Biomechanical Evaluation of Various Stitch Techniques for Mid-substance Achilles Rupture Repairs

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INTRODUCTION: As the strongest and thickest tendon in the human body, surgical repair of the Achilles tendon requires high strength while also limiting elongation. Mid-substance repairs are particularly reliant on suturing techniques, which typically utilize either the whip stitch or a locking stitch. While the whip stitch is efficient to perform, it is prone to failure via suture pullout. The locking stitch, like the Krackow, improves security with lower risk of pullout, but it requires significantly more needle passes, and thus takes more time to perform. A locking whip stitch has recently been introduced, which creates a locking suture mechanism while limiting needle passes. Repair techniques that leverage these stitch methods along with added reinforcement, such as a gift box or transverse baseball stitch, aim to improve clinical outcomes by minimizing tendon elongation and sustaining the substantial loads during daily activities the Achilles tendon endures. The purpose of this study was to evaluate the biomechanical properties of three repair techniques for an Achilles mid-substance repair. It was hypothesized that the groups that utilize a locking stitch technique will have better biomechanical performance than a whip stitch.

METHODS: This was a controlled biomechanical study that utilized a total of 30 fresh frozen human cadaveric lower leg specimens (20 specimens from 5 Male and 5 Female; 10 specimens from 3 Male and 7 Female; Average Age 72 ± 10 years). The specimens were randomly assigned to one of three groups (Figure 1), where the first two groups utilized a two-part needle with Size 2 suture (EasyWhip® - Winter Innovations, Knoxville TN) to perform a whip stitch gift box (WG) and a locking whip stitch gift box (LG). The third group utilized a curved needle with Size 2 suture (FiberWire® - Arthrex, Naples FL) to perform the conventional Krackow with a transverse baseball stitch (KB). Each specimen was dissected to isolate the calcaneus and Achilles. A mid-substance Achilles tendon rupture was simulated with surgical blade, and the repair was performed by a fellowship-trained orthopaedic surgeon. The gastrocnemius soleus complex was secured in high strength resin to allow fixation of each specimen to the test frame (Figure 2). Samples were preconditioned from 20-100 N for 10 cycles to normalize viscoelastic properties, followed cyclic loading from 20-100 N at 1 Hz for 1,000 cycles. If samples survived cyclic loading, load to failure was performed at a rate of 25.4 mm/s. The mean and standard deviation were calculated for ultimate failure loads (UFL). A Kruskal–Wallis test with Bonferroni correction was used to analyze test parameters. A one-way ANOVA with post hoc Tukey and Games–Howell tests was performed to compare tendon characteristics. Statistical significance was set at $\alpha = 0.05$.

RESULTS: Thirty total samples were tested, with ten samples per group (WG = 10, LG = 10, KB = 10) (Figure 3). UFL were 230 ± 47 N for WG, 437 ± 71 N for LG, and 292 ± 96 N for KB. LG repairs had significantly greater ultimate failure loads than both KB ($p = 0.018$) and WG ($p < 0.001$). KB demonstrated significantly higher stiffness and lower peak-to-peak elongation compared to WG ($p < 0.001$ and $p = 0.021$, respectively), with no significant differences between KB and LG for these measures. Elongation at failure was significantly lower in KB compared to both WG ($p < 0.001$) and LG ($p = 0.020$), while WG and LG did not differ significantly. UFL load was not significantly associated with tendon thickness, repair-site width, or repair length (all $p > 0.37$), suggesting construct geometry was not a confounding factor.

DISCUSSION: The LG is a promising repair technique that limits the number of needle passes while also reinforcing the construct with a gift box. The WG technique offered limited strength and experienced the highest elongation, whereas adding a locking mechanism to the whip stitch through the LG technique offered significant advantages by improving repair strength and limiting early re-rupture. The LG technique demonstrated significantly greater ultimate failure loads than both KB and WG. KB and LG performed similarly with respect to peak-to-peak displacement, which is a measure of steady state elongation during cyclic loading. While KB achieved significantly lower elongation at failure than LG, this was likely due to the transverse baseball stitches, which served to hold the tendon junction approximated together. However, this did not appear to result in increased strength. Future studies could investigate this technique in conjunction with a transverse baseball stitch to limit elongation. As a cadaveric model, this study does not account for biological healing or functional outcomes, warranting further investigation in clinical settings.

SIGNIFICANCE/CLINICAL RELEVANCE: Achilles tendon repairs must balance biomechanical strength with surgical efficiency to enable early mobilization and reduce re-rupture risk. This study demonstrates a new LG technique that offers superior failure strength compared to traditional methods, representing a promising alternative for clinical repair.

IMAGES AND TABLES:

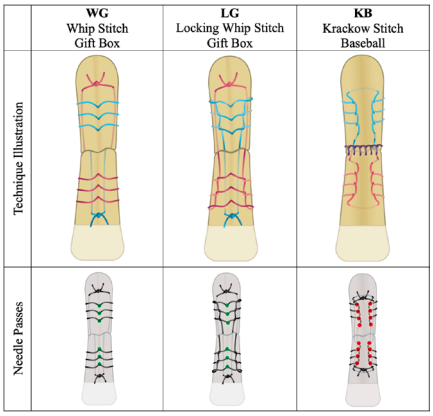

Figure 1. Illustration of test groups.

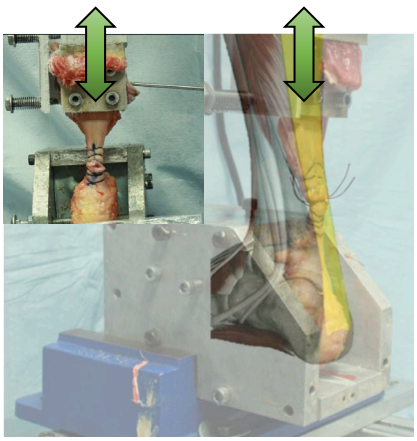

Figure 2. Testing setup

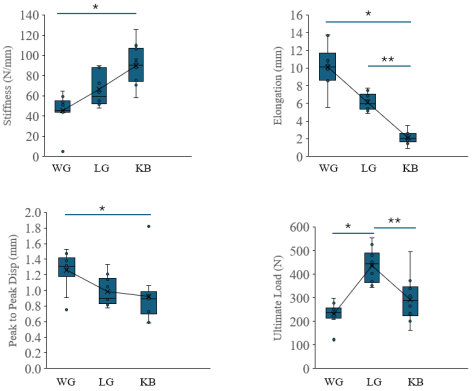

Figure 3. Comparison of Biomechanical Data for each group