

Review article

TUTANKHAMUN'S INNERMOST SHRINE: 100 YEARS OF TREATMENT

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Abstract:

Howard Carter and Alfred Lucas carried out extensive investigation and detailed study to analyze and identify all the materials that the ancient Egyptian craftsmen used to make the magnificent shrines of Tutankhamun. They successfully identified the wood used for the panels, as well as the components of the gesso layers, tenons, metal tongues, door hinges, hoops and the gold used for gilding. Samples were investigated and studied in situ in Cairo or were sent to London; a process which at that early stage in archaeological research is considered an excellent scientific approach and is one of many leaps that aided the advancement of archaeological technological studies. As conservators, we all try to adhere to current standard analytical procedures, with the aim of analyzing an artifact and assessing its preservation state prior to any conservation treatments, especially if it is in a pristine condition. However, what if the artifact has been for years on exhibit in a museum? Rarely would it be untouched by conservators, and we would have to be really fortunate to find old conservation records. Due to the importance of the Tutankhamun collection, all the objects were given extra care and were treated in situ before their transfer to Cairo. Aiming to stabilize the objects that had been buried for centuries, materials were ordered in hundreds of kilograms due to the size and number of objects. The questions today are which materials and methods were used for the treatment of these objects and how appropriate were they? A detailed investigation of the fourth innermost shrine of Tutankhamun, which included 3D scanning, helped in the documentation of many previous techniques that were applied over the years since around 1925. The study aims to focus on how previous treatments have either prevented further deterioration of the shrine or are the cause of new problems during the application of new treatments.

1. Introduction

The innermost shrine, JE 60668; Exhib. 1319, Carter's Number 239, is the smallest among a set of four nesting shrines surrounding the sarcophagus. The shrine is made up of five separate sections, and is distinguished by featuring a barrel-vaulted roof instead of the typical sloping one, with the roof and cornice crafted as a single piece. fig. (1), It is primarily made of cedar wood (*Cedrus libani*) with other types of wood used for structural elements such as tenons and dowels [1]. The wood is covered with coarsely woven linen to stabilize the multi-layered polychrome str-

ucture and reduce damage caused by wood movement. The fabric, a simple tabby weave, is part of a layered system coated with two gesso layers—a coarse inner layer and a fine outer layer—composed mainly of calcite, with traces of quartz. The binding medium is animal glue [2]. An uneven black layer, absent in some areas, was found between the gilding and the coarse gesso and may have served as a base for the gold leaf. The colour of the gold leaf varied across different parts of the shrine, ranging from bright yellow-gold to dull yellow-gold, and in some areas,

to a distinctive dull reddish-brown. Analysis revealed the presence of gold with small amounts of silver [3]. The dull red-gold surface showed elevated levels of silver and sulphur. These findings agree with those of Frantz and Schorsch [4], who attributed the reddish-purple coloration to silver-gold sulphide (AgAuS) tarnish, resulting from high sulphide ion activity commonly found in sealed burial environments. Alternating wooden tenons and copper tongues were used to secure the roof to the body of the shrine (TAA.i.3.9.1) [5]. The shrine is mainly decorated with protective texts and scenes. The barrel-vaulted roof is built against two vertical boards with the winged solar disc on the outside. On the doors Isis and Nephthys protect the king with their winged arms. The interior walls of the shrine are inscribed with Chapter 17 of the *Book of the Dead*. On the ceiling the sky goddess Nut spreads her protective wings over the sarcophagus of the king [6]. The exterior gilded surfaces of the shrine display the four sons of Horus, as well as the deities Geb, Thoth, and Horus.



**Figure (1)** The fourth (Innermost) Shrine (Carter 239), and detailed pictures showing the east panel (front) with doors, the north, south and west panels.

### 1.1. Condition assessment of the shrine

From the time of their discovery, it was evident that the shrines suffered from extensive deterioration, a process that began when they were installed within the confined space of the tomb. The fourth and innermost shrine was constructed slightly too small to fully enclose the sarcophagus. To overcome this issue, the workers assembling the shrine left the joints between the framework of the side panels and end panels slightly open. Additionally, they trimmed the inner surface of the frieze of the west end panel and made minor adjustments to the inner corners at the North and South-East (CARD 239-07) [7]. Carter also mentioned that “the western ends of the four great shrines that shielded the sarcophagus were in a worse condition than the front eastern ends, and that ... many objects coming from the west walls had suffered rather more than those on the east side” [8]. He attributed this to moisture seeping through cracks in the limestone rock, which increased humidity levels on that side. The process of dismantling of the shrine caused further deterioration and weakened the fragile gilded gesso layer, which detached from the wooden substrate in several areas. The most significant damage occurred at the points where the different sections of the shrine, held together by mortise and tenon joints, made contact. Additionally, due to the limited space within the burial chamber, the dismantled sections had to be propped against the walls and left in place until all the funerary possessions were removed. This most likely added stress on the various layers encasing the wooden shrine. In Carter's notes of 21 October 1930, he describes spending an entire week repairing the roof section (a single piece) of the fourth (innermost) shrine, which had been stored at the south end of the antechamber since its dismantling (TAA i.2.4.061.jpg) [9]. Eventually, all sections of the shrines were placed in wooden cases and stored in the tomb of Ramses IX (TAA i.2.4.065.JPG) [10,11]. Carter was faced with the final challenge of transferring Tutankhamun's remaining belongings to Cairo, a task that was not completed until the spring of 1932, when the last of the fragile funerary objects arrived at the Cairo museum [8]. His description made it clear that the shrines were extremely fragile and in a very delicate state. In his journal entries from 22 to 31 October, 1930, he mentions that “Many of the roof sections were in a very bad condition, and even though we waxed them and filled in the weak parts, I doubt whether they will travel without further injury to them” (TAAI.2.4.063.JPG) [12,13].

### 1.2. Treatment and conservation of the shrine, 1924-1932

A wealth of data was left behind due to the systematic documentation of all actions taken during the discovery of Tutankhamun's tomb. Howard Carter

and Alfred Lucas went above and beyond meticulously documenting their efforts to maintain the integrity of the funerary belongings of Tutankhamun, and to ensure their safe arrival in Cairo. This documentation included first aid before dismantling, *in situ* conservation, packing, and detailed analysis and identification of some of the materials used by ancient Egyptian craftsmen to create the magnificent possessions of Tutankhamun. For the shrines, they identified the types of wood used for the panels, tenons and dowels [14,15]. Plenderleith determined the composition of one of the shrines' metal tongues to be a copper alloy with a small amount of tin (not exceeding 1.6%) and traces of gold [16]. For gilding in general, they noted that a layer of "gesso [was] being employed instead of plaster of Paris because this latter is not sufficiently hard to permit of the burnishing of gold" [17] and that it was composed of calcium carbonate and glue [17]. They attributed the dull yellow/dark red appearance of the gold leaf to tarnishing and the presence of alloying metals such as silver, copper and traces of iron [18]. Moreover, the bottom edges of the shrine were bound with copper sheet, which was identified as "copper 97.2%, tin 2.5% and Silver 0.3%" [18]. Samples were analysed and studied both *in situ* in Cairo and in London [19], a process which, at such an early stage in archaeological research, represented a groundbreaking scientific approach. Their work is one of the early milestones that significantly influenced the advancement of archaeological science and conservation practices. Alfred Lucas' experiments and contributions laid the foundation for modern conservation materials and methods. Together with Arthur Mace, he developed an impressive system of documenting the condition and treatments applied to individual objects using cross-referenced index cards, which are still preserved at the Griffith Institute in Oxford [20]. Strangely enough, while going through the index cards no specific reference to the treatment of the shrine was found, necessitating a study of the treatments applied to similar materials. It is evident that minimal intervention was employed, an approach that is highly valued today and defined as minimal intervention. An exception to this was the use of paraffin wax. The objects were cleaned of dirt using soft bristle brushes and bellows, while surface accretions were removed using benzene applied using soft brushes. Lucas noted that "benzene and soft brush are much better than water. Water tends to enter cracks and split gesso more". (TAA i2.12a.2.11) [21]. "Detached areas were secured with "celluloid (cellulose nitrate) in amyl acetate" (TAA i2.12a.1.4) [22], or by using "a warm saturated solution of Paraffin wax in benzene (warmed in the sun)" applied with a small pipette. Excess wax was removed while still soft, using benzene and a soft brush" (TAA i2.12a.1.1) [23]. For removing tarnish from gilding Carter used "dilute ammonia" followed by rinsing with water

(TAAi.2.12a.1.38 verso) [24]. In cases where the gold's red hue "red of the gold" washed off with water, a dry brush was used instead [25]. Paraffin wax was extensively used for the consolidation of the gilded gesso layers, filling cracks and reattaching detached areas. It had been one of the principal field consolidants for a wide range of objects since at least the late 19<sup>th</sup> century, when it was advocated by Flinders Petrie [26]. Its use on gilded wooden surfaces is well documented—for instance, Mace and Winlock applied it to the gold leaf over gesso decoration on the second coffin of Senebtisi [27]. The idea of using paraffin wax emerged during photography sessions. Lucas noted in his records from the earliest season 1923-1924, that "Every time the box [the painted casket, No. 21 Carter's register, JE 61 467] was moved for photography or examination, its condition became slightly worse. After careful consideration and a preliminary experiment on one corner, it was decided to treat [the entire box] with melted paraffin wax". The blisters were pressed down while the wax was still warm, and larger cracks "were filled up with plasticine before applying the wax" (TAA i.2.12a.1.02.jpg) [28]. Carter elaborated on his decision, stating that "courage was needed to take the step, but we were thoroughly justified by the results, for the wax penetrated the materials and held everything firm". He also noted that the colors were unaffected and "seemed to become more brilliant than before". This success led to the extensive use of paraffin wax on objects made of wood and gilded gesso including the innermost shrine [29]. An amazing revelation came to our attention in Howard Carter's excavation diary: their understanding of facing weak, delaminated areas before dismantling and transporting. Carter's notes from 28 January 1924 reveal their technique: "pasted paper over the bad parts of the panels preparatory to removal..." (TAA i.2.1.105.jpg) [30]. It is worthy to note that in one of the shrines a small piece of printed paper that had been pasted on to the panels was found as evidence verifying this treatment process, fig. (2). After stabilizing the fragile areas, the different sections were packed into wooden boxes and transported to Cairo, where the shrines were reassembled and displayed in glass showcases on the upper floor of the Cairo Museum.



Figure (2) remains of old pasted paper used for facing the shrines

### 1.3. Intermediate phase 1932-2017

Over the following years, there are no detailed records of the different conservation restoration measures undertaken by the conservators at the museum. What is certain is that the glass showcases were opened several times every year for dusting and ventilation. Dr. Nadia Lokma carried out some conservation work to address delaminated and detached areas of the shrine<sup>(a)</sup>. The shrines were regularly monitored for flaking or detachment, and immediate first aid treatments was applied whenever necessary. Different working groups from the GEM and the Egyptian museum in Tahrir were formed over the years to perform detailed documentation, non-destructive analysis, and condition assessments of the fourth innermost shrine. In preparation for the opening of the Grand Egyptian Museum (GEM) and the anticipated transfer of Tutankhamun's treasures and funerary collection, preliminary discussions were held to plan ahead and determine how to proceed with the delicate condition of some of the objects. Several Tutankhamun conferences in 2015, 2016, and 2017 were organized to consult and seek advice from specialists worldwide. The biggest challenge was the transfer of the shrines due to their fragile state of preservation. It was concluded that the shrines would require elaborate conservation and restoration before being transported to the GEM. In 2016, an ICOM CIPEG-mission, alongside Egyptian specialists and conservators, conducted a preliminary investigation and condition assessment of the outermost shrine. Following this, in 2017, His Excellency Dr. Khaled El-Enany, the Egyptian Minister of Antiquities, appointed a team of conservators from the Grand Egyptian Museum (GEM), the Egyptian Museum in Tahrir, and the Faculty of Archaeology, Cairo University to plan and execute the transfer of the innermost shrine of Tutankhamun to the GEM. This effort involved over 30 professionals. After an initial planning stage, a preliminary plan was devised. Due to the limited space within the old glass showcase, the first step was to dismantle and remove the showcase. Once this was accomplished, the different working groups were able to work on the documentation, investigation and treatment of the shrine.

### 2. Materials and Methods

A detailed investigation of the fourth innermost shrine of Tutankhamun was conducted using advanced 3D scanning technology. The digital model of the shrine was created using a handheld mid-precision scanner (Eva, Artec3D), which employs white structured light and a 1.3 MP camera. The scanner has an accuracy of 0.1 mm and a maximum point resolution of 0.5 mm. Artec Studio 13 Software was utilized to operate the

scanner and process the raw scan data. The process began with fine registration to align sequential frame pairs on each of the scans captured on different sides of the shrine. The auto-alignment tool was then used to match the overlapping scans within the same 3D space. The sharp fusion feature was used to fuse all the scans and create a single mesh with a resolution of 100  $\mu\text{m}$ . Finally, a texture was applied to the model to obtain a realistic appearance, documenting and describing the shrine in its true form. This digital model serves as a life model for the object, capturing its width, height and depth in a virtual reality format. In addition to 3D scanning, X-Radiography was performed using an X-vast 200 system, a GE Wireless digital detector DXR250C-W (16"x16"), and an x-ray source (Radioflex 200sps - Rigaku Corporation). This technique was used to assess the condition of the wood and gilded gesso, the positioning of tenons and metal tongues, and whether the metal has corroded and affected the surrounding wood. Non-destructive portable X-ray fluorescence (p-XRF) was employed to analyze the metallic components and gilding of the shrine. Reflectance transformation imaging (RTI) and Ultraviolet (UV) light were also used to document previous conservation materials. These methods collectively provided comprehensive documentation of the shrine's current condition, the manufacturing techniques used, and the conservation materials applied over the years. Data loggers were placed both inside and outside to monitor the temperature and environmental conditions.

### 3. Results

The investigation and condition assessment of the shrine, utilizing X-radiography, 3D scanning, RTI-imaging and UV light, revealed significant areas of deterioration despite extensive treatments with wax and other materials over the years. Cracks, major areas of loss, and delamination were identified, with the most critical risk being the severe detachment of the tarnished gilded gesso layer from the inner side of the roof. These findings enabled the mapping of various aspects of deterioration using AutoCAD, providing a clear understanding of the shrine's condition and guiding future conservation efforts, fig. (3).

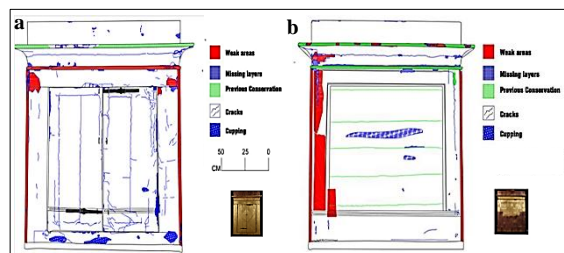
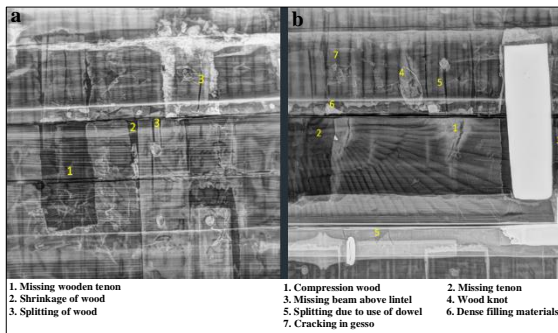


Figure (3) mapping of the different deterioration aspects of the **a.** east panel (front), **b.** west panel using AutoCAD.

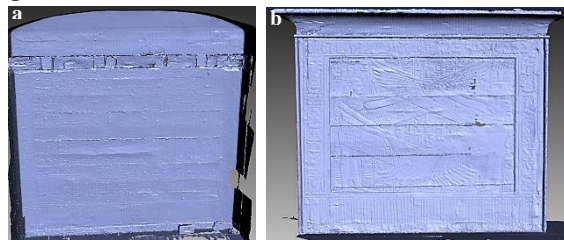
X-ray radiography revealed that the wood of the shrine remains in a relatively stable condition, fig. (4). However, some of the tenons have suffered from splitting due to the tension caused by the wooden dowels and the shrinkage of the tenons over time. Others, particularly those used to join the side panels to the ceiling, are partially or entirely missing in the upper part of the panels, likely as a result of the shrine's previous dismantling performed by Carter. Many tenons were sawn through to facilitate this process. Despite these missing tenons, the stability of the shrine is not compromised, as most of the metal tongues remain intact. Carter noted that "the tongues are made of wood and copper alternate" (card 239-14) [31], highlighting the use of different materials in securing the ceiling of the shrine. This combination of wood and copper elements played a crucial role in maintaining the structural integrity of the shrine over millennia.



**Figure (4)** X-ray radiography revealing **a.** the condition of the wood, **b.** the position of the metal tongues and hoops.

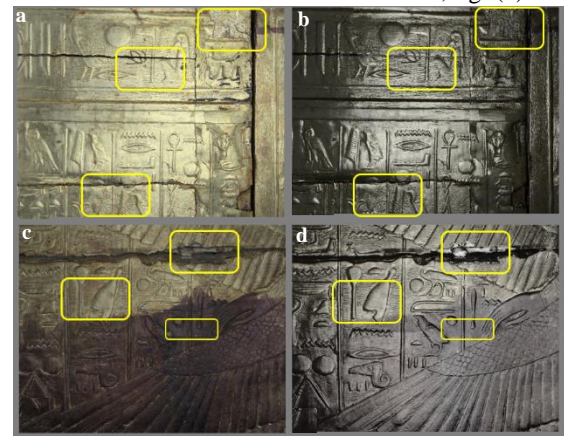
There are eight metal hoops for the two door bolts and seals, each approximately 0.8 cm in diameter. Carter described them as "silver coated copper handles of staple-like form" (CARD 238-21) [32]. Some of these metal hoops are covered with a thin, crystalline black material that can be rubbed off in places, staining the fingers. Lucas identified this material on several other silver objects as silver sulphide (TAA i.2.12a.5.15.jpg) [33]. Additionally, natural wood defects, such as wood knots, are evident, along with areas where ancient wood filler – composed of gesso and glue - was used to fill voids during the shrine's manufacture. The missing wooden planks, the position of metal and sawn wooden tenons, and the missing sections in the cornice were carefully documented to ensure these factors were considered during the dismantling process. 3D scanning has become an essential tool in recent years for digital documentation, shape analysis, conservation evaluation, and digital restoration of museum collections [34]. The 3D images provided detailed documentation of all inscriptions, deterioration aspects, and insights into ancient manufacturing techniques and technological

practices of that period. Areas of unsupported delamination, flaking and loss were particularly evident in the corner posts and at the points of contact between the roof and side panels. Figure (5-a) shows the missing wooden planks in the interior west side, the position of wooden and metal tongues, and buckling of gilded gesso, while fig. (5-b) of the exterior west side displays delamination of gilding, wax protruding from the gaps between the wooden planks and missing areas in the cornice. The 3D scanning proved especially valuable in documenting extensive areas of delamination and detachment of the gilding layers, and vulnerable areas requiring immediate treatment and conservation. This comprehensive documentation has been critical in planning the shrine's preservation and restoration efforts.



**Figure (5)** **a.** 3D scanning of the interior west side showing missing wooden planks, **b.** exterior west side showing protruding wax, buckling and missing areas in the cornice.

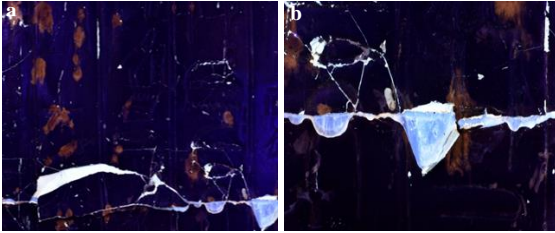
Reflectance Transformation Imaging (RTI) proved invaluable in documenting specific manufacturing details, such as the size of the overlapping gold leaf and the techniques used in its application, revealing different levels of workmanship. It also highlighted areas where modern gold leaf had been applied during previous restoration work, providing a clear distinction between ancient and modern interventions, fig. (6).



**Figure (6)** RTI photographic images; **a.** & **b.** top - missing areas in gold leaf revealing coarse gesso; middle and bottom - creases in the gold leaf, **c.** & **d.** top - paraffin wax seeping out; middle - creases in the gold leaf; bottom - faint border indicating overlap in gold leaf.

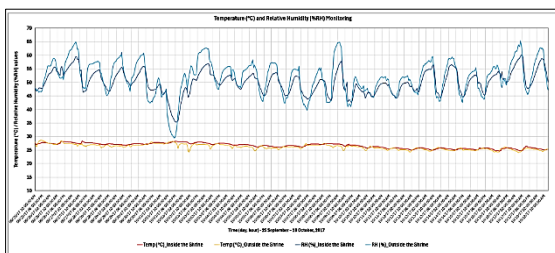
Ultraviolet light (UV) imaging, further emphasized previous conservation treatments, particularly the

presence of paraffin wax protruding from cracks in the wooden panels, fig. (7). This wax, while initially used to stabilize the shrine, has caused significant stress on the delicate gilded layers over time. These imaging techniques have provided critical insights into both the original construction methods and the long-term effects of past conservation efforts.



**Figure (7)** UV light used to document previous conservation treatments. The gilded surface appears cracked and fragmented, with evidence of lifting or displacement of the uppermost layers. This displacement is due to wax expansion beneath the surface, pushing apart fragile layers of gesso and gold leaf.

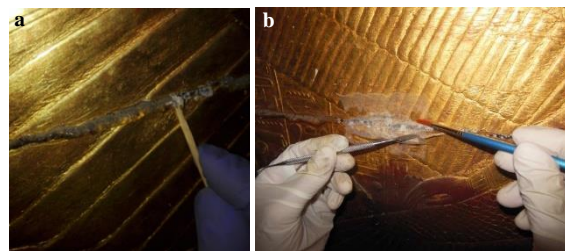
Data collected from the data loggers placed both inside and outside the shrine revealed fluctuations in temperature and relative humidity (RH%), fig. (8). The temperature values outside and inside the shrine were closely correlated, with a maximum of 28.5 °C, a minimum of 26 °C, and an average of 26.6 °C. Overall, the temperature remained relatively stable, with minimal fluctuations. In contrast, the relative humidity showed more significant variations. Outside the shrine, RH ranged from a maximum of 65.4 % to a minimum of 29.5 %, with an average of 51.8 %. Inside the shrine, RH % fluctuated between a maximum of 60 % and a minimum of 35 %, averaging 50 %. The highest relative humidity (RH) values were recorded in the early mornings (between 6 and 8 am), while the lowest RH values occurred in the late afternoons (around 4 to 6 pm). Relative humidity displayed significant daily fluctuations, ranging from 5% to 15% both inside and outside the shrine, with larger deviations of 25% to 30% recorded on certain days. These fluctuations in humidity, compared to the more stable temperature, highlight the need for careful environmental control to protect the shrine's delicate materials from potential damage caused by moisture changes.



**Figure (8)** fluctuations in temperature and relative humidity collected from data loggers placed inside and outside the shrine

#### 4. Conservation/Restoration

Principles of minimal intervention, reversibility, and material compatibility, were taken in consideration, with each treatment adapted to the specific condition and material sensitivity. Decisions regarding treatment levels and materials were made following thorough visual and analytical assessment, prioritizing the long-term stability of the shrine while preserving the original material. The conservation process began with the careful removal of accumulated dust using soft brushes. Harder accumulations were gently reduced with wooden spatulas and further cleaned with cotton swabs dipped in toluene. Cleaning the roof section revealed multiple cracks, missing areas, and tarnished gilding, highlighting the shrine's fragile state. The thick paraffin wax protruding from larger cracks was meticulously reduced using wooden spatulas, a painstaking and precise procedure requiring significant patience, fig. (9-a). Detached gilded gesso layers were stabilized using 5%-7% w/v Paraloid B72, an ethyl methacrylate copolymer in acetone, while larger detached areas required higher concentrations of 10 % - 15 % w/v Paraloid B72. In some sections of the detached roof, concentrations of up to 25% w/v Paraloid B72 were applied. Cracks were filled using a mixture of Microballoon filler and Paraloid B72. During the conservation work, several misplaced gilded gesso fragments were identified. These fragments were carefully removed and reattached to their original positions. All vulnerable areas were stabilized through consolidation, with detached gilding secured using 1 %-2 % w/v Klucel G, a hydroxypropylcellulose in ethyl alcohol, fig. (9-b).



**Figure (9)** a. reducing the bulging wax layer, b. fixing detached gilding using 1%-2% w/v Klucel G in ethyl alcohol.

A large void (missing area) in the cornice was temporarily consolidated using Balsa wood and cotton wool to prevent further loss of the weak edges during dismantling, fig. (10). This temporary measure will be reversed once the shrine reaches its final destination. Finally, all vulnerable areas were faced using 9 g. tissue paper and 1% w/v Klucel G in ethyl alcohol. The interior of the shrine was almost entirely faced, fig. (11), while the exterior facing was postponed until closer to the dismantling date. The shrine was then housed in a temporary showcase, prepared for dismantling and transfer to its new home at the Grand Egyptian Museum (GEM).



**Figure (10)** temporary consolidation of a large void with balsam wood



**Figure (11)** facing performed on the interior of the shrine using 9g. tissue paper and 1% Klucel G. w/v in ethyl alcohol

## 5. Discussion

Over the past century, Tutankhamun's innermost shrine has gone through a remarkable journey of discovery, conservation, and study. From the moment Howard Carter and his team first unveiled the shrine in the 1920s, it has triggered both fascination and challenges. The early conservation work, led by Carter and Alfred Lucas, were revolutionary for their time. They accurately documented the shrine's construction and materials, identifying the types of wood, gesso layers, and gilding techniques used by ancient craftsmen. They employed materials like paraffin wax to stabilize the fragile shrine, which, while effective in preserving Tutankhamun's funerary possessions to this day, is considered controversial by modern conservation standards. Paraffin wax can penetrate deeply into porous materials such as wood, textiles, or painted surfaces, and once applied, it cannot be completely removed. In warm conditions, it softens and may seep out through cracks, displacing surface layers and contributing to structural instability in fluctuating climates. Over time, it can become brittle, crack, or discolor, leading to both physical and visual deterioration of the object [35]. In the decades that followed, conservators continued to monitor the shrines' condition, addressing issues like delamination, and the effects of environmental fluctuations. Periodic first aid treatments were carried out to mitigate these

effects, though detailed records of these interventions were not available. Modern investigative techniques, including 3D scanning, X-radiography, and RTI imaging, have provided valuable information about the shrine's construction, current condition, and past conservation efforts. These tools allowed for precise mapping of deterioration, identification of ancient manufacturing techniques, and the planning of targeted treatments using reversible materials. By understanding the ancient manufacturing materials and techniques used and revealing all the past conservation treatments using scientific approaches, it was possible to plan and execute the stabilization of such a fragile composite artifact. The successful transfer of the shrine to the Grand Egyptian Museum (GEM) stands as a demonstration to the combined commitment of generations of conservators, archaeologists, and specialists working together to safeguard our cultural heritage.

## 6. Conclusion

*The extensive work carried out by Howard Carter, Alfred Lucas and Arthur Mace in documenting, analyzing and conserving the vast collection of Tutankhamun's funerary possessions is deeply appreciated. Their detailed records, excavation diaries, and publications have laid the foundation for modern archaeometry and conservation science. While some of the materials and methods used for the consolidation of the composite shrines are now considered less suitable by today's conservation standards, the authors believe that these early efforts played a crucial role in preventing further deterioration. Although, these measures didn't entirely stop the delamination and detachment of the gilded gesso, nor fully protect the shrine, they have, to a large extent, contributed to maintaining its stability over the years, despite unfavorable environmental factors. The current conservation team and specialists are, in many ways, following in the footsteps – Carter and Lucas – carrying out similar processes of documentation, investigation into manufacturing techniques and condition assessment. All necessary conservation treatments were completed before dismantling the shrine and transferring it to its new destination. Modern investigative techniques have enhanced our understanding of the shrine's history and helped greatly in revealing the secrets of the past and applying suitable conservation materials. Nevertheless, the current approach prioritizes minimal intervention, with an emphasis on preserving the integrity of the object.*

## Endnote

(a) Personal communication

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