Changes in Core Suture Geometry within Repaired Flexor Tendons: an X-ray Evaluation

INTRODUCTION

Early mobilization of repaired flexor tendons promotes healing and better outcomes than immobilization. Tension on the reconstruction however produces gap formation at the repair site, which is detrimental. Much progress has been made in the optimization of repair techniques to minimize gapping. Notably, this has involved multi-strand techniques and the use of locking suture configurations. Nevertheless, the changes in suture geometry when the repair is strained, and the relationship this has to gap formation have not apparently been characterized. Therefore, we present a novel X-ray technique to qualitatively examine the three-dimensional changes in the core suture configuration under tension.

MATERIALS AND METHODS

25 sheep hind deep flexor tendons were randomized into 5 repair groups of n=5 each. Tendons were cut at the long vinculum and a core suture performed in the proximal stump. The techniques used reflected a preference for 2-strand and 4-strand method, using different grasping and locking variants of each. Namely, these repairs were the modified Kessler (Figure 1A); Pennington modified Kessler (Figure 1B); loop-locking cruciate (Figure 2A); and, cross-locking cruciate (Adelaide repair) (Figure 2B). The final group was a novel technique we termed the “interlocking modification of the Adelaide repair” (Figure 2C). This simply involved an interlinking of the proximal end of the locking-crosses. 3-0 multifilament stainless steel wire (Ethicon. Somerville, NJ) was used for all repairs. Suture purchase was standardized at 10mm. The transverse strand in the Kessler groups was passed 7mm from the tendon end. The grasping loops in cruciate repair were one third of the tendon diameter. The cross-locks in the Adelaide groups were 2.5mm.

Anteroposterior (AP) and lateral X-rays were taken immediately after repair using a MX 20 Radiography system (Faxitron X-Ray. Lincolnshire, IL). The suture strands were then statically loaded to 35N and held at this tension for 30 seconds. X-rays of the tendon were repeated post-tensioning. A fixed length calibration device was included in the X-ray as a reference measure. Relative suture lengths within the tendon were compared before and after tensioning using Image J 1.41o (National Institute of Health).

RESULTS

2-strand repairs

Comparison of the AP images revealed considerable shortening of suture length within the tendon consistent with the formation of gap (Figure 1). Significant narrowing of the tendon at the transverse suture component was observed, but this was less evident with the Pennington configuration. However, this factor only contributed to part of the gapping tendency. In the grasping configuration, we witnessed a complete loss of the Kessler “pretzel” with transformation to a U-shaped configuration. Although significant constriction of the Kessler loops is noted with the Pennington technique, they were not completely lost. Importantly, the position of the transverse strand remained relatively constant in both scenarios.

Several changes were also apparent on the lateral films, including tendon buckling, and more importantly a change in the angle of the exposed Kessler loop relative to the longitudinal axis of the tendon. Again, the transverse suture component remained in position on the lateral projections.

4-strand repairs

Significant cheese-wiring of the loop-locks was noted with a large resultant propensity for repair site gap (Figure 2). In contrast, the cross-locking variants tightened under tension, but did not cheese-wire. Changes were similar for both the standard and interlocking variants of the Adelaide repair, as was the flattening out of the cross-lock “pyramids” seen on lateral projections. A similar amount of bucking was noted for all repair techniques. The relative length of suture elongation at the repair site was much less for the Adelaide repairs compared to the loop-locking and 2-strand techniques.

DISCUSSION

Several factors influence gap formation and these are intimately related to the three-dimensional changes in suture geometry. This examination looked at the core suture in isolation to exaggerate the geometric effects. Stainless steel suture was used because of favorable radiocontrast within the tendon. While this material has been used for flexor tendon repairs, its poor handling properties make it less preferred to other braided non-absorbable materials. Importantly, the findings were replicated when using Iodine contrast impregnated 3-0 Ethibond Excel sutures, but with inferior image quality. The sample size of n=5 per group, while small, was representative considering the in vitro nature of the study and high reproducibility of findings.

X-ray is a useful method of investigating suture configuration changes in situ. This evaluation provides a valuable new insight into the behavior of prevalent flexor tendon repair constructs. The resistance of locking configurations to suture pullout is known to be greater than grasping configurations. The Adelaide repair is favorable because of its relative strength and simplicity compared to other 4-strand repairs. We believe the interlocking modification of the Adelaide repair will further improve the performance of this technique. A comprehensive biomechanical study of this new method is currently being conducted in our laboratory.