Biomechanical Comparison of Whip Stitch and WhipLock™ Stitch

Objective

The purpose of testing was to compare biomechanical properties of the whip stitch and WhipLock™ stitch using EasyWhip®, a novel two-part suture needle. This testing specifically evaluated the ultimate failure load and elongation, two bench metrics often considered indicative of clinical success of a suture method.[1] Testing was performed on two different ACL graft sources, the semitendinosus tendon (ST) and the quadriceps tendon (QT). The ST is a smaller tissue source that requires bundling to create a graft of sufficient diameter[2], whereas the QT is a thicker, more robust option that is gaining popularity.[3]

Test Groups

The whip stitch is a technique that enables surgeons to rapidly suture soft tissue. A key benefit of the whip stitch is its ability to suture both sides of the tissue with a single needle pass. However, the whip stitch concentrates suture forces on the central line of the tissue, making it prone to failure from tissue damage.[4]

Locking suture techniques like the Krackow have been shown to improve load distribution and biomechanical performance[5], however they require twice as many needle passes and take longer to complete. The WhipLock™ is a new approach to a locking suture technique enabled by the two-part needle design of EasyWhip®. It achieves a locking mechanism but requires 50% fewer passes than a Krackow and the same number of needle passes as a whip stitch.

Both the whip stitch and WhipLock™ stitch can be created with EasyWhip®, and the key differences between the stitch methods are shown in Figure 1.

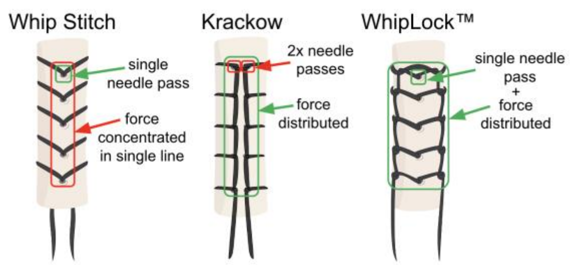

Figure 1: Stitched tendon graphics highlighting benefits (green) and drawbacks (red) for each method.

Methods

Grafts were isolated from human cadaver specimens and prepared by fellowship-trained orthopedic surgeons. QT whip stitch and WhipLock™ groups contained 8 samples each, for a total sample size of 16. ST whip stitch and WhipLock™ groups contained 12 samples each, for a total sample size of 24. Overall, 40 graft constructs were tested. Testing was performed on an MTS Bionix with a 5kN load cell. Samples were preconditioned to normalize viscoelastic effects. Thereafter, they were loaded to 50-200 N for 500 cycles at 1 Hz and then ramped to failure at 20 mm/min. Peak to peak elongation and ultimate failure load was recorded for each sample, averaged, and compared across groups.

Results[6,7]

Elongation and ultimate load results are summarized in Figure 2. Average elongation for both the whip stitch and WhipLock™ was 2.1mm in the QT. In ST, elongation was significantly lower for the WhipLock™ than the whip stitch, at 1.6mm and 3.4mm respectively.

For ultimate load in the QT group, the whip stitch had a significantly higher load than the WhipLock™, at 379N and 343N respectively (p=0.02). In the semitendinosus tendon group, the opposite occurred as the whip stitch had significantly lower average peak load than the WhipLock™, at 241N and 340N respectively (P=0.001).

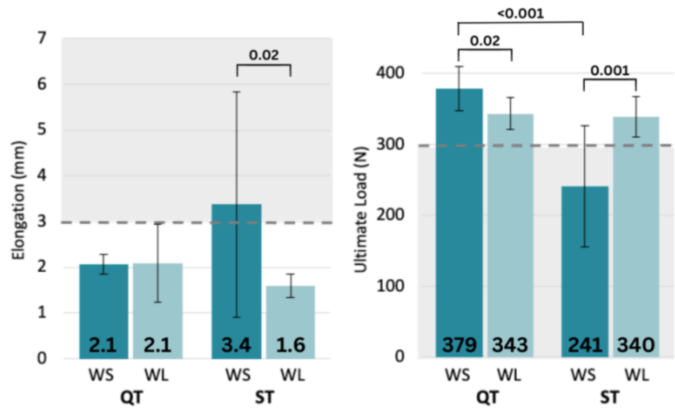

Figure 2: Peak to peak elongation (mm) and ultimate loads (N) for whip stitch (WS) and WhipLock™ (WL) stitch in QT and ST. The grey area represents clinical failure thresholds.

Discussion

For the QT group, the whip stitch and WhipLock™ had equivalent elongation, but significantly different ultimate load. Elongation for both groups was 2.1mm, well below the clinical failure threshold of 3mm.[8] The whip stitch had a higher average peak load by 40N. The clinical failure threshold for an ACL graft has been cited as 300N[9] Although the difference is statistically significant, it may not be clinically relevant because values for both groups far exceed 300N.

For the ST group, the WhipLock™ had a significantly lower elongation as well as significantly higher ultimate load. WhipLock™ achieved a nearly 100N increase in ultimate load demonstrating that the WhipLock stitch facilitated a stronger construct in a weaker tendon. Additionally, the ST group secured by a whip stitch did not surpass the 300N clinical failure threshold. Meanwhile, the WhipLock™ achieved elongation of 1.6mm, while the whip stitch elongation was 3.4mm, which does not meet the cited clinical failure threshold of 3mm for elongation.

Conclusion

The use of a WhipLock™ instead of a whip stitch on smaller, less robust tissue, like the semitendinosus tendon, can improve biomechanical performance through higher ultimate load and lower elongation. In more robust tissue, like the quadriceps tendon, either stitch method may be sufficient to achieve biomechanical security. Results are based on bench testing of ex-vivo tissue. Correlation to clinical results in humans is unknown.

References

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