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ORIGINAL RESEARCH

# Allograft Reconstruction of Irreparable Peroneal Tendon Tears: A Preliminary Report

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## ABSTRACT

**Background:** Peroneal tendon injuries represent a significant but underappreciated source of lateral ankle pain. Partial thickness tears of the peroneus brevis amenable to direct repair techniques are common. Irreparable tears are uncommon and require more complex surgical decision-making. Intercalary segment allograft reconstruction has been previously described as a treatment option; however, there are no reports of the outcomes of this technique in the literature. We present our results utilizing this technique.

**Materials and methods:** A retrospective chart review was conducted to identify all patients who underwent intercalary allograft reconstruction of the peroneus brevis. Mechanism of injury, concomitant operative procedures, pertinent radiographic findings, pre- and postoperative physical examination, intercalary graft length, medical history, visual analog scores (VAS) for pain, short form-12 (SF-12) physical health survey, lower extremity functional scores (LEFS), and complications were reviewed.

**Results:** Eight patients with eight peroneus brevis tendon ruptures requiring reconstruction were indentified. Mean follow-up was 15 months (range, 10-31). The average length of the intercalary segment reconstructed was 12 cm ± 3.9 (range, 8-20). The average postoperative VAS decreased to 1.0 ± 1.6 from 4.0 ± 2.2 ($p = 0.01$). No patient had a higher postoperative pain score than preoperative pain score. Average postoperative eversion strength improved from 3.5 ± 1.2 to 4.81 ± 0.37 ($p = 0.03$). The average SF-12 survey improved from 41.1 ± 12.3 to 50.2 ± 9.31 ($p = 0.06$). The average LEFS improved from 53.3 ± 17.0 to 95.25 ± 10.0 ($p = 0.02$). Four patients experienced sensory numbness in the sural nerve distribution, and two of these were transient. There were no postoperative wound healing complications, infections, tendon reruptures or reoperations. No allograft associated complications were encountered. All patients returned to their preoperative activity levels.

**Conclusion:** Allograft reconstruction of the peroneus brevis can improve strength, decrease pain, and yield satisfactory patient-reported outcomes. Importantly, this can be successfully performed without incurring the deleterious effects associated with tendon transfer procedures. Our results suggest that allograft reconstruction may be a safe and reasonable alternative in the treatment of irreparable peroneal tendon ruptures.

**Level of evidence:** Therapeutic level IV.


**Keywords:** Peroneal tendon, Tendon rupture, Allograft, Tendon reconstruction.

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## INTRODUCTION

Peroneal tendonopathy is a source of lateral ankle pain and dysfunction that is often overlooked and underappreciated.[1,2] The symptoms of peroneal tendon disorders are also often vague and misdiagnosed on initial presentation.[2-4] Peroneal tendon dysfunction can be attributed to tendonitis, chronic tenosynovitis, subluxation, fraying, longitudinal fissuring, partial tears and complete tears.[5-9] These abnormalities can be observed with concomitant chronic ankle instability, cavovarus foot deformities, low-lying peroneus brevis muscle bellies, superior peroneal retinacular insufficiency, fibular bone spurs, and following severe ankle sprains.[6,10-12]

Several classification systems have been described to characterize peroneal tendon tears in order to improve the decision-making in operative management.[4,13] Acute partial thickness tears can often be tubularized or repaired primarily. However, chronic tendon injuries often require other treatment options including autologous tendon transfers, tendon lengthening, allograft reconstructions or synthetic graft reconstruction.[14-19] Redfern and Myerson[20] have proposed an algorithm for systematically addressing peroneal tendon tears based on the intraoperative findings. If one tendon is torn and irreparable, tenodesis of the two peroneal muscles is recommended. Others have recommended tendon transfer, which has also been reported with satisfactory results.[21] While both of these offer a relatively simple and perhaps less technically demanding options, the results of autologous tendon transfers are often hampered by donor site morbidity and theoretically alter normal gait mechanics.

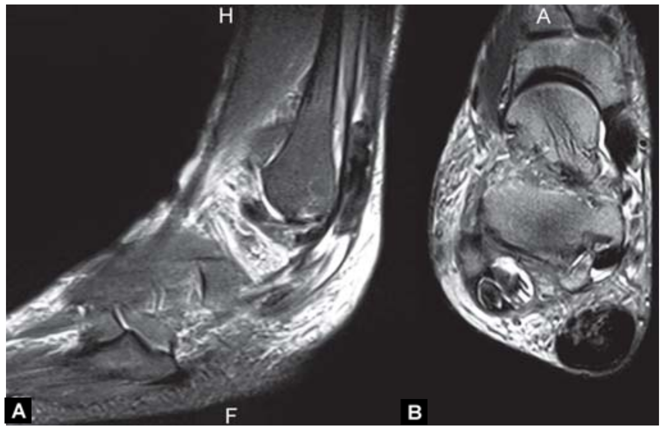
The use of an allograft tendon for reconstruction of an intercalary segment defect is a novel technique with several advantages. Allograft reconstructions include shorter operative times and a greater availability of graft sizes.[22] Additionally, by restoring the muscle-tendon unit, preinjury gait mechanics can potentially be restored without sacrificing the function of donor or local tendons. Numerous authors have reported satisfactory results of peroneal tendon reconstructions with autograft transfer.[21,23,24] More recently, the use of acellular dermal matrix has been reported.[25] We have previously published our surgical techniques for allograft reconstruction.[26,27] To our knowledge there are no reports of the clinical results of single stage allograft reconstructions of peroneal tendons. The purpose of our study was to review the clinical outcomes associated with this technique at our institution. We hypothesized that the use of tendon allografts in the treatment of peroneal tendon ruptures is safe, effective, and yields favorable patient reported outcomes.

## MATERIALS AND METHODS

After institutional review board approval, a retrospective review of the senior author's (JAN) practice database at Duke University Medical Center was performed. A perioperative current procedural terminology (CPT) code database identified patients with irreparable peroneal tendon ruptures that had been reconstructed utilizing tendon allografts between July 2007 and April 2011. Patients' charts were reviewed and assessed for details of their mechanism of injury, concomitant operative procedures, any pertinent radiographic findings, pre- and postoperative physical examination, intercalary graft length, medical history, visual analog scores (VAS) for pain, short form-12 (SF-12) physical health survey, lower extremity functional scores (LEFS) and complications.

## STUDY POPULATION

Eight patients were identified to have undergone intercalary segment peroneal tendon allograft reconstructions. Approximately 40% (3 of 8 patients) reported an acute inversion injury where they experienced an audible 'pop' about the ankle immediately preceding presentation, the remaining 60% (5 of 8 patients) were presumed to have chronic tears. Their mean age was 54 (range, 22-70) years at the time of surgery. Mean follow-up was 15 months (range, 10-31 months). Four patients were male and four were female. Five of eight surgeries were performed on the left side and three on the right. All eight cases involved tears of greater than 50% of the cross-sectional area of the peroneus brevis tendon. Concomitant procedures included Brostrom-Gould lateral ligament reconstruction (one patient), peroneus longus tenosynovectomy (three patients), excision of peroneus longus (one patient), peroneus longus repair (two patients), Dwyer calcaneal osteotomy (one patient), peroneus longus to brevis transfer (one patient), dorsal closing wedge osteotomy of 1st metatarsal (one patient), and fibular groove deepening (one patient). All patients underwent preoperative magnetic resonance imaging (MRI), which revealed a tear of one or both of the peroneal tendons (Figs 1A and B). Average preoperative ankle eversion strength as categorized by the medical research council (MRC) grading scale was 4 ± 1.2. There was one patient with anterior drawer translation greater than 5 mm with the ankle in a position of neutral dorsiflexion. Four patients (50%) were noted to have varus malalignment of their hindfeet. There were no patients with neuropathic abnormalities. There was one patient with noninsulin-dependent diabetes mellitus; otherwise, medical comorbidities were noncontributory. Average preoperative SF-12 physical health and LEFS were 41.10 ± 12.3 and 53.3 ± 17.0, respectively. The average preoperative VAS for pain was 3.5 ± 1.2 (range, 1-7).




**Figs 1A and B:** (A) Preoperative T2-weighted MRI sagittal section at the level of the fibula depicting a complete rupture of the peroneus brevis and longus tendons, (B) T2-weighted MRI axial section of the same patient's tendon tears shown at the level of the ankle joint

## OPERATIVE TECHNIQUE

All operative procedures were performed by the senior author (JAN) and an orthopaedic resident or fellow. Patients were positioned in the lateral decubitus position. Preoperative antibiotics were administered. A thigh tourniquet was used to improve visualization. A longitudinal incision was fashioned over the posterolateral fibula. The incision was extended distally to the base of the fifth metatarsal (Fig. 2). The lesser saphenous vein and sural nerve were identified and protected when encountered while dividing subcutaneous tissue. The peroneal tendon sheath was then identified and opened proximally to distally. The contents were examined for evidence of crowding within the fibular groove, presence of an accessory peroneal muscle, presence and extent of tenosynovitis, as well as the status of the superior peroneal retinaculum (Fig. 3). The proximal peroneus brevis muscle was then identified and freed from surrounding tissue. The distal end was debrided until healthy appearing tissue was encountered. The distal tendon stump was then identified at the base of the fifth metatarsal (Fig. 4). The defect length of the tendon was measured and an appropriately sized frozen peroneal tendon allograft was thawed (Fig. 5). In 75% (6 of 8) of our cases, there was enough distal tendon stump of the peroneus brevis remaining to secure the tendon allograft to native tendon. Two cases involved an avulsion of the distal tendon from the fifth metatarsal in addition to a tendon defect requiring the use

**Fig. 2:** The incision utilized extends from an approximated point predetermined based on the preoperative MRI to the base of the fifth metatarsal

**Fig. 3:** A peroneus brevis tendon rupture is shown with an intact peroneus longus tendon and superior peroneal retinaculum

**Fig. 4:** The distal peroneus brevis tendon stump is identified at its insertion on the base of the fifth metatarsal

**Fig. 5:** The length of the intercalary segment necessitating allograft interposition is approximated

**Fig. 6:** The peroneal tendon allograft fixed to the native distal tendon stump via a Pulvertaft weave is shown

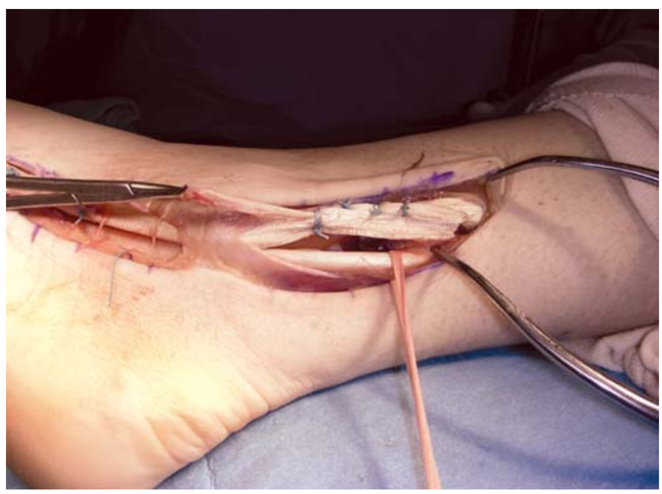


**Fig. 7:** Proximal fixation of the allograft to the native tendon is shown

of suture anchors to secure the allograft distally. If the tendon was avulsed, a bleeding bone bed was prepared at its anatomic footprint. The allograft was then fixed to bone distally at the base of the fifth metatarsal with a 3.5 mm suture anchor. If there was an adequate tendon stump remaining attached to the fifth metatarsal, the allograft tendon was secured to it using a Pulvertaft weave and braided nonabsorbable suture (Fig. 6). Prior to fixation proximally, appropriate muscle-tendon unit tension of the reconstruction was approximated. This was done by placing the foot in neutral inversion and eversion, as well as neutral ankle dorsiflexion. The proximal muscle stump was then pulled distally and the length of 50% of its excursion was noted. The allograft length was set from the remaining gap length when the proximal muscle and tendon were held in this position of 50% excursion. A Pulvertaft weave was also performed proximally and secured to the native muscle-tendon unit using braided nonabsorbable suture. The allograft was weaved through the native muscle/tendon three times (Figs 7 and 8). The peroneal tendon sheath was closed with absorbable sutures. The wound was closed in layers over a Hemovac drain. A sterile dressing and bulky splint was applied. Sutures were removed at 14 days and a non-weightbearing short-leg cast was applied. At 4 weeks, weight bearing was progressed as tolerated in a controlled ankle motion boot and patients were allowed to remove the boot to dorsiflex and plantarflex the ankle. Inversion and eversion were permitted after 6 weeks, and the ankle was then protected in an Aircast stirrup (DJO; Vista, CA) for ambulation. At 12 weeks, a physical therapy strengthening program was prescribed and unprotected shoe wear was permitted.

## STATISTICAL ANALYSIS

A two-tailed Student t-test was used for comparison of pre- and postoperative VAS pain scores, strength and subjective patient reported outcomes. The criterion for significance was set at $p < 0.05$. Continuous variable averages were expressed as mean ± standard deviation when applicable.

## RESULTS

In all eight cases, the peroneus brevis was deemed to require reconstruction by the senior surgeon. The average length of the intercalary segment reconstructed was 12 cm ± 3.9 (range, 8-20). There were no differences in outcomes based on tendon graft length. Six of eight patients (75%) had a partial tear or gross tendinosis of their peroneus longus tendon; one patient had a complete rupture of both peroneal tendons. The average postoperative VAS for pain improved from 4.0 ± 2.2 to 1.0 ± 1.6 ($p = 0.01$). No patient had a higher postoperative pain score than preoperative pain score. All patients improved strength postoperatively compared to their initial preoperative evaluation. Average postoperative eversion strength was 4.81 ± 0.37 ($p = 0.03$). Six of eight patients (75%) achieved full 5/5 eversion strength. The average postoperative SF-12 physical health survey improved to 50.2 ± 9.31, which approached significance ($p = 0.06$). The average lower extremity functional score significantly improved to 95.25 ± 10.0 ($p = 0.02$). There were no patients with postoperative lateral ankle instability as assessed by drawer and talar tilt testing. Four patients experienced sensory numbness in the sural nerve distribution, and two of these were transient in nature. There were no neuropathic pain complications or cases of complex regional pain syndrome. Six of eight patients (75%) had postoperative high resolution sonographic analyses of their reconstructed tendons, which all demonstrated that the allograft tendon was intact and gliding appropriately. There were no postoperative wound healing complications, infections, tendon reruptures or reoperations. All patients returned to their preoperative activity levels. Of note, one patient returned to professional dancing, one patient returned to running 5 km races, and one patient returned to cycling distances of greater than 25 miles.

**Fig. 8:** The final reconstruction prior to layered closure is shown

## DISCUSSION

The literature contains numerous reports regarding the surgical treatment of partial and complete tendon ruptures of the foot and ankle. The most common tendons addressed are the Achilles, posterior and anterior tibialis, and the peroneal tendons. When irreparable tears are appreciated, options for restoring the function of the damaged tendons include tenodesis, tendon transfer of a local tendon, and tendon reconstruction. Irreparable tears of the peroneal tendons are relatively rare and, as a consequence, there is a dearth of high level evidence to guide the management of these more complex injuries.

For tears of the peroneus brevis, Krause and Brodsky[4] were the first to propose surgical treatment criteria based on the severity of the tendon tear and remaining healthy tendon. They suggested that tears that involved less than 50% of the cross-sectional area of the tendon should be treated with excision of the involved segment and tubularization of the remaining tendon. For tears involving greater than 50% of the area of the tendon, tenodesis to the peroneus longus was recommended. They presented a series of 20 patients with peroneal brevis tears, nine of which were treated with peroneus brevis excision and tenodesis to the peroneus longus. Eleven were treated with tubularization.[4] They did not find a significant difference in outcome between groups. While all of the patients in the tenodesis group were satisfied with their results, only four of the nine had resumed unlimited activities and two-thirds had pain with activity.[4] This is not unusual for patients undergoing surgical repair of peroneal tendon injuries. Steel and DeOrio[28] reported that more than 50% of their patients undergoing surgical treatment of peroneal tendon tears had residual symptoms resulting in 90% of patients returning to work, but only 46% were able to return to sports participation.

Other authors have reported on the results of tenodesis procedures of the peroneal tendons as well. Both Sobel et al[29] and Thompson et al[30] reported outcomes of tenodesis of peroneus longus to brevis in the setting of painful os peroneum syndrome. In the six patients who underwent excision of the os and tenodesis of the peroneus longus to the brevis, four had excellent results and two had good results with one case of residual peroneus brevis tendonitis. Thompson et al reported on three patients who had the same procedure.[30] While none of the patients developed a dorsal bunion, a theoretical risk of tenodesing the peroneus longus to the brevis, two patients did develop a stress fracture of the second metatarsal. These data suggest tenodesis of the peroneus longus and brevis may have deleterious affects on the normal biomechanics of the foot and ankle.

The classification system proposed by Krause and Brodsky[4] is helpful in guiding the treatment of isolated peroneus brevis tears, but complete tears of both peroneal tendons are not addressed. Redfern and Myerson[20] have presented the largest, yet most heterogeneous, series of patients requiring surgical treatment of concomitant peroneal tendon tears. Based on their findings, they developed a treatment algorithm based on intraoperative findings. For type I tears in which both the peroneus longus and brevis are grossly intact, tubularization is recommended following the excision of any split or fraying of the tendon. For type II injuries, characterized by the tear of one tendon associated with one tendon remaining with adequate excursion, tenodesis proximally is recommended. Finally, for type III injuries in which both tendons were torn, several options were proposed. If no proximal muscle excursion was appreciated (Type IIIa), FDL transfer was recommended. If proximal muscle excursion was present (Type IIIb) and the area of injury was without significant fibrosis, one-stage tendon reconstruction was performed with hamstring allograft. If tissue bed scarring was present, a two-stage reconstruction utilizing a silicone rod placement followed by reconstruction with hamstring allograft was performed. Sixteen of their 28 patients (57%) underwent direct repairs. Five (18%) underwent tenodesis procedures. Three (11%) underwent FDL transfer. Three (11%) underwent staged reconstructions. One (4%) underwent single stage allograft reconstruction. The majority of their patients achieved good or excellent results as quantified by their postoperative American Orthopaedics Foot and Ankle Society (AOFAS) scores. However, only 31% of their patients achieved normal peroneal strength postoperatively. There was an unusually high rate, nine of 29 feet (31%), of postoperative complications in their series. These included superficial wound infections, wound dehiscence, sural neuritis, complex regional pain syndrome, adhesive tendonitis, and one repair failure. Additionally, half of their patients had continued problems with pain.

Under the classification system listed above, all eight of our patients demonstrated type IIIb peroneal tendon tears of the peroneus brevis. Tissue bed scarring did not prompt a staged reconstruction for any our patients. Redfern and Myerson also agreed with previous authors who had noted that proximal muscle excursion was of utmost importance in determining the surgical approach.[20] However, they also noted that despite mobile and viable appearing proximal muscle and the use of a minimally invasive technique, they encountered substantially more scarring during their second procedures than anticipated. They have therefore extended their indications for single-stage transfers. This is a potential explanation for our more favorable outcomes. Perhaps our threshold for intercalary allograft reconstruction was lower than theirs. It is possible that patients who are reconstructed as opposed to repaired with tendons that are disrupted at or near the threshold for reconstruction do better postoperatively. Unfortunately, a control group for direct comparison of these marginal situations is not available and certainly a limitation to our study.

Tendon transfer procedures have also been reported with satisfactory results.[20,21,24,31] Although functional outcomes have been acceptable, there are clearly some disadvantages to the described techniques. Tendon transfers can necessitate additional incisions, which can lead to increased surgical time, diminished range of motion, development of stress fractures, and an alteration in the normal kinematics of the foot and ankle.[14,18,29,30] Transfers can be performed in the setting of acute or chronic peroneal tendon tears with the use of the flexor hallucis longus (FHL), flexor digitorum longus (FDL), or plantaris tendons. Wapner et al[24] reported their long-term results of the use of a staged protocol where the diseased or ruptured peroneal tendon was excised and replaced with a silicone rod. After 3 months they transferred the FHL into the newly formed tendon sheath. All patients had undergone previous operative procedures prior to presentation, and they felt as though their native peroneal muscle units were atrophied beyond salvage for primary reconstruction. Approximately 60% (4/7) regained full 5/5 peroneal muscle strength and 70% (5/7) achieved excellent outcomes. All patients returned to work for the exception of the workers' compensation patient and almost 90% (6/7) stated that they would undergo the surgery again. In their series they did not address concomitant ruptures of the peroneus longus tendons because the distal portion was too enmeshed in scar. They felt that the morbidity of further dissection into the plantar foot outweighed any potential benefit. Furthermore, they did not report any negative consequences from the loss of the dynamic peroneus longus function and felt that the results of their staged reconstruction were more favorable than the alternative procedures, including full time bracing or hindfoot arthrodesis. Although the authors do report excellent outcomes, it should be noted that no objective biomechanical comparison of patients with and without peroneus longus function, as well as those in whom the change of the function of the FHL to a primary everter was performed.

The use of musculoskeletal allografts have increased substantially in all orthopaedic surgical subspecialties.[32,33] Allografts offer the advantages of shorter operative times, lack of graft site morbidity or donor site complications, and an unlimited supply. Their main drawbacks include risk of disease transmission, cost, risk of inferior mechanical properties due to processing techniques, and potentially longer incorporation times.[32,34,35] The risk of bacterial infection following allograft implantation is far grater than that of viral infection. Since 1995, approximately 30 cases of bacterial infections arising from contaminated allograft tissue have been reported.[32,35,36-38] The estimated risk of transmission of human immunodeficiency virus (HIV) has been estimated to be approximately 1 in 1.6 million from allograft soft tissue and bone.[39] Although ideally any transplanted tissue would be sterilized prior to implantation, human tissue can not be completely sterilized without altering its biomechanical properties. Sterilization of allograft tissues is therefore not required by the Food and Drug Administration (FDA). Nonetheless, the procurement and processing techniques of allograft tissue are closely monitored to decrease the likelihood of contamination or disease transmission. The proprietary processing techniques by which commercially available allografts are disinfected vary greatly by tissue bank. Therefore, it is critical that the surgeon is aware of the processes utilized to process grafts at their institution to inform their patients of the risks and benefits. The Biocleanse formula (Regeneration Technologies Incorporated; Alachua, FL) was used to disinfect all the allograft tendons used in patients in this study. The manufacturer claims that treatment with this formula does not alter the biomechanical properties of their grafts and report no instances of disease transmission in over 1 million implants since 2004.[40] Although, these claims have not been substantiated in the literature, anecdotally we can confirm that we have not observed any adverse events related to allograft tissue treated with this formula at our institution.

The use of an acellular dermal matrix (GraftJacket, Wright Medical Technology, Arlington, TN) to augment the repair of tears affecting greater than 50% of the peroneal tendons has also recently been reported.[25] Peroneal strength was returned to normal in 6 of 11 patients (55%), and all achieved 'good' or 'excellent' scores on the AOFAS ankle-hindfoot measure, although the study population was quite small.

This study is limited by its small sample size, retrospective nature, and lack of a control group. It would be also be valuable to compare the objective kinematics of tendon transfer *vs* tendon reconstruction with an intercalary segment allograft and whether or not these changes affect long-term outcome, which we would expect would further support intercalary reconstruction over autologous transfer.

To our knowledge, this study represents the first clinical series reporting the clinical outcomes of single-stage intercalary segment allograft reconstruction for the treatment of irreparable peroneal tendon tears. This study also demonstrates that the use of allograft can restore peroneal tendon strength, decrease pain, and yield satisfactory patient reported outcomes. It should also be noted that this can be done without donor site morbidity and sacrificing healthy local tendons which can potentially alter foot function and biomechanics. Finally, with no serious complications, it demonstrates that the use of allograft is a safe and reasonable alternative in the treatment of peroneal tendon ruptures that warrants further investigation.

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