Peroneal Tendon Tears: Evaluation and Treatment

James W. Brodsky and Daniel D. Bohl

1 Introduction

Patients with peroneal tendon tears present with lateral ankle pain, which has a broad differential diagnosis that includes ankle sprain, chronic lateral ligament laxity, fractures of the anterior calcaneal process and lateral talar process, subfibular impingement, ankle, subtalar and calcaneocuboid joint osteochondral lesions, peroneal tendonitis, and peroneal anatomic anomalies, subluxation or dislocation. Notably, because many of these pathologies are the result of inversion injuries, which can affect the ankle or the hindfoot, or both, they are often multiple, concurrent, and/or difficult to distinguish. Preceding trauma may range from multiple incidents of remote mild injury, to cases of progressive and insidious onset, or to an acute episode of severe injury. Overall, peroneal tendon tears are thought to account for about a third of patients with lateral ankle pain [1]. The variable history and wide range of potential pathologies often lead to a delay in diagnosis.

Conservative treatment for peroneal tendon tears may include immobilization with a cast or walking boot, bracing, physical therapy, nonsteroidal anti-inflammatory medications, and activity modification, and is variably successful, depending on the patient's goals and activities, the chronicity and severity of pain and dysfunction, and the stage in the natural history at which the patient presents to the surgeon. Many, if not most, cases ultimately require surgical reconstruction. As the understanding of the pathophysiology, imaging, and operative outcomes has advanced, so too have the specific indications and surgical techniques.

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2 Anatomy, Etiology, and Pathophysiology

Most patients with peroneal tendon tears present for evaluation of chronic lateral ankle symptoms, with only a minority presenting with an acute injury [2]. As many as half of patients may recall an initial event marking the onset of their ankle pain; however, that event is usually remote with subsequent resolution followed by gradually progressive chronic symptoms [2, 3].

There are two main theories regarding the pathophysiology of peroneal tendon tears. The first, most important, and best documented is that mechanical stress is the primary cause of peroneal tendon tears. This is strongly supported by the typical patterns of tear location, which have few exceptions, and by the characteristic difference in those patterns between the peroneus brevis and the peroneus longus tendons. A mechanical etiology is supported by the fact that tears occur at the bony prominences that serve as fulcrums, or pulleys for the tendons as they change direction [2–5]. These act as pulleys to convert tendon motion in one plane to a vector in a different plane. For the peroneus brevis, that fulcrum is the posterolateral bony edge at the tip of the fibula. For the peroneus longus, it is most commonly the cuboid groove, and less often, the peroneal tubercle of the calcaneus. The second theory is that tears occur at regions of hypovascularity [6, 7], postulating that an attenuated blood supply deprives the tendons of oxygenation and nutrition, predisposing to injury and diminished healing potential. Of note, these regions are similar to the above-noted areas of mechanical stress. The pathophysiologic and pathoanatomic patterns of tears of each of the two peroneal tendons will be discussed in turn, beginning with the tendon that is most commonly injured.

2.1 Peroneus Brevis

The most common pattern by far is longitudinal split tearing of the peroneus brevis centered at the inferior-lateral tip of the fibula, comprising 73% of all tears (Fig. 1) [8]. When the tendon subluxes or dislocates over the posterolateral edge of the retromalleolar groove, the fibular fulcrum becomes the source of friction, gradually fraying and then splitting the tendon with repetitive motion of each step [3, 9]. The peroneus longus, which is posterior to the brevis at the malleolus, compresses it against the bone, contributing to the subluxation and compounding the mechanism of damage [3].

At least two studies support the vascular theory of injury to the peroneus brevis tendon, finding a “watershed” area at the retromalleolar groove [6, 7], while two other studies refuted this concept, finding that the tendon is well vascularized throughout [10, 11].

When considering the pathophysiology of peroneus brevis tears, the superior peroneal retinaculum deserves specific mention [2, 12]. Inversion injury of the ankle can lead to attenuation of the tissue of the superior peroneal retinaculum, allowing

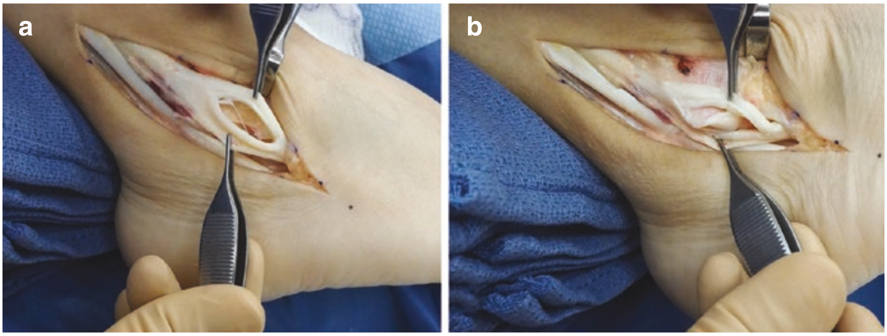


Fig. 1 Intraoperative photos of a longitudinal split tear of the peroneus brevis. (**a**) The typical appearance of a longitudinal split tear of the peroneus brevis is a flattened tendon with a longitudinal window of several centimeters within its mid-substance. (**b**) The typical location of a longitudinal split tear of the peroneus brevis is at the tip of the fibula, within and just distal to the retromalleolar groove. Intra-sheath subluxation of part of the tendon likely contributes to tearing of the tendon as the tip of the fibula pieces through. (Used with permission from James W. Brodsky, M.D. Baylor University Medical Center, Dallas, USA)

Fig. 2 Intraoperative photo of an insertional tear of the peroneus brevis. In this location, tears tend to be more degenerative than mechanical in nature. Insertional tears are generally multiple, incomplete, and longitudinal in nature. (Copyright 2020, James W. Brodsky, M.D. Baylor University Medical Center, Dallas, USA)

brevis subluxation. Moreover, the origin of the retinaculum on the lateral surface of the fibula can become widely elevated [12, 13], allowing intra-sheath or frank subluxation/dislocation of the peroneus brevis, which in turn may further attenuate the retinaculum. A similar pattern may result from chronic retromalleolar overstuffing due to tendinopathic enlargement, accessory peroneal musculature (i.e., peroneus quartus), or a low-lying muscle belly of the peroneus brevis [14–16].

A distinct form of tendon tear occurs at the insertion of the peroneus brevis into the base of the fifth metatarsal (Fig. 2), although little has been written on this subject [17]. In our experience, this can be seen on MRI, but most often presents as multiple, incomplete, longitudinal splits in the fibers of the tendon just proximal to the insertion. In this location, it appears to be more degenerative than mechanical, and is less consistently symptomatic.

2.2 Peroneus Longus

Isolated peroneus longus tears are the least common, representing 8% of all tears [8]. They occur most often at the cuboid tunnel, much less often at the peroneal tubercle, and in the region in between, where the peroneus longus is redirected from moving in line with the long axis of the leg to an acutely angled distal-medial trajectory across the plantar foot (Fig. 3) [3, 18]. While the mechanical theory is clearly supported by tears occurring along this prolonged fulcrum, the vascular theory has been less well supported for the peroneus longus [6, 7, 10, 11]. Above the peroneal tubercle, the peroneus longus and brevis share a tendon sheath; below the peroneal tubercle, they are divided into two separate sheaths. Enlargement or irregularity of the peroneal tubercle can cause increased wear on the peroneus longus at that level [4, 19, 20].

In about 4–30% of the general population, there is a sesamoid bone, the os peroneum, within the peroneus longus just proximal to the cuboid groove and serving to increase tendon power, just as other sesamoid bones do at the hallux, or the knee (the patella) [5]. The os peroneum can become fractured, osteophytic, or enlarged, causing the so-called painful os peroneum syndrome [21], but more importantly, those changes cannot occur without accompanying tearing and degeneration of the peroneus longus tendon in which it is embedded.

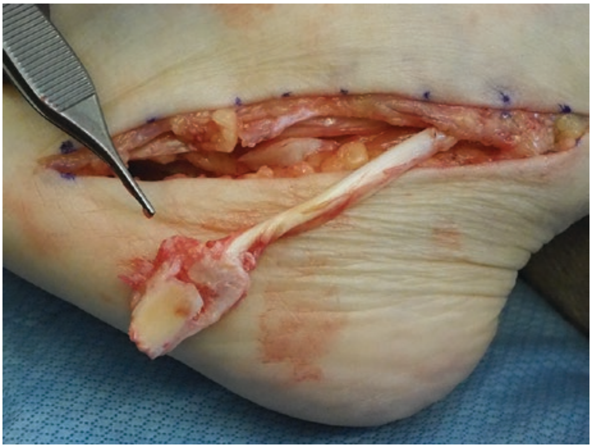


Fig. 3 Intraoperative photo of a peroneus longus tear just proximal to the os peroneum. The peroneus longus has been transected just distal to the os peroneum in preparation for peroneus longus to brevis transfer. (Copyright 2020, James W. Brodsky, M.D. Baylor University Medical Center, Dallas, USA)

3 Diagnosis

3.1 Physical Examination

The peroneus brevis inserts on the base of the fifth metatarsal, rendering it the primary abductor of the forefoot [22]. The peroneus longus inserts on the base of the first metatarsal, rendering it the primary plantarflexor of the first ray. Both tendons pass lateral to the axis of the subtalar joint and slightly posterior to the axis of the tibiotalar joint, rendering them primary evertors of the hindfoot. They are considered weak plantarflexors of the tibiotalar joint, although a recent study showed significant loss of ankle plantarflexion power and moment when neither is functioning [23]. In order to isolate their effects, the tendons are best examined with the tibiotalar joint in plantarflexion.

The most consistent examination findings are tenderness to palpation, swelling, and enlargement along the tendons. This is especially true for peroneus brevis tears. In one review, tenderness was present in 100% of patients with surgically confirmed tears of the peroneus brevis [2]. Swelling was present in 90%. Tenderness and swelling at and proximal to the lateral malleolus is more consistent with a peroneus brevis tear, whereas tenderness and swelling from the peroneal tubercle to the cuboid groove is more consistent with a peroneus longus tear [2, 18]. The examiner should also be able to distinguish distal tenderness and swelling at the peroneus brevis insertion from that at the peroneus longus in the cuboid groove due to the peroneus brevis's more dorsal location.

Pain with resisted eversion is another commonly noted physical exam finding; however, like tenderness to palpation and swelling, it may frequently also occur with tendinitis, and so cannot be used in isolation to confirm a tear. Pain may also be provoked with passive inversion of the hindfoot, which tensions both peroneal tendons over their bony fulcrums. The tendons should also be evaluated in the clinic for intra-sheath subluxation, although in the absence of frank dislocation, peroneal instability may be difficult to detect.

Finally, it is critical that the examiner conduct a thorough examination of the lower extremities, with a focus on identifying confounding or contributing diagnoses. The examiner should note hindfoot and forefoot position and range of motion, because cavovarus deformity predisposes to peroneal tendon tears [8] and may require treatment in some cases. While peroneal tendon tears can be seen in planovalgus deformities, especially when associated with lateral ligament instability, the diagnosis can be confounded by subtalar or subfibular impingement. Lateral ligament instability commonly co-occurs with peroneal tendon pathology and may need to be simultaneously addressed. Sural neuritis, Achilles pathology, and hindfoot arthritis can occasionally confound the picture as well.

3.2 Radiography

The imaging assessment starts with plain film radiography, including anterior-posterior, oblique, and lateral views of both the foot and the ankle. It provides information on alignment of the hindfoot and forefoot and helps to rule out potentially confounding conditions such as hindfoot arthritis. For example, when present, an os peroneum will be visible in its normal location. The os lies within the peroneus longus tendon at the level of the calcaneucobid joint and proximal cuboid groove. Migration of the os peroneum proximal to the calcaneocuboid joint indicates a peroneus longus tear distal to the os [5], as seen on the 45-degree internal rotation and lateral views of the foot (Fig. 4) [24]. Fracture of the os peroneum often represents a peroneus longus tear through the os. Hypertrophy of the os peroneum seen radiographically can support painful os peroneum syndrome in the absence of a definitive peroneus longus tear [21].

3.3 Magnetic Resonance Imaging (MRI)

MRI is the definitive imaging modality for peroneal tendon tears, but requires certain refinements and an experienced reader for best results. MRI was initially reported to have poor diagnostic ability with respect to peroneal pathology. However, improvements in MRI technology and better evidence regarding clinical-radiographic correlation has now positioned MRI as the leading imaging modality

Fig. 4 Plain film radiographs of a proximally migrated os peroneum (arrow). (**a**) Lateral view. (**b**) 45-degree internal rotation oblique view. (Used with permission from James W. Brodsky, M.D. Baylor University Medical Center, Dallas, USA)

for peroneal evaluation [2, 25–28]. Peroneal tendon tears are diagnosed both by changes in the shape of the tendon, including splits into distinct strands, and by increased signal (edema) within the tendon. The single most important and essential innovation is a para-axial oblique reconstruction because it is oriented at 90 degrees to the tendons at and just below the lateral malleolus (Fig. 5a–c). This gives the most accurate depiction of the morphology, and signal within the peroneal tendons, which is much more difficult on the routine exam along the axial and coronal planes of the ankle joint. T2 fat-suppressed images are essential to judge signal within the tendons.

A critical concept regarding MRI of the peroneal tendons surrounds the "magic angle effect." [28, 29] This is a phenomenon of MRI technology in which a tendon intersecting the magnetic vector at 55 degrees appears with factitiously heterogeneous signal on both T1 and T2 sequences. Unfortunately, this is approximately the natural position of the peroneal tendons at the tip of the lateral malleolus, the most common area of peroneus brevis injury. Acquisition of MRI images in the para-axial oblique plane perpendicular to the tendons at this location mitigates the magic angle artefact. Authors have also provided evidence for imaging in alternate positions [30] and with specific sequences [31] to mitigate this effect. We image in 20 degrees of plantarflexion which separates the two peroneal tendons within the sheath by reducing tension and mitigates the magic angle effect on the most critical portion of the peroneus brevis.

Tears of the peroneus brevis appear as c-shaped or split tendons; abnormal intratendinous signal can vary based on the age of the tear (Fig. 5a, b) [25]. The oblique views can aid evaluation for subluxation and dislocation out of the retromalleolar groove, injury to the fibrocartilaginous ridge, and attenuation and detachment of the retinaculum from the fibula (false pouch) [32].

Tears of the peroneus longus appear as a linear or round area of increased intratendinous signal between the peroneal tubercle and cuboid groove (Fig. 5c, d) [33, 34]. These are well visualized on the peroneal oblique views more proximally, as well as coronal images of the ankle more distally. Oblique coronal images of the ankle perpendicular to the metatarsals can be added for a true cross section of the peroneus longus as it courses along the lateral hindfoot. Complete disruption with a defect is more common in longus than brevis tears.

Despite the power of MRI, the importance of a careful history and physical examination cannot be overstated, as demonstrated in a study showing a high rate of peroneal tendon pathology on MRI in asymptomatic patients [35].

3.4 Ultrasound

Ultrasound can be a useful modality for diagnosis of peroneal tendon pathology [36]. A study of patients who underwent both ultrasonic evaluation and operative intervention found that ultrasound's sensitivity for detecting tears is 100%, specificity 85%, and overall accuracy 90% [37]. The disadvantage of ultrasound is that it is

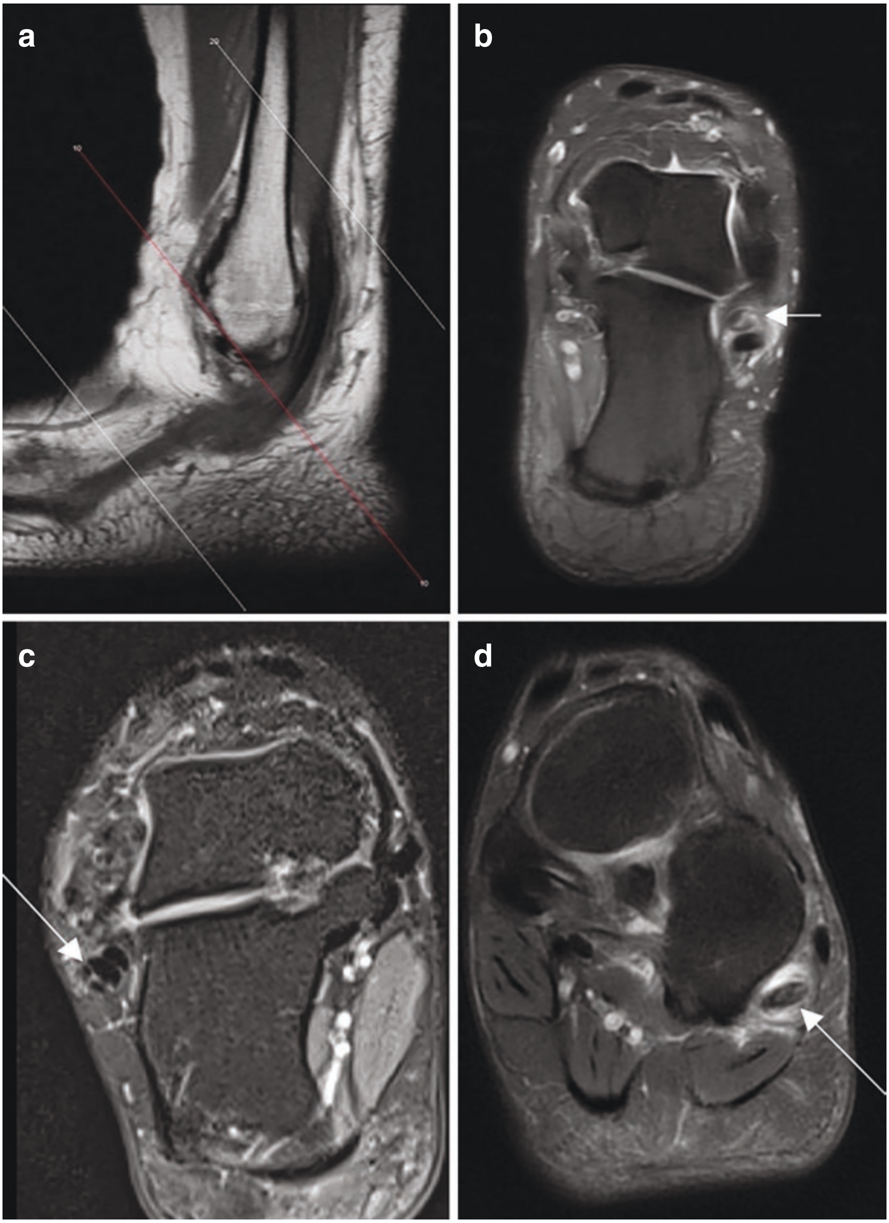


Fig. 5 Peroneal tendon tears on MRI. (**a**) Sagittal reconstruction showing orientation of para-axial reconstructions. (**b**) Para-axial reconstruction showing peroneus brevis tear at the level of the retromalleolar groove. (**c**) Peroneal oblique reconstruction showing peroneus longus split tear near the level of the peroneal tubercle. (**d**) Coronal reconstruction showing peroneus longus tear within the cuboid groove. (Used with permission from James W. Brodsky, M.D. Baylor University Medical Center, Dallas, USA)

much more highly dependent on experience and expertise than MRI. Trained ultrasonographers are much less readily available in the USA, although more common in other countries.

4 Treatment

4.1 Conservative Treatment

Conservative treatment for peroneal tendon tears consists of immobilization in cast or walking boot, physical therapy, nonsteroidal anti-inflammatory medications, activity modification, and bracing. If the symptoms are chronic and/or severe, or if the patient has failed conservative management, it is reasonable to proceed with advanced imaging and consideration of surgical reconstruction.

4.2 Tendonoscopy

Groups of authors have advocated tendoscopy for cases of patients with persistent symptoms but negative imaging, as well as more advanced cases. They describe experience including debridement, synovectomy, and even tendon and retinacular repair and reconstruction [13, 16, 38–40].

4.3 Classifications to Guide Surgical Treatment

Two major classification systems have pushed forward our understanding of treatment for peroneal tendon tears. The first was proposed by Krause and Brodsky in 1998 and concerned the most common pattern, tears of the peroneus brevis tendon [2]. These authors proposed that peroneus brevis tears be divided into grades 1 and 2, based on intraoperative observation. By this system, grade 1 tears have <50% total cross-sectional area injured and should be repaired by debridement and tubularization, as there is enough remaining healthy tendon to bear the functional load once repaired. In contrast, grade 2 tears have >50% total cross-sectional area injured and should be reconstructed with resection of the injured segment and tenodesis to the peroneus longus. The 50% threshold was analyzed in a cadaveric study [41]. Wagner et al. recently tested cyclic loading and load to failure in cadaver specimens with partial longitudinal resection of the peroneal tendons, up to 66%. There were no tendon failures after 100 cycles, and the study raised interesting questions, but no conclusions can be drawn for three reasons. The number of cycles were extremely few, and so cannot be interpreted as clinically relevant; it is not possible extrapolate the biomechanical function of an undiseased cadaver tendon to a pathologic one; and there are other issues which determine the outcomes of partially resected tendons more than mechanical strength, that is, that the primary mode of failure is scarring, adhesion, and degeneration of the residual repaired tendon. The authors' rationale for excision and tenodesis in severe cases has been further reinforced by their subsequent observation that the peroneus brevis, when repaired, commonly scars to the deep tissue and to the peroneus longus, causing pain and restricted motion.

The second classification was proposed by Redfern and Myerson in 2004 [42]. These authors expanded on the prior classification to include both peroneus longus tears and concomitant tears of both the peroneus brevis and peroneus longus. In their algorithm, for tendons that are grossly intact, the authors recommend debridement and tubularization (analogous to Krause and Brodsky grade 1, but without a specified threshold). When one tendon is severely torn, and its muscle belly has good excursion, the authors recommend tenodesis to the adjacent tendon. Finally, if one tendon is severely torn and its muscle belly lacks excursion, or if both tendons are severely torn, the authors recommend reconstruction with a tendon transfer or tendon graft.

4.4 Tendon Repair

In general, for tendons with small reconstructable tears, the recommended procedure consists of tenolysis, synovectomy, excision of the degenerated unhealthy appearing tendon, and tubularization of the remaining healthy appearing tendon. Techniques for tubularization vary, including recommendations for absorbable suture to minimize soft tissue irritation[2] and nonabsorbable suture to maximize strength and durability [42]. In one clinical study comparing suture types, there was no difference between absorbable and nonabsorbable suture in patient outcomes [43]. Once the tendon has been repaired, the superior peroneal retinaculum is reconstructed, as described below. Postoperatively, patients are splinted for 2 weeks, placed into a non-weight-bearing cast for 2 weeks, and then progressed to a controlled ankle motion boot for an additional 4–6 weeks. Physical therapy begins at 8 weeks postoperatively.

Reported outcomes have been generally positive following debridement and repair. Krause and Brodsky reported that 91% of 11 patients who underwent debridement and repair of the peroneus brevis were satisfied with their outcome [2]. Those authors also reported an AOFAS score of 85 postoperatively. Demetracopoulos et al. reported improvement in VAS pain scores and 94% return to full sporting activity among 34 patients undergoing debridement and repair (24 brevis only, 3 longus only, 7 both tendons) [44]. Among 71 patients undergoing debridement and repair of the peroneus brevis, Steginsky et al. reported that 76% of patients returned to pre-injury activities, but only 62% performed at preinjury levels [45]. Nevertheless, 85% of patients reported satisfaction and 91% indicated they would undergo the procedure again. Finally, Steel and DeOrio reported less promising results in a study of 29 patients undergoing debridement and repair that was focused on return to sport [43]. These authors reported that 46% of patients returned to at least some sport, whereas 42% returned only to activities of daily living (the remaining 12% did not play sports prior to injury). Moreover, 54% continued to experience swelling and 31% pain at rest.

4.5 Tenodesis

For tendon tears above or approaching 50% of the cross-sectional area, or for tears that are very long or complex, debridement and repair is unlikely to be successful [2]. Such repairs tend to result in scarring and adhesion to the deep surface, the peroneal sheath, and the adjacent tendon causing persistent pain which is usually unrelieved by conservative measures. Moreover, scarring of the previously debrided tendon and loss of excursion render it mechanically ineffective.

In most cases of a severe tear of one tendon, most often the peroneus brevis, but with a relatively well-preserved adjacent tendon, the best solution is tenodesis (or transfer) to the adjacent tendon above and below the zone of the tear, and excision of the damaged segment (Fig. 6). This has the advantages of simplicity, the use of autogenous tissue, the mechanical similarities of the two peroneals, and the preservation of the function of the corresponding muscle. In addition to a straightforward surgical technique, there is a low risk of complications.

For a severely torn peroneus brevis tendon, the operative technique of peroneus brevis to longus tenodesis proceeds as follows. First, the site of proximal tenodesis is identified. The site should be sufficiently proximal both to be well above the zone of the damaged and torn tendon, and also proximal to the superior peroneal retinaculum such that the bulk of the tenodesis does not pass through the retromalleolar groove or retinaculum. The appropriate level is corroborated by the change to

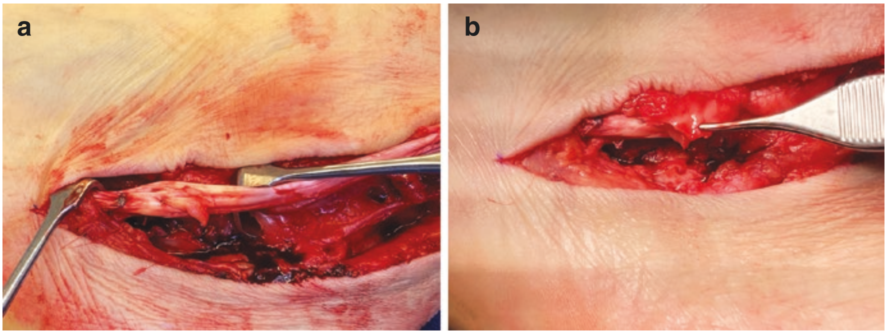


Fig. 6 Intraoperative photo of a peroneus brevis to longus tenodesis. (**a**) Prior to reconstruction of the superior peroneal retinaculum. (**b**) With the superior peroneal retinaculum in the forceps in preparation for retinacular reconstruction. (Copyright 2020, James W. Brodsky, M.D. Baylor University Medical Center, Dallas, USA)

normal color and texture of the tendon, compared to the zone of injury. At the site of the tenodesis, the adjacent tendon surfaces are debrided of synovium and roughened. It is important to tension the tendons appropriately. To do so, the surgeon should position the ankle in neutral and the hindfoot in eversion. The surgeon may gently pull the proximal end of the torn tendon distally to stretch the proximal musculotendinous unit. The tenodesis is done with nonabsorbable suture, usually 0 or 2–0 in size, in a pattern such as a complex running stitch, which has been shown to be strongest for early motion [46]. To minimize symptomatic prominence of the knots and to avoid strangling the tendons, mattress sutures are used so that the suture never loops around the tendons. Ideally, the knots are placed internally between the tendons, but never on the surface, because the knots can be painful, or erode the skin in this area that lacks a subcutaneous fat layer.

Second, a decision must be made whether to reconstruct the retinaculum before or after the distal portion of the reconstruction. When in doubt, the safest and most reliable result is obtained by performing it at this point with, of course, the tendon located behind the lateral malleolus. The reason is that the most accurate measure of final alignment and length (and therefore, the tension) of the reconstruction occurs when the tendon is located in its functional position behind the fibula. Third, the site of distal tenodesis or tendon transfer is identified. A tenodesis is performed just proximal to the peroneus brevis insertion, so that the force of the two muscles act through the native insertion on the fifth metatarsal base. If the distal peroneus brevis insertion is degenerative or otherwise unsuitable, the longus is transferred directly to base of the fifth metatarsal using suture anchors, a biointerference screw, suturing to itself through a drill hole, or a combination thereof. Fourth, the diseased portion of the peroneus brevis tendon is excised. Finally, if the superior peroneal retinaculum is not yet reconstructed, it is done, which is described in the next section.

For a severely torn peroneus longus tendon, the technique is almost the same as for the brevis, with the exception of the distal tenodesis or transfer. After the proximal tenodesis of the longus to the brevis above the superior peroneal retinaculum, the diseased portion of the peroneus longus is excised down to the level of the cuboid groove. Distal to the cuboid groove, the longus is inaccessible as it courses along the plantar aspect of the foot, and so the longus is simply tenotomized at the level of the cuboid groove. The peroneus brevis and longus muscle bellies both contract through the peroneus brevis tendon which runs through the retromalleolar groove and acts through its native insertion on the base of the fifth metatarsal.

Postoperatively, patients are splinted for 2 weeks, placed in a weight-bearing cast for 4 weeks, and then allowed to weight bear as tolerated in a boot for an additional 4–6 weeks. The patient is instructed to begin gentle home range of motion exercises when casting is discontinued, and physical therapy begins at 12 weeks.

Krause and Brodsky reported that 100% of nine patients who underwent tenodesis of the peroneus brevis to the peroneus longus were satisfied with their outcome [2]. Those authors also reported an AOFAS score of 86 postoperatively. Among 14 patients undergoing peroneus longus to peroneus brevis tenodesis, Burkhard et al.

reported postoperative AOFAS score of 86 and no difference in isokinetic eversion compared to the contralateral foot [47]. Finally, among 12 patients with peroneus longus tears associated with pathology of the os peroneum who underwent peroneus longus to peroneus brevis tenodesis, Stockton and Brodsky reported AOFAS score increased from 61 to 92, SF-36 score increased from 36 to 52, and VAS scores decreased from 6.3 to 1.0 [5].

4.6 Superior Peroneal Retinaculum Reconstruction

Reconstruction of the superior peroneal retinaculum is essential in all cases, to prevent development of recurrent subluxation or dislocation. The surgeon's task includes a judgment regarding the volume and tightness of the retinaculum, ensuring that the tendons are neither too tightly compressed nor is the retinaculum so loose that the tendon may subluxate around the fibula again. A pants-over-vest type suture is recommended because it is self-adjusting, depending on the tension applied. This allows control over the volume and tightness of the retinacular reconstruction. Placing the knot posteriorly makes it less likely to be symptomatic. The authors use 2–0 nonabsorbable suture. If the retinaculum was stripped from the lateral surface of the fibula (intra-sheath dislocation), it must be reattached to the bone at the same time. This can be done by roughening the fibular cortex, and passing the retinacular sutures through a series of small drill holes along the posterolateral fibular margin. The sequence of retinacular reconstruction is critical in many peroneal reconstructions, and is especially critical in allograft reconstructions for loss of both peroneal tendons (see below), because the main risk is loss of power through stretching of the allograft over time.

For any peroneal reconstruction, if the entire tendon construct is excessively short, it will not fit behind the lateral malleolus, or if it is made to do so by force, the ankle is pushed into plantarflexion. The retinacular repair will be under stress, and will be more likely to fail.

In some cases, the superior peroneal retinaculum is attenuated, and reconstruction of the inferior peroneal retinaculum is a valuable adjunct. It is wise to keep this in mind during the initial distal dissection, and to maximally preserve the flaps of the inferior peroneal retinaculum.

4.7 Reconstruction for Concomitant Tears of Peroneus Brevis and Longus

Patients in whom both tendons have severe and unreconstructable tears present the greatest surgical challenge to restoration of peroneal function (Figs. 7 and 8). The primary choices include autologous tendon transfer or allograft substitution, which are described below.

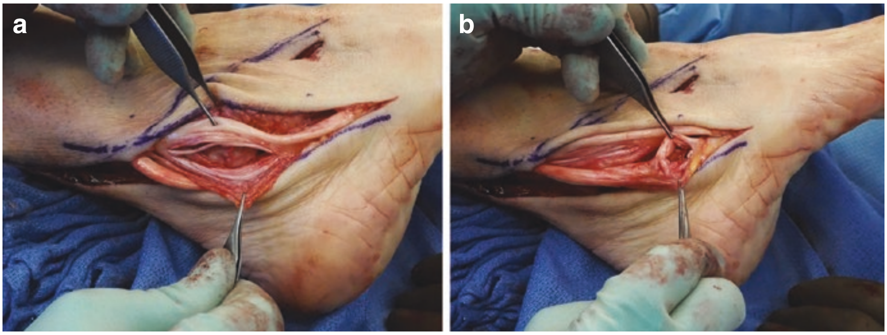
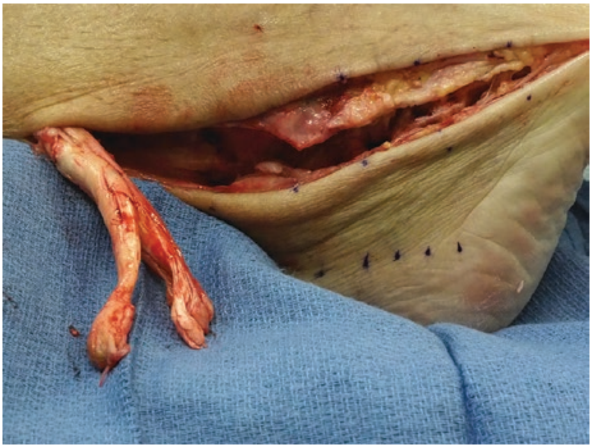


Fig. 7 Intraoperative photo of a patient with both peroneus brevis (**a**) and peroneus longs (**b**) tears. (Used with permission from James W. Brodsky, M.D. Baylor University Medical Center, Dallas, USA)

Fig. 8 Intraoperative photo of a patient with both peroneus brevis and peroneus longus complete ruptures resulting from prolonged and severe interstitial degeneration and nonviable tendon. (Copyright 2020, James W. Brodsky, M.D. Baylor University Medical Center, Dallas, USA)



4.8 Flexor Hallicus Longus (FHL) and Flexor Digitorum Longus (FDL) Transfers

For these techniques, the tendon is harvested at the knot of Henry, passed proximally and laterally around the tibia and fibula, and then attached to the lateral border of the foot, either through tenodesis to the insertion of the peroneus brevis or by direct transfer to the base of the fifth metatarsal, as described in the section on peroneus brevis reconstruction.

In a series of FDL or FHL transfers for eight patients with unreconstructable concomitant tears, Jockel and Brodsky reported that AOFAS score increased from 64 to 86, with seven of eight patients reporting good-to-excellent results and returning to preoperative activity levels [48]. In a study of nine patients with FHL (five patients) or FDL transfers (4 patients), Seybold et al. found that all patients were satisfied with their results at mean 35.7 months [49]. Two patients developed tibial neuritis, and patients had about 75% of eversion strength compared to their contralateral side. Sherman et al. studied 15 patients who underwent FDL transfer, finding that all were satisfied with the surgery and reported a reduction in VAS of 5.6 points [50]. Patients had on average 42% of eversion strength compared to the contralateral side. Wapner et al. proposed a staged FHL transfer to reduce the risk of tendon adhesions and scarring, wherein stage one consists of peroneal excision and placement of a Hunter rod into the residual peroneal sheath, and stage two, 3 months later, consists of removal of the Hunter rod and transfer of the FHL into the improved peroneal sheath. Among seven patients, six had complete relief of symptoms and returned to full pre-injury activity levels. They reported five excellent, one good, and one fair result. However, other authors have noted high levels of scarring even with this staged protocol. Without evidence of superiority, staged procedures are not currently performed.

There are several reasons to suspect that the FHL transfer may be superior to the FDL transfer for peroneal tendon reconstruction: (1) anatomic studies have demonstrated that FHL harvest results in a longer usable tendon length [51], (2) the muscle belly is larger [52], (3) the strength is greater with comparable excursion [53], and (4) there may be a lower risk of tibial nerve injury [49].

The major advantage of using FHL/FDL tendon transfer is the use of autologous tissue. The disadvantages are, first, that the muscles are weak functional substitutes for the peroneal muscles. Specifically, based on a study using MRI to estimate muscle strength [52], (1) the strength of the FHL was about half the combined strength of the two peroneals, (2) the strength of the FDL was about half the strength of either peroneal alone, and (3) muscles are further weakened beyond these numbers in a transfer because of changes in line of pull and tensioning. Analogous to FDL "transfer" for posterior tibial tendon dysfunction, tendon transfer for peroneal dysfunction might be best thought of, and utilized as, an intercalary autograft tendon bridge, rather than a true tendon transfer. In other words, the goal of reconstruction should be to restore best possible function of the native peroneal musculotendinous units, by reestablishing their insertion on the lateral border of the foot. Second, the FHL and the FDL transfers are anatomically limited options because the musculotendinous junctions are very distal. This is exacerbated in the course of using either one for a transfer because as the transferred flexor tendon is tightened, the musculotendinous junction is drawn even further distally. This is a problem when the peroneal tendon tears are severe, multiple, and especially, when the proximal extent of the tears is at or above the superior peroneal retinaculum.

4.9 Allograft Transfers

In cases of severe, irreparable tears of both the peroneus brevis and longus, allograft reconstruction is an important, and possibly the best option (Fig. 9). Allograft tendons can be used to span the intercalary defect after excision of one or both peroneal tendons. This concept was originally advocated for by Redfern and Myerson as

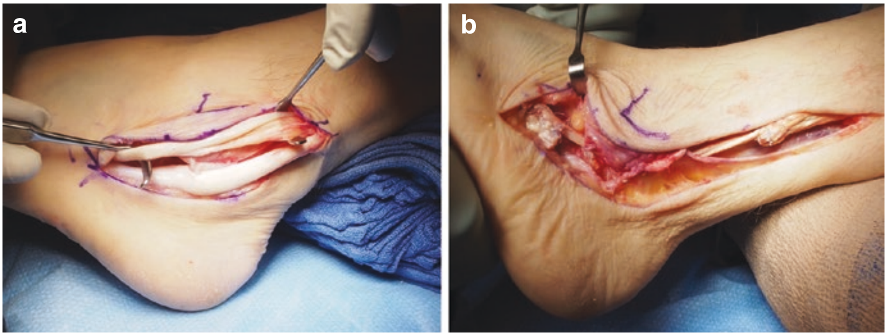


Fig. 9 Intraoperative photo of a patient with both peroneus brevis and peroneus longus tears treated with peroneal tendon allograft. (**a**) Tears of both the peroneus brevis and peroneus longus tendons prior to debridement. (**b**) In the final construct, the allograft serves as an intercalary segment between the native peroneal tendons proximally and the peroneus brevis insertion distally. The allograft reconstruction is seen deep to a reconstructed peroneal retinaculum. (Copyright 2020, James W. Brodsky, M.D. Baylor University Medical Center, Dallas, USA)

ideal in cases where the muscle belly or bellies have intact excursion [42]. The technique is indicated because these are the most severe of all peroneal tears, or any peroneal pathology. In many cases, the unreconstructable condition of the tendons is insufficiently described as concomitant "tears." Rather, many of these cases have had previous surgery, and some have not, but they are often scarred into an adherent mass which has no motion and may have entirely lost the morphology of actual tendons. The zone of tendon damage extends very proximally into the lateral compartment, often far above the superior peroneal retinaculum. Surprisingly, most of these cases still have viable proximal muscles.

The goal of reconstruction is to bridge the very large gap between the proximal peroneal musculotendinous units and the brevis insertion on the lateral border of the foot. Only a free tendon graft can bridge these defects, which can extend from the base of the fifth metatarsal to just distal to the peroneal muscles, anywhere from 18 to 25 cm, or more. While an autologous hamstring could be harvested, use of cadaver allograft has fewer surgical complications and lower morbidity. These cases are technically demanding and require long follow-up, but most patients obtain a functional result with pain relief, demonstrable tendon excursion, and excellent improvement in gait.

A clinical study by Mook et al. reported on allograft peroneal tendon reconstruction, but interpretation of its results is complicated by the heterogeneity of the procedures included in the study. Eleven of 14 procedures involved reconstruction of the peroneus brevis alone, two of the peroneus longus alone, and only one for both tendons [54]. Hence, this study is not representative of the allograft reconstruction of irreparable and concomitant tears of both tendons advocated for in the previous two paragraphs, and is better seen as a studied alternative to tenodesis in cases of severe single-tendon tears. In any case, at mean 17 months follow-up, there were improvements in VAS pain score and patient-reported outcomes of a similar magnitude as those seen for peroneal tenodesis [2, 5, 47].

4.10 Hindfoot Arthrodesis

In some cases of reconstruction for tears of both peroneal tendons, no form of tendon reconstruction alone is sufficient to restore function. For example, in patients with very chronic tears, in whom there is extensive fatty infiltration and scarring of the peroneal muscles, or in elderly patients with weak muscular function, the reconstruction is best done by or in combination with hindfoot arthrodesis. This can be triple arthrodesis, to hold the hindfoot and midfoot sufficiently everted to assure a plantigrade position for standing and walking. Another option is the use of subtalar arthrodesis in eversion, with concomitant peroneal reconstruction. The arthrodesis reduces the load on the tendon reconstruction, while preserving more hindfoot/midfoot motion.

4.11 Concomitant Procedures for Associated Pathologies

Taniguchi et al. have recently proven the association of cavovarus deformity with peroneal tendon tears, and the subtypes thereof, and elucidated which radiographic measurements of cavovarus are significant [8]. Numerous authors have recommended correction of these deformities simultaneous to peroneal tendon reconstruction [42, 43, 44], although there are neither established criteria for its indications nor for the surgical techniques. The authors choose reconstructive procedures based on whether the hindfoot varus is driven by the forefoot (in most cases, plantarflexion of the first ray) or the hindfoot (usually stiff and/or arthritic subtalar joint in varus). In addition to correction of cavovarus deformities themselves, the association of cavovarus deformities with other pathologies, such as lateral ankle ligament instability, ankle varus, and lateral talar dome osteochondral lesions, should be recognized, as these are often surgically treated at the same time as the peroneal tendons [5, 8, 42–44, 46].

4.12 Complications

Sural nerve branches invariably cross the skin incision to approach the peroneal tendons. As a result, by far the most common complication is skin numbness anterior to the distal portion of the incision, distal to the peroneal tubercle, followed by injury to the main portion of the sural nerve more proximally. The latter can result in retrograde dysesthesias and pain in the lower leg. Wound healing complications are the next most common complication due to the subcutaneous position of the peroneal tendon retinaculum and the lack of subcutaneous tissue over the ankle and hindfoot. Peroneal complications including recurrent tears, scarring, or complete tendon degeneration require revision reconstruction of higher complexity. For example, a failed brevis repair might merit a tenodesis; a failed tenodesis might merit a tendon transfer or allograft.

4.13 Postoperative Rehabilitation

Postoperative rehabilitation for peroneal tendon reconstruction varies from author to author and from procedure to procedure, but in our experience is most commonly 6–8 weeks. Timing of initiation of therapy is highly variable. In general, we immobilize patients for 2 weeks in a splint, followed by 4 to 10 weeks in a progression from casts to boots, from non-weight-bearing to weight-bearing, and from immobilization to controlled active motion. These are modified depending upon the extent of the reconstruction. Repairs require the least postoperative protection, and allograft reconstruction for tears of both peroneals require the most. Physical therapy is very helpful to most patients once healing and immobilization are complete.

5 Summary

Peroneal tendon tears present most commonly as chronic lateral ankle and/or hindfoot pain and swelling, with variable levels of diminished ability and endurance, from participation in sport, to walking in activities of everyday life. There may or may not be a history of an inciting inversion event. Physical examination is key for differentiating peroneal pathology from other causes of lateral ankle pain, and MRI is the most definitive confirmatory diagnostic test. Published surgical classifications, based on intraoperative findings, guide operative management, but in general, small, reconstructable tears can be debrided and repaired, although a substantial number will fail through scarring or recurrent tears. For larger, unreconstructable tears, reconstruction options include tenodesis to the adjacent tendon, FHL or FDL tendon transfer, or allograft substitution. Retinacular reconstruction is critical, and in some patients the surgical treatment of associated cavovarus deformity must be done. While further study will advance our understanding of surgical techniques and outcomes, most patients obtain meaningful and lasting pain relief and improvement in function.

References

1. Sammarco GJ, DiRaimondo CV. Chronic peroneus brevis tendon lesions. Foot Ankle. 1989;9(4):163–70.
2. Krause JO, Brodsky JW. Peroneus brevis tendon tears: pathophysiology, surgical reconstruction, and clinical results. Foot Ankle Int. 1998;19(5):271–9.
3. Brandes CB, Smith RW. Characterization of patients with primary peroneus longus tendinopathy: a review of twenty-two cases. Foot Ankle Int. 2000;21(6):462–8.
4. Celikyay F, Yuksekkaya R, Almus F, Bilgic E. Tenosynovitis of the peroneal tendons associated with a hypertrophic peroneal tubercle: radiography and MRI findings. BMJ Case Rep. 2014;2014:bcr2013200204.

5. Stockton KG, Brodsky JW. Peroneus longus tears associated with pathology of the os peroneum. Foot Ankle Int. 2014;35(4):346–52.
6. Mota Gomes T, Guerra-Pinto F, Soares S, et al. The vascularization of the peroneal tendons: an anatomic study. Foot Ankle Surg. 2020;27:450.
7. Petersen W, Bobka T, Stein V, Tillmann B. Blood supply of the peroneal tendons: injection and immunohistochemical studies of cadaver tendons. Acta Orthop Scand. 2000;71(2):168–74.
8. Taniguchi A, Alejandro SF, Kane JM, Daoud Y, Tanaka Y, Ford SE, Brodsky JW. Association of cavovarus foot alignment with peroneal tendon tears. Foot Ankle Int. 2021;42(6):750–6. PubMed ID: 33847151.
9. Munk RL, Davis PH. Longitudinal rupture of the peroneus brevis tendon. J Trauma. 1976;16(10):803–6.
10. Sobel M, Geppert MJ, Hannafin JA, Bohne WH, Arnoczky SP. Microvascular anatomy of the peroneal tendons. Foot Ankle. 1992;13(8):469–72.
11. van Dijk PA, Madirolas FX, Carrera A, Kerkhoffs GM, Reina F. Peroneal tendons well vascularized: results from a cadaveric study. Knee Surg Sports Traumatol Arthrosc. 2016;24(4):1140–7.
12. Raikin SM, Elias I, Nazarian LN. Intrasheath subluxation of the peroneal tendons. J Bone Joint Surg Am. 2008;90(5):992–9.
13. Vega J, Golanó P, Dalmau A, Viladot R. Tendoscopic treatment of intrasheath subluxation of the peroneal tendons. Foot Ankle Int. 2011;32(12):1147–51.
14. Trono M, Tueche S, Quintart C, Libotte M, Baillon J. Peroneus quartus muscle: a case report and review of the literature. Foot Ankle Int. 1999;20(10):659–62.
15. Miller CP, Smith SE, Goodman EM, et al. Peroneal sheath volumes are greater in patients with peroneal pathology compared with controls. Foot Ankle Spec. 2020; https://doi.org/10.1177/1938640020950897.
16. Bojanić I, Knežević I, Dimnjaković D. Importance of space-occupying anatomical variations in peroneal tendoscopy. Foot Ankle Int. 2020;42:448. https://doi.org/10.1177/1071100720966325.
17. Squires N, Myerson MS, Gamba C. Surgical treatment of peroneal tendon tears. Foot Ankle Clin. 2007;12(4):675–95, vii
18. Sammarco GJ. Peroneus longus tendon tears: acute and chronic. Foot Ankle Int. 1995;16(5):245–53.
19. Bruce WD, Christofersen MR, Phillips DL. Stenosing tenosynovitis and impingement of the peroneal tendons associated with hypertrophy of the peroneal tubercle. Foot Ankle Int. 1999;20(7):464–7.
20. Taki K, Yamazaki S, Majima T, Ohura H, Minami A. Bilateral stenosing tenosynovitis of the peroneus longus tendon associated with hypertrophied peroneal tubercle in a junior soccer player: a case report. Foot Ankle Int. 2007;28(1):129–32.
21. Sobel M, Pavlov H, Geppert MJ, Thompson FM, DiCarlo EF, Davis WH. Painful os peroneum syndrome: a spectrum of conditions responsible for plantar lateral foot pain. Foot Ankle Int. 1994;15(3):112–24.
22. Gomes MDR, Pinto AP, Fabián AA, Gomes TJM, Navarro A, Oliva XM. Insertional anatomy of peroneal brevis and longus tendon – a cadaveric study. Foot Ankle Surg. 2019;25(5):636–9.
23. Chinitz N, Bohl DD, Reddy M, Tenenbaum S, Coleman S, Brodsky JW. Preoperative gait analysis of peroneal tendon tears. Foot Ankle Int. 2022;43(2):233–43. Pubmed ID: 34596438.
24. Bianchi S, Bortolotto C, Draghi F. Os peroneum imaging: normal appearance and pathological findings. Insights Imaging. 2017;8(1):59–68.
25. Major NM, Helms CA, Fritz RC, Speer KP. The MR imaging appearance of longitudinal split tears of the peroneus brevis tendon. Foot Ankle Int. 2000;21(6):514–9.
26. Wang XT, Rosenberg ZS, Mechlin MB, Schweitzer ME. Normal variants and diseases of the peroneal tendons and superior peroneal retinaculum: MR imaging features. Radiographics. 2005;25(3):587–602.
27. Taljanovic MS, Alcala JN, Gimber LH, Rieke JD, Chilvers MM, Latt LD. High-resolution US and MR imaging of peroneal tendon injuries. Radiographics. 2015;35(1):179–99.

28. Gyftopoulos S, Bencardino JT. Normal variants and pitfalls in MR imaging of the ankle and foot. Magn Reson Imaging Clin N Am. 2010;18(4):691–705.
29. Erickson SJ, Cox IH, Hyde JS, Carrera GF, Strandt JA, Estkowski LD. Effect of tendon orientation on MR imaging signal intensity: a manifestation of the "magic angle" phenomenon. Radiology. 1991;181(2):389–92.
30. Mengiardi B, Pfirrmann CW, Schöttle PB, et al. Magic angle effect in MR imaging of ankle tendons: influence of foot positioning on prevalence and site in asymptomatic subjects and cadaveric tendons. Eur Radiol. 2006;16(10):2197–206.
31. Ieong E, Rafferty M, Khanna M, Walker M, Rosenfeld P. Use of fat-suppressed T2-weighted MRI images to reduce the magic angle effect in peroneal tendons. Foot Ankle Spec. 2019;12(6):513–7.
32. Adachi N, Fukuhara K, Kobayashi T, Nakasa T, Ochi M. Morphologic variations of the fibular malleolar groove with recurrent dislocation of the peroneal tendons. Foot Ankle Int. 2009;30(6):540–4.
33. Rademaker J, Rosenberg ZS, Delfaut EM, Cheung YY, Schweitzer ME. Tear of the peroneus longus tendon: MR imaging features in nine patients. Radiology. 2000;214(3):700–4.
34. Khoury NJ, el-Khoury GY, Saltzman CL, Kathol MH. Peroneus longus and brevis tendon tears: MR imaging evaluation. Radiology. 1996;200(3):833–41.
35. O'Neil JT, Pedowitz DI, Kerbel YE, Codding JL, Zoga AC, Raikin SM. Peroneal tendon abnormalities on routine magnetic resonance imaging of the foot and ankle. Foot Ankle Int. 2016;37(7):743–7.
36. Lee SJ, Jacobson JA, Kim SM, et al. Ultrasound and MRI of the peroneal tendons and associated pathology. Skelet Radiol. 2013;42(9):1191–200.
37. Grant TH, Kelikian AS, Jereb SE, McCarthy RJ. Ultrasound diagnosis of peroneal tendon tears. A surgical correlation. J Bone Joint Surg Am. 2005;87(8):1788–94.
38. Urguden M, Gulten IA, Civan O, Bilbasar H, Kaptan C, Cavit A. Results of peroneal tendoscopy with a technical modification. Foot Ankle Int. 2019;40(3):356–63.
39. Guelfi M, Vega J, Malagelada F, Baduell A, Dalmau-Pastor M. Tendoscopic treatment of peroneal intrasheath subluxation: a new subgroup with superior peroneal retinaculum injury. Foot Ankle Int. 2018;39(5):542–50.
40. Vega J, Batista JP, Golanó P, Dalmau A, Viladot R. Tendoscopic groove deepening for chronic subluxation of the peroneal tendons. Foot Ankle Int. 2013;34(6):832–40.
41. Wagner E, Wagner P, Ortiz C, Radkievich R, Palma F, Guzmán-Venegas R. Biomechanical cadaveric evaluation of partial acute peroneal tendon tears. Foot Ankle Int. 2018;39(6):741–5.
42. Redfern D, Myerson M. The management of concomitant tears of the peroneus longus and brevis tendons. Foot Ankle Int. 2004;25(10):695–707.
43. Steel MW, DeOrio JK. Peroneal tendon tears: return to sports after operative treatment. Foot Ankle Int. 2007;28(1):49–54.
44. Demetracopoulos CA, Vineyard JC, Kiesau CD, Nunley JA 2nd. Long-term results of debridement and primary repair of peroneal tendon tears. Foot Ankle Int. 2014;35(3):252–7.
45. Steginsky B, Riley A, Lucas DE, Philbin TM, Berlet GC. Patient-reported outcomes and return to activity after peroneus brevis repair. Foot Ankle Int. 2016;37(2):178–85.
46. Wagner E, Ortiz C, Wagner P, Guzman R, Ahumada X, Maffulli N. Biomechanical evaluation of various suture configurations in side-to-side tenorrhaphy. J Bone Joint Surg Am. 2014;96(3):232–6.
47. Burkhard MD, Wirth SH, Andronic O, Viehöfer AF, Imhoff FB, Fröhlich S. Clinical and functional outcomes of peroneus longus to brevis tendon transfer. Foot Ankle Int. 2021;42:699. https://doi.org/10.1177/1071100720982592.
48. Jockel JR, Brodsky JW. Single-stage flexor tendon transfer for the treatment of severe concomitant peroneus longus and brevis tendon tears. Foot Ankle Int. 2013;34(5):666–72.
49. Seybold JD, Campbell JT, Jeng CL, Short KW, Myerson MS. Outcome of lateral transfer of the FHL or FDL for concomitant peroneal tendon tears. Foot Ankle Int. 2016;37(6):576–81.

50. Sherman TI, Koury K, Orapin J, Schon LC. Lateral transfer of the flexor digitorum longus for peroneal tendinopathy. Foot Ankle Int. 2019;40(9):1012–7.
51. Seybold JD, Campbell JT, Jeng CL, Myerson MS. Anatomic comparison of lateral transfer of the long flexors for concomitant peroneal tears. Foot Ankle Int. 2013;34(12):1718–23.
52. Jeng CL, Thawait GK, Kwon JY, et al. Relative strengths of the calf muscles based on MRI volume measurements. Foot Ankle Int. 2012;33(5):394–9.
53. Silver RL, de la Garza J, Rang M. The myth of muscle balance. A study of relative strengths and excursions of normal muscles about the foot and ankle. J Bone Joint Surg Br. 1985;67(3):432–7.
54. Mook WR, Parekh SG, Nunley JA. Allograft reconstruction of peroneal tendons: operative technique and clinical outcomes. Foot Ankle Int. 2013;34(9):1212–20.