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'Like-with-like': A comparison of natural and synthetic stitching threads used in textile conservation

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ABSTRACT

This paper reports research undertaken to investigate thread types used in textile conservation by quantitatively evaluating tensile strength and damage to conserved samples. A literature review and questionnaire sent to textile conservators were used to establish the most commonly used threads for laid-thread couching treatments and the rationale behind thread choice. Most common threads found were two-ply hair silk and polyester Tetex as well as other fine polyester, silk and cotton varieties. Three natural fibre plain-weave artefact samples conserved by laid-thread couching with five different thread types (lace cotton, hair silk, *organsin,* Skala and Tetex) were subjected to either tensile strength testing or a fixed-load experiment for two weeks. The tensile strength tests determined that the conservation treatment provided effective support and different thread types did not give statistically different results. The fixed-load experiment determined that longer time periods created more damage, even with lighter loads.

INTRODUCTION

This research set out to compare a selection of natural and synthetic fibre stitching threads commonly used in textile conservation. The aim was to better understand the relationship between the stitching threads and conserved natural fibre artefact samples. A group of conserved historic textile artefacts was prepared. The artefacts were subjected to tensile strength tests and fixed-load tests, and any damage caused to the artefacts by the stitching threads was evaluated.

Threads in textile conservation are primarily used to consolidate areas of weakness or loss within a textile artefact by stitching them onto a new support fabric. Some conservators believe that synthetic materials are too strong for natural fibre textiles and may cause additional damage to the artefacts. This relates to the debate of using 'like-with-like' materials when performing conservation treatments. Generally, this refers to the use of a conservation material with similar properties to the artefact being conserved. The theory is that the similar material is more sympathetic to the properties of the artefact, although in fact there are some differences in material properties between historic aged artefacts and new conservation materials. The opposing view is open to using a wider range of material varieties, allowing more choice when deciding upon the most suitable material for treatments. This research aimed to explore this debate using objective, quantitative data.

Previous research and discussion has centred around the choice of synthetic or natural fibre threads and stitching or adhesive treatments, rather than the impact of different threads on artefacts. Although research has been carried out to investigate the effects of different support fabrics (Ordonez and Ordonez 1984, Brooks et al. 1995, Asai et al. 2008), little research has been done on the threads used in these studies. Conservation documentation and literature often contain information on the threads used, though there is often little explanation of why that particular thread was chosen. Two previous studies were used to inform the methodology of this research (Landi 1988, Ellis 1997), although in general there is a lack of qualitative information or quantitative tests on threads and how they affect and interact with the artefacts they are supporting. The testing done by Landi inspired the fixed-load tests and the single-strand thread testing done by Ellis gave a starting point and a comparison for the threads tested in this research.

To give context to the tests, a short questionnaire was sent to textile conservators internationally to establish the usual practice when choosing threads for treatments using laid-thread couching. Forty-one responses were received, with the largest number of replies coming from the United Kingdom and the United States. The most common threads used were two-ply hair silk and Tetex (a polyester filament, formerly Stabiltex), as well as fine polyester, silk and cotton varieties. However, continental European respondents had a strong preference for natural fibre threads.

Research questions

To provide textile conservators with quantitative data on the relationship between the stitching threads used and the textile artefacts, the following questions were formulated:

- Can the most appropriate thread type for natural fibre artefacts be objectively determined by tensile strength testing conserved samples?
- Can this research contribute to the debate surrounding the desirability of using 'like-with-like' materials?
- Can the point at which an artefact is damaged be determined through tensile strength testing?

TESTING

Tensile testing was carried out on both threads and fabrics, as described below. Tensile testing enabled the mechanical properties of the threads and samples to be characterised and quantified. Breaking load, maximum elongation and tenacity were calculated for the threads and fabrics, and maximum elongation was calculated for all conserved samples as the maximum load was fixed.

The breaking load is the force at which the sample fails in newtons (N). The maximum elongation is the maximum distance that the sample extended during the test in millimetres (mm).

Tenacity is only relevant for the threads as it relates the breaking force of the thread to the linear density (tex). This enables a direct comparison between different threads.[1]

Single-thread testing

Before testing the artefact samples, the threads themselves were tested in order to establish their properties. The threads tested were: 185/2 lace cotton, two-ply hair silk, two-ply silk *organsin* (organzine) and polyester filaments Skala and Tetex. Tensile testing was carried out on an Instron 5544, with an extension speed of 10 mm per minute and a 100 N Instron Static Load Cell. International Standard (ISO 5079-1995) was used as a guideline for the testing procedure. Testing was carried out in ambient conditions.

The results of these tests can be seen in Figures 1 and 2. Figure 1 shows the load-elongation behaviour of all threads. The yield point is the point in the curve where there is a marked decrease in the slope. The part on the curve before the yield point is referred to as the elastic region and indicates the materials' resistance to extension with the applied force. Changes

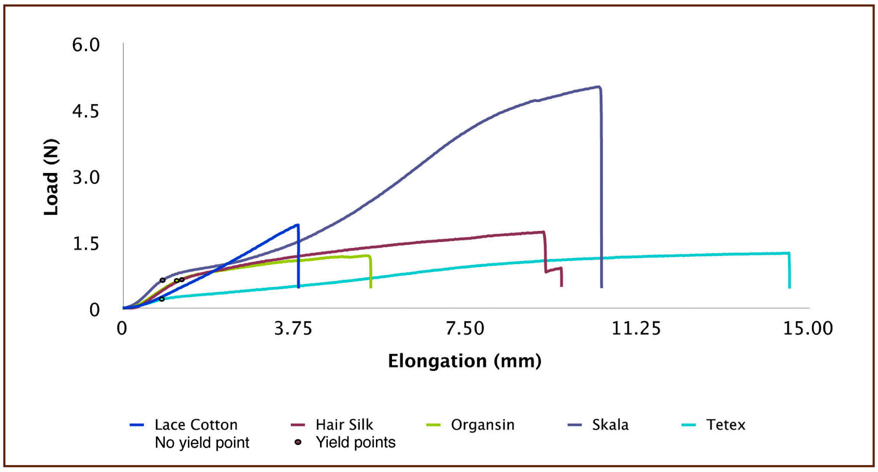

Figure 1
Load/elongation curves of all tested threads

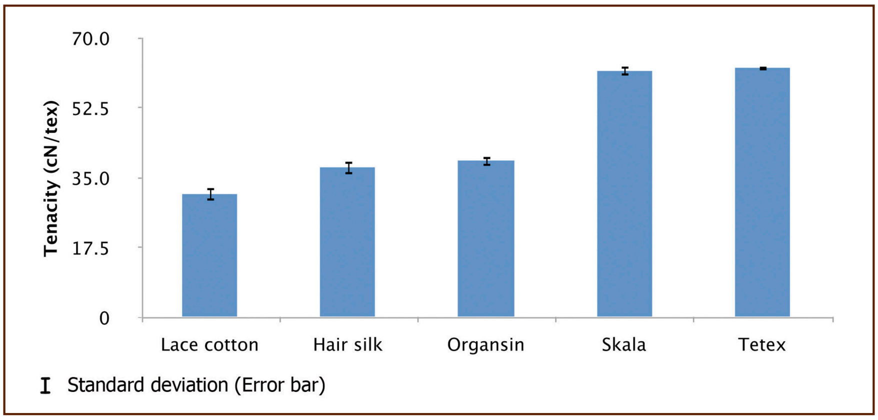

Figure 2
Tenacity of threads tested

which occur to the material within the elastic region are recoverable and temporary. The section after the yield point is the plastic region where the molecular structure of a material has become permanently deformed. Although Skala and Tetex have both the highest maximum breaking load and maximum breaking elongation respectively, they have the lowest yield points, resulting in poor elastic recovery. The tenacities of the different threads can be seen in Figure 2, where it is clear that threads composed of similar materials (e.g. hair silk/*organsin* which are both silk, and Skala/Tetex which are polyester) have a similar tenacity, although due to their varied tex values this is not apparent from Figure 1.

Sample preparation

Conserved artefact samples were prepared to represent a common conservation stitching treatment. The artefact sample fabrics were chosen to give a range of the natural fibre types most commonly seen in textile artefacts. Cotton, silk and wool tabby weave fabrics were chosen. All were naturally aged, had a limited amount of visual degradation and were as alike in weave structure as could be obtained.

The samples were cut in half and a treatment was chosen to represent the conservation of a cut or tear in an artefact. The horizontal cut was chosen to represent the maximum damage that an artefact may be subjected to. Each sample was prepared using identical materials and method. To minimise the number of variables, a medium weight silk habotai was used for all the patch supports. Five rows of laid-thread couching stitches were placed across the sample at 6 mm apart following the warp yarns of the artefact to hold the cut line together evenly. These rows were offset by 2 mm at the ends so every other row was on the same weft line (Figure 3).

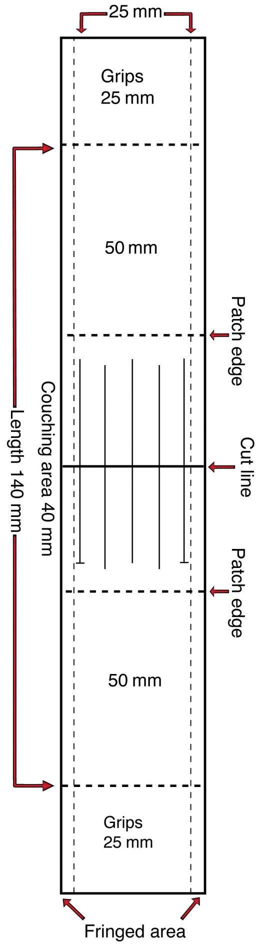

Figure 3

Template for sample preparation

Tensile testing of conserved samples

Conserved new artefact samples underwent pre-testing to failure to determine a load for subsequent tensile strength testing. This load was determined by visual examination of samples during testing to failure; 8 N was found to be enough force to cause distortions in the weave without failure of any components.

Tensile testing was carried out on an Instron 5544, with an extension speed of 10 mm per minute and a 1 kN Instron Static Load Cell following British Standard (BS EN ISO 13936-1:2004) for the determination of slippage resistance of yarns at a seam in woven fabrics as a guideline. This method was chosen to quantify the change a couched conservation treatment makes to an artefact. The goal of this test is not to break any of the components but to determine how much the seam (or conserved cut in this case) separates the yarns in the fabric when placed under a specific load (8 N). It uses the load-elongation graphs of a sample with no seam and a sample with a seam (or conserved artefact sample) superimposed on top of each other. This allows the change in length, or elongation, to be measured (Figure 4).

Figure 5 shows the elongation of all the different samples. Although some differences are visible, these were very small. The error bars indicated that there are statistically significant differences between the different fabrics. However, there are no significant differences between the threads within each fabric group of cotton, silk and wool. For example, the error bar of silk with lace cotton overlaps the error bar of silk with hair silk and therefore they were not statistically different in elongation and the different thread type did not give statistically different results. This also indicated that the conservation treatment was effective in that there was no (or very little) measurable difference in elongation between the original

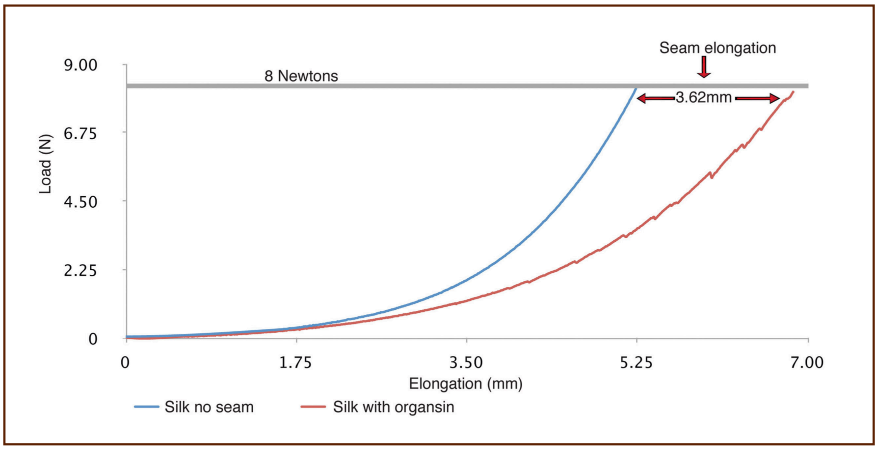

Figure 4

Seam elongation method adaptation, silk artefact versus silk conserved with *organsin* artefact with no cut and the conserved artefact with a cut. The treatment was considered effective because the combination of the couching stitches and the patch support used on the cut samples gave very similar elongation measurements to those of the undamaged samples. The greatest statistically different measurement was with the silk artefact, because the error bars from the conserved artefact samples and the original artefact did not cross the same line. However, the conserved silk artefacts were no more than 1 mm longer than the unconserved silk, a small amount considering the sample's testing length of 140 mm.

Samples were examined by microscopy and photographed before and after testing. Selected samples were also evaluated with scanning electron microscope (SEM) at several stitch points to give a high-definition close-up of any damage incurred.

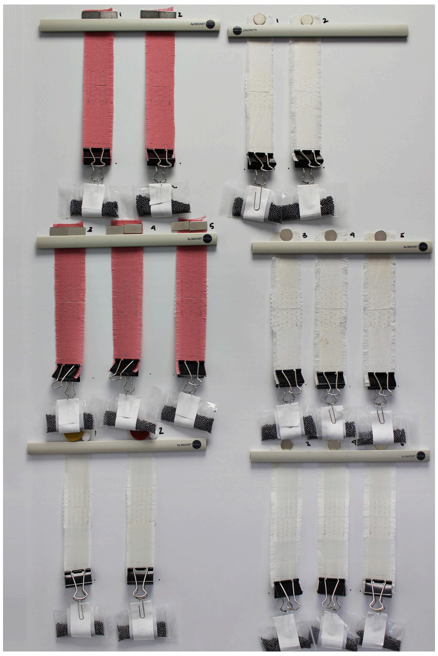

Figure 6
Setup for fixed-load experiment

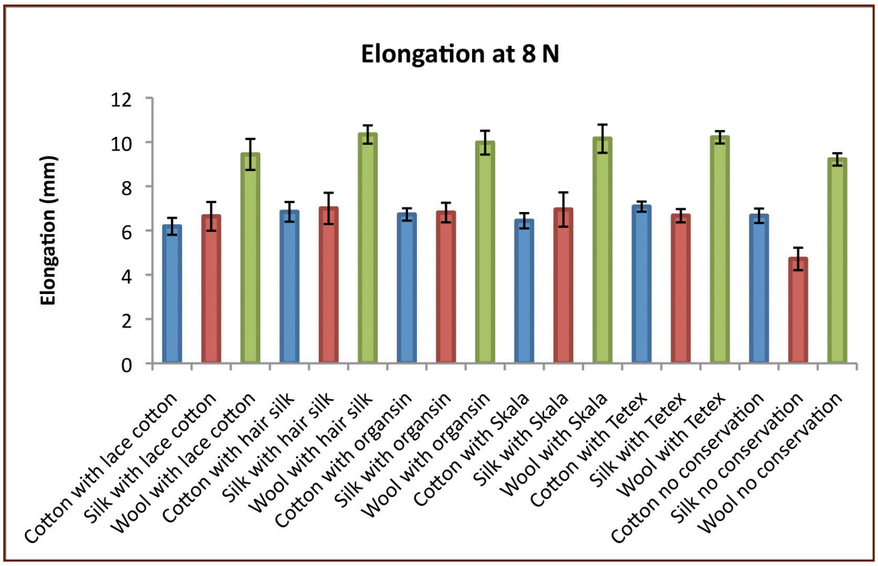

Figure 5
Elongation with standard deviation for all conserved artefact samples and unconserved fabrics

Fixed-load testing of conserved samples

This test procedure was chosen as a more realistic representation of the amount of force experienced by an artefact in museum situations and to introduce the factor of time. One of each of the prepared artefact samples was suspended on a magnetic board (Figure 6). Fifty-gram weights (~ 0.5 N) were attached to the bottom edge of the samples as an approximation of the force experienced by an object on vertical display. The testing was performed in ambient conditions. The samples were suspended for two weeks and photographs taken every three days. Maximum elongation and initial recovery were measured using Adobe Illustrator software. Table 1 shows the elongation measurements of the silk artefact sample stitched with the different threads over the duration of the experiment. Initial recovery measurements were based on the photos taken just before the weights were removed and just after their removal. The elongations varied by sample, but overall were too small to depict graphically. The damage observed using a stereomicroscope showed that samples subjected to the fixed-load test displayed greater damage than samples that underwent the tensile strength test. Types of damage observed varied from weave distortions, increasing size of stitch holes and damage to the stitching threads by being extended past their elastic recovery state.

Table 1

Elongation of conserved silk artefact fixed-load test

Day	Lace cotton	Hair silk	*Organsin*	Skala	Tetex
With 50-g weight					
Day 1 (mm)	0.60	0.92	0.84	0.82	0.81
Day 3 (mm)	0.74	0.97	0.88	0.85	1.10
Day 7 (mm)	0.97	1.00	0.93	0.85	1.30
Day 11 (mm)	1.10	1.00	0.98	0.89	1.30
Day 15 final (mm)	1.20	1.00	0.98	0.89	1.30
Weight removed					
Final measurement (mm)	0.92	0.84	0.83	0.72	1.12
Initial recovery (mm)	0.28	0.16	0.15	0.17	0.18

COMPARISON OF TESTING METHODS USING MICROSCOPY

Comparison between tensile testing and fixed-load testing was performed using images obtained from stereomicroscopy. Damage to the samples was evaluated by visual analysis with the aid of computer software. A ratings system was used, with 0 being no damage and 6 being the highest level of damage seen. It should be noted that only one sample of each artefact and thread combination was examined and that the ratings could only achieve a certain level of precision. Table 2 shows a selection of the ratings given to tensile tested and fixed-load tests. Samples conserved with Tetex gave the highest damage ratings, while samples conserved with the lace cotton gave the overall lowest damage ratings. This may be due to Tetex's high elongation rates and fine filament yarn structure, and lace cotton's softer staple structure.

Table 2

Selection of damage ratings for fixed-load tests and tensile strength tests

Test	Sample	Comments	Rating (1–6)
Fixed-load	Cotton artefact w/ lace cotton	Weft pulled down by 1 row, slight weave distortions	2
Tensile tested	Cotton artefact w/ lace cotton	Stitching hole larger, slight weft pull; compression at backstitch	2
Fixed-load	Cotton artefact w/ Tetex	Weft pulled down by 1.5 row, slight distortions; backstitch compression	4
Tensile tested	Cotton artefact w/ Tetex	Weft pulled down more than 1, backstitch compressions	4
Fixed-load	Silk artefact w/ hair silk	Weft pulled down by 1 row, weave distortions; backstitch compression	5
Tensile tested	Silk artefact w/ hair silk	Possible 'cutting' of yarns, slight compression	3
Fixed-load	Silk artefact w/ Tetex	Weft pulled by 1.5, thread very damaged; more compression	6
Tensile tested	Silk artefact w/ Tetex	More compression, thread damaged	3

The 'after' photos used to determine the damage were taken several days after testing and any damage seen can be considered permanent. In general, the fixed-load samples displayed greater damage than the tensile strength tested samples, despite the smaller load. This was particularly noticeable on the silk artefacts, as can be seen by distortions made to the weave structure and the size of the hole created at the stitch point (Figure 7).

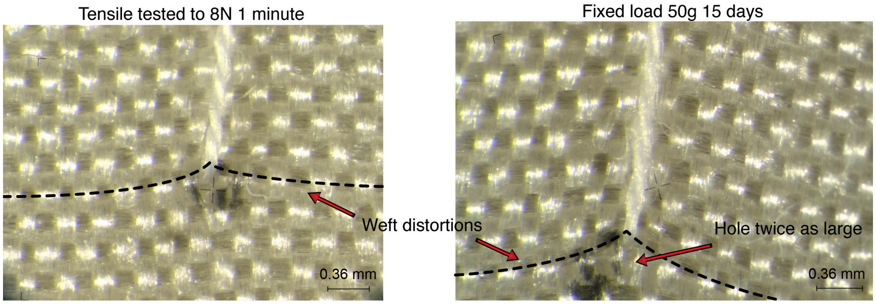

Figure 7
Optical micrograph of silk artefact with lace cotton after testing. Left: tensile strength tested rating of 1; Right: fixed-load tested rating of 5

The stitching techniques affected the type and degree of damage observed. The laid-thread couching layout resulted in weave deformations between the rows, especially noticeable on the silk artefact. As the stitching was carried out by hand and by a number of people, several observations were made based on variables in the stitching techniques:

- A cross-stitch which was not exactly on grain, opposed to a perpendicular cross-stitch, caused distortions and pulled the weave more.
- Slightly wider cross-stitches caused less weave damage through compression while a very short stitch pulled the weave together.
- In general, it was observed that inserting the needle between the yarns of the weave structure was not possible, even on the wool artefact's more loosely woven structure. Less distortion was observed if the vertical stitch went through the middle of the weave yarns rather than towards the edge of the yarn or between the yarns (Figure 8).
- On a backstitch start and finish, more damage was caused by compressing the weave if the stitches went through the same point than if they were staggered slightly.

Further experimentation is required in this area to quantify the observations seen in this research.

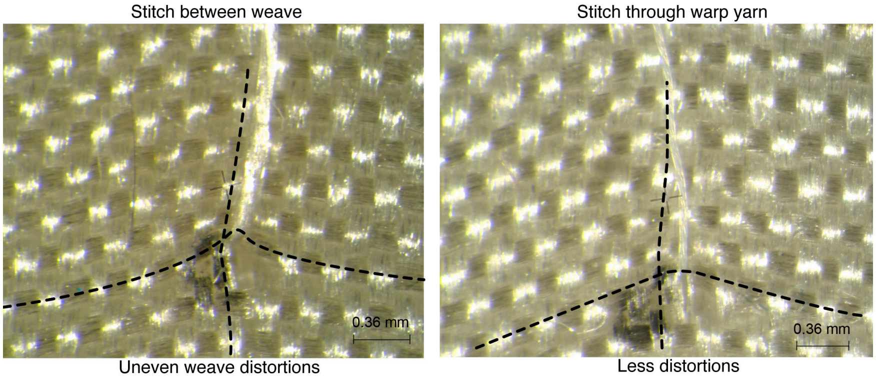

Figure 8
Optical micrograph of stitch placement: silk with *organsin* and silk with Tetex after testing

CONCLUSIONS

The questionnaire showed that there is no clear preference for either natural or synthetic threads with the exception of Continental Europe, where natural fibres were preferred.

Tensile testing showed that more damage was caused to samples with a 0.5-N load over two weeks than when an 8-N load was applied over a short time. This implies that loading over time is an important factor which needs further investigation, especially as this scenario is common in museum displays. The tensile strength tests revealed that the conserved artefact had comparable properties to the undamaged artefact, proving that the conservation treatment was effective.

As predicted, the artefact material affects the damage type and severity. The stereomicroscope evaluation determined that stitching techniques and layouts greatly affected damage. When considering the 'like-with-like' debate, it was concluded that the threads' different chemical compositions had little effect on the results. Whether the thread has a filament or staple yarn structure may have had a greater effect on the conserved artefact's properties and damage incurred. As seen in the fixed-load test, for example, the staple structure of the lace cotton thread allowed more absorption of the load and gave better recovery, while the fine filament structure of Tetex was unable to absorb the load before the artefacts' structure was affected. Skala and Tetex's early yield points result in permanent mechanical damage to the threads with poor elastic recovery that could make them undesirable for some stitching treatments.

This research is one of the first projects undertaken on the relationship between stitching threads and artefacts, and further work is necessary to fully understand the complex nature of the subject. Some important areas of exploration should be in the stitching layouts and techniques, incorporating different aspects of the threads and artefacts such as ageing, dyeing and environmental effects, and testing different time periods. However, this research has provided quantifiable scientific data in a subject area that previously relied upon subjective opinions. Observations made in this work may influence how textile conservators choose their stitching threads, perform their stitched treatments and evaluate past treatments with the goal of accomplishing a successful conservation treatment which provides support to irreplaceable historic artefacts without instigating new damage.

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NOTES

[1] For more in-depth information on all tensile strength testing see Morton and Hearle 2008, 274–321.

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MATERIALS LIST

Egyptian Gassed Cotton 185/2 thread
Jo Firth Lacemaking and Needlecraft
West Yorkshire, UK
www.jofirthlacemaking.co.uk/

Hair silk, 2-ply undyed silk thread
Talas
Brooklyn NY, USA
http://talasonline.com

Organsin soie tube 1000 m, silk thread
Au Ver à Soie
Paris, France
info@auverasoie.fr
www.auverasoie.com

U81 Skala™ 360 filament polyester thread, undyed
William Gee
London, UK
info@williamgee.co.uk
http://williamgee.co.uk/

Tetex TR® (Stabiltex™), polyester fabric
Plastok Associates Ltd.
Birkenhead, Wirral, UK
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