Flexor Hallucis Longus Tendon Transfer: A Biomechanical Analysis of A Terminal Whipstitch and Bone Tunnel Length
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The following authors have conflicts to disclose:

Jessica Lee, MD and Chad Williams, MD
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FHL tendon to calcaneus transfer with interference screw fixation is commonly used in the surgical treatment of chronic achilles tendinopathy.

This study assesses the relative integrity of biotenodesis screw FHL tendon fixation with respect to two construct variables:

- incorporation of a terminal whipstitch
- tunnel depth: complete vs. incomplete tunnels
Sixty fresh frozen cadaver FHL tendons and 28 calcanei from male and females ranging from 63-97 years in age were harvested for biomechanical analysis in four sets of fixation constructs.

Fourteen specimen pairs were fixed with one tendon incorporating a terminal 2.0 non-absorbable synthetic fiber suture whipstitch of the distal 20 mm of the tendon and one without a whipstitch.

Sixteen specimen pairs were fixed with either a full depth tunnel (spanning proximal to distal calcaneal cortices) or a 25 mm unicortical tunnel.

Following fixation, all constructs were mounted proximally into a pneumatic test frame with soft tissue vise grips. Cadaver models were mounted distally with Steinmann pins and synthetic bone models were mounted distally with vice clamps. Constructs were then subjected to 1000 dynamic load cycles between 10 and 100 Newtons. They were then subjected to increasing load at a constant rate until elongation occurred signifying clinical load to failure and until construct failure occurred signifying absolute load to failure.

All comparisons were carried out in native bone and synthetic models (to control for fixation site heterogeneity).
Figure 1. Fixation constructs. A. Complete tunnels were utilized for both the whipstitch and non-whipstitch groups. B. Hemi-section of synthetic bone model demonstrates the unicortical nature of the partial tunnel. C. Fixation in native bones with Steinmann pins distally.
Results: Whipstitch vs. No Whipstitch

- In synthetic bone models, addition of a whipstitch demonstrated significantly stronger mean clinical load (253.68 N vs 177.24 N, p = .008) and maximum load to failure (294.31 N vs 194.57 N, p = .001) compared to native FHL tendons.

- In the native bone models, there was no significant difference between mean clinical (198.26 N Whipstitch vs 172.07 N Non-Whipstitch; p = .29) and maximum loads to failure (245.05 N Whipstitch vs 172.07 N Non-Whipstitch; p = .07) respectively between groups. In the non-whipstitch group, a majority of specimens failed to complete cyclical loading.
In comparison of constructs using full and partial tunnels in synthetic bone, there were no statistical differences in mean clinical load (200.96 N Full vs 228.31 N Partial, p=.63) and maximum load to failure (192.69 N Full vs 217.74 N Partial, p=.73).

In native bone models, a majority of tendon pairs failed to complete cyclical loading in testing. Of the remaining pairs, there was no significant difference the mean clinical (226.53 N Full vs 295.01 N Partial, p=.2), and maximum loads (219.97 N Full vs 312.64 N partial; p=.2) to failure.
Table 1. Constructs with and without a whipstitch were tested to clinical and maximum load to failure in both synthetic and cadaver bone models for comparison.
Table 2. Constructs with complete and partial tunnels were tested to clinical and maximum load to failure in synthetic and cadaver bone models for comparison.
The mode of failure in the majority of all groups (whipstitch, or no whipstitch; full, or partial tunnel) was pull out of the tendon from screw-bone interface, leaving the screw in the bone. Secondary modes of failure included native tendon rupture and loss of fixation of the tendon by the construct clamp.

Use of a terminal whipstitch confers greater fixation strength to FHL tendon to calcaneus biotenodesis.

Complete and partial tunnel constructs are equivocal in their biomechanical integrity as demonstrated in a bone substitute model.

The data produced from the bone substitute model demonstrates the superiority of the whipstitch technique as well as the non-inferiority of the partial tunnel technique.
References

References Continued