REVIEW ARTICLE

Allograft Reconstruction for Chronic Irreparable Foot and Ankle Tendon Ruptures

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Abstract

Tendon ruptures around the foot and ankle are relatively common and frequently misdiagnosed, causing patient consultation in chronic scenario. A wide variety of surgical techniques have been described for tendon reconstruction. To our knowledge, there is no gold standard procedure; several drawbacks are associated with techniques that use nearby tissue for reconstruction due to the sacrifice of healthy structures, which can imbalance the foot and cause loss of strength. In consequence, tendon allografts appear as an attractive alternative due to less morbidity and conservation of nearby soft tissue. This article reviews the different reconstruction techniques and shares our experience in foot and ankle tendon allograft reconstruction.

Keywords: Chronic tendon ruptures, tendon reconstruction, tendon allograft.

1. INTRODUCTION

Tendon injuries around the foot and ankle are a frequent reason for consultation, particularly in the young and active population.[1] Presentation varies widely, ranging from tendinosis to irreparable tendon tears. Since acute tendon tears have been largely described in medical literature and direct repair has yielded excellent results, we will not discuss them in this review. However, in the chronic situation, the scenario differs greatly: tendon healing occurs with fibrotic scar tissue, which lacks the biomechanical properties of the healthy tendon, leading to functional impairment. A myriad of reconstruction techniques has been reported, including tenodesis, tendon transfers, turndown flaps, autografts, and allografts, among others[2]; however, currently, there is a paucity of evidence with no comparative studies regarding how to effectively approach this challenging situation specifically for foot and ankle tendon repair. Hereby, we present a literature review and our approach to this problem.

Allografts have been widely used in orthopedic surgery, especially in knee surgery for anterior cruciate ligament (ACL) reconstruction. Studies guarantee its safe use and effectiveness with no higher infection risk and equivalent failure rates when compared with autografts.[3] Although allograft tendon reconstruction has been used for several chronic tendon tears in other locations, such as patellar and distal biceps tendon tears,[4,5] its use has not been as popular in foot and ankle surgery. A broad range of other techniques available, such as tenodesis and tendon transfers for reconstruction, may partially explain this situation.[6] Nevertheless, allografts have recently gained popularity in lateral and medial ankle instability,[7-10] supporting reliability and safe use in foot and ankle conditions.

2. ALLOGRAFT RECONSTRUCTION FOR IRREPARABLE PERONEAL TENDON TEAR

Peroneal tendon pathology is a common cause for persistent ankle pain and instability. The spectrum of manifestations ranges from synovitis, tendinosis, and dislocation, to partial or complete tendon tear.[11] Multiple factors contribute to generate peroneal tendon issues, including retromalleolar groove overcrowding, repeated ankle sprains, and cavo-varus foot deformity, among others.[12-17] Peroneal tendon tear diagnosis is difficult and frequently underdiagnosed. More commonly, this injury occurs in a watershed zone, presenting a challenging situation.[18] Several surgical procedure treatments have been described in the literature.[12,15,19-25]

Irreparable peroneal tendon ruptures are conventionally described as tears involving more than 50% cross-sectional area,[26] which are relatively rare, and for that reason, the evidence is scarce.[15] However, this threshold has recently been challenged, suggesting that perhaps 30% of the remaining tendon is enough to maintain function.[27] Redfern & Myerson[23] propose an algorithm depending on intraoperative findings. They suggest that if irreparable tear is present in one tendon and the other is healthy, tenodesis should be performed. However, when both tendons are torn, graft or tendon transfer should be considered, depending on muscular excursion.[23] Nevertheless, a biomechanical study showed that tenodesis is unable to restore native tension at the peroneal tendon's insertion when compared to allograft.[24]

To date, there is no gold standard treatment for irreparable peroneal tendon ruptures, but tenodesis and deep flexor tendon transfers are

commonly used.[20-22,28] However, these procedures have been unable to recover patients to their previous level of activity nor eliminate all symptoms.[29] In addition, several disadvantages have been reported with their use such as ancillary incisions, longer operative times, alteration in normal gait kinematics, stress fractures, and diminished range of motion.[15,22,24]

In search of other alternatives, allograft reconstruction appears as an attractive option aiming to preserve ankle anatomy and function—mostly eversion and plantar flexion strength.[12] To our knowledge, there are only a few studies that discuss this issue, comprising small series and case reports for allograft reconstruction. Pellegrini *et al*.[18] published the case of a patient with previous peroneal tenodesis surgery who presented with persistent residual pain and weakness. An allograft reconstruction was achieved for both peroneal tendons, resulting in a significant reduction in pain and resumption of the patient's previous activity level after 17 months postoperative. Figure 1.

The same author presented a case with a peroneal tear in the context of rare variation, consisting of peroneal longus and brevis arising from the same muscle belly.[12] After debridement, primary repair or tenodesis was not feasible, thus an allograft reconstruction was performed. Eighteen months postoperative, the patient was able to resume previous activity with minimal ankle pain.[12] The largest series was performed by Mook *et al.*[15]; they included 14 patients undergoing intercalary segment peroneal tendon allograft reconstruction for irreparable tears. All patients improved functional scores and full eversion strength, 5/5 muscular strength was achieved in 9/14 patients postoperatively with an average of 4.7 ± 0.5 ($p = .003$), according to the Medical Research Council (MRC), with no major complications and satisfactory patient self-reported outcomes. All of these studies conclude that the use of peroneal tendon allograft is a safe and a reasonable option for peroneal tendon reconstruction. [Figure 1]

Fig 1. Peroneus Brevis tendon reconstruction with peroneus tendon allograft using proximal and distal Pulverstaft weaving technique, sutured with 2-0 fiberwire.

3. ALLOGRAFT RECONSTRUCTION FOR CHRONIC ACHILLES TENDON RUPTURE

Achilles tendon rupture is a common injury that affects primarily young, active people with a peak incidence between 35-50 years old,[1,30] and also recently older patients who practice sports more frequently. Diagnosis is made according to clinical findings in which a positive Thompson test in conjunction with an asymmetric Achilles tendon flexor tone have a very high sensitivity.[1] Despite the latter, neglected Achilles tendon rupture diagnosis can be as high as 20-36%.[6,30] These patients heal with a fibrotic scar lacking normal tension and strength, which cannot restore normal function and leads to considerable functional morbidity with balance loss and gait dysfunction.[1,6,30] The treatment objective is to regain flexor strength to reincorporate the patient's preinjury desired level of activity, and this can be achieved by different means with good results in the acute setting.[31]

There is no treatment consensus for chronic Achilles tendon rupture, the definition of which can vary from 4 to 10 weeks after injury.[1,32] In this scenario, termino-terminal repair is not always feasible and multiple techniques have been described, including procedures which debilitate proximal muscular belly, tendon transfers, tendon autograft and allograft reconstructions. To date, there is no evidence-based guideline for chronic Achilles tendon rupture management. Allograft tendon reconstruction arises as an attractive option, since it is capable of preserving the miotendon unit with the characteristic caudal rotation feature,[30] does not occupy neighboring tissues for repair,[33] prevents morbidity of the donor site, and is available in a greater amount.[6] Augmentation has also been described, arguing that this generates a construct with greater biomechanical resistance, which would allow early and more aggressive rehabilitation, resulting in early reintegration to previous activity with lower re-rupture rates.[34]

Achilles allograft reconstruction techniques with or without augmentation have been described using interposition allograft,[6,30,35] bone block fixation[6,33] or even synthetic substitutes.[36] Huang *et al.*[34] published a case series of 59 patients with acute Achilles rupture using allograft augmentation for termino-terminal repair. Earlier return to activities was found, 11.2 weeks on average, with good functional and satisfactory tendon strength. They had one complication consisting of a hypersensitivity case, despite using lyophilized and gamma irradiated tendon, which resolved only with steroid treatment. Hanna *et al.*[33] conducted a study where they used allograft with bone block fixation in 6 patients with more than 5 cm tendon GAP after tendinopathic tissue debridement. Patients reported good satisfaction, and muscle trophism and strength results were obtained with no re-ruptures, although no functional scales were performed. They reported one infection in one patient who identified as a smoker. However, other complications have been reported in relation to this technique, such as fragmentation of the tuberosity of the calcaneus, heterotopic ossification,[37] and delay of union[6] in relation to the bone block fixation. To date, Ofili *et al.*[6] have the largest case series of allograft reconstruction for chronic Achilles rupture. Fourteen patients were included, and intercalar graft or bone block fixation was used when there was not enough distal stump. They reported satisfactory results and achieved single heel rise in all patients. They stated that MRI was not reliable to preoperatively measure tendon gap, as in all cases the resultant

intraoperative gap was wider, suggesting that surgeons should not rely on this modality to decide their surgical option. [Figure 2]

4. ALLOGRAFT RECONSTRUCTION FOR ANTERIOR TIBIAL TENDON RUPTURE

Rupture of the anterior tibial tendon is a relatively rare lesion,[38,39] which can lead to a significant alteration in the gait pattern.[40] Classically, two forms of presentation are described[41] including traumatic injuries and degenerative lesions. Of these, degenerative lesions are the most frequent and often go unnoticed by patients, due to a compensatory mechanism of the Extensor Hallucis Longus (EHL) and Extensor Digitorum Longus (EDL)[42] resulting in delayed diagnosis which makes treatment difficult.[41] Since there are no prospective, good quality studies, and all knowledge about this condition is based on small clinical series and/or case reports, the best treatment option is unknown.[43] Historically, conservative treatment has been proposed in elderly patients with low functional demand.[41] Markarian *et al*.[44] retrospectively evaluated 16 patients with rupture of the anterior tibial tendon and found no significant differences in their functional results between the surgical and non-surgical groups. Functional limitations (persistent dropfoot, slapfoot gait, limitations in walking) have been described after conservative management.[40] Other more recent studies advocate favoring surgical treatment over non-operative management, because of better functional results, greater strength in ankle dorsiflexion, and a better gait pattern.[45-47]

Anagnostakos *et al*.[48] proposed a treatment algorithm depending on intraoperative findings and location of the rupture. In general, they performed reparative techniques in defects smaller than 4 cm and reconstructive surgery for defects greater than 4 cm. Within the reparative techniques, one of the most used is primary repair with or without elongation of gastrocnemius.[41] In addition, tendon re-excision has been described in cases of avulsion of the tibialis anterior.41 Sapkas *et al*.[49] used a free-sliding tibial anterior graft harvested from the proximal stump of the tendon. The sliding tendon lengthening[50] can be performed when there is a gap between the two ends of the ruptured tendon. Despite observing a lower ankle dorsiflexion strength with these reparative techniques, no apparent functional repercussion has been documented.[51,52] When the defect between stumps of the ruptured tendon cannot be covered by the native tendon, reconstructive surgical techniques are necessary. EHL and EDL transfers have been performed with functional results and high levels of satisfaction, comparable to a primary repair.[45,53] Other options include tendinous autograft, Peroneus brevis,[54] Semitendinosus,[55] Gracilis,[56] Plantaris,[46] EDL,[46] and Achilles,[46] with good results and satisfactory return to previous activity level.[54-56]

In order to avoid morbidity associated with tendon transfers or autograft reconstruction,[57] reconstructive techniques with allograft have been explored.[41,58,59] Aderinto *et al*.[58] published a case of reconstruction with Achilles allograft, where the patient, 8 years after surgery, maintained a good walking pattern and active dorsiflexion of the ankle. Huh *et al*.[59] retrospectively reviewed 11 patients with anterior tibial tendon ruptures in which they used allograft to reconstruct large tendon defects, obtaining satisfactory functional and strength results, with a single complication corresponding to one patient developing transient neuritic pain. Allograft reconstruction appears as a safe and reliable option to manage

chronic ruptures of the anterior tibial tendon, without the morbidity of the donor site.[41,59]

5. DISCUSSION

Allografts have been widely used for ligament reconstruction around the ankle joint but not frequently for tendon reconstruction, probably due to the broad availability of surgical techniques that include nearby soft tissues.[6] Indications for reconstruction include all tears that cannot be primarily repaired by termino-terminal suture[1] and revision surgery.[18] Care must be taken in patients with prolonged muscular inactivity which can develop fibrofatty infiltration, evaluated in magnetic resonance imaging (MRI) with more than >30% compromise; this procedure is contraindicated for such patients.[1] The authors obtained a full leg MRI in order to estimate fibrofatty degeneration, in an approximation to the Goutallier classification used in shoulder surgery.[60] Other relative contraindications include poor soft tissue coverage, poor metabolism control and neuropathy in diabetic patients.

A number of advantages have been described with the use of allograft over autograft. Allograft allows for preservation of anatomy and function of nearby tendons for reconstruction,[1,33] replacement of diseased for healthy tendon,[30] maintained balance of the foot,[24] and transference of the healing process to a more vascularized area.[33] In addition, allograft over autograft permits more tendon availability, less intraoperative time, no need for additional surgical approach, and in consequence, less morbidity.[33]

There is concern about allograft safety, mainly in relation to infection and disease transmission. However, in all available studies, none reported infectious or disease transmission; there is only one case of hypersensitivity that resolved in a conservative way.[34] In addition, HIV transmission risk has been stipulated to be 1 in 1.6 million cases.[61] In our experience, we had one case of superficial wound infection that was managed conservatively, with good results. Other drawbacks include cost, less biomechanical attributes due to processing, and longer times of incorporation.[15,33,62]

To date, there is no comparative clinical study that compares the use of allograft versus other techniques; however, some biomechanical studies have tried to elucidate this problem. A cadaveric model of tenodesis versus allograft reconstruction for irreparable peroneal tendon tear was conducted by Pellegrini *et al*.[24] They demonstrated that the tension in the insertion of the peroneus brevis was only reestablished by allograft reconstruction, in contrast to tenodesis, which did not even reach a third of the native tension. In addition, tenodesis showed increasing tension in healthy peroneal longus tendon that may augment first ray plantar flexion, which can be deleterious in a previous cavo-varus hindfoot scenario. In regards to this matter, Seybold *et al*. found that peroneal tendon transfer results in more than a 55% decrease in strength and eversion power, and results in balance deterioration.[22]

Huh *et al*.[59] conducted the largest series in allograft reconstruction of anterior tibial tendon, gathering 11 cases through seven years. All patients were previously studied with MRI to confirm diagnosis, evaluate tendon gap and determine muscular fatty infiltration. Despite that fatty infiltration was a contraindication for the authors, they did not expand their argument nor determine a threshold value for when not to perform reconstruction. Care was taken to preserve the extensor retinaculum to avoid bow-stringing and they even reconstructed the

retinaculum in one case with tissue matrix augmentation. Positive results in pain, strength and functional scores were reported, but the strongest data came from four patients where they did not find any difference between both legs in peak inversion-dorsiflexion moment or step length during gait analysis.

In general, reconstruction with allograft is commonly performed using a proximal and distal pulverstaft technique, seeking to improve strength due to multiple suture and contact points for tissue integration and cellular ingrowth.[63] We have observed that this type reconstruction usually produces a bulk distal stump and may produce local discomfort with normal shoe wear, in particular with peroneal or anterior tibialis tendons. Therefore, we preserve the distal insertion when possible and reattach the reconstructed tendon to bone using bone anchors. After this, we suture the reconstructed tendon to the original insertion to avoid a bulk stump and maintain native tendon insertions, hoping that anatomy function will be preserved.

In Achilles reconstruction, Ofili *et al*.[6] reported the largest study, with 14 patients included. All of them achieved single heel rise and returned to preinjury level of activity. Two bone block distal fixations were performed during the study period, with one presenting union delay. In our experience, 4 Achilles reconstructions were performed with 2 cases of bone block fixation with good functional results and no complications. Both of our cases were performed after failed surgery for insertional Achilles tendinopathy, were the distal tendon was not suitable to be preserved and therefore bone block fixation was selected. [Figure 2] If the distal stump is suitable for preservation, the gap can be closed weaving any allograft tendon, were Semitendinosus is our preference. To preserve a surgical option in case allograft reconstruction surgery fails, we do not transfer the Flexor hallucis tendon nor open the deep fascia over it.

Figure 2

Fig. 2:
Achilles tendon reconstruction for Achilles insertional tendinopathy after failed surgery using bone block fixation and proximal Pulverstaft weaving technique sutured with 2-0 fiberwire.

In our experience, we have performed fifteen cases of allograft reconstruction (8 men and 7 women). Four Achilles, 4 anterior tibial, 4 peroneal tendons, 2 EHL, and 1 posterior tibial tendon (PTT) have been reconstructed using allograft [Figure 3]. To date, the mean follow up is 18 months (12–25). The functional results have been measured by AOFAS score, obtaining a mean preoperative of 45 (33 - 55) and postoperative AOFAS of 63 (57 - 75) and 81 (70 - 90) at 6 and 12 months, respectively. Complications occurred in one patient corresponding to a superficial wound infection that was managed satisfactorily with wound dressing. All patients returned to the preinjury level of activity and were satisfied by the procedure.

Figure 3

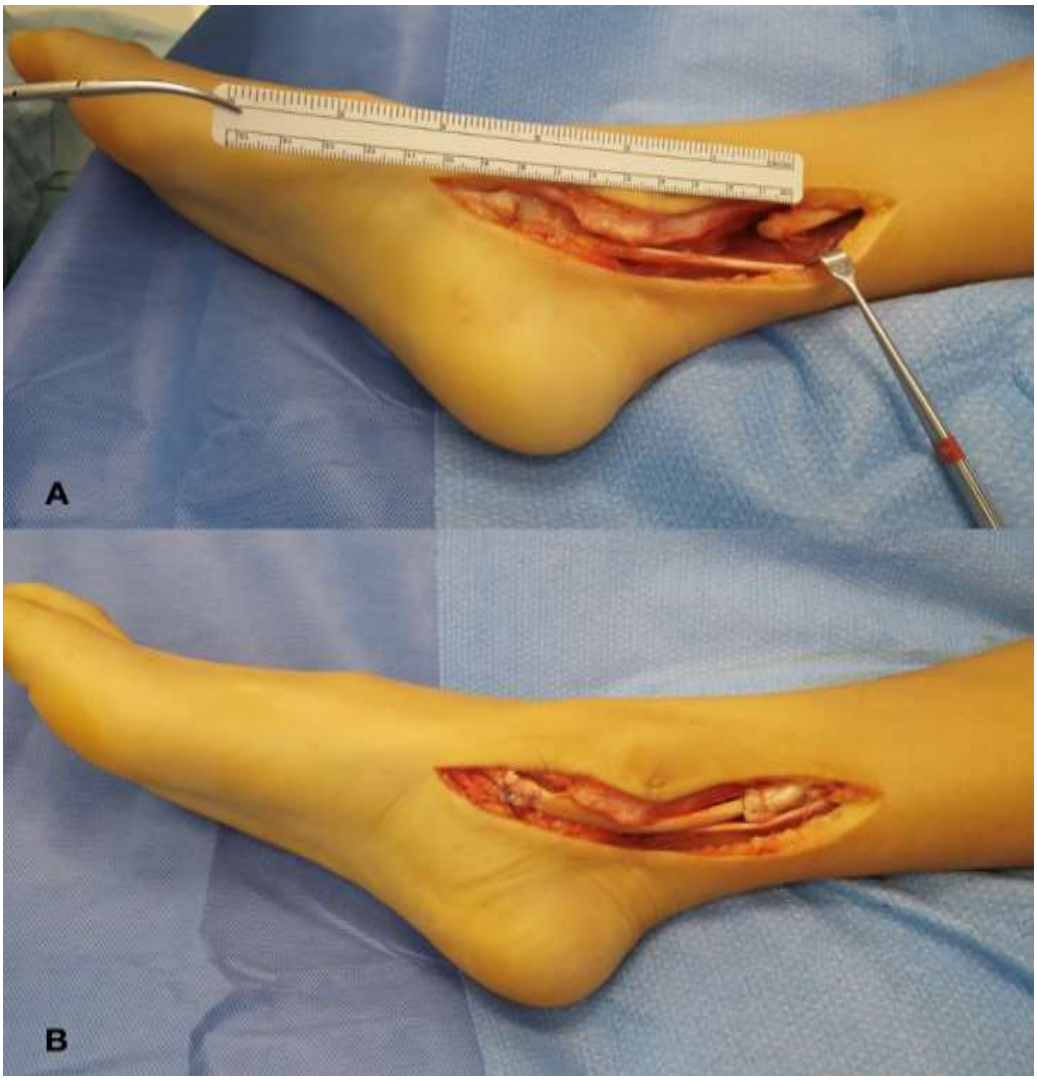

Fig 3. PTT allograft reconstruction; A. Tendon gap of approximately 8 cm after disease tendon debridement; B. Final result after tendon reconstruction using tendon allograft, with proximal Pulverstaft and distal bone anchor augmented with distal stump using 2-0 fiberwire.

6. CONCLUSION

Despite surgical efforts to reconstruct anatomy after irreparable tendon tear around the foot and ankle, evidence is scarce and more clinical studies are needed to elucidate the best treatment option in this challenging situation. Decisions regarding whether to reconstruct with an allograft should take into consideration patient preferences and potential risks. Allograft reconstruction of irreparable tendon tears appears as an attractive option with the goal of preserving anatomy and function of the myotendinous unit, maintaining strength and balance without sacrificing any adjacent structure or adding morbidity. Further comparative clinical studies should be performed to justify allograft reconstruction over other techniques.

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