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MEDIEVAL METALS, MODERN MINDS: CONSERVING AND EXHIBITING HISTORIC COINS THROUGH AI

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Abstract:
This study discusses the nature of microchemical surface and conserving of two coins dates back to Ayyubid and the Zengid periods with microscopic examination, Scanning Electron Microscope (SEM) coupled with (EDX) and X-ray diffraction (XRD which used to identify and analyze the metal and corrosion products on these coins' surfaces which confirmed that the two coins are made of copper or its alloys, but they are covered with corrosion products in different areas on both sides of the coins, with other signs of damage such as pitting and erosion. For the conservation of the coins, it was necessary to remove the corrosion layers covering the coins completely. The treatment and conservation process were carried out by carrying out the cleaning stages, including mechanical and chemical cleaning, then the coins had been rinsed, dried, coated and stabilized with acrylic resin in preparation for museum display. To display the ancient coins, a smart display showcase managed by artificial intelligence was proposed to display the various ancient coins by presenting an idea to display the coin in a modern display showcases that suits the visitor in terms of visibility, and height and has specifications in the manufacture of modern materials that are not harmful to metals and are attractive at the same time, supported by artificial intelligence features to control the safe display showcase for archaeological coins through applications that can be installed on mobile phones and are useful in museum management Museum curators and restorers by controlling safe display conditions.

1. Introduction

Coins are a valuable source of information about the economy, history, and art. In addition to the alloy's composition, written papers typically provide further information in the form of effigies, brief inscriptions, and helpful symbols [1]. Because coins are made of metal and have uniform patterns, it might be challenging to pinpoint the true origin of the oldest coins. Greece was the birthplace of coin. Greece was a country where coin was frequently used. Coins have been around for more than 2,000 years [2]. Islamic coins covered a territory that stretched from Malaya and Indonesia in the east to Spain and Morocco in the west during a period of approximately 14 centuries. In practical terms, the coin of the Near and Middle East following the establishment of Islam in the seventh century is referred to as "Islamic coinage." [3,4]. The use of Naskh lettering on gold, silver, and copper coins, the last metal (copper), come to Egypt in substantial amounts for several centuries, is the only noteworthy development for the final years of Ayyubid and Zengid in Egypt [5]. After being exposed to atmospheric gases for a century, metals begin to corrode. This can happen in both aerobic and anaerobic micro-environments, and chloride ions are a fundamental component of the corrosion process, either by influencing the oxidation process' kinetics or by aiding in the formation of corrosion products [6]. In order to reduce the harmful effects of moisture, increased oxygen supply, and residual chlorides, stabilization of artifacts following excavation is crucial [7], Coins and other archeological metals are typically subjected to the corrosion process when they are buried in the ground for extended periods of time or when they are exposed to unfavorable environmental conditions, such as excessive humidity and air pollution. In recent years, important studies have been conducted to characterize changes occurring in archaeological metals to understand their corrosion mechanism and morphology as well as conservation conditions. The long-term burial conditions in soil cause various corrosion morphologies in archaeological metals, from a thin corrosion layer to a completely corroded and mineralized artifact [8]. Metal corrosion is impacted by several factors that are difficult to identify with precision [9]. According to the following equation, metal corrosion results from a process known as "redox," which occurs between the metal and oxidizing substances found in the surrounding environment [10]. The primary constituents of air are a complicated com-bination of several gases, including sulfur dioxide, nitrogen oxides, and ozone. Damage to several artifacts can result from these tiny concentrations [11]. In enclosed environments, metals are susceptible to corrosion, and the degree of internal corrosion rises with increased relative humidity and is contingent upon the kind and quantity of contaminants present [12,13]. As temperature rises, so does the rate of chemical interactions between the metal and its surroundings. This is because temperature influences the variables that regulate the rate of diffusion and oxygen solubility, which in turn impacts the pace of corrosion [14]. Apart from outside pollution sources, metals can also be exposed to some indoor contaminants found in confined environments. NH_3, O_3, H_2S, SO_2, NO_2, O_3, HCl, HNO_3, and Cl^- are some of these pollutants [15]. The primary factors influencing the rate of atmospheric corrosion are contaminants found in the atmosphere and the amount and frequency of wetness, or the pace at which metal surfaces become dry [16], However, since there are two main ways that air pollutants are transported—through dry and wet deposition processes—humidity, precipitation, and wind are crucial factors that determine the kind of electrolyte present at the metallic contact [17]. Cuprite, the first product of copper corrosion, is formed epitaxially when copper reacts directly with water molecules or dissolved oxygen. Because of its high electrical conductivity, cuprite facilitates the precipitation. Depending on the environment in which the copper trace is present, these processes result in the formation of different copper corrosion products, such as corrosion products made of carbonates, sulphates, sulphides, or chlorides [18]. The durability of metal artifacts during preservation and exhibition may be jeopardized by the process of corrosion. Concentrations of gaseous substances that release slowly, such ethanoic (acetic) acid or carbonyl sulphide, can accumulate to significant amounts in enclosed spaces like exhibition cases, which might hasten the corrosion of some metal artifacts [19]. The exhibition of museum objects is one of the most important stages in highlighting their historical, cultural, and artistic significance. These artifacts are on display in a special showcase made of materials that are secure for them. This study aims is to investigate the nature of corrosion grown during the long-time and identify its products that will help us understand the corrosive factors and the degradation mechanisms, Identifying corrosion compounds and analyzing them using appropriate methods, Cleaning the coins from the deterioration aspects and the corrosion products in order to discover as much as possible the surface topography, and to reveal the surfaces details Stabilize the coins against further deterioration, Also, the research was based on a modern way to display ancient coins using artificial intelligence where the idea that exhibit cases need to be made of strong, non-toxic materials, just like storage containers. The same requirements should apply to all lining materials, especially those that come into close touch with coins. Coins are an often-overlooked source of information about the links between rulers in a region's history. They are able to supply the whole power structure at the minting time and place, ranging from the local governor to the caliph [20].

2. Studied Coins

2.1. *Coin no. 1*

IT is the Mayyafariqin's Ayyubids, al-Ashraf Muzaffar al-din Abul Fath Musa Ibn Al'Adil I, 607-617 AH / 1210-1220 AD, Al-Ashraf Musa reigned in Damascus from 626-635 / 1229-1237, however the caliph and only name on all coins minted in Damascus during that time was al-Kamil Muhammad I [21]. The obverse of the coin, fig. (1-a) shows a turbaned prince holding an orb. The obverse also shows the word (al-Ashraf) and the rest is not legible. The coin's reverse, fig. (1-b) shows the words "al-Imam al-Naser L'din Allah Amir al-Muaminin al-malik al-Kamel Mohammad. Date: The coin was minted in (648-652 AH)- (1250-1254 AD) al-Ashraf's reign. Size and Weight: This is a dirham, weighs ~10.6 grams, and is ~35.5 mm in diameter.

Figure (1) **a**. obverse side shows a turbaned prince holding an orb, **b**. the words "al-Imam al-Naser L'din Allah Amir al-Muaminin al-malik al-Kamel

2.1. *Coin no. 2*

dates back to The Zengids. The Zengids were a powerful dynasty based in Mosul. Their coins are of a particular interest as they were not designed purely inscriptional but, unlike most other Islamic coins, bore images. The obverse of this dirham, fig. (2-a) shows a bust with two Victories above; they hold palm branches in their hands. The Cufic inscription on the reverse gives the names and titles of the issuer, fig. (2-b). Date: The coin was minted in (1149-1170) date back to Emir Qutb ad-Din Mawdud. Size and Weight: This is a dirham, 11.44 gm, and is 28 mm in diameter.

Figure (2) **a**. obverse side shows a bust with two Victories above; they hold palm branches in their hands, **b**. the names and titles of the issuer, Emir Qutb ad-Din Mawdud (1149-1170).

3. Materials and Methods

3.1. *Visual observation and microscopic examination*

In order to describe the examined coins, ascertain their state, and recognize the many kinds of corrosion products that have covered them using a Smart-Eye USB Digital Microscope at a magnification of 500-X to 1000-X the corroded surfaces of the coins were inspected both visually and microscopically. Microscopic analyses were performed to identify the morphological characteristics of the corrosion products and investigate the patina's composition.

3.2. *Scanning electron microscope (SEM) coupled with (EDX)*

The surface of the coins was examined and analysed using scanning electron microscopy (SEM) and energy dispersive spectrometry (EDX), which allowed for the determination of the microstructure of the coins' surfaces as well as the appearance of deterioration spots and the distribution of chemical elements on the corrosion layer and in the core. Using a scanning electron microscope (SEM) (FEI-QUANTA 200 SEM), Landing Voltage 20.0 K.V., WD 8.4 mm, Magnification x30 with High vacuum Mode at Central Lab, SEM micrographs and EDX spectra of the chosen coins were acquired. Egypt's Minia Univ. is a center for microanalysis and nanotechnology.

3.3. X-ray diffraction (XRD)

The coin was analyzed using X-ray diffraction (XRD) to determine the composition of the crystalline corrosion products of the coin, to comprehend the corrosion mechanism, and to determine the types of conservation treatment. X-ray diffractograms were recorded using a JSX60PA JEOL diffractometer (Japan), equipped with Ni-filtered Cu_k radiation (=1.54056), and operated at 35 kV and 20 mA in the Central Lab. For Microanalysis and Nanotechnology, Minia Univ., Egypt.

4. Results

4.1. *Visual observation and microscopic examination*

Visual inspection and microscopic examination shown in fig$_s$. (3) revealed that a thick layer of deposits, encrustations, and corrosion products coated the discovered ancient coins. The alteration crust that developed on the mineralized surface of the alloy was a clear indication of the consequences of the chemical processes that altered its surface. Examinations under a microscope revealed that the coins were heavily corroded, with a thick coating of corrosion in several areas. In addition, the microscopical analysis revealed that the coins had pitting, erosion and blurring of several text areas on both sides as well as partial edge loss. Furthermore, black and green corrosion products are covering the corrosion on the two sides.

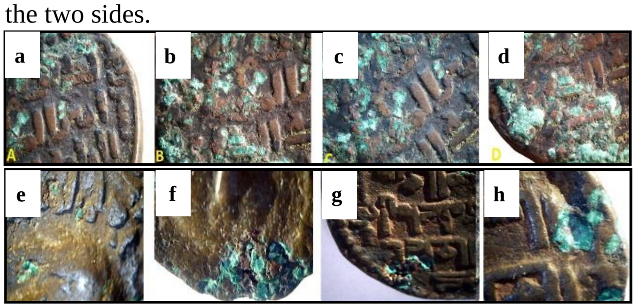

Figure (3) USB photomicrograph of the Coin 1 surface deterioration; **a**. erosion, **b**. pitting, **c**. black corrosion, **d**. green corrosion. Coin 2 surface shows; **e**. erosion of letters, **f**. corrosion products, **g**. corrosion products within the surface, **h**. loss of part of the edge with corrosion product inside.

4.2. *SEM-EDX*

SEM study a surface of two coins shown in fig. (4) presented a degradation in surface shape and structure. The metallic coin's surface core contains separate pitting, holes, and uneven topography. There are also regions of darkness, which indicate pitting corrosion. The results show that the coins surface and inscriptions were partially obscured by a layer of corrosion products that covered them. This composite layer is plainly visible in SEM photomicrographs. Also, the results show that these coins were heavily corrosion layers and fragile and the surface pattern is irregular, granular, widespread, and covered with crystallized components.

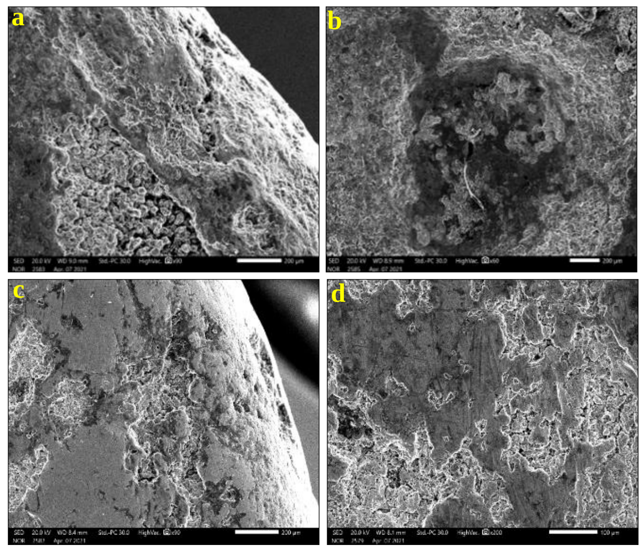

Figure (4) SEM photomicrographs show surface morphology of; **a.** Coin 1, revealing pits, corrosion products, and numerous holes on parts of the surface; **b.** Coin 1, revealing corrosion products mixed with a black corrosion layer on the surface, **c.** Coin 2 revealing corrosion products on parts of the surface (pitting corrosion), **d.** Coin 2 revealing corrosion spread over different parts of the coin.

EDX analysis of two coins detected prior to cleaning are displayed in tab. (1) & fig$_s$. (5-a & b) and explain it with graphical fig$_s$. (5-c & d). The contaminating elements identified in the coin's corrosion layer by EDX analysis include Cu, O and C in the two coins as a major element, which are connected to the composition of metals. Also, there are minor elements Si, Ca, Mg, K, Cl, and Al in the coin 1. and Si, Cl, and Ca in the coin 2. Furthermore, the components Si, Al, S, Ca, Mg, and Cl show how closely soil constituents and corrosion products are related, Especially the chloride ion which strongly indicates that these coins were affected by an environment rich in chlorides. These results suggest that all of those materials are exogenous elements that came from soil contamination during the patina formation process or even from soil particles that were mixed with corrosion products, carbon and oxygen both confirm this description. These results show that copper corrosion products make up the majority of the corrosion layer, the results also show that the majority of the corrosion products on the coin's surface are composed of copper (Cu) and chlorine (Cl), respectively. This suggests that as a corrosion product where chloride is present on the coins surface especially coin 1.

Table (1) EDX analysis of the chemical composition (weight %) of the two coins.

Elements/ Wt.%	C	O	Mg	Al	Si	Cl	K	Ca	Cu	Total
Coin 1	20.23	37.86	0.65	1.00	8.88	0.69	0.82	4.22	25.64	100.00
Coin 2	20.75	17.26	Nd	Nd	0.51	1.30	Nd	0.39	59.79	100.00

***Nd:** not detected*

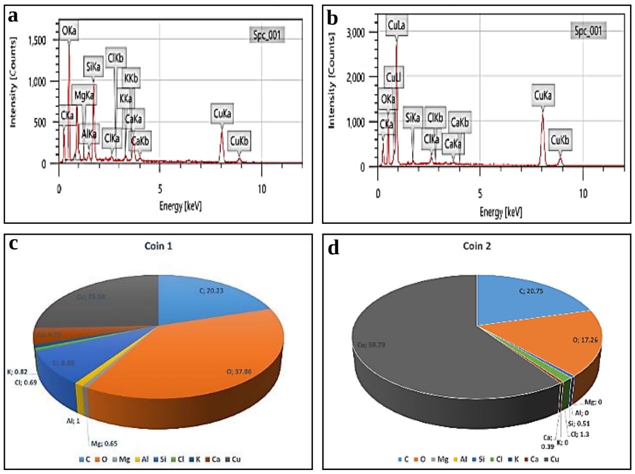

Figure (5) EDX spectra and graphical results of the two coins; **a.** coin 1 surface, **b.** coin 2 surface, **c.** a graphical form of the % major and minor elements distribution (wt.%); coin 1, **d.** coin 2

4.3. *XRD*

X-ray analysis of both coins confirmed the presence of various corrosion products, which appear in the tab. (2) & fig. (6), where the distinctive corrosion products vary in their different colors. The analysis confirmed the presence of primary components of the discovered corrosion products are Tenorite (CuO) exhibits a black corrosion layer, Nantokite CuCl a green corrosion layer and Cuprite (Cu_2O) a reddish corrosion layer as well as calcite ($CaCO_3$) and other soil remnants, Also, presence of quartz (SiO_2) clearly in coin 1 compared to coin 2. Coin 1 indicated the presence of carbon dioxide (CO_2) combined with copper to form a of copper (II) carbonates (Malachite $Cu_2CO_3(OH)_2$) in the green corrosion layer. While coin 2 was characterized by the presence of atacamite ($Cu_2(OH)_3Cl$) and paratacamite ($Cu_2(OH)_3Cl$) as corrosion products characterized by their bright green color as a result of the presence of chlorides that reacted with the metal surface of the coin. These results demonstrate a strong correlation with the EDX results which confirmed presence of soil elements such as C, Si and Ca that increasing specially in coin 1 also presence of Cl element more in coin 2, these results are present in the spectra in the two coins, these results confirm the extent of their correlation with XRD analysis, which showed the presence of copper carbonates, copper chlorides, and calcite that were found in extremely thin layers, according to XRD analysis. These results helped to suggest the surface composition of the corrosion products. We deduced from previous results that the majority of the coins composition was copper or its alloys, which underwent chemical transformations to produce the corrosion products that we could distinguish by analysis results.

Table 2. corrosion compounds identified using XRD analysis of the two coins.

Corrosion products	Formula	Color	Coin 1	Coin 2
Tenorite	CuO	Black	√	√
Cuprite	Cu_2O	Red	√	√
Nantokite	CuCl	Green	√	√
Paratacamite	$Cu_2(OH)_3Cl$	Green	–	√
Atacamite	$Cu_2(OH)_3Cl$	Green	–	√
Malachite	$Cu_2CO_3(OH)_2$	Green	√	–
Calcite	$CaCO_3$	White	√	√
Quartz	SiO_2	White	√	–

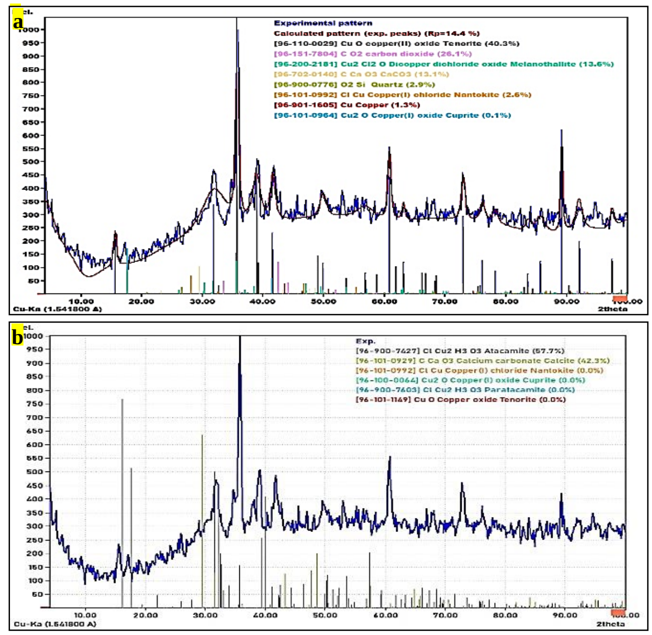

Figure (6) XRD patterns for the coin's corrosion products; **a.** coin 1, **b.** coin 2

5. Discussions

The analytical archaeological study of the two coins surface confirms that the coin 1 date back to the Ayyubids of Mayyafariqin, al-Ashraf Muzaffar al-din Abul Fath Musa Ibn Al'Adil I, 607-617 AH/210-1220 AD and coin 2 date back to Zengid, Emir Qutb ad-Din Mawdud, 1149-1170 AD. Because of this, one of the most crucial studies for determining the dates of various historical periods is the examination and analyzation of archaeological coins. Examined under a USB microscope, the coins showed severe corrosion types and layers, pitting, loss of part of the edge, and partial deforms of the coin's letters on both sides. The colors of apparent corrosion on before being cleaned were green and black and raw hard corrosion. These deformed coverings of corrosion products and remnant dirt covered up the fine details of the coin surface. SEM analysis of the coin's exterior shows how the surface's structure and form have deteriorated. The metallic surface of the coins has holes and an uneven topography with the spread of pits. Additionally, there are black areas that refer to pitting corrosion. These results indicate that the coins' letters and surface were partially covered with corrosion products in layers which SEM examination makes this composite layer readily visible. Archaeological artifacts made of copper-based alloys age and develop a patina on their surface as a result of change [22]. The composition and thickness of the patina are influenced by the original alloy's composition as well as its environmental surroundings [23]. Certain varieties of patina can produce a compact covering that is often described as a "noble" patina in literature due to its attractive look. These patinas that separate and protect the metal from other environmental influences, However, if these layers are contaminated with air pollutants or soil components during the burial stage, it turns into corrosion products that damage the metal surface [24]. Through the previous SEM results that showed the presence of pits, holes, missing parts of the edges of the coins, and missing parts of the writing letters on the surface of the coins, which confirms the coins exhibited three types of corrosion (pitting corrosion, erosion corrosion, and crevice corrosion). The metal gradually develops holes as a result of the highly localized attack of pitting corrosion. Chemical attacks, such as those caused by chlorides, can cause a pit to form [25]. Additionally, a high velocity electrolyte flow causes erosion-corrosion, which is accelerated by the abrasive action. Because of the removal of a protective oxide from the film surface, fresh alloy is left vulnerable to corrosion, which can be compared to considerably larger-scale pitting [26]. Regarding the third form of corrosion, which appears to be the preferred term for metal-metal gaps, it is called crevice corrosion. Metals frequently corrode more readily in the tiny, protected volume of a fissure formed by contact with another substance. The substance could be a component of an insoluble solid deposit, such as mud or sand. When exposed to air, a crevice's internal corrosion may be brought on by water retention, yet the exterior surfaces may drain and dry [27]. Before the treatment and conservation procedures, EDX analysis of the two coins' surfaces revealed that Cu, O, and C were the main elements in the corrosion layer, which is related to the metal composition. Additionally, the coins 1 and 2 contain the minor elements Si, Ca, Mg, K, Cl, and Al, respectively. Additionally, the correlation between soil contents and corrosion products is demonstrated by the components Si, Al, S, Ca, Mg, and Cl. In particular, the chloride ion strongly suggests that these coins were impacted by an environment rich in chlorides. The results obtained point to that the corrosion layer is primarily composed of copper corrosion products, and that the majority of the corrosion products on the coin's surface are made of copper (Cu) and chlorine (Cl). This implies that both coins' surfaces contain chloride as a corrosion product. The results of the X-ray diffraction (XRD) analysis showed that the main compounds of the identified corrosion products are Tenorite (CuO) in a black corrosion layer, Nantokite CuCl, Cuprite (Cu_2O), calcite ($CaCO_3$), and presence of quartz (SiO_2). Also, in particular, the analysis confirmed that Coin 1 contains carbon dioxide (CO_2) and copper (Cu) indicates the presence of copper (II) carbonates (Malachite $Cu_2CO_3(OH)_2$) in the green corrosion layer as a result of reacting carbon dioxide with the coin's metal surface. as well coin 2 was characterized by the presence of atacamite ($Cu_2(OH)_3Cl$) and paratacamite ($Cu_2(OH)_3Cl$) as corrosion products characterized by their bright green color as a result of the presence of chlorides that reacted with the metal surface of the coin. These results exhibit a strong close connection with the EDX results. The results concluded that the coins mostly consist of copper, which underwent chemical changes that led to the appearance of copper corrosion products on the two coins. The copper oxidation process begins with the selective dissolution from the phase of the solid copper solution. The dissolved copper is able to dissolve the metal surface through reactions with anions found in the soil, such as carbonate and chloride. The concentration of oxygen increases significantly as the levels of copper decrease. This activity results in the production of copper oxides, which give off a reddish-brown patina [22]. It has been observed that tenorite forms as a thin, black layer on top of the red cuprite alteration result. One of the copper oxidation forms that makes up natural patinas is the tenorite CuO. Its presence on the coin's surface, as confirmed by the study, suggests that the object was heated either before or during burial [28]. Coins buried in soil for an extended length of time are susceptible to corrosion due to three main factors: water, carbon dioxide, and chloride ions [29]. It was determined that malachite, one of the main corrosion products on coins surfaces, was the outcome of local cell activity primarily brought on by carbon dioxide, oxygen, and water. Cuprite and malachite are commonly reported corrosion products on archaeological copper alloys [30]. Also, because the soluble chloride salts in the soil or environments cause chloride ions to pass through the oxide layer, a greenish substance known as nantokite (CuCl) may have developed close to the original metal surface and is now covered in the other corrosion products [31]. Humid or salty subterranean conditions cause buried coins products' surfaces to develop chlorides [32], The main long-term stability concern is finding Paratacamite ($CuCl_2.3Cu(OH)_2$) and atacamite ($Cu_2(OH)_3Cl$) inside the corrosion layers in large quantities or in almost constant presence [33]. Its presence is a strong indication of ongoing destructive active corrosion, customarily called bronze disease. Because the copper is attacked by the chlorine ion from its oxides or carbonates, they often stratify on the coin's surface, converting the copper to cuprous chloride [34].

6. Treatment and Conservation Processes

6.1. *Treatments*

Several conservation techniques were selected based on the previous results and their efficacy and applicability in order to successfully create a methodology that can be employed safely and efficiently in the conservation of these coins [35]. Conservation procedures should be carried out with caution and respect towards the integrity of the object [36]. When it comes to methods, mechanical cleaning is always better than chemical ones since they are easier to manage, don't require harsh chemicals, and have less impact on the metal alloy. Due to difficulties in controlling reactions during chemical treatments, mechanical cleaning is preferred for copper/ bronze artifacts [37-39]. The mechanical cleaning was done carefully so as not to harm the coin's original surface. The two coins were thoroughly cleaned after a general surface examination, when further care was required, the cleaning process was done under a microscope to avoid harming or removing important areas by using digital microscope with a magnification of 50-X to 500-X. Soft, smooth corrosion and soil residues had to be removed throughout the cleaning process which called for the use of mechanical tools like paint brushes, fiber brushes, metallic scalpels, spatulas, dental picks, needles, and wooden or stick-shaped utensils which have been used with great care and caution [40]. In cases where it is difficult to remove corrosion products by mechanical methods when mechanical cleaning proved ineffective in removing persistent corrosion layers the chemical cleaning was used without causing damage to the object's original surface where the coins were one example that can used chemical treatment together with clever mechanical cleaning since it is important to extract as much information as possible where this allowed us to see through the surface to the original topography [41,42]. It found out that in order to expose the surface characteristics, the remnants corrosion had to be removed, and it was done by adding ethanol to the surface to damp and soften, making them simpler to remove [43]. Furthermore, the two coins were cleaned, and the chloride ions were removed using sodium sesquicarbonate ($Na_3H(CO_3)_2.2H_2O$), a salt that contains sodium carbonate (Na_2CO_3) and sodium bicarbonate ($NaHCO_3$). The coins were submerged in five weight percent sodium sesquicarbonate and allowed to soak. While the coins were being cleaned, the solution was often changed and sometimes checked. To remove corrosion, the solution was gently stirred, and soft brushes or cotton swabs were utilized. Following that, it was wiped and given one more water wash [44,45]. The coins were finally washed with deionized water and then acetone dried. After completely drying, either by air drying or by using gentle, lint-free clothing [46]. After that, the coins were covered with benzotriazole as a corrosion inhibitor to protect it from damage when exposed to the display or storage environment. corrosion inhibitors are considered one of the materials that have a major role in protecting antique metals, Inhibitors are substances that help preserve metals stability by inhibiting and delaying the formation of corrosion products including coins [47]. To protect the coins from environmental deterioration agents like high relative humidity and polluting gases, which can cause corrosion, it was first soaked in a solution of benzotriazole (BTA, 3g) dissolved in 100 ml of ethanol to prevent any ongoing corrosion and avoid more outbreaks. After that, the coin was immersed in ethanol to eliminate any remnants of BTA. When an insoluble copper–BTA coating was formed passive film, it acts as a barrier to protect the copper/bronze artifact from moisture and oxygen [48]. BTA effectively prevents copper and its alloys from corroding [49]. Then they were covered with a protective coat that has various resistance and protection properties against damaging atmospheres, and coatings play a major role. In the process of protecting the metal surface, due to its great resistance and properties that prevent the metal surface from being affected by various damaging factors [50, 51], where the coins were coated with a 3% solution of Paraloid B72 (A co-polymer of methyl acrylate and ethyl methacrylate with a molar ratio of 70: 30%). Because of its excellent adherence, mechanical resilience, reversibility, transparency, and reasonable long-term stability, metal conservators frequently employ it to cover metal objects. Three brushing times of the 3% Paraloid B72 solution were used to cover the coins in a layer of protection and to guarantee that the details and microporous surface have an appropriate dry film thickness, coating must be applied repeatedly [52,53]. fig. (7) shows the images of the coins after the end of the treatment.

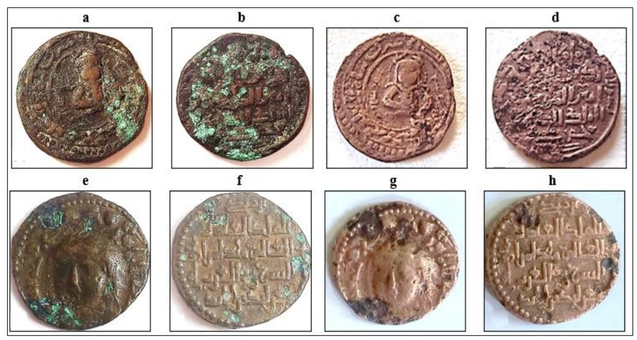

Figure (7) **a.** the obverse of the coin 1, **b.** the reverse of the coin 1, before the conservation processes, **c.** & **d.** the same coin after the conservation processes, **e.** the obverse of the coin 2, **f.** the reverse of the coin 2 before the conservation processes, **g.** & **h.** the same coin after the conservation processes.

6.2. *Proposal for coins showcase*

A recent museum design idea included a variety of display strategies that took into account the object's characteristics, the interpretation of the exhibition, the presenting setup, and the physical contact of putting collections on show for the general public. Maintaining the viewer's focus inside the exhibition through information transfer and topic matter communication is essential when constructing a showcase. Failure to do so will result in the visitor losing interest in the display. Ideally, the design of the display unit is one of the influencing factors on the museum mission. It is important to evaluate each material that will be utilized for an exhibit case inside to make sure it won't potentially corrode. Once the coins have been restored, the showcases that will be used to display them should be constructed of unique, identical materials that do not come into contact with the coins and keep clear of dangerous materials like acidic cardboard, poly (vinyl chloride), vulcanized rubber, and oil-based paints. This would allow it to become an inventive model that could be applied to other antique coins [54]. To be sure the safety of the materials used in the manufacture of the showcase must be detect certain toxic substances, spot testing might be conducted by the conservation laboratories or museum workers [55-57]. With the addition of smart computing technologies to facilitate attracting visitors. Computing technologies and artificial intelligence (AI) are already commonplace in practically every industry. Artificial intelligence (**AI**) and computer technology are being applied to art museums to enhance the tourist experience, better the preservation of artworks, and make these collections easier to access. The design of the museum exhibition is a combination of science and art for visual arrangement, design of interior space, and finishing material selection according to exhibit item specifications [58].

6.2.1. Contents of the showcase

Vertical display showcases are designed in line with modern museum display trends, equipped with artificial intelligence technology, and either one can be used. fig. (8-a, b & c), and schematic and graphical representation is shown in fig. (8-d & e).

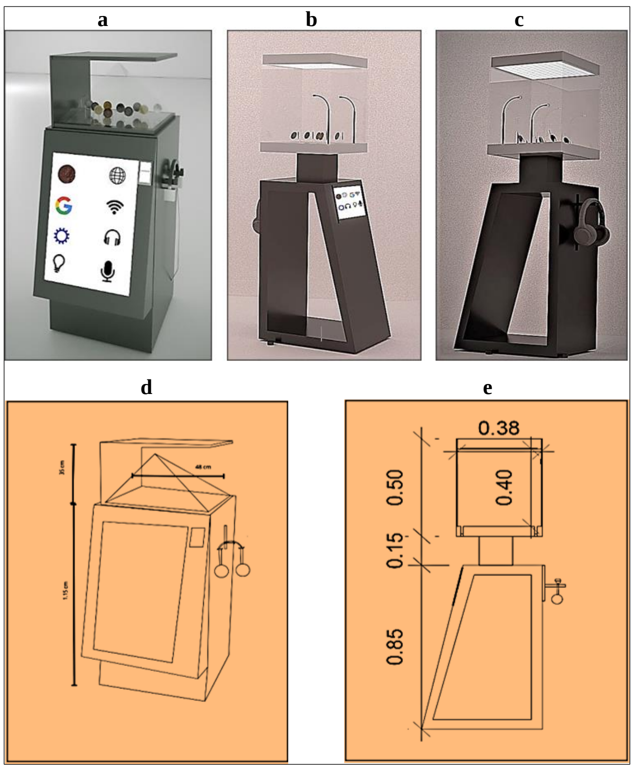

Figure (8) a proposed design of two showcases for coins, **a.** 1st showcase shape, **b.** 2nd one showcase shape from the front, **c.** 2nd showcase shape from the back. A schematic drawing with approximate dimensions of showcases shape, **d.** 1st showcase, **e.** 2nd showcase.

The showcases are made of high-quality and environmentally friendly material, The outer body of the showcases is made of rust-resistant metal, and the coin display unit is made of tempered glass, anti-reflective glass. The showcases are composed of: a) Two different shapes of glass units for displaying coins inside, fig. (9-a & b). Showcase shape is the element of physical or spatial containment, it is the composite of all points forming the internal or external surface of a composition [59]. **b)** The lighting design is LED bulbs are sensitive to the visitor with two different designs, fig. (9-c & d). Lighting is the process of controlling light to meet a recognized need. It is predicated on the understanding of control technology and light sources. No museum has a "perfect" light source; instead, there are light sources that can be tailored for a particular purpose [60], Since LED lighting uses less energy than halogen lighting, the white LED bulb is a good choice for this purpose. Due to their low levels of unwanted UV and IR radiation, units survive longer and generate very little heat [61]. **c)** Two designs of holders, the first shape is semi-circular glass holders for each coin inside a hollow glass that can hold coins vertically and has a large thickness and fixed to the floor of the showcase that allows it to be stable inside the showcase and allows the two sides of the coin to be seen, the second is a tripod holders made of plexiglass that allows for secure holding of coins, fig. (9-e & f). Collections can be effectively displayed with holders. When an object is on display, a holder serves as a support to keep it in place. It stops movement that could put the thing under stress, particularly if it is fragile or structurally weak, or in the case of an earthquake [62]. **d)** a touch screen tablet containing many applications connected to the Internet, some of which are related to the visitor, such as an application that helps the visitor when running it to tell the history of the coins in the showcase, an icon for controlling the lighting, and an icon for sound, where there is an earphone another side to the showcase. **e)** An application, which is the most important, and it is specialized for the museum official and has a secret number. This application monitors the internal devices of the showcase, such as a device that measures humidity, temperature, and lighting, and gives daily measurements of the state of the vault and its environment from the inside. Also, Attached to the showcase double lock system or integrated alarm system for protection.

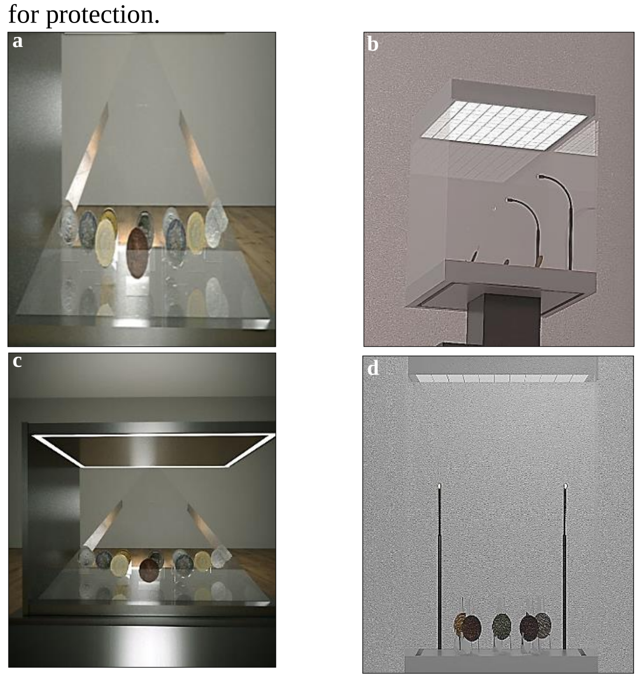

Figure (9) **a**. & **b.** glass units design inside the showcase, **c**. & **d.** the lighting designs inside the showcases, **e**. & **f**. Two designs of holders for each coin.

6.2.2. Mechanism of the showcase

Many academics point out that public spaces like museums serve as important instruments for society's larger learning and knowledge institutions [63]. To be sure, some museums across the world have already begun deploying AI across various parts of their operations. A recent museum design idea included a variety of display strategies that considered the object's characteristics, the interpretation of the exhibition, the presenting setup, and the physical contact of putting collections on show for the general public. In order to maintain a visitor's interest in the display after two gallery tours, it is imperative that museum designers maintain the visitor's focus inside the exhibition through effective information transfer and subject matter communication. That is dependent upon how the objects are arranged and the concept of the display [64]. Another major factor affecting the condition of exhibit conservation is the low air quality within museums. Because of the materials used in their creation, the displays may be extremely susceptible to the effects of the interior micro-climate, even if they are mostly housed in a controlled atmosphere. Exhibits at museums therefore need to be shielded from any potential harm. Monitoring the primary microclimate characteristics and maintaining exact values for temperature, humidity, and light is crucial to halting and preventing the process of exhibiting deterioration [65]. It's generally known that collections, whether on display or in storage, are rarely maintained under ideal environmental conditions. And sometimes they're awful. This is particularly true for items that are vulnerable to moisture, such ancient metals. Often, it is not feasible to attain ideal conditions due to budgetary limitations or structural limitations [66]. Additionally, in order to produce a more realistic approach and improve the experience of virtual visitors, displays and item exhibiting are meant to be more dynamic and interactive rather than static and authoritative in character. The online interactive exhibition's key components include: a variety of contexts that allow users to seamlessly connect to the gallery; excellent instructional design; proactive learning contexts; a good balance between education and entertainment; and data on every object, its condition, and how to handle it [67, 68]. Therefore, the showcases were equipped with some artificial intelligence features: sensors were added to recognize small and large changes in temperature and humidity and communicated them through an application that can be used through a computer or mobile phone. In addition, an alarm device was added inside the showcases that can notify those in charge of the display if the museum indicates that there is a leakage inside the showcase from external pollutants, relative humidity, and high temperatures, provided that this warning notifies the museum administration through messages on the mobile phone or issuing a beep on the laptop or mobile devices to alert. LED bulbs are situated apart from the showcase and may be adjusted in quantity, The showcase is also provided with sensors that work to self-extinguish the internal lighting of the vaults or reduce its intensity when there are no visitors in the museum, and when it senses that a visitor is approaching a certain distance the showcase turns on itself and turns on the light gradually. The showcases were also provided with a self-control unit that, when the power goes out inside the museum, works automatically by creating a suitable environment for the pieces on display, temporarily and for a period of two hours, in order to reduce the impact of the shutdown of the internal environment control devices inside the museum until the power is restored. A program is also added that works to determine the condition of the antiquities and the extent of the changes that have occurred to them by providing them with the necessary information and the appropriate environment for preserving the coin. Additionally, museums may make use of generative AI's superiority in predictive analysis to better allocate resources amid high demand. Artificial intelligence (AI) is used to improve their climate sustainability by monitoring environmental factors at museums that might impact on the lifetime of artifacts, such as temperature, humidity, and light exposure. Also, AI has applications in both preservation and restoration. is a key player in the field of condition assessment and preventive conservation which uses analytics algorithms to predict objects deterioration, It analyzes high-resolution photographs of artifacts to identify and evaluate degradation, including fading, fractures, and other damage by allowing curators to take preventative action to safeguard the collections and minimize, if not eliminate, of the restoration high expenses. Additionally, machine learning algorithms can recommend the best restoration techniques, assisting conservators in maintaining the objects' integrity. Regular AI use will not only free up staff time but also guarantee greater consistency and correctness in data submissions, improving qualitative credibility [69,70]. In general, AI may help with heritage access in a variety of ways, incorporating pedagogical design, interface design, and/or participatory design, for scholars, professionals, and visitors like [71].

7. Conclusion

This article has studied two coins, conservation processes, and display them in a showcase supported by artificial intelligence. The first one (coin 1) dates to Ayyubids of Mayyafariqin, al-Ashraf Muzaffar al-din Abul Fath Musa Ibn Al'Adil I, 607- 617 AH/1210-1220 AD and coin 2 date back to the Zengid, Emir Qutb ad-Din Mawdud, 1149 Zengidby studying of the writings and inscriptions found on the

coin's surface. A USB microscope and SEM examination proved that the coins suffer from deterioration aspects and different kinds of corrosion, pitting, erosion, partial edge loss, and partial writing blurring on both sides. Also, The EDX and XRD analysis results proved exhibit strong concordance. EDX analysis of the two coins included: Cu, O and C in as a major element. Also, elements Si, Ca, Mg, K, Cl, and Al in the coin 1. and Si, Cl, and Ca in the coin 2 as the minor elements. The elements Si, Al, S, Ca, Mg, and Cl show how closely soil constituents and corrosion products are related, Especially the chloride ion which strongly indicates that these coins were affected by an environment rich in chlorides, while the XRD results confirmed the presence of primary components of the discovered corrosion products are Tenorite (CuO) exhibits a black corrosion layer, Nantokite CuCl a green corrosion layer and Cuprite (Cu_2O) a reddish corrosion layer as well as calcite ($CaCO_3$) and other soil remnants, Also, presence of quartz (SiO_2) clearly in coin 1 compared to coin 2. Coin 1 indicated the presence of carbon dioxide (CO_2) combined with copper to form a of copper (II) carbonates (Malachite $Cu_2CO_3(OH)_2$) in the green corrosion layer, while coin 2 was characterized by the presence of atacamite ($Cu_2(OH)_3Cl$) and paratacamite ($Cu_2(OH)_3Cl$) as corrosion products characterized by their bright green color as a result of the presence of chlorides which reacted with the metal surface of the coin. Based on the results of the examination and analysis, the coins were restored by different cleaning methods. The coins have undergone mechanical cleaning by different tools, then, chemical cleaning used when mechanical cleaning proved ineffective in removing some corrosion products layers without causing damage to the coin's original surface. followed by stabilization and coating. Finally, a display showcase was designed to display the restored coins, meeting the requirements of modern museum display, made of durable, non-harmful materials and has featuring artificial intelligence applications and elements that facilitate the display and provision of information about each coin, providing ideal conditions and secure control by museum management and restorers.

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