Luxor International Journal of Archaeological Studies
PRINT-ISSN: 2535-1788 / **ONLINE-ISSN:** 2974-4121
[HTTPS://LIJAS.JOURNALS.EKB.EG/](https://lijas.journals.ekb.eg/)
Volume 3, Issue 1, July 2020: pp. 21-38

Application of Digital Restoration Techniques in the Restoration and Preservation of One of the Photographic Images from Al-Aqsa Mosque Album at the Central Library - Alexandria University

Hebatallah S. El-Menshawy, [1, *] Mohamed Ahmed Helal [2]

[1] Conservation and Restoration Department, Bibliotheca Alexandria, Alexandria, Egypt

[2] Faculty of Fine Arts, Alexandria University, Alexandria, Egypt

Abstract

This research aims to shed light on the preservation status of one of the photographic images from the archives of the Central Library at Alexandria University, focusing on its notable deteriorations and the underlying factors. The study encompasses a comprehensive restoration and preservation process, beginning with digital restoration techniques, thorough documentation, and mechanical dry cleaning methods. Further steps involve wet and chemical cleaning processes, followed by the meticulous separation of the image from its secondary support, reinforcement, and treatment procedures, as well as the meticulous completion of any missing components and color retouching. Finally, the paper explores various preservation methodologies tailored to the specific characteristics of the photographic image under scrutiny. Preliminary investigations reveal the significant impact of the coastal environment on the image's condition, with relative humidity emerging as a pivotal factor in the degradation of its layers. Notably, employing a 3% concentration of calcium hydroxide nanoparticle solution alongside Klucel G reinforcement at a 4% concentration proves most effective in addressing acidity issues within the photographic image under study.

Keywords

Digital restoration; Completion of missing parts; Paper support; Calcium hydroxide nanoparticles; Manual restoration.

Article History

Received: 11/3/2020

Accepted: 23/5/2020

DOI: 10.21608/lijas.2020.357299

* مراسلة المؤلف: heba.elmenshawy@bibalex.org ؛ heba.elmenshawy79@gmail.com

تطبيق تقنيات الترميم الرقمي في ترميم وحفظ إحدى الصور الفوتوغرافية من ألبوم المسجد الأقصى بالمكتبة المركزية – جامعة الإسكندرية

هبة الله صلاح المنشاوي، [١] محمد أحمد هلال [٢]

[١] قسم الترميم والصيانة، مكتبة الإسكندرية، الإسكندرية، جمهورية مصر العربية

[٢] كلية الفنون الجميلة، جامعة الإسكندرية، الإسكندرية، جمهورية مصر العربية

الملخص

يهدف هذا البحث إلى إلقاء الضوء على حالة الحفظ لإحدى الصور الفوتوغرافية من أرشيف المكتبة المركزية في جامعة الإسكندرية، مركزًا على التدهور الملحوظ لها والعوامل الكامنة وراء ذلك، حيث تشمل الدراسة عملية شاملة لترميم وحفظ الصورة، تبدأ بتقنيات الترميم الرقمي، والتسجيل والتوثيق الشامل، وطرق التنظيف الجافة الميكانيكية، كما تتضمن الخطوات المتبعة في عمليات التنظيف الرطب والكيميائي، تلتها مرحلة فصل دقيقة للصورة عن الحامل الثانوي، وإجراءات تقوية ومعالجة، بالإضافة إلى استكمال دقيق للأجزاء المفقودة وإصلاح واستكمال الألوان، وأخيرًا، يتناول البحث طرق الحفظ المتنوعة المصممة خصيصًا لخصائص الصورة الفوتوغرافية موضوع الدراسة بناء على الدراسات الأولية التي كشفت تأثير البيئة الساحلية الكبير على حالة الصورة، حيث يظهر الرطوبة النسبية كعامل رئيسي في تدهور طبقاتها، وبشكل ملحوظ، أعطى استخدام تركيز ٣% من محلول نانو هيدروكسيد الكالسيوم جنبًا إلى جنب مع التقوية باستخدام Klucel G بتركيز ٤% فعالية أكبر في علاج مشكلة الحموضة داخل الصورة الفوتوغرافية موضوع الدراسة.

الكلمات الدالة

الترميم الرقمي؛ استكمال الأجزاء الناقصة؛ الحامل الورقي؛ نانو هيدروكسيد الكالسيوم؛ الترميم اليدوي.

Introduction:

Photography, or photogrammetry, is a term derived from Greek, meaning "drawing with light," similar to the ancient art of drawing. Through the lens, the photographer reproduces the scene in front of them onto a medium, which can then be used to recreate the scene later. The final image material is considered the most important part in printing because it actually embodies the photographic information. If there is nothing else known about the photographic image other than the nature of the final image material (Reilly et al., 1988). Photography is also known as the process of producing images and scenes through light effects; the rays reflected from the scene create an illusion inside a light-sensitive material, which is then processed, resulting in an image representing the scene (Werner, 1989).

The first beginnings of photographic image production date back to the nineteenth century, in the year 1830, primarily relying on the reception and sensitivity of silver compounds present on the paper surface to light. It is customary and well-known that silver compounds tend to darken when exposed to light. Satisfactory photographic printing did not emerge until 1839 when the attractive process of photogenic drawing was introduced (Eleonore and Vigneau, 1999). This process is considered one of the most prevalent types of printing operations over the past two centuries (Teper, 2009). Photographic printing primarily relied on the light sensitivity of silver compounds. It is established that silver compounds darken when exposed to light. To keep pace with advancements in knowledge and technology, new standards have been added alongside the periodic updating of old standards. After more than five years have passed since a standard's introduction, it may be considered obsolete and significantly revised; therefore, it is important to ensure that the version being used is the latest (Reilly, 2009).

Examination and analysis of photographic images are among the most important stages in the restoration and preservation of photographic images. They serve various purposes, being crucial and beneficial in the dating of photographic images and their main components, identifying their origins and sources. Additionally, they assist in diagnosing the current condition of the photographic image and in developing appropriate treatment and restoration plans if necessary (Clark, 2009). Microbiological deterioration processes are common problems in photographic image collections, considered major factors in damage. Fungi have a significant impact on the content of the photographic image, extending to the reduction of silver particles, one of the components of the photographic image (Lourenço, 2009). Despite the seriousness of disasters and major accidents, they are not the only threats to the stability and safety of photographic prints. There are other dangers due to storage conditions, the surrounding environment, and human factors, all of which can cause significant damage to photographs and photographic prints (Abdullah, 2010). Environmental conditions, including temperature, relative humidity, light, and air components, are among the most important primary factors responsible for the deterioration of photographic images (Brimble, 1992).

In 1990, a charter was established outlining the methods and importance of preserving photographic images (Clark, 2009). The most important processes for treating and conserving photographic images involve removing foreign materials that cause deterioration using traditional methods, with the possibility of replacing elements and components of the photographic image (such as packaging materials, image support, and frame) in the case of damage caused by poor-quality materials, replacing them with high-quality suitable materials. Proper handling of photographic images is also crucial to avoid future damage (Carme, 1996). Additionally, the Inpainting technique has been adapted for the restoration of photographic images, removing defects resulting from manufacturing processes or environmental factors over time. It fills in the missing area based on another similar part of the image (Patel, 2012).

Based on the foregoing, the primary goal in managing and preserving photographic collections should always be based on using photographic images in ways that do not contribute to their destruction. To be successful, preservation efforts need to be comprehensive in every aspect of collection storage and use (Kopperl, 2007). Storage conditions and storage materials are the foundation of all preservation efforts for photographic prints in the nineteenth century. Unlike sudden shocks that occur when a print is damaged during processing or improper use, the factors and forces of deterioration that threaten photographic images also, operate slowly in storage conditions and situations. This deterioration often occurs so slowly as to not attract attention. Relative humidity, air pollution, and temperature in the storage environment are responsible for chemical processes that lead to deterioration. These factors are responsible for the destruction of photographic images and prints by allowing mold, bacteria, and insects to thrive (Reilly, 2009).

Moreover, the display environment is harsher than the storage environment because it adds the factor of light damage to all other environmental effects. Photographic prints should be packaged in acid-free paper, and the paper should be non-transparent to prevent excessive light exposure. Additionally, careful handling is essential, as photographic prints can be severely damaged if stored or displayed improperly. The use of low-quality materials containing hazardous chemical components can also pose a serious threat to photographic prints (Nishimura, 1993). Therefore, the display system or storage environment for photographic prints must provide basic protection for all collection materials. It is essential to carefully and meticulously select the storage space and packaging to avoid contributing to the deterioration of the intended collection (Hendriks and Ross, 1998).

The problem lies in the lack of comprehensive preservation strategies specifically designed for the problems and challenges facing historically significant deteriorating photographic images, such as those found in the archive of the Central Library at Alexandria University. Despite the availability of a range of restoration techniques, there is a gap in the practical methods that adequately address the layers of photographic images exposed to damage and the factors causing this damage. Therefore, this research aims to bridge this gap by developing and implementing a meticulous restoration and preservation process focused on a specific photographic image from the archive of the Central Library at Alexandria University. This will be achieved through the integration of digital restoration techniques, comprehensive documentation, and mechanical dry cleaning methods, along with wet and chemical cleaning processes. The goal is to halt continuous deterioration, restore the image to its original state, and complete missing parts while performing color retouching.

Historical and archaeological documentation:

Historical and archaeological documentation is essential in restoration work. It involves conducting artistic and historical studies as primary steps, gathering and recording all data and information about the photographic image being researched from an artistic perspective. This includes studying the historical period, determining the type of photographic image, as well as identifying the photographer, their artistic style, and the photographic images they captured. This meticulous process ensures a high level of proficiency in the restoration process.

The case study image is represented by one of the photographic images in an album of pictures of the Al-Aqsa Mosque, preserved in the Central Library of Alexandria University. It contains a collection of photographic images depicting the plaza between the Al-Aqsa Mosque and the Dome of the Rock during one of the Islamic holidays. One of these examples is the case study image, which is a photographic image (Silver Gelatin) mounted on a secondary paper support, with scene data located below the image. The image is black and white and matte. The album of Al-Aqsa Mosque pictures was granted by the President of the Supreme Council of Palestine on the date of 27 Ramadan 1347 AH and was preserved in the holdings of the Central Library of Alexandria University under registry number (404). The album includes (14) plates of photographic images of the Al-Aqsa Mosque. It is worth mentioning that the dimensions of the album are 32.5 × 38 cm, with a width of 5 cm for the album's spine. The secondary holder for the photographic image measures 36.6 × 32.4 cm, and the dimensions of the photographic image itself are 29 × 23 cm. The image is documented as image number (5) within the album.

	
Fig. No. (1) Shows the cover of the Al-Aqsa Mosque album.	**Fig. No. (2) Shows the inside of the Al-Aqsa Mosque album.**

	
Fig. No. (3) Shows the case study photographic image inside the Al-Aqsa Mosque album.	**Fig. No. (4) Shows the case study photographic image from the Al-Aqsa Mosque album.**

The photographic documentation:

The photographic documentation of the case study photographic image was conducted using a digital camera, along with computer programs such as Photoshop, before, during, and after the restoration process. This stage is of utmost importance, aiming to establish the originality of the photographic image and document it for future reference to determine the original lines and color grades. Several important rules are observed during this process, starting with taking overall shots, then detailed shots of each part individually, and complete documentation of all the details of the image, including the secondary support, primary support, and the photographic image itself.

Documenting through drawing:

This type of documentation is done through hand drawing using a specific drawing scale. It records the artifact with all its features and aspects, including cracks, dirt, missing parts, and others, with utmost precision. This type of recording is of great importance not only for documenting the artifact and its condition but also because it establishes a close relationship and thorough study between the restorer and the artifact through drawing the finest details. The process of recording through drawing may take a long time, but it proves to be more beneficial. These drawings undergo artistic and scientific review before being whitened and inked. Sometimes, in cases where it is difficult to follow the drawing method on the enlarged image or for specific circumstances, the drawings may be made using the tracing method. Additionally, some drawings are transferred using the original colors. All aspects of damage have been documented by creating a copy of the case study photograph using computer software. Then, all aspects of damage are annotated on it, as shown in Figure (5).

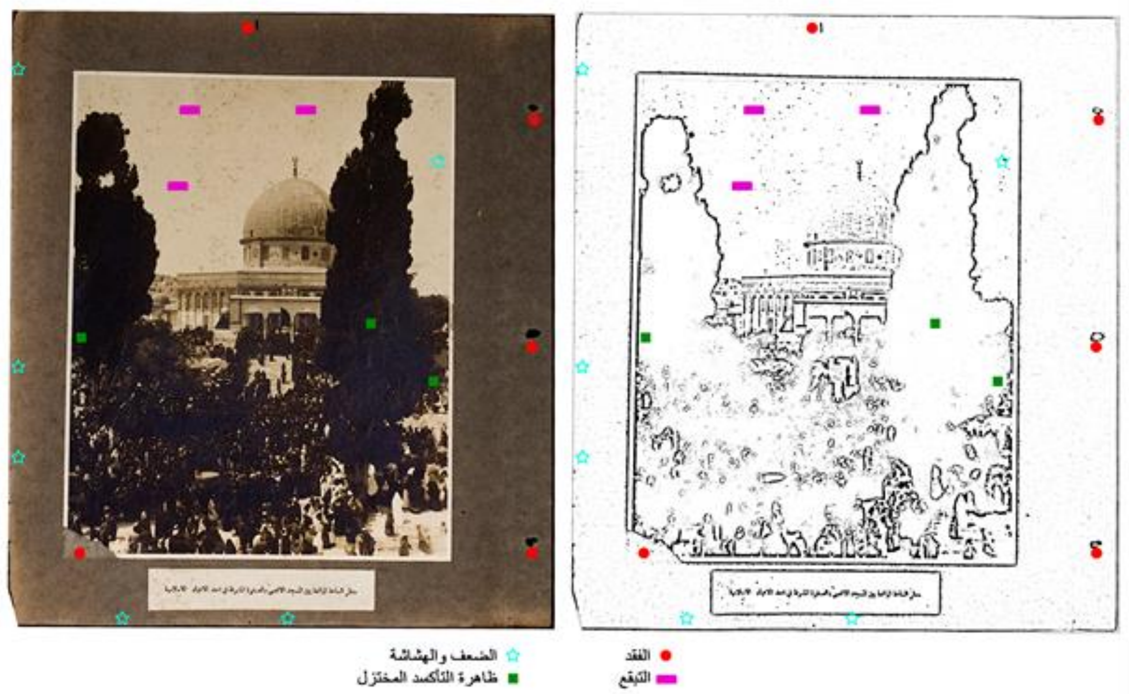

Fig. No. (5) Shows the documentation by drawing of the main aspects of damage to the case study photographic image.

The state of preservation of the case study photographic image:

Before commencing the restoration and conservation process, the restorer must prepare a detailed report on the condition of the photographic image. This involves recording all data associated with the case study photographic image in a datasheet specifically designed to assist the restorer in the restoration process, as illustrated in Table (1).

Table No. (1) Shows a registration form for a photographic image prepared by Author.

Photographic Image Registration Form
Image Information and Data: - Image Preservation Number: ………. - Description and Identification of the Image: ………. - Date of the Image: ………. - Restorer's Name: ………. - Type and Classification of the Image: ………. - Collection: ……….
Preservation and Display: - Edges and Housing (Photograph Housing) - Frame: □ Exists □ Does not exist - Back support: □ Exists □ Does not exist - Protective Transparent for the Image Polyester Film:

- Other Materials:
<u>Primary Image Support:</u> ▫ Paper ▫ Glass ▫ Polyester ▫ Other Type ***Dimensions of the Primary Image Support:*** Length: ……….Width: ………. ***External Appearance of the Image Surface:*** ▫ Glossy ▫ Matte ***Method of Attaching the Image to the Secondary Holder:*** ▫ Side Supports ▫ Adhesive
<u>Secondary Support:</u> Description: ………. ▫ Album Paper ▫ Natural Cardboard ▫ Synthetic Cardboard (Wood Pulp) ▫ Cotton Linen Paper ▫ Canson Paper
<u>Binding Layer:</u> Description: ………. ▫ Smooth Insulating Layer ▫ Layer Showing Paper Fibers
<u>Aspects of Deterioration:</u> ***- Primary Paper Support:*** ▫ Damp ▫ Surface Dirt ▫ Stains ▫ Fungal Growth ▫ High Acidity ▫ Fungal Damage ▫ Insect Attack ▫ Cuts ▫ Loss ▫ Holes ▫ Fragility ▫ Protrusions and Cracks ***- Binding and Final Image Support Layer:*** ▫ Good ▫ Poor ▫ Average ▫ Peeling ▫ Reduced Oxidation Phenomenon ▫ Cracks ▫ Fading and Discoloration ▫ Scratches and Detachment
<u>Suggested Treatment:</u> ▫ Does not need treatment ▫ Needs treatment ▫ Remove from the housing ▫ Detach from the secondary Support Cleaning: ………. Lacuna and tears Treatment: ………. Completion and Holes: ………. Digital Restoration: ………. Restoration End Date:

Through the registration, documentation, and examination using various techniques, it was observed that there is loss at the bottom left of the image due to the erosion of the image edges. Additionally, there is weakness at the edges of the secondary support, which is the paper support on the left side of the image. Furthermore, there are brownish-colored spots on the surface of the photographic image indicating the transfer of gelatin and acidity from the secondary support to the outer surface of the photographic image. Moreover, there is evidence of Silver Mirroring, which is the transfer and oxidation of silver to the surface of the image, particularly noticeable in areas with darker tones.

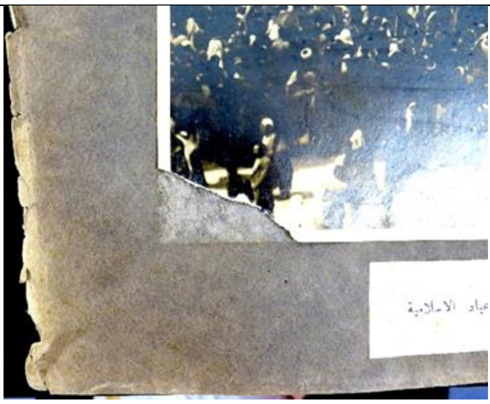	
Fig. No. (6) Shows a visible fungal and discoloration stain on the surface of the secondary paper support.	**Fig. No. (7) Shows the spread of brownish color spots on the surface of the photograph.**

The stages of restoration and preservation for the case study photograph image:

The action plan focuses on conducting an applied study in this research for one of the photographic images using a scientific approach, aiming to establish a scientific methodology for restoring black and white photographic works, including artistic and historical documentation of the photographs. It involves studying the current condition of the photographic images, identifying key areas of damage and the factors causing them, and proposing a restoration and preservation plan, which includes:

- Digital restoration.
- Sterilization and halting active biological deterioration.
- Engineering, decorative, and photographic documentation.
- Mechanical cleaning.
- Scientific tests for ink and gelatin stability.
- Chemical cleaning.
- Separating the photographic image from the secondary support.
- Treatment and reinforcement of the photographic image and secondary support.
- Completion of missing parts.
- Color completion and retouching.

- Reattaching the photographic image to the secondary support.
- Methods of preserving photographic images for display or storage.

- Restoration Using Digital Restoration Technology:

Before commencing manual restoration and conservation operations, it was necessary to digitally restore the case study photographic image using digital restoration technology. This was done to work with the printed copy instead of the original, valuable copy, thus avoiding continuous handling of the original copy by specialists, researchers, museum curators, and librarians. Introducing modern technology into photographic images has aided in the advancement of preservation and image processing. Digital restoration technology involves performing various processes on the photographic image using computer software, which plays a significant role in restoring the image to its original condition before suffering severe damage such as cracks, crevices, tears, and loss of some image information. This requires significant challenge and considerable effort to restore it to its original state.

Digital restoration directly and effectively aids manual restoration operations. After completing digital restoration, the restorer can use digitally processed photographic images in the completion process to restore the original photographic image, ensuring harmony, coherence, and balance between the completed parts and the rest of the original photographic images. The following are the stages of restoring the case study photographic image using digital restoration and computer software. There are some important steps to consider when digitally restoring photographic images:

1. Creating a copy of the original photographic image to work on.
2. Adjusting the dimensions of the image and cropping it as needed (Crop tool).
3. Formatting/restoring (retrieving) missing and required parts of the photographic image as needed.
4. Removing unwanted patterns.
5. Adjusting lighting highlights on shadows and the entire image, and in colored images, adjusting skin tone as well.
6. Adjusting the brightness and contrast of the image.
7. Making the basic lines of the image clear and sharper (Sharpen).

- Digital Restoration Stages:

- *Step 1:*

In this step, the dimensions of the desired image are determined, and the surrounding area is cropped using the Crop tool. Then, the stages of restoring the photographic image begin, where specific menus in Photoshop are used. These menus include the Patch Tool, the Clone Tool, and the Healing Tool. These tools are used interchangeably to digitally restore the photographic image.

- *Step 2:*

In this step, the image is corrected using the Patch Tool. The area to be corrected is selected, and then clicking in the middle of the selection while dragging it to a similar area in the image. The selection is then released, ensuring that the alignment is maintained.

- *Step 3:*

After correcting all the damaged parts in the image using the Patch Tool, the Healing Brush Tool and the Clone Stamp Tool are utilized. These tools are alternated as needed. Additionally, the Spot Healing Tool can be used to remove various spots in the image. The Clone Stamp Tool is employed to correct the edges of the image, as the results of using the Patch Tool and Healing Brush Tool may affect the edges unfavorably. All these steps are executed on every part of the image until the digital restoration of the photograph is complete.

- *Step 4:*

In this subsequent step, all the used layers are selected and grouped together. Then, a new layer is created from this group and renamed "Noise." The next action involves reducing the noise in the image through the Filter menu. Standard values are applied, typically Detail = 20 and Strength = 8, to reduce the noise effectively.

- *Step 5:*

After reducing the noise as outlined in the previous step, the next step involves sharpening the image edges, also known as High Pass Sharpening. This process enhances the sharpness of the image edges. Then, from the Layer menu, Overlay is chosen instead of Normal.

- *Step 6:*

In this final step, the contrast in the image is enhanced using the Curves command, which can be accessed by pressing Ctrl + M. Additionally, the Levels command is used to improve the color contrast of the image, accessed by pressing Ctrl + L. With these adjustments, the digital restoration of the photograph is completed using Photoshop.

Fig. No. (8) Shows the steps of digital restoration for the case study photographic image.

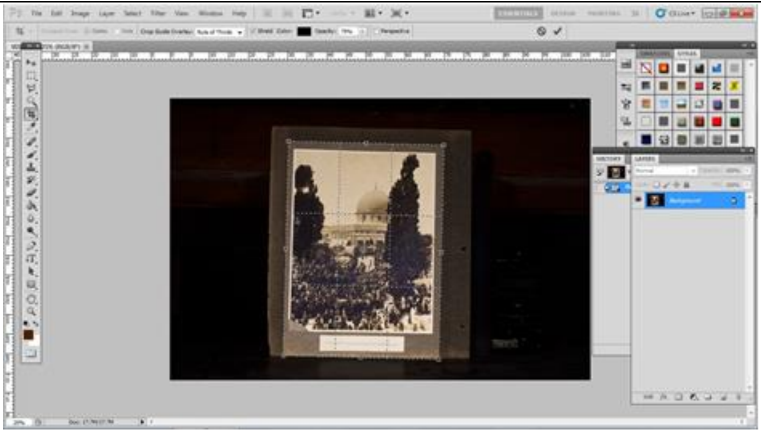

Fig. No. (9) Shows the steps of digital restoration for the case study photographic image.

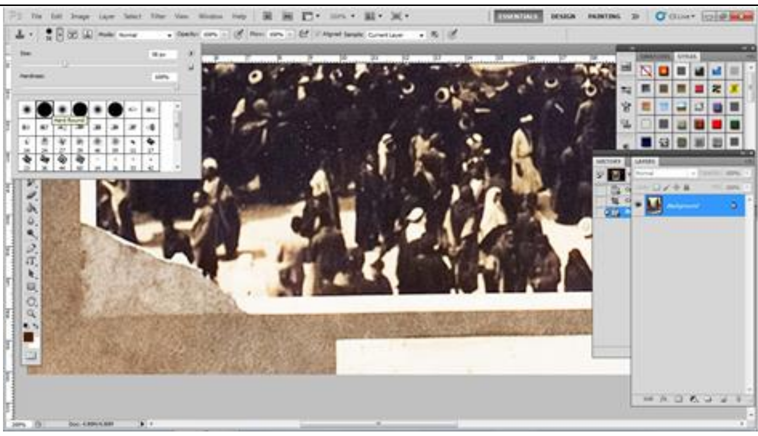

Fig. No. (10) Shows the steps of digital restoration for the case study photographic image.

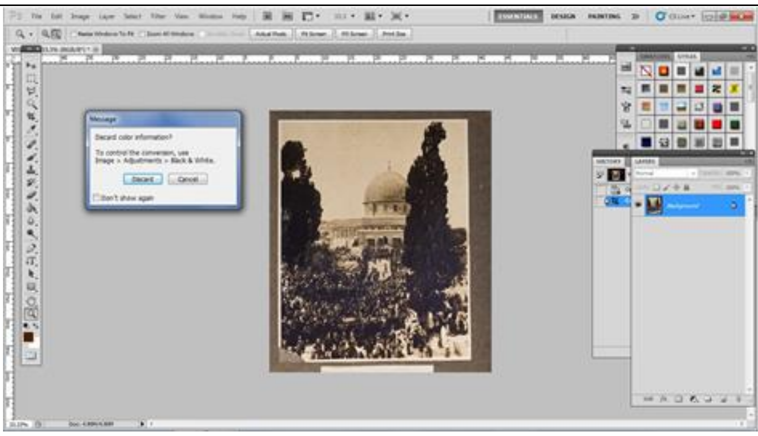

Fig. No. (11) Shows the steps of digital restoration for the case study photographic image.

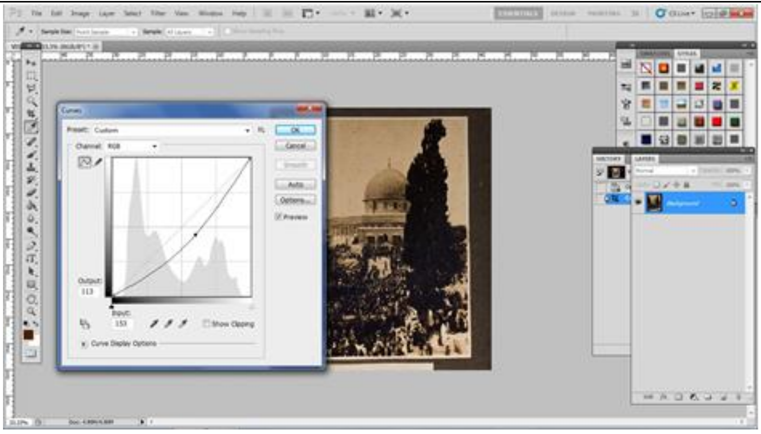

Fig. No. (12) Shows the steps of digital restoration for the case study photographic image.

Fig. No. (13) Shows the case study photographic image before digital restoration.

Fig. No. (14) Shows the case study photographic image after digital restoration.

- ***Mechanical Cleaning:***

The photograph was cleaned both on the front and back to remove dust and pollutants using a soft dry brush. A specialized eraser designed for photographs was also used to eliminate any traces of dirt or dust adhered to the surface.

Fig. No. (15) Shows the stages of mechanical cleaning for the case study photographic image.

Fig. No. (16) Shows the stages of mechanical cleaning for the case study photographic image.

- ***Chemical Cleaning:***

A test was conducted in an inconspicuous area of the image to assess the gelatin stability using a drop of 50% ethyl alcohol solution. A very slight grayish coloration was observed, likely due to some dust and contaminants present on the surface. Subsequently, the cleaning process involved moistening a cotton swab with 70% ethyl alcohol, with extreme care and speed, followed by quick drying using absorbent filter paper to remove surface dust. On the backside of the image, a stability test for the seal was performed, revealing instability of the ink used in the seal. Therefore, a fixative substance (Ethyl Acetate) $C_4H_8O_2$ was used. The presence of lead in the signature was also tested and found to be stable. Additionally, fungal growth was observed on the surface of the paper holder, so the affected areas were sterilized using isopropyl alcohol (C_3H_7OH) 70% alcohol + 30% water, noting that the fungus was inactive.

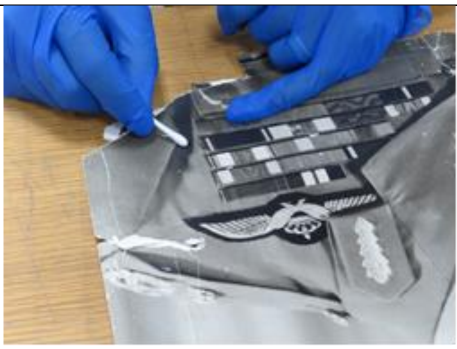	
Fig. No. (17) Shows the stages of chemical cleaning for the case study photographic image.	**Fig. No. (18) Shows the stages of chemical cleaning for the case study photographic image.**
	
Fig. No. (19) Shows the ink test for the seal on the background of the secondary support.	**Fig. No. (20) Shows the signature test with a pencil on the secondary support.**

- ***Separation of the photographic image and removal of adhesives and traces of the secondary support:***

It was found that the photographic image was only attached to the secondary support from the four sides of the image. Therefore, the image was separated and removed from the secondary support in a simple and easy manner. After separation, it was noticed that there were traces of cardboard and adhesive, specifically animal glue, on the back of the image. These traces were lifted and removed from the back of the image using Carboxymethyl cellulose (8%) and ethyl acetate was used to remove the adhesives associated with the preservation numbers located on the back of the image. The adhesives present on the secondary paper support were also removed using the same method and steps. After separating the image from the secondary paper support, the paper holder was immersed in distilled water to remove any dirt and remnants of adhesives. Then, it was placed under a press between two drying sheets.

Fig. No. (21) Shows the separation of the image from the secondary support.

Fig. No. (22) Shows the removal of adhesive residue and the secondary support from the back of the photographic image.

Fig. No. (23) Shows the secondary support and the background of the image after separation and removal of the adhesive residue.

Fig. No. (24) Shows the secondary support and the surface of the image after separation and removal of the adhesive residue.

Fig. No. (25) Shows the stages of removing the adhesive residue from the secondary support of the image.

- The treatment and consolidation process:

Involved preparing calcium hydroxide nanoparticles in ethyl alcohol at a concentration of one gram per liter. The secondary holder and the photographic image were then immersed in this solution. After completion and thorough drying in the air, reinforcement from the back was carried out using a 4% concentration of Klucel G.

	
Fig. No. (26) Shows the preparation of calcium hydroxide nanoparticles for acidity treatment.	**Fig. No. (27) Shows the treatment of acidity in the image using calcium hydroxide nanoparticles.**

- ***Completing Missing Parts of the Case Study Image:***

The missing parts of the case study photographic image were completed using multiple methods. During the restoration process, digital restoration was employed. After digitally processing the image and printing it on specialized restoration paper, specifically Japanese restoration paper of the same thickness and weight as the photographic paper, the printed image was then utilized in the completion and restoration processes, as illustrated. The restorer relies on digital restoration for both completion and manual restoration operations because the overall appearance and form are harmonious and consistent in terms of colors and completion with the original image. This assists researchers and museums in preserving heritage photographic images without damage. They are digitally processed and used in manual restoration, resulting in the outcome that the restored photograph closely resembles the original photograph before deterioration and damage.

The restoration process also involved repairing cracks, gaps, and areas where the surface of the photograph had separated using Carboxymethyl cellulose (CMC) along with Japanese tissue paper. On one side, the tissue paper was used, and on the other side, Japanese restoration paper, which had the image printed on it, was utilized. Additionally, a specialized graphite pencil for photographic images was employed for color retouching if necessary. Missing parts of the image due to damage or loss were also restored using appropriate Japanese restoration paper matching the thickness of the photographic image, along with the use of tissue paper on the other side. Carboxymethyl cellulose (CMC) was used for adhesion, and after completing the restoration, the secondary paper support was reinforced and strengthened. The photograph was then reattached to the secondary support. It's worth noting that the restoration process was carried out without adding any color retouching. The aim of the restoration was solely to complete the missing parts without achieving aesthetic harmony between the missing parts and the rest of the image. In some cases, the restorer may choose not to complete the missing parts and leave them as they are.

During the restoration of the case study photograph to complete the missing part, Japanese restoration paper (Kozo paper) and Japanese tissue paper were used. Additionally, a specialized graphic pencil was used to address color retouching in the photographic images. After completing the restoration of the photograph, the secondary support was reinforced and strengthened. The photograph was then reattached to the secondary support, with Japanese tissue paper links made to facilitate adhesion. These links acted as a bridge between the secondary support and the photograph, preventing direct adhesion of the photograph to the secondary support once again.

	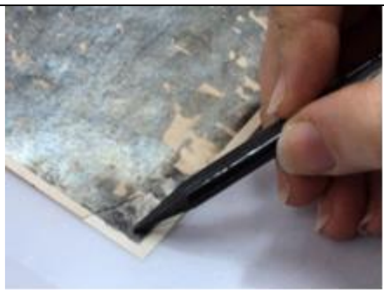	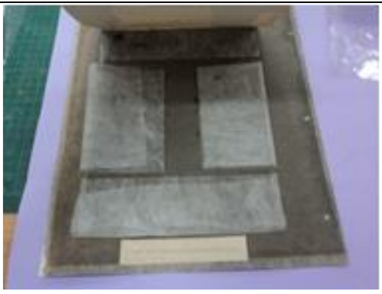
Fig. No. (28) Shows the stages of completing the missing parts of the case study photographic image.	**Fig. No. (29) Shows the stages of completing the missing parts of the case study photographic image.**	**Fig. No. (30) Shows the preparation of the secondary support for reattaching the case study photographic image onto it.**

	
Fig. No. (31) Shows the case study photographic image before restoration.	**Fig. No. (32) Shows the case study photographic image after restoration.**

Conculsion:

This research presented an applied study on the restoration and preservation of a photograph from the Al-Aqsa Mosque album, preserved in the Central Library at Alexandria University. The study aimed to address the visible damage to the photograph and identify the causes leading to this damage. Examination and analysis revealed the significant impact of the environment, particularly the coastal environment surrounding the preservation environment and the high relative humidity, on the damage to the photographic image. Through the use of a variety of restoration and preservation techniques, including digital restoration and traditional restoration processes such as mechanical and chemical cleaning, as well as consolidation, this research demonstrated the possibility of combining digital restoration techniques alongside traditional restoration processes to create a thoughtful integration of modern technology with traditional methods. The use of digital restoration tools allowed for precise correction of defects and damage in the image, ensuring the preservation of its original appearance and integrity. Moreover, the study demonstrated the effectiveness of using a 3% concentration of nano-calcium hydroxide solution alongside consolidation using Klucel G at a 4% concentration in treating the high acidity within the image.

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