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A NEW METHOD OF LINING OIL PAINTINGS USING POLYURETHANE

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ABSTRACT

Mechanical factors that affect oil paintings like scratching, shaking, percussion, tapping behind the Canvas easel will affect the oil painting layers including painting layer, On the other hand, the materials used in lining oil paintings such as glue, wax or synthetic resins do not prevent or reduce the resulting deterioration caused by previous factors, so there was a necessity for searching for a substance that reduces the previous deterioration sorts. In this study, the experimental research goal is shown to compare this material with the materials used in lining. Samples of linen and cotton fabric were made, lining them with four adhesive materials, the work of industrial obsolescence, measuring the resistance of these samples to the tensile strength and elongation and strength of puncture and flexion. The processes were monitored by Electron microscope scanner used before and after the industrial limitation and image. The results showed that polyurethane, which was compared with the rest of the other lining materials, is more resistant to the mechanical forces that affect the oil paintings. The case study was done on ancient oil paintings, from a collection of the Mohammed Ali Museum in Egypt. It is an antique painting dating back to 1898, where the experimental results were applied and can be lined with a new material (polyurethane).

KEYWORDS: oil painting, Lining, Polyurethane, Conservation, Restoration.

1. INTRODUCTION

We tend to painting's lining when maintaining oil painting to fix the ruptures, cracks and tears that occur in the canvas Support, to strengthen the old painting support, and when the support is in a State of vulnerability and severe weakness (Plenderleith and Werner, 1971; Caldararo, 1987; Plenderleith, 1998) or to fix the appearance of flaking the colors or splits (Kennish, 2017).

There are several methods used in lining the oil paintings, where the lining of the paste Glue is one of the oldest of these operations (Young and Ackroyd, 2001; Stoner and Rushfield, 2013) The other important methods are lining with wax and natural resin, and lining using the BEVA 371 (Berger, 1972; Kronthal et al., 2003).

This research has proven that the previous methods of lining have defects. The most important defects are that they do not resist the mechanical damage factors such as punctures, percussions, frictions or raptures as resisted by the new material used in lining in this research. In addition, it does not resist flexions or laxity of the Canvas in case of painting laxity, displacement or dropping the keys from the corners of the Stretcher Bar Frame (Thomson,1985).

Because the Canvas easels have a role in causing the ruptures of all the layers of the painting, as well as in the cracks of the layers of the painting, especially when there is friction or percussion on the Canvas easel .If there is shaking or any kind of stress that results from the different factors, the lining material must contain some resistance to prevent any of these factors from occurring (Hackney, 2017).

In this research, we will highlight a new material we will use in lining oil paintings and have the properties of greater resistance to mechanical damage mentioned above. This material is polyurethane, where laboratory experiments that we have conducted in this research proved that the polyurethane material has these characteristics: resistance to mechanical damage and penetration between the support fibers. In addition, we will work on applying the restoration of ancient oil paintings and lining by this material.

2. RESEARCH OBJECTIVE

The purpose of this research is to search for a new material characterized by a new property not found in the materials used in the lining of oil paintings. This property aims to maintain the integrity of the oil painting after lining, and resist mechanical stresses such as bending, tearing, puncture and elongation Thus, it reduces the occurrence of some damage. Also, this new material has the same characteristics of materials previously used in the lining, and there are no defects in these materials (El-Sheikh et al., 2017).

3. METHODS AND EXPERIMENTS

3.1 *Samples Processing*

Four materials were prepared for the process of lining for being studied; these include animal glue (gelatin glue), It consists of a group of carbon compounds, hydrogenates, oxygen and nitrogen, and contains a high percentage of gelatin, coedrin and a percentage of keratin (Horie, 1987), The animal glue was prepared by adding 75 g of glue to 900 cm ^{3} of water in a bowl, leaving it for a day with water, then put it on low heat and stirring until it became homogeneous (Barron's,1997).

The second material is beeswax with natural resin; bee wax is a complex mixture of hydrocarbons, esters and free fatty acids (Horie, 1987) , The wax mixture was mixed by mixing five parts of beeswax with three parts of natural resin (the collophony) and one part of turpentine (Ackroyd, 2002) , Where they were placed on a low heat until they became homogenous. The third substance is Beva 371 in el form and ready for lining, and the fourth material is polyurethane, which were obtained ready from the Egyptian market and sold as closed package as in Fig.1.

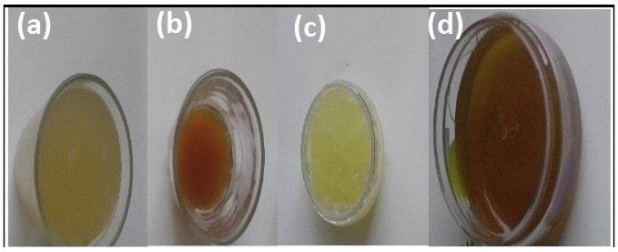

Figure 1. Preparation of lining materials: (a) glutinous glue; (b) wax mixture; (c) Beva 371 ;(d) polyurethane

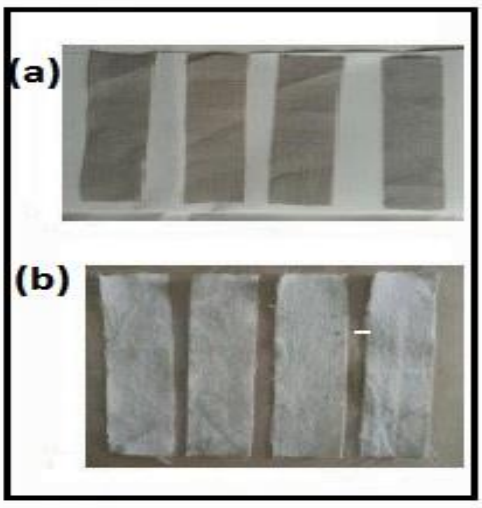

Figure 2. Preparation of textile samples: (a) linin samples; (b) cotton samples

After that, two types of textile were equipped as supports for the lining process, which consist of support of clear linen with a number of wrap and weft (13 x 11) cm², and a cotton clear support with a number of wrap and weft (13 x 11) cm². It was noticed that the preparation of the wrap and weft in the same pile and the same textile in both types, and the samples were in size (5×20) cm, Fig.2.

After that, the Samples were equipped with the application of a ground painting layer and a layer of paint. In the ground painting layer; the same ingredients; the same application technique and the same quantity of materials were taken into account. Also in the painting layer, the same colored materials should be the same; the same medium and the same application technique. All applied by one artist and under the same circumstances.

The next step is by performing the lining process, where the same amount of material is taken into each sample and using the brush, and the use of thermal ironing to complete the lining process, Fig.3.

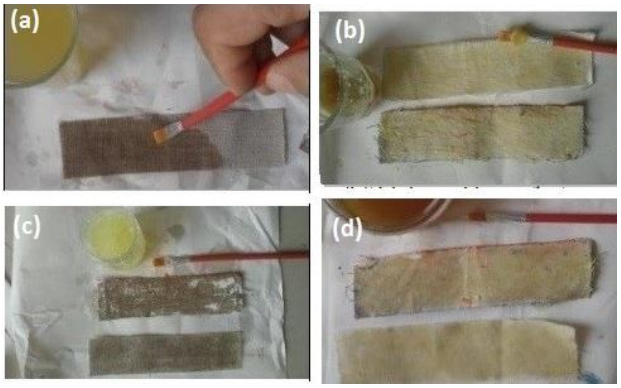

Figure 3. The process of lining the four samples: (a) the lining of the glue; (b) lining with wax; (c) lining in Beva371; (d) polyurethane lining

In the end, samples were taken to measure them prior to industrial limitation and samples for measuring them after industrial limitation. The number of samples was 32 samples, Fig.4.

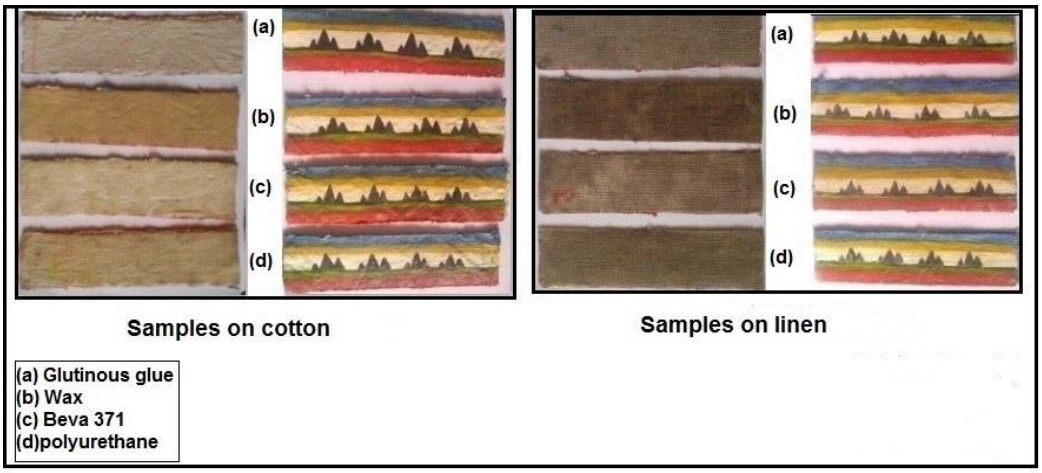

Figure 4. After processing all samples

3.2 *Executing the Experiment and Tests*

Industrial aging and sampling were carried out for 100 hours, at 65° and 80% RH. The samples were examined before and after industrial aging as follows[1] :

a. Examine the strength of the mechanical resistance of the samples and the following devices,
   - Tensile strength and elongation strength on (EN ISO13934: 1999 Maximum Force & Elongation test). Depending on the following operating conditions: (Load range: 100 kgf (kilogram force); Extension range: 100 mm; Gauge length: 100 mm; Speed: 100 / min; Preload: 1.0 kgf; Auto return: On).
   - Pinhole strength and bending resistance force on test apparatus (EN ISO 12236: 1996 Geotextiles - Static Puncture CBR). Depending on the following operating conditions:(Load range: 500 N; Displacement limit: 80 mm; Test speed: 1.0 N; Break detect: 70%; Auto reverse: On).

b. Scanning Microscope (SEM).
   The scanning electron microscopy (SEM) of the samples was carried out to show the effect of the lining material and its penetration into the fibers.

1- Tests and measurements were carried out at the National Institute for Standard (NIS), Egypt

3.3 RESULTS AND DISCUSSION

1. For linen samples

Table 1 gives the data per test.

Table 1. *The results of mechanical resistance tests of linen samples before and after industrial aging*

Name of test	Name of the sample	Before aging	After Aging	Percentage of loss	Standard deviation
Tensile strength (kgf)	The lining of the glue	247.3	161.5	**85.8**	**42.9**
	Lining with wax	200.5	132.8	**67.7**	**33.85**
	Lining in Beva	204.7	196.4	**8.3**	**4.15**
	Polyurethane linings	170.1	169.7	**0.4**	**0.2**
Percentage of elongation (%)	The lining of the glue	13.4	8.34	**5.06**	**2.53**
	Lining with wax	18.88	2.64	**16.24**	**8.12**
	Lining in Beva	14.5	10.9	**3,6**	**1.8**
	Polyurethane linings	22.4	20.48	**1.92**	**0.96**
The strength of puncture resistance (N)	The lining of the glue	380.4	178.6	**201.8**	**100.9**
	Lining with wax	386.7	229.3	**157.4**	**78.7**
	Lining in Beva	90.3	233.9	**256.4**	**71.8**
	Polyurethane linings	353.7	271.3	**82.4**	**41.2**
Strength of flexure (mm)	The lining of the glue	11.9	5.67	**6.23**	**3.11**
	Lining with wax	11.26	8.66	**2.6**	**1.3**
	Lining in Beva	11.6	10.10	**1.5**	**0.75**
	Polyurethane linings	14.16	12.95	**1.21**	**0.60**

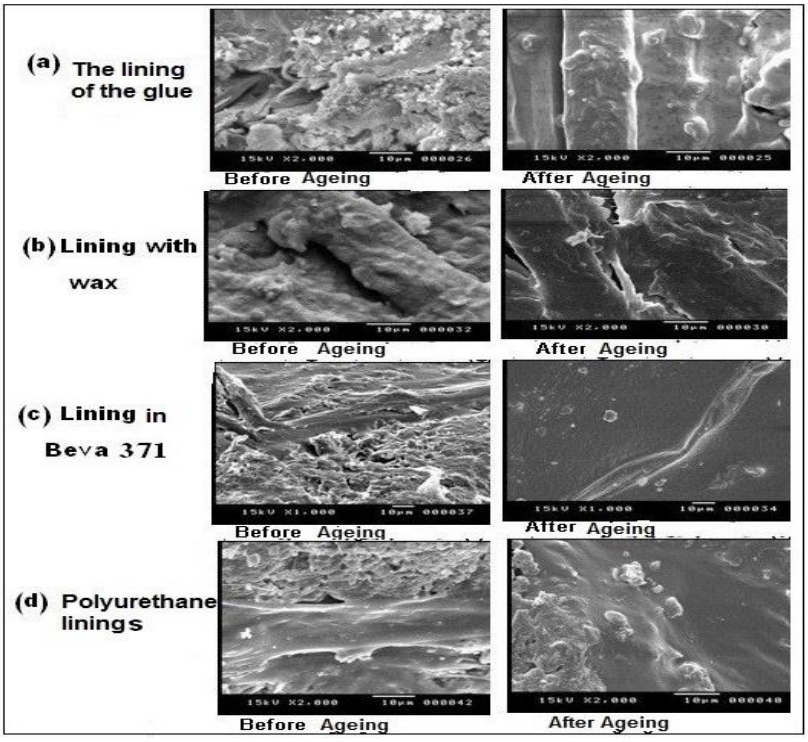

Figure 5. the scanning electron microscopy of linen samples before and after industrial aging.

2. *For cotton samples*

The Table 2 give the data for mechanical resistance tests.

Table 2. The results of mechanical resistance tests of linen samples before and after industrial aging

Name of test	Name of the sample	Before aging	After Aging	Percentage of loss	Standard deviation
Tensile strength (kgf)	The lining of the glue	216.7	117.9	**98.8**	**49.4**
	Lining with wax	178.9	117.5	**61.4**	**30.7**
	Lining I BEVA	212.1	116.2	**95.9**	**47.95**
	Polyurethane linings	219.7	209	**10.7**	**5.35**
Percentage of elongation (%)	The lining of the glue	16.75	8.94	**7.81**	**3.90**
	Lining with wax	18.77	14.76	**4.01**	**2**
	Lining in BEVA	15.6	11.29	**4.31**	**2.15**
	Polyurethane linings	22.38	19	**3.38**	**1.69**
The strength of puncture re-sistance (N)	The lining of the glue	349.9	186.9	**162**	**81.05**
	Lining with wax	341.1	222.7	**118.4**	**59.2**
	Lining in BEVA	370.8	260.4	**110.4**	**55.2**
	Polyurethane linings	263.2	196.1	**67.1**	**33.55**
Strength of flexure (mm)	The lining of the glue	13.97	10.5	**3.47**	**1.73**
	Lining with wax	10.13	9.21	**0.92**	**0.46**
	Lining in BEVA	13.14	9.85	**3.29**	**1.64**
	Polyurethane linings	13.23	13.15	**0.08**	**0.04**

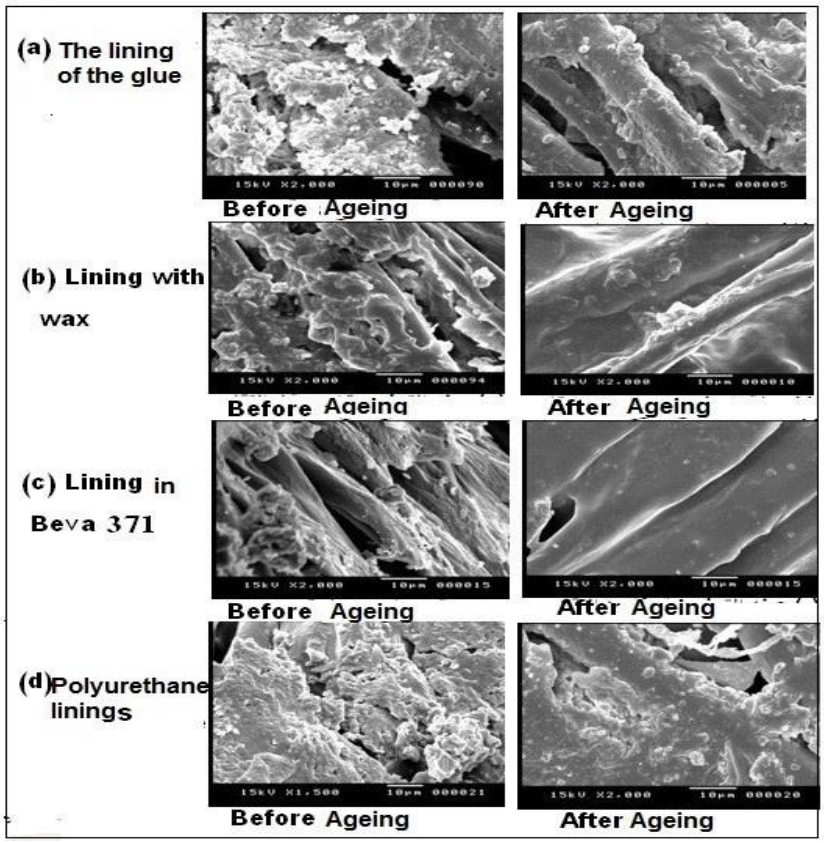

Figure 6. the scanning electron microscopy of cotton samples before and after industrial aging

The mechanical properties of the samples tested showed the resistance of the tensile strength, the percentage of elongation, Pore strength resistance and flexural force, which are shown in the tables, and by calculating the percentage of loss which equals (The value after the industrial obsolescence minus the value before the statute of limitations) Polyurethane was the best, as the loss was always the lowest, Also, when calculating the standard deviation of the samples, the amount of dispersion in the sample loss value was the lowest in the polyurethane, and this result was the best in both linen and cotton textile, so this material prevents or greatly reduce the occurrence of many damages.

The examination in the electronic microscope (SEM) shows that the polyurethane, in addition to the Beva 371, was the best in terms of penetration between textile fibers after the industrial limitation. Therefore, if we look at the figure 5. (a,b), we note that linen fibers were not affected by the adhesion of glue and wax after industrial limitation but remained clear. In the picture (c,d) we note that the adhesive material of the Beva as well as polyurethane has completely covered the fibers, in figure 6.(a) The cotton fiber did not affect the animal glue material, but the picture (b) showed that the wax covered the cotton fiber after the obsolescence covered partially, as well as the picture (c) where the Beva covered the cotton fiber completely, while the image (d) of the polyurethane was partially covered and permeated in the cotton fiber, bearing in mind that the linen support gave better results than the cotton support.

These results support that polyurethane is the best for the process of lining oil paintings, in terms of resistance to external mechanical forces such as tensile, puncture, friction,shearing, percussion and other external emergency factors that are exposed to oil paintings during transport or in the stores or exposed to blows.

And the idea and method of the implementation of laboratory experiments where Bradley mentioned that the tightening of samples is the basis for testing the tensile strength and shear strength, through the device, and usually in the laboratory of quality (Bradley,1984; Hodgkinson, 2000) The polyurethane has excellent cutting strength while retaining flexibility and shock resistance and has good electrical properties, less resistance to combustion and resistance to biological damage (Russell and Berger, 1982). Has stated that lining oil paintings with any solid, fixed or stabilized material will reduce the movement of the respirator and shrinkage. According to Hansen, this material was used in the restoration of Archaeology as wood, leather and plastic adhesives, as well as for stone, cement and brick adhesives, and it was evaluated to strengthen porous materials and strengthen the skin, wood and other protein materials (Hansen and Agnew, 1990).

This material has high adhesion properties. It is strongly associated with mechanical and physical strength, acts as an adhesive material, has strong thermal and chemical stability and good electrical properties. It is also resistant to weather and light conditions (Sung, Gwon et al., 2016), The polymer can be removed by the condensation in solvents such as dichloromethane, and then the gel is removed from the surface ((Horie, 1987).

4. CASE STUDY

4.1 Archaeological registration of the oil painting

The oil painting is a collection of the Museum of Manial (Mohammed Ali Museum) that belongs to the Egyptian Ministry of Antiquities. It is registered in the museum records under record number (104) and trace number (80), and it was stored in the museum's warehouse.

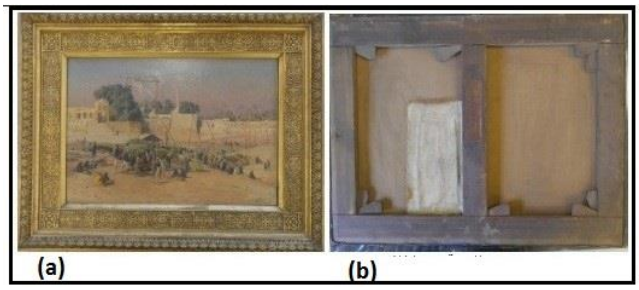

Figure 7. the Oil painting: (a) from the front; (b) from the back

The painting represents a scene of a market on the Nile River in one of the Egyptian rural areas for traders selling reeds, where women sit in front of some baskets with vegetables on display. Some men sell reeds on carts, there are also a group of sailboats on the beach. At the top of the painting is a group of houses on the other side of the river, a mosque and an old house with an outside staircase.

The dimensions of the painting are rectangular form (69) cm long and (46) cm width, and the width of the golden frame (14) cm.

4.2 Date of painting

The dating of paintings is often concerned with confirming their association with a specific painter, or at least a specific date. The painting is signed by the French orientalist Eugene Girardet (1853-1907) and has no history but is signed by the artist in the lower right corner (Fig. 8 a). Also on the Stretcher Bar Frame is a paper label written in French, The Stretcher Bar Frame for Canvas from

France to Egypt, where it is written in the name of (E.GERFAUD). The title is Paris-Provence, Fig. 8b. There is also another sticker on the golden frame in a circular way back to the same company and the same title as in Fig. 8c, This indicates that the artist has brought with him the technical tools to draw this painting from France to Egypt and shipped it either chassis or golden frame.

In 1898, he traveled to Egypt and Palestine and drew many scenes in Cairo and Jerusalem. His style of work increasingly showed an increasing influence of impressionist artists (Thornton, 1994), The history of this painting dates back to 1898 when the artist visited Egypt.

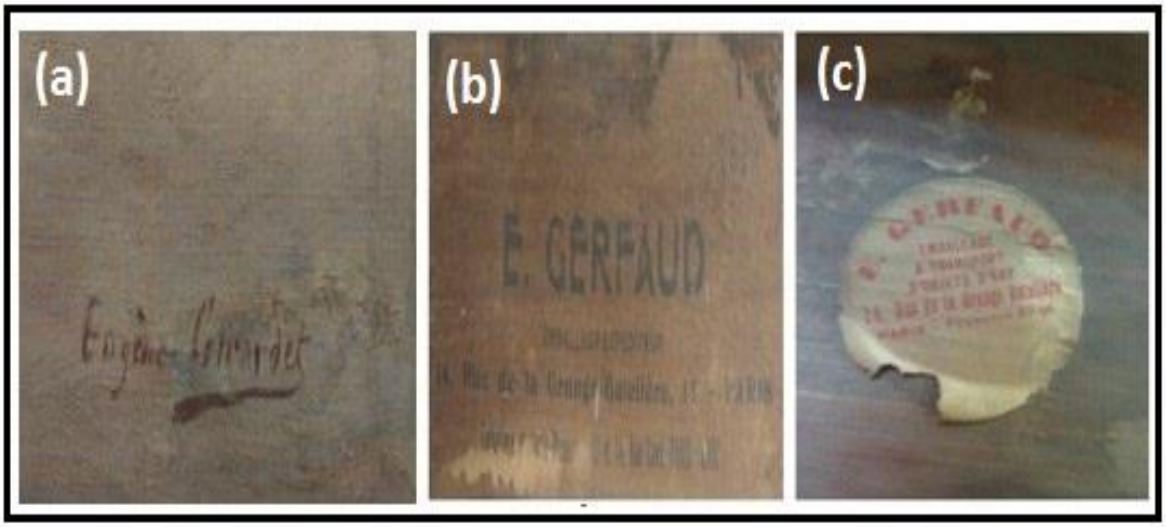

Figure 8. (a) the artist's signature; (b) posters found on the Stretcher Bar Frame; (c) posters found on the golden frame.

4.3 Tests and analyzes

Samples were collected carefully from the destroyed edge, using a micro scalpe (salma et al., 2016) The following tests were performed:

- ***Ultraviolet examination***; used to study the surface and the various manifestations of deterioration on it, such as give an idea of cracks, fractions, and places of frills in the previous - restoration.
- ***Scanning using a light microscope (USB)***; has been used to study the external appearance of the surface of the painting, and knowledge of the type of fabric used in terms of the number of filaments of warp and weft.
- ***Analysis and teste of a device (SEM) with EDAX***; where we were able to identify the type of textile fibers used in the cloth carrier and the type of colored material, using a SEM Model JEOL JSM 5400 LV: EDX Link ISIS – Oxford Detector High Vacuum.
- ***X-Ray Diffraction (XRD) Analysis***; This method was used to identify the white matter type in the ground layer of the imaging as well as the identification of the colored materials, the device used is A Philips X-Ray Diffraction Equipment, Model PW / 1710 with Fe-Filter at 40 KV, 30 MA, has used Scanning Speed 0.02 / Sec. Analysis Program: Match 2014 + PDF4 2015.
- ***Analysis using (FTIR) analysis***; to determine the type of medium used as a bonding material on the ground painting, the device used by the Jasco Model 4100.
- ***Analysis using the method of gas chromatography***; to identify the quality of the oil medium used in the oil painting, which is one of the most important ways to identify the fatty acids that make up the oil medium (Gimeno-Adelantado, Mateo-Castro et al. 2001), the device used A GC 6890N Network GC system (Agilent Technologies, USA) with a 5973 Network Mass Selective Detector; a 7683 Series Injector.

4.4 Discussion of tests and analyzes

4.4.1 The number of warp and weft in the canvas

Through the scanning of the optical microscope (USB) to the surface of the painting shows that the texture structure of the support of the simple type, 1: 1, and the number of wrap and weft for each is (30×30) cm², figure (9), and identified the type of Canvas easel used, during the microscopic examination of the fibers of the canvas and using the Hertzberg dye it became clear that the canvas type was cotton canvas.

Figure 9. the structural structure of the support

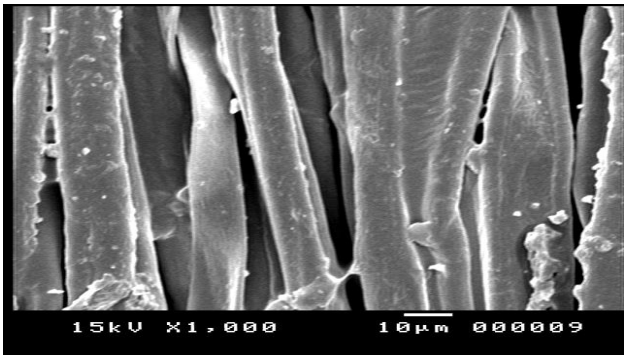

Figure 10. the fiber of the canvas through scanning electron microscopy (SEM)

4.4.2 *Type of canvas*

Through scanning with the scanning electron microscopy (SEM), and Compared to the standard images of fiber, both linen and cotton, which is likely to be used as a support of this painting shows that the type of fiber is cotton, as in Fig. 10.

4.4.3 *The type of white filler material on the ground painting layer*

The x-ray analysis showed that the white matter used in the ground painting layer is Zinc Oxide (ZnO), (Card No. 01-075-1526), as shown in Fig.11.

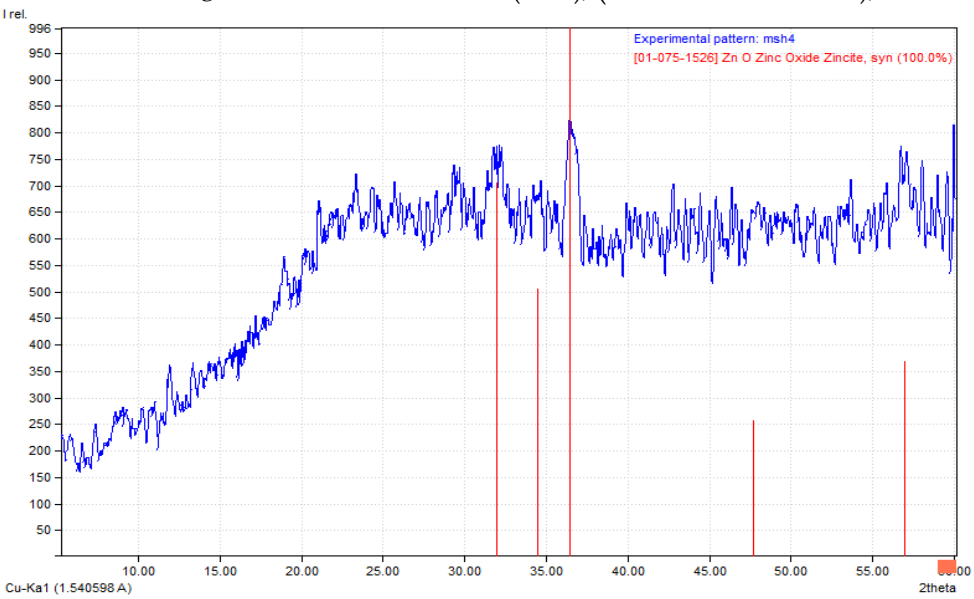

Figure 11. Analysis of white matter through an XRD device.

4.4.4 *Type of colored materials*

The **red color** was identified by XRD and it was found that the Indian red (hematite) Fe_2O_3, (Card No. 98-901-4881) Representing 32.5% of the sample taken from the painting, Mixed with zinc white color (card number 04-004-6457) which constitutes 67.5%, as in Fig. 12, and through the electronic microscope scanner with EDAX, Fig. 13.

Therefore, we find that the zinc oxide in this sample is high because the color of red hematite mixed with a high proportion of white zinc,

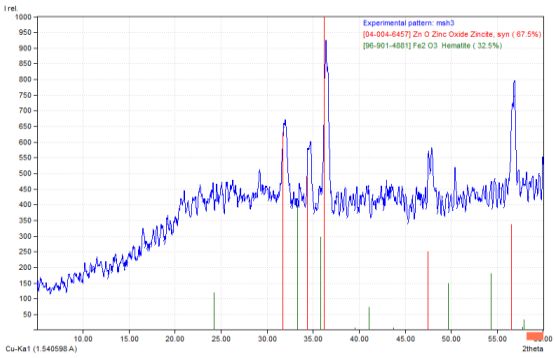

Figure 12. Type of red color hematite through analysis (XRD).

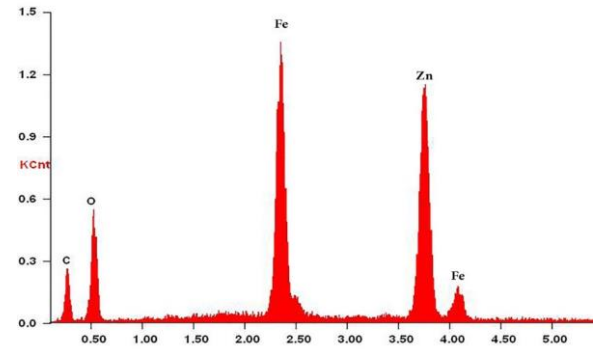

Figure 13. The red color of the hematite by analyzing the EDAX scanner electron microscope

The **gray color** was identified by the (XRD) examination and it was shown as Zinc Oxide ZnO (card number 04-013-6609), The ratio is 63.7% Mixed with black graphite C, (Card No. 01-075-1621), and its percentage 36.3% (Fig.14).

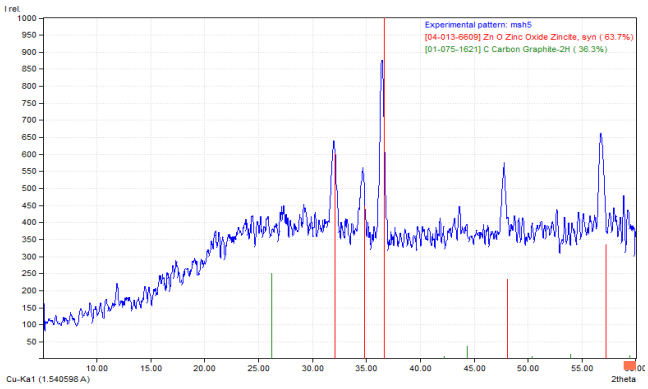

Figure 14. The type of gray color through analysis (XRD).

The **blue color** was identified by the XRD probe and it was shown as blue Sky Co_2SnO_4 (Cerulean Blue), Card No. 96-591-114; Representing 12%, the mixture is high with white zinc where it is formed 88%, (card number 96-230-0451) as shown in Fig. 15, and also through the electronic microscope scanner supplied with the EDAX unit as in Fig. 16. It turns out to be a blue sky.

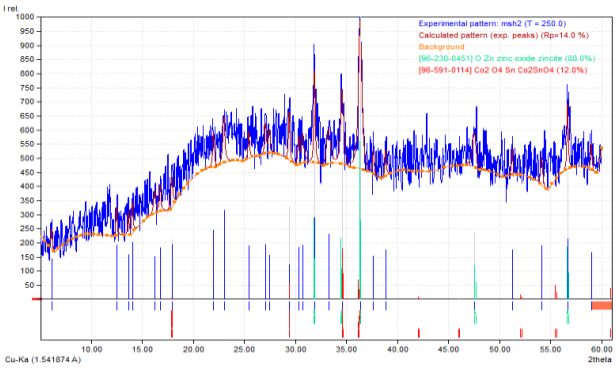

Figure 15. The type of blue color by analysis (XRD).

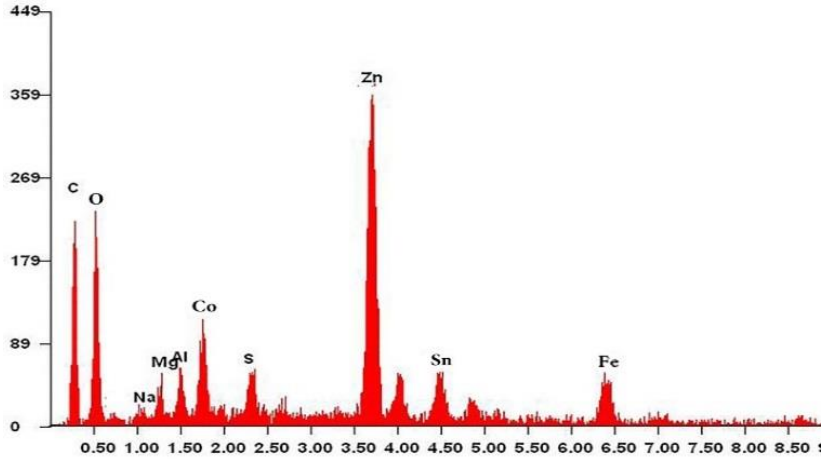

Figure 16. The type of blue color by analyzing the electronic microscope scanner supplied with the EDAX unit

4.4.5 Type of bonding material in the ground painting layer

By using FTIR and comparing the active groups in the standard sample (Derrick et al., 1999), and the sample under study, the adhesive material on the surface of the imaging is animal glue, Where it appeared (N- H Stretching band) at the peak 3431.71 CM^{-1}, and appeared C-H Stretching band at the Peak 2924.52 cm^{-1}, as well as the group C-O Stretching band appeared at 1664.27 CM^{-1}, and the bending band C-H appeared at 1380.78CM^{-1} (Fig. 17).

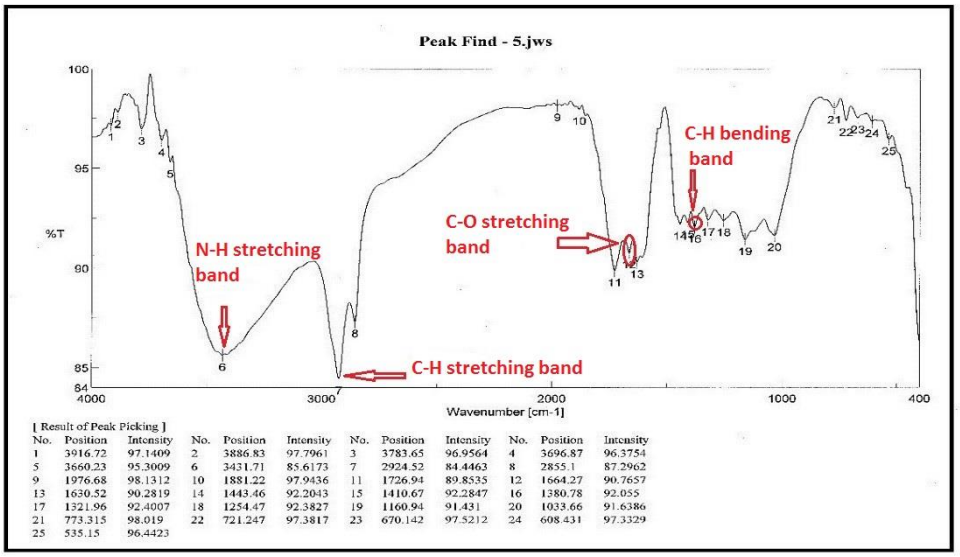

Figure 17. The bonding material in the surface of the imaging is animal glue

4.4.6 The color medium type

The results of the analysis showed that the color medium used was linseed oil. The percentage of palmitic acid C16 to Esteric C18 was 1.49. This percentage indicates that the oil used is linseed oil. The following table shows the fatty acids in the sample, and Fig.18 explains the result of the chromatography analysis of a GC-MS device.

Table 3. The fatty acids in the sample of GC-MS chromatography analysis.

Fatty Acids	Retention (Min)	Content %
Palmitic C16	19.54	6.58
Stearic C18	23.28	4.43
Oleic C18-1	24.17	18.51
Linoleic C18-2	25.21	17.25
Linolenic C18-3	27.12	53.21

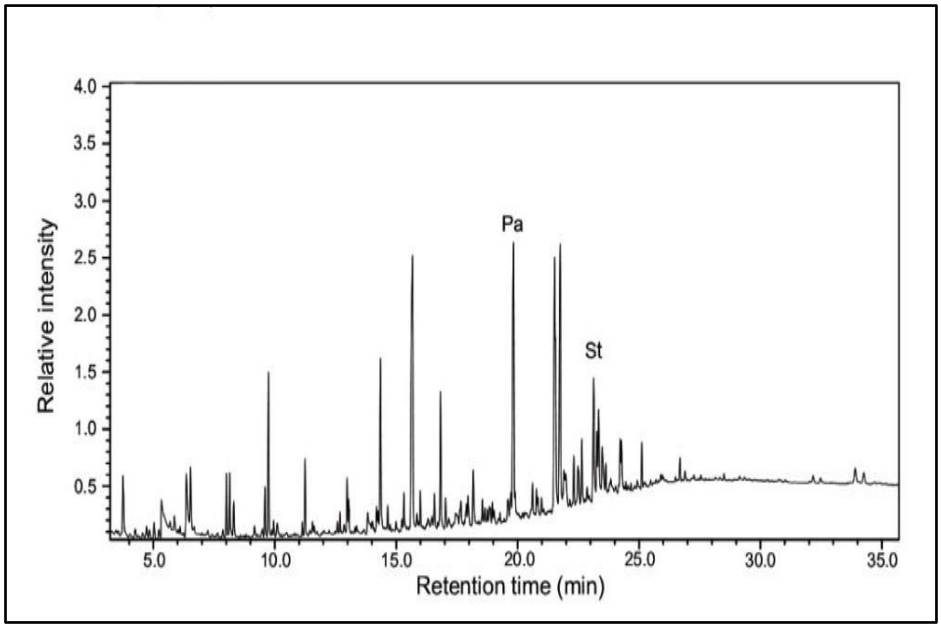

Figure 18. The GC-MS chromatography analysis.

4.5 Documentation and Deterioration

The layer of the support suffered from the appearance of damage large and clear is a large piece in the form of a rectangle caused by mechanical damage in the center of the painting, where it was found that a previous restoration, Through the background, is a patch, as in Fig.19.

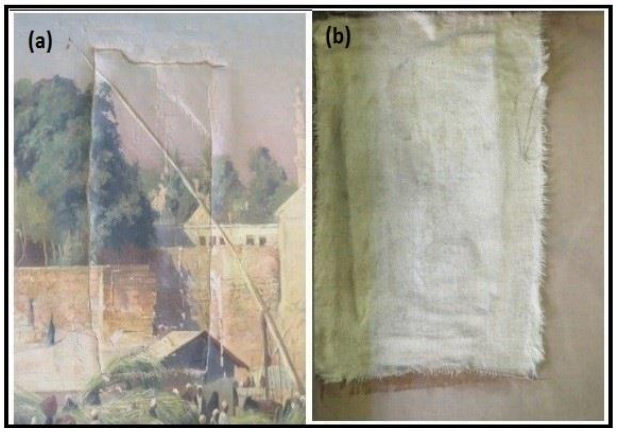

Figure 19. (a) cutting forward; (b) the patch from the back

In addition, the painting layer suffers from a flaking color (Fig.20a), a retouching located in different areas of the painting layer (Fig. 20b). The varnish layer shows yellowing and staining.

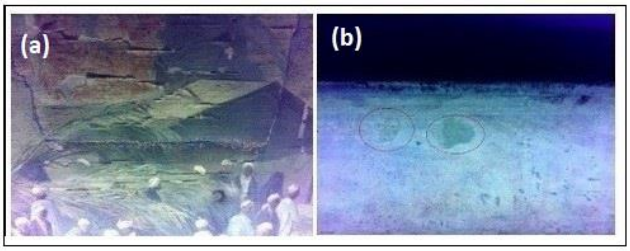

Figure 20. (a) color flaking; (b) old color retouching

4.6 Treatment and Restoration

The painting was cleaned through mechanical cleaning using soft brushes to remove dust and smears from the back of the painting and forward.

The painting layer was reinforced by BEVA 371, (Krotha et al., 2003), where it was placed on the surface of the canvas several layers, waiting between the first layer followed by until the full drying (Fig. 21a), and then the individual was fed by the cauter (Mohie, 2005) (Fig. (21b).

Figure 21. The process of strengthening the painting layer: (a) Individual Beva by brush; (b) Individual BeVA by cauter.

The old patch was then removed, by tested for adhesion strength and then removed.

The lining was made using a clear cotton textile, where it was well washed. The polyurethane was chosen for the lining of the painting based on the experimental results carried out by the researcher.

The painting was placed first on a flat table, after securing the face with aluminum foil on the cardboard paper for not sticking the plate to the table during the lining process and the excess of it to the surface where the painting is placed upside down, the new support was placed on the back of the painting. Through the upside-down cup, the new support was replaced from the center and towards the sides until each support was confirmed. without the need for thermal heating, and then was left and put a weight of Asp to dry.

Figure 22. The process of lining with polyurethane.

Toluene was given a good result in the process of removing the varnish after the first alcohol tested in a hidden area of the painting and then the Toluene was the best in the removal.

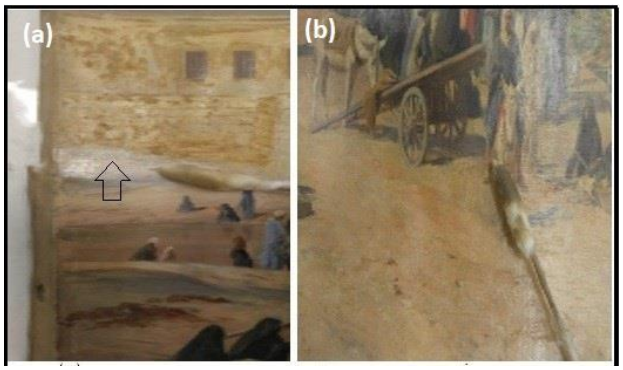

Figure 23. The process of removing the varnish layer

Figure 24. The re-application of the varnish layer

A mixture of calcium carbonate ($CaCO_3$) with white zinc (ZnO) was made by 2: 1 (Szmit-Naud, 2003) and was placed as a ground layer of form, Retouching is very important procedure to finish the restoration process (Salamh et al; 2016), Acrylic colors were used for retouching, and acrylic colors are more stable and chemical, do not melt in water, and resist climate changes and good adhesion (Bestetti and Saccani, 2014) . To re-apply a new varnish layer, a varnish of acrylic resin is used in modern varnishes., (bdacril, methyl methacrylate), has been applied through spraying by applying the painting to a flat table, making sure that the spray is sprayed and covers all parts of the painting surface (Mohie and Korany, 2018). The modern varnish extracted from synthetic resins is better than varnish obtained from natural resins (Mayer, 1991).

6. CONCLUSION

The new material that was used in this research for the lining of oil paintings, which is polyurethane, which proved through laboratory experiments that it maintains the integrity of the oil painting, and thus reduce the occurrence of some of the deterioration, as it proved resistance to the forces of the hole and tensile strength and bending forces and resistance to elongation ratio, before or after industrial limitation, by calculating the percentage of loss before and after industrial obsolescence.

This material has proved its ability to resist previous damage factors both with linen textile and cotton textile, where in both types it gave the best results for the rest of the other lining materials.

Polyurethane has also produced good results through its penetration between the textile fibers after lining, as well as the BEVA 371, as this penetration increases the integrity of the textile and the strength of its resistance to external mechanical forces.

These practical results were applied to an antique oil painting from the Mohamed Ali Museum in Egypt, a painting by the French artist Eugène Gerardi and its history in 1898. The painting applied to it contains damage caused by human damage with a large cut.

The lining was made using polyurethane, which was first reinforced by BEVA 371, and was applied in retouching colors using acrylic colors and varnish of modern acrylic (bdacril).

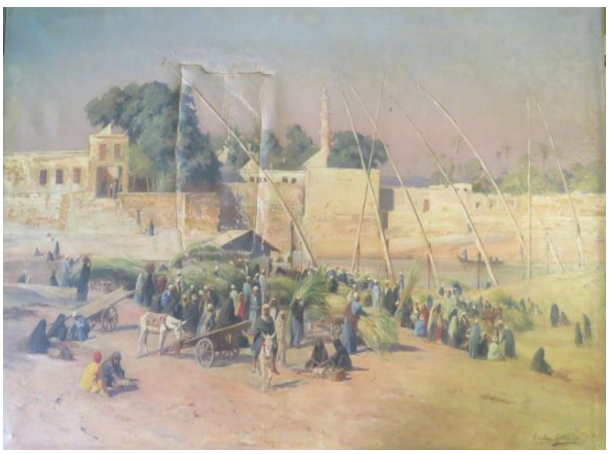

Figure 25. The oil painting before restoration

Figure 26. The oil painting after restoration

REFERENCES

Abdel-Ghani, M. (2015) Dating a coptic Icon of anonymous painter by spectroscopic study of Pigment Palette. *Mediterranean Archaeology & Archaeometry*, Vol.15, No.1, pp. 1-16.

Ackroyd, P. (2002) The Stucural Conservation of Canvas Painting, changes in attitude and practice since the early 1970s, *Studies in Conservation*, Vol. 47, Issue sup1, Reviews in Conservation 3, pp. 3-14.

Berger, G. A. (1972). Formulating adhesives for the Conservation of Paintings. *Studies in Conservation* **17**(sup1), pp. 613-629.

Bestetti, R., Saccani, I. (2014) Materials and methods for the self-production of retouching colours. *International Meeting on Retouching of Cultural Heritage RECH2*. 24-25 October, pp. 26-38.

Bradley, S. (1984) Strength testing of adhesives and consolidants for conservation purposes. *Studies in Conservation* **29**(sup1): 22-25.

Barron's. (1997) *All About Techniques in Oil,* Canada, pp. 38-39.

Caldararo, N. L. (1987) An outline history of conservation in archaeology and anthropology as presented through its publications. *Journal of the American Institute for Conservation* **26**(2), pp. 85-104.

Derrick, M.R., Stulik, D., Landy.J.M.,(200) Infrared Spectroscopy in Conservation Science, *The Getty Conservation Institute,* Los Angles, 181.

El-Sheikh, S.M, Mona F. Ali, Kholod K. Salama (2017) Low cost pulps with microemulsions for cleaning of fresco painting surfaces. SCIENTIFIC CULTURE, Vol. 3, No 1, pp. 41-46. DOI: 10.5281/zenodo.192843.

Emile- Male, G. (1976) The Restorer‘ s Hand Book of Easel Painting.NewYork, 107.

Gimeno-Adelantado, J., R. Mateo-Castro, M., Doménech-Carbó, F., Bosch-Reig, A., Doménech-Carbó, M., Casas-Catalán and L. Osete-Cortina. (2001) Identification of lipid binders in paintings by gas chromatography: Influence of the pigments. *Journal of Chromatography A* **922**(1-2), pp. 385-390.

Hackney,S. (2017) Paintings on Canvas: Lining and Alternatives', *Tate Papers*, No2 , accessed 17 August.

Hansen, E. F.., N. Agnew. (1990) Consolidation with moisture-curable isocyanates: polyureas and polyurethanes. ICOM Committee for Conservation, 9th triennial meeting, Dresden, *German Democratic Republic*, 26-31 August 1990: preprints.

Hodgkinson, J. M. (2000). *Mechanical Testing of Advanced Fibre Composites*, Elsevier Science.

Horie, C. (1987). *Materials for conservation: organic consolidants. Adhesives and Coatings*, London.

Kennish, M. J. (2017). *Practical handbook of estuarine and marine pollution*, CRC press.

Kronthal, L., J., Levinson, C. Dignard., E. Chao and J. Down (2003). BEVA 371 and its use as an adhesive for skin and leather repairs: background and a review of treatments. *Journal of the American Institute for Conservation* **42**(2), pp. 341-362.

Mayer, R. (1991). *The artist's handbook of materials and techniques*

Mohie, M. A. ., M. S. Korany (2018). Study of Materials and Techniques for the Conservation of Two Miniature Paintings. *Conservation Science in Cultural Heritage* **17**(1), pp.101-116.

Plenderleith, H. J. (1998). A history of conservation. *Studies in Conservation* **43**(3), pp. 129-143.

Plenderleith, H. J. ., A. E. Werner (1971). *The conservation of antiquities and works of art: treatment, repair and restoration*.

Russell, W. H. and G. A. Berger (1982). The behavior of canvas as a structural support for painting: preliminary report. *Studies in Conservation* 27 (sup1), pp. 139-145.

Salama,K.K.,.Ali,M.F ., Moussa, A.M. (2016) Experimental Study of The Retouching Materials applied on el Sakakeny palace, *Scientific Culture*, Vol.2 No 3, pp. 1-4.

Salama,K.K .,.Ali,M.F .,. Moussa, A.M (2016) Deterooration factors facing mural paintings in el sakakeny palace (problems and solutions), *Scientific Culture*,Vol. 2, No 3, pp. 5-9.

Stoner, J. H. and R. Rushfield (2013). *Conservation of easel paintings, Routledge*, p.928

Sung, G., Gwon,J.G, Kim, J.H. (2016). Characteristics of polyurethane adhesives with various uretonimine contents in isocyanate and average alcohol functionalities. *Journal of Applied Polymer Science* 133 (31), pp. 133-151.

Szmit-Naud, E. (2003). Research on materials for easel painting retouches: part 2.*The picture restorer* (24), pp. 5-9.

Thomson, G. (1994) *Museum Environmena*. Second Edithion. The national gallery, London: 66.

Thornton, L. (1994). *The Orientalists: Edition en langue anglaise*, ACR Edition.

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