Intrasynovial flexor tendon repair: A biomechanical study of variations in suture application in human cadavers

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SIGNIFICANCE: A substantial number of injuries to the upper extremity include lacerations to the intrasynovial flexor tendons of the hand. Although significant advances have been made in the treatment of tendon transections, the formation of repair-site adhesions and the development of repair-site gap formation leading to tendon rupture have led to highly variable clinical outcomes.

INTRODUCTION: To improve the functional outcomes of intrasynovial tendon suture, prior experiments evaluated the impact of individual technical modifications used in the repair process. There have been few studies, however, that have assessed the combinatorial effects of those suture modifications in an integrated biomechanical study, including a sample size sufficient to make definitive observations on repair technique. In the current study, we performed a systematic biomechanical examination of five of the most commonly studied factors in flexor tendon repair: core suture caliber, core suture strands, core suture purchase, peripheral suture caliber, and peripheral suture purchase. In order to determine the impact of each variable on the biomechanical characteristics of midsubstance tendon suture, the five factors were varied in cadaveric flexor tendon repairs. Our hypothesis was that the number of core suture strands and the caliber of the core suture would have the greatest effect on the biomechanical properties of the repair.

METHODS: Study Design: 256 intrasynovial flexor tendon lacerations followed by surgical repair were performed in human cadavers. The repairs were then tested in tension to determine the repair-site biomechanical properties. The aggregate effects of five separate independent factors for flexor tendon repair as well as their combinatorial effects with respect to each other were evaluated. The following variables were varied in this study: core suture caliber (4-0 or 3-0), number of core suture strands crossing the repair site (4- or 8-strand), core suture purchase (0.75 cm or 1.2 cm), peripheral suture caliber (6-0 or 5-0), and peripheral suture purchase (superficial or 2 mm). Core suture was braided nylon (looped Supramid Extra); peripheral suture was monofilament Prolene. Demographic information was not available for three of the tendons; therefore, 253 repairs were used in the final analysis. There were 32 experimental groups with n=7-9 repairs per group. Biomechanical testing: Repairs were tested biomechanically using methods described previously. To calculate cross-sectional area (CSA), the dimensions of the tendon were measured using a laser micrometer 3-8 mm distal to the repair grasping loops. Tendons were preconditioned to a preload of 1 N followed by five triangle wave cycles between 0-1 mm at a rate of 0.3mm/s. Tendons were then tested in tension until failure at a strain rate of 0.005/s. Failure mode (i.e., suture pullout or suture breakage) was recorded. Statistical methods: The analysis was performed using SAS (v9.2). Outcomes across five possible repair parameters (core suture, strands, core purchase, peripheral suture, and peripheral purchase) were compared using Generalized Estimating Equations (GEEs) with an exchangeable correlation matrix to account for the correlation of multiple measurements within each cadaver. CSA was selected as a covariate due to its clinical relevance and discrimination. Ancillary GEE models were performed to test the one interaction effect that was considered clinically relevant: core suture caliber and number of core suture strands.

RESULTS: The data used for statistical analyses consist of 47 cadavers (where 21 were female) with average age of 79 ± 12. The GEE models revealed that the most significant factors affecting the biomechanical properties of the repair were the number of core suture strands and the peripheral suture purchase. Core suture caliber significantly affected a small number of biomechanical properties. Core purchase and peripheral suture caliber did not affect any mechanical properties. Core suture caliber: Moving from 4-0 to 3-0 caliber Supramid suture produced significant decreases in extension at maximum load and significant increases in maximum load and toughness. Core suture strands: Increasing from 4 to 8 strands crossing the repair site resulted in significant decreases in extension at 20 N and extension at maximum load (Figure 1). Significant increases were seen in load at 2 mm of gap formation, maximum load, stiffness, and toughness. Core suture purchase: Changing core suture purchase from 0.75 cm to 1.2 cm produced statistically significant increases in maximum load to failure and toughness (Figure 1). Peripheral suture caliber: Increasing peripheral suture caliber produced a significant decrease in extension at maximum load and a significant increase in toughness. Peripheral suture purchase: Altering peripheral suture purchase from superficial to 2 mm resulted in significant decreases in extension at 20 N and extension at maximum load (Figure 1). Significant increases were seen in load at 2 mm of gap formation, maximum load, stiffness, and toughness. Excluding the effect of strands: When strand choice was not an option (as might be the case in some clinical scenarios), the conclusions described above remained unchanged. Interactions: When examining the interaction between core suture caliber and the number of core suture strands, only the outcome measure toughness revealed a significant interaction. There was no significant interaction effect between these two factors for the other nine biomechanical outcomes.

DISCUSSION: 1) This is the first study that examines specifically the combinatorial effects of suture modifications in an integrated biomechanical study; 2) We recommend that surgeons continue to pursue multi-strand repairs, as eight total strands crossing the repair offered substantially better biomechanical properties than did four strands; 3) The addition of a peripheral suture with 2mm purchase is recommended to prevent gap formation and augment repair-site strength; and 4) Since core suture caliber exerted significant effects on several biomechanical properties, the use of 3-0 suture could further enhance the properties of the repair.

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Figure 1: Increasing the number of strands and increasing the peripheral suture purchase led to increases in all three outcome measures. Note the striking effect of peripheral suture purchase on load at 2mm. Results are shown for 4-0 core suture caliber.

Figure 2: There was a significant effect of core suture caliber and the number of strands on the failure mode. Increasing the core suture caliber shifted the failure mode from suture breakage to suture pullout. Increasing the number of strands shifted the failure mode from suture breakage to suture pullout.

Figure 3: The following properties were significantly affected by core suture purchase: load at 2mm gap (+), load at maximum gap (+), stiffness (+), extension at maximum load (+), and toughness (+).