Biomechanical Strength and Bulk Comparisons Between the Open-Book Technique and the Pulvertaft Method for Peroneal Tendon Transfer: A Pilot Study

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ABSTRACT

Background: The Pulvertaft method has classically been used for the transfer of various tendon injuries owing to its biomechanical strength; however, this method has been shown to be bulky. We describe the open-book technique, which can offer comparable structural integrity with a decreased bulk. The purpose of this study was to determine whether the open-book technique is biomechanically equivalent to the Pulvertaft method for treating peroneal tendon injuries.

Methods: We evaluated five pairs of human cadaveric ankles. Within each pair, one specimen was randomly assigned to either the Pulvertaft or the open-book group. Using sharp dissection, the tendons were severed in a standardized method. Transfer was performed using one of the two randomly assigned techniques. The transferred peroneal tendons were stressed on a mechanical tensioning device until failure. Data were recorded and analysis was performed.

Results: There was a statistically significant difference ($P < 0.001$) between the thickness of the Pulvertaft method (7.6 mm) and open-book technique (5.7 mm). There was also a statistically significant difference in elongation, with the Pulvertaft undergoing more elongation at yield (9.7 mm vs 3.7 mm, respectively; $P = 0.04$). No statistical difference was detected in elongation at peak ($P = 0.52$), load at yield ($P = 0.9$), or peak load ($P = 0.69$).

Conclusions: The open-book technique appears to be a viable biomechanical alternative to the Pulvertaft method for peroneal tendon transfer. The peak load, load at yield, and elongation at peak were biomechanically equivalent. The open-book technique was found to provide a significant decrease in thickness, which could prove advantageous when dealing with anatomical locations.

Keywords: Tendon Transfer, Peroneal Tendons, Pulvertaft, Open-Book

INTRODUCTION

Surgically incised or ruptured peroneal tendons are commonly treated with operative transfer. For about 50 years, the Pulvertaft method has been a classic transfer technique that involves weaving the tendons inside one another and then suturing these weaves in place. Although this method results in a biomechanically stable junction, the weaved tendons can be quite thick and bulky. The added bulk of the transfer is often volumetrically problematic when used in an anatomical location with a limited soft-tissue envelope.

Multiple tendon transfer techniques have been described, including double loop, lasso tendon transfers, loop tendon methods, side-to-side, and the spiral linking technique.[1,2] When results of failure and ultimate load tests were evaluated, most transfer techniques provided equivalent or increased biomechanical strength. However, the volumetric bulkiness of the transfer footprint remained a concern. Another potential alternative method, called the open-book technique, involves the splicing and inlay of one tendon inside of the other with a locked running suture securing the transfer. This results in a transfer with an end product that is more anatomically sized (Mckee DM, unpublished data, October 2018).

A recent study suggested[3] that when applied to the extensor tendons of the hand, the open-book technique provides equivalent biomechanical strength while also decreasing the size burden of the transfer. To our knowledge, no study has specifically examined the different transfer techniques for peroneal tendons. This investigation sought to determine if these findings would hold true when applied to the peroneal tendons in the lower extremities.

METHODS

Five pairs of human cadaveric ankles and feet were used. Each cadaveric specimen was handled, stored, and disposed of in accordance with the guidelines and regulations of the Texas Tech University Health Sciences Center, which were set forth by the State Anatomical Board. Before dissection, inspection was performed to ensure equal tissue quality within pairs and absence of previous injury to the peroneal tendons.

To help minimize confounding variables, we chose to use a matched pair design for our study. For each pair of cadavers, one extremity was randomly assigned to either the Pulvertaft or open-book group. Randomization was performed using an Excel spreadsheet (Microsoft, Redmond, WA).

Careful dissection of the specimens was performed, taking care to identify the peroneal tendons including their musculotendinous junction and bony attachments. To control for the amount of tendon used in the transfer, we determined a location for our transection to be 2.5 cm proximal to the distal tip of the lateral malleolus. This location was identified and marked on each specimen. Volumetric data were recorded for each tendon. The tendons were transected, and the transfer was performed using the randomly predetermined technique.

For the Pulvertaft group, the weave consisted of three passes of the peroneus longus through the peroneus brevis performed over the 2.5 cm area (Figure 1). Each pass was secured in place on either side with a 3-0 Ethibond horizontal mattress suture (Ethicon, Somerville, NJ).

The open-book technique was performed in the same 2.5-cm area. The peroneus brevis was opened longitudinally without violating the posterior aspect of the tendon. The peroneus longus was then inlayed into the 2.5-cm opening. The tendon flaps of the peroneus brevis were

Figure 1. *Using the Pulvertaft method, the peroneus longus is secured to peroneus brevis with three passes and secured with sutures.*

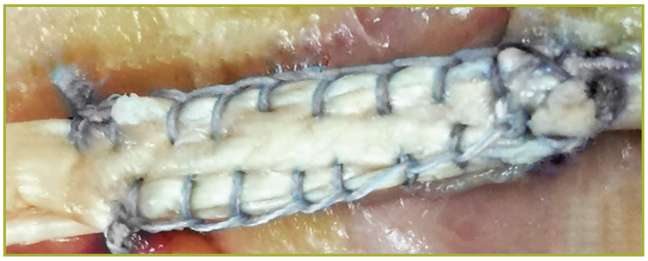

Figure 2. *Using the open-book technique, the peroneus longus is secured inside the peroneus brevis with running, locking Krackow stitches.*

then closed over the peroneus longus and secured in place with a running, locking, 3-0 Ethibond, Krackow suture (Figure 2). Before healing, it was hypothesized that a major component of the strength being tested was the result of suturing. To help account for this hypothesis, the same suture was used for both groups.

After the transfer, each tendon set was harvested from its cadaver. This removed any remaining soft tissue from the musculotendinous junction. Next, the transferred tendons were measured, ensuring that there was sufficient tendon (about 5 cm) proximally and distally to the transfer site. This allowed the testing device to attach to the tendon. The tendon size could vary from one cadaver to the next, which usually depended on the location that was being tested. To help control for this variability, all tendons were harvested at the same predetermined location. Additionally, to help account for the differences due to general body habitus, we randomized the cadavers to have one limb in each group.

After completing the harvest, the transferred tendons were fixed into sigmoid-shaped clamps covered in coarse grit sandpaper to prevent slippage. These clamps were then inserted into a Materials Testing System servohydraulic activator for stress analysis (Insight 10 kN, MTS Inc, Eden Prairie, MN). For conformity, the peroneus longus was inserted into the superior clamp and the peroneus brevis was inserted into the inferior clamp (Figure 3). The amount of visible

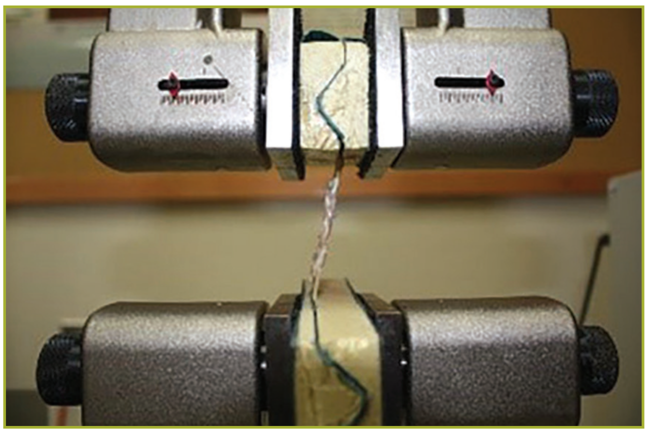

Figure 3. *A secured tendon transfer placed in the Materials Testing System for biomechanical analysis. The superior clamp contains the isolated peroneus longus, whereas the inferior clamp holds the isolated peroneus brevis portion of the transfer.*

Table 1. Comparison of thickness and biomechanical strength values between the Pulvertaft method and open-book technique used for tendon transfer

Variable	Pulvertaft mean (SD)	Open-Book mean (SD)	*P* value[a]
Peroneal longus thickness (mm)	3.1 (0.626)	2.9 (0.489)	0.66
Peroneal brevis thickness (mm)	2.4 (0.33)	2.2 (0.401)	0.43
Pulvertaft weave thickness (mm)	7.6 (0.941)		< 0.001
Open-book thickness (mm)		5.7 (0.825)	
Elongation at peak (mm)	16.3 (9.49)	12.5 (5.89)	0.52
Elongation at yield (mm)	9.7 (4.61)	3.7 (1.89)	0.04
Load at yield (N)	139.6 (92.81)	93.4 (46.60)	0.9
Peak load (N)	167.8 (88.18)	168.3 (70.31)	0.69
Strain at yield	0.19 (0.09)	0.15 (0.19)	0.69

SD, standard deviation.
[a]*P* value calculated using student *t* test.

tendon between the clamp and transfer junction was kept at roughly 1.5 cm. The baseline for testing was in a resting position with no pretension force applied. We then used TestWorks 4 software (MTS Systems Corporation, Eden Prairie, MN), zeroed all force and position monitors, and initiated the sequence. The rate-of-pull was constant at 0.5 mm per second until failure was detected by the Materials Testing System. All the data were recorded and the analysis was then performed using SPSS Statistics 22.0 (IBM, Armonk, NY). To help facilitate data analysis, a student *t* test was performed. Differences were considered to be statistically significant between groups when *P* was less than 0.05. In this study, we were most interested in the peak load because it represented the maximum force that each method was able to sustain before failure.

RESULTS

As seen in Table 1, no statistical differences were detected between the open-book technique and Pulvertaft method regarding elongation at peak ($P = 0.52$), load at yield ($P = 0.9$), and peak load ($P = 0.69$). Statistical significance was noted when comparing the average thickness of the Pulvertaft weave of 7.6 mm to the open-book transfer of 5.7 mm ($P < 0.001$), and when the Pulvertaft group underwent additional elongation at yield (9.7 mm versus 3.7 mm, $P = 0.04$). These results suggest that use of the open-book technique would provide greater strength while maintaining a smaller anatomical footprint. It should be noted that the mode of failure for all specimens was at the suture-tendon junction.

DISCUSSION

When managing peroneal tendon transfers, we found that the open-book method appears to be a feasible alternative to the classically used Pulvertaft method. The open-book technique was biomechanically equivalent to the Pulvertaft method in peak load, load at yield, and elongation at peak. Because these results suggest biomechanical equivalence, we feel that the open-book technique is a suitable alternative.

The main difference between the two options is the bulk of the transfer. The bulky nature of the Pulvertaft transfer can lead to complications with tendon gliding. This can result in discomfort that could be avoided with a more anatomical transfer technique. In contrast, animal studies on the open-book technique[4-6] have shown that the length of transfer does not change the strength or stiffness of the transfer. However, the Pulvertaft method gains significant strength after a fourth weave, requiring more tendon length that contributes to increased bulk.[7-9]

In our analysis, the open-book technique was found to have a significant decrease in thickness compared to that of the Pulvertaft method. This decreased bulk provides a more anatomical transfer that may prove advantageous when dealing with an anatomic location known for having fewer soft-tissue envelopes. Notably, research on the open-book technique has focused only on the flexor and extensor tendons of the hand. Thus, to our knowledge, the current study is the first to assess the equivalence and volumetric aspects between the Pulvertaft method and open-book technique for managing peroneal tendon transfer.

Despite the promising results, the current study has limitations. The first limitation is the number of transfers performed. Our analysis consisted of only five pairs of tendons, which is likely too underpowered to determine significance; subsequently, the results should be considered with caution owing to the low sample size. The second limitation is that we did not evaluate the healing and ultimate consolidation of the transferred tendon. It could be hypothesized that the healing process would alter the biomechanical integrity of the transfer.

Overall, the findings of the current study showed equivocal biomechanical strength between the Pulvertaft method and open-book technique when used for managing peroneal tendons. Additionally, we found a reduced bulkiness associated with the open-book technique. A future line of study could use an animal model to compare the two transfer techniques in regard to healing and ultimate integration of the transfers.

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