximately 136 cm in height and 98 cm in width. There are two notable exceptions to this standard: *São Francisco recebendo os estigmas* (Saint Francis Receiving the Stigmata), inventory no. PNM 10, and the painting currently under study, Beata Ludovica Albertoni. Before undergoing restoration in 2024 by a private studio, the first painting measured

[1] An exception is *São João de Capistrano* (inventory no. PNM 7643), which is attributed, though unsigned, to the Italian painter Francesco Trevisani.

129 cm by 94 cm. However, as part of the conservation intervention, its dimensions were adjusted to align with the rest of the series, now matching the 136 cm by 98 cm format. The differing dimensions of *Beata Ludovica Albertona* remain a point of focus within the thesis and will be discussed in greater detail in the following chapters, both in the diagnostic assessment and the description of the treatment intervention.

2.3 MATERIALS AND CONDITION REPORT

2.3.1 AUXILIARY SUPPORT: STRAINER

The painting was mounted on a rectangular wooden strainer, comprised of four thin, non-beveled fixed members (Figure 2.2). The construction of the strainer revealed a combination of joint techniques: the top left and both bottom corners were assembled using a variation of the Mortise and Tenon joint (Buckley, 2021a) (Figure D.1a,b), whereas the top right corner employed a half-lap joint (Figure D.1c). Two crossbars were integrated into the strainer structure, each connected with half-lap joints. Notably, the crossbars were not interlocked but instead overlapped, with the vertical crossbar positioned above the horizontal one. However, the strainer bars' width were inadequate for the dimensions of the painting, which could lead to instability into the canvas tension, creating creases.

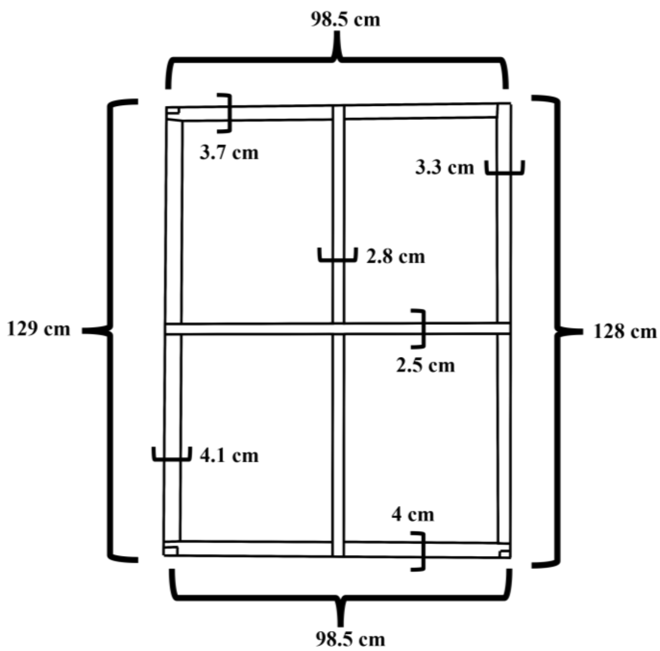


Figure 2.2: Diagram of the strainer's dimensions before the treatment intervention.

Evidence of additional tack holes was observed on both the strainer and the canvas, which did not align with the current tacks (Figure 2.8). This misalignment suggested the possibility of a previous re-stretching of the canvas or the replacement of the original wooden support. The corners of the strainer remained relatively stable and free from distortion. In contrast, the crossbars exhibited minor warping, with the vertical bar bending inward toward the canvas. The wooden surface of the strainer showed signs of localized wear and damage, including scratches (Figure D.2a), splinters (Figure D.2b), material loss (Figure D.2c), and natural wood irregularities such as knots (Figure D.3a).

In certain areas, the wooden strainer exhibited cracks around the points where tacks were inserted (Figure D.3b). Tack holes, some containing remnants of metallic elements, were visible along both the sides and back of the strainer (Figure D.3c), with dark stains surrounding some tacks (Figure D.4a). The surface of the strainer was coated with a layer of superficial dust, with dirt deposits particularly concentrated on the bottom edge and horizontal crossbar (Figure D.4b). Additionally, localized white stains, resembling drops of paint, were present in some areas (Figure D.4c).

The strainer has also been damaged by an infestation of xylophagous insects that has caused significant deterioration. The upper right portion of the strainer's member was the most severely affected, showing substantial wood loss and brittleness (Figure 2.3).

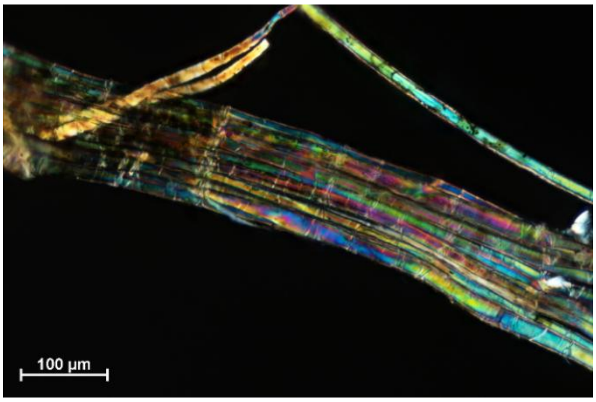
Figure 2.3: Material loss due to xylophagous insects attack.

This damage significantly compromised the strainer overall stability, as the bars could not provide proper tension in the canvas. Over 50 exit holes were visible, primarily on the upper member and the horizontal crossbar (Figure 2.4), where some displayed lighter-colored wood, suggesting a relatively recent insect attack. However, the lack of sawdust and the absence of visible insects indicated that the infestation was probably no longer active.

Figure 2.4: Xylophagous insect exit holes on the horizontal crossbar.

2.3.2 PAINTING SUPPORT: CANVAS

The canvas consists of a single piece of fabric, possibly made of linen at a first observation (Young, 2021). This was later confirmed by viewing both longitudinal and transverse sections of the collected fibers under OM (Figure 2.5) that showed characteristics of a flax fiber when compared with reference data. The longitudinal cylindrical fibers reflected iridescence under polarized light and exhibited knots and joints throughout the fiber (Zimniewska et al., 2011). The transverse section exhibited pentagonal fiber cells and the presence of the lumen (Catling & Grayson, 1982).



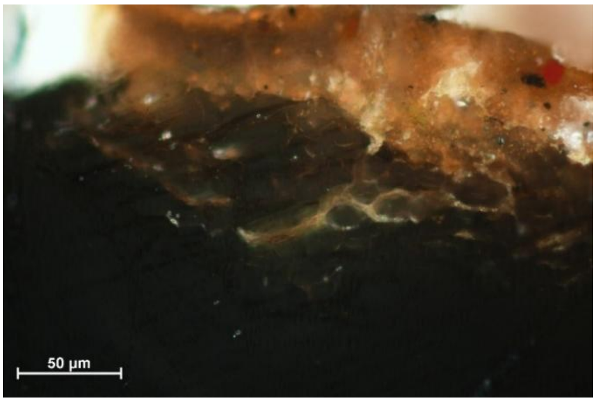


Figure 2.5: Longitudinal view of the fiber from the original canvas under OM: cross polarized light, total magnification 200x (left) and transverse view of the fiber from the PNM_S2 cross-section sample under OM: cross polarized light, total magnification 500x (right).

The canvas has a plain, open weave and relatively fine texture (Figure D.5a) with an average of eight-by-eight threads cm^2. The absence of a visible selvage edge complicated the identification of the weft and warp directions.

Cusping is evident along all edges of the canvas, aligned with the fabric losses likely caused by the previous tacks that were used to stretch the painting (Figure 2.6).


Figure 2.6: Cusping on the right (left) and upper side of the painting (right).

It was observed that the canvas was previously reduced in size along its entire lower edge, as indicated by a clean linear cut and a lesser evident cusping of the canvas (Figure 2.7). Additionally, the folding of the canvas possessed paint layers on the lower and upper part of the tacking edge (Figure 2.11), unlike the right and left edges, contributing to the suggestion that the painting underwent a modification of its original dimensions at an undetermined point in time.

Figure 2.7: Cut canvas at the lower part of the painting.

The canvas had not been previously lined and showed signs of aging and oxidation, including darkening of the fibers that reduced the fabric's flexibility to a certain degree (Kirsh & Levenson, 2000). This lack of flexibility was particularly observed along the tacking margins. Additionally, a significant accumulation of dust and dirt was visible on the back, and sides of the canvas (Figure D.5b). The reverse side displayed localized dripping stains (Figure D.5c) as well as white marks resembling paint droplets (Figure D.6a).

Deformations and creases were evident along the edges of the canvas where it folded over the strainer bars, with the most significant distortion observed at the vertical crossbar (Figure D.6b). This was possibly attributed to the insufficient canvas tension, the use of an unsuitable strainer and RH fluctuations.

The fixing elements, which appeared to be metallic tacks, were in poor condition, exhibiting rust. No staining of the fabric around the tacks has been observed (Figure D.6c). Not all tacks effectively secured the canvas, resulting in uneven tension across the painting (Figure 2.8). Specifically, the top edge contained 18 tacks, of which 12 did not make contact with the canvas. The bottom edge had 12 tacks, with 4 failing to secure the fabric. The left side contained 24 tacks, all of which were in contact with the canvas, while the right side had 21 tacks, 6 of which did not contact the fabric.

Figure 2.8: Tacks that do not provide tension to the canvas.

Evidence suggested that a previous frame was likely secured with tacks inserted from the front, as indicated by punctures visible at the corners on the front of the entire canvas (Figure 2.9). Nevertheless, no corresponding tack holes were present on the current strainer before restoration.

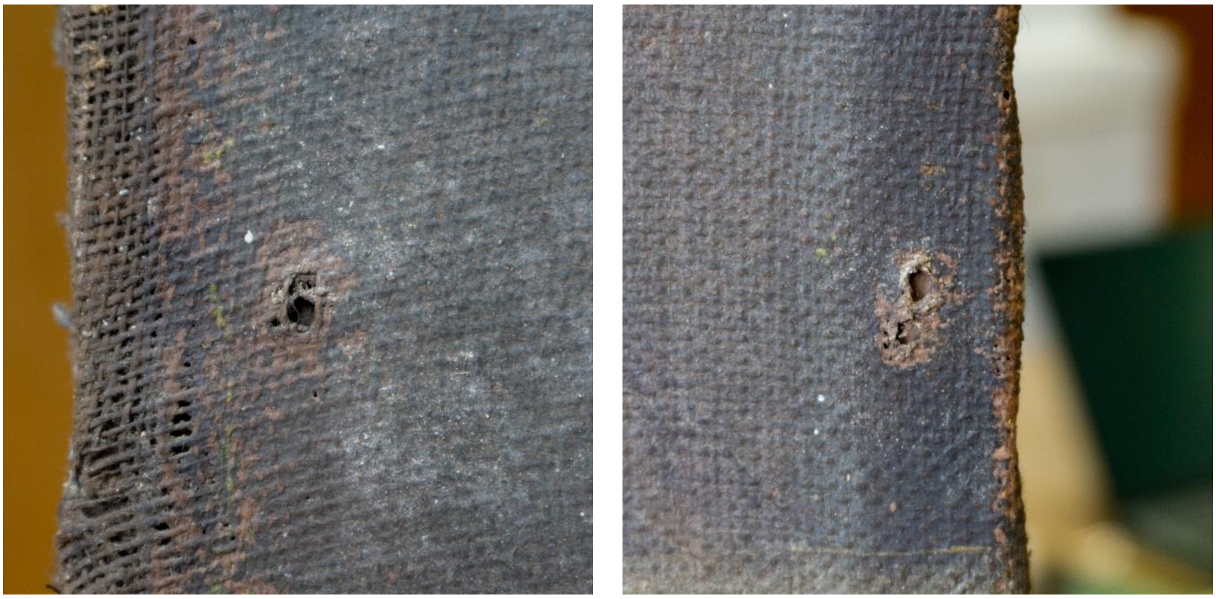


Figure 2.9: Punctures in front of the painting, possibly from a previous frame.

The canvas exhibited two tears (Figure 2.10). On the left side, an "L"-shaped tear measuring 1.1 cm had resulted in the severing of seven vertical threads. Access to this damaged area from the reverse side was obstructed due to its position directly in front of the strainer. On the right side, a horizontal tear measuring 2.7 cm was visible, with fourteen vertical threads severed, some still partially connected. Additionally, five horizontal threads were torn, one of which hung loosely, disrupting the fabric's weave pattern. The precise locations of these tears, along with the punctures, are documented in the degradation mapping (see Appendix E).

Figure 2.10: Tears on the painting, left and right side, respectfully.

The tacking margins were partially compromised, exhibiting significant losses likely due to oxidation. These deteriorated edges lacked sufficient length to be adequately folded over the strainer and maintain proper tension. This issue, amplified by the tacks that failed to fully secure the canvas, created uneven tension across the painting. As a result, damage has extended to the preparation and pictorial layers, which will be discussed in subsequent sections. The insufficient tension in upper area of the canvas was greater than the lower half, which, while under slightly more tension, still experienced inadequate support. This has resulted in fewer mechanical cracks and less advanced deterioration in the lower paint area.

2.3.3 PREPARATION LAYER

A first examination with the naked eye revealed a reddish-brown preparation layer characterized by a thin to medium application thickness and an average texture (Figure D.7a). No evidence of an underlying size layer was observed. Examination of the cross-sections under OM facilitated the identification and characterization of the stratigraphy of the pictorial layers (Figure 2.14). Under visible light, the preparation layer appeared to consist of a single, opaque layer, composed of reddish-brown pigments with a very fine grain size, combined with larger white to greyish pigment size particles.

The combined thickness of the preparation and paint layers allowed the fabric's weave to remain visible on the surface of the pictorial image (Figure D.7b). The preparation layer appeared to have been applied either by the artist or within an artist's studio, as it ends at the edges of the pictorial area and does not extend over the original tacking margins (Kirsh & Levenson, 2000). However, in the painting's state before intervention, likely due to a change in dimensions of the canvas, the preparation and paint layers extended over the tacking margins at both the top and bottom edges (Figure 2.11).

The preparation layer demonstrated fair adhesion to the canvas overall, though its condition varied across the painting. The upper part, where the canvas tension was insufficient, showed more pronounced degradation compared to the lower part. The surface exhibited mechanical cracks (Figure 2.12), with localized areas of active flaking, although in minor intensities. Flaking was primarily concentrated in the middle-to-upper regions of the painting, particularly around the lacunae and the tear on the right side (Figure 2.10). The adhesion between layers remained stable, with the observed lacunae resulted from the separation of the preparation layer from the canvas rather than a failure between the preparation and paint layers.

Figure 2.11: Preparation layer stopping at the pictorial area on the right tacking edge (left) and paint layers on the top tacking margins (right).

Figure 2.12: Detail of the mechanical cracks.

2.3.4 PAINTING LAYERS

Under magnification, the paint layer was assumed to be a mixture of pigments and an oil binder in an approximately average ratio, both by visual examination and in concurrence with traditional techniques (Eastaugh et al., 2021). Even under a thicker layer of surface dirt that covered the entire image, it was possible to observe the painting's technique. The texture was generally uniform, with variations in application thickness. Thicker impasto was slightly evident in lighter areas, such as the flesh, the veil of the central figure and cherubs (Figure D.8a). Visible brushstrokes were present in the areas mentioned prior, and the top-right corner of the painting (Figure D.8b). The paint appears to be opaque and to have been applied in layers, as observed in the stratigraphy (Figure 2.13). Above the preparation layer, two lighter paint layers are discernible, characterized by a wide range of pigment grain sizes, from very fine white particles to medium-large paint size grains.

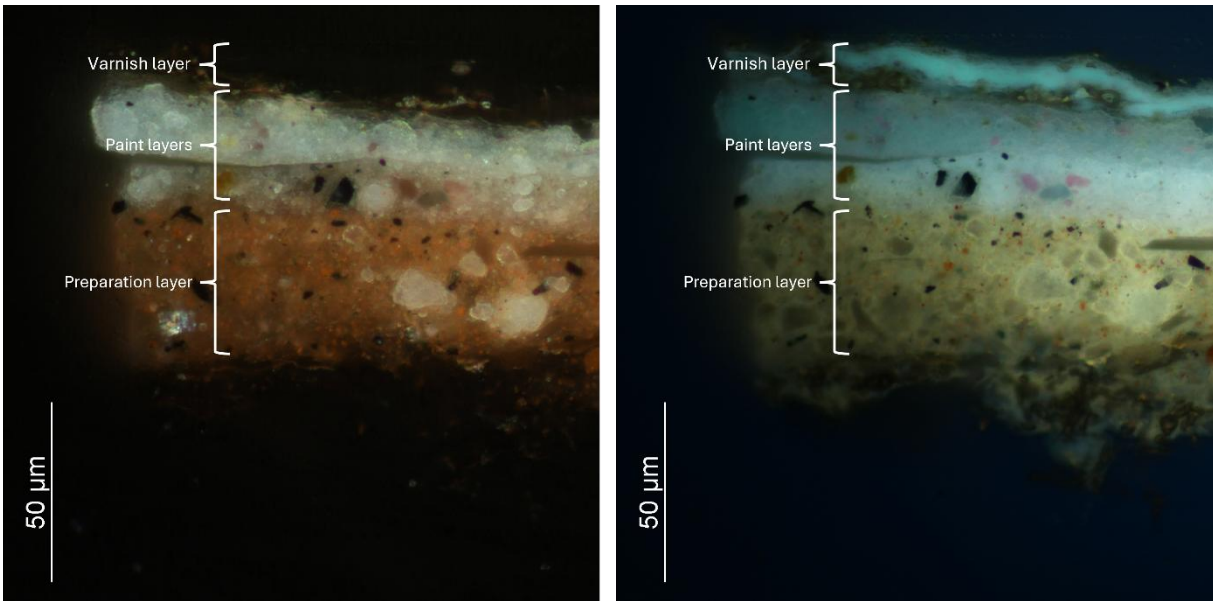


Figure 2.13: Stratigraphy of PNM_2_2024_S1, located in the sky area, photographed with OM at 500x magnification under incident visible (left) and UV radiation (right).

The surface displayed small, jagged islands of mechanical cracks that were randomly distributed and connected, with no consistent directional pattern to the craquelure (Bucklow, 1997; Bucklow, 2021) (Figure 2.12). Around the central puncture, mechanical cracks exhibited a circular pattern, likely resulted from an impact (Figure D.9a). In the lower left and right corners, diagonal cracks were visible, indicative of the uneven canvas tension (Figure 2.14). Additionally, scratches consistent with mechanical damage were evident in these areas (Figure D.9b).

Minor localized abrasions were noticeable, particularly at the corners of the painting, likely caused by contact with the frame, as well as around the tack holes on the front of the canvas, where the preparation layer was exposed (Figure 2.14). In regions of active flaking, slightly localized cupping was visible (Figure 2.15). The paint layers exhibited relatively good cohesion. The instance of paint layer separation was only apparent in the sky region, where a darker layer of paint from the tree area has detached, revealing the bright blue sky beneath (Figure D.9c).

Numerous lacunae were present, particularly in the upper portion of the painting, where the separation occurred between the preparation layer and the canvas (Figure 2.15).

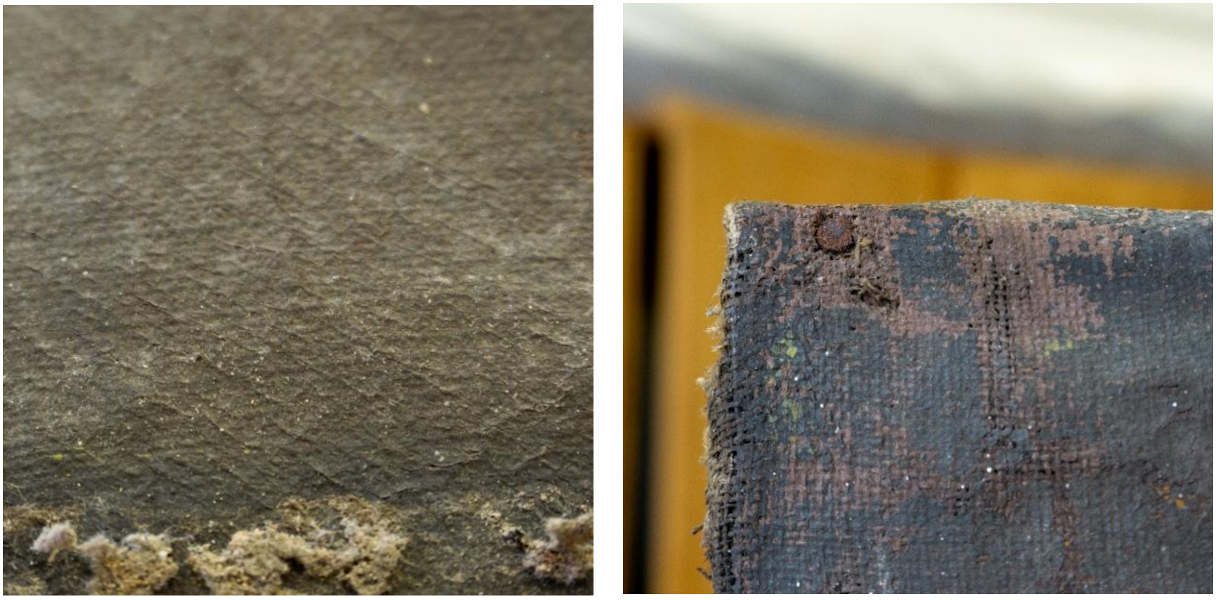


Figure 2.14: Diagonal mechanical cracks on the bottom corners (left) and abrasion on the corners of the painting.

Figure 2.15: Detail of the cupping (left) and lacunae on the upper part of the canvas (right).

2.3.5 VARNISH/SUPERFICIAL LAYERS

Under standard lighting conditions, the varnish appeared darkened and yellowed, with its presence further confirmed by a greenish fluorescence visible under UV radiation (Figure A.3) and OM (Appendix G.4). The varnish layer was not analyzed, however it was likely composed of a natural resin (Horie, 2010; Phenix & Townsend, 2021). The overall condition of the varnish's surface was poor, as the aged and oxidated varnish and a thick accumulated surface dirt layer obscured the clarity of the image. Notably, dirt deposits were concentrated at the lower portion of the painting, where the frame has contacted the canvas (Figure 2.16).

The surface also displayed various stains and deposits of foreign materials of differing origins (Figures D.10). Fingerprint marks were noticeable near the top of the canvas, close to the tacking margins (Figure D.11a), while drip stains of possibly water origin were also evident (Figure D.11b). Additionally, thin yellow overpainting was scattered along the edges of the paint layer (Figure 2.16), and a piece of paper has been glued to the lower right side, near the edge of the painting, both likely the result of contact with the frame (Figure D.11c).

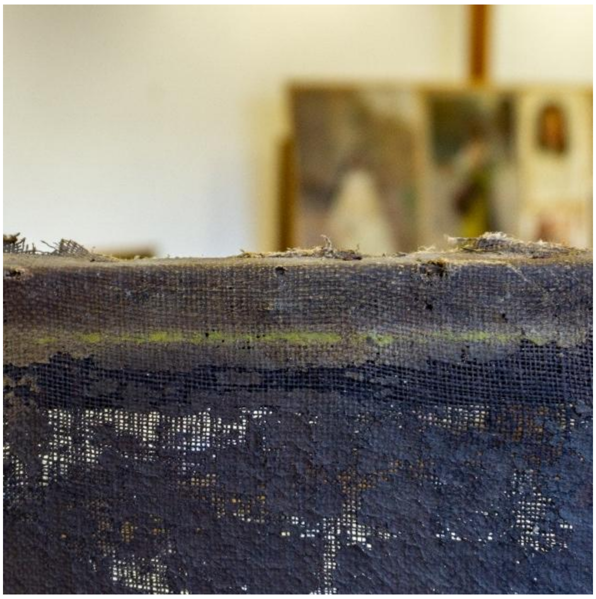


Figure 2.16: Deposits of dirt (left) and yellow overpaint (right).

Further deterioration was observed in the form of fungal growth, characterized by whitish, raised, and scattered areas on the lower part of the painting, accompanied by dirt deposits (Figure 2.17). This fungal infestation was likely due to improper storage, possibly on the floor, which led to the accumulation of moisture over time. The fungal growth samples were examined by Dr. Catarina Pinheiro, conservator-restorer and analytical laboratory-biology at LJF. According to Pinheiro (2024), the presence of *Fusarium sp., Mucor sp.,* and/or *Alternaria sp.* was suggested based on the observation of hyphae and sporangiospores, although there was insufficient evidence to definitively identify the specific fungi involved.

Additionally, the white globular spores found on the surface may be attributed to common fungi such as *Aspergillus* or *Penicillium*, even though their characteristic sporangiospores were not observed (Pinheiro, 2024).

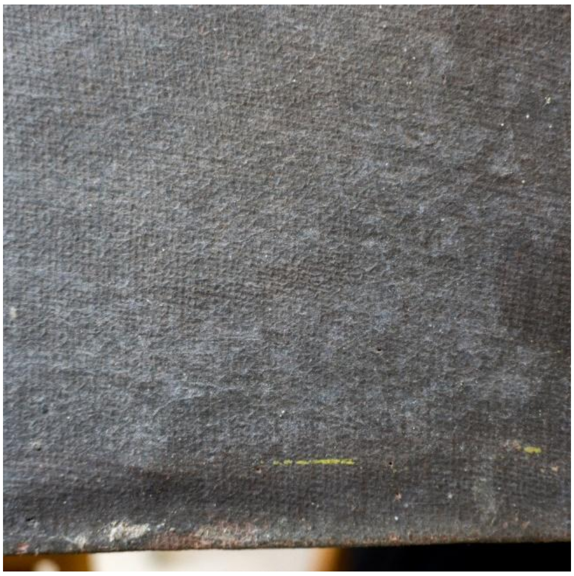


Figure 2.17: Fungus infestation on the lower part of the painting.

2.3.6 DIAGNOSIS SUMMARY

As outlined in the previous sections, the painting *Beata Ludovica Albertona* was executed in oil on canvas and mounted on a wooden strainer. The paint was applied in relatively thin layers and exhibited areas of subtle localized impasto. The strainer was in poor condition, with its structural integrity significantly compromised, causing uneven tension in the canvas and undermining the stability of the painting. The painting appeared to have been re-dimensioned, evident from the mismatched tacking holes, the cut canvas on the lower margin, and the paint layers present on the top and bottom tacking margins. The painting was uniformly covered with a thick layer of superficial dust and dirt, alongside an aged varnish layer and the presence of fungi on the lower half of the canvas. Consequently, a complex craquelure pattern developed across the entire surface, accompanied by localized paint flaking, cupping and lacunae, predominantly concentrated in the upper portion of the canvas. Immediate concerns involved structural instabilities, including the deteriorated strainer, shortened oxidized tacking margins, and active paint delamination, all of which compromised both the material integrity and aesthetic unity of the work.

2.3.7 CONSIDERATIONS BEFORE INTERVENTION

Storage conditions

The painting was in contact with a wall when it was exhibited (timeline in Appendix C), which possessed a certain degree of porosity. This may have contributed to the gradual deterioration of both the canvas and its frame, probably caused by the fluctuations of RH and temperature, and the microclimate created between the painting and the wall (Dixon, 2021). Additionally, there was no environmental control in the storage room, with no temperature or humidity records.

During storage, the painting was suspended on metal grids, which provided some degree of air circulation (Figure 2.18). The painting was subjected to the environment of the storage, which, according to Dr. Sergio Gorjão (personal communication, October 17, 2024), while relatively stable, was nonetheless subjected to an unavoidable certain degree of fluctuation in temperature and RH.

Figure 2.18: Storage room with metal grids in PNM. Photograph by @PNM.

Changing the dimensions of the painting

As outlined in the introduction and diagnostic analysis, the painting belongs to a series dedicated to the Third Order of Saint Francis (see Chapter 2.2). Given this historical context, it is plausible that the paintings have remained together as an integrated group since their creation.

Before treatment, the painting measured 128.5 cm on the upper left side, 128 cm on the upper right, and 85.5 cm in width. These dimensions did not match the original format. Evidence of later modifications included tacking holes in the strainer that did not align with the current tacks, suggesting a non-original strainer, and possible alterations to the frame size. Additional indications were paint layers extending into the upper and lower tacking margins, as well as a cut along the lower canvas edge.

At the request of Dr. Sérgio Gorjão, director of PNM, and with approval from LJF, the painting's dimensions were adjusted to match the other works in the series, believed to reflect its earlier format. The height was increased in total by approx. 4 cm. This decision was supported by the absence of compositional elements in the cut lower margin (Figure 2.7), ensuring that no new visual information was introduced. This aesthetic adjustment shaped the treatment strategy, particularly the structural interventions.

3

TREATMENT OF THE PAINTING *BEATA LUDOVICA ALBERTONA*

3.1 INTERVENTION PROPOSAL

A treatment proposal was developed at an early stage to determine the sequence in which each step of the intervention would be executed. However, certain decisions were adjusted throughout the process based on the painting's response to the intervention and its needs. According to the diagnosis described in Chapter 2.3, the adjusted proposal before the intervention was defined as follows:

1. Remove the superficial dust and dirt on the front and back of the painting;
2. Local consolidation around areas of flaking and lacunae;
3. Apply an overall facing;
4. Remove the painting from the strainer;
5. Brush and flatten the tacking margins and clean the back of the canvas;
6. Perform the strip-lining;
7. Secure the painting under temporary tension and relax, flatten the canvas and paint layers;
8. Remove the facing, perform the surface cleaning with aqueous methods and varnish removal;
9. Perform the thread-by-thread tear-mending and inserts for punctures;
10. Filling of the losses;
11. Mount the painting on a new stretcher;
12. Filling the re-dimensioned bottom strip;
13. Isolation varnish layer and inpainting;
14. Final varnish layer.

Initial plans proposed performing aqueous surface cleaning and varnish removal prior to structural treatments, as this would allow the painting to remain under tension and reduce the risk of deformation. Removing the thick layers of surface dirt and aged varnish was also expected to facilitate subsequent structural interventions, which constitute the focus of the theoretical section of this dissertation. However, this sequence was revised following preliminary solubility tests, which indicated that an initial overall consolidating facing was necessary to restore cohesion and adhesion of the paint layers, particularly in areas where abrasion was exposed on the upper part of the canvas weave.

3.2 STUDY OF STRUCTURAL TREATMENTS

3.2.1 INTRODUCTION

When addressing the structural treatments of a painting, it is essential to first understand the inherent complexity of its layered construction. Traditional easel paintings are typically composed of multiple layered materials, each serving a specific functional and aesthetic purpose (Kirsh & Levenson, 2000).

Although pigment characterization lies beyond the scope of this thesis, the painting under study appears consistent with practices typical of 18th-century European easel paintings, such as the use of pigments bound in a drying oil medium (Eastaugh et al., 2021), applied over an oil-based preparation layer (Stols-Witlox, 2021). Each layer possesses distinct physical and chemical properties, resulting in heterogeneous responses to internal and external factors, particularly fluctuations in RH and temperature (Andersen & Fuster-López, 2019; Heiber et al., 2021) that change the way each material dries and ages (Loon et al., 2021). Consequently, different aging processes, driven by environmental factors, inherent vice, or interlayer interactions can compromise the structural stability of the painting (Loon et al., 2021).

As outlined in the diagnostic assessment (see Chapter 2.3), the paint layers exhibited aging cracks, localized flaking, cupping, and lacunae, which appeared to be linked mainly to external factors (Loon et al., 2021). Hackney et al. (2021) observed that, because each layer carries different tensile loads, RH and temperature fluctuations represent the primary cause of the tension migration between individual layers. As the paint layers become less elastic with age (Loon et. al., 2021), fluctuations of RH cause the linen canvas to expand and contract (Young, 2021), forming cracks (Michalski, 1990; Slotsgaard et al., 2024). This repeated mechanism of tension realignment in the painting's plane, as the tension is primarily now in the canvas, culminates in flaking, cupping, and eventual material loss, as paint islands detach from the canvas (Mecklenburg & Tumosa, 1991; Hackney, 2004; Hackney et al., 2021).

Because the type of deteriorations found in the painting were primarily at a structural level, it was decided to focus the theoretical chapter on structural treatments. They encompass a variety of interventions designed to ensure or bring back the stability of a painting, alongside recovering the aesthetic properties (Heiber et al., 2021). The structural treatments addressed in both the theoretical section and practical intervention were the consolidation and application of a facing, flattening of the paint layers and deformations, strip-lining and thread-by-thread tear-mending.

3.2.2 TRADITIONAL AND MODERN PRACTICES

The ethics and methodologies of structural treatments in painting conservation have undergone substantial change since the early 20th-century. A pivotal moment was the 1974 Greenwich Conference on *Comparative Lining Techniques*, which reshaped conservation practices and prompted a fundamental reassessment of structural interventions (Andersen & Fuster-López, 2019; Hackney et al., 2021; Scharff, 2023), particularly regarding lining treatments (Hackney, 2004).

Lining, the adhesion of an auxiliary fabric, sometimes with interleafs, to the reverse of the original canvas, aims to stabilize, reinforce, and transfer tension onto the lining support (Andersen & Fuster-López, 2019; Hackney et al., 2021). The treatment was utilized historically to ensure that a painting is safe for subsequent treatments by treating a degraded canvas, or simply a painting suffering from flaking paint layers, cupping, tears, or degraded tacking margins (Hackney et al., 2021). Consequently, it was employed as an overall treatment for paintings (Ackroyd, 2002), in an attempt to address a wide range of structural deteriorations simultaneously (Heiber et al., 2021).

As presented by Hackney et al. (2021), early practices involved the use of glue-paste adhesives and linen for the lining canvas with a combination of heat, moisture and pressure to treat paintings, later followed by the development of wax-resin lining in the 19th-century. The impregnation of the canvas of both glue-paste and wax-resin practices provide both possibilities and limitations. Glue-paste lining provides a strong and stiff support, which is efficient at flattening extreme surface deformations (Ackroyd, 2002; Hackney et al., 2021), however, it is hydroscopic, prone to dimensional changes and adhesive failure in environments with extreme levels of RH, causing further cracking in the painting (Andersen & Fuster-López, 2019; Hackney et al. 2021). Wax-resin lining solves some moisture-related concerns yet introduce new limitations, including the aging of the mixture, increased weight, paint darkening, and influences on retreatability (Ackroyd, 2002; Hackney et al., 2021). Furthermore, wax-resin lining still absorbs moisture, however at a lower rate than glue-paste lining (Andersen & Fuster-López, 2019). Both practices risk damage if excessive heat, moisture, or pressure, especially with hand irons, are applied, leading to discoloration, impasto flattening, or the imprint of the canvas weave onto paint layers (Hackney, 2004; Hackney et al., 2021).

Despite these limitations, lining is still performed on paintings with severe structural failure, such as extensive tears or compromised canvases, and in cases of re-lining when earlier interventions deteriorate (Ackroyd, 2002). Modern practices tend to favor refined techniques, including low-pressure suction and vacuum hot tables, alongside alternative materials and adhesives (Hackney et al., 2021).

Since the 1974 Greenwich Conference, modern practices increasingly emphasize individualized, preventive, minimal, and retreatable alternatives to lining, with decisions tailored to each painting's condition rather than standardized solutions (Ackroyd, 2002). Although not all concerns have been resolved, progress has been made in understanding how paintings are composed and react to the environment and our actions (Hackney, 2004). Moreover, the development of innovative materials and methods (Ackroyd, 2002), along with research on adhesives behavior, play a role in the stability of a painting (Andersen & Fuster-López, 2019), a theme that recurs in subsequent chapters.

3.2.3 ADHESIVES IN STRUCTURAL TREATMENTS

As stated by Andersen and Fuster-López (2019), structural treatments often involves the careful introduction of adhesives (and occasionally new materials such as fabrics or fillers) to a painting, whose aging properties, mechanical behavior and application methods must be critically evaluated, as they irreversibly change the structural stability of a painting. Furthermore, the selection of adhesives should allow for future retreatability, to align with the specific needs and original integrity of the painting by balancing the possibilities and limitations of the materials and interventions.

This subchapter will be referenced throughout the structural treatment chapters and aims to provide a table with a concise summary of the general properties of the adhesives discussed in the literature and later used in the empirical tests and interventions. Other adhesives mentioned in the literature that were considered are also included for comparison.

Table 3.1 Adhesive properties reported in the literature. Note: Collagen strength is measured in Bloom units and is only comparable within animal glues.

Adhesive		Properties							
		Composition	Solubility	Mechanical properties	Temperature behavior	pH	Viscosity	Visual properties	Stability
Natural	Gelatin	Animal collagen	Hot water (Goltz, Birkenbeul et al., 2021; Horie, 2010)	Medium to high bloom strength, depending on the source of collagen (Schellmann, 2007). Good bond strength and fluid properties (Down, 2015).	T_g = 45°C at 50% RH (Down, 2015)	Neutral (Goltz, Birkenbeul et al., 2021) Mammalian gelatin = 5.0-6.5 (Schellmann, 2007).	Low viscosity (Goltz, Birkenbeul et al. 2021; Burg & Seymour, 2023)	Clear, colorless, glossy finish (Goltz, Birkenbeul et al., 2021).	Light resistant (Goltz, Birkenbeul et al., 2021). Stable in dry, neutral conditions. (Horie, 2010). Shrink on drying (Goltz, Birkenbeul et al., 2021). Prone to biodegradation (Andersen & Fuster-López, 2019). Highly hygroscopic (Kite & Thomson, 2006; Horie, 2010; Andersen & Fuster-López, 2019).
	Rabbit skin glue		Water (Schellmann, 2009)	Strong contractive strength (Down, 2015) Effective consolidation with medium–high Bloom strength (Burg & Seymour, 2023) High and more elastic than hide glue (Schellmann, 2009) Stronger than cold water fish glue (Schellmann, 2009) Flexible but weak structural strength (Kite & Thomson, 2006).	Mammalian gelation temperature = 30-35°C (Schellmann, 2007) T_d = 40-41°C (Schellmann, 2007).	5.0-7.5 (Down, 2015; Burg & Seymour, 2023)	High to very high (Down, 2015; Schellmann, 2009)	More colored and less transparent than gelatin or SG (Schellmann, 2007).	Less sensitive to moisture than hide glue (Schellmann, 2009). Brittle at low humidity (Down, 2015). Shrinkage on higher temperature, faster than fish glue (Horie, 2010).

	Fish glue		Water Insoluble in oils, organic solvents (Petukhova & Bonadies, 1993)	Medium, and more elastic than hide glue, (Schellmann, 2009) Can withstand the highest shear and peel forces (Poulis et al., 2022) Low to medium bloom strength, when compared to SG, RSG. (Burg & Seymour, 2023)	Gelation temperature = 8°C T_d = 15-36°C (Down, 2015)	3.5-5.0 (Down, 2015, Burg & Seymour, 2023)	Liquid fish glue = high	Nearly colorless, clear when dried in thin films. Glossy depending on the concentration	Less stable than cold liquid hide glue (Schellmann, 2009) Cold water fish are more sensitive to moisture than mammalian and warm water fish (Bridarolli et al., 2022).
	Sturgeon glue (SG)		Water (Petukhova & Bonadies, 1993)	Very strong and flexible, Highest collagen (Goltz, Birkenbeul et al. 2021) Medium to high bloom strength (Burg & Seymour, 2023) Higher ductility and lower gel point in the same concentration of solids (Flock, Demuth et al., 2020).	T_d = 29°C Gel point = approx. 15–17°C (Flock, Demuth et al., 2020)	6.0-7.0 (Burg & Seymour, 2023) 6.0-7.5 (Down, 2015)	Low (Burg & Seymour, 2023) Lower viscosity than rabbit skin glue (Down, 2015)	Nearly colorless (Goltz, Birkenbeul et al. 2021) Clear when dried in thin films (Schellman, 2007)	More stable than mammalian gelatine. However still sensitive to moisture (Poulis et al., 2022). Availability limitations and shorter shelf life (Burg & Seymour, 2023).
Semi-synthetic	MC	Methylcellulose	Polar solvents, water (Horie, 2010)	Strong and resilient film (Down, 2015)	T_g = 140°C (Horie, 2010)	5.0-5.7 (Down, 2015)	-	Clear film with minimal gloss (Down, 2015; Goltz, Birkenbeul et al. 2021)	Good photochemical stability (Pataki-Hundt, 2018). No biodeterioration (Down, 2015). Prone to photochemical degradation, discoloration, and subsequent loss of adhesion (Burg & Seymour, 2023).
	Klucel® G	Hydroxypropyl cellulose (HPC)	Ethanol, water, polar and non-polar solvents. (Horie 2010; Goltz, Birkenbeul et al. 2021; Burg & Seymour, 2023).	Weak bonding strength with poor penetration ability (Goltz, Birkenbeul et al. 2021; Burg & Seymour, 2023).	T_g = 105°C (Down, 2015)	5.0-8.8 (Down, 2015)	Tends to be viscous (Goltz, Birkenbeul et al. 2021) MW=370,000 g/ mol (Burg & Seymour, 2023) 3000 mPa (Horie, 2010)	Transparent, matte finish (Burg & Seymour, 2023)	Rather stable (Feller & Wilt, 1990). Some discoloration, loss of weight and viscosity in long-term aging (Down, 2015). Hygroscopic (Poulis et al., 2022) Susceptible to biological attack (Horie, 2010).

Synthetic	**BEVA® 371 O.F.**	EVA + paraffin + urea-aldehyde resin, with 40% solid content in aliphatic and aromatic solvent (Burg & Seymour, 2023).	Aromatic hydrocarbon, naphtha, benzine, acetone (Down, 2015; Burg & Seymour, 2023).	Medium cohesive strength (Down, 2015) Strong and flexible (Goltz, Birkenbeul et al. 2021).	T_g = -28°C (Poulis et al., 2020) Heat activation at 60-65°C (Down, 2015; Goltz, Birkenbeul et al., 2021).	Unaged = 7.57, becomes more acidic when light aged (Down, 2015).	-	Waxy, matte finish It will change the physical and aesthetic characteristics of the surface (Burg & Seymour, 2023).	Slight yellow long-term (Down, 2015). Requires more polar solvents on aging (Ploeger et al., 2014; Burg & Seymour, 2023). Good ductility; medium shear strength under museum conditions (Poulis et al., 2020). Non-hygroscopic; stable to RH/temperature fluctuations; strength loss above 35 °C (Poulis et al., 2022). Requires higher peel strength after aging (Shah et al., 2024).
	Plextol® B500	Acrylic aqueous dispersion based on an Ethyl Acrylate and Methyl Methacrylate based copolymer (Horie, 2010)	Aromatic hydracarbons, xylene, toluene, ethanol, acetone, ethyl methyl ketone (Howells et al., 1984)	High adhesive strength (Duffy, 1989).	T_g = 9°C (Horie, 2010)	9.5 (Horie, 2010)	Good penetration and wetting properties Low viscosity (Howells et al., 1984)	Glossy	Better aging properties than PVA (Horie, 2010; Goltz, Birkenbeul et al., 2021). Yellow and unstable under heat/light (Howells et al., 1984; Down, 2015). Higher shear and peel strength require after aging (Shah et al., 2024).
	Lascaux® 4176 Medium for Consolidation	Aqueous dispersion of an acrylic copolymer based on acrylic ester, styrol, and methacrylic ester (Burg & Seymour, 2023)	Esters, aromatic hydrocarbons, ketones, acetone, toluene (Marriott, 2010; Burg & Seymour, 2023).	Strong, flexible, adhesive strength and penetration capacity (Marriott, 2010).	MFFT = 4°C, Can be heat-activated (Marriott, 2010).	8.5 (Burg & Seymour, 2023)	Low viscosity; good penetration (Burg & Seymour, 2023).	Dries to a clear film (Marriott, 2010).	Stable, retrains solubility (Marriott, 2010). Showed color change after aging (Pataki-Hundt, 2018).

	Lascaux® 498HV	Thermoplastic copolymer butyl-methacrylate dispersion, thickened with acrylic ester acid.	Dilutable with water. Water insoluble after drying. Soluble in acetone, alcohol, toluene, xylene Insoluble in white spirit.	Dries as a viscous elastic film	MFFT= 5°C T_g = 13°C (Kelly et al., 2020)	8-9 (Manufacturer Datasheet)	-	-	-
	Primal® E-330S	Acrylic aqueous dispersion	consistent with acrylic dispersions (Horie, 2010).	Durable and good adhesion strength Chemical, UV and heat resistance	T_g = 13°C MFFT = 10°C	9.5-10.5 8-9 (Manufacturer Datasheet)	Low viscosity	White, milky liquid	Aging properties consistent to acrylic dispersions (Horie, 2010).
	Evacon-R®	EVA	Water (Burg & Seymour, 2023)	Adequate working time (Demuth et al., 2011). EVA copolymers have an internal softening effect, being more flexible, softer and less tensile than PVA adhesives (Flock, Demuth et al., 2020). Contains few plasticizers; may include calcium carbonate and cellulosic thickener (Burg & Seymour, 2023).	-	Neutral (Demuth et al., 2011; Burg & Seymour, 2023)	Relatively viscous (Burg & Seymour, 2023)	-	Resistant to hydrolysis (Burg & Seymour, 2024) Better aging stability than PVA (Flock, Demuth et al., 2020).

3.2.4 CONSOLIDATION AND FACING

Introduction

Consolidation is a key structural treatment that stabilizes and reattaches detached or weakened paint layers to their underlying support, thereby restoring the cohesion and adhesion necessary to prevent further material loss (Goltz, Birkenbeul et al., 2021; Burg & Seymour, 2023). Consolidation is particularly necessary when the paint exhibits flaking, lifting or delamination. Depending on the degree of degradation, consolidation may be performed locally with a fine brush or on the overall surface. One method involves the use of a facing, in which the adhesive is applied through layers of thin papers, such as Japanese tissue, either selectively or across the entire surface (Goltz, Birkenbeul et al., 2021). Facing serves to temporarily protect and secure fragile paint layers during handling or subsequent interventions, while also supporting the consolidation and flattening of vulnerable areas (Bobak, 2003; Down, 2015).

Requirements for adhesives

The selection and application of adhesives for consolidation and subsequent structural treatments require careful consideration of their composition, solubility, compatibility with original materials and potential future interventions, working properties, and long-term effects under storage and display conditions (Goltz, Birkenbeul et al., 2021). According to Burg and Seymour (2023), suitable adhesives should form stable films, be physically and chemically compatible with original materials, such as the binding medium or in case of the reactivation of the sizing layer, and demonstrate good aging properties, including resistance to yellowing or solubility changes. Potential visual alterations, such as gloss change or staining must also be considered, particularly when adhesive residues may remain visible between cracks (Burg & Seymour, 2023). Furthermore, adhesives should exhibit a T_g above room temperature to prevent dirt pick up, failure or deformation under normal storage and display. While complete reversibility is rarely achievable in consolidation, especially when adhesives penetrate microcracks and layered structures (Down, 2015), best practice recommends selecting materials that support retreatability, or ease of removability in the case of facings (Goltz, Birkenbeul et al., 2021). Adhesives must also balance flexibility and strength and should secure fragile paint layers without exceeding the paint's cohesive strength, therefore minimizing the risk of additional stress (Burg & Seymour, 2023). Alongside adhesive strength, other key properties include drying time, wettability and how well the adhesive flows into the desired area, where factors like viscosity can be controlled by properties such as molecular weight or adjusting the concentration (Down, 2015; Burg & Seymour, 2023).

Choice of adhesives based on literature and empirical tests

Both natural and synthetic adhesives mentioned in the literature for consolidation facings were considered for testing according to the criteria outlined above. Synthetic adhesives are recommended in cases of advanced paint-layer degradation or when the layer is sensitive to water (Burg & Seymour, 2023). Among these, aqueous acrylic adhesives such as Lascaux® 4176 are preferred over PVA adhesives due to their favorable working and aging properties, though they form a glossy film upon drying (Goltz, Birkenbeul et al., 2021). Animal glues provide greater cohesive strength and stiffness than synthetic adhesives (Mecklenburg et al., 2012) but are more sensitive to fluctuations of RH and temperature (see Table 3.1). Cellulose ethers can also improve the stiffness of linen canvases, thus consolidating them, however, just as animal glues, cellulose ethers can lose some tensile strength with increased RH (Bridarolli et al., 2020). Moisture can still compromise the performance of synthetic adhesives, particularly those with a T_g below room temperature (Poulis et al., 2022). While BEVA® 371 remains stable under RH changes (Mecklenburg et al., 2012), its tendency to yellow over time is now being investigated (Burg & Seymour, 2023). For these reasons, animal-based and semi-synthetic adhesives with slow drying, low viscosity, sufficient adhesive strength, water solubility, ease of residue removal, retreatability, and compatibility with both original materials and future treatments were prioritized over fully synthetic options (Burg & Seymour, 2023).

The choice of consolidating adhesive was narrowed to fish glue and the cellulose-based Klucel® G. Literature findings (Table 3.1) were combined with empirical tests (Appendix G.1) to inform the decision, illustrated through the star diagram (Figure 3.1).

The five-star diagram serves as a visual tool for illustrating the possibilities and limitations associated with material selection. It enables a clearer comparison of various material properties using a 1-to-5 scale, with 1 indicating less favorable and 5 yielding better result, resulting in a star-shaped graphical representation. Furthermore, this representation will be employed in subsequent decision-making processes related to the structural treatments.

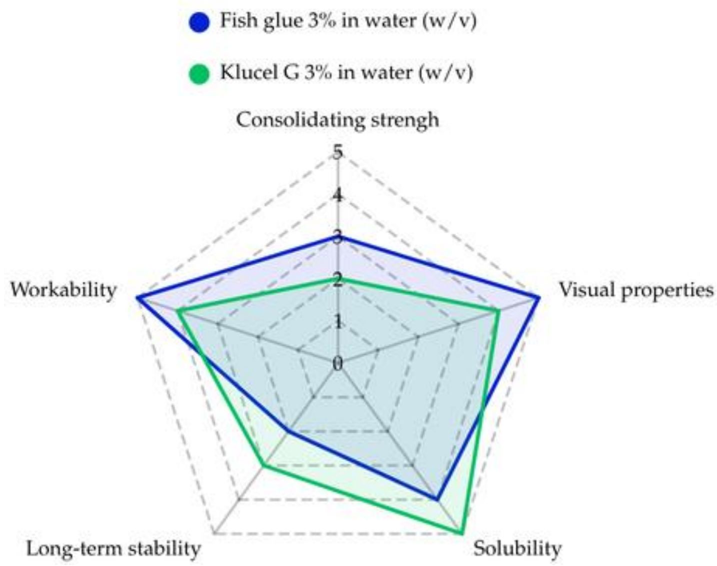


Figure 3.1: Star diagram summarizing the adhesive choice for consolidation.

Fish glue and Klucel® G presented comparable possibilities and limitations. Both are compatible with original materials, susceptible to biodegradation and hygroscopic (Burg & Seymour, 2023). Additionally, animal-based glues have the possibility to reactivate the size layer. However, fish glue, while less stable long-term than Klucel® G and more sensitive to RH and temperature fluctuations, contracts upon drying, offering additional consolidation of flaking paint (Table 3.1). In empirical tests (Appendix G.1) Klucel® G has the possibility of being solubilized in a wider range of solvents, such as ethanol, when compared to fish glue, while 3% fish glue in water (w/v) exhibited better workability, lower viscosity for permeation into paint layers, and stronger consolidating force than 3% Klucel® G. It restored adhesion and cohesion effectively, securing flaking particles and abrasion along the upper canvas weave, while having better visual properties than Klucel® G. Based on both the literature review and experimental results, 3% fish glue in water (w/v) was selected as the adhesive for consolidation.

3.2.5 STRIP-LINING

Choice between lining or strip-lining

The painting *Beata Ludovica Albertona* has not undergone any previous lining or strip-lining interventions. Despite signs of aging, such as the slight fiber oxidation (see Chapter 2.3.2), the canvas remained structurally stable and continued support to paint layers, while the existing tears were relatively minor (approx. 1.1 and 2.7 cm). The tacking margins, however, were deteriorated, with a certain degree of oxidation, too narrow, and in some areas completely missing, preventing effective re-stretching over the auxiliary support (Figure 2.8).

Taking into consideration the planned re-dimensioning of the painting (see Chapter 2.3.7) and the need to restore structural integrity, the choice followed a less invasive approach, while prioritizing the painting's long-term stability and allowing for future procedures, such as a full lining, if needed (Bobak, 2003).

Introduction

Strip-lining is considered a less invasive structural treatment than overall lining (Ackroyd et al., 2002). It is employed when the original tacking margins are inadequate to maintain proper canvas tension or allow for effective re-stretching (Hackney, 2004). The treatment restores structural integrity in the painting by adhering fabric strips only to the reverse of the tacking margins (Heiber et al., 2021), thereby reinforcing their strength, stiffness and improving their capacity to withstand tension (Bobak, 2003).

Despite these possibilities, strip-lining presents certain limitations. Strip-lined paintings are not as structurally robust as overall lined works, and while remaining hygroscopic, the strip-ling area may respond differently to fluctuations in RH (Bobak, 2003). Moreover, since tension is realigned within the treated area, stress can accumulate along its edges, potentially altering the craquelure pattern (Ackroyd, 2002; Bobak, 2003).

Requirements for the adhesive

An important factor to consider when selecting an appropriate adhesive for lining or strip-lining fabric is the intended future location for the painting (Hackney et al., 2021). In the case of the painting *Beata Ludovica Albertona*, the fluctuation of RH and temperature in the environment of PNM needs be considered (see Chapter 2.3.7).

As Shah et al. (2024) stated, lining techniques, which are also used in strip-lining, can be divided in cold-lining and heat-seal, both requiring the application of pressure while the adhesive is drying. The application methods offer distinct possibilities and limitations. Cold-lining minimizes heat and moisture by using solvents to reactivate the adhesive, while heat-sealed impregnates the canvas surfaces while the warmed adhesive is fluid (Shah et al., 2024).

Choice of adhesives based on literature and empirical tests

Traditionally, as with overall lining (see Chapter 3.2.2), strip-lining employed glue-paste and wax-resin mixtures (Heiber et al., 2021). Following the 1974 Greenwich Conference mentioned earlier, synthetic adhesives were increasingly tested and adopted for both lining and strip-lining, gaining prominence in the 21st-century (Hackney et al., 2021). Literature identifies

BEVA® 371 as the most common adhesive used for strip-lining, followed by acrylic dispersions (Ackroyd et al., 2002).

The selection of the strip-lining adhesives and fabric was informed by a comparison of the literature review (Table 3.1) with a series of empirical tests). Adhesives tested included BEVA® 371 in white spirit 1:1 (v/v) ratio, BEVA® 371 Film, and the acrylic aqueous dispersions Plextol® B500 in toluene 10:1 (v/v) ratio, Lascaux® 498HV, and Primal® E-330S in toluene 2:3 (v/v), all of which exhibit favorable aging properties (see Table 3.1).

The empirical tests compared workability, as well as shear and peel strength, with the goal of achieving sufficient bond strength while ensuring ease of retreatability (Figure 3.2). Two fabrics (linen and synthetic) were adhered to a primed linen specimen with the selected adhesive, and their performance was compared (full results in Table G.3)

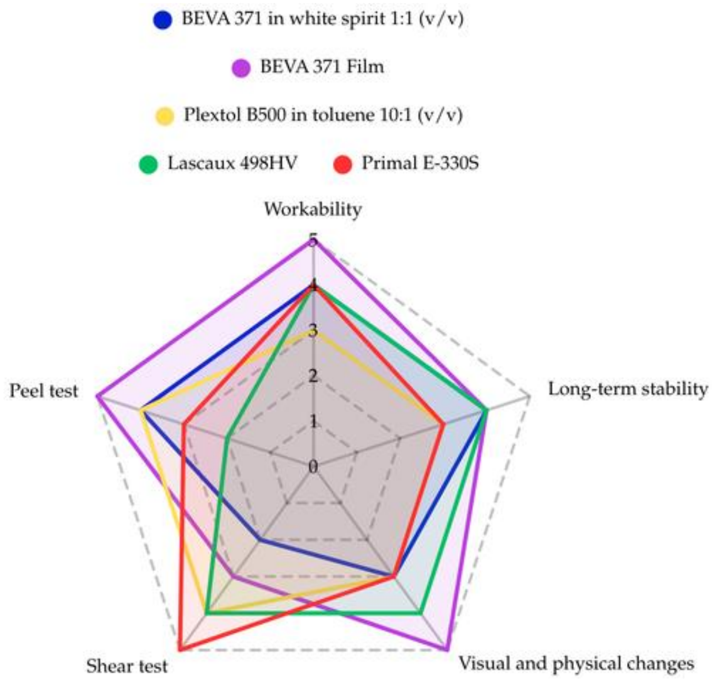


Figure 3.2: Star diagram summarizing the adhesive choice for strip-lining.

Results showed that acrylic dispersions generally produced higher shear strength than BEVA® 371 variants, with diluted Primal® E-330S performing best. Failure observed in BEVA® 371 in white spirit 1:1 (v/v) and BEVA® 371 Film samples under medium pulling force were likely due to insufficient heat application during specimen preparation, as both adhesives typically demonstrate greater shear strength than Plextol® B500 (Shah et al., 2024). In peel tests, Lascaux® 498HV required the greatest force for separation, while diluted BEVA® 371 and Plextol® B500 showed moderate removability. BEVA® 371 Film proved the most consistent and safely removable. The acrylic dispersions left some residues on the primed canvas after the peel test and presented to be stiffer. Diluted BEVA® 371 resulted in the stiffest specimens, whereas BEVA® 371 Film retrained full flexibility and showed no perceptible permeation into either linen or synthetic fabrics. The quantity of adhesive introduced to the strip-lining fabric remained minimal, was distributed uniformly, and left no residues on the original primed canvas.

Overall, BEVA® 371 Film demonstrated the most favorable balance of properties and was selected as the strip-lining adhesive. It provided good shear and excellent peel performance, combined with no toxicity, straightforward application, as the adhesive strips only required cutting and heat activation, without the use of solvents. Although long-term stability of BEVA® 371 continues to be studied, research confirms its retention of shear strength and removability in aging tests. (Shah et al., 2024).

Selection of fabric

As noted by Hackney et al. (2021), fabrics selected for lining and strip-lining must combine minimal texture and thickness with sufficient stiffness and tension to keep the tension plane close to the paint film. Linen continues to be used (Ackroyd et al., 2002) because its structural compatibility with original canvases (Andersen & Fuster-López, 2019; Hackney et al., 2021) and its similar aesthetic qualities (Ackroyd, 2002). It responds to fluctuations in RH and water exposure in ways comparable to historical canvases (Young, 2021). However, as Andersen and Fuster-López (2019) note, if a painting is re-stretched without support from a sufficiently stiff fabric, the shear stress is reduced between the canvases, while the in-plane movements caused by RH fluctuations increase the shear force between the canvas and the paint and preparation layers, thereby aggravating cracking and delamination at the strip-lining edge. Structurally, systems where linen is employed exhibit high adhesive strength, creating stronger bond points while holding more adhesive, potentially risking failure of the original canvas (Bianco et al., 2014).

Synthetic fabrics, particularly polyester, have been proposed as alternatives (Ackroyd, 2002; Hackney, 2004), and was chosen for the strip-lining intervention. Polyester is thin, flexible, chemically stable (Hackney et al., 2021), and less hygroscopic than natural fibers, making it more resilient to environmental fluctuations (Rey & Melodia, 2010). Adhesive failure is more common in polyester systems, facilitating separation without damage to the original canvas (Rey & Melodia, 2010). In addition, thin polyester reduces the likelihood of in-plane deformations at the strip-lining edge (Hackney, 2004).

3.2.6 TEAR-MENDING AND INSERTS

Introduction

According to Heiber et al. (2021), thread-by-thread tear-mending involves carefully reattaching torn threads, adding inserts to fill gaps with additional fibers, reinforcing the canvas, and reconstructing the original weave pattern. This method aspires to restore the canvas' mechanical properties, such as the original tension, stress tolerance, and flexibility, while also rebuilding the visual appearance of the canvas in areas where the painting has experienced tears or ruptures (Flock, Possart et al., 2020).

Adhesive requirements

Adhesive for tear-mending must be selected according to the fabric type, whether cellulosic or synthetic, as different materials require distinct adhesive properties. According to the research of Flock, Demuth et al. (2020), effective tear-mending adhesive should provide strong adhesion with minimal material, precise application, good wetting, and controlled penetration into the fibers. Additionally, cohesive strength should be slightly lower than that of the threads, ensuring controlled bond failure under stress and avoiding further damage. And appropriate balance of flexibility and stiffness is required to accommodate canvas movements under environmental fluctuations, while maintaining structural integrity. A T_g between 40-65°C is recommended to prevent reactivation at room temperature. Neutral pH is essential to minimize fabric degradation, particularly fragile textiles. Ideally, adhesives should be easily retreatable, either swellable or soluble in water, or thermoplastic and reactivated with heat, while not altering visual appearance, demonstrating long-term stability and resistance to aging (Flock, Possart et al., 2020).

Choice of adhesive based on literature and empirical tests

Based on availability, literature and empirical tests, various adhesives were selected to assess the different requirements needed to adhere different kinds of bonds, found in Table 3.2.

Table 3.2: Recommended bond types and strength for linen threads.

Adhesive	Composition	Recommended bond type and strength in literature
20% SG + 10% WS (1:1 v/v)	Animal collagen + polysaccharides (Down, 2015)	Preferred adhesive for thread-by-thread tear repair (Down, 2015; Heiber et al., 2021). Mixture of 20% SG + 13% WS (from Foodgel® or Wheat Paste® no. 301) provided high Ultimate Tensile Strength results with an overlap joint (Demuth et al., 2011).

25% SG + Arbocel® BWW 40 (20:1 v/w)	Animal collagen + cellulose fibers (Flock, Demuth et al., 2020).	It showed high ultimate tensile forces (Fmax) in overlap joints, therefore it could be used for butt joints (Flock, Demuth et al., 2020).
Evacon-R©	EVA (Flock, Demuth et al., 2020)	Can be considered a slightly stiffer alternative for bridging threads (Flock, Demuth et al., 2020). High ultimate tensile strength on overlap joints (Demuth et al., 2011). Lower tensile strength than PVA (Flock, Demuth et al., 2020).
Araldite® 5-minute	Epoxy resin (Horie, 2010).	Can be used for butt-joints and reinforcements on repaired tears along the edges of the painting (Demuth et al., 2011; Down, 2015; Heiber et al., 2021). May be effective for butt-joints in polyester and wax-impregnated linen fabrics (Demuth et al., 2011). Generally strong adhesives (Down; 2015; Demuth et al., 2011). Performed worse due to the lack of intermingled fibers in uniaxial overlap joint tests (Demuth et al. 2011).
VESTAMELT® 730-P1	Copolyamide hot-melt adhesive.	Polyamides are recommended for butt-joints when the ends of the threads do not overlap (Heiber et al., 2021). Low melting ranges offer worse bond strength for polyamide heat activated adhesives (Flock, Demuth et al., 2020). Overlapped joints of hot melt adhesives generally showed poor ultimate tensile strength (UTS) in both dry and humid conditions (Demuth et al., 2011).

The empirical tear-mending tests were conducted on linen threads mock-ups joined with overlap joints using the selected adhesives (see Table G.4). Bond performance under uniaxial tension was first assessed subjectively by hand-pulling the bond threads, followed by dynamometer measurements on five samples per adhesive. Average bond strengths were calculated, compared, and ranked on a 1–5 scale (Figure 3.3).

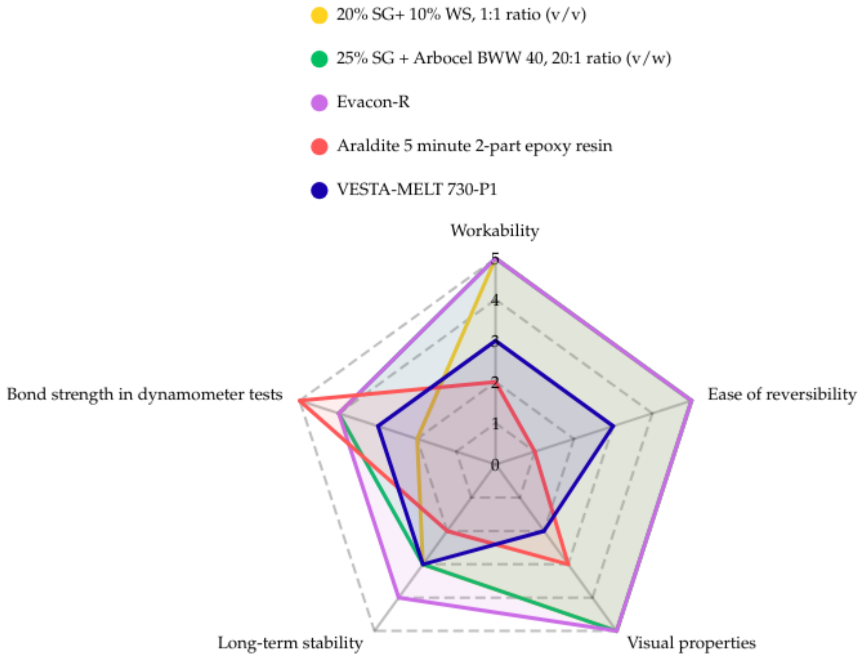


Figure 3.3: Star diagram summarizing the adhesive choice for tear-mending.

Results confirmed the high adhesive strength of epoxy resins reported in the literature (Table 3.2), with Araldite® 5-minute two-part epoxy resin showing the strongest bond. 25% SG + Arbocel® BWW 40 (20:1 v/w) and Evacon-R® demonstrated similarly good strength, while 20% SG + 10% WS (1:1 v/v) produced the weakest bonds. SG mixtures and Evacon-R® offered excellent workability, easy correction, and good retreatability due to their water solubility and neutral pH (Down, 2015; Flock, Demuth et al., 2020). In contrast, VESTAMELT® 730-P1 required a learning curve for effective application, and the epoxy resin proved the most difficult to use due to rapid curing and minimal margin for error. Polyamide and epoxy resins also showed poor retreatability and aging properties (Flock, Demuth et al., 2020; Heiber et al., 2021).

SG mixtures presented additional possibilities, including compatibility with other adhesives, excellent visual properties (no darkening or gloss change) and favorable drying time (Down, 2015; Demuth et al., 2011; Heiber et al., 2021). However, limitations include the requirement of daily fresh preparation, susceptibility to microbial attack (Down, 2015; Heiber et al., 2021), and their lack of long-term stability testing, though the behavior could be comparable to other natural-based adhesives (Table 3.1).

Based on these results, and given that most bonds in the intervention were butt joints, 25% SG + Arbocel® BWW 40 (20:1 v/w) was selected. The addition of Arbocel® BWW 40 cellulose fibers provides not only increased bond strength (Flock, Possart et al., 2020), but also useful bulking properties for inserts (Burg & Seymour, 2024).

3.3 INTERVENTION

The treatment intervention for the painting *Beata Ludovica Albertona* was a concrete case where the treatment proposal needed to be constantly updated as the restoration progressed and the painting was better understood. Initially, the biggest challenges were thought to be related to structural treatments. Although they are still an important section of the intervention, the surface cleaning brought particular needs that needed to be addressed, adapting the treatment order and steps.

Burg and Seymour (2023) recommend surface cleaning prior to consolidation, as dirt may become trapped between paint craquelure, permanently altering the painting's appearance. However, preliminary solubility tests revealed that the cotton swab was potentially causing some paint layer abrasion on the upper parts of the weave, where cracks were already present (Figure 3.4)[2]. This led to the decision to re-adjust the treatment proposal and apply a consolidating facing before proceeding with the other steps, as the upper area in the painting appeared to be more fragile (see Chapter 2.3.4), in form of flaking and cupping.

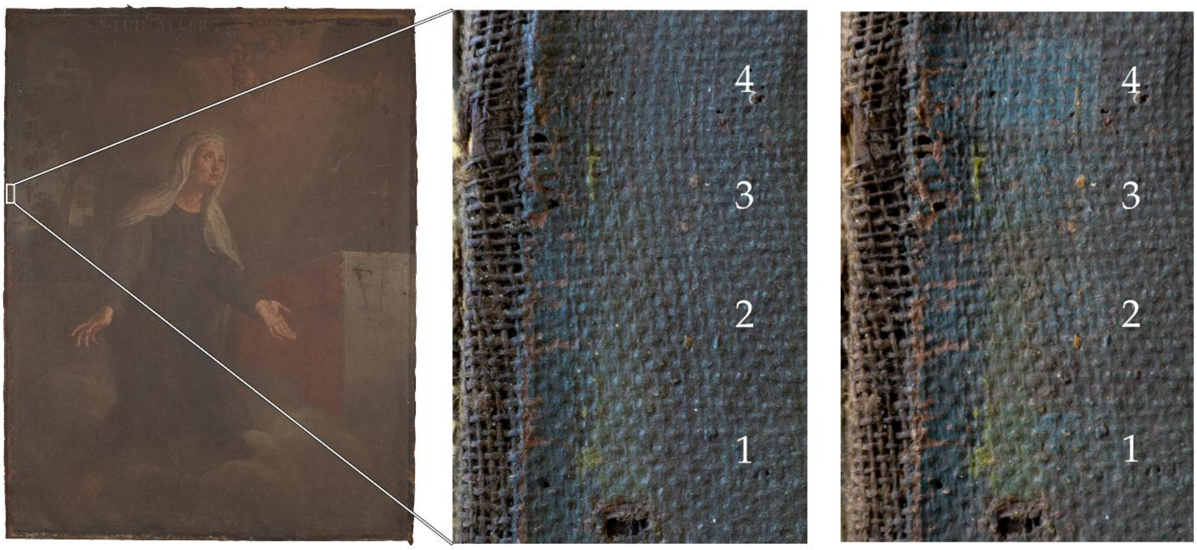


Figure 3.4: Detail in the sky area of the preliminary solubility tests, before (left) and after (right). Legend: 1) Deionized water; 2) Tap water; 3) TAC 0.3%; 4) Synthetic saliva.

[2] Four aqueous solutions were initially used to perform the tests. They were further described and improved upon in Appendix G.4.

3.3.1 REMOVING THE SUPERFICIAL DUST AND DIRT

The treatment began with dry mechanical cleaning using a soft brush and a controlled-suction conservation vacuum cleaner (Figure 3.5). This process was applied to the overall surface of the painting, including the lower area affected by fungal infestation, the tacking margins, the reverse of the canvas (with the painting positioned vertically), and beneath the creases. Areas of degradation exhibiting flaking or loss were carefully avoided, and their surroundings were brushed with particular caution.

Figure 3.5: Dry cleaning the surface of the painting.

The deposits of dirt on the lower part of the painting were softened with cotton immersed in deionized water and then carefully removed with a scalpel (Figure 3.6).

Figure 3.6: Removing deposits with a scalpel.

3.3.2 CONSOLIDATION

Local consolidation

After superficially cleaning the painting, the next step was to improve and stabilize the adhesion of the paint layer to the support through local consolidation. As described in the Chapter 3.2.4, the concluded choice for the consolidating adhesive was fish glue. First, local consolidation was performed with 3% and 8% fish glue in water (w/v). The 8% fish glue adhesive was applied with a fine brush around the lacunae (Figure 3.7), and the right tear, while the 3% concentration was used in areas where more active flaking was present, which allowed the adhesive to flow in the cracks more easily. Afterwards, the residues of glue were cleaned with a cotton swab and deionized water.

Figure 3.7: Local consolidation near the lacunae.

Facing

Before this intervention, the painting was temporarily secured with pins on the loose sections of the tacking edges, so the potential distortion of the canvas would be minimized during the added moisture of the facing. The facing was applied using 3% fish glue in water over thin Japanese papers that were cut in rectangles, with their edges frayed. They were placed in a puzzle pattern, meaning one wet section was always surrounded by dry areas. The fish glue was maintained at around 35°C in a water bath and was brushed over with a brush over the Japanese paper in a crossed movement (Figure 3.8).

Figure 3.8: Applying the fish glue on the Japanese paper.

3.3.3 PRELIMINARY STEPS FOR STRIP-LINING

Brushing and flattening the tacking margins

To prepare the painting for the following treatments, such as strip-lining, the canvas needed to be fully accessible from the back. The painting was turned facing down and removed from the strainer. Because the tacking margins exhibited a certain degree of oxidation, the canvas was separated from the tacks just by slightly pulling away.

The back of the canvas was superficially cleaned again, using steel brushes of different roughness (Figure 3.9).

Figure 3.9: Cleaning the back with a steel brush.

After dry cleaning, the tacking margins were first softened with controlled moisture by laying on the canvas a blotting paper that was sprayed with water and then covered with a silicone-coated Melinex® sheet and then flattened with controlled temperature (around 100ºC) using a conservation hot spatula.

Flattening the paint layers

To not interfere with the reactivation of the strip-lining adhesive, it was decided to also flatten the paint layers at this stage. The painting was turned facing up, and with silicone-coated Melinex® sheet placed on the surface, the painting was flattened using controlled gradual temperature. The flattening happened locally, first by warming up the area, constantly checking the surface with the fingers, and gradually applying more pressure until the flaking and cupping paint felt that it flattened. After each area was flattened, it was placed under weights.

Cleaning the back of the canvas

With the paint layers secure and flattened, it was then decided to further clean the back. To control the moisture introduced to the canvas, it was decided to use an aqueous gel. As consulted in Chapter 3.2.4, even with its low adhesive properties, the cellulose-based Klucel® G can be used as a gelling agent (Burg & Seymour, 2023) and simultaneously provide some consolidating power to the canvas. This has been used as consolidant for fabric supports, such as silk (Gill & Boersma, 1997) and linen fabrics (Thompson & Kataoka, 2011). Cellulose ethers can also be used as an alternative to stabilize linen canvases instead of starch sizing (Yurovetskaya, 2023).

A 10% Klucel® gel in water and ethanol 1:1 (w/v) was prepared. Ethanol was incorporated to accelerate evaporation while the residues were removed, further limiting the moisture introduced to the canvas, while providing some antifungal properties (Sequeira et al., 2012; Sala-Luis et al., 2024). The gel was applied with a brush, left on the surface for roughly 5 seconds to allow the swelling of the dirt, then removed mechanically with a palette knife (Figure 3.10). Afterwards, the excess was removed with cotton swabs, cleaning in a circular motion at first, then along the weave directions (Figure 3.11)

From this point in the intervention, once the painting had been removed from the strainer, to minimize distortion, it was consistently kept under some temporary tension or supported under weights, either locally or across its entire surface.

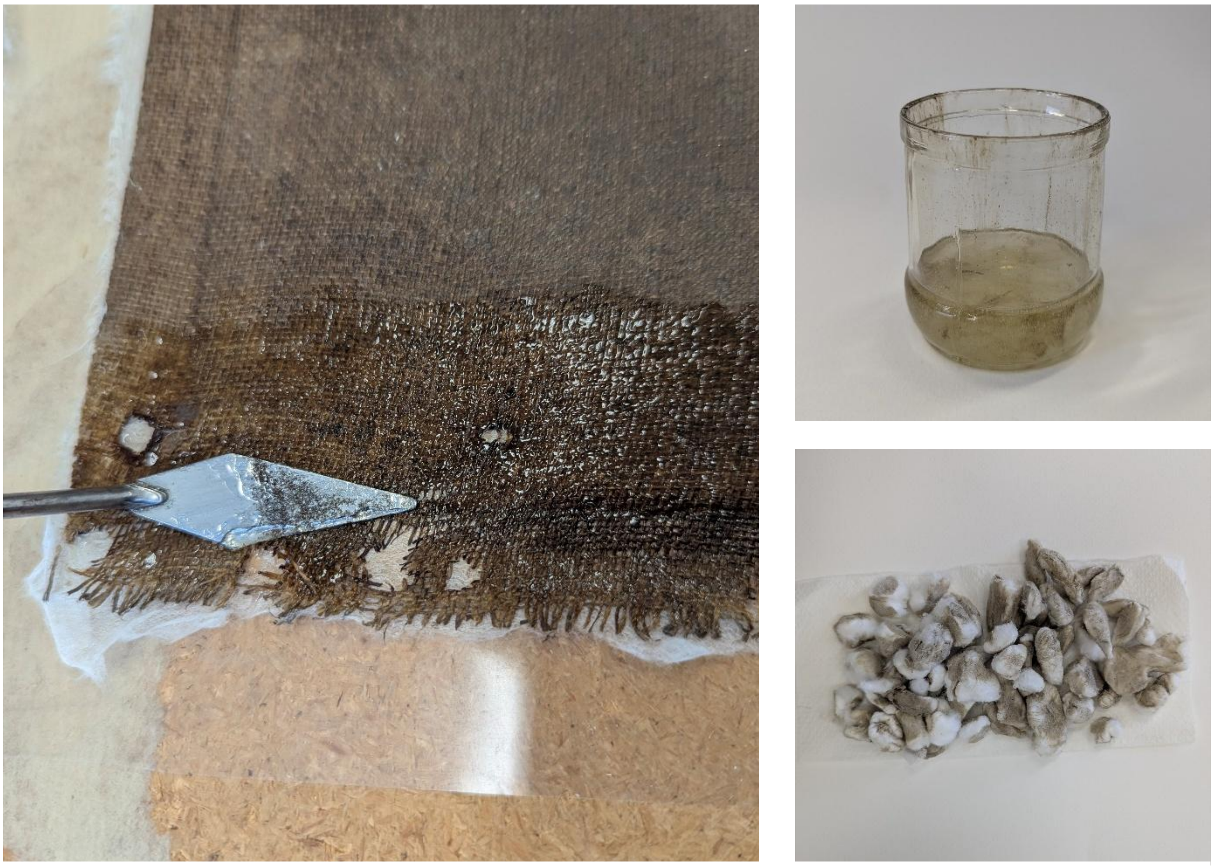


Figure 3.10: Removing the gel with the palette knife (left), and the gel and cotton after cleaning (right).

Figure 3.11: During the cleaning of the back.

3.3.4 STRIP-LINING

For the strip-lining, the choice of materials, as mentioned in Chapter 3.2.5, was BEVA® 371 Film and polyester canvas (see Appendix H for suppliers). Firstly, the rectangular strips of canvas were cut with 12 cm height, then six horizontal threads were removed (approx. 0.5 cm) and "feathered" with a scalpel to make a smoother transition on the side which will be adhered to the canvas (Figure 3.12).

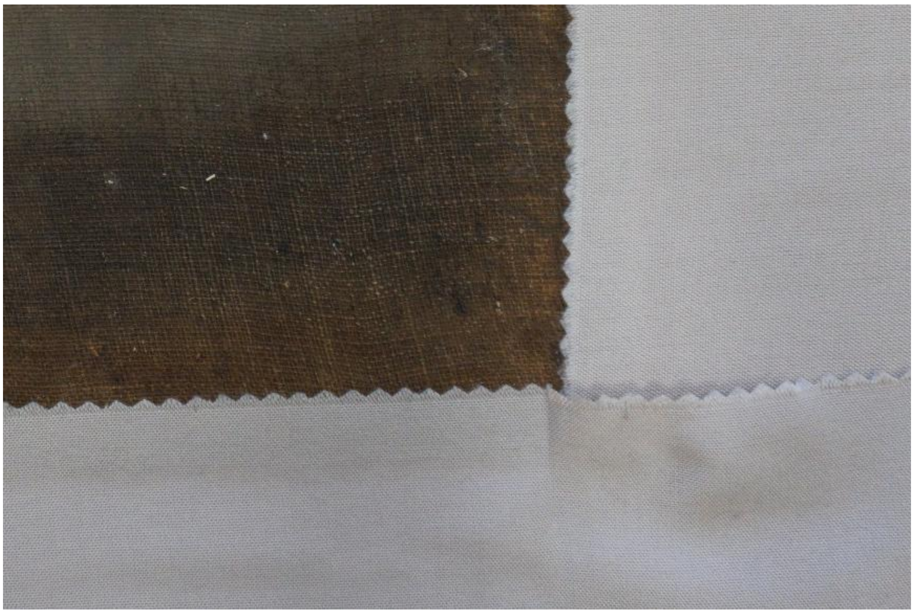


Figure 3.12: The edges of the strips which were cut and "feathered".

The BEVA® 371 Film was cut to cover the 2.5 cm overlap with the back of the canvas and the tacking margins and then adhered with a hot spatula (approx. 100ºC) to each strip-lining fabric, followed by cold weights. The motion was slow, starting from the middle of the strip towards the edges, to minimize deformations. After the BEVA® 371 Film was applied to the strip-lining fabric, the feathered area was cut with pinking shears, creating a crooked line. With the painting still facing down, the next and final step of this intervention was to adhere the strip-lining fabric to the back of the original painting, using the same principle just described (Figure 3.13).

Figure 3.13: Back of the canvas after strip-lining and aqueous cleaning.

3.3.5 REMOVING THE FACING

After strip-lining, the painting was turned facing up and stretched on a temporary wooden loom using pins, to keep tension within the canvas. Following the tests developed for consolidation (see Appendix G.1), it was observed that the consolidating facing improved the adhesion between the paint layers and canvas, especially on the higher points of the canvas weave. The initial treatment proposal included removing the facing and performing the surface cleaning and varnish removal at the same time. During the removal of the facing and the start of surface cleaning, it was observed that the abrasion on the higher parts of the canvas weave was still present, however hidden under a thick layer of surface dirt. Upon realization, the intervention proposal was adjusted, to only carefully remove the facing, with a second consolidation decided as a preventive measure. This would ensure that the subsequent surface cleaning and varnish removal would not worsen the cracks and abrasion present on the upper parts of the canvas weave.

As for the intervention, the facing removed with warm deionized water and cotton swabs. The movement was maintained with caution and controlled positions, by not applying much force and moisture to the surface of the painting, with the aim of only softening the adhesive and removing the Japanese paper (Figure 3.14).


Figure 3.14: Removing the facing.

3.3.6 SECOND OVERALL CONSOLIDATION

The second consolidation was made using 3% fish glue in water. The adhesive was prepared, warmed to approx. 35°C in a water bath to increase penetration and brushed over the whole surface of the painting (Figure 3.15).


Figure 3.15: Applying the fish glue.

3.3.7 SURFACE CLEANING AND VARNISH REMOVAL

Following the second overall consolidation, a thorough plan was developed to more efficiently remove the thick surface layer of dirt using aqueous methods. Various aqueous solutions were tested. Preliminary solubility tests began with the simplest systems and were subsequently refined by adjusting solution properties as needed (Burg & Seymour, 2022a). The primary objective was to minimize moisture exposure to the canvas and paint layers while also efficiently removing both surface dirt and aged varnish. This was achieved through the use of gels, which allowed controlled cleaning with reduced moisture (Baij et al., 2020).

Among the tested solutions (see Appendix G.4), the gel formulated with Carbopol® EZ-2 and surfactant Ethomeen® C25 showed the most satisfactory results. Other preparations, including 1.5% TAC, Abietic acid and Deoxycholic acid were also effective for removing the surface dirt and aged varnish but failed to limit the moisture content introduced to the painting, while also requiring rinsing. Therefore, an aqueous gel with surfactant properties based on Carbopol® EZ-2 and Ethomeen® C25 was chosen to carry out the surface cleaning and varnish removal. Tests also revealed that aqueous systems were successful in removing the varnish, as oxidized natural resins require more polar solvents as they age (Phenix et al., 2021). This was also confirmed under the UV lamp.

The gel was applied with a brush, left for approx. 3 minutes under a Melinex® sheet, with the excess removed first with dry cotton swabs, and later emersed in acetone. The process was repeated, until no more gel residues were present on the surface. To be noted that just the removal of the gel picked up dirt and varnish on the cotton swab. After, the area needed further cleaning with cotton swabs in deionized water, warmed to approx. 70°C (Figure 3.16).

Figure 3.16: Detail of the surface cleaning and varnish removal of the white vail. Removing the gel (left), and half cleaned area after drying (right).

The overall surface of the painting was cleaned by areas. With a similar approach when facing the painting, the cleaning was performed by alternating between wet and dried areas, with the goal of avoid considerable wet areas and to achieve a uniform result. After each section was cleaned, blotting paper and weights were placed on top of the area. The cleaning intervention started with the lighter areas and moved to the darker parts of the composition once the painting's behavior was understood (Figure 3.17 and 3.18), with the main figure and cherubs being fully cleaned the last. The red altar showed the most sensitivity to both the tested solutions and mechanical action. It was decided to only use deionized water there, warmed to approx. 70°C, and light rolling movement of the cotton swab which showed the best results. Additionally, the localized deposits of dirt on the main figure and cherubs that were not picked up by the cotton swab were carefully removed with a scalpel.

Figure 3.18: Cleaning details of the figure's face (left), and the lighter area of the composition (right).

Figure 3.17: Upper lighter area of the painting during cleaning.

After removing the facing and performing the surface cleaning and varnish removal, it was possible to observe the complete surface of the composition, and the elements that were hidden under the thick layer of dirt and aged varnish (Figure 3.19).

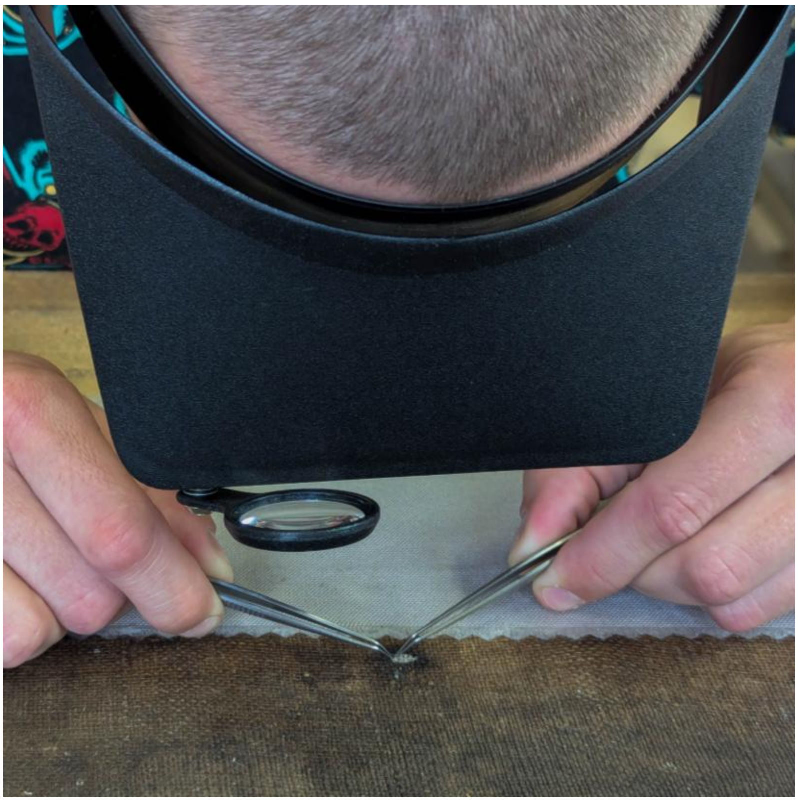
Figure 3.19: The painting before any intervention (left), and after surface cleaning and varnish removal (right).

3.3.8 TEAR-MENDING AND INSERTS

Tear-mending and insert application were performed after surface cleaning and varnish removal to prevent adhesive reactivation and bond failure from the moisture and mechanical action of cotton swabs. At this stage, the right tear appeared to be flattened and consolidated, however with some threads mispositioned, not following the canvas weave. To correct that, with the painting facing down, the threads were carefully softened with deionized water and placed in the correct position using tweezers (Figure 3.20). The ends were adhered with a butt joint with 25% SG and Arbocel® BWW 40 (20:1 v/w) (see Chapter 3.2.6).

Figure 3.20: Repositioning the threads.

For the punctures, where it was not possible to create canvas inserts, the gaps were filled with linen threads, recreating the weave, then adhered with butt joints with 25% SG and Arbocel® BWW 40 (Figure 3.21).



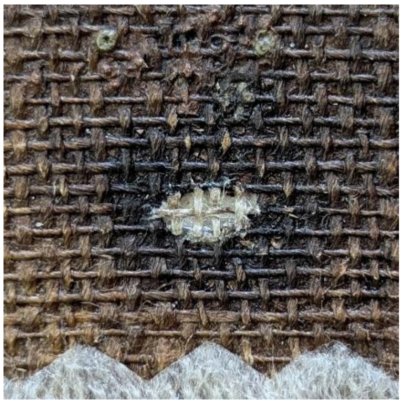


Figure 3.21: Creating the canvas weave (left) and preparing area for applying BEVA® 371 Film adhered Nylon Gossamer reinforcement (right).

To reinforce the area of the tears and punctures, where it was necessary, BEVA® 371 Film was adhered to a Nylon Gossamer fabric (Kite, 1996), colored with watercolors to match the canvas, cut in an approx. shape of the tear (with an overlap on the original canvas of approx. 2 mm), and then adhered to the back of the canvas with controlled temperature and weights (Figure 3.21).

For the bigger puncture losses, inserts of linen canvas with a similar weave were prepared first by priming the canvas (Fuster-López, 2021) with a gelatin, PVA and calcium carbonate mixture (see Chapter 3.3.9), then cutting them in the shape of the loss. The inserts were applied on the polyester canvas, following the original canvas' weave. They were adhered first to the BEVA® 371 Film that was part of the strip-lining intervention with control temperature of approx. 100°C through a silicone-coated Melinex® sheet. The edges of the inserts were then adhered to the original canvas with the butt joints and the 25% SG and Arbocel® BWW 40 mixture (Figure 3.22). There was no need for reinforcements on those inserts, as the strip-lining canvas provided support.

Figure 3.22: Detail of the inserts after they were adhered.

3.3.9 FILLING THE LOSSES

Losses were filled using a mixture of 1 g gelatin, 9 mL water, a small amount of PVA, and calcium carbonate to the desired consistency, following the recipe outlined by Burg and Seymour (2024). This traditional formulation, composed of an animal-based binder and inert bulking filler, has long been used in conservation for its relative stability (see Table 3.1), compatibility with traditional materials, and ease of removability with aqueous solutions (Fuster-López, 2021). While animal-based fills may shrink during drying and cure to a brittle material, the addition of PVA mitigates these limitations by enhancing flexibility and reduction of shrinkage (Burg & Seymour, 2024).

Firstly, a layer of the more diluted filler consistency was brushed over the lacunae to prevent cracking and provide better adherence of the filler to the canvas (Figure 3.23). After the first layer has dried (Figure 3.24), a second layer was applied to build mass up to the height of the paint layer without overlapping with the original. The excess was then removed with cotton swabs in deionized water up to level of the surrounding areas.

Figure 3.24: Applying the filler with a brush.

Figure 3.23: Upper part of the painting after the first layer of infill material.

3.3.10 PROPOSAL FOR THE CONTINUATION OF THE TREATMENT

The full conservation treatment could not be completed within the internship timeframe. Primary structural interventions were successfully conducted, including consolidation and reinforcement of the tacking margins through strip-lining. With long-term structural stability restored, the painting can now be re-stretched if required, allowing the remaining interventions to proceed. Since the painting still required additional work to achieve full reintegration into the Devotional Iconography group of the Third Order of Saint Francis, prior to its eventual exhibition in PNM, the following steps of the treatment would be carried out by a painting conservator of LJF.

The next step involves infilling the lower strip created during the canvas re-dimensioning. One of the options being considered is BEVA® GESSO-P, a filler composed of EVA, hydrogenated hydrocarbon resins, long-term stabilizers, and chalk as the bulking material (Burg & Seymour, 2024). Suitable for shallow losses, it can be prepared in varying consistencies and heat-activated onto the area of loss (Fuster-López, 2021). The resulting flexible film may be textured either while wet or after drying with heat (Burg & Seymour, 2024). Marques (2014) previously studied this filler in a comparable case as the painting under study, where a large, flexible, textured replacement was required. The mixture of diluted BEVA® GESSO-P in toluene 3:1 was casted in two thin layers onto a textured silicone mold and subsequently adhered to the painting during relining. Alternatively, BEVA® GESSO-P may be applied in situ directly onto the strip-lining canvas before re-stretching, although prior testing would be necessary.

The painting will then be mounted on a new conservation stretcher. As Buckley (2021a, 2021b) notes, stretchers should incorporate appropriate tensioning systems with beveled and beaded bars to minimize canvas contact, thereby reducing the risk of cracks and creases. Additionally, given the painting's dimensions, crossbars are also required to ensure structural stability.

The final stage concerns visual reintegration, requiring a compatible layering system for varnish and inpainting. A sequence proposed in the literature of Goltz, Proctor et al. (2021) and Burg & Seymour (2022c) that could be carried out may involve:

1. As base inpainting, **Gouache** is a matte, opaque, water-soluble inpainting medium bound with gum Arabic (Digney-Peer et al., 2021), used as the initial chromatic reintegration layer over the infilled losses, matching the base color of the preparation layer (Christensen, 2011)
2. As an isolating varnish, **Paraloid® B 72** is a stable ethyl methacrylate/methyl acrylate copolymer with high MW, preventing excessive sinking and ensuring good aging stability (Goltz, Proctor et al., 2021; Burg & Seymour, 2022c). It is soluble in highly aromatic solvents (e.g., xylene, Shellsol® A100) or polar solvents (acetone, ethanol).

Applied as the first varnish layer, it saturates the paint and allows accurate chromatic reintegration (Digney-Peer et al., 2021).

3. As inpainting medium, **Laropal® A81** is a stable urea-aldehyde resin with low MW, which would be used as a binder for pigment inpainting (Goltz, Proctor et al., 2021). It is soluble in hydrocarbon solvents with 35–40% aromatic content and in oxygenated solvents such as alcohol or acetone (Burg & Seymour, 2022c). Although compatible with Paraloid® B-72, its solubility parameters require careful selection of solvent blends to avoid interaction with the isolating layer (Goltz, Proctor et al., 2021).

   The choice of chromatic reintegration is debated, where mimetic inpainting of the losses would seamlessly reintegrate the painting as a whole (Burg & Seymour, 2022c). For the re-dimensioned area, possible approaches include leaving the infilled strip flat and tonally matched to the preparation layer, ensuring the intervention remains legible without distracting the viewer. Since the lower margin contains no significant motifs or visual elements, mimetic reintegration does not introduce additional information and would focus on blending the edges of the clouds supporting the central figure with the darker blue background. To enhance aesthetic uniformity, the canvas texture is also reproduced on the infilled area.
4. As a final varnish, **Regalrez® 1094** is a stable hydrogenated hydrocarbon resin with low MW and good aging properties (Rie & McGlinchey, 1990; Burg & Seymour, 2022c), soluble in 100% aliphatic hydrocarbons, aromatic, non-aromatic or non-polar solvents (Goltz, Proctor et al., 2021). Recommended as a final varnish (Goltz, Proctor et al., 2021), it can be applied over Laropal® A81 inpainted areas using aliphatic solvent blends with less than 25% aromatic content (Smith & Johnson, 2008).

4

CONCLUSION

This thesis presented the treatment of the 18th-century oil painting *Beata Ludovica Albertona*, by an unknown artist, from Palácio Nacional de Mafra. The study provided historical context and, through careful observation, non-invasive photo-documentation and micro-samples examination, established a diagnosis of deteriorations. The painting, executed in oil on canvas and mounted on a wooden strainer, displayed structural instability and loss of readability. It exhibited weakened tacking margins, and extensive surface degradation, including craquelure, localized lacunae, dirt, aged varnish, and fungal infestation. Evidence of re-dimensioning was also identified along the upper and lower tacking margins.

The intervention was guided by a theoretical framework, complemented by empirical tests, prioritizing structural treatments and adhesive use. These tests informed decisions on materials and techniques, balancing efficacy and retreatability. The intervention included consolidation, cleaning the back, flattening the paint layers, strip-lining, surface cleaning, varnish removal, tear mending, and filling of losses, which successfully recovered the structural and aesthetical integrity of the painting. Although the treatment was not completed during this internship, further steps included filling the lower re-dimensioned strip, inpainting, varnishing, and the reintegration of the work within the Devotional Saints of the Third Order of Saint Francis ensemble.

Nonetheless, certain limitations must be acknowledged. The empirical tests relied on subjective material evaluation, which, although valuable, would benefit from more rigorous protocols and broader material comparisons to yield objective and reproducible results.

Future research should expand the material and pigment characterization of this painting and the wider group of Devotional Iconography of the Third Order of Saint Francis, to clarify their authorship, chronology, and potential shared provenance. Finally, once the intervention is concluded, a preventive conservation plan addressing storage and exhibition conditions at Palácio Nacional de Mafra would be essential to ensure the long-term preservation of the painting.

BIBLIOGRAPHY

Ackroyd, P. (2002). The structural conservation of canvas paintings: changes in attitude and practice since the early 1970s. *In Studies in Conservation, 47:sup1, 3-14.*

Ackroyd, P., Phenix, A. & Villers, C. (2002). Not lining in the twenty-first century: Attitudes to the structural conservation of canvas paintings. In *The Conservator, 26:1*.

Andersen, C. K., & Fuster-López, L. (2019). Insight into canvas paintings' stability and the influence of structural conservation treatments. In D. Rogala, P. DePriest, E. Charola, & R. Koestler (Eds.), *The Mechanics of Art Materials and its Future in Heritage Science (Vol. 10, pp. 13-20)*. Smithsonian Institution Scholarly Press.

Avery, C. (1997). Bernini: Genius of the Baroque. Thames and Hudson.

Baij, L., Hermans, J., Ormsby, B., Noble, P., Iedema, P., & Keune, K. (2020). A review of solvent action on oil paint. *Heritage Science, 8(43).*

Bianco, L., Avalle, M., Scattina, A., Croveri, P., Pagliero, C., & Chiantore, O. (2014). A study on reversibility of BEVA® 371 in the lining of paintings. *Journal of Cultural Heritage*, *16*(4), 479–485.

Bobak, S. (2003). The Limitations and Possibilities of Strip-Lining. In Bustin, M & Caley, T (Eds.), *Alternatives to Lining: Structural Treatment of Paintings on Canvas without Lining*. UKIC.

Bridarolli, A., Freeman, A. A., Fujisawa, N., & Łukomski, M. (2022). Mechanical properties of mammalian and fish glues over range of temperature and humidity. *Journal of Cultural Heritage*, *53*, 226–235.

Bridarolli, A., Nualart-Torroja, A., Chevalier, A. , Odlyha, M. & Bozec, L., (2020). Systematic mechanical assessment of consolidants for canvas reinforcement under controlled environment. *Herit Sci 8, 52*.

Buckley, B. A. (2021, June 23b). *Stretchers and Strainers: Materials and Equipment*. AIC. https://www.conservation-wiki.com/wiki/Stretchers_and_Strainers:_Materials_and_Equipment.

Buckley, B. A. (2021a). Stretchers, tensioning, and attachments. In J. H. Stoner & R. Rushfield (Eds.), *Conservation of Easel Paintings* (Second Edition). Routledge.

Bucklow, S. (1997). The description of craquelure patterns. *Studies in Conservation*, *42*(3), 129–140.

Bucklow, S. (2021). The classification of craquelure patterns. In J. H. Stoner & R. Rushfield (Eds.), *Conservation of Easel Paintings* (Second Edition). Routledge.

Burg, J. V., & Seymour, K. (2022a). Dirt and Dirt Removal (Dry and Aqueous Cleaning). Paintings conservation part 1. Cultural Heritage Agency of the Netherlands (RCE).

Burg, J. V., & Seymour, K. (2022b). Varnish Removal. Paintings conservation part 2. Cultural Heritage Agency of the Netherlands (RCE).

Burg, J. V., & Seymour, K. (2022c). Varnishing and Inpainting/Retouching. Paintings conservation part 6. Cultural Heritage Agency of the Netherlands (RCE).

Burg, J. V., & Seymour, K. (2023). Consolidation of Paint and Ground. Paintings conservation part 3. Cultural Heritage Agency of the Netherlands (RCE).

Burg, J. V., & Seymour, K. (2024). Filling Losses in Paint. Paintings conservation part 4. Cultural Heritage Agency of the Netherlands (RCE).

Catling, D. & Grayson, J. (1982). Identification of Vegetable Fibres. Chapman and Hall.

Christensen, C. (2011). Gouache. In C. Metzger, C. Maines & J. Dunn (Comps.), *Painting Conservation Catalog Volume 3: Inpainting. (164-175).* American Institute for Conservation.

Demuth, P., Vogel, H., Nägler, C., & Reuber, L. (2011). Review: Adhesives for thread-by-thread tear mending in torn fabric-supported paintings*. Proceedings of Symposium 2011: Adhesives and Consolidants for Conservation: Research and Applications.*

Digney-Peer, S., Thomas, K., Perry, R., Townsend, J., & Gritt, S. (2021). The imitative retouching of easel paintings. In J. H. Stoner & R. Rushfield (Eds.), *Conservation of Easel Paintings* (Second Edition). Routledge.

Dixon, T. (2021). Framing, glazing, backing, and hanging of paintings on canvas. In J. H. Stoner & R. Rushfield (Eds.), *Conservation of Easel Paintings* (Second Edition). Routledge.

Down, J. (2015). Adhesive Compendium for Conservation. (First Edition). Canadian Conservation Institute.

Duffy, M. C. (1989). A Study of Acrylic Dispersions Used in the Treatment of Paintings. *Journal of the American Institute for Conservation*, *28*(2), 67–77.

E.C.C.O. (2003). "E.C.C.O. Professional Guidelines (II)". https://www.ecco-eu.org/wp-content/uploads/2021/03/ECCO_professional_guidelines_II.pdf Last accessed 24th of August 2025.

Eastaugh, N., Nadolny, J., & Lowengard, S. (2021). Pigments in Western Easel Painting. In J. H. Stoner & R. Rushfield (Eds.), *Conservation of Easel Paintings* (Second Edition). Routledge.

Feller, R. L., & Wilt, M. H. (1990). *Evaluation of cellulose ethers for conservation*. The Getty Conservation Institute.

Flock, H., Diebels, S., Jägers, E., & Demuth, P. (2020). New Investigations of Adhesives for Tear Repair of Canvas Paintings. *Studies in Conservation*, *66*(6), 321–341.

Flock, H., Diebels, S., Jägers, E., & Possart, W. (2020). Thread-by-thread tear mendings in conservation of canvas paintings: a problem of reproducibility in bonding qualities. *The Journal of Adhesion*, *97*(14), 1336–1357.

Fuster-López, L. (2021). Filling. In J. H. Stoner & R. Rushfield (Eds.), *Conservation of Easel Paintings* (Second Edition). Routledge.

Gill, K., & Boersma, F. (1997). Solvent reactivation of hydroxypropyl cellulose (Klucel G®) in textile conservation: Recent developments. *The Conservator, 21(1), 12–20.*

Goltz, M. V., Birkenbeul, I., Horovitz, I., Blewett, M., & Dolgikh, I. (2021). Consolidating of flaking paint and ground. In J. H. Stoner & R. Rushfield (Eds.), *Conservation of Easel Paintings* (Second Edition). Routledge.

Goltz, M. V., Proctor, R. G., Whitten, J., Mayer, L., Myers, G., A., A. H., & Swicklik, M. (2021). Varnishing as part of the conservation treatment of easel paintings. In J. H. Stoner & R. Rushfield (Eds.), *Conservation of Easel Paintings* (Second Edition). Routledge.

Hackney, S. (2004). Paintings on Canvas: Lining and Alternatives. In *Tate Papers no.2,*. https://www.tate.org.uk/research/tate-papers/02/paintings-on-canvas-lining-and-alternatives , accessed 29 August 2025.

Hackney, S., Reifsnyder, J., Marvelde, M., & Scharff, M. (2021). Lining easel paintings. In J. H. Stoner & R. Rushfield (Eds.), *Conservation of Easel Paintings* (Second Edition). Routledge.

Heiber, W., Tomkiewicz, C., Scharff, M., & Levenson, R. (2021). Tear mending and other structural treatments of canvas paintings, before or instead of lining. In J. H. Stoner & R. Rushfield (Eds.), *Conservation of Easel Paintings* (Second Edition). Routledge.

Horie, V. (2010). Materials for Conservation. (Second Edition). Elsevier.

Howells, R., Burnstock, A., Hedley, G., & Hackney, S. (1984). Polymer dispersions artificially aged. *Studies in Conservation*, *29*(sup1), 36–43.

Kelly, K. S., Herrmann, J. K., Chipman, A., Davis, A. R., Khan, Y., Loew, S., & Youket, M. H. (2020). Heat- and Solvent-Set Repair Tissues. *Journal of the American Institute for Conservation*, *61*(1), 24–54.

Kirsh, A., & Levenson, R. S. (2000). Seeing through paintings: Physical examination in Art Historical studies. In Yale University Press eBooks.

Kite, M. (1996). "Gloves", Preprints of the ICOM Committee for Conservation 11th Triennial Meeting Edinburgh, U.K., 1-6 September 1996, vol. 2, ed. J. Bridgland, London: James and James.

Kite, M., & Thomson, R. (2006). Conservation of leather and related materials. In *Routledge eBooks*.

Lark., K. M. (2020). *Bernini's Blessed Ludovica Albertoni: Drapery and the Permeability of the Body* [master's thesis, University of Washington]. http://hdl.handle.net/1773/45775.

Lloyd, K. J. (2010). Baciccio's Beata Ludovica Albertoni Distributing Alms. *Getty Research Journal 2, 1-18.*

Loon, A., Noble, P., & Burnstock, A. (2021). Ageing and deterioration of traditional oil and tempera paints. In J. H. Stoner & R. Rushfield (Eds.), *Conservation of Easel Paintings* (Second Edition). Routledge.

Marques, R. R. (2014). Analysis and Treatment of a Nineteenth Century Oil Painting [master's thesis, NOVA School of Science and Technology]. http://hdl.handle.net/10362/14198.

Marriott, S. (2010). Material focus: Lascaux 4176 Medium for Consolidation. *The Picture Restorer, 37.*

Mecklenburg, M. F., & Tumosa, C. S. (1991). Mechanical Behavior of Paintings Subjected to Changes in Temperature and Relative Humidity. In M. F. Mecklenburg, *Art in Transit: Studies in the Transport of Paintings*. editor. 173–216. National Gallery of Art.

Mecklenburg, M. F., Fuster-López, L., & Ottolini, S. (2012). A look at the Structural Requirements of Consolidation Adhesives for Easel Paintings. *Adhesives and Consolidants in Painting Conservation. 7-23*.

Michalski, S. (1990). Time's Effects on Paintings. *Shared Responsibility: Proceedings of a Seminar for Curators and Conservators*. National Gallery of Canada, pp. 39–53.

Morrison, R., Bagley-Young, A., Burnstock, A., van den Berg, K. J., & van Keulen, H. (2007). An Investigation of Parameters for the Use of Citrate Solutions for Surface Cleaning Unvarnished Paintings. *Studies in Conservation*, *52*(4).

Museus e Monumentos de Portugal. (n.d). *Inventory file PNM 2, Beata Ludovica Albertona* [Unpublished manuscript].

Pataki-Hundt, A. (2018). Characteristics of natural and synthetic adhesives. *Konsolidieren und Kommunizieren 122-130.*

Petukhova, T., & Bonadies, S. D. (1993). Sturgeon Glue for Painting Consolidation in Russia. *Journal of the American Institute for Conservation*, *32*(1).

Phenix, A., & Burnstock, A. (1992). THE REMOVAL OF SURFACE DIRT ON PAINTINGS WITH CHELATING AGENTS. *The Conservator*, *16*(1).

Phenix, A., & Townsend, J. (2021). A brief survey of historical varnishes. In J. H. Stoner & R. Rushfield (Eds.), *Conservation of Easel Paintings* (Second Edition). Routledge.

Phenix, A., Wolbers, R., Townsend, J., Zumbühl, S., Bartoletti, A., Lee,.L., & Ormsby, B. (2021). Removal of Varnish: organic solvents as cleaning agents. In J. H. Stoner & R. Rushfield (Eds.), *Conservation of Easel Paintings* (Second Edition). Routledge.

Pinheiro, C. (2024). Avaliação da contaminação biológica | Beata Ludovica Albertoni, nº Inv PNM2, Palácio Nacional de Mafra. Relatório Técnico do Laboratório Analítico do LaboratórioJosé de Figueiredo. Processo 67_24. Museus e Monumentos de Portugal, E.P.E.

Ploeger, R., Rie, R. E., McGlinchey, C. W., Palmer, M., Maines, C. A & Chiantore, O. (2014). The long-term stability of a popular heat-seal adhesive for the conservation of painted cultural objects. *Polymer Degradation and Stability, 307-313*.

Poulis, H., Seymour, K., & Mosleh, Y. (2020). The Influence of Loading, Temperature and Relative Humidity on Adhesives for Canvas Lining. In A. Ashton (Ed.), *IOP Conf. Series: Materials Science and Engineering* (First Edition, Vol. 949). journal of physics: conference series.

Poulis, J. A., Mosleh, Y., Cansell, E., Cimino, D., Ploeger, R., De La Rie, E. R., McGlinchey, C. W., & Seymour, K. (2022). Mechanical and physical characterization of natural and synthetic consolidants. *International Journal of Adhesion and Adhesives*, *117*, 103015.

Puglisi, C. R. (1992). [Review of *Bernini and the Idealization of Death: The Blessed Ludovica Albertoni and the Altieri Chapel.*, by S. K. Perlove]. *Renaissance Quarterly*, *45*(1), 170–173.

RAIZ (2025, August 25). *Beata Ludovica Albertona*. http://raiz.museusemonumentos.pt/DetalhesObra?id=992581&tipo=OBJ.

Rey, M. S. & Melodia, F. R. (2010). Mechanical Strength Parameters on Polyester Fabrics. Treatment Applied in Support of Large Canvas Painting: The Expulsion of the Merchants from the Temple" by Artist Saverio Lillo. (1734-1796). *Arché*. Publicación Del Instituto Universitario De Restauración Del Patrimonio De La Upv, 4-5.

Rie, R. E., & McGlinchey, C. W. (1990). NEW SYNTHETIC RESINS FOR PICTURE VARNISHES. *Studies in Conservation*.

Sala-Luis, A., Oliveira-Urquiri, H., Bosch-Roig, P., & Martín-Rey, S. (2024). Eco-Sustainable Approaches to Prevent and/or Eradicate Fungal Biodeterioration on Easel Painting. *Coatings*, *14*(1), 124.

Scharff, M. (2023). To Treat or Not to Treat: That Is the Question; Structural Treatment of Canvas Paintings from a Danish Perspective. In C. Schwarz, I. McClure, & J. Coddington (Eds.), *Conserving Canvas* (pp. 18-27). The Getty Conservation Institute.

Schellmann, N. C. (2007). Animal glues: a review of their key properties relevant to conservation. *Studies in Conservation*, *52*(sup1), 55–66.

Schellmann, N. C. (2009). Animal Glues – their adhesive properties, longevity and suggested use for repairing taxidermy specimens. *NatSCA News, Issue 16, 36 - 40.*

Sequeira, S., Cabrita, E., & Macedo, M. (2012). Antifungals on paper conservation: An overview. *International Biodeterioration & Biodegradation*, *74*, 67–86.

Shah, N., Seymour, K., Poulis, J. A., & Mosleh, Y. (2024). A Comparative Study of Bond Strength, Reversibility, and Projected Long-Term Durability of Lining Techniques for the Structural Stabilisation of Canvas Paintings. *Studies in Conservation*, *70*(5), 386–403.

Slotsgaard, T. L., Pastorelli, G., Buti, D., Scharff, M., & Andersen, C. K. (2024). Crack morphology and its correlation with ground materials used in paintings by Danish portrait painter Jens Juel. *Journal of Cultural Heritage*, *69*, 47–56.

Smith, G. D., & Johnson, R. (2008). Strip 'Teas' - Solubility Data for the Removal (and Application) of Low Molecular Weight Synthetic Resins Used as *Inpainting Media and Picture Varnishes. WAAC Newsletter, Volume 30, Number 1, 11-19.*

Stols-Witlox, M. (2021). Grounds, 1400-1900. In J. H. Stoner & R. Rushfield (Eds.), *Conservation of Easel Paintings* (Second Edition). Routledge.

Thompson, J., & Kataoka, M. (2011). From Mummies to Modern Dress: Adhesive Treatments in Textile Conservation at the Museum of Fine Arts, Boston. *Proceedings of Symposium 2011: Adhesives and Consolidants for Conservation: Research and Applications,* October 17-21.

Wolbers, R., Stavroudis, C., & Cushman, M. (2021). Aqueous methods for the cleaning of paintings. In J. H. Stoner & R. Rushfield (Eds.), *Conservation of Easel Paintings* (Second Edition). Routledge.

Young, C. (2021). History of fabric supports. In J. H. Stoner & R. Rushfield (Eds.), *Conservation of Easel Paintings* (Second Edition). Routledge.

Yurovetskaya, A. (2023). Structural Conservation of Canvases in Russia from the 1960s to the Present: Evolution of Methods and Approaches. In C. Schwarz, I. McClure, & J. Coddington (Eds.), *Conserving Canvas* (pp. 47–52). Getty Publications.

Zimniewska, M., Wladyka-Przybylak, M., & Mankowski, J. (2011). Cellulosic Bast Fibers, Their Structure and Properties Suitable for Composite Applications. In: Kalia, S., Kaith, B., Kaur, I. (Eds.) *Cellulose Fibers: Bio- and Nano-Polymer Composites.* Springer.

A PHOTOGRAPHIC DOCUMENTATION OF *BEATA LUDOVICA ALBERTONA, BEFORE TREATMENT*

Figure A.1: Normal light photograph of the front of the painting *Beata Ludovica Albertona,* inv no. PNM 2. @LJF Luís Bravo, 2024.

Figure A.2: Normal light photograph of the back of the painting *Beata Ludovica Albertona,* inv no. PNM 2. @LJF Luís Bravo, 2024.

Figure A.3: UV fluorescence photograph of the front of the painting *Beata Ludovica Albertona,* inv no. PNM 2. @LJF Luís Bravo, 2024.

B | DEVOTIONAL ICONOGRAPHY GROUP OF THE THIRD ORDER OF SAINT FRANCIS

Table B.1: Group of paintings in dedication of the Third Order of Saint Francis, large series. Information and images taken from http://raiz.museusemonumentos.pt/ (last accessed: August 23, 2025). If the information was taken from their representative inventory file, is marked with "*".

Beata Ludovica Albertona
PNM 2
18th-century
128.5 x 98.5 cm/
129 x 99 cm*

São Francisco recebendo os estigmas
PNM 10
18th-century
136 x 98 cm

São Roque
PNM 11
18th-century
136 x 98 cm

São Pedro de Alcântara
PNM 12
18th-century
135 x 99 cm

Mártires de Gorcum / Mártires Gorcumienses
PNM 13
1730
136.5 x 98.5 cm

Santo António
PNM 15
18th-century
136 x 98 cm

São José e o Menino Jesus
PNM 16
18th-century
136 x 98 cm

Santa Inês
PNM 204
18th-century
135 x 99 cm*

Santa Isabel da Hungria
PNM 456
18th-century
136 x 97 cm

Santa Clara de Assis
PNM 3170
18th-century
135 x 98 cm

São Diogo de Alcalá / São Diego de San Nicolás
PNM 3171
18th-century
136 x 99 xm

Mártires de Marrocos
PNM 3172
1730*
136 x 98 cm*

São João de Capistrano
PNM 7643
1730
136 x 98 cm

C | TIMELINE OF THE PAINTING

Table C.1: History of the location of the painting, with the reference after each section.

Date	Event
The painting may have been manufactured in Rome (Inventory file no. PNM 2).	
1711	PNM began construction (https://www.museusemonumentos.pt/en/museus-e-monumentos/palacio-nacional-de-mafra, September 29, 2025).
1730	Basilica of PNM was consecrated (https://www.museusemonumentos.pt/en/museus-e-monumentos/palacio-nacional-de-mafra, September 29, 2025).
Approx. 1736	The painting has been physically in the Mafra Palace since the founding of the Brotherhood of the Third Order by King João V (personal communication with Dr. Sergio Gorjão, October 17, 2024).
1834	Transferred to the Crown (Ministry of Ecclesiastical Affairs) / Coroa (Ministério dos Negócios Eclesiásticos) (inventory file no. PNM 2).
1867	The Brotherhood of the Third Order disbanded; however, the painting remained part of the collection, belonging to the Convent of Mafra (personal communication with Dr. Sergio Gorjão, October 17, 2024).
November 21, 1876	Loaned to the Hospital of Our Lady of Sorrows (Mercy in Mafra) / Hospital de Nossa Senhora das Dores (Misericórdia in Mafra) (inventory file no. PNM 2).
1911	The painting was assigned to the Museum of PNM, as it was recognized as always being part of its history (personal communication with Sergio Gorjão, October 17, 2024; RAIZ, 2025).
1911	Moved to the National Palace of Mafra (personal communication with Dr. Sergio Gorjão, October 17, 2024).
March 30, 1949	Reincorporated into the Palace's collection, together with three other paintings, by the order of the General Directorate of Public Finance / Direcção Geral da Fazenda Pública (inventory file no. PNM 2; RAIZ, 2025).
March 30, 1949	Exhibited in room no. 1 of the Palace (inventory file no. PNM 2).
Beata Ludovica Albertona was on display in the sacred art section on the first floor of the building between 1949-1980 (personal communication with Dr. Sergio Gorjão, October 17, 2024).	
1980	Stored in the room attached to the Sacristy of the Chapel of Our Lady of Deliverance / Sala anexa à Sacristia da Capela de Nossa Senhora do Livramento (inventory file no. PNM 2).
1986	Stored in the room of D. Ana de Jesus Maria / Quarto de D. Ana de Jesus Maria (inventory file no. PNM 2).
August 29, 2000	Stored in the North Tower, Room 10 / Torreão Norte - Sala 10 (inventory file no. PNM 2).
December 3, 2013	Stored in the North Tower, Room 9 / Torreão Norte - Sala 9 (inventory file no. PNM 2).
February 18, 2015	Stored in the North Tower, Room 7 / Torreão Norte - Sala 7 (inventory file no. PNM 2).
June 3, 2024	Entered Laboratório José de Figueiredo.

D | DETAIL PHOTOGRAPHS OF *BEATA LUDOVICA ALBERTONA*, BEFORE TREATMENT

D.1 AUXILIARY SUPPORT: STRAINER

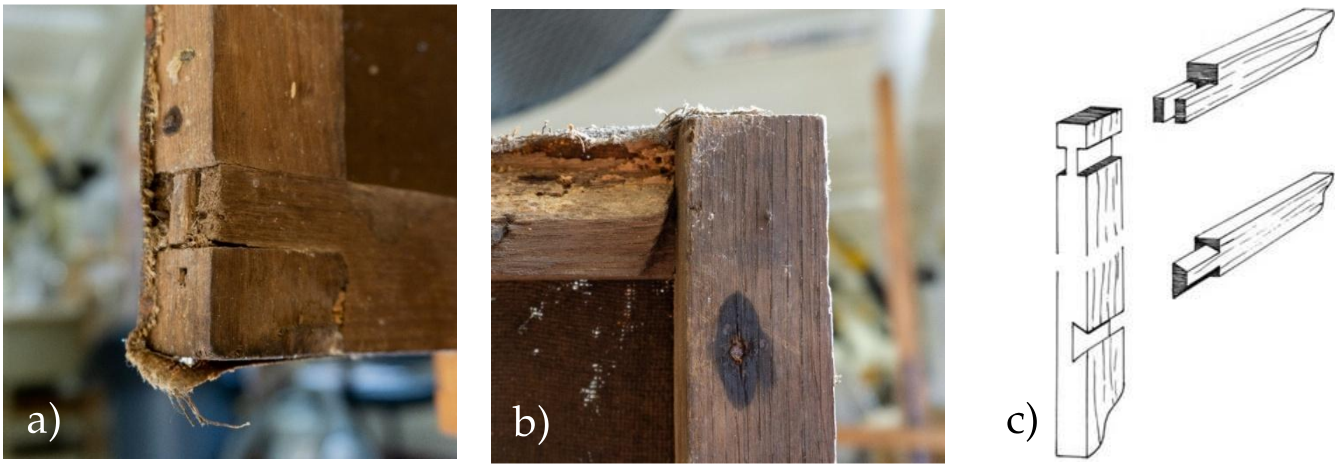


Figure D.1: a) Bottom left corner joint; b) Upper right corner with half lap joint; c) Illustration with a shouldered bridle joint. Illustration taken from: https://www.conservation-wiki.com/wiki/Stretchers_and_Strainers:_Materials_and_Equipment , last accessed: October 3, 2024.

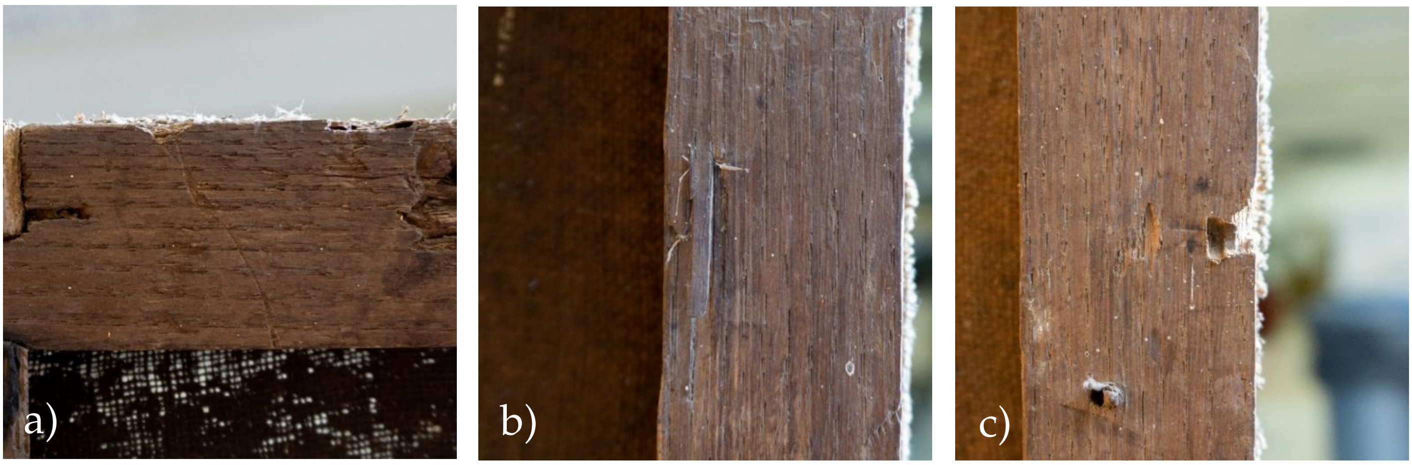


Figure D.2: a) Scratch on top of the strainer bar; b) Splinter on the right side of the strainer; c) Material loss on the right side of the strainer.

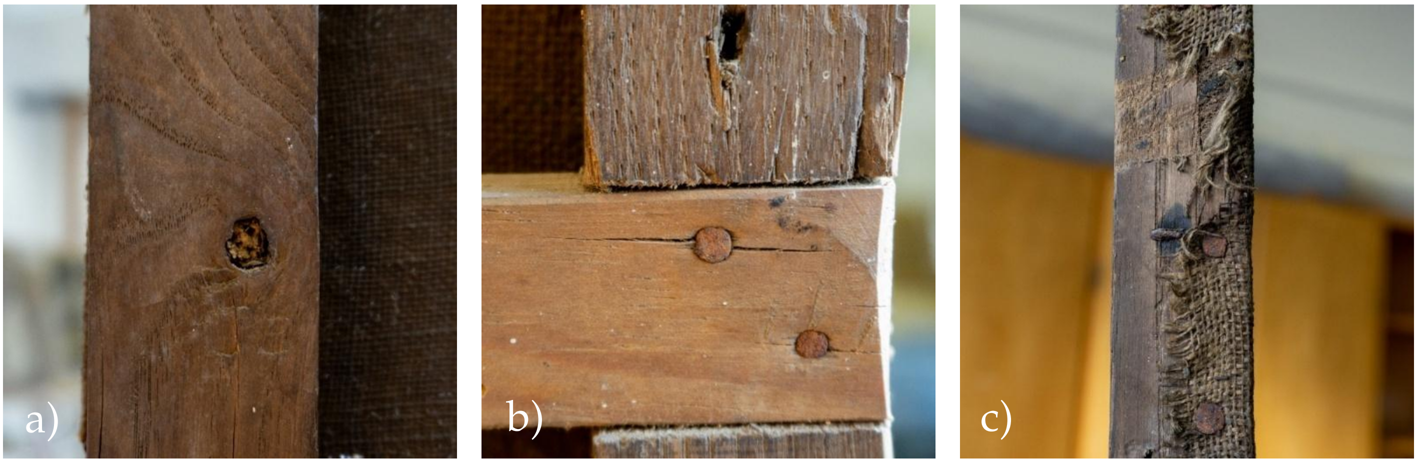


Figure D.3: a) “Knot” on the left side of the strainer; b) Cracks in the wooden strainer; c) Tack remnants disconnected from the canvas.

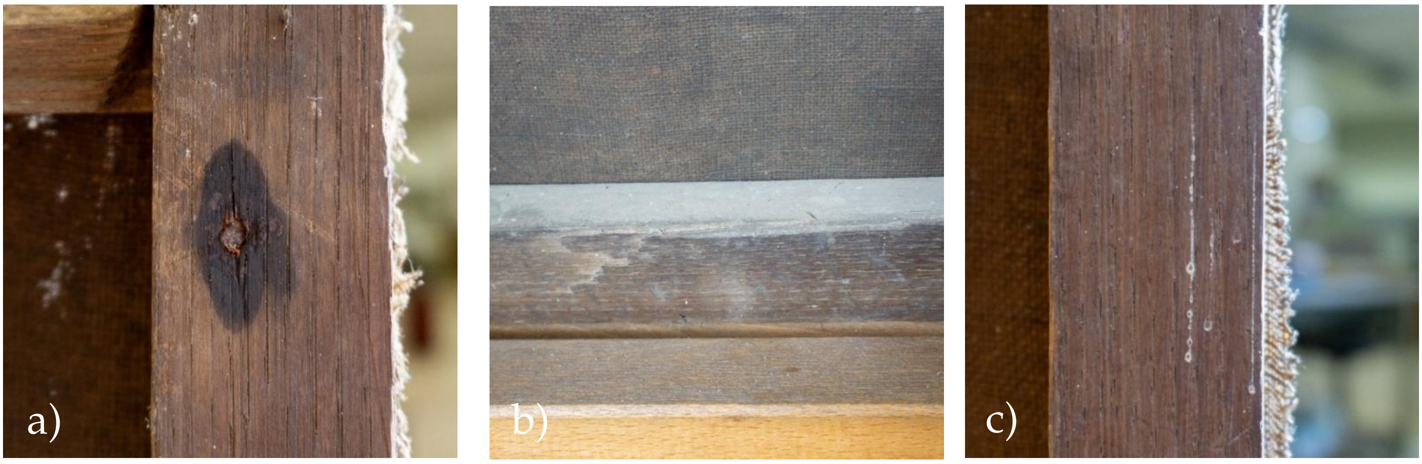


Figure D.4: a) Stain surrounding a rusted tack; b) Deposited dirt on the lower strainer member; c) White stain, possibly white paint on the right side of the strainer.

D.2 PAINTING SUPPORT: CANVAS

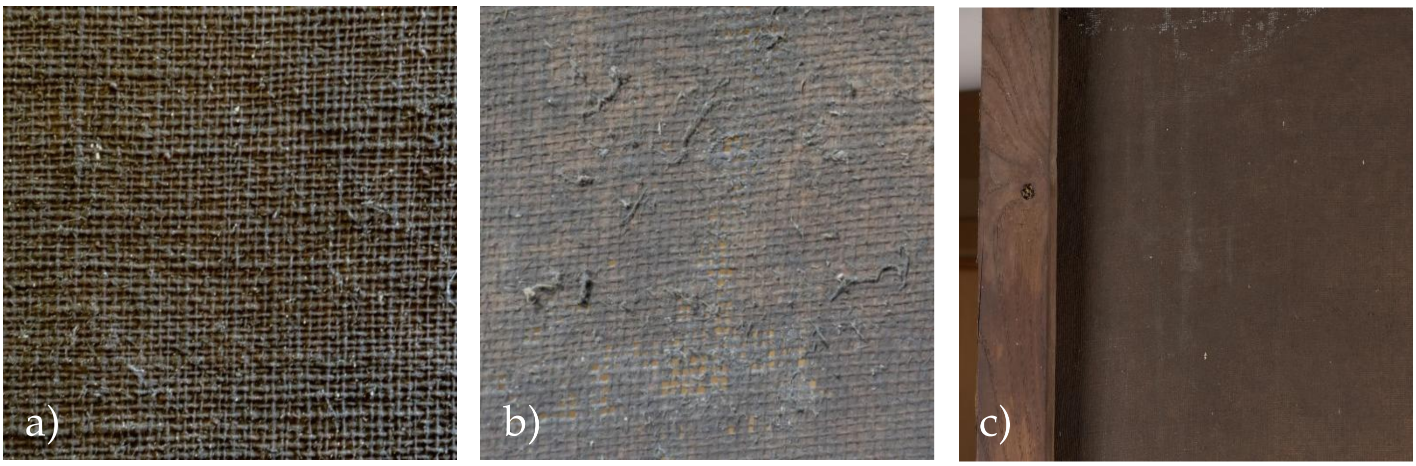


Figure D.5: a) Detail of the fabric weave; b) Accumulated dirt on the on the back of the canvas; c) Dripping stains on the back of the canvas.

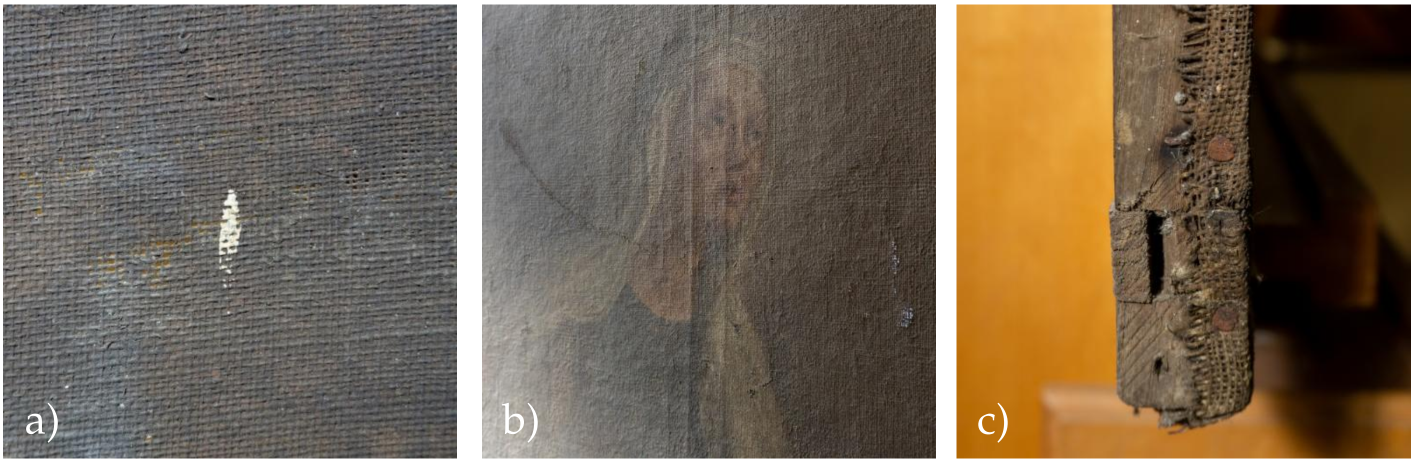


Figure D.6: a) White stain, possibly white paint on the back of the canvas; b) Crease created by the vertical crossbar; c) Rusted tacks on the tacking margins.

D.3 PREPARATION LAYER

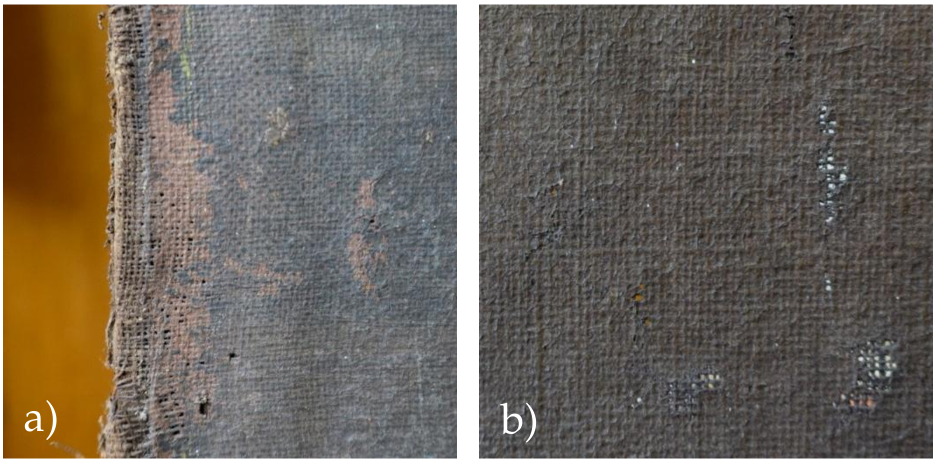


Figure D.7: a) Separation between paint layer and preparation layer; b) Detail of the weave texture on the painting layer.

D.4 PAINTING LAYERS

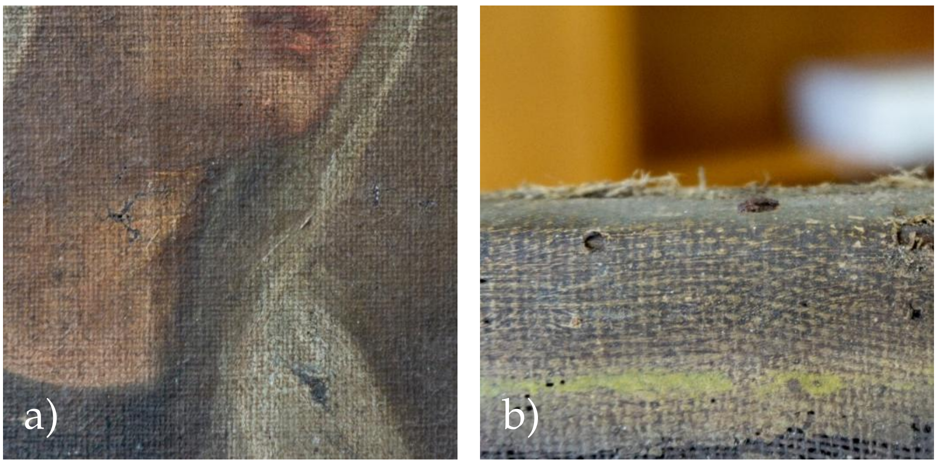


Figure D.8: a) Detail of the impasto; b) Detail of the brush strokes at the top of the canvas.

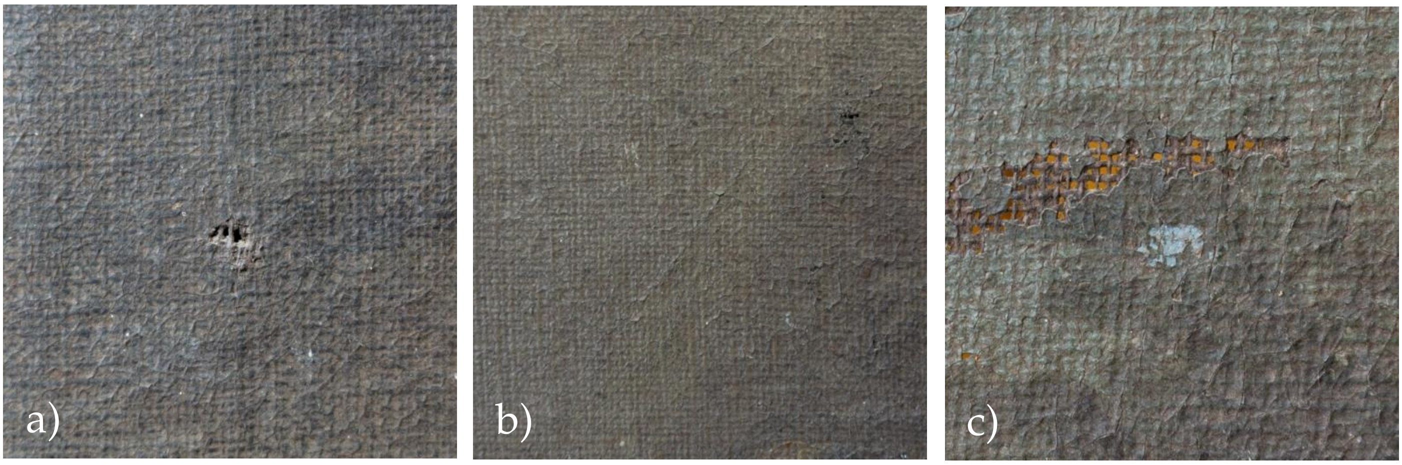


Figure D.9: a) Detail of middle puncture; b) Scratch on the paint surface, c) Separation between paint layers.

D.5 VARNISH / SUPERFICIAL LAYERS

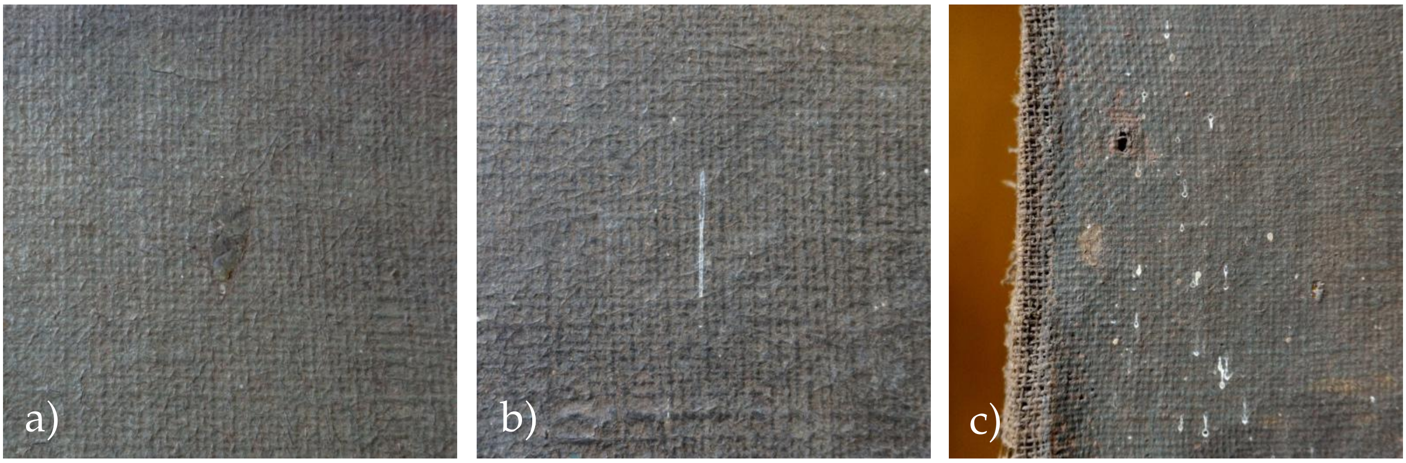


Figure D.10: a) Stain; b) White stain, c) White drops of possibly paint.

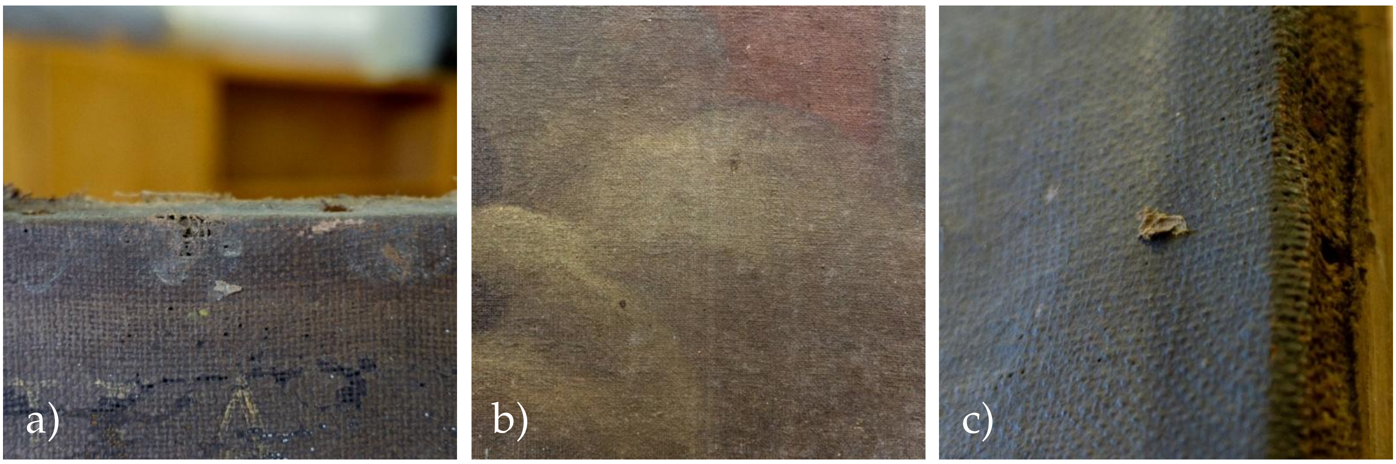


Figure D.11: a) Fingerprints on the upper part of the painting; b) Possibly water drip stains; c) Possibly paper adhered to the surface of the painting due to the contact with the frame.

E | MAP OF DAMAGES

Figure E.1: Degradation mapping of the front of the painting.

Table E.1: Location of the punctures and tears. Legend (starting point): L = Left side, R = Right side, T = Top, B = bottom.

Punctures	Dimension	Coordinates
1	Approx. 50 mm	L = 1.60 cm, T = 1.2 cm
2	Approx. 10 mm	L = 1.3 cm, T = 5.3 cm
3		L = 1.7 cm, T = 15.8 cm
4		L = 1.5 cm, T = 25.8 cm
5		L = 1.5 cm, T = 34.6 cm
6		L = 1.5 cm, T = 35.5 cm
7		L = 1.5 cm, T = 47.3 cm
8		L = 1.5 cm, T = 58.5 cm
9		L = 2 cm, T = 68.1 cm
10		L = 2 cm T = 79.5 cm
11		L = 2 cm T = 90.6 cm
12		L = 2 cm T = 101.8 cm
13		L = 2 cm T = 112.4 cm
14		L = 2.7 cm T = 117.5 cm
15		L = 1.7 cm, T =123 cm
16		L = 50 cm T = 105,2 cm
17		R = 1 cm T = 10.5 cm
18		R = 0.8 cm T = 20.2 cm
19		R = 0.6 cm T = 31.2 cm
20		R = 0.6 cm T = 44 cm
21		R = 0.8 cm T = 55.6 cm
22		R = 0.6 cm T = 67.6 cm
23		R = 2.5 cm T = 68 cm
24		R = 0.8 cm T =79.1 cm
25		R = 0.8 cm T = 89.9 cm
26		R = 0.5 cm T = 100.5 cm
27		R = 1 cm T = 112.1 cm
28		R = 0.4 cm, T = 123.3 cm
29		L = 9 cm T = 1 cm
30		L = 11.3 cm T = 0.3 cm
31		L = 12 cm T = 0.4 cm
32		L= 24.5 cm T = 0.1 cm
33		L = 32.5 cm T = 0.2 cm
34		L = 36.5 cm, T = 0.3 cm
35		L = 47 cm T = 0.3 cm
36		L = 48.5 cm T = 0.2 cm
37		L = 60.8 cm T = 0.1 cm
38		L = 70.2 cm T = 0.1 cm
39		L = 79.5 cm T = 0.1 cm
40		L = 86.5 cm T = 0.2 cm
41		L = 89.7 cm T = 0.1 cm
Tears		
1	1.1 cm	L = 1 cm T = 58 cm
2	2.7 cm	R = 9.3 cm, T = 44 cm

F ANALYTICAL SECTION

F.1 INSTRUMENT DESCRIPTION

Optical Microscope (OM)

The optical microscope (OM) is an Axioplan 2ie Zeiss microscope equipped with transmitted and incident halogen light illuminator (tungsten light source, HAL 100); UV light (mercury light source, HBO 100 illuminator); and a digital Nikon camera DXM1200F, with Nikon ACT-1 application program software, for microphotographs. Samples were analyzed with 10x ocular lenses and 20x/50x objective Epiplan lenses (giving a total optical magnification of 200x, and 500x).

For the incident and transmitted light (normal light) the samples were analyzed under crossed polars – polarizer and analyzer filters; and for UV light the Zeiss filter set 2 [BP 300-400, FT 395, LP 420] was used. The scales for all objectives were calibrated within the Nikon ACT-1 software.

Cross-sections (with Technovit® resin)

Samples were prepared using the Kulzer Technovit® 2000 LC system. Samples were mounted in an embedding mold using a Technovit® 2000 LC fixing paste. Each mold was filled with Technovit® 2000 LC resin, a light curing, one component, highly transparent embedding resin based on methacrylate, and then polymerized with blue-light in a Technotray CU unit. Samples were then removed from the embedding molds and polished with a set of Micromesh abrasive sheets (micron graded silicon carbide crystals from grade 320 to grade 8000) without any lubricant.

F.2 TEAR-MENDING EMPIRICAL TESTING

For the experimental conditions of the tear-mending empirical tests, the uniaxial tensile empirical tests were performed first by pulling one thread for each adhesive type in opposite directions, which subjectively the same force, to compare the bond strength.

The dynamometer empirical tests were performed under the guidelines and support of Ana Margarida Cardoso, a Senior Technician at LJF, where 25 strands of fibers with 300 mm in length were cut, then weighed, calculating the average weight (g) of each fiber. The linear density in Tex = (G/L) x 1000 was calculated for each fiber. In the equation, G is the mass of the thread (g) and L is the length of the thread (m). Using the MICROSELECT® digital micrometer, the thickness of the fibers was measured in five points, after which the fibers were rotated at 90° and measured again in five points. The average weight of the thickness of the fibers were calculated in millimeters (mm).

The tensile tests were then performed with the Hounsfield® dynamometer, model H5K-T, using the 100 N load cell, with the following test configuration:

1. Load range: 10 N
2. Extension range: 0.1 mm
3. Speed: 20 mm/min
4. Measuring length: 300 mm
5. Elongation 1%: 1
6. Elongation 2%: 2
7. Approach speed: 20 mm/min
8. Preload: 0 N

Table F.1: Physical properties of the fibers.

Mock-up ID	Average weight (g)	Average linear density (Tex)	Average thickness (mm)
20% SG + 10% WS (1:1 v/v)	0.110	182.44	1.7
25% SG + Arbocel® BWW 40 (20: 1 v/w)	0.100	165.67	1.7
Evacon-R®	0.114	189.84	1.7
Araldite® 5-minute Two-Part Epoxy Resin by Ceys	0.101	166.12	1.7
VESTAMELT® 730-P1	0.108	177.69	1.7

Table F.2: Mechanical properties of the fibers in the dynamometer tests

Adhesive	Max. force (N)	Tenacity (N/Tex)
20% SG + 10% WS (1:1 v/v)	2.6194	0.0144
25% SG + Arbocel® BWW 40 (20: 1 v/w)	9.9203	0.0599
Evacon-R®	4.9425	0.0263
Araldite® 5-minute Two-Part Epoxy Resin	7.2823	0.0440
VESTAMELT® 730-P1	5.7921	0.0327

F.3 SAMPLING AREAS FOR CROSS-SECTION

Figure F.1: Sampling areas for cross-sections.

Table F.3: Code for identification of cross-sections

Sample	Color	Area
PNM_2_2024_S1	Blue	Sky
PNM_2_2024_S2	Red	Altar
PNM_2_2024_S3	Dark blue	Right strip of the painting

F.4 CROSS-SECTION SAMPLES – NORMAL AND ULTRAVIOLET LIGHT

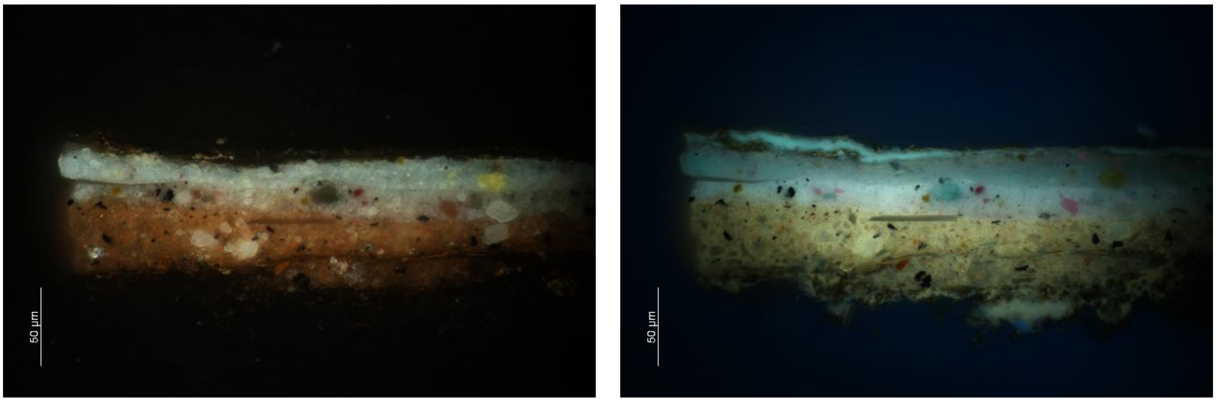


Figure F.2: Cross-section PNM_2_2024_S1, photographed with OM at 500x magnification under incident visible (left) and UV (right) radiation.

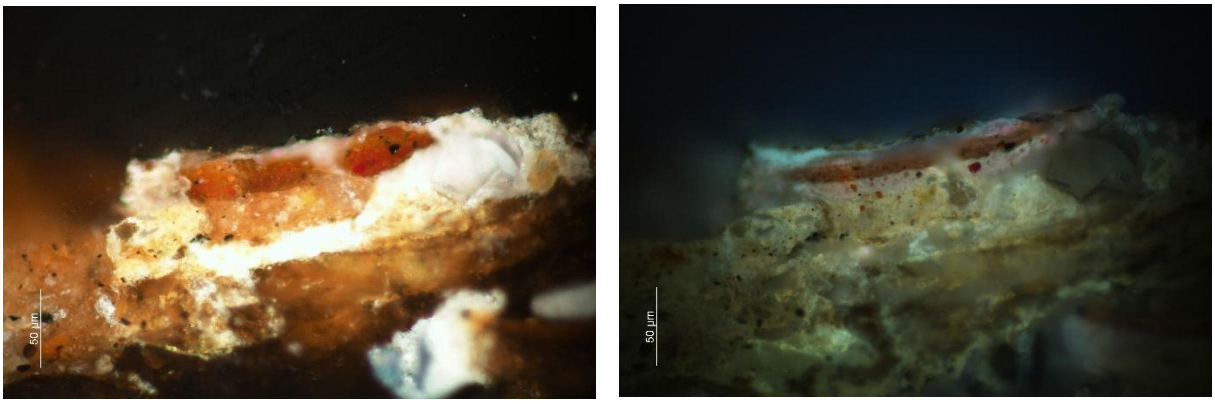


Figure F.3: Cross-section PNM_2_2024_S2 detail photographed with OM at 500x magnification under incident visible (left) and UV (right) radiation.

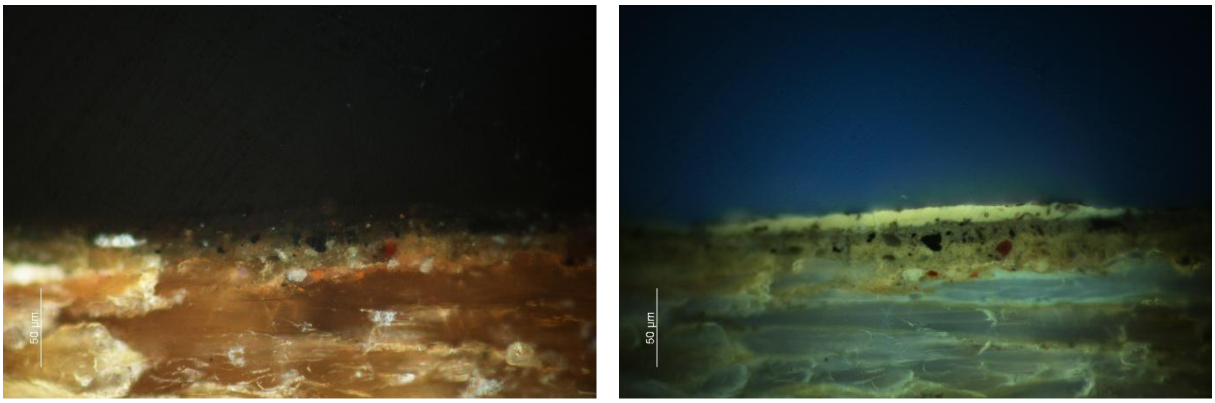


Figure F.4: Cross-section PNM_2_2024_S3 detail photographed with OM at 500x magnification under incident visible (left) and UV (right) radiation.

G | EVALUATING EMPIRICAL TESTS

G.1 CONSOLIDATION AND FACING

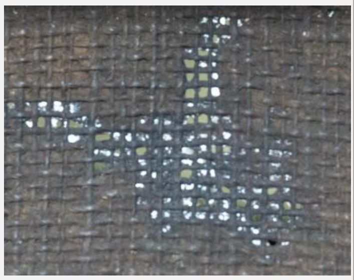
The chosen adhesives for testing were fish glue and Klucel® G in water in the following concentrations: 1.5, 3, and 5% (w/v). These were applied with a brush on top of the thin Japanese paper to assess which percentage would yield the best consolidation result. The test results and observations are presented in Table G.1, evaluated on a scale from 1-5, where 1 denotes the lowest performance and 5 the highest, depending on the case. Different properties of the adhesives were observed while applying, such as viscosity (1 means low and 5 high viscosity), ease of application, permeation capabilities and drying time. After the area had completely dried, a slight peel test was performed on the corner of a Japanese paper test area to feel the resistance and strength of the adhesive bond. The facing was then softened and removed with cotton swabs and warm water. During the cleaning process, the amount of time and force to remove the residues and surface clean was compared to an "unfaced" area (5 means it took less time and force to clean the area). After the full removal of the Japanese paper and surface residues, the observation of whether the area still exhibited flaking or abrasion even after applying a consolidating facing was assessed.

Table G.1: Observations while developing the tests for the consolidation facing.

Fish glue	Observations
1.5%	Viscosity: 1 Ease of Application: 5 Permeation of adhesive: 5 Drying time: 5 Adherence to surface: 4 Ease of removability: 5 Paint particles on cotton swab: 2 * No change in the Japanese paper appearance after drying was observed.
3%	Viscosity: 3 Ease of Application: 5 Permeation of adhesive: 5 Drying time: 4 Adherence to surface: 5 Ease of removability: 4 Paint particles on cotton swab: 5 * After drying, the area of the Japanese paper appeared as if it had a layer of glossy adhesive film.

	* Using the same action time as it took to clean the area with 1.5%, while the area was drying, it appeared that there was more dirt (darker colors) in the lower parts of the canvas weave. The dirt could be further removed by applying more pressure.
5%	Viscosity: 4 Ease of Application: 4 Permeation of adhesive: 4 Drying time: 3 Adherence to surface: 5 Ease of removability: 3 Paint particles on cotton swab: 5 * After cleaning, the area was glossy, however it appeared darker when viewed from an angle. * Where the areas was cleaned, small shiny particles were seen on the paint layers, previously not present / covered by surface dirt.
Klucel® G	
1.5%	Viscosity: 1 Ease of Application: 5 Permeation of adhesive: 5 Drying time: 5 Adherence to surface: 3 Ease of removability: 5 Paint particles on cotton swab: 2 * No residues while cleaning. It felt as if no adhesive was present on the surface, and the cleaning was done on an “unfaced” area. * Paint particles seen on the cotton swab and some abrasion caused on the paint layers.
3%	Viscosity: 4 Ease of Application: 5 Permeation of adhesive: 4 Drying time: 4 Adherence to surface: 4 Ease of removability: 4 Paint particles on cotton swab: 3 * The viscosity felt comparatively to 5% Fish glue. * Matte adhesive film on the Japanese paper after drying. * Less paint particles seen on the cotton swab than 1.5%, but still present.
5%	Viscosity: 5 Ease of Application: 5 Permeation of adhesive: 3 Drying time: 3 Adherence to surface: 5 Ease of removability: 3 Paint particles on cotton swab: 3 * It took the most time to dry, had a layer of gel on the surface. * Most pronounced adhesive film on Japanese paper after drying. * Appeared that more abrasion was caused.

Table G.2: Facing removal tests, with DinoLite photography comparing the before and after of the area.

Fish glue 3% in water (w/v)		
Area	**Before**	**After**
Blue sky	 	 
Upper area	 	 
Notes	1. Paint layer stable after consolidation, especially in areas where it was crumbly. 2. The cracks along the canvas weave, in some slight areas, appeared to have closed / flattened. 3. After removing the facing, cracks were more visible, due to the surface dirt covering in them. 4. Some surface stains / dirt was removed; the facing did not consolidate the dirt. 5. The adhesive film could be seen between the open weave of the canvas, acting as a size layer. 6. The adhesive did not stain or penetrate through the back of the painting. 7. The paint flaking has been flattened, some new cracks formed, and the least amount of paint loss. 8. The cracks became more prominent due to the cleaning of the surface. There were some areas where cracks had a slight glossiness to them (possibly because the adhesive was present). Some slight abrasion caused. 	

Klucel® G 3% in water (w/v)		
Area	**Before**	**After**
Blue sky	 	 
Upper area	 	 
Notes	1. More paint loss caused than 3% Fish glue. 2. No adhesive residue on the fibers. 3. The canvas appears to have darkened on the back 4. The cracks become more prominent due to the cleaning of the surface. 5. Some surface dirt / deposits were successfully removed.	

G.2 STRIP-LINING

The shear force and peel strength empirical tests were prepared with specimens of linen and polyester canvases (Table G.3). They were adhered with different adhesives to a primed canvas (labeled A) with a single overlap joint. All canvases were cut to a dimension of 100 x 30 mm (length by width). The same was done for the linen (labeled B1) and synthetic (labeled B2) canvases that were used as strip-lining testing material. The linen canvases were washed in boiling water prior to the tests. For the shear tests, the overlapping was 30 mm between canvas A (base) and canvases B1 and B2, which had a 5 mm fringing of the threads that overlapped the base canvas. For the peel tests, the overlapping was 60 mm in length (leaving 20 mm on the top and bottom of the specimen without any adhesive, thus improving workability). The adhesives were applied with a brush, or heat activated (such as BEVA® 371 Film) only on specimens B1 and B2. The samples were then placed under weights for the solvent to evaporate. The result were graded from 1-to-5, where 1 denotes the lowest performance and 5 the highest, depending on the case. The long-term stability results were selected according to the literature mentioned in Table 3.1.

Table G.3: Results and observations from the Shear and Peel empirical tests conducted for the strip-lining intervention.

	BEVA® 371 O.F in white spirit 1:1 (v/v) 3 layers			
	Linen		**Synthetic fabric**	
	Shear	**Peel**	**Shear**	**Peel**
Workability (ease of application, ease of removability)	4			
Long-term stability	4			
Visual appearance (permeation in the strip-lining canvas, residues left behind, glossiness change)	3		3 * Adhesive bled outside application area.	
All specimens had white, waxy residue that permeated to the other side of the strip-lining canvas.				
Physical effect on specimen (stiffness change, 1 means the highest stiffness, with 5 being the lowest stiffness)	2	2	3	3
Average of visual and physical effects on specimens: 3				
Empirical tests results (Shear: Higher number means the bond was stronger when compared to other adhesives. Peel: Higher number means it was easier to remove)	**2** * The pulling force ripped the primed canvas.	**4**	**2** * Bond failed	**4**
No adhesive residue on the original canvas after tests. Average: Shear = 2, Peel = 4				
	BEVA® 371 FILM			
	Linen		**Synthetic**	
	Shear	**Peel**	**Shear**	**Peel**
Workability	5			

Long-term stability	4			
Visual appearance	5		5	
No permeation of the adhesive on all specimens				
Adhesive effect on canvas	5	5	5 * The primed canvas' weave can be seen through the sample.	5
All specimens were the most flexible. Average of visual and physical effects on specimens: 5				
Empirical tests results	**3** Bond failed * White pulling, the strip-lining canvas was more flexible	5	**3** Bond failed	**5**
The adhesives on all specimens remained on the strip-lining canvas. Average: Shear = 3, Peel = 5				
	PLEXTOL® B500 in toluene (10:1) Heat activated			
	Linen		**Synthetic fabric**	
	Shear	**Peel**	**Shear**	**Peel**
Workability	3			
Long-term stability	3			
Visual appearance	4		3 * Some scattered glossy residues	
Adhesive effect on canvas	3	3	2	* The strip-lining canvas detached from the primed canvas (A).
Empirical tests results	**2** * Bond failed	*** Test failed**, removed the strip-lining without any force. * Adhesive remained on the strip-lining canvas.	1 * Bond failed instantly.	5 * Peeling failure, no pressure required.
Overall failure test				
PLEXTOL® B500 in toluene 10:1 (v/v) solvent evaporation under weights				
	Linen		**Synthetic fabric**	
	Shear	**Peel**	**Shear**	**Peel**
Workability	3			
Long-term stability	3			
Visual appearance	4		3	

			* Adhesive permeated with some glossy residues	
Some slight distortion and warping / line created on the canvas bond, due to the weight pressure				
Adhesive effect on canvas	3	3	2	2
Average of visual and physical effects on specimens: 4				
Empirical tests results	**4** * Bond did not fail. It detached slightly on the edges.	**3**	**4** * Bond did not fail, one corner is slightly detached.	**4** * Left some unform residues on the primed canvas.
Average: Shear = 4, Peel = 4				
LASCAUX® 498HV solvent evaporation under weights				
	Linen		**Synthetic fabric**	
	Shear	**Peel**	**Shear**	**Peel**
Workability	4			
Long-term stability	4			
Visual appearance	4		4 * Some slight permeation (overall darkening with some spots).	
Adhesive effect on canvas	3	4	3	3
Average of visual and physical effects on specimens: 4				
Empirical tests results	**4** * Bond did not fail, a slight detachment of the canvas corner.	**2** * Some patches of adhesive remained on the primed canvas	**4** * Bond did not fail, slightly detached on the edges.	**2** * Left some relatively big patches on the primed canvas.
Average: Shear = 4; Peel = 2				
PRIMAL® E-330S in toluene 2:3 (v/v) solvent evaporation under weights				
	Linen		**Synthetic fabric**	
	Shear	**Peel**	**Shear**	**Peel**
Workability	4			
Long-term stability	3			
Visual properties	4		4	
A brief change in appearance, faintly glossy in all specimens				
Adhesive effect on canvas	3	3	3	3
Average of visual and physical effects on specimens: 3				
Empirical tests results	**5** * Strongest bond, no detachments.	**2** * Some residue on the primed canvas	4 * Bond did not fail, no detachments.	**3** * The adhesive remained on the strip-lining canvas, with minimal residue on the primed one.
Average: Shear = 5; Peel = 3				

G.3 TEAR-MENDING

The empirical tests for tear-mending involved the creation of a mock-up, on which linen threads were mounted on a strainer, with more or less the same force, cut in the middle, and adhered with the chosen adhesives. They were bonded with an overlap joint with intermingled fibers. Each adhesive had six samples. The role of this empirical test is to determine the physical and mechanical behavior of the bonds, when subjected to uniaxial tension. For determining the strength of the adhesive bonds, subjective tests involved pulling the thread from the ends with relatively equal forces, while the dynamometer used a machine to perform more consistent uniaxial pulling forces (see Chapter F.2 for Analytical parameters). For the subjective tests one thread was compared, while the dynamometer tested five threads per adhesive. The average bond strength between the five threads for each adhesive in the dynamometer tests were calculated then compared to the other adhesives. Higher force values, measured in Newtons (N), indicate stronger pull forces over the corresponding elongation, measured in millimeters (mm) (Figure G.1). The results were graded from 1-to-5, 1 being the weakest bond observed, while 5 is the strongest (Table G.4).

The adhesives tested were:

1. 20% SG + 10% WS (1:1 v/v)
2. 25% SG + Arbocel® BWW 40 (20:1 v/w)
3. pH neutral Ahesive Evacon-R®
4. Araldite® 5-minutes Two-Part Epoxy Resin by Ceys®
5. VESTAMELT® 730-P1 by Evonik®

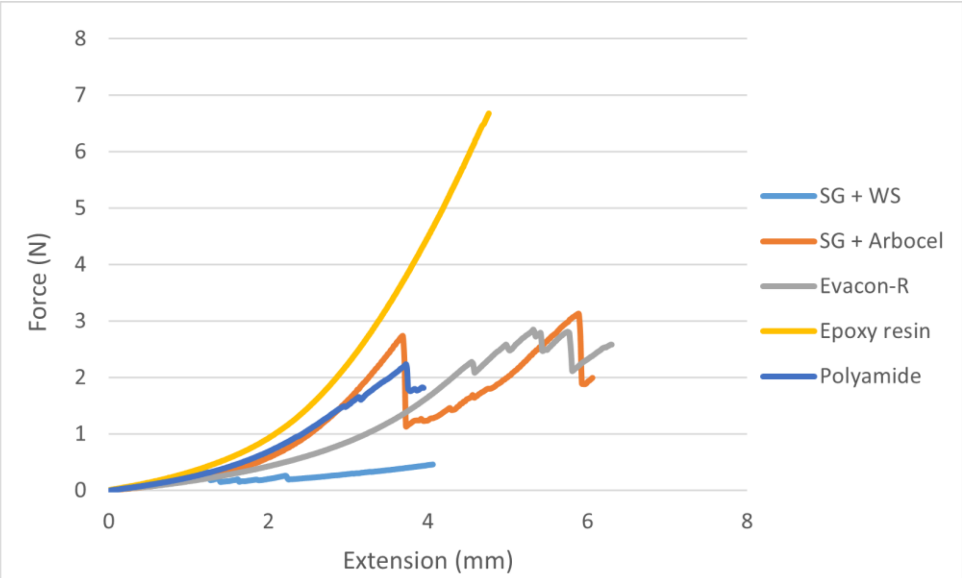


Figure G.1: Results from the uniaxial dynamometer tests.

Table G.4: Results and observations for both workability of the subjective and uniaxial dynamometer empirical tests for tear-mending.

Adhesive	Workability	Subjective bond strength	Dynamometer Bond strength	Bond behavior on uniaxial dynamometer tests
20% SG+ 10% WS (1:1 v/v)	Very good workability = 5 The threads were slightly wet to grab the ends to perform the overlap bond with intermingled fibers. The two parts of the adhesive were kept in a syringe and put on a glass slide suspended over warm water (40°C), in a 1:1 proportion. The drying time was good, while keeping the bond under weights.	2	2	All joints broke in the middle of the bond.
25% SG + Arbocel® BWW 40 (20:1 v/w)	Very good workability = 5 The threads were slightly wet to grab the ends to perform the overlap bond with intermingled fibers. Good drying time.	4	4	All broke in the middle of the bond. Sample no. 4 had a long string hanging on for longer. Sample no 5 snapped abruptly.
Evacon-R®	Good workability = 5 Good drying time, took slightly more time than the SG mixtures.	2	4	All joints broke in the middle of the bond.
Araldite® 5-minute Two-Part Epoxy Resin	The long cure variation was hard to work with. It required over 8 hours for the adhesive to harden. The 5-minute variation was easier to work with, but still messy, because of the mixing of the two parts. The quick curing led to the need of minimal mistakes to be performed = 2	4	5	All joints broke in the middle of the bond. Sample no. 6 had a long string hanging even after the bond failed.
VESTAMELT® 730-P1	It is hard to understand how to properly use it. After some attempts it became way easier to apply = 3	5	3	Sample no. 3 and 4 broke before the bond and they had a long thread hanging. Sample no. 5 broke in the middle of the adhesive Sample no. 6 broke at the edge of the adhesive bond Sample no. 7 broke before the bond.

G.4 SURFACE CLEANING AND VARNISH REMOVAL

Tested cleaning solutions

- **Deionized water**

  Water is a versatile polar solvent, which can have its properties adjusted to better fit the need of removal of different kinds of materials (Wolbers et al., 2021). As stated by Burg and Seymour (2022a), deionized water has had the mineral salts content removed and should have a pH value close to neutral. As for the conductivity, deionized water is a hypotonic solution, which implies that it has a fewer concentration of solutes and more of a solvent than the surface to be cleaned.

- **Triethanolamine (TEA) and Xanthan gum gel**
  The TEA gel is only utilized with deionized water to limit the moisture introduced to the painting. TEA is an organic buffer used to balance and maintain a solution within the safe pH values in an oil painting (6.0 – 8.5) (Wolbers et al., 2021; Burg & Seymour, 2022a). Xanthan gums are water-based polymer polysaccharides that are used to form highly viscous physical gels even at low concentrations (0.5 – 2% w/v) (Wolbers et al. 2021). They are non-toxic, biodegradable and stable at any pH (Burg and Seymour 2022b).
- **Chelating agents**
  Triammonium Citrate (TAC)
  Chelators, such as TAC, are water soluble molecules that can attract and bind metal ions using ligands to form a complex (Wolbers et al., 2021; Burg & Seymour, 2022a). A 1-2% TAC aqueous solution (w/v) was shown to be effective in removing dirt deposits in the study of Phenix and Burnstock (1992), while also being able to remove inorganic, particulate materials and organic components (Morrison et al., 2007). Burg and Seymour (2022a) stated that even low concentrations TAC can be effective, with concentrations greater than 2% not being recommended. Additionally, they state that the area should be rinsed afterwards so that the chelator does not continue to react chemically with the paint.
  Synthetic saliva
  Human saliva has been used in the past to remove accumulated dirt on paint surfaces (Wolbers et al., 2021). Because of the dimensions of the painting, the synthetic variation has been picked because of the added compounds, such as enzymes and ions, with the addition of TAC. Additionally, because enzymes are non-volatile, it is recommended to rinse the area afterwards (Burg & Seymour, 2022a).
- **Surfactant agents**
  Resin soaps
  As noted by Wolbers et al. (2021), **Deoxycholic acid** and **Abietic acid** have been utilized as surfactants because they can often solubilize specific substrate materials. Deoxycholic acid is a weak bile acid that forms a soap when combined with a basic compound tends to bind specifically to free fatty acids, while Abietic acid is a natural resin acid that can solubilize other di- and tri- terpenoid materials (Wolbers et al., 2021). Resin soaps can be also useful for varnish removal on the principle of "like dissolves like"

(Burg & Seymour, 2022a), as natural varnishes become more sensitive to water and more acidic when aged (Wolbers et al., 2021).

Carbopol® EZ-2 and Ethomeen® C25 gel

It was finally decided to test the properties of the surfactants in a gel, therefore limiting the moisture introduced to the painting. This solution is a physical gel made by mixing the polyacrylic acid resin gelling agent Carbopol® EZ-2, which has the property of forming a clear, viscous gel (Wolbers et al., 2021) with a polyethoxylated amine with surfactant properties, Ethomeen®. Ethomeen® C25 is a polar amine, and is used for polar solvent systems, such as ethanol. Carbopol can also work as a suspension aid (Wolbers et al., 2021) and partly as a chelating agent in the presence of water (Burg & Seymour, 2022b). Burg and Seymour (2022b) states that water should not be used to rinse the gels, as it may break the intra-molecular bonds between the polyacrylic resin and the surfactant, possibly allowing free ionized Ethomeen® particles to bond to charged oil molecules. To rinse the gel made with Ethomeen® C25, they recommend a more polar solution, but still safe for the painting, such as isopropanol, ethanol or acetone.

Results summary

The solutions were tested in various areas of the painting. The cleaning action of all solvents was made mechanically with a cotton swab and with different methods of application and action time, as the solutions behaved differently. The differences introduced varying degrees of moisture to the painting, which needed to be considered. The general observation after performing the tests showed that the 5% TEA gel in water proved to be the least efficient method among the solutions tested here, as it only limited the moisture introduced to the painting, without providing a noticeable improvement (such as a slight softening of the surface dirt) over deionized water. The 1.5% TAC, Abietic acid and Deoxycholic acid solutions in water showed good results, where they successfully removed the surface dirt and aged varnish, with 1.5% Abietic acid in water being slightly more efficient. However, all of these three solutions required the area to be rinsed after cleaning, thus introducing more moisture, where the aim now is to minimize it. Carbopol® EZ-2 and Ethomeen® C25 gel showed the most promising results, as seen in Figure G.2. The gel provided the most cleaning efficacy, while limiting moisture, and causing the least abrasion to the surface. For those reasons, it was chosen as the main method of performing the cleaning intervention.

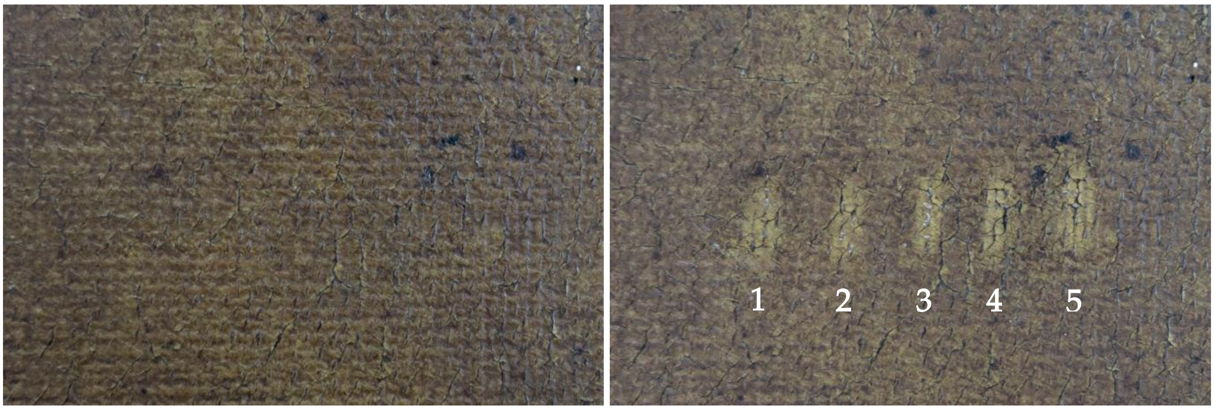


Figure G.2: Results from the cleaning tests, before (left) and after (right) of the yellow beam of light area. Legend: 1) TAC 1.5% in water (w/v); 2) 1.5% Abietic acid in water (w/v); 3) 1.5% Deoxycholic acid in water (w/v); 4) 2 g Carbopol® EZ-2 (w/v) in 10 mL deionized water and 20 mL Ethomeen® C25 in 100mL Ethanol (v/v) gel; 5) 5 mL TEA (v/v) and 2g Xanthan Gum (w/v) in 100 mL deionized water.

H MATERIALS

H.1 SUPPLIER INFORMATION

Table H.1: Contact information for suppliers of materials used during the intervention of the painting *Beata Ludovica Albertona.*

Material	Supplier	Date of purchase
100% POLYESTER SYNTHETIC CANVAS Ref: R1400035	CTS https://ctsconservation.com/en/	July 2024
Arbocel® BWW 40	LJF Stock	-
BEVA® 371 Film	LJF Stock	-
BEVA® 371 O.F	Productos De Conservación S.A. - info@productosdeconservacion.com	-
Calcium Carbonate Ref: R0100005	CTS https://ctsconservation.com/en/	2024
Carbopol® EZ 2	Productos De Conservación S.A. - info@productosdeconservacion.com	-
Ethanol 96%	AGA - https://aga.pt/	-
Ethomeen C/12 Reg: 780804	LJF Stock	-
Fish glue Ref Kremer #63080	Kremer Pigmente GmbH & Co.KG – www.kremer-pigmente.com	2024
Gelatin, powdered Ref Kremer #63045	AgarAgar Quinta y Galan S.L. - info@agaragar.net	2025
Klucel® G	AgarAgar Quinta y Galan S.L. - info@agaragar.net	2024
Nylon Gossamer	https://www.picreator.co.uk/	2024
PVACOL R® Acid-Free PVA **Adhesive**	Restaurar & Conservar http://www.restaurarconservar.com/	2025
Sturgeon glue CAS: 9000-70-8	Kremer Pigmente GmbH & Co.KG – www.kremer-pigmente.com	2024
SYNTHETIC SALIVA (SSC) Ref: R0300044	CTS https://ctsconservation.com/en/	2024
Triethanolamine	Riedel-de Haën AG, D-30926 Seelze, Germany	-
Xantham Gum Ref Kremer #63450	Kremer Pigmente GmbH & Co.KG – www.kremer-pigmente.com	2024
Triammonium citrate Q1K/58-100	AgarAgar Quinta y Galan S.L. - info@agaragar.net	June 2024
Wheat Starch	Roquette® https://www.roquette.com/	11.03.2024

2025 ȘTEFAN CĂTĂLIN ANTONESCU TREATMENT OF AN 18TH-CENTURY OIL PAINTING BEATA LUDOVICA

NOVA SCHOOL OF SCIENCE & TECHNOLOGY