Egypt. J. Chem. **Vol. 67**, No. 12 pp. 475 - 484 (2024)

Egyptian Journal of Chemistry

http://ejchem.journals.ekb.eg/

BEVA 371 as Restorator Material for a Wooden Coffin from El-Lahoun Excavations

Eman Nabil*

Department of Archaeological Sciences and Excavations Faculty of Archaeology Ain Shams University

Abstracts

The study aims to restore a wooden coffin excavated from El-Lahoun Area, Fayoum, dating back to the late era. The coffin understudy has a unique layered installation, as the textile was used to bind the wooden coffin body to the ground layer. The study focuses on the importance of using the common chemical properties of wood and fabric, and selecting restorator materials suitable for bonding different parts. Several analyses were carried out to study the technique of coffin manufacturing and to draw up a map of its damage manifestations. The visual and microscopic examination showed the deterioration of surface of the coffin. The polarized microscope revealed that the textile used was linen. The optical microscope (OM) revealed that wood of the coffin was sycamore and parts of the dowal was made of tamarix. The color pigments of the coffin were identified Using Scanning Electron Microscope (ESEM-EDX). : Calcium carbonate for white, hematite for red and copper oxide for green. The Fourier transform infrared spectrometer showed that the material used in the colored preparatory layers may be animal glue. The study succeeded in dealing with multi-layered composite bodies in addition to using the BEVA 371 injection technique under separate tissue layers.

Keywords: Pigment , BEVA (371), Coffin, Composite objects, Multi-layered coffin.

1. Introduction

Coffins in ancient Egypt was the most important element in the burial process because they were the shelter or place of the corpus [1]. The wooden coffins industry evolved from the pre-dynastic era to the Greek-Roman era, and the manufacturing technique varied according to the era [2]. Accordingly, the restoration method could vary. The difference in the manufacturing technique was because each era had special religious beliefs and customs [3]. El-Lahoun coffins suggest the development of ancient Egyptian art through the ages, denoting continuous historical episodes. Therefore, the design and structure of the discovered wooden coffins varied and denoted the chronology of historical periods and the social level of the owner, as well as religious beliefs. For instance, some coffins were rectangular, and others were square. Furthermore, different types of wood were used in the coffin industry throughout the ages [4].El-Lahoun coffins are characterized by multiple and diverse preparatory layers, from colored gesso to mud layers [5].The coffin understudy is one of the wooden coffins discovered by the Egyptian mission in the El-Lahoun Area. It is a masterpiece characterized by decorative elements that reflect the development of the art of wooden coffins. The ancient Egyptians used textile as a unique technique to link the wooden coffin body to the ground layer, resulting in greater cohesion between the layers. The ancient Egyptian's aim of using the textile layer in to linkthe preparation layers was achieved. However, having the textile layer with fluctuations of stretching and shrinkage between the textile and the wood caused the uplifting of the textile layer bearing the colored painting grounds and separation from the coffin body. As a result of the strong cohesion between the textile layer and the preparatory layer, it is difficult to choose adhesives between the textile layer and wood. It is more difficult to apply a non-destructive method to the textile bearing the preparatory layers. Therefore, the research aims to choose the appropriate adhesive to bond the textile layer to the wood under certain, such as the ease of application using injection in order not to cause

*Corresponding author e-mail: eman.nabil@arch.asu.edu.eg.; (Eman Nabil).
EJCHEM use only: Received date 29 March 2024; revised date 24 April 2024; accepted date 08 May 2024
DOI: 10.21608/EJCHEM.2024.280239.9531

rupture of the textile and crumpling of the colored preparatory layers, the high binding strength between the textile and wood, the ability to penetrate below the textile layers to repair as much uplift and detached space as possible without hardening, flexibility, and consolidation of the textile and wood. Although there are several consolidation and adhesive materials with a great ability to restore and strengthen wood, such as Paraloid B72, Klucel G, Primal, Legolas 1094, and Klucel E [6], the status of the coffin made it different. The coffin is a unique model of composite monuments. Its major problem was the separation of textile from the wood and Since the surface of textile and wood are regular at the microscopic or the molecular level [7], when assembled, particle granules from each surface are not enough to allow the formation of bonds and adhesion except with a material that fills the gaps between surfaces [8]. Additionally, the material used must interact with both surfaces and have sufficient strength and consolidation to paste the two sides (wood and textile), This was helped by the similarity of the chemical properties of wood and textile. Both types are of plant origin and their main components are (cellulose, lignin and hemicellulose), with the proportions differing according to the type of plant. Therefore, the study aims to select a bonding material that has the ability to strengthen the textile and wood together, in addition to the function of the basic adhesive .Preferably, the adhesive is liquid so that it is able to comply with the irregular surface of the solid material (wood and textile) with the filling of pores and cracks on both surfaces. Adhesion depends on the viscosity of the material, the nature of the restored surface, and the surface tensions between different surfaces and similar in their chemical properties [9]. When the surface tension of the wood and textile is less than that of the adhesive, the liquid adhesive spreads on the surface and gives a high bonding force [10]. It was necessary to search for materials that have the ability to consolidation both wood and taxtile and at the same time has high adhesive strength and do not affect the painted layers of the gesso. The choice was made after many experiments with PEVA (371). BEVA is a plastic adhesive introduced in the 1970s. Its use has expanded from the conservation of oil paintings to the conservation of textiles. It is a copolymer of ethylene vinyl acetate, cyclohexanone resin, hydrobutyl alcohol phthalate ester and paraffin. [11].Its use as an adhesion and consolidation material has varied. It was used in the mid-1980s to the 1990s in skin treatment, conservation and restoration of tears and cracks, assembling cuts in textile, as well as support and enforcement of the painting, especially the one carried out on textile support. Additionally, it has distinctive qualities in the elasticity of the textile and preserving its properties and does not cause any softening or shrinkage of the applied material, making it safe to apply to the most sensitive materials, such as textiles [12]. It can be used in the form of a film or solution. It is used as a film using heat or pressure and in the form of a solution dissolved in the toluene and in the presence of heat to redissolve and giving it higher cohesion force when frozen. In addition, BEVA (371) has high adhesive strength, does not affect the colored gesso layers, and gives a smooth surface after application, providing a natural feeling of restoration [13]. Prior to the commencement of restoration and the application of appropriate materials for restoration work, many tests and analyses were carried out to identify the causes and mechanisms of damage.

2. Materials and Methods

All examination and analysis work was carried out in the Ancient Egyptian Museum.

2.1Description of the Monument:

A wooden coffin with a human body shape consists of two parts: the bod and the cover. It contains a mummy dating back to the late era. It was found in the excavations of El-Lahoun, Fayoum. The cover on Osiris's body with a beard, and the chest is decorated with a necklace in white, light blue, black, and red with inlaid eyes. There is also a hieroglyphic inscription band surrounding the foot area. It is 175cm long, 39cm high at the head, and 27cm wide at the shoulder. This coffin is a unique model in terms ofmanufacturing technique. It has several layers up to five. The body is made of wood panels assembled by various wooden interlocks and topped with a textile layer to increase the binding force between the coffin layers. It is topped with the preparatory layer, which covers the textile layer, topped with the whitewash layer prepared for painting and decoration, followed by the color layer. The ancient Egyptians were creative in using colors to paint the facial features and decorate the chest in different colors, see Fig (1).

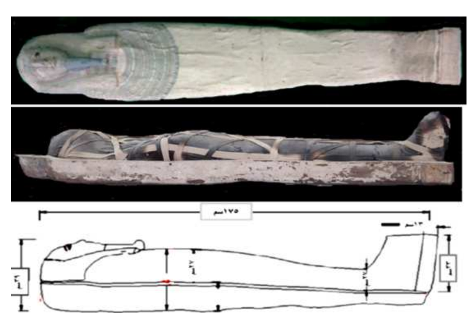

Figure 1: General View of the coffin before restoration

2.2Visual examination

A visual examination of the entire coffin surface was carried out to identify the manifestations of visible damage, determine the types of examinations and analyses of studying the technique of manufacturing, and develop a restoration plan. It is important to identify any deterioration aspects, such as deep and surface cracks, missing parts, breakage, and holes resulting from insects.

2.3 Digital microscopy

The digital or portable microscope is one of the simple means used to make a surface check of the monument without the need to move it or take a sample. The employed microscope used a focus range of (10: 500 mm) and a magnification of (1000mm).

2.4 Optical microscopy(OM)

An optical microscope, **the**Stereo DV 20 apparatus, was used with transmitted light. It was equipped with an optical B 9 digital camera to identify the wood. It was employed to examine wood sections to identify the type of wood used in coffin planks and wooden dowels by preparing microscopic slides for Thin sections were obtained in the three principal anatomical directions: transverse (TS), tangential (TlS), and radial (RlS). It was also used to identify remnants of dead insects inside holes by carefully isolating insects and installing them on glass slides to study under reflected light.

2.5 Polarized microscope(PLM)

The polarized microscope was used to recognize the type of textile by polarizing light in two perpendicular directions. The polarized microscope, Zeiss brand, Imager A1m model, connected to Axiocam MRc5 camera, and connected to Fujitsu Siemens computer screen was used.

2.6 Microbiological investigation

Isolation media

The media used for the isolation of fungi: Potato dextrose• agar medium, PDA (Nissui). • lignin cellulose medium and lCM.9• modified Czapeck's medium by adding lignin cellulose as a carbon source instead of sucrose. The media used for the isolation of bacteria: • Nutrient agar medium (Nissui).

2.7 Fourier-Transform Infrared Spectroscopy(FTIR)

The Fourier Transfer Infrared Spectrometer produced by the SHIMADZU Company was used to identify the linking material used on the preparatory layer.

2.8 Investigation and Analysis by SEM – EDAX

The Scanning Electron Microscope(SEM)-EDAX Inspect S produced by FEI Company was used with an image resolution of 512 by 442, an image pixel size of 1.73 µm, an acc. voltage of 20.0 kv, and a magnification of 399.

3 Results and Discussion

3.1 Diagnosis of damaged manifestations

Visual and microscopic examination revealed that the entire coffin was covered with a layer of dust and dirt. It was found under inappropriate conditions, neglected, and exposed to unsafe storage, resulting in many deterioration aspects, such as weakness, fragility, microbiology damage, separation of the wood panels in the contact areas, severe insect effects, and a broken side in the base of the coffin at the head area. Additionally, it suffered from breakageand loss in some wooden joints with a separation of interlock places between the beard and face, loss in some parts of wood, loss in the area of eye inlaying, delicate and deep cracks in the apparent parts of wood, and loss in the textile layer in different parts. The coffin had a separation between the textile layer and the wooden body, a separation between the gesso layer and the textile, as well as fragility, weakness, and tear in some parts of the textile. There was peeling in the preparatory layers and other colored layers, loss in the preparatory layer in different parts, deep and delicate cracks in several parts, uplifting in different parts of the preparatory layer, and loss in parts of the layers as a result of the inappropriate preservation, several delicate and deep cracks in the colored layer, partial or total separation of some colored crusts, and fading in the colored layer, Fig. (2a- b).

Figure 2: Visual and microscopic examinations of the coffin.

3.2 Identification of wood

Wood is a natural rawmaterial that the ancient Egyptian manufacturers had knew and mastered in terms of use and form by knowing its anatomical, physical, and chemical properties [14]. However, Egypt lacked good types of wood; the ancient Egyptians imported good types [15] and used local and imported types in the wooden coffins and joints that survived [16]. Wood type can be identified by studying the anatomical structure of wood compared to standard samples. Preparing TS, TLS, and RLS sections of a sample from the body of the coffin and one of the wooden dowals and comparing them with a standard sample revealed that the coffin was made of sycamore wood and the dowal was made of tamarix wood, Fig (3a. b).The anatomical features of Ficussycomorus were shown by OM in transmitted light: A - transverse section (TS) showing vessels solitary or in radial multiples of 2 to 4 and axial parenchyma vasicentric in bands more than three cells wide; B - tangential section (TLS) showing rays of two distinct sizes, withlarger rays commonly 4 to 12 seriate; C - radial section (RLS) showing body ray cells procumbent with one to 4 rows of upright and square marginal cells. The examination of the anatomical characteristics of the dowals showed that it was from the wood of Tamarix Sp. By OMin transmitted light: A. Transverse section(TS) showing wood semi-ring-porous to diffuse, vessels solitary and in small clusters and axial parenchyma present in vasicentric or confluent distribution; B. tangential section (TLS) showing multiseriate rays commonly 5–20 cells in width; C. radial section (RLS) showing heterocellular rays with procumbent, square and upright cells mixed throughout the ray; D. detail of the radial section (RLS) showing simple perforation plates and vessel pits alternate [17].

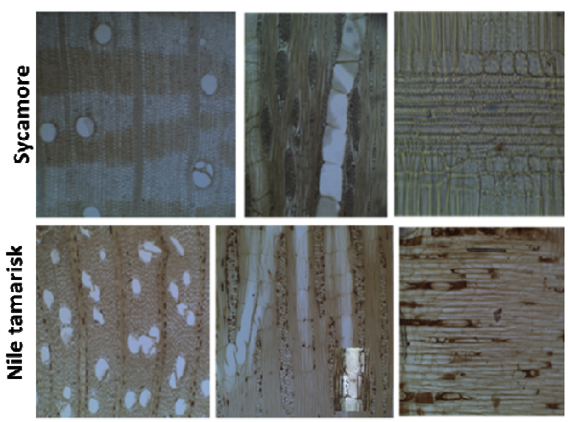

Figure 3: Micro-images of wood slices under the microscope illustrate the anatomical properties of sycamore and nile tamarisk (Tamarix nilotica Ehrenb.), (T = transverse section, L = tangential longitudinal section and R = radial longitudinal section).

3.3 Identification of isolated insects

Insect molts were found in one of the holes. After isolation and preparation on microscopic slides, they were examined under the optical microscope and identified as Attagenus pellio, a harmful insect that destroys stored products, especially organic materials such as wood, carpets, and textiles [18]. It has an oval shape of 4-6 mm long and a shiny black or brown color with two spots of white hair on the reddish brown sheathed wing [19], Fig. 4.

Figure 4: Isolated insects identified as (A) black carpet beetles (Attagenus unicolor) and (B-C) insect growth stages

3.4 Identification of fungi

Examining the results of microbiological isolates of the coffin demonstrated that a large number of fungi were found. This could be due to the existence of the mummy inside the coffin, a primary source of microbiological infection. Four types of fungi (i.e., Penciliumsp, Cladosporiumsp, Aspergillusniger, and Aspergillusflilus) were identified, (Fig.5).

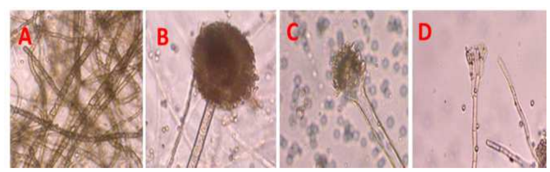

Figure 5: Isolated fungi identified as (A) Pencilium (B) Cladosporium (C) Aspergillus niger (D) Aspergillus flilus.

3.5 Identification of textile

Textile is one of the oldest industries that the ancient Egyptians knew [20]. Linen was one of the most famous fibers used in the textile industry. The ancient Egyptian textile had a thread pointing to the left in the form of the letter (s). Additionally, the textile varies in fluffiness, delicateness, thickness, and roughness from one type to another [21]. Examining the textile fibers on the surface of the coffin using the digital and polarized microscope illustrated the type of linen textile, the direction of weaving in the form of (s), and the weaving method (18x24 cm2), (Fig.6).

Figure 6: Investigation of the textile: (A) Textile is identified as linen. (B) Textile quality 16×24 threads per 1cm²

3.6 Identification of pigments and preparatory layer

It is important to study the preparatory layer, metal pigments, and color media in the coffin prior to restoration so that the appropriate materials can be selected for restoration and the appropriate solvents can be chosen during cleaning and consolidation without adverse effects on the preparatory or color layers.

3.6.1 White wash

ESEM-EDX analysis of the whitewash layer, which was commonly used by the ancient Egyptians to prepare the painting ground [22-23] and was often prepared by a mixture of calcium carbonate with animal glue as a bond material [24]. The analysis demonstrated a high percentage of calcium (Ca), along with oxygen (O) and carbon (C), suggesting that the whitewash layer could be calcium carbonate (Chalk). The presence of silicon (Si) and aluminum (Al) elements indicated the possible presence of alumina and quartz silicate materials (SiO_2) [25], Fig. (7a).

3.6.2 Red pigment

Most red pigments used in ancient Egypt were earthy colors containing iron oxide, especially hematite (αFe2O3) [26]. The ESEM-EDX analysis of the red pigment proved the presence of hematite as a red pigment besides calcite, quartz, and gypsum, Fig. (7b).

3.6.3 Green pigment

The ESEM-EDX analysis revealed the presence of copper, silica, and quartz. The green pigment in ancient Egypt was made of malachite and copper [28]. The presence of copper suggested that the green pigment could be copper, especially with copper oxide (Cu2o), Fig (7 c).

3.6.4 Definition of the color medium

The use of animal glue as a bonding material for colored substances was common in ancient Egypt. The FT-IR analysis of a composite sample of the preparatory layer with color pigments and a comparison of a sample of animal glue demonstrated the existence of the distinctive functional groups of animal glue, i.e., (N-H 1500-1565 cm^{-1}). This result was confirmed by N-H at 3200-3500 cm-1 and the corresponding ranges for carbonate (1490-1370 cm^{-1}, 910-870 cm^{-1} (Fig 7 d).

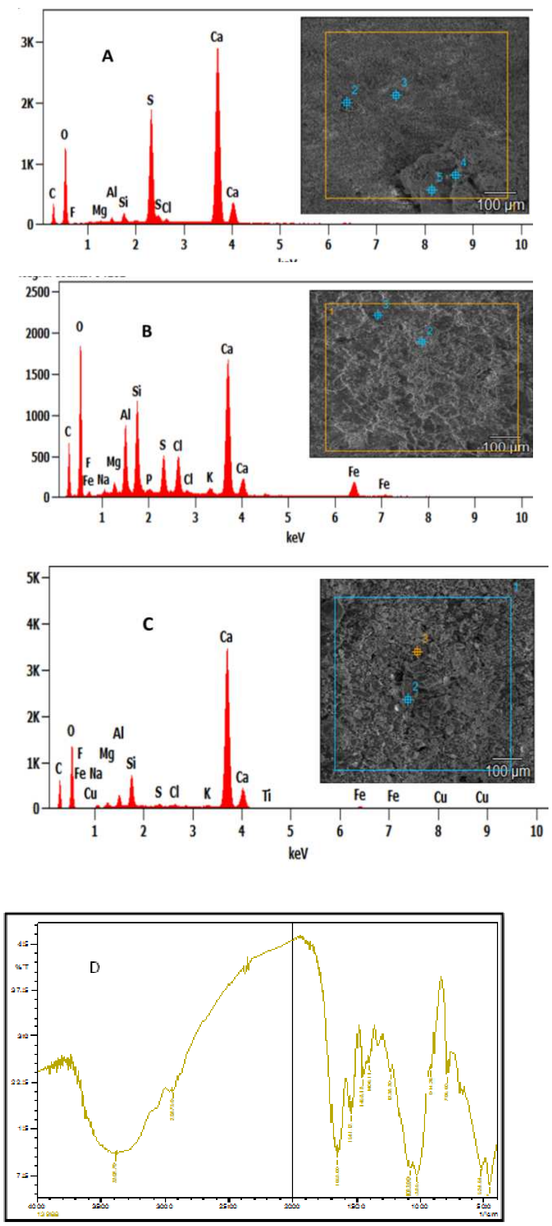

Figure 7: SEM images and EDX analysis of pigments used on the coffin (A = White B = Red and C = Green pigments). FT-IR spectrum of the binder material (D)

4. Stages of treatment

Microbiological examination revealed that the severe fungal infection of the coffin could primarily be due to the existence of the mummy inside the coffin. Therefore, a team of specialists moved the mummy from the coffin to carry out the required restoration work. On the other hand, the restoration of the coffin started with fumigation using a mixture of natural oils that proved successful in fumigating wet wood [29]. However, the use of these oils not limited tohaving microbiological swabs to ensure that the coffin was free of infection. A mixture of thyme and cinnamon in ethanol was used because of its fungicidal effect and because it significantly reduces the vitality of the microorganisms in wood [16] through the preparation of a tight room and the follow-up of the microbial load at intervals of 3- 6-10 days [30]. It was found that the fungal and bacterial infection decreased significantlyafter 10 days decreased significantly, but the period of fumigation was extended for 15 days to ensure that the coffin was free of infection. The treatment was carried out by preparing a tight room with the coffin inside and using dissolved oils mixture in ethanol and in-room distribution of Petri dishes to be sterilized by sublimation of essential oils, Fig (8).

Figure 8: Stages of fumigating the coffin using natural oils (thyme and cinnamon in ethanol) inside a sealed room.

4.1 Backing and numbering of completely separate parts

Prior to the restoration stages, wooden parts that were completely separate and prone to loss were wrapped, and a box backed in Japanese paper was prepared for preservation until reassembled in the coffin after numbering and locating each part in the coffin, Fig. (9).

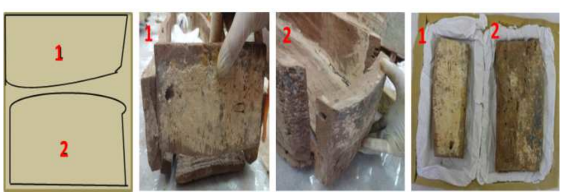

Figure 9: Packaging and preserving the separate coffin parts.

4.2 Primary insuranceof separate crusts and phases of cleaning and consolidation

Prior to cleaning, slices of Japanese paper and Klucel G with a concentration of 0.5% were used to secure separate crusts until the final installation. After ensuring that the surface of the coffin and the separate crusts were secured, the stages of mechanical cleaning were initiated using soft brushes and a handheld air blower to remove the dust and dirt attached to the coffin surface from inside and outside. Additionally, manual scrapers were used to clean surface calcifications after the completion of cleaning work and to start comprehensive consolidation of the wood of the coffin from inside using Paraloid B72 with a concentration of 7% by brushes. The external surface of the colored preparatory layers was consolidated using Klucel G at a concentration of 1% by the spraying technique. The application method depends on the nature of the monument's surface, Fig. (10 a.b.c.d).

Figure 10: Conservation processes include: (A) securing lifting flakes, (B) cleaning and removing dirt and (C & D) consolidation stages.

4.3 Fixing and reattaching separate textile layers

Examining the coffin cover showed separation between the wooden coffin body and the layers of textile bearing the painted layers because of the different rates of expansion and shrinkage between the different coffin layers. This stage is critical for restoration due to the severe cohesion of the textile layer bearing the preparatory layers. Thus, the injection was adopted below the textile layers after making various tests of some materials (BEVA 371, Klucel G, Paraloid B, and Primal 33 Ac72).

- BEVA 371 is a common material in textile conservation [11]. Many tests were conducted to determine its strength, effectiveness, variables affecting the strength of the bond according to the purpose of the use, as well as the selection of the appropriate concentration.
- Klusel G, at a concentration of 5% dissolved in ethyl alcohol, is an organic solvent widely used in the consolidation of books and preparatory and colored layers with high viscosity [31].
- Paraloid B 72 (20%) dissolved in acetone is a widely used material as a consolidation and adhesive material for wood (32), either in toluene or Isopropyl alcohol. It is used (5: 20%) with filling material in the consolidation and completion of wooden pores resulting from insect infection. Additionally, it is used at (20: 60%) dissolved in acetone as an adhesive material for wood [33].
- Primal Ac 33 is widely used in restoring stone. It dissolves in water and has a high pasting strength. However, it has high plasticity with clay and gesso [34-35].

After testing the selected materials, the results were as follows:

- Paraloid caused a color change in the preparatory layers with the difficulty of the application process when the concentration was raised to 20%, which gave suitable adhesive strength.
- Klusel G was fragile as an adhesive with a concentration of up to 5%. At high concentrations, there was difficulty in application.
- Primal gave high adhesive strength, but the water medium was an impediment during injection.

- BEVA 371 gave the best results in terms of ease of injection, the ability to penetrate below the textile, and high flexibility and consolidation of the textile layer while not affecting the color degree of the preparatory layer. A concentration of 10% dissolved in toluene was used by injection below the textile layer by pressing the top surface of the preparatory layer using silicon paper. BEVA could penetrate the textile and wood to give the desired result in spreading and installing the textile layer separated from the wooden body of the coffin in addition to the ability to strengthenthe textile and wood, Fig. (11).

Figure 11: Stages of fixing the textile layers separated from the wooden body of the coffin. (A) Before Fixing.(B) during Fixing.(C) after Fixing

4.5 Reassembly of separate panels at the base of the coffin

After completing the consolidation of wood and cracks at the base of the coffin, the separate panels were reassembled as a result of the loss of some wooden dowels and joints. The reassembly was completed after dismantling the panels and cleaning the connections from the inside. New dowals of processed Swedish wood of the same size as theold dowels were prepared to tighten the separate parts. Paraloid B72 was injected with a concentration of 40% to install wooden connections and dowels in their designated locations. Furthermore, assembly utilized metal clamps after good wrapping of wood parts using safe materials to prevent direct friction between metal clamps and the monument's surface while leaving them to complete the drying of the assembly material. Then, any increase resulting from the use of paraloid was removed by cotton dipped in toluene and good cleaning in assembly places and returning wood panels for normal placement. In the case of damaged wooden joints in one of the non-separated panels, the panels were completely disconnected and replaced while following the same steps mentioned above, Fig. (12).

Figure 12: Stages of replacing damaged joints and reassembling separate panels.

4.6 Completion

Some parts of the wooden box were separated and needed to be supplemented to prevent continuous loss of wood and protect the mummy insect infection, dust, and dirt in the coffin body. These parts were handled using scientific methods of completion by drawing a sketch with the exact sizes of the parts to be completed. The completion was carried out as follows:

- Completion used balsa wood and Paraloid B72 (60%) to assemble the modern part to the old one using the completion mixture (glass microballon with Paraloid (15%) and adding colored oxides that fit the color of wood to fill the spaces and finalize the completion process as shown in (Fig. 13a).

- To complete the consolidation of the missing parts of the preparatory layers, a mixture of glass microballoons with paraloid (15%) and colorful oxides corresponding with the color of the preparation layer was prepared. Then, the lost parts were filled using planers with a low level of completion to clarify the difference between modern restoration and the preparatory layer, Fig. (13b). In sum, the precise and deep cracks were completed by the same technique and the same mixture, Fig. (14) Shows the coffin after the restoration work was completed.

Figure 13: A) Stages of completing the missing parts of the coffin body using balsa wood. B) Stages of consolidation of the missing parts of the gesso layers by mixture of (glass microballoons with paraloid).

Figure 14: Coffin after restoration.

5 Conclusion

-Visual and microscopic examination helped identify aspects of deterioration on the surface of the coffin. (PLM) revealed that the fabric used was linen. Use OM to examine the wood of the coffin's body which is sycamore andseethat parts of the wooden dowells are tamarisk. Coffin color pigments were identified using XRD: calcium carbonate for white, hematite for red, copper oxide for green, and carbon for black. FTIR showed that the material used in the colored preparatory layers may be animal glue.

-The use of a box covered with Japanese paper succeeded in completely backing the separate wooden parts, and this technique is very important as a first step for restoration.

- PEVA (371) has been shown to have the ability to strengthen textiles and wood together, in addition to acting as an adhesive.

- Irregular surfaces at the microscopic or molecular level when assembled, the molecular grains from each surface are not sufficient to allow the formation of bonds and adhesion except with a substance that fills the gaps between the surfaces. This was confirmed by (Costa, 2007),and (Charles, 2012) and proven by the use of PEVA(371).

- The similarity of the chemical properties of wood and fabric with the difference in the surface helps in choosing an adhesive that has the ability to strengthen both textiles and wood, in addition to the function of the basic adhesive.

- The injection technique is an important technique, especially with multi-layered objects.

6 Conflicts of interest

We would like to stress that there are no known conflicts of interest associated with this publication, and there has been no significant financial support for this work that could have affected its outcome.We confirm that the manuscript has one author. I am responsible for providing revisions and final approval of proofs. I confirm that I have provided a valid and up-to-date e-mail address that the corresponding author can access

7 Acknowledgment

The authors are very grateful to Dr. Samir Kamel Elyzayati head of Cellulose and Paper Department and Vice President of Chemical Industries Research Institute (Former), National Research Centre (NRC), Egypt, for continuous supporting.

8 References

1- Bader, N. and Al-gharib, W. (2013), “Assessment of deterioration and conservation of a polychrome wooden coffin, from Al-Arish Museum, Egypt,” International Journal of Conservation Science, Vol.4, No. (4), pp. 397-412.

2- Andrew, M. and Sylvia, M. (2011), Pigments on Some Middle Kingdom Coffins, in Color and Paintings in Ancient Egypt, 9th ed, British Museum Press, London, P.13.

3- Zidan, Y., Handoussa, T., Hosni, H., & El Hadidi, N. (2006), “The conservation of wooden Graeco-Roman coffin box,” E-Preservation Science, Vol. 3, pp. 27-33.

4- Genestar, C. and Palou, J. (2006), “SEM–FTIR spectroscopic evaluation of deterioration in an historic coffered ceiling,” Analytical and Bioanalytical Chemistry, Vol. 384, No. (4), pp. 987–993.

5- Nabil, E. (2020a), “The technique of manufacturing and molding of wooden coffins in ancient Egypt,” Studies in the Arab World Monuments, Vol. 23, No. 22, pp. 32-58.

6- Gentle, N. (1998), “A decade and a half of hindsight: Two adhesive treatments reconsidered. In J. Lewis (Ed.), Adhesive tnsatments mvisited (pp. 27-30). UKlC Textile Section, London.

7- Charles R. (2012),Wood Adhesion and Adhesives. Handbook of Wood Chemistry and Wood Composites (pp.216-273)

8- Costa, M. (2007), “Microtopographic and rugometric inspection of wood artifacts,” Wood Science for Conservation of Cultural Heritage – Florence/ the International Conference, Cost Action Ie0601, 8-10 November, Florence, Italy.

9- Browning, B.L,:- (2012). The chemistry of wood. Interscience Publisher, USA.

10- Nabil, E., Mahmoud, N., Youssef, A., & Kamel, S. (2020), “Influence of polymers loaded with ZnO and TiO2 nanoparticles on thermal resistance of archaeological wood,” Egyptian

Journal of Chemistry, Vol. 63, No. 11, pp. 4645 – 4657.

11- Kronthal, L., Levinson, J., Dignard, C., Chao, E. & Down, J. (2003), "Beva 371 and its use as an adhesive for skin and leather repairs: Background and a review of treatments," Journal of the American Institute for Conservation, Vol. 42, No. 2, pp. 341-362.

12- Salama, K., Ali, M., & Moussa, A. (2016), "Experimental study of the retouching materials applied on elSakakeny palace," Scientific Culture, Vol. 2, No. 3, pp. 1-4.

13- Nabil, E., Khattab, T. & Kame, S. (2021), "Multi-technique characterization and conservation of an ancient Egyptian fabric from King Khufu first solar ship," International Journal of Organic Chemistry, Vol. 11, No. 3, pp. 128-143.

14- Nilsson, T. & Rowell, R.)2007), "Historical wood – structure and properties," Wood Science for Conservation of Cultural Heritage – Florence/ the International Conference, Cost Action Ie0601, 8-10 November, Florence, Italy.

15- Nabil, E., Mahmoud, N., Youssef, A., Saber, E. & Kamel, S. (2018), "Evaluation of physical, mechanical, and chemical properties of cedar and sycamore woods after heat treatment," Egypt. J. Chem., Vol. 61, No.6, pp. 1131 – 1149.

16- Blanchette, R. (2000), "A review of microbial deterioration found in archaeological wood from different environments," International Biodeterioration & Biodegradation, vol. 46, pp. 189-204.

17- Bernal, R., Valente, A. and Pissarra, J. (2011), "Wood identification of 18th century furniture. Interpreting wood naming inventories," International Journal of Conservation Science, Vol. 2, No. 3, pp. 165-178.

18- Igde, M., Acici, M., Igde, F. and Umur, S. (2019), "Carpet beetle anthrenus verbasci, linnaeus 1767: A new seasonal indoor allergen: Case report," Turkiye Klinikleri Journal of Medical Sciences, Vol. 29, No. 6, pp. 1729-1731.

19- Notton, D. (2018), Identifying Insect Pests in Museums and Heritage Buildings, Natural History Museum, London.

20- Singh, P., Sharma, E., and Fatima, N. (2017), "A case study on conservation of textiles in Allahabadmuseum, Uttar Pradesh," Asian Journal of Home Science, Vol. 12, No. 1, pp. 296-303.

21- Houck, M. (2009). Identification of Textile Fibers, Woodhead Publishing, Sawston.

22- Eastaugh, N., Walsh, V., Chaplin, T., and Siddall, R. (2004), The Pigment Compendium, A Dictionary of Historical Pigments, Elsevier Butterworth-Heinemann, Oxford.

23- Nabil, E. (2020 b), "Scientific methods for the treatment of Ibis mummy's wooden coffin," Egyptian Journal of Archaeological and Restoration Studies, Vol. 10, No. 1, pp.9-21.

24- Mahmoud, H. (2011), "A preliminary investigation of ancient pigments from the Mortuary Temple of Seti I, El-Qurna (Luxor, Egypt)," Mediterranean Archaeology and Archaeometry, Vol. 11, No. 1, pp. 99-106.

25- Ismail, Y. Abdrabou, A. and Abdallah, M. (2016), "Non-destructive analytical study and conservation processes of Pharaoh Tut Ankh Amen´s model boat," Conservation Science, Vol.7, No. 1, pp. 15-28.

26- Nabil, E., Mahmoud, N. and Kamel, S. (2017), "Investigation and analysis study of an Old Kingdom Cheops first boat oar blade," Journal of Ancient Egyptian Interconnections, Vol. 16, pp. 87–98.

27- Colinart, S. (2001), "Analysis of inorganic yellow color in ancient Egyptian painting," in Ed. W. Davies, Color and Painting in Ancient Egypt (pp. 1–4), British Museum Press, London.

28- Derrick, M., Stulik, D. and Landry, J. (1999), Infrared Spectroscopy in Conservation Science, The Getty Conservation Institute Press, Los Angeles.

29- Björdal, C. and Nilsson, T. (2001), "Observations on microbial growth during conservation treatment of waterlogged archaeological wood," Studies in Conservation, Vol. 46, No. 3, pp. 211–220.

30- Pedersen, N., Björdal, C., Jensen, P., and Felby, C. (2012), "Bacterial degradation of archaeological wood in anoxic waterlogged environments," In (Ed.) S. Harding, Stability of Complex Carbohydrate Structures: Biofuels, Foods, Vaccines and Shipwrecks (pp. 160–187), The Royal Society of Chemistry, Cambridge.

31- Attia, M., Mahmoud, N. and Abd Alkareem, A. (2019), "New method of lining oil paintings using polyurethane," Mediterranean Archaeology and Archaeometry, Vol. 19, No. 2, pp. 9-21.

32- Young, C. and Ackroyd, P. (2001), "The mechanical behaviour and environmental response of paintings to three types of lining treatment," National Gallery Technical Bulletin, Vol. 22, pp. 85-104.

33- Trăistaru, A., Timar, M., Câmpean, M., Croitoru, C., and Sandu, I. (2012), "Paraloid B72 versus Paraloid B72 with nano-ZnO additive as consolidants for wooden artefacts," Materiale Plastice, Vol. 49, No. 4, pp. 293-300.

34- Mohie, M. and Korany, M. (2018), "Study of materials and techniques for the conservation of two miniature paintings," Conservation Science in Cultural Heritage, Vol. 17, No. 1, pp.101-116.

35- Federica, A., Marco, B. Marie-Laure, P. Alfonso E. Giulia, G .Sandra, R., Barbara, D., Cristian, P., Antonella, D., Silvano, P., Francesca, G., and Manuela, R. (2020), "Essential oils as alternative biocides for the preservation of waterlogged archaeological wood," Microorganisms, Vol. 8, No. 12, pp.1-25.