Application of optical coherence tomography (OCT) for real time monitoring of consolidation of the paint layer in *Hinterglasmalerei* objects

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ABSTRACT

Optical coherence tomography (OCT) is a fast non-contact and non-invasive technique for examination of objects consisting of transparent or semitransparent layers. Since it is a useful tool for inspection of *Hinterglasmalerei* paintings, the aim of the experiment was to explore its feasibility for monitoring of the consolidation process, which plays the most important role in the conservation treatment of such artefacts.

Keywords: optical coherence tomography, SOCT, Hinterglasmalerei, reverse painting on glass, monitoring, consolidation, conservation, paintings

1. INTRODUCTION

The aim of this contribution is to explore the possibilities of using optical coherence tomography (OCT) as a tool for monitoring of the specific conservation process, which is the consolidation of a detached paint layer in paintings on glass support. OCT is a depth-resolved, non-contact and non-invasive imaging technique providing cross-sectional images of internal structure of objects whose layers absorb/scatter near infrared light moderately.[1] Because of its micrometer axial resolution it became a routine medical diagnostic tool. Since 2003 it has been also used for examination of artworks.[2]

Reverse painting on glass (*Hinterglasmalerei*) technique involves applying colours directly onto a sheet of glass, without firing. Since the painting is intended to be eventually viewed through the glass support, the whole artistic process must be reversed in such a way that the layers crucial for the final aesthetic appearance (the contour, glazes and highlights) are lying directly on the glass, followed by more opaque background paints. The technique has had many variations concerning painting materials and methods, depending on the time and place of objects' origin.

Although some researchers claim that reverse painting on glass was used as early as in the antiquity, the oldest known artefacts are decorative pieces dating from Renaissance Italy. The technique later spread throughout Europe and finally was adapted by folk artists in South Germany and Central Europe and was especially popular from late eighteenth until middle twentieth century (Fig. 1). More detailed insight into the technicalities and history of the *Hinterglasmalerei* technique is given in elsewhere.[3, 4]

The typical conservation problems, unfortunately inherent to the technique, are caused by poor adhesion of the colours to the glass. Different types of detachments of the paint layer vary from slight delamination, through flaking of the deformed paint, to loosing the adhesion at almost whole surface of the painting. The fragility of such objects demands handling with the utmost care. This excludes transportation and, sometimes, even placing the painting in a vertical position. In such cases, performing the proper consolidation of the paint layer becomes the most important and difficult task for the conservator-restorer.

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Figure 1. An example of *Hinterglasmalerei* technique: "Saint Wendelin" – nineteenth-century reverse painting on glass from the collection of the Ethnographic Museum in Toruń, view in scattered light

It has been already proved that optical coherence tomography is a useful technique for examination of reverse painting on glass artefacts.[4,5] It provides access to the most important layers of a painting, enables the assessment of its deterioration (by direct recording of various stages of detachment formation), and helps to evaluate the results of past conservation treatments (Fig. 2). The latter includes tracing of the presence of consolidation binders and evaluation of their recent adhesion to the glass support, as well as filling in the blisters of paint. The latter is not only decisive for safety of the painting but also for its aesthetic appearance, since the detachments are visible as milky shades under the glass. The OCT instrument is also fairly easily transportable and may be easily adapted for operation with an artwork mounted in any orientation. It is especially convenient for work with reverse painting on glass objects. Given their fragility, they should be examined in a horizontal position with the paint layer facing upwards.

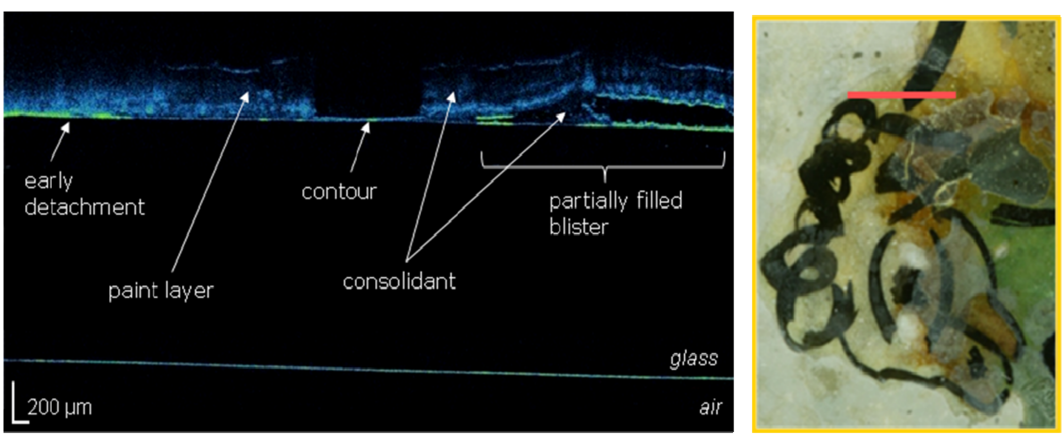

Figure 2. The OCT examination of the painting from Fig. 1, showing various stages of deterioration and former conservation intervention

Since the OCT technique has been found useful for imaging of detachments and consolidation adhesives,[4,5] the authors decided to continue the experiment and seek way to monitor the consolidation process in real time.

2. METHODOLOGY

Six model paintings were prepared, according to old recipes,[6] using different variations of *Hinterglasmalerei* technique. Detachments of the paint layer were artificially induced by placing the samples in harmful climate conditions or by applying sublimating agent (cyclododecane) to the glass support prior to painting – Fig.3.

Figure 3. Model painting with artificially induced detachments

Three commonly used consolidation adhesives[7-9] of different properties were tested. From the vast range of synthetic resins two were chosen: Paraloid B-72, 10% solution in toluene, and Regalrez 1094, 10% solution in toluene. Paraloid is a photostable acrylic resin of extremely high molecular weight (weight average MW: 65 128,[10] whereas Regalrez 1094 is a hydrocarbon one and has very low molecular weight (weight average MW: 900.[11] When prepared in the same percentage solution in the same solvent, they form solutions of different viscosity (higher for the acrylic) and thus, penetration (faster for the hydrocarbon resin). The solutions were applied onto the back surface of the paint layer using a small brush with none or very little pressure. The third consolidation adhesive chosen for the experiment contained no evaporating solvent. It consisted of 1 pbw Regalrez 1094 and 4 pbw Cosmolloid 80H (synthetic wax). The composition was pre-melted, applied warm to the back surface of paint and finally melted and pressed into the detachments with an electric heated spatula.

The region of monitoring in all cases was 7 mm. The model paintings were mounted horizontally, with the paint layer facing upwards. In case of severely detached paint layer it is the only safe positioning, which also enables the proper performing of the consolidation treatment.

In order to evaluate the consolidation process the following phenomena were taken into account: the way and speed of penetration of the adhesive as well as the extent of filling in the blisters. The structure of the sample was also inspected after prolonged time to check the permanency of the consolidation effect, including the position of the deformed paint flakes.

3. EXPERIMENTAL

The OCT instrument used for this report has been constructed in the Nicolaus Copernicus University and dedicated for the examination of objects of art. The construction details may be found in our previous publications.[4, 12] In brief, the spectral modality of Fourier-domain OCT technique has been adopted. The instrument comprises a broadband ($\Delta\lambda = 107$ nm, central wavelength 845 nm) superluminescent source (LS). The axial resolution is equal to 4 µm (in air) and the lateral one is about 30 µm. The in-depth limit of imaging of about 2 mm makes OCT tomography especially suitable for imaging layered structures.

For the experiment described in this report, the instrument was used exclusively in the B-scan mode, providing cross-sectional views comprising 2000 vertical lines (A-scans). Since the standard acquisition time for obtaining one A-scan is 50 µs (40 µs exposition + 10 µs camera dead time), the whole cross-section (B-scan) was registered every 0.1 s. However, if needed, additional delay was added after the acquisition of every A-scan to slow down the registration from 10 frames/s to 1 frame/s.

Due to the specific demands of the consolidation process, the OCT head had to be placed underneath a perforation in the sample supporting table (Fig. 4). This way the probing beam was approaching the paint layer from below and through the glass. Some blur of the image caused by the dispersion in the glass was compensated numerically.

An infrared camera was additionally used for obtaining a preview of the probing beam from the outer side of the paint layer, which enabled precise application of the consolidation adhesive in a recorded spot.

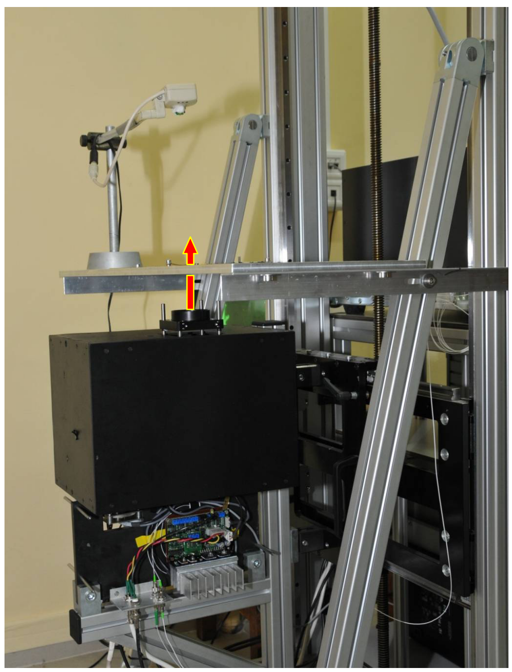

Figure 4. The configuration of the OCT instrument used in this study. The sample has been placed on the table, and probing beam was approaching it from the bottom (arrow)

4. RESULTS

The aim of the experiment was to evaluate the suitability of optical coherence tomography for monitoring of the consolidation treatment. This includes observation and recording of the process in real-time, as well as an evaluation of the results after prolonged time. Therefore, the results presented below should be treated as exemplary and not as a systematic research on conservation materials and methods.

4.1 Regalrez 1094 in toluene

The experiment was started with the consolidation trial using fast-penetrating composition of 10% carbohydron resin Regalrez 1094 in toluene. The OCT monitoring revealed full penetration of the adhesive between the flakes of the paint layer and the glass support within one second – Fig. 5b. However, after another one second two of twelve monitored flakes returned to their original state (the adhesive did not stay underneath) – Fig. 5c. The monitoring of the consolidation process within the same sample performed over prolonged time (up to 150 seconds after applying the adhesive) showed that after approximately 50 seconds 100% of the space under the paint detachments in the observed area became eventually filled with air again. This was due to the evaporation of the solvent combined with no visible repositioning of the deformed flakes.

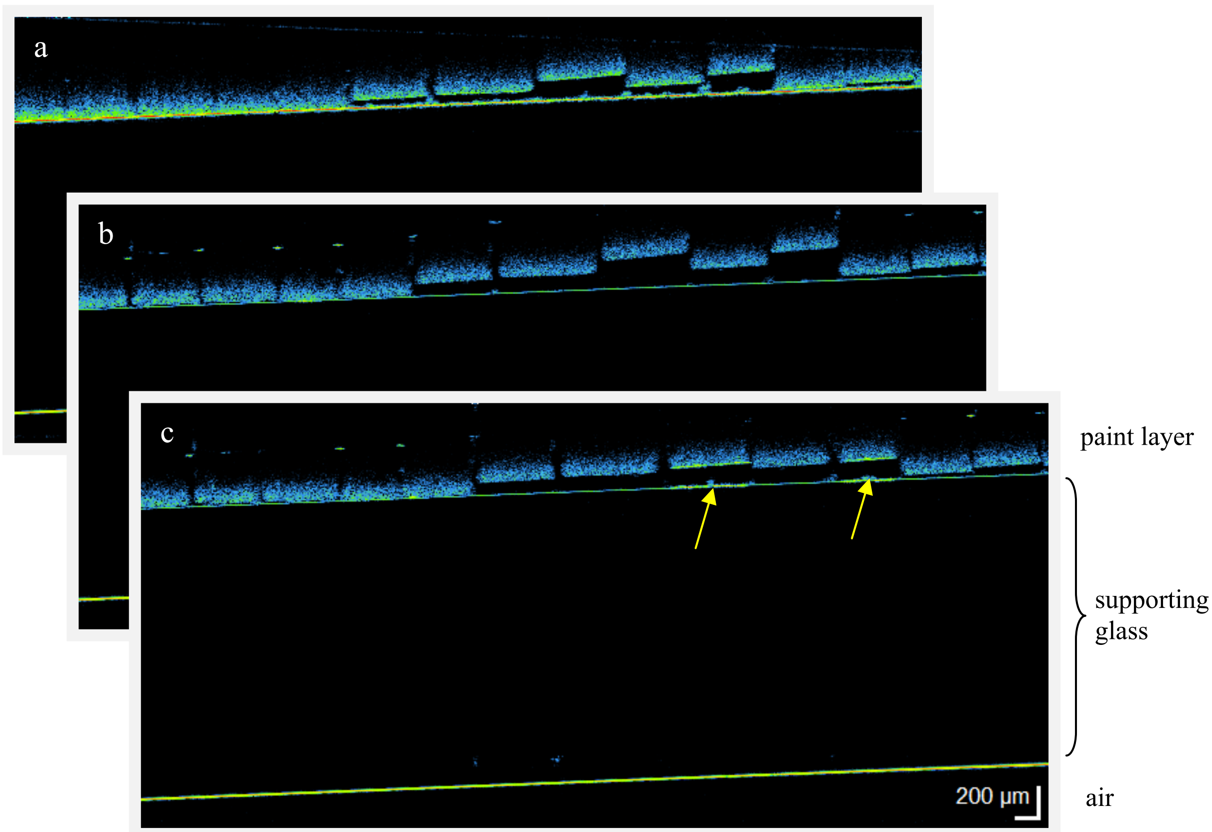

Figure 5. Frames obtained from the monitoring of the consolidation process performed with Regalrez 1094. First frame (a) shows the sample before the consolidation process: space under all the flakes is filled with air and the upper surface of glass reflects probing light strongly, due to high difference between refraction indices of glass and air; (b) all the space is filled with consolidant, its upper layer is visible as dots above slots between flakes, glass surface reflects light moderately; (c) spaces under two flakes are filled with air again (arrows)

4.2 Paraloid B-72 in toluene

Another flaked area of the same sample was treated with the 10% solution of acrylic resin Paraloid B-72 in toluene. Due to the higher viscosity and slower penetration of the composition (by comparison with Regalrez) the adhesive tended to stay longer in one spot: 5 seconds after application of the consolidant 100% of the detachments were filled in. Unfortunately, the general mechanism of the consolidation process turned out to be the same as before. When observed after 3 minutes all of the flakes were again not adhering to the glass – Fig. 6.

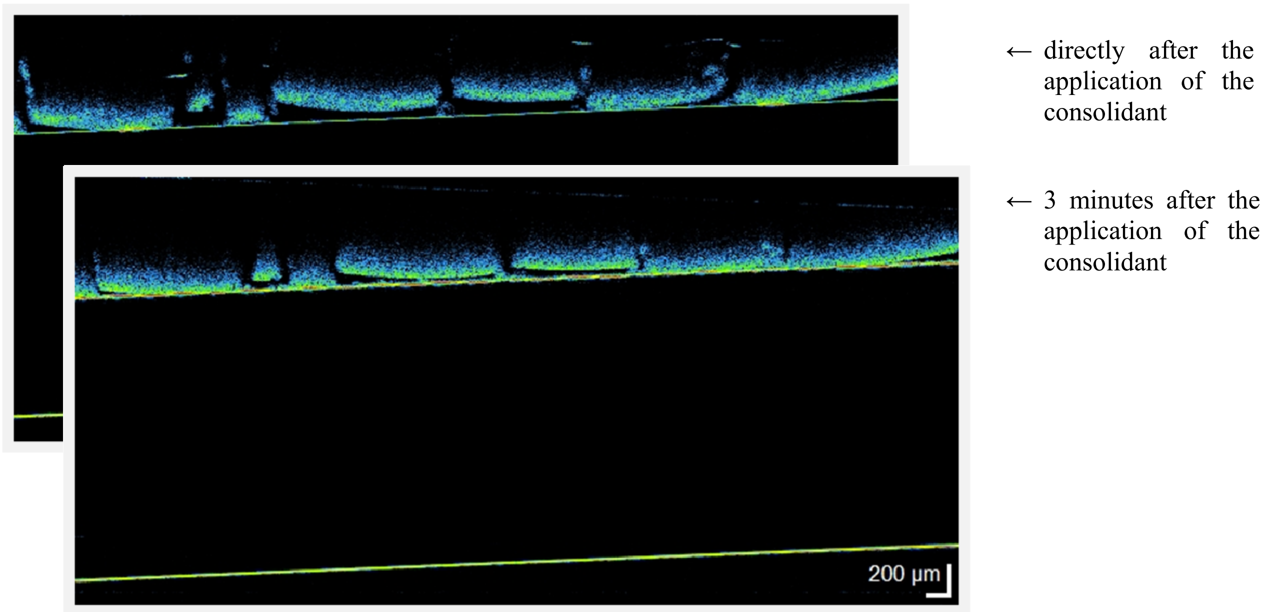

Figure 6. Monitoring of the consolidation treatment by means of Paraloid B-72 shows total reverse of the process within 3 minutes after the application of the adhesive

4.3 Regalrez with Cosmolloid, melted

The last set of trials was performed by means of different consolidation procedure. A composition of 1 pbw Regalrez 1094 and 4 pbw Cosmolloid 80H (synthetic wax) was melted and introduced into the detachments. The OCT monitoring revealed that the actual consolidation started the moment the electric spatula was able to liquidise the adhesive and press out the air from under the detachments. This took 18 seconds and resulted in long-lasting satisfactory effect of the consolidation – which was checked after 180 seconds when the consolidation adhesive cooled down completely.

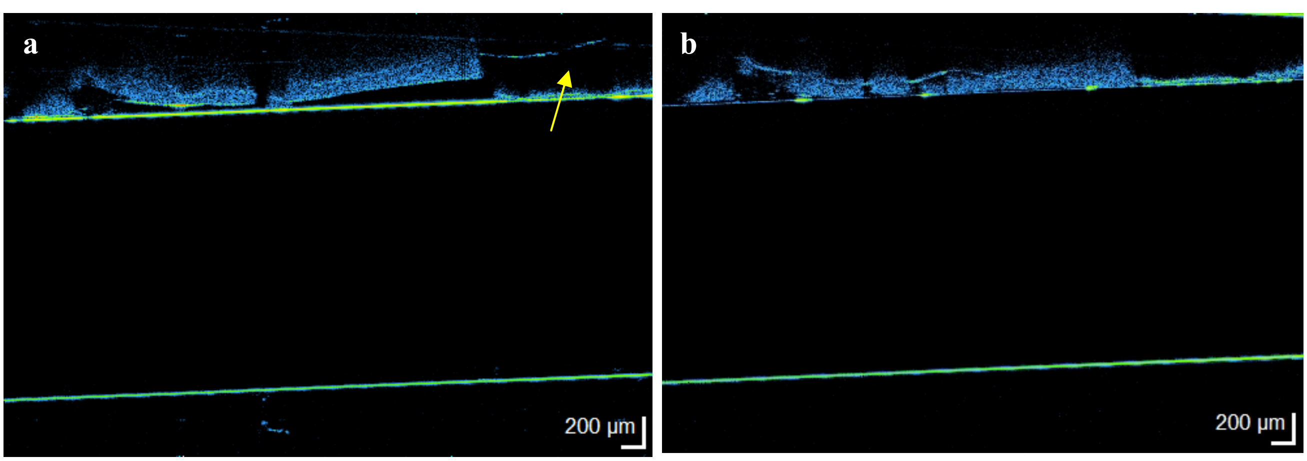

Figure 8. Monitoring of the consolidation treatment by means of composition of Regalrez 1094 and Cosmolloid 80H. (a): image collected after the application of the adhesive, before the final melting with the electric heated spatula. Wax-resin binder lies on the flakes and a loss of paint layer (arrow) but is not adhering to the glass; (b): in result of applying heat and pressure during the consolidation all flakes are repositioned, flattened and permanently adhered to the glass surface

5. CONCLUSIONS

In result of the performed experiments the applicability of optical coherence tomography for monitoring of the consolidation treatment was proven. Through-glass examination enables direct observation of the detachments of paint layer. Observation and recording of the process of filling in the blisters in real-time was possible, as well as the evaluation of the effects of the treatment after prolonged time.

Consequently, the optimal conservation materials and procedures may be employed for the consolidation process. In addition, it should be stated that dealing with objects consisted of unpredictable materials and of such fragility as *Hinterglasmalerei* paintings demands a flexible approach from the conservator-restorer. The conservation materials and methods should be carefully tested and chosen for the specific object of art. The authors therefore recommend using the OCT monitoring at least during the search for effective means for the consolidation of a reverse painting on glass artefact.

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