Looped versus Single Stranded Flexor Tendon Repairs: A Cadaveric Mechanical Study

Ryan P. Calfee, MD, MSc, Sean Boone1, Jeffrey G. Stepan, MD2, Daniel A. Osei, MD1, Stavros Thomopoulos, PhD1, Martin I. Boyer, MD, MSc3.
1Washington University School of Medicine in St Louis, Saint Louis, MO, USA, 2Hospital for Special Surgery, New York, NY, USA.


Introduction: A substantial number of injuries to the upper extremity include lacerations to the intra-synovial flexor tendons of the hand(1). Despite advances in surgical techniques and rehabilitation protocols, repair site elongation or rupture continues to result in poor clinical outcomes. Biomechanical experiments have shown that that increases in core suture caliber(2-4) as well as number of core suture strands(3-5) lead to greater repair strength during the first six weeks following repair. Current techniques use looped suture to increase the number of core strands. A ring of suture is loaded onto a single needle, resulting in two strands pulled through the tissue with each pass. This allows placement of the core suture with half of the number of needle passes through the tendon compared to passing single suture strands. Whereas the total number of suture strands remain constant, the use of looped suture diminishes the number of passes and alters the proximity of strands. The effect of these changes on the interaction between the tendon and the core suture and upon total strength of repair is unknown. It is also unknown whether or not the use of looped suture has a similar effect when 3-0 and 4-0 strand core sutures are used, given the different areas available for tendon-suture interaction and intrinsic strength of these two sutures of differing caliber. Therefore, the purpose of this study was to evaluate the time zero ex-vivo mechanical repair properties of a 4-strand flexor tendon repair performed with looped suture, versus an identical repair performed with single stranded suture. The null hypothesis was that the repairs would be mechanically equivalent.

Methods: Four pairs of matched fresh human hands were used. All flexor digitorum profundus tendons and the flexor pollicis longus tendons were harvested from both hands and transected in zone 2 (N=40 tendons). Tendon cross-sectional areas were measured using a handheld caliper assuming an elliptical cross section. Tendons were then randomized to be repaired with either 3-0 or 4-0 polyfilament caprolactam. The paired tendons were then assigned to the looped suture group or to the non-looped suture group. Repairs using looped suture used a non-locking modified Kessler technique, and repairs
using single stranded suture used a nonlocking modified double Kessler technique (Figure 1). Tendons repaired with looped suture were repaired with a core purchase of 10mm and single stranded suture with core purchases of 8 and 12 mm. Epitendon repair was not performed to minimize variability. Twenty repairs were completed with the 3-0 suture caliber and 20 repairs were completed with the 4-0 suture caliber. All repairs were performed by 2 hand fellowship-trained attending surgeons. The mechanical properties of the repaired tendons were determined from uniaxial tensile tests to failure at a strain rate of 0.005/s. A two-sided paired Student’s t-test was used to determine differences in tendon cross-sectional area and continuous mechanical properties according to suture type (looped suture versus single stranded suture groups). The McNemar exact test was used to analyze for differences in the method of repair failure. No statistical comparisons were made according to suture caliber (3-0 versus 4-0), as these repairs were not performed on matching limbs and thus differences in tendon properties between cadavers could introduce systematic error. Statistical significance was defined as P < 0.05.

Results:

There was no significant difference in cross-sectional area between tendons repaired with 3-0 looped and 3-0 single stranded (P = 0.97) or 4-0 looped and 4-0 single stranded (P = 0.22). The 3-0 looped repairs demonstrated inferior mechanical properties compared to the 3-0 non-looped repairs: load required to produce a clinically relevant 2 mm gap(6) was decreased (P=0.02), rigidity (the slope of the load-strain plot) was decreased (P = 0.01), and maximal load to failure was decreased (P = 0.04) (Figure 2). Failure modes were significantly different between 3-0 looped and 3-0 single stranded suture, with looped suture failing predominantly by suture pullout compared to single stranded repairs, which failed by suture breakage (P = 0.02) (Figure 3). When comparing looped 4-0 repairs to single stranded repairs using 4-0 caliber suture, mechanical properties were statistically similar. Failure modes did not reach significance for 4-0 looped and single stranded.
Discussion: In summary: 1) The data indicate a statistically significant increase in the mechanical properties of single stranded suture repairs compared to looped suture repairs when 3-0 caliber suture was used. 2) 3-0 single stranded repairs failed by suture breakage, whereas 3-0 looped repairs failed predominately by suture pullout. This finding suggests that failure of the 3-0 looped repair is due to weakened tendon purchase, as each doubled suture strand passed within the same needle tract creates only a single point of interaction between suture and tendon. These data suggest that single strand repairs may prove mechanically advantageous, as the increased number of passes through the tendon increases the tendon-suture interaction and increases tendon pullout strength. 3) 4-0 looped repairs failed by suture rupture in 40% of instances. The force required for pullout was not significantly different from the force required to rupture 4-0 suture. These data suggest that if a tendon will accept 3-0 suture, the additional time to complete a 4 strand repair with single-stranded suture is mechanically beneficial at time zero. This study had several limitations. First, we elected not to perform circumferential suturing of the repair, as non-identical placement of the additional suture could influence results. Second, this study was an ex vivo investigation, and only provided time zero data. Third, we cannot predict the mechanical impact of looped versus single stranded repairs using alternative suture configurations or with increased number of core suture strands.

Significance: Based on time zero ex-vivo biomechanical data, we anticipate that if an injured tendon can accommodate a 3-0 caliber suture, 4-strand repairs are optimized when using single-stranded suture as opposed to looped suture.

ORS 2015 Annual Meeting
Poster No: 1881