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History, Technology, and Treatment of a Painted Silk Folding Screen Belonging to the Palace-Museum of Golestan in Iran

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Abstract
This study aimed to design and establish effective methods of conserving and restoring a double-sided silk folding screen in the Golestan museum of Iran. We examined the structure, techniques, pigments, silk type and extent of degradation of the artifact. Investigations and analysis were used to identify the pigments using noninvasive methods. Fourier transform infrared spectroscopy (FT-IR), a Scanning Electron Microscope (SEM-EDX) and X-ray fluorescence (XRF) analysis were used for identifying the pigments and fibers. The first step was to estimate why the painted side did not have any noticeable degradation compared with the whole structure and dyed side, which had suffered substantial physical decay. The effectiveness of several combinations of fungicides in preventing the fungal deterioration of the silk artifact was tested and Dichlorophen was selected. The cleaning process was carried out with low powered vacuum suction, a soft brush and soft rubber. To restore the folding screen, the paper conservation based method was used. Therefore the remounting process was done using self-adhesive Japanese tissue paper to attach the support to the silk in order to avoid stitching through the painted surface. Consolidation was not deemed necessary because the paint surface was not actively flaking. Since the treatment method applied in this study could successfully conserve and restore the artifact with minimal destructive impact, it is worth replicating in similar conservation projects.

Key words: *painted silk, Chinese folding screen, consolidation, fungicide, treatment.*

Introduction

The selection of appropriate conservation and restoration methods for historic textiles is a considerable problem. The structure of these artifacts and the lack of knowledge pertaining to the destructiveness of various treatments increase the degree of vulnerability for historical textiles, especially those in a non-standard condition. The treatment plan suggested for textile museum objects includes cleaning, consolidation and restoration. Identification of the type of textile is the first step in the treatment process, followed by non-destructive consolidation [1]. Choosing the consolidants, fungicides and application methods are important challenges faced during consolidation. For instance, some materials and methods that are suitable to treat one part of the object may be harmful for other parts, or they damage ancient objects by fading dyes, creating dryness and decreasing fibre strength [2].

The history and structure of a folding screen is one way of selecting a conservation method. The type, age and weighting agent on physical and chemical decay are additional items that must be considered when determining effective conservation treatments [3 - 6].

There are a large number of chemical and non-chemical methods for cleaning and preventing the fungal deterioration of textiles. Using enzymes is a cleaning method for the removal of adhesives that consolidate with acrylic resins [4]. Cleaning with a low suction cleaner composed of 95% ethanol and 5% methanol and consolidation with Klucel G adhesive were suggested by Anne Haldane (2008). Lascaux, Klucel G (SD), Tylose MH300(SD), Mowilith DM5 (E), and 498 HV (E) are other common materials used for consolidating ancient textiles [1, 7].

Fungicides used for the preservation of historical textiles are varied. Choosing the most appropriate depends on the type of fabric and the environmental conditions in which it will be used. Ekibon, which is composed of methyl bromide (as an insecticide) and ethylene oxide (as a fungicide), is a material used for treating silk artifacts that have deteriorated as a result of fungi and insect attacks [4]. Lichenicide 246 and Dichlorophene are two of the most common fungicides used for historical textiles [8]. In a recent study by Abdel-Kareem, the combination of polymers and fungicides such as Neo-Desogon were also used, which is reduced degradation by fungal deterioration [2].

This study dealt with a historical Chinese folding screen from the Palace-Museum of Golestan in Iran. The folding screen was a rare sample of silk folding screens, and it had not been conserved or restored since it was transferred to Iran. Also any treatment process was highly sensitive.

Figure 1. Chinese folding screen examined in this study.

The special ornamental aspects of this screen presented cleaning and fumigating challenges for conservators because the silk folding screen was painted with mineral pigments that are sensitive to cleaning materials. This paper illustrates the wide range of materials that are present in this textile object and demonstrates the importance of understanding the properties of these component materials when formulating conservation strategies for this object. The main aim of this study was to develop and establish a strategic plan for the conservation of a historical folding screen based on paper conservation at the Golestan Museum.

Figure 2. Accumulation of dust and some tea and water stains on the surface of the fabric.

Materials

Chinese folding screen

Historically silk has been used for various purposes because of its strength and elegance. One of the many ways silk fabrics have been used is painting on silk, which is an old Asian technique which has led to the creation of significant and exquisite artifacts. In the production of such works of art, Chinese painted silks, with their extraordinary visual grace, were considered; therefore, these objects are preserved and protected throughout the world [5].

From ancient times, China, Japan and other eastern countries have used folding screens as decorative elements. The oldest recorded use dates back to the 8th century B.C, and some samples were reported in Han Dynasty (2 B.C – 2 A.D) tombs. In Japan, a standing folding screen in a single form was reported on Buddhist altars in the Horyu-ji tomb of Nara. The base of these folding screens is composed of wood, covered by several layers of paper connected with starch glue [4].

Most of the fine artwork found on folding screens was done on silk or paper. Two different silk painting methods were used. In the first method, thick, golden colours were used, whereas the second method relied on mineral pigments and thin colors. Calligraphy also played an important role in the decorations of a folding screen [5].

Description of the folding screen

This study examined a Chinese folding screen from the late 19th century located in the Palace-Museum of Golestan. The screen has different designs and ornaments on both sides of a silk background. Metal embroidery on a background of dark silk is visible on one side of the screen. A painting on non-dyed silk is visible on other side of the screen. In 1306, A.H *Naser al-Din Shah*, during his third trip to Europe, visited Paris when an exhibition of the art and industry of China and Japan was being held. During his visit to the exhibition, he purchased many artifacts and instruments to be used in the royal palace. One of these was referred to as a "jelotakhtekhabi" (translated as "front bed") in the book *Memoires of Third Travel of Naser al-Din Shah*, Volume I: "*... A front bed with a dragon on one side and gold embroidery and a peacock on the other side...*" [9].

This folding screen is the only object in the inventory of the Qajar monarchy that is comparable to the jelotakhtekhabi. The screen is composed of four symmetric sheets which are 194.2 cm high and 74.6 cm wide, depicting a war with a dragon. Each sheet is composed of one piece of light silk with a plain weave. The wooden frames have metal relief ornaments.

Folding screen ornamentation

The motif of war with a dragon that is painted on the folding screen (***Figure 1***) is a popular theme in the mythology of China, India and Iran. It was used to indicate a God or hero experiencing an extraordinary event [10]. This motif has the same interpretation in the mythologies of other nations. In other national cultures, the dragon would be satisfied only by a sacrifice, usually a virgin princess, and killing the dragon becomes an important part of the story. Frequently the hero kills the dragon by cutting off its head (or heads) and the princess marries him out of appreciation.

The dragon in the picture on the folding screen has a pulled flaked body with a long mustache, horn and four claws, similar to Song Dynasty dragons (960 - 1127 A.D). The dragon floats in clouds, which is an allegory of the meandering way. This image was first seen dur-

Figure 3. Detached silk exposing the underlying layer and tears in the surface of the silk, evident in different areas.

ing the Han Dynasty (202 B.C - 220 A.D). It refers to one of the Chinese dragon's duties, which was to bring the spring rain.

Methods

Analysis of the Silk Folding Screen

Analysis of the structure

The wefts and warps of the sample were investigated under Transmitted Optical Light Microscopy to determine the weaving technique. Fibres from warp and weft yarns of the object were examined in longitudinal views at a magnification of 400× [11].

A visual inspection of the sample revealed that the folding screen was degraded but still in fair condition. It was strong enough to allow it to be handled and examined. However, a large amount of dust and dirt had accumulated and tea or water stains had marred the folding screen (***Figure 2***). There was also some physical damage to the surface. For example, small tears were visible on the surface that may have been created by an encounter with a sharp object (***Figure 3***).

Biological deterioration analysis

The initial visual examinations showed the object had suffered from biological damage. Some of the edges and the end of one of the sheets showed evidence of biological damage due to fungal growth, caused by damp, dark conditions (***Figure 4***), and was also likely the result of many years of being kept in the storage room of the Golestan Palace in an unsuitable and uncontrolled environment. However, the dyed layer on the test sample showed no damage and had good strength.

Two methods were used to examine the fungi species of the deteriorated textile: the cotton swab and wool fibre techniques. However, because of the destructive effect of the wool fibre method in this case the cotton swab technique was applied. In the current technique, sterile swabs were used to distribute fungi on the media of malt extract agar from the surface of the object where fungal growth was observed in Petri dishes. The dishes were incubated at 28 °C for 4 weeks until the growth of colonies. For purification and identification of fungi, the fungi developed were isolated in pure culture on slants of the media [12]. The fungal species were identified according to standardised methods by consulting the appropriate manuals [13, 14].

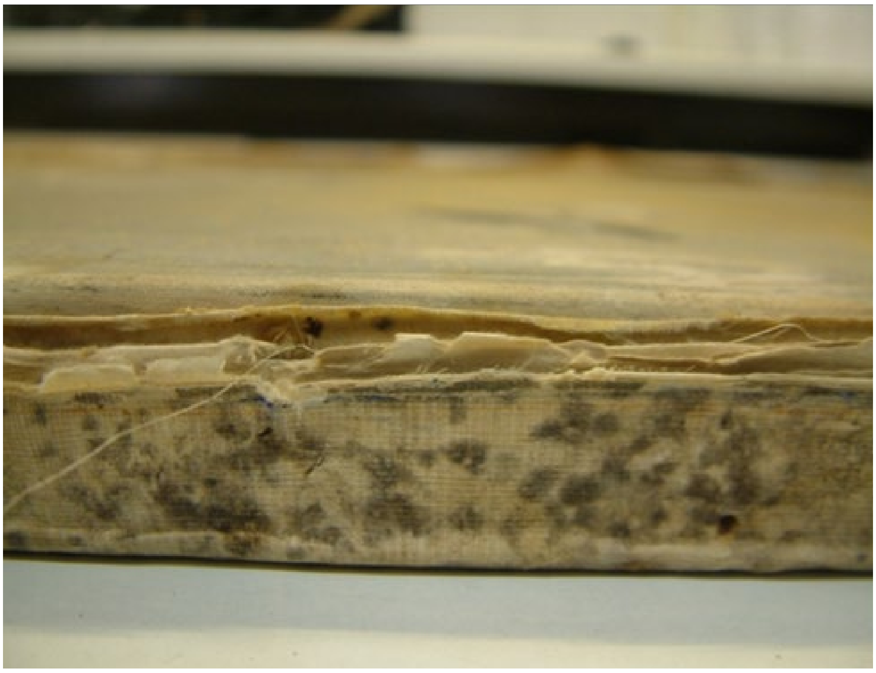

Figure 4. Infected areas of fungi at the edges of the folding screen.

Table 1. *Cleaning and solubility test.*

<table>
<tr><th rowspan="2">Solvent</th><th colspan="2">Migration of colour of:</th></tr>
<tr><th>motifs</th><th>medium</th></tr>
<tr><td>Water (moist soap)</td><td rowspan="11">Yes</td><td rowspan="3">yes</td></tr>
<tr><td>Water (cold steam)</td></tr>
<tr><td>Water (hot steam)</td></tr>
<tr><td>Water & ethanol (1-2 ratios)</td><td>little migration</td></tr>
<tr><td>Water & ethanol (2-2 ratios)</td><td rowspan="2">yes</td></tr>
<tr><td>Water & ethanol (3-1 ratios)</td></tr>
<tr><td>Acetone</td><td>no</td></tr>
<tr><td>Trichloroethylene</td><td rowspan="2">yes</td></tr>
<tr><td>Tetrachloroethylene</td></tr>
<tr><td>Soft rubber</td><td rowspan="3">No</td><td rowspan="3">no</td></tr>
<tr><td>Vacuum cleaner</td></tr>
<tr><td>Ethanol</td></tr>
</table>

Table 2. *Pigment used in Chinese painting identified by Skelton at the Winterthur Museum & CIGNA and a researcher from the Art University of Isfahan.*

Possible pigments used	Identified elements	Colour
Bone black	$C + Ca (PO_4)$	black
White lead	Pb, Ag	gray
Vermilion, white lead	Pb, Ag, Hg, Sn	red
Organic compound & white lead	Pb, Ag	bright red
Indigo & white lead ground	Pb, Ag	blue
Indigo & white lead ground	Pb, Ag	bright blue
Iron oxide & white lead ground	Pb, Ag, Fe, K	brown
	Au	golden
Gamboge's & white lead	Pb, Ag, K, Sn	yellow
White lead	Pb, Ag	white

Dye and pigment analysis

Firstly the stability of the pigments was tested by rolling a slightly dampened cotton swab over their surface, gradually exposing them to moisture for a prolonged period of time. A review of literature on Chinese painted silk artifacts revealed

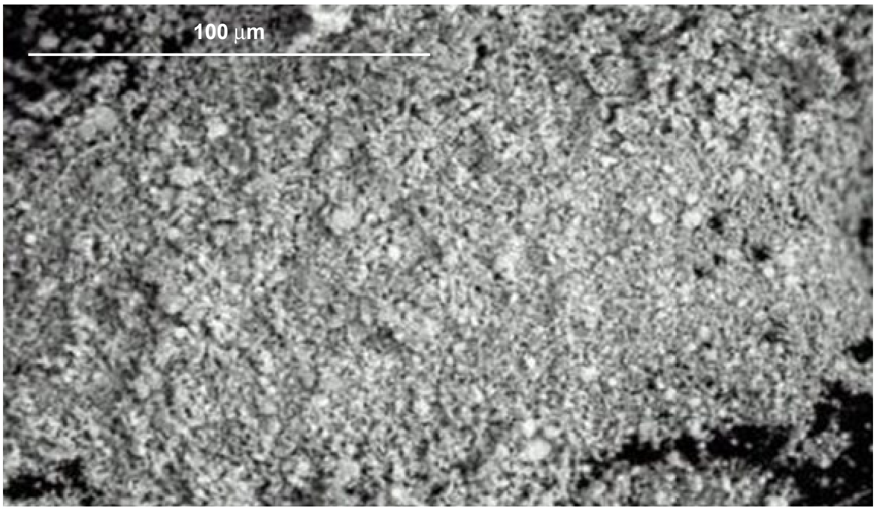

Figure 5. *SEM image with 100 µm magnification showing that the white background layer of the sample was composed of white lead, similar to other Chinese paintings.*

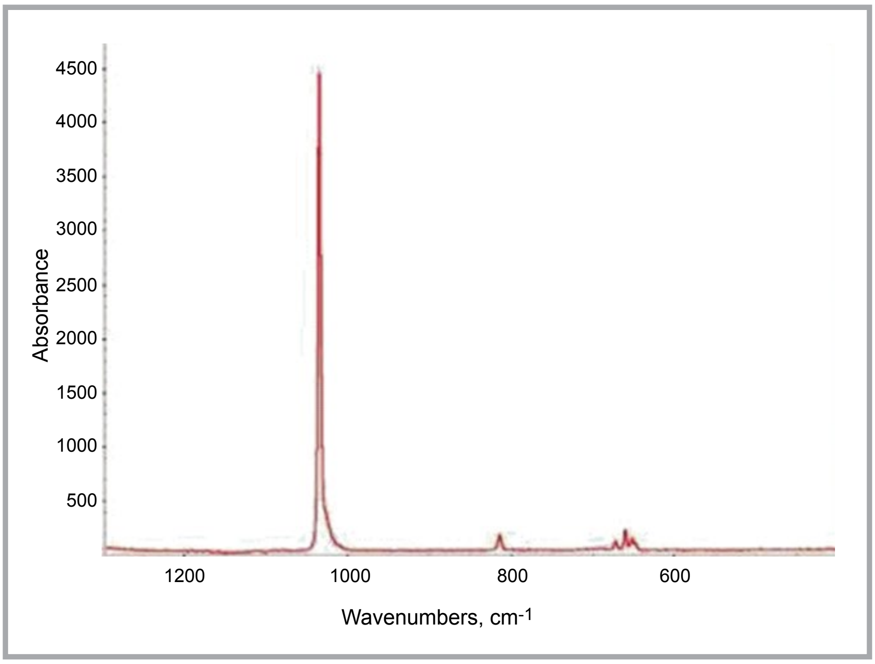

Figure 6. *Raman microscopic diagram showing that the white background layer of the sample was composed of white lead.*

that there is no splitting in the painted area in silk ground fabrics because the use of white leads to characteristic bright colors [3]. Therefore to make sure about the reason of the sound situation of folding screen, the medium on the sample was examined using XRF. There was also concern that an aqueous treatment would exacerbate the problem by creating an environment that would cause the degradation of the silk. It was therefore necessary to formally identify the pigments present. However, because of the lack of portable non-destructive XRF in the Art Laboratory at the University of Isfahan, it was not possible to model all the pigments. Therefore the Henry Francis du Pont Winterthur Museum and Raman microscopy were used to identify the dyed layer that had migrated. XRF analysis of non-migrating parts was done in the Art Laboratory at the University of Isfahan.

Evaluating the cleaning process suggested

The purpose of cleaning is to remove harmful materials which may cause physical or chemical damage to a sample. The selection of suitable cleaning methods and materials depends on the structure and condition of the sample. Several substances were tested against the pathology of the folding screen. A summary of the results can be found in ***Table 1***.

Treatment of silk folding screen with fungicides

Fungal deterioration can lead to the very fast decay of organic museum materials such as paper, textiles, wood, etc. [15 - 17]. The organic components of textiles and their ability to absorb and retain moisture from the surrounding environment in museums makes them highly susceptible to fungal deterioration. Also in this case high humidity accompanied by a lack of ventilation in storage rooms in the Golestan Museum enhances fungal growth on the silk folding screen. In addition, such a historical case required special knowledge to apply an appropriate biocide without any destructive effect on the object, either in the short or long term.

There are a large number of studies that have been carried out on industrial [18 - 20] and conservative fungicides (21, 22) used for the protection of museum textiles [8, 23 - 25]. The most important factors to select the best material as a fungicide used for the preservation of museum textiles were a low toxicity to humans, no negative effects on the properties of textiles or materials connected with it [25], and resistance to washing. In addition, repeated application of fungicides may damage the material, thus single - application solutions were needed that would remain effective for a longer duration without being detrimental to the materials [26]. In this study, several methods were investigated to find the best one to prevent fungal growth and increase the fibre strength of the sample.

Results and discussions

Analysis of silk folding screen

The results of the folding screen`s morphology revealed that the screen material is a silk taffeta made from threads of low twist, which is more suitable for painting because of short interlacements; smaller twist of threads can make the fabric surface smoother and also more suitable for painting. In the sample, thirty-eight warps and forty wefts are used per 1 cm^2 [27].

The results of the inoculation showed that *Acremonium, Cladosporium*, *Alternaria*, *Aspergillus* and *Penicillium* were the most dominant fungal species found on the historical Chinese folding screen. The pH test indicated that the mean pH content of the area that was infected by fungi was 5 and the other, unaffected parts had a pH of 7.

A list of possible pigments and identified elements can be found in ***Table 2*** (see page 71), which are the result of an XRF pigment analysis done by Skelton and the Art Laboratory at the University of Isfahan. The following typically Chinese pigment characteristics are demonstrated in the table below.

Table 2. Pigment used in Chinese painting identified by Skelton at the Winterthur Museum & CIGNA and a researcher from the Art University of Isfahan.

Results of the FT-IR, SEM (***Figure 5***) and Raman microscopic diagrams (***Figure 6***) showed that the white dye and white ground layer of the sample consisted of a pigment that contained white lead (***Figure 7***). White lead ($2PbCO_3{\cdot}Pb(OH)_2$) was used in other Chinese paintings. The silk was prepared with a white background 50 µm thick and then a black colour was used to form the principle lines of the image (***Figure 8***). This colour could have also been combined with others without losing its power [3]. The technique of the present folding screen is called the Chinese white technique. Hulton states that "In this technique white paint is used to form a base to give greater depth to the paint laid over it. Also details can be painted onto the white paint without a loss of clarity and it can be mixed with other colours to alter the strength of the tones" [28]. White lead creates a layer that resists most mediums. The saponification properties of white lead result in a smooth surface on the fibres, thus the light absorption was decreased and only a small amount of structural damage discovered [29, 30]. That is the reason why all the pigments were found to be in good condition and showed no sign of degradation.

An observation of the medium solution revealed that the medium of the sample was a protein-based material (fish glue), much like other Chinese watercolour paintings.

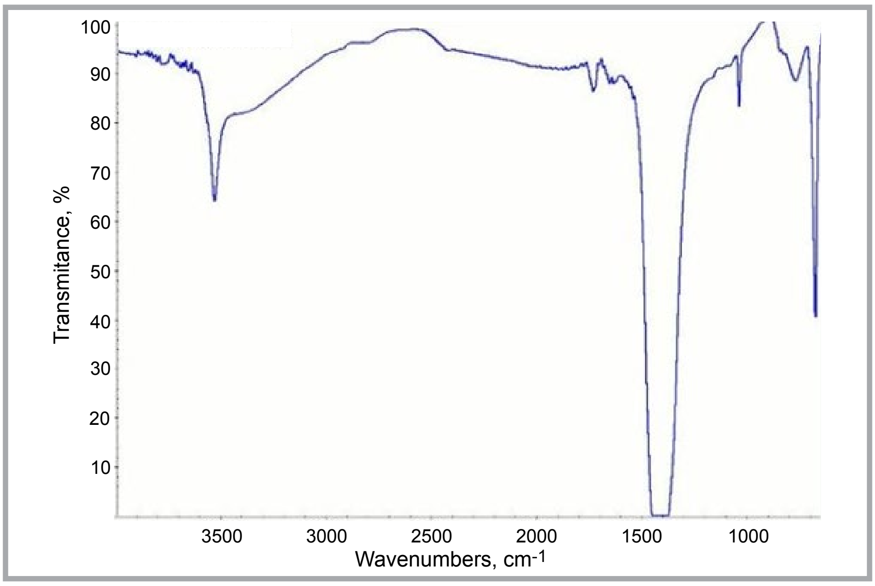

Figure 7. *FT-IR analysis showing the white dye of the sample. As is the case with most Chinese paintings, it was composed of white lead.*

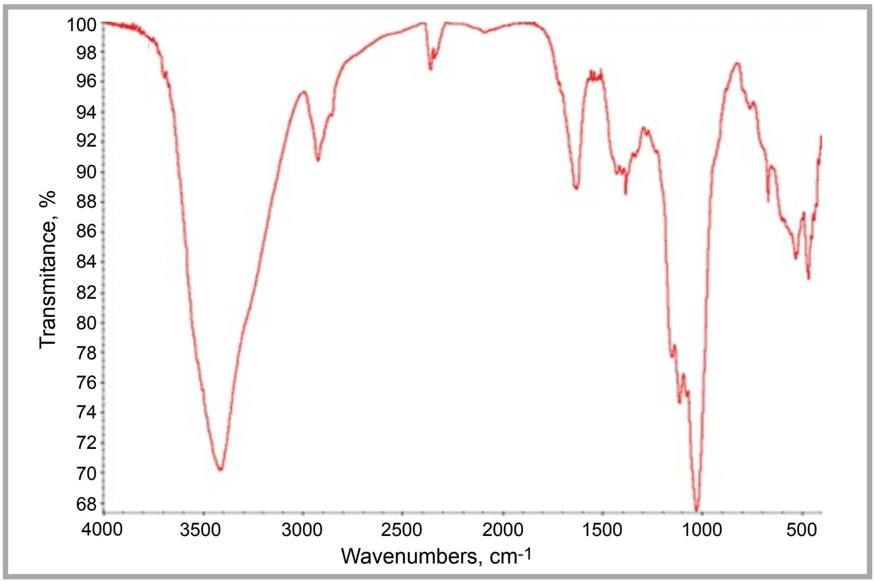

Figure 8. *FT-IR analysis showing that the white background layer of the sample, like other Chinese paintings, was composed of white lead.*

Strategic plan for conservation

Cleaning process

The pathology of the sample showed that the largest problem facing the folding screen was the accumulation of dust and some tea and water stains on the surface of the fabric. In ***Table 1***, several materials are shown that were tested for cleaning the sample. The results of the investigation show that all colours proved to be sensitive under moisture and therefore needed to be fixed because a large amount of water would be introduced during the cleaning process. Moreover water can cause shrinkage, stress and distortion, therefore the cleaning process was carried out with low powered vacuum suction, a soft brush and soft rubber. These methods are the most common and safest used to clean textiles [30, 32].

The surface dirt was wiped off with a soft brush and low powered vacuum suction [33]. Where the surface was determined durable enough, cleaning was continued with the soft rubber, which was a rubber sponge produced by the Lascaux Company used for stain removal when the various solvents did not have a satisfactory effect on the stains. Any remaining bits of rubber were removed by a low powered vacuum cleaner. This cleaning was the most important factor in the improved appearance that was the result of the entire treatment.

Fumigation

Fungal deterioration was one example of decay of the folding screen, therefore emergency treatment against fungal

Figure 9. The old paper support was removed using tweezers or fingers.

growth was undertaken. The impregnation method was used as it had been confirmed that the compound of 1% dicholophen (2,2-methylenebis(4-chlorophenol)) in ethyl alcohol was the best method of application in the long term protection of textile from fungus. There was no change in the colour of the sample and no apparent damage after the fumigation process [8, 34, 35].

Evaluating the method suggested for the restoration process

After fumigation of the sample with dichlorophen, a restoration method was selected that would not cause further damage to the silk and pigments. Many treatment materials can cause irreversible damage to silk objects. In the first step, the old paper support was removed using tweezers, a scalpel or fingers. This process took several hours and did not use any water (***Figure 9***). Restoring the small tears on the surface of the sample was the next step.

Several investigations were carried out to find the type of paper and adhesive that would be compatible with the textile. Fortunately there were not any areas that had suffered extensive loss where silk was required to fill the holes or loose threads which needed to be stitched to a support. In addition, the thickness of the folding screen was the main reason for avoiding the stitching method for restoration. Hence the method used for paper conservation was to produce a pre-prepared paper film that could be solvent re-activated in situ. Extensive methods were considered to find an appropriate combination of the paper type and adhesive concentration that would work for textiles.

Experiments included dissolving Lascaux 498 HV in water. Among the variety of tissue papers, the lightest weight paper tested was Tengujo, with Lascaux 498 HV diluted with water (10%).This type of adhesive has a pH of 8 - 9 and great elasticity; it is reversible and permanently soluble in acetone, toluene and xylene but insoluble in water once dry. In addition, the manufacturer claims that the polymer is non-cross linking and non-yellowing [1, 36].

Figure 10. The self-adhesive tissue paper was heated with a 50 °C iron to attach it to the Chinese folding screen.

The self-adhesive tissue paper was heated with a 50 °C iron to attach it to the textile (***Figure 10***). The use of heat-set adhesives allowed to avoid the use of moisture during the restoration process; however, the support fabric used with these adhesives was very lightweight. There are pros and cons of the method described. The mends were intended only to hold the split together, flat, in plane, and without pulling which would create more tension. If the screen is ever strained again, the lightly attached mends will split before the screen itself.

At the end of the conservation and treatment process, lost pigment was retouched using watercolour paint (***Figure 11***).

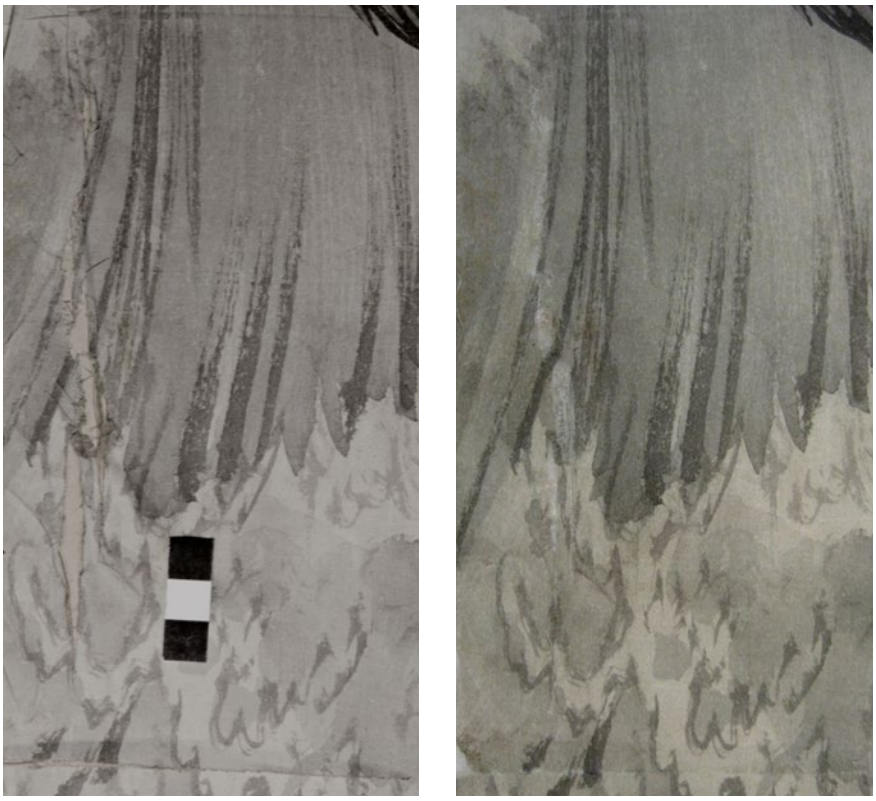

Figure 11. Image of the sample before and after restoration.

Conclusion

The painted side of the Chinese silk folding screen was evaluated to determine the structure, techniques and extent of degradation in relation to the medium. FT-IR, SEM-EDX and XRF analyses were carried out to identify the pigments, medium and type of silk.

The results of FT-IR analysis show that the painted side of the folding screen was made of raw silk without any further processing such as the addition of sizing. The medium contained a large amount of white lead. The saponification properties of white lead resulted in a smooth surface on the fibres, thus the light absorption was decreased and only a small amount of structural damage was discovered.

A proper conservation approach should include steps such as cleaning, reinforcement and restoration methods. This research did not undertake a fungicide study to evaluate the effect of various combinations on the degraded fabric. Only the fungicide dichlorophen was used for treatment of the sample because it completely prevented fungal growth and was the least harmful to the historical textile.

The cleaning method and adhesive suggested, Lascaux 498 HV, examined in this study were suitable and effective for use in the non-aqueous treatment process of the historical Chinese silk folding screen. This paper focused on finding a safe, less destructive and new method of supporting the damaged area in an unusual but successful treatment. The current study will be a guide for conservators who seek to conserve and restore historical folding screen artifacts similar to this object.

Acknowledgements

Financial support by high impact research grants from the University of Malaya (UM.C/625/1/HIR/ASH/023) is gratefully acknowledged.

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Received 15.04.2013 Reviewed 04.08.2013