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Biomechanical Analysis of Suture Anchor vs Tenodesis Screw for FHL Transfer

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Abstract

Background: Chronic Achilles injury is often treated with flexor hallucis longus (FHL) tendon transfer to the calcaneus using 1 or 2 incisions. A single incision avoids the risks of extended dissections yet yields smaller grafts, which may limit fixation options. We investigated the required length of FHL autograft and biomechanical profiles for suture anchor and biotenodesis screw fixation.

Methods: Single-incision FHL transfer with suture anchor or biotenodesis screw fixation to the calcaneus was performed on 20 fresh cadaveric specimens. Specimens were cyclically loaded until maximal load to failure. Length of FHL tendon harvest, ultimate load, stiffness, and mode of failure were recorded.

Results: Tendon harvest length needed for suture anchor fixation was 16.8 ± 2.1 mm vs 29.6 ± 2.4 mm for biotenodesis screw (P = .002). Ultimate load to failure was not significantly different between groups. A significant inverse correlation existed between failure load and donor age when all specimens were pooled ($\rho = -0.49$, $P < .05$). Screws in younger specimens (fewer than 70) resulted in significantly greater failure loads ($P < .03$). No difference in stiffness was found between groups. Modes of failure for screw fixation were either tunnel pullout (n = 6) or tendon rupture (n = 4). Anchor failure occurred mostly by suture breakage (n = 8).

Conclusion: Adequate FHL tendon length could be harvested through a single posterior incision for fixation to the calcaneus with either fixation option, but suture anchor required significantly less graft length. Stiffness, fixation strength, and load to failure were comparable between groups. An inverse correlation existed between failure load and donor age. Younger specimens with screw fixation demonstrated significantly greater failure loads.

Clinical Relevance: Adequate harvest length for FHL transfer could be achieved with a single posterior incision. There was no difference in strength of fixation between suture anchor and biotenodesis screw.

Keywords: flexor hallucis longus transfer, tendon transfer, Achilles tendon tear, Achilles tendinosis, suture anchors, interference screws, biomechanics, pullout strength, tendon length

In the setting of chronic Achilles tendon injury, flexor hallucis longus (FHL) tendon transfer to the calcaneus has been a successful operative treatment option for augmenting degenerative Achilles tendon.* Wapner et al[27] were the first to report on a technique for harvesting the FHL tendon for transfer to the calcaneus. They harvested the FHL tendon through an additional medial midfoot incision at the knot of Henry to achieve sufficient tendon length for fixation through a calcaneus bone tunnel. Newer technologies such as biotenodesis screws and bone suture anchors have since evolved, allowing surgeons to achieve strong bony fixation with less tendon harvest length.[2,12,21,24] When harvesting the FHL for transfer to the calcaneus, a single posterior incision avoids the need for extended dissection and mitigates the risk of damage to surrounding structures, most notably the medial plantar nerve. However, concern exists as to the ability to obtain adequate fixation with less tendon length. To

* References 3, 4, 6-10, 13, 15, 16, 17, 18, 19, 22, 25, 27-32.

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our knowledge, there exist no studies directly comparing the biomechanical profiles of suture anchor and biotenodesis screw fixation for FHL transfer to the calcaneus.

This study aimed to compare the pullout strength and length of tendon harvest needed for fixation of the FHL to the calcaneus using a biotenodesis interference screw or suture anchor. We hypothesized that there would be no significant difference in pullout strength between the 2 fixation techniques. We also hypothesized that the suture anchor fixation technique would require significantly less tendon harvest length to achieve adequate fixation compared with the biotenodesis screw fixation technique, making it more feasible for a single posterior approach.

Materials and Methods

Single-incision FHL transfers to the calcaneus were performed on 10 matched pairs (n = 20) of fresh frozen cadaveric below-knee specimens (5 per sex) randomized to receive either bone tunnel interference screw fixation directly anterior to the Achilles or suture anchor fixation. One matched pair was selected at random and used as a trial for both the anchor and screw constructs. A posterior approach was used just medial to the midline. The length of FHL tendon harvested for graft was recorded from the musculotendinous junction to the distal aspect of the tendon. The length of the tendon was measured with a ruler. This was done to the deepest point in the tarsal canal that could be directly visualized when the tendon was cut. The FHL tendon was then tensioned with the calcaneus in 10 degrees of plantarflexion of the ankle. The FHL tendon was then secured to the calcaneus, using either a Bio-Corkscrew FT 5.5-mm × 15-mm suture anchor with 2 No. 2 Fiberwire sutures (Arthrex, Naples, FL) or a BioComposite Tenodesis Screw, 5.5 mm × 15 mm (Arthrex). The tendon was cut at the level of the bone for the anchor and at the level of bone plus an additional 15 mm for the tenodesis screw. The anchors and screws were inserted superoposterior to inferoanterior (Figure 1). The specimens were dissected to the calcaneus and FHL tendon only and mounted in an Instron (Norwood, MA) material testing machine.

Cyclic loading (20-60 N, 100 cycles, 4.5 N/s, 5-N preload) was performed, followed by a load-to-failure protocol (1.25 mm/s) with a 10-kN load cell. Ultimate load (N), stiffness (N/mm), and modes of failure were recorded. Data were analyzed by repeated-measures analysis of variance and least significant difference post hoc test (mean ± SE), and Spearmen's correlation was performed for effect of age. The trial specimens were not included in the final data analysis.

Results

The mean length of tendon harvested was 36.1 ± 2.3 mm (range, 20.0-51.0 mm) with an average of 35.7 ± 3.3 mm (range, 22.0-46.0 mm) and 36.6 ± 3.5 mm (range, 20.0-51.0 mm) harvested for the anchor and screw groups, respectively. The length of tendon needed for suture anchor fixation (16.9 ± 2.1 mm) was significantly less than that needed for biotenodesis screw fixation (29.7 ± 2.4 mm, P = .002; Table 1). Four specimens failed during cyclic loading. Three of the 4 that failed had received screw fixation while 1 received anchor fixation. Overall, the mean load to failure in the anchor group (188.8 ± 25.8 N) was comparable to that measured for the biotenodesis screw group (171.6 ± 39.6 N, P = .759; Table 2). In addition, a significant inverse correlation was found with failure load and donor age when all specimens were pooled, where increasing age led to a decrease in amount of load to failure ($\rho = -0.49$, $P < .05$; Figure 2). The fixation stiffness in both groups was comparable (49.7 ± 9.3 N/mm screw vs 35.5 ± 3.9 N/mm anchor, P = .259; Table 3). However, stiffness in the screw group (69.6 N/mm) was significantly greater than that of the anchor group (26.9 N/mm) in specimens from female donors (P = .008). There was no difference in stiffness between fixation groups in male donor specimens (P = .432; Table 4). The mode of failure for screw fixation was pullout of tunnel (n = 6) and tendon rupture (n = 4), whereas anchor failure occurred mostly by suture failure (n = 8).

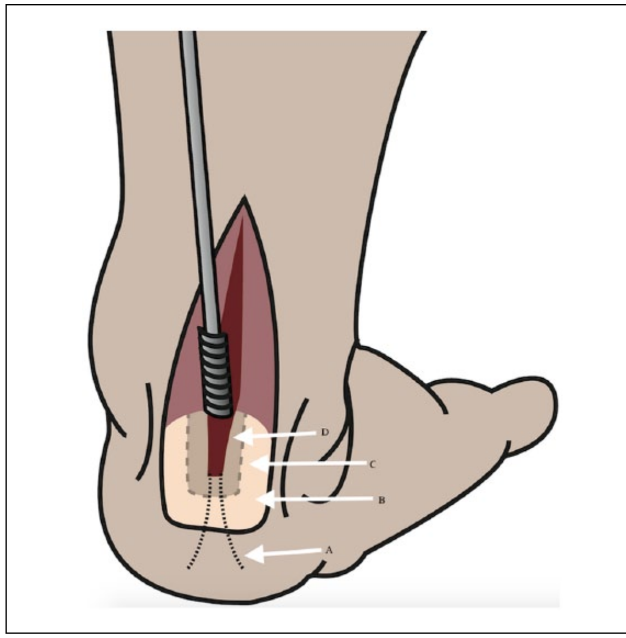

Figure 1. Diagram of the screw insertion showing the sutures (A), the calcaneus (B), the bone tunnel (C), and the tendon (D).

Discussion

Flexor hallucis longus tendon transfer has been shown to be a very successful operative treatment for chronic Achilles rupture or tendinosis. Historically, this procedure has been

Table 1. Length of Tendon Harvested and Used.

			Anchor Group			Screw Group		
Matched Pair	Age, y	Sex	Specimen (Pair, R/L)	Tendon Harvested, mm	Tendon Used, mm	Specimen (Pair, R/L)	Tendon Harvested, mm	Tendon Used, mm
1	80	F	1L	30	14	1R	36	28
2	66	F	2L	26	10	2R	26	25
3	63	M	3L	45	15	3R	47	40
4	62	M	4R	45	13	4L	42	40
5	66	M	5L	22	12	5R	20	20
6	79	M	6L	46	30	6R	51	33
7	39	F	7R	26	14	7L	27	22
8	79	F	8R	45	22	8L	44	31
9[a]	62	F	9L	32	7	9R	33	17
10	74	M	10R	40	22	10L	40	28
			Mean	35.7 ± 3.3	16.9 ± 2.4		36.6 ± 3.5	29.7 ± 2.4
			P value					.002[a]

Abbreviations: F, female; L, left; M, male; R, right.
[a]Trial pair not included in final averages.

Table 2. Cyclic Loading and Load-to-Failure Results.

Anchor Group			Screw Group		
Specimen	Failure in Cyclic	Load to Failure, N	Specimen	Failure in Cyclic	Load to Failure, N
1L	N	177.3	1R	N	191.2
2L	N	324.5	2R	Y	55.9
3L	N	114.6	3R	N	251.3
4R	N	243.4	4L	N	214.8
5L	Y	60.3	5R	N	325.4
6L	N	183.6	6R	Y	36.4
7R	N	248.2	7L	N	335.1
8R	N	184.6	8L	N	81.2
9L	N	80.0	9R	N	134.1
10R	N	162.7	10L	Y	52.0
Mean		188.8 ± 25.8			171.6 ± 39.6
P value					.759

Abbreviations: L, left; N, no; R, right; Y, yes.

performed using a 2-incision technique to harvest maximal tendon length for bone tunnel fixation through the calcaneus. The development of newer fixation techniques has allowed surgeons to achieve adequate fixation with a shorter graft harvest through a single posterior incision. Using the posterior technique gives enough tendon length for fixation and allows the surgeon to avoid weaving the tendon through and around the calcaneus. A dorsal incision was used due to the posterior location of the FHL, which was still connected to the tibia. The screw was inserted at a Deadman's angle, 45 degrees to the parallel, to increase pullout strength. Interference screw fixation has demonstrated significantly higher pullout strength compared with the more traditional bone tunnel technique in a previous cadaver model.[3] There have been few studies directly comparing suture anchor and interference screw fixation strength for tendon transfer in foot and ankle surgery. In a study by Nunez-Pereira et al,[21] interference screw fixation showed greater pullout strength for split anterior tibial tendon transfer to the cuboid, but both fixation techniques achieved pullout strength values capable of sustaining normal physiologic stresses. When comparing suture anchors and interference screws for lateral ankle stabilization in a porcine model, interference screws again showed significantly greater failure strength.[12] However, a recent cadaveric study comparing the biomechanical characteristics of fixation with suture anchors with those of interference screws in lateral ankle reconstruction showed equivalent strength of fixation for both techniques.[14] Both fixation techniques used in this study demonstrated comparable pullout strength.

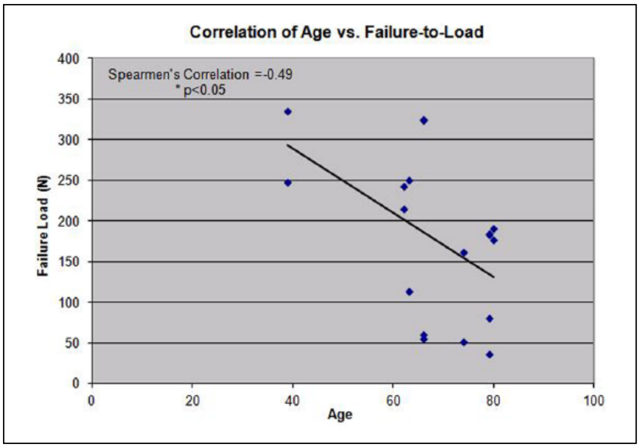

Figure 2. Correlation of age vs failure to load.

Table 3. Fixation Stiffness.

Anchor Group		Screw Group	
Specimen	Stiffness	Specimen	Stiffness
1L	25.8	1R	30.0
2L	25.2	2R	69.9
3L	43.9	3R	31.8
4R	27.8	4L	29.3
5L	59.1	5R	35.4
6L	43.7	6R	16.5
7R	31.4	7L	79.9
8R	25.5	8L	99.8
9L[a]		9R[a]	25.4
10R	36.9	10L	54.5
Mean[a]	35.5 ± 3.9		49.7 ± 9.3
P value			.259

Abbreviations: L, left; R, right.
[a]Trial pair not included in averages.

Table 4. Comparison of Fixation Stiffness Between Male and Female Donor Specimens.

Female Donors			Male Donors		
Specimen	Anchor Stiffness	Screw Stiffness	Specimen	Anchor Stiffness	Screw Stiffness
1L	25.8		3L	43.9	
1R		30.0	3R		31.8
2L	25.2		4R	27.8	
2R		69.9	4L		29.3
7R	31.4		5L	59.1	
7L		79.9	5R		35.4
8R	25.5		6L	43.7	
8L		99.8	6R		16.5
9L[a]			10R	36.9	
9R[a]		25.4	10L		54.4
Mean	26.9	69.6		42.3	33.5
P value		.008[a]			.432

Abbreviations: L, left; R, right.
[a]Trial pair not included in averages.

The benefits of the single-incision harvest are numerous. Most notably, there is a decreased risk of damage to the medial plantar nerve.[20] By obviating the need for a second medial plantar incision, the neurovascular structures in close proximity to the knot of Henry remain undisturbed, and scar tissue formation along the plantar surface of the foot is no longer a concern.[11] Due to connections with the knot of Henry, patients may have preserved distal FHL tendon fixation through a tenodesis effect with the flexor digitorum longus (FDL). Furthermore, chance for wound complication is minimized with 1 incision vs 2 incisions. Harvest through a single posterior incision is also faster and technically less challenging than performing an extended dissection through the midfoot.

But, with an extended dissection through a medial plantar incision, physicians are able to harvest a longer autograft and suture the remaining FHL stump to the nearby FDL tendon after harvest in an effort to preserve plantarflexion strength of the first metatarsophalangeal joint (MTP).[1,10,13,18,22,26] Studies have shown, however, that although there is decreased plantarflexion strength of the first MTP when the FHL stump is not sutured to the FDL, patients report no noticeable deficit in clinical function.[5,23] Moreover, there are often connections in between the FHL and FDL tendons at the knot of Henry. This allows active first interphalangeal (IP) joint flexion with concomitant FDL activation. Although the power may be less, the connections are still preserved through this method.

There are a number of limitations in this study. This is an in vitro cadaver model simulating initial pullout strength. The pullout strength of each fixation method will only be relevant to the immediate postoperative period to assess risk of failure before the transferred tendon fully incorporates into the calcaneus.

Conclusion

We believe that both suture anchors and interference screws provide adequate fixation for FHL transfer to the calcaneus. Tendon harvest through a single posterior incision was acceptable for both fixation techniques, although the suture anchor technique required less tendon length. Future randomized clinical controlled trials would be necessary to fully elucidate the benefits and shortcomings of each technique.

Declaration of Conflicting Interests

The author(s) declared the following potential conflicts of interest with respect to the research, authorship, and/or publication of this article: Mark C. Drakos, MD, is a paid consultant for Extremity Medical and Fast Form, neither of whose products are involved in the current study. No funds were received in support of this study.

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