Direct Radiological Visualization of the Effect of Loading on Four Suture Configurations Used in Flexor Tendon Repair

Xiaoke Dong[1], Min He[1], Christopher Fang[2] and Sandeep Jacob Sebastin[1],
(1)Hand and Reconstructive Microsurgery, National University Hospital Singapore, (2)Yong Loo Lin School of Medicine , Singapore

Introduction

Any tendon core suture technique may be divided into three components, longitudinal, transverse, and a link component (Figure 1). All techniques have the longitudinal and link components and may or may not have the transverse one. The link component represents the junction between 2 longitudinal or 1 longitudinal and 1 transverse component.

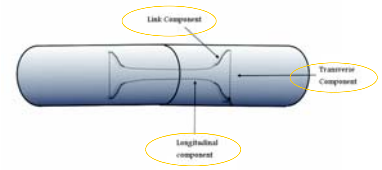

Figure 1.

Based on relationship of the transverse and longitudinal component, we have identified 4 distinct type of link suture configurations. (Figure 2).

Firstly the arc design where the transverse suture component passed below longitudinal suture component. Next is the loop design: Transverse suture component passed above longitudinal component. This can be simple or complex depending on the number of loops made. Lastly is the knot design where there is no transverse component. The longitudinal components are secured using a knot.

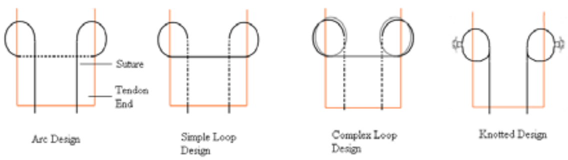

Figure 2. 4 types of link components

Objective

1. To observe how the 4 type of link components deform under radiological guidance and understand how sutures unravel in real time.
2. Compare the pull out strength between the 4 types

Methods and Materials

- Forty flexor tendons from the 1st ray of fresh frozen porcine limbs were harvested. They were divided into 4 groups of ten tendons. Each group underwent one of the previously mentioned suture designs (Figure 2)
- 0.5mm stainless steel wire was used as suture material. Only one half of a tendon repair was simulated. The transverse components (or knot) were placed 1 cm from the cut end of the tendon. The free ends of the sutures and the tendon were anchored to a jig secured to an Instron machine (Figure 3).
- A radiopaque ruler was fixed parallel to the tendon. The tendon was loaded using the Instron machine at 50mm/Min until failure (suture rupture or pull out). The deformation of the suture was observed directly using an image intensifier. Additionally data with regards to the ultimate force prior to rupture/ pull-out was obtained.

Figure 3. Set up of experiment

Results

- All repairs failed by suture pull-out.
- In the arc design, the loop unravels and then the transverse suture component flips over the longitudinal component before pulling out.
- In the simple loop design, there is an initial constricting effect that is followed by behaviour similar to the arc design.
- In the complex loop design, there is a progressive constricting effect before gradual pull out of the suture.
- In the knot design, constriction of the knot is seen before it pulls out of the tendon.
- Pull out strength was compared (Figure 5) and the complex loop group was statistically stronger than the other 3 designs.

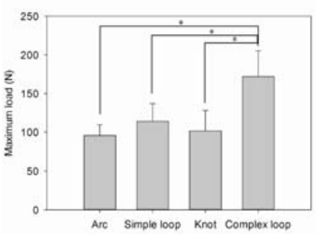

Figure 5. Comparison of the pull out strengthen

Discussion

This is the 1st published research that allows the direct visualisation of the deformation of the sutures under radiological guidance. When the transverse component is deep to the longitudinal component, the suture flips over under tension (Figure 5). When the transverse component is superficial to the longitudinal component, there is constriction of the sutures before pull out (Figure 6).

We also found that the complex loop is also the configuration with the strongest pull out strength. This is also statistically significant.

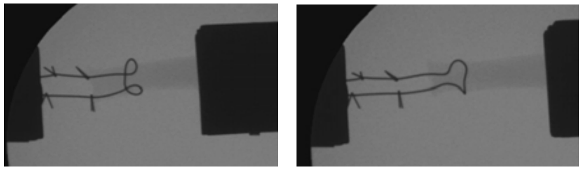

Figure 5. Deformation of arc link component, before (left) and after (right).

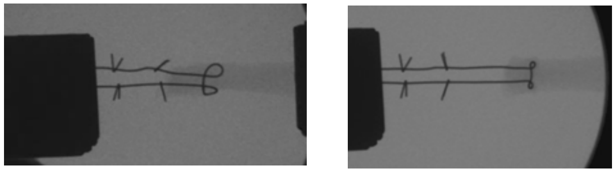

Figure 6. Deformation of simple loop link component, before (left) and after (right).

Hotokezaka (Figure 7) proposed the locking loops unravel by the twisting of the tendons fibres. However, there has been no previous physical evidence of such an occurrence.

We found that for the arc (Figure 8) and knotted group, the tendon remains uniform in the video throughout the experiment. At the area where the link component is, the diameter of the tendon either decreases slightly or remains the same and this change follows the link component as the wire pulls out. For the loop groups (Figure 9 and 10), there is increased diameter of the tendon in the video at the position for the link component. The increase in tendon diameter is more prominent in the complex loop group.

We believe that the observation of increased diameter at point of unravelling of the link component supports Hotokezaka's hypothesis.

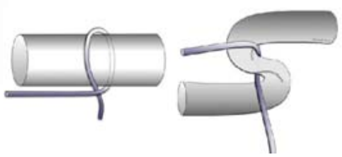

Figure 7. Hotokezaka's hypothesis how locking loops unravel in relation to tendon fibres

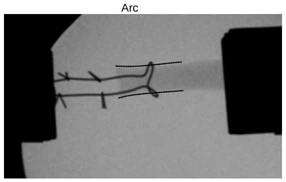

Figure 8.

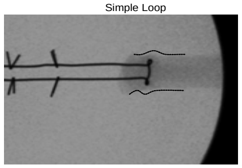

Figure 9.

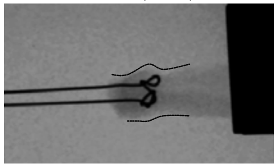

Figure 10.

Conclusion

Most flexor tendon suture techniques use one of the four suture designs illustrated in this study. Our study has shown that the deformation pattern is different between the four suture designs. The arc and simple loop design deform by unravelling of the loop, whereas the complex loop constricts before pulling out. The tendon grasping ability of the complex loop design was also the strongest.

Contact

Name: Dr Dong Xiaoke
Institute: National University Hospital Singapore
Department of Hand and Reconstructive Microsurgery
Email: xiaoke.dong@mohh.com.sg
Phone: +65-96253000

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