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DIAGNOSIS OF THE DETERIORATION AND CONSERVATION OF BES POTTERY JAR FROM THE TOMB OF PETAH UMM UYA IN SAQQARA

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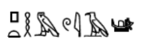
Abstract
The purpose of this study was the chemical characterization and conservation of the Bes pottery jar. Pottery jars were important in Egypt from prehistoric times until the end of late history; they had their ideological symbolism and important role in daily life. "Bes" jar is a kind of healing jar, which was known and spread during the end of the New Kingdom and Late Period of ancient Egypt. AutoCAD, digital microscope, and polarized microscope (PLM) were used to clarify the deterioration state of the pottery jar. The XRD method was used to investigate the mineralogical composition of the pottery jar. Besides, the pottery's internal morphology and chemical composition were studied using scanning electron microscopy with energy dispersive X-ray spectroscopy (SEM-EDX). The examination revealed that the selected pottery jar exhibited numerous cracks, dust accumulation, salt crystallization, and black spots. PLM showed the presence of several minerals, such as calcite, quartz, biotite, and plagioclase. SEM-EDX analysis revealed high calcium oxide concentrations due to the use of calcium carbonate in the slip layer, besides chloride salts. XRD analysis indicated that quartz was the predominant mineral in all the samples. Additionally, calcite, diopside, anorthite, halite, and dolomite were also detected in varying proportions. The pottery jar underwent various treatments, including mechanical and chemical cleaning. In addition, dental gypsum and grog were used in the completion process. Furthermore, the paraloid B-72 was used to achieve the consolidation process.

***Keywords**: Pottery; Deterioration; PLM; SEM-EDX; XRD; Conservation Science*

Introduction

Pottery was one of the most important productions by the ancient Egyptians from prehistoric periods. It represents a vital record and source of analysis for understanding various ancient times. The study of pottery has made significant contributions to the understanding of various periods in Egyptian history [1]. Ancient Egyptians utilized pottery in the same way that we do now. Egyptians started making pottery around 4,000 BC. Old Kingdom potters successfully introduced the potter's wheel. Through the study of ancient pottery's material, technological aspects, and form of ancient pottery, archaeologists have successfully determined the date of Egyptian sites [2]. Petah Umm Uya () held significant positions of great importance during the reign of King Ramses II, signifying his close association with the royal palace and his elevated status within it towards the end of King Ramses II's rule. One of the most important of these titles was "Royal Scribe". In addition, he held the priestly title

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"High Priest", "Supervisor of the Treasury of the Temple of Millions of Years", and "King of Upper and Lower Egypt (Ramses II) in the Possessions of Amun in Memphis" [3].

In Saqqara, a cemetery was discovered containing several tombs for the great men of the new kingdom [4], especially the tomb of Horemheb, the final Pharaoh of Ancient Egypt's 18th Dynasty. He had two tombs: the one he commissioned as a private citizen at Saqqara near Memphis [5] and the tomb KV 57 in the Valley of the Kings [6]. Within the excavation site, there are tombs belonging to esteemed individuals from the nineteenth Dynasty of the modern state. These tombs serve as a valuable addition to the existing tombs from the eighteenth Dynasty. Besides, Horemheb, the military commander's site, is the most important. The importance of discovering this tomb is due to the positions held by its owner, "Petah Umm Uya," as the royal scribe, chief of the treasury, chief supervisor of livestock, and responsible for divine offerings in the temple of Ramesses II in Thebes. Petah Umm Uya was an ancient Egyptian official who lived under King Ramses II in the 19th Dynasty, around 1250 BC [2].

Among the significant archaeological finds in the tomb are a few pottery vessels lacking specific archaeological features that indicate they date to King Ramses II. They are generally similar to the pottery of the late era [7], with some patterns of pottery vessels that were prevalent in Palestine then [8]. The type of pottery and whether it is local can be determined by studying and analyzing the composition of these pottery vessels. It is known that Nile silt is devoid of straw, but it is full of fine and coarse sand particles and mica. It is soft and homogeneous silt that burns between 700 and 750°C. It was used since the Badari period and remained known during the ancient era, reappearing in the Middle Kingdom's late stages and continuing during the Second Intermediate Period. It was rarely used in making local pottery models and in lining bread molds. Archaeological excavations in Elephantine showed that this clay was used to manufacture hemispherical cups and small bowls since the middle of the Twelfth Dynasty and until the Thirteenth Dynasty, and perhaps in making small funeral vessels [9].

The cult of "Bes" was widely known in ancient Egypt. Additionally, he was believed to be the god of music, joy, and childbirth. Therefore, it was believed that Bes protected women and children [10]. In ancient Egypt, some gods had temples, while others were worshipped at home. These lesser gods were occasionally referred to as 'demons' and were depicted with intimidating appearances intended to ward off evil spirits. The god "Bes" was considered fun-loving and drove away evil forces. His image appears on household objects like mirrors, decorative pots, and wine jars [11]. Early representations of "Bes" depicted him as a lion-legged guy with a mane and tail. Over time, his image changes, becoming smaller, but he keeps the lion's shape and carries knives or a tambourine [7]. The ancient Egyptians believed that "Bes" was protected from evil spirits trying to infiltrate the house. In addition, it was believed that "Bes," a protector, was a protective deity for married couples and pregnant women [12].

This style of jars was used in ancient Egypt to preserve liquids, especially milk and water. It was used to feed children with milk from "Bes" jars in the hope that milk would turn into a medical treatment or medicine, which was common at the end of the New Kingdom and the Late Period. So, many jars or vessels were made in the shape of "Bes" or its head instead of him. The liquid within these jars was believed to acquire the god "Bes" healing properties. So, it was often used in medical practices and in protecting pregnant women and children [13]. A good characterization of archaeological pottery contributes to the process of preservation, restoration, and assistance in archaeological studies that include (i) the source of historical raw materials, (ii) changes in archaeological artifacts caused by burial processes, and (iii) the determination of firing temperature [14]. This study aimed to investigate the pottery jar to identify the various aspects of its deterioration. Besides, intervention is needed to carry out the necessary restoration operations to preserve this jar.

Experimental part

Materials

A Bes pottery jar was selected from the tomb of Petah Umm Uya in Saqqara. This jar represents fine Nile silt fabric with one vertical handle, a long cylindrical neck, a ridge around the rim, and a ring base. One side of the jar displays a depiction of the god Bes, created using a combination of incised and applied relief decoration. It is noted in the current jar that it is complete. Besides, the neck is characterized by elongation. In addition, a similar jar was found in Fayoum among nine pottery vessels of the near shape as the current style. The age of this jar can be determined by comparing it to a similar jar housed in the Petrie Museum of Egyptian Archaeology at University College London (UC 2888). This similar example dates to the era of Dynasty 26÷29. Therefore, it can be said that this jar's date is probably back to the end of the new kingdom and the Late Period [7] (Fig. 1).

Fig. 1. Bes Jar from the tomb of "Petah Umm Uya"

This jar suffers from various aspects of deterioration. So, various examination and analysis techniques were employed to determine the causes of the pottery jar's damage. To facilitate discussion, the archaeological samples were coded (Table 1).

Table 1. Different pottery jar samples under study

Samples Code	Samples Description
B1	includes all parts of the body
B2	part of the surface with salts and dust

Methods

One of the primary and most significant methods for determining the problems with the pottery jar is through this examination. It is possible to determine the object's condition and provide a preliminary evaluation through visual examination.

The pottery jar's dimensions and the various types of damage were recorded using AutoCAD version 2020. An USB Digital Microscope (model PZ01, magnification from 10 to 500×) was used .

Thin sections of pottery samples were prepared to determine the petrographic composition and then analysed using a polarized microscope (PLM). Nikon ECLIPSE LV100POL polarized microscope (DS-FI1) was used. The petrographic examination reveals numerous microscopic features that aid in the description of the main minerals.

This study used SEM Model Quanta 250 FEG (Field Emission Gun) connected to an EDX Unit (Energy Dispersive X-ray Analyzes), with the following technical specifications: 30kV accelerating voltage, magnification 14 to 1,000,000×, and resolutions for Gun.1n, FEI Company, Netherlands.

Cu-radiation (λ = 1.542Å) at 45kV, 35mA, and scanning speed 0.04 o/sec were used with Malvern PANalytical X-Ray Diffraction equipment model X`Pert PRO with a secondary monochromator. The diffraction peaks between $2\theta = 2^o$ and 60^o, corresponding spacing (d, Å) and relative intensities (I/I^o) were obtained. The diffraction charts and relative intensities are obtained and compared with the International Centre for Diffraction Data (ICDD) files.

Results and discussion

The main goal of this stage is to identify the different types of deterioration, as a visual examination is one of the most crucial steps in the restoration process. This jar suffers from a heavy accumulation of salts and dust on the outer surface, in addition to losing a large part of the nozzle (Fig. 2).

Fig. 2. Bes's pottery jar under study

The dimensions of the pottery jar were clarified and documented using the AutoCAD program. In addition, recording the different aspects of deterioration, such as the presence of dirt, salts, and sand that have spread out on the surface (Fig. 3).

Optical microscopy (OM)

To determine the various aspects of damage that are invisible to the naked eye, this microscope was used to examine the pottery jar at magnification between 20 and 200× [15]. The accumulation of salts and dirt on the pottery jar's surface is also visible through examination (Fig. 4).

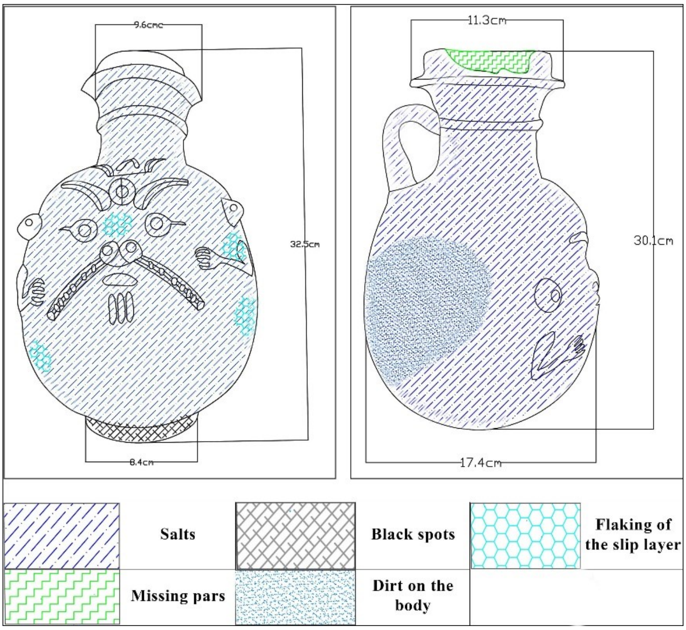

Fig. 3. AutoCAD documentation of the various aspects of pottery jar deterioration.

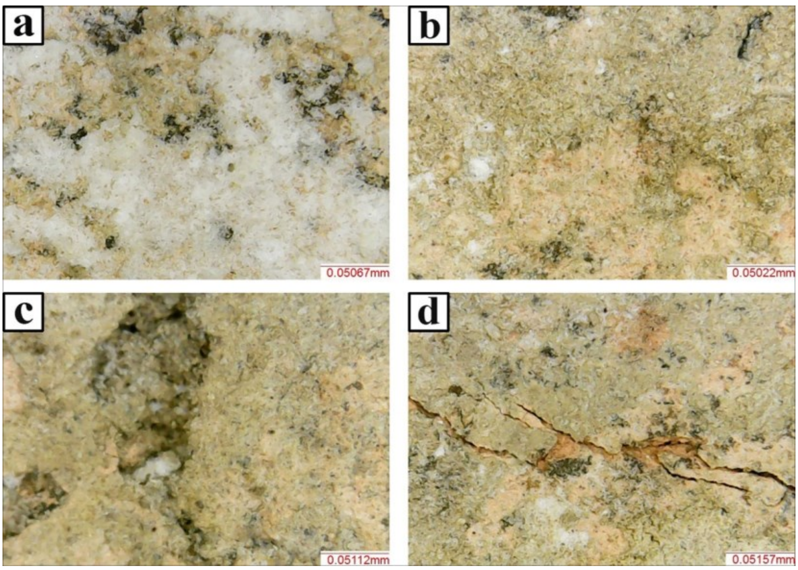

Fig. 4. The deterioration present in the pottery Jar: **(a)** dense salts which cover large parts of the body with the presence of black spots; **(b)** accumulation of dust on the outer surface; **(c)** pits and holes filled with dirt and sand; **(d)** cracks extending from the slip layer to the depth of the body.

Polarized Microscopy (PLM)

A polarizing microscope can be used to study the shape, size, and nature of various types of embedded grains and the pottery matrix, allowing the identification of raw materials that make up archaeological pottery [14]. It is clear from the examination that sample B1 consists of calcite (C), which was used as part of the components of the outer slip layer applied to the surface. In addition, the sample contains quartz (Q), one of the most common components of pottery [16, 17]. In addition, biotite (Bi) was present in the sample, indicating that the clay used was Nile clay. Clay is the matrix in pottery jars, and sand or straw is the fillers, which archaeologists refer to as admixtures. The materials used in ancient Egyptian pottery frequently include these organic or inorganic additions [18] (Fig. 5a and b). On the other hand, sample B2 contains plagioclase feldspar (Pl), indicating that the raw clay was obtained from the Nile. The presence of plagioclase crystals in the sample indicates an increase in firing temperatures above 800°C [19]. In addition, different grain sizes and shapes of quartz can be found in the iron oxide-rich ground (Fig. 5c and d). The size of the granules in the jar ranges from fine to coarse. It seems that the arrangement of the grains and their form determine the texture. Additionally, the kind of clay, shaping method, surface treatment, and firing all affect the texture [20].

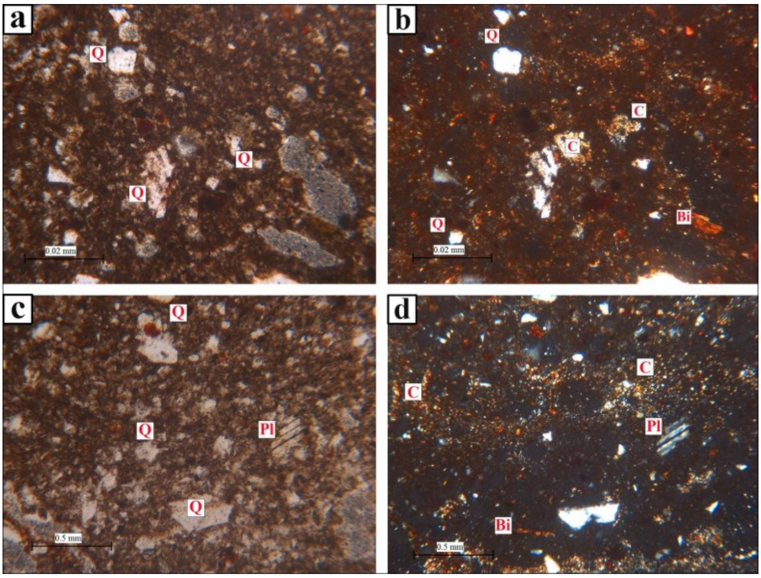

Fig. 5. The results of the polarized microscope's examination:
(a, b) sample B1; **(c, d)** sample B2

SEM-EDX

Examination using SEM helps to study the condition of the pottery body. It is clear from the first microscopic image a heavy accumulation of salts, dust, and sand on the outer surface. Furthermore, the abundance of dust on the surface is caused by long-term burial in the soil, which results in surface deformation and the covering of the slip layer (Fig. 6a). Besides, the second microscopic image shows cracks of different sizes, extending from the surface of the pottery body, in addition to the fragility of the pottery body and the penetration of salts into the pottery body. Cracks in pottery can occur due to two main reasons: the swelling of the clay as it absorbs moisture, or the uneven drying process leading to shrinkage. Additionally, certain cracks can be attributed to internal pressures caused by salt crystallization within the pottery. (Fig. 6b).

SEM-EDX analysis has become widely used for identifying the main components of the pottery body [21]. SEM-EDX analysis results reveal that sample B1 contains a high percentage of calcium oxide because of using calcium carbonate in the slip layer (Table 2). In addition to increasing the proportion of silica, aluminium and iron oxide, which are the main components of clay. Besides, the analysis revealed the presence of a ratio of magnesium oxide, indicating that the clay consists of montmorillonite $[(Na,Ca)_{0.3}(Al,Mg)_2Si_40_{10}(OH)_2 \cdot n(H_20)]$ (Fig. 7a).

While a high ratio of chloride salts, particularly sodium chloride, is present in Sample B2, which may have migrated from the nearby soil. Additionally, there is a tiny percentage of sulfate salt (Fig. 7b). The formation of salt crystals is a significant form of damage observed in pottery that has been buried in soil. This is particularly noteworthy because pottery is a material that readily absorbs water-containing salts from the surrounding soil due to its hygroscopic nature [17].

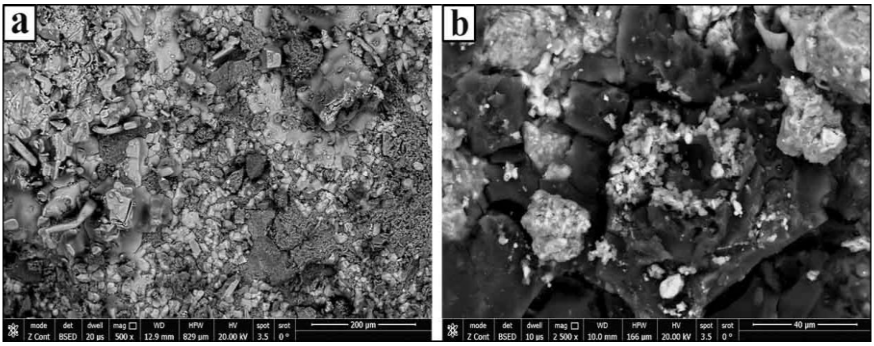

Fig. 6. SEM examination of a pottery jar:
(a) the surface accumulation of salts, dust, and sand; **(b)** various sizes of cracks, ranging from fine to medium in size.

Table 2. The element concentration (Wt. %) in pottery jar samples

	Elements								
Sample code	O	Na	Mg	Al	Si	S	Cl	K	Ca	Fe
B1	20.71	1.59	4.95	9.14	33.40	-	-	0.64	23.54	6.03
B2	13.93	26.34	0.36	1.23	2.77	0.22	39.05	0.49	13.02	2.59

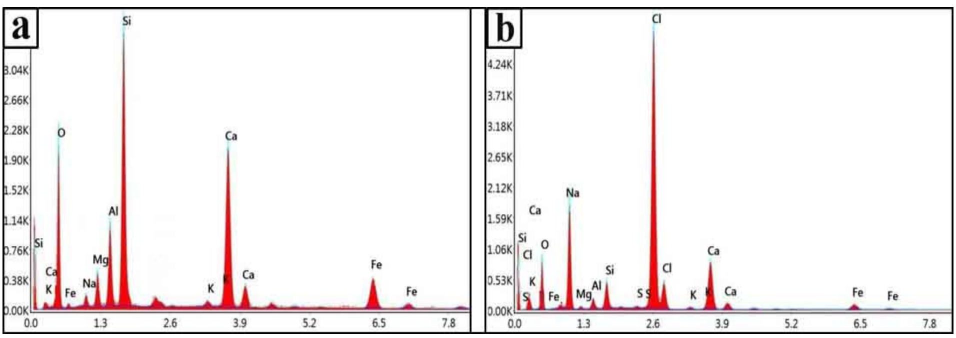

Fig. 7. SEM-EDX spectra results: **(a)** B1; **(b)** B2.

XRD Mineralogical Analysis

The most frequently used method for quantitatively characterizing mineralogical composition is X-ray diffraction (XRD) [22]. The XRD results of the samples examined are shown in Table 3 and Fig. 8. Sample B1 consists of a variety of components, including quartz, calcite, diopside, anorthite, tridymite, and dolomite (Fig. 8a). Quartz is one of the sample's fundamental components. Calcite is one of the main components of the white outer lining layer. In addition, pottery from that period was distinguished by adding calcareous clay to treat the outer surface during the shaping process [23]. The presence of diopside indicates a rise in temperatures between 850°C - 900°C. Besides, it is considered one of the types of silicate that forms at high temperatures. Dolomite may be a component of the slip layer or raw material for molding [24]. Determining archaeological pottery firing temperatures is critical in understanding ancient humans' technological practices [16].

The mineral content of the clay used, the firing conditions, and the duration of the firing process will all affect the composition of the pottery body [21]. Anorthite is related to clay minerals. Calcite decomposition in the presence of quartz and clay minerals may result in the crystallization of anorthite at appropriate temperatures [25]. Tridymite is a polymorph of high-temperature silica. In addition, it is formed at a temperature higher than 870°C [26]. Sample B2 contains quartz, calcite, illite, halite, and magnesium sulfate, according to the XRD pattern (Fig. 8b). Illite is categorized as traces from the surrounding soil and dense dirt adherent to the outer surface. In addition, due to the influence of the burial environment on the pottery object, halite and magnesium sulfate appear in high percentages, and they are considered water-soluble salts. The salts migrate from the surrounding soil to the pottery jar, causing optical distortion and forming cracks and separations in the outer slip layer [27].

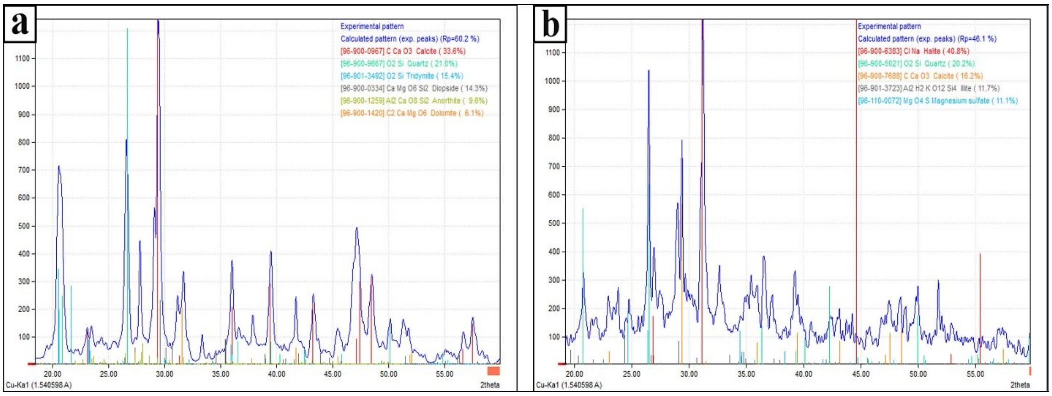

Fig. 8. The pottery samples' XRD patterns: (a) sample B1; (b) sample B2

Table 3. X-Ray diffraction results for pottery jar components (%)

Component	Chemical composition	B1	B2
Quartz	SiO_2	21	20.2
Calcite	$CaCO_3$	33.6	16.2
Diopside	$CaMgSi_2O_6$	14.3	--
Illite	$KAl_2(Si,Al)_4O_{10}(OH)_2$	--	11.7
Anorthite	$CaAl_2Si_2O_8$	9.6	--
Tridymite	SiO_2	15.4	--
Halite	NaCl	--	40.8
Magnesium sulfate	$MgSO_4$	--	11.1
Dolomite	$CaMg(CO_3)_2$	6.1	--

Treatment and conservation of the pottery jar

Cleaning

The first and most difficult task is cleaning. Before cleaning an object, it is essential to comprehend the type of dirt and how the surface has changed over time. The primary objective of cleaning pottery artifacts is to remove any undesirable materials without causing damage to the surface of the pottery itself [28].

Mechanical cleaning removes foreign material from an object's surface using an external force. This process is highly controlled and favored to reduce the need for additional chemical methods. Simple tools are used for the majority of mechanical cleaning [29]. Soft and coarse brushes of various shapes and sizes were used to remove dirt from the surface [30].

Cotton swabs immersed in ethyl alcohol (50% in distilled water) were used for chemical cleaning to remove solid stains. Furthermore, dirt was eliminated using acetone. To prevent the high concentration of the utilized solutions from harming the slip layer, the treated surface was regularly diluted with distilled water [31]. The jar under investigation had some salt deposits. First, soft hairbrushes and scalpels were used to remove the salts of chlorides mechanically. Next, a cotton poultice saturated with distilled water was used to extract the soluble salts of halite. The time required to extract soluble salts varied according to the size of the pottery objects [32] (Fig. 9).

Fig. 9. Various cleaning techniques: (a) mechanical cleaning; (b) chemical cleaning

Completion

The completion process's importance appears in preserving the archaeological pottery from erosion of the missing part's edges [33]. This process is crucial for pottery objects because it strengthens the artifacts and prepares the finished object for museum display. Depending on the condition of the pottery, the completion can be applied using the appropriate filler. Dental gypsum was combined with grog (new pottery powder) and Primal AC33 15% to fill in the missing part. Because it is chemically inactive, this mixture is regarded as a good filler that can be used to complete pottery [34] (Fig. 10a).

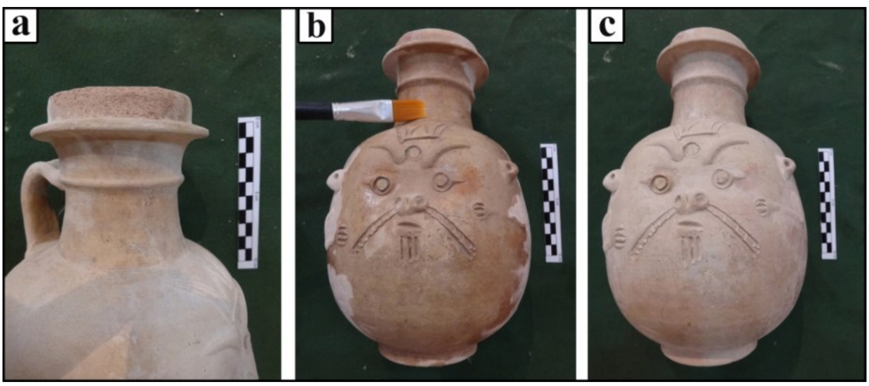

Fig. 10. The pottery jar's various stages of treatment: (a) after applying the completion material; (b) applying the consolidation material; (c) the jar pottery after completion.

Consolidation

Consolidation is considered one of the primary goals of archaeological pottery conservation. This process aims to achieve stability while improving physical and mechanical properties [35]. Consolidation is typically applied as the final step to provide long-term strengthening and protection against atmospheric conditions. Various polymeric materials are used for this purpose, but nanomaterials have been successfully used for the last few decades [30]. Paraloid B72 5% / ZnO 3% nanocomposites were used based on experimental approaches. Brushing was used to apply the consolidation material, which was done three times in two hours. Polyethylene sheets were used to cover the surface to stop the consolidation material from evaporating too quickly [36] (Fig. 10b).

Conclusions

"Bes" jars vary, ranging from small cups to large jugs. It can be used to store medications. It also had an ornament or inscription depicting the face of "Bes", the god of medicine. This type of jar can be considered one of the first medical jars known in ancient Egypt. The micrograph photo revealed cracks spreading throughout the body and a significant accumulation of salts, dust, and sand on the exterior surface. A polarized microscope showed the presence of various grain sizes and shapes of quartz. The results of various analytical techniques (SEM/EDX, XRD) revealed that the clay used to make the pottery jar consists of montmorillonite due to a magnesium oxide ratio. Besides, calcite is abundant due to the use of calcareous clay to treat the outer surface. Based on XRD analysis, it was estimated that the pottery jar's firing temperature was between 850°C - 900°C. Due to the poor state of the pottery jar, various restoration stages had to be carried out to keep it from damage. A cleaning process was conducted to remove the solid accumulation and salts. In addition, the missing part was completed using dental gypsum and grog. Finally, the pottery jar was strengthened using Paraloid B72 5% / ZnO 3% nanocomposites.

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