POSTERIOR TIBIALIS TENDON REPAIR/ AUGMENTATION TECHNIQUES

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Posterior Tibial Tendon Dysfunction (PTTD) is a commonly recognized etiology of adult acquired flatfoot. Acute or chronic rupture of the posterior tibial tendon is not very common, but may result from microtrauma1, causing edema, hemorrhage, and scarring,[2] all of which weaken the posterior tibial tendon. Myerson et al. reported on a group of seventy-six patients, forty-seven of whom had inflammation, rupture, or both, of the posterior tibial tendon in association with a seronegative inflammatory disorder.[3] Holmes and Mann[4] correlated histories of hypertension, diabetes, obesity, steroid use, and previous trauma with dysfunction of the posterior tibial tendon. They found a statistical correlation between rupture of the posterior tibial tendon with obesity and to a lesser extent hypertension. It is essential for a foot and ankle surgeon to be aware of the treatment options available for the various stages of this disease process. Numerous classification schemes have been developed to stage PTTD progression, aiding in potential procedure selection. For this paper, the Johnson and Strom classification[5] (J&S) will be utilized as a reference staging system (Table I). This paper gives an extensive review of the tendon procedures utilized in the early stages of PTTD (J&S I and II). Emphasis is placed on the specific techniques which facilitate retrieval of the FDL and TA tendons and various techniques of anastomosis that have been used by the senior author for many years.

Table 1

JOHNSON AND STROM PTTD CLASSIFICATION SYSTEM[5]

	Stage definition	Recommended Treatment
Stage I	Functionally intact PTT w/ peritendinitis and/ or mild tendon degeneration, mobile nml aligned hind foot (HF), mild weakness on single heel rise test, negative too-many-toes sign, mild to moderate focal medial pain along the PPT course	Synovectomy with tendon debridement and repair after failed conservative therapy of three months
Stage II	Elongated PTT, mobile valgus positioned HF, marked weakness on single heel rise test, positive too-many-toes sign, and moderate pain medially along PTT course	Synovectomy and tendon debridement w/FDL tendon augmentation
Stage III	Elongated/ ruptured PTT, fixed valgus position HF, marked weakness/ or inability to do single heel rise test, positive too-many-toes sign, moderate medial pain along PTT course, and possible moderate lateral pain	Synovectomy and tendon debridement w/FDL tendon augmentation and STJ arthrodesis
Stage IV (Myerson's addition)	Rigid HF, valgus angulation of talus with ankle joint degeneration	Triple arthrodesis

TENOSYNOVECTOMY

Kulowski first described tenosynovitis of the posterior tibial tendon, in 1936, followed by Lipscomb, in 1950.[6] Since then other authors have taken interest in pathology and treatment of the posterior tibial tendon.[7,8,9,10]

After 2-6 months of conservative therapy has failed, surgical treatment is entertained. When choosing a surgical procedure, the clinician should consider age, weight, activity of the patient, and the stage of the deformity. Myerson[3] suggests the least invasive procedure that will decrease pain and improve function.

Synovectomy is indicated when there is a progression of tenosynovitis or tendinitis of the intact tendon despite conservative therapy.[1-30] According to Mann,[11] synovial tissue rarely progresses above the medial malleolus and distal to the tendon insertion. Those that agree with Mann, place the incision over the posterior tibial tendon starting from below the tip of the medial malleolus to the navicular.[11,12] If hypertrophic synovial tissue extends proximal to the medial malleolus the incision is extended in order to excise all hypertrophic synovial tissue. Another incision has been used to visualize the entire PTT. This incision is centered over the PTT and extends from the musculotendinous junction all the way down to the insertion of the posterior tibial tendon leaving a 1-cm strip of flexor retinaculum adjacent to the medial malleolus to prevent subsequent dislocation of the posterior tibial tendon.[3,5,13]

After the tendon sheath is opened, the inflamed synovial tissue is excised and the PT tendon is carefully inspected, looking for pathology (Table 2). Small flap tears are debrided and larger tears are debrided and sutured. Repairs to the PT tendon are made with 0, 2-0, 3-0, or 4-0 nonabsorbable sutures for additional strength and to ensure healing.[2,15,16,17] Care should be taken to avoid strangulation of the tendon. Further, excessive bunching of the tendon can cause the tendon to bind to surrounding tissue and restrict motion.

If significant disease and bulbous degeneration of the tendon is noted it should be debrided, and the tendon should be thinned so it can pass easily behind the medial malleolus. If the tendon is found to be enlarged more than 1.5 times its normal size, a wedge can be removed from the substance to debulk the tendon and the gap should be sutured closed.[5] If the flexor retinaculum was released it should be repaired immediately posterior to the medial malleolus. Some authors close the tendon sheath11 while others recommend leaving the tendon sheath open to minimize subsequent adhesions.[3]

Postoperatively Mann[11] recommends patients be non-weight bearing in a well-padded short-leg dressing, incorporating plaster splints, immediately after surgery. Sutures are removed at 10-12 days and a short-leg cast applied; patient told to ambulate as tolerated. After 3 weeks the patient is weaned out of the short-leg cast and resumes activities as tolerable. Others prefer a short leg cast for four to six weeks,[5,15,19] after which an air stirrup or shoe with a 0.25-inch medial heel and sole wedge are worn until the patient is asymptomatic. Athletic activity begins when strength reveals eighty percent of the strength of the contralateral side19. Numerous authors have reported on their surgical results utilizing tenosynovectomy alone (Table 3).

Table 2

TYPES OF PT PATHOLOGY IDENTIFIED ON SURGICAL EXAM[1]

An avulsion or attritional tear at the insertion of the tendon into the tubercle of the navicular.

Varying degrees of degeneration of the tendon between the medial malleolus and the tubercle of the navicular.

An extremely thickened tendon, with longitudinal fissures, generally intact but sufficiently attenuated that it is no longer functional.

Erosion of the spring ligament complex, which usually along the medial and plantar aspect of the TNJ.

Complete disruption of the posterior tibial tendon with loss of continuity.

PRIMARY REPAIR

Since the initial description of partial rupture of the PT tendon by Key in 1953, numerous authors have reported on rupture of the tendon.[13,22,23] Mueller correlated a pes planovalgus foot type with both a cause and result of rupture of the tendon.[26]

Following tenosynovectomy, primary repair may be the only further step needed. Primary repair of the posterior tibial tendon can be performed when the rupture is in the acute phase[27,28] and involves a relatively short portion of the tendon, usually just distal to the medial malleolus.[29] However, disruption of the posterior tibial tendon rarely occurs spontaneously.[1,13] Anzel et. al[26] analyzed 1,014 cases of tendon disruption and found only 3 of the posterior tibial tendon, two lacerations and one rupture. Griffiths reported 4 injuries of the posterior tibial tendon out of 20 cases of tendon injuries, 3 lacerations and 1 spontaneous rupture. Spontaneous rupture only occurred once in the absence of rheumatoid arthritis.[22]

A turn down technique has been described for primary repair of PT tendons.[1,30] The tendon was split longitudinally 5cm proximal to the defect. The most terminal 5 to 10 mm was left intact. Using 4-0 or 6-0 nonabsorbable suture, 1 or 2 sutures were placed in the distal aspect of the tendon. The tendon was rotated 180 degrees and reattached to its destination.[30] A Z-plasty tendon lengthening of the proximal end of the tendon and subsequent end-to-end anastomosis was also used for primary repair.[1,19] This repair produced a full range of inversion with diminished strength.[1]

Tendon grafts for rupture repair, although minimal, are present in the literature and include a free extensor hallucis brevis graft,[26] fascia lata,[31] free extensor digitorum longus graft,[2] tibialis anterior, plantaris, tendo Achilles, peroneus brevis, and the peroneus tertius tendons.[1] No procedures or results were given.

Primary repair of the tendon is generally not possible because of the retraction of the two segments that follows rupture. Should the tendon be intact, its substance is usually sufficiently degenerative to prevent primary repair.[32,33,34] Most agree that attempts to restore function of the posterior tibial tendon by direct repair have not been satisfactory or deemed inadequate.[1,17] Woods presented two cases in which a primary repair of the posterior tibial tendon was performed. He found primary repair to be effective in restoring some, but not all, normal function.[35]

FDL TENDON AUGMENTATION

The goal of PTTD treatment with tendon augmentation is to provide a satisfactory antagonist to the unopposed peroneus brevis. Since 1974, when Goldner et al[1,33] published a retrospective study on flat foot repair managed with adjacent flexor tendon (FHL or FDL) PTT reinforcement, and medial plantar ligament reinforcement, multiple authors have described techniques of FDL augmentation in the repair of PTTD.[5,25]

The FDL to PTT tenodesis incorporated with tenosynovectomy is the most commonly advocated procedure when dealing with a mobile, supple foot without evidence of fixed hindfoot or forefoot deformities, i.e. stage II J&S.[1,5,11,15,17,18,19,32,35,36,44] For a tendon transfer to succeed there must be a full range of motion in the involved joints11 with a lack of equinus as a contributing factor to the deformity. Many authors recommend incorporating a TAL or gastrocnemius recession as a component of the surgical treatment.[1,11,18,27,41,45]

When performing the FDL-PTT tenodesis, the majority of literature describes an initial incision over the course of the PTT from the first metatarsal cuneiform joint to approximately 10 to 12 cm proximal to the medial malleolus.[1,5,11,15,19,31] The PTT sheath should be opened beginning at the insertion, the tendon inspected 360°, and proceed proximally until diseased tendon is

Table 3

RESULTS OF SYNOVECTOMY OF STAGE I PTTD

Author	Year	Number of patients	Surgical procedure performed	Results
Ghormley	1953	11	Surgical synovectomy	8 complete relief of pain
Williams	1963	12	Division of the tendon sheath	11 complete relief of pain
Teasdall	1994	19	Synovectomy and debridement of the symptomatic PTT	14 pain free, 3 minor pain, 1 moderate pain 1 severe pain
Crates	1999	7	Six patients underwent synovectomy, Six patients tendon augmentation	All patients healed and pain free
Mann	1999	12	Synovectomy and debridement of the symptomatic PTT	74% complete relief of pain

discovered, or ruled out. It has been recommended by multiple authors that a 1 cm section of the flexor retinaculum posterior to the medial malleolus be left intact when exploring the tarsal tunnel[15,36] maintaining tarsal tunnel integrity, preventing future tendon bowstringing.

The FDL tendon is then identified just deep to the PTT and retinacular compartment opened. The FDL is traced into the plantar aspect of the foot to the level of the medial cuneiform. The crossing of the FDL and FHL tendons (Knot of Henry-KOH) is clearly identified and FDL tendon released proximal to their intersection. Other authors have described different methods of distal FDL release, summarized in Table 4.

Once released, if the PTT sheath is free of disease, the FDL tendon is pulled back into the foot and passed through the PTT sheath.[1,11,15,19,40] If the sheath presents with significant pathology, it is recommended that the tendon remain in its existing sheath and be freed distal to the medial malleolus.[12,19,46] One author recommends the excision of the intervening septum between the PTT and FDL tendon tarsal tunnel compartments before closure of the sheath.[1]

A vertical hole is then drilled through the navicular centro-medially in a dorsal to plantar direction, exiting slightly lateral to the insertion of the PTT on the navicular to ensure adequate bone bridge to prevent failure.[11,19] It is important that the hole is not made too far laterally because the insertion of the tendon would be moved too close to the axis of the STJ and a loss of inversion strength may result.[11] The FDL tendon is passed from plantar to dorsal through the navicular hole, and it is sutured back onto itself with a nonabsorbable suture (0, 2-0, 3-0, or 4-0[11,15,18]), the foot in maximum inversion and plantar flexion.[12,15,17,19,21,31,36,37,41,42,45] The exact tension under which to secure the tendon is of some debate, with no consensus found in the literature.[21] It has been recommended that the FDL be tightened enough to prevent eversion of the heel beyond neutral,[32] pulling the FDL tendon to maximum tension before suturing,[5,15] or FDL tension be placed half-way between maximum tension and resting tension with the foot in inversion and slight plantarflexion,[11,38] while still others make no mention of it, avoiding the issue altogether.[17]

If FDL tendon length proves inadequate to suture back on itself, then it may be secured to the periosteum on both the dorsal and plantar surfaces of the navicular or medial cuneiform with nonabsorbable suture.[1,11,15] Other methods of tendon implantation security include suturing the tendon within the navicular with 2-0 nonabsorbable suture and drill holes,[17] into the sustentaculum tali with a bone anchor,[17] into a viable PTT stump at the insertion,[15,36] or into the periosteum while reefing the spring ligament.[17] If an accessory navicular exists within the PTT insertional stump, multiple authors recommend the ossicle be resected prior to its utilization in the FDL tenodesis.[1,5]

If the PT muscle and tendon stretch and elasticity remain on intraoperative inspection, it may be used proximally and distally to augment the tenodesis.[1,5,11,15,19,36,45] The use of the PT muscle and proximal tendon in the FDL augmentation have been shown to increase inversion power 20-25% over the 50-85% of normal inversion power that is to be expected after an isolated FDL repair1.[9] After the PTT is resected a minimum of 1.5 inches proximal to the medial malleolus, to avoid impingement during excursion,[11,15,17] the proximal PTT stump is sutured in a side to side tenodesis to the FDL tendon. It has been recommended by several authors that sharp débridement be performed to remove the paratenon and roughen apposing tendon surfaces, encouraging fibrosis between the tendons and minimizing slippage.[15,16] If the PTT and muscle were found to be

Table 4

FDL RELEASE VARIATIONS AT THE KNOT OF HENRY (KOH)

Release of the FDL proximal to the KOH without ligature tenodesis[3,5,24]

Release of the FDL proximal to the KOH after ligature tenodesis is performed with nonabsorbable suture[1,6,7,11,29]

Release of the FDL just proximal to the tendon becoming digital slips, thus providing additional length for the repair[5,24]

Table 5

ANCILLARY OSSEOUS PROCEDURES

Medial calcaneal displacement osteotomy[3,7,8,9,22,24,28]
Lateral calcaneal opening wedge osteotomy
Medial calcaneal closing wedge osteotomy
Lateral column lengthening[3,8,9,24]
Opening medial cuneiform plantar-flexory osteotomy[9]
Navicular-medial cuneiform fusion[9]
Medial cuneiform-first metatarsal fusion
Talonavicular fusion[9]

Table 6

GAZDAG AND CRACCHIOLO[26] SPRING LIGAMENT GRADING SYSTEM AND TREATMENT

	Definition	Treatment
Grade I	Single or multiple longitudinal tear within the mid-substance or at the insertion of the ligament at the sustentaculum tali or navicular with normal ligament tension	Repaired with 2-0 nonabsorbable sutures
Grade II	Loose ligament, with or without a visible tear in the mid-substance or insertion	Repaired with ligament augmentation with the use of the distal stump of the uninvolved in the pathological process, or with tibialis anterior augmentation
Grade III	Complete rupture of the ligament	

fibrosed and unsalvageable, then the proximal PTT should be allowed to dangle without incorporation into the tenodesis. It has been recommended in this scenario that an additional osseous procedure,[27,31] or arthroeresis[21,27,31] be incorporated into the repair believing the FDL inadequate to replace the PTT alone (Table 5).

Plication of the spring ligament prior to FDL tendon reinsertion is another topic of debate. Johnson and Strom felt it unnecessary to perform a spring ligament reefing,[5] however many author believe it to be an essential aspect of functional restoration.[1,11,12,17,19,27,36,37] For those that advocate its reefing, the most common procedure was the excision of a vertical ellipse encompassing primarily the superomedial calcaneal navicular ligament overlying the talonavicular joint. This is then reapproximated in a pants-over-vest technique and closed with nonabsorbable suture.[1,11,12,19,27,36,41,43,44] Other authors recommendations include the distal stump of the PTT,[17,37] or plantaris tendon[41] be utilized to augment the spring ligament.

Gazdag and Cracchiolo strongly advocate spring ligament repair, believing that its repair is necessary to strengthen the static support of the hindfoot.[37] In their study of 22 patients, 18 underwent operative repair prior to tendon transfer. In their evaluation, they used a 3 stage grading system (Table 6) to assess and treat the spring ligament pathology. The results of their study are based on a series of subjective criteria including limitations of daily or recreational activities, ability to walk an unlimited distance, and overall patient satisfaction (Table 7). Ultimately, Gazdag and Cracchiolo concluded it was not possible to determine from the study if repair of the ligament will give an over-all better result.

Table 7

GAZDAG AND CRACCHIOLO OUTCOME SUMMARY

# Of pts	Spring ligament grade	Ave. follow-up	Results
7	Grade 1	24-33 mo.	1 poor 1 fair 5 excellent
7	Grade 2	24-40 mo.	1 poor 1 fair 5 excellent
4	Grade 3	24-43 mo.	4 excellent

During closure, repair of the flexor retinaculum posterior to the medial malleolus needs to be performed to prevent bowstringing.[19] Weil and Weil Jr. suggest a running stitch with non-absorbable suture.[48] As with the tenosynovectomy, some authors close the PTT sheath, while others do not.[1,2,19,31,35]

Post operatively for the FDL transfer, authors generally recommend at least 4 weeks in a non-weight-bearing short leg cast, in slight plantar flexion, and inversion.[1,11,12,15,19,21,36] In two-week increments, the cast is changed, placing the foot into a more neutral position with each change. Once neutral is obtained, the cast is left on an additional 4-6 weeks. Some authors begin partial-weight-bearing the patient at 4-6 weeks in the cast[15,36] or a CAM walker.[3] By 8 weeks the patient is in a shoe with arch supportive insert[1,11,15,19] consisting of a deep heel cup, good medial longitudinal support and slight varus post to the heel.[15] Aggressive physical therapy is then initiated for 3-6 weeks. Churchill and Sferra reported a full return to sports in 6 months.[19] Many long-term studies have been published regarding the success of the FDL augmentation with and without osseous procedures. (Table 8) There is one documented re-rupture in the literature. Ouzounian reported a rupture of the FDL at the navicular 41 months post repair.[49] The patient was treated with a slide lengthening and reattachment to the navicular. The patient was at full activity after the initial repair, but has only regained partial normal activity level after the re-rupture repair. Michelson and Conti reported failure rates as high as 50% two years after repair.[12]

Utilization of the FHL tendon instead of the FDL has been described in the literature. The FHL tendon is of equal size, and strength to the PTT. Its anatomic position is similar to the FDL, although it requires a more extensive dissection. The procedure begins in the same manner as the FDL transfer, with the same skin incision, and exposure, examination, repair, and tenosynovectomy of the PTT performed as before. The FHL tendon is identified beneath the sustentaculum tali and traced distally to the knot of Henry. The FHL tendon can be secured at the knot of Henry to the FDL tendon, depending on surgeon's preference, with non-absorbable suture.[33] The FHL is divided proximal to the anastamosis, identified posterior to the ankle joint, and delivered proximally through its tunnel to be rerouted anterior to the neurovascular bundle and adjacent and inferior to the PTT.[15] The FHL tendon is then passed through the PTT sheath to the navicular and inserted through a drill hole in the same manner as the FDL, or sutured to the periosteum of the navicular tuberosity distally, and anastamosed side-to-side to the PTT using non-absorbable suture with the foot held in a position of equinus and inversion.[33] As in the FDL transfer, if the PTT is significantly pathologic, a débridement is performed, and the PTT insertion and muscle used only after inspection has proven them viable to incorporate. The reefing of the spring ligament was recommended as an adjunct to the procedure by Goldner et al.[33] The PTT

Table 8

FDL TRANSFER OUTCOME RESULTS

Author	No. of Patients	PTTD stage	Follow-up	Results
Conti et al	20	J&S Stage II correlation	6.7-24.4 mo.	6 of 20 deemed failure due to recurrent pain or deformity
Shereff	17	J&S II	11-60 mo.	Subjectively 16 of 17 patients satisfied with procedure
Jahss	6	J&S Stage II correlation	10-36 mo. unaffected side	20-25% increase in power over
Quinn and Mendicino	2	J&S Stage II correlation	6-12 mo.	Pain free at 6 mo.- 1 yr.
Mann	20	J&S Stage II correlation	Not listed	All patients remained symptomatic, but improved subjectively
Mann and Thompson1	16	J&S Stage II correlation	13-56 mo.	12 pt excellent, 1 good, 3 fair, 1 poor
Mann and Thompson1	73	Not listed	27-165 mo.	64 pt satisfied, 11 dissatisfied
Feldman et al	11	J&S II	25-48 mo.	6 pt excellent (5 w/100% relief), 3 good, 2 poor
Myerson and Corrigan	32	J&S Stage II correlation	14-48 mo.	30 pt satisfied w/ many experiencing 94% relief
Pomeroy and Manoli *	17	J&S II	17.5 mo.	15 pt w/ mean AOFAS increase 17.5–82.8, 2 pt w/o sig. increase from pre-operative score

*Pomeroy and Manoli in their study transferred the FDL to the medial cuneiform sheath may be closed over both tendons, and tissues closed anatomically. Goldner et al performed a TAL with his two reported cases, listing equinus as a major deforming force in the late stage II foot.[33]

Goldner et al reported a postoperative course of a long leg cast for 4 weeks, followed by short leg walking cast for 3 weeks, and aggressive physical therapy at 7 to 8 weeks, with return to normal shoe gear by 3 months.[33] In their report, 2 patients were followed, and at 10 months and 2 years both patients could perform full activity without deficit. They recommended immobilization for a minimum of eight weeks to allow for adequate tendon maturation.

Though this tendon is the most similar to the PTT in its relative strength and thickness, its utilization has not become commonplace when compared to the FDL. This may be due to the need for the additional dissection required as compared to the FDL tendon. The concern regarding the loss of function of the FHL has also been raised. Quinn and Mendicino state that the FHL functions later in the gait cycle then the FDL, and is more important to normal gait.[15] However, Goldner et al reported the loss of the FHL tendon did not cause significant postoperative complications in patient gait or daily activities.[33] No long-term studies have been performed with results to support or negate an advantage of the FHL tendon over the FDL tendon.

TIBIALIS ANTERIOR TENDON TRANSFER (COBB PROCEDURE)

Although the FDL and FHL are the most commonly encountered tendon transfers in the literature for PTTD augmentation, the split tibialis anterior (TA) transfer continues to grow in popularity. Authors such as Weil endorse the Cobb procedure because they do not like the concept of sacrificing the FDL due to its important biomechanical role in the foot.[50]

Lowman, using it as a suspension structure, passing it under the navicular in an attempt to reconstruct the arch50, first described utilization of the TA for flatfoot reconstruction in 1923. Around 1979, Nigel Cobb started utilizing a split TA tendon transfer for the treatment of tibialis posterior tendon dysfunction/disorders.[51] Since its advent, authors such as Janis, Weil, and Helal have published reports on its use.[32,50,52] Weil et al use this procedure in the symptomatic PTD patient with positive MRI findings of disruption/elongation of the PT tendon and no clinical forefoot abductus.[50] Cobb adds that the foot must be supple, with full passive correction available in the subtalar and midtarsal joints.[50] Mahan and Flanigan1 describe its use in the J&S stage I PTD in conjunction with tendon debridement.

Cobb initially described the procedure utilizing a medial incision starting 10-12 cm proximal to the ankle extending to mid first metatarsal shaft.[51] Dissection is carried down to the diseased PT tendon, which is resected. A secondary anterior incision 10 cm in length is then made over the anterior muscle compartment. The tibialis anterior tendon is subsequently split proximally near the muscle belly, and the anterior half is passed distally through its sheath to its insertion. The tendon is then passed plantar, posterior, and medial through a drill hole in the medial cuneiform, into the PT sheath and passed across the deficit produced by the removal of diseased tendon. With the foot plantarflexed, inverted, and adducted, the split tibialis anterior tendon is sutured to the proximal stump of the PTT with transverse sutures.

Weil et al modified the procedure making 2 separate incisions, one over the course of the PTT from behind the medial malleolus to the base of the 1st metatarsal base, and another 1 cm incision in the anterior leg over the TA tendon 5 cm proximal to the ankle.[50] Further, they detach the medial half of the tendon and instead of making a drill hole in the medial cuneiform, describe a subperiosteal channel under the medial cuneiform. Finally, they interweave it within the PTT securing it with absorbable and nonabsorbable suture, enough for a double thickness repair. Janis et al use a dissection approach similar to Weil et al, but describe a drill hole from proximal dorsal to distal plantar through the navicular instead of the medial cuneiform. They also describe an "end-weave" tenodesis, placing three stab incisions in the proximal stump of the PT tendon and weaving the split TA tendon through these stab incisions, reinforcing them with nonabsorbable suture.[52]

Postoperatively Cobb described nonweightbearing for 6 weeks, easing the cast from a supinated position to a neutral one in 2-week intervals.[51] Helal described the same procedure in patients with PT rupture with 3 weeks NWB followed by 4 weeks WB with a plaster cast.[32]

Janis et al reviewed 17 cases of Cobb procedures and found pain relief and ability to walk to be fair to excellent in 15 of 17 cases. 92% of the cases were able to return to previous activities, with the average time to return being 3 months.[52] In another study by Weil et al with an average follow-up of 29 months on five patients, pain reduction went from an average of 7.2 (pain scale 1-10 with 10 being worst) to an average of 1.1.[50] Helal performed Cobb procedures on 6 patients (2 bilateral), noting five patients being "restored to normal". One of the bilateral cases had residual deformity but fewer symptoms. Helal reported better results with the Cobb versus the other augmentation techniques including the FHL and FDL transfers.[32] The Cobb procedure, although minimally described in the literature, appears to be a useful adjunct in the repair/ augmentation of the PTD patient.

ADDITIONAL TENDON AUGMENTATIONS

Song and Deland[40] reported on the utilization of a Peroneus Brevis tendon (PBT) transfer for treating PTTD. The indications for its utilization was a smaller than normal FDL tendon during augmentation. They reported only a 10% recurrence over a two-year period. In their procedure the FDL transfer was performed as previously described. But after the observation of an inadequate FDL, an additional incision was made over the base of the fifth metatarsal to expose and release the PBT from its insertion. An additional incision was made above the level of the ankle along the PBT. The tendon was freed and passed behind the tibia and into the medial wound. The PBT was passed through the PTT sheath and into the same navicular bony tunnel as the FDL transfer. Following a medial calcaneal displacement osteotomy, the tendons were secured in the tunnel with the foot in a plantar flexed and inverted position by securing them to the periosteum and surrounding soft tissues with non-absorbable suture.

Thirteen patients underwent the PBT transfer and were retrospectively identified. They were then matched to patients of the same age and length of follow-up to patients that underwent standard reconstruction without PBR transfer, finding no significant difference in the inversion or eversion strengths of the two groups when compared at 20 months. It was concluded that although a PBR transfer does not increase inversion strength, it can be used to augment a small FDL without causing significant eversion weakness.

AUTHOR'S SURGICAL APPROACH TO PTTD

Regardless of whether you are performing a simple debridement, isolated tendon repair or augmentation repair procedure with tibialis anterior or flexor digitorum longus, the incisional approach to expose the PT tendon remains essentially the same; only the length of the incision varies to any significant extent. Success of any of the procedures begins with complete exposure and visualization of the PT tendon itself and must include the full extent of diseased tendon. Ancillary incisions will be required to perform the augmentation repair techniques used to reinforce the repair.

Proper incision planning requires careful digital palpation of the tendon from its insertion at the navicular tuberosity proximally into the leg (Figure 1). The incision is carefully mapped out directly overlying the tendon itself and is based upon the clinical findings and MRI interpretation of the extent of disease. Once the incision is performed, dissection is carried down to the level of the overlying deep fascia and flexor retinaculum, a very distinct layer of tissue readily separated from the overlying subcutaneous tissue. Hemostasis is acquired with electrocautery and/or ligatures of absorbable sutures. Areas of bulbous formation or out-pouching are commonly appreciated and represent underlying areas of tendon disease and healing as well as active synovitis, which can be quite profound.

The tendon is carefully palpated again. A small 1-2 cm incision is made directly overlying a readily palpable area of the tendon usually adjacent to the medial malleolus; it may be just proximal or distal to the malleolus depending on the extent and nature of pathology. In most cases significant fluid will immediately exude from the tendon sheath and represents inflammatory changes which have been present along the course of the tendon (Figure 2). The tendon will be readily visualized. A tendon passer or groove director is then inserted into the sheath along the tendon's course to guide complete and accurate incision of the sheath; it is carried distally to the level of the navicular tuberosity and proximally to the level of healthy, normal appearing tendon. This aspect of the surgery is most important to ensure complete closure of the fascia over the tendon following successful repair. The incision should not be

Figure 1. Skin incision planning with incision drawn directly over the course of tendon based upon careful palpation. Cross hatch marks help ensure accurate closure of skin following surgical repair.

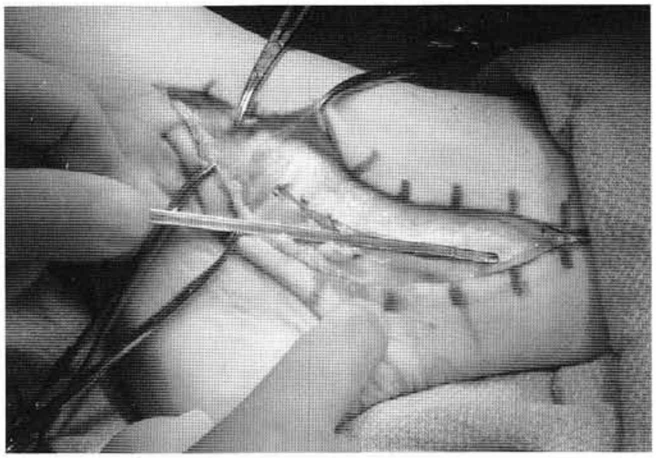

Figure 2. A section of the skin incision has been completed and dissection carried down to the deep fascia overlying the tendon. Incision stab incision into the tendon sheath confirms proper placement. Inflammatory fluid can normally be seen exuding from the sheath. The groove director aids in precise opening of the PT tendon sheath.

onto the medial edge of the tibia itself or overlying the next compartment housing the flexor tendon. On rare occasion the device will not follow the course of the tendon and will be resisted by an area of adhesion of the ruptured tendon to the sheath. In such cases several small stab incisions are made and the areas eventually connected to provide full exposure.

Complete debridement of the tendon and tendon sheath is performed (Figures 3,4). Areas of synovitis and pannus-like formation are débrided from the sheath and tendon. The tendon is removed from its compartment to ensure complete and thorough removal of as much diseased tissue as possible. The tendon itself is likewise débrided. Careful inspection of the tendon on all surfaces will reveal the extent of pathology including longitudinal ruptures, transverse ruptures, degenerated and retracted tendon. In some cases the outer surface will show minimal or no disease while the underside of the tendon demonstrates extensive tendon disease. This can be alarming to the inexperienced or novice surgeon sometimes causing the surgeon to think than an error has been made with assessment of the extent of disease and whether surgery should have even been attempted.

The senior author, while being aggressive with the debridement process, attempts to leave some tendon as a scaffold for the repair. On occasion this means leaving a scaffold of abnormal tendon on which to build but is felt important to the overall repair construct. We try not to complete excise full thickness area leaving a complete void of the PT tendon itself.

At this point, an intraoperative decision is made as to whether a direct primary repair or repair with tendon

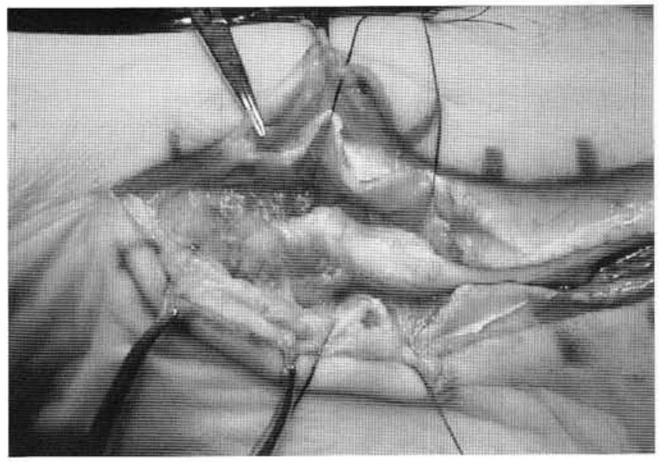

Figure 3. Sheath has been opened for initial inspection of the tendon. The insertion is readily visualized and demonstrates significant tendon disease with areas of adhesive synovitis.

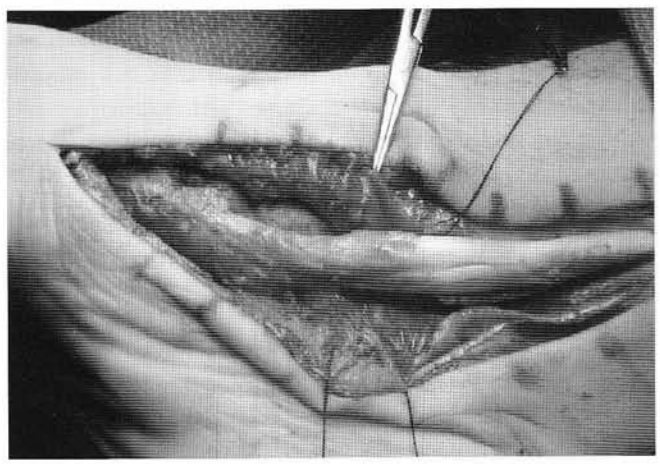

Figure 4. All adhesions have been released and synovitis debrided. Compromise of the tendon is appreciated including longitudinal slits on the superior surface.

transfer or augmentation procedure will be performed. This decision is easy and even obvious in some cases and in other cases, quite difficult. A number of factors will influence the decision of the type of repair including the surgeon's personal philosophy and experience, the patient's overall foot type and biomechanical function (i.e. degree of pronatory instability) as well as other factors such as the patient's overall body type, weight, functional demands and ability to be compliant and complete the postoperative rehabilitation and physical therapy requirements. It is important that surgical experience alone is not the determining factor as this will preclude the patient from receiving the best tendon repair technique to ensure the best functional outcome.

Direct primary repair is performed in patients when the remaining tendon bulk and mass are sufficient and the areas of rupture readily repaired using conventional tendon repair techniques. Longitudinal tears and slits are repaired using internal continuous locking stitches and/or an external continuous suture technique. We prefer a combination of non-absorbable polyester braided suture such as Polydek® (Deknatel DSP, Fall River, MA) or Ethibond® (Ethicon, Somerville, NJ) supplemented with synthetic absorbable braided sutures such as Vicryl® (Ethicon, Somerville, NJ). Other absorbable sutures can also be used and will depend on the experience and preference of the surgeon. We typically employ sutures of 0 or 2-0 size; rarely is larger diameter suture needed in our experience. When partial or complete transverse ruptures are present more sophisticated suture technique may be necessary such as the Bunnel, Kessler-Tajima, Lateral Trap and/or Krackow techniques, which will reapproximate the tendon ends and provide a secure repair with or without augmentation. A Z-plasty lengthening of the tendon rupture site is also sometimes indicated. If we are satisfied with the overall repair construct we will proceed with closure. If not, the repair is then augmented and reinforced with either the tibialis anterior or flexor digitorum longus or in rare cases both tendons.

Immediately adjacent to the PT tendon, in the next (second) compartment of the flexor retinaculum, is the flexor digitorum longus tendon (Figure 5). It is most readily visualized proximal to the medial malleolus; the more proximal the dissection, the more readily visualized is the tendon. Proximally a thin membrane of tissue and a layer of paratenon separate it from the PT tendon. As the tendon progresses more distally it is well contained in its own compartment with a distinct fascial layer dividing the second and first compartments. The FDL follows a specific will-defined fibrous tendon tunnel as it progresses into the plantar aspect of the foot. A tendon passer will readily demonstrate the course of the tendon as it progresses distally into the plantar aspect of the foot deep to the intrinsic musculature at the plantar medial side of the foot. The paratenon and fascial tissues surrounding the FDL are completely excised including the fascia at the level of the medial malleolus, which separates the two compartments. This in effect places the PT and FDL tendons into one larger compartment. The laciniate ligament and deep fascia overlying the tendon is not directly incised, as the FDL tendon is completely accessible through the same initial fascial incision and dissection described above to expose the PT tendon.

If the tendon pathology of the PT tendon is proximal to the medial malleolus one can perform a simple side-to-side anastamosis of the PT and FDL tendons without the need to dissect the tendon more distally. The side to side anastamosis is performed most commonly with 2-0 or 0 braided polyester sutures with a continuous interlocking stitch which passes through each of the tendons (Figure 6), or if desired in a manner which tubularizes both tendons circumferentially; although usually not necessary, both techniques can be performed together.

In most cases the tendon pathology of the PT tendon includes or is confined to the area immediately adjacent to the medial malleolus or the area between it and its insertion into the navicular tuberosity. In these cases, or in situations where the insertion of the PT tendon is significantly compromised, the FDL tendon will be detached distally, usually just proximal to the Master Knot of Henry; it will be secured to the tuberosity itself with a soft tissue anchor or more commonly through a drill or trephine hole from plantar to dorsal. The function of the FDL tendon is preserved through its

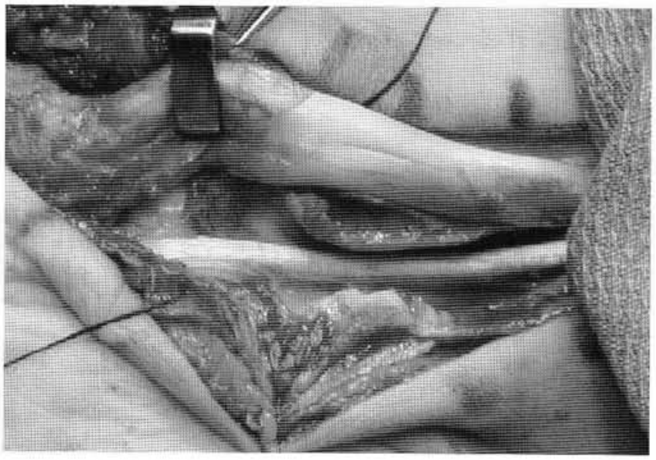

Figure 5. The PT tendon has been pulled out of its tunnel and retracted. The FDL sheath has been opened along the course of the tendon immediately adjacent to the PT tendon. The portion of the sheath dividing the two tendons has been excised. Following repair both tendons will be closed in one compartment.

Figure 6. Completion of first stage of side-to-side anastamosis of PT and FDL tendons. An additional suture will be placed tubularizing the two tendons.

attachment to the flexor hallucis tendon at the Master Knot of Henry, a more than convenient anatomic configuration that ensures preservation of flexor tendon function to the lesser toes. Procurement of the distal end of the FDL tendon is perhaps the most meticulous and detailed aspect of this surgery and if not performed meticulously can be intimidating to even the most experienced surgeon.

A curved tendon passer is the key instrument to follow the FDL into the plantar vault of the foot with minimal disturbance to the surrounding soft tissues and neurovascular structures that are in close approximation to the FDL tendon. The skin incision is carried distally to the level of the medial cuneiform; the subcutaneous dissection is carried to the level of the deep fascia. The abductor hallucis muscle is undermined and retracted inferiorly. Natural planes of separation are readily identified with meticulous dissection minimizing trauma and damage to the tissues. A tendon passer is passed through the compartment of the FDL tendon into the plantar aspect of the foot. Under direct visualization and palpation, the fascia is released providing ready, immediate visualization and access to the flexor tendon as it passes deep beneath the intrinsic musculature to the knot (Figure 7). Proximal tension is placed on the tendon to confirm it is the FDL tendon. Eventually, as one progresses more distally, proximal traction will cause simultaneous plantarflexion of the hallux and lesser toes indicating you have now reached the point at which the FDL and FHL tendons are joined. It is just proximal to this point that the FDL tendon is transected. Before cutting the tendon, proximal traction is again placed on the FDL tendon to withdraw as much of the tendon into direct visualization before cutting. The FDL tendon has now been harvested and is ready for transfer into the navicular tuberosity.

There are several techniques for transferring the tendon. The tendon can be sutured side to side to the PT tendon or more commonly interwoven through the PT tendon through a series of longitudinal slits typically no longer than 1.0 cm (Figure 8). In some cases we have simply delivered the entire tendon down a central defect of the PT tendon and referred to this technique as a "hot dog and bun" configuration. In this case a continuous interlocking stitch is performed which is circumferential around the entire tendon repair complex. It is important to ensure that appropriate "physiologic" tension is placed on the tendon before suturing and/or anchoring the tendon to the navicular.

While soft tissue anchors are commonly employed and seemingly the "in-vogue" technique, the senior author discourages this technique in favor of a more physiological approach. The tendon is passed from plantar to dorsal through a trephine hole in the navicular tuberosity simulating the normal attachment of the PT tendon (Figure 9). Depending on the size of the trephine hole, bone can be packed into the hole to secure the attachment. Finally, the tendon is sutured to the surrounding periosteum with suture of choice.

Another technique we have commonly employed is a split transfer of the Tibialis Anterior (TA) tendon especially in situations where there is medial column instability or supinatus or where greater tendon bulk is required to reconstruct the TP tendon. While there is no conclusive evidence that this transfer technique is superior to the FDL transfer described above, we feel that a partial split transfer of the tendon may weaken the TA muscle slightly, giving advantage to its opposing muscle

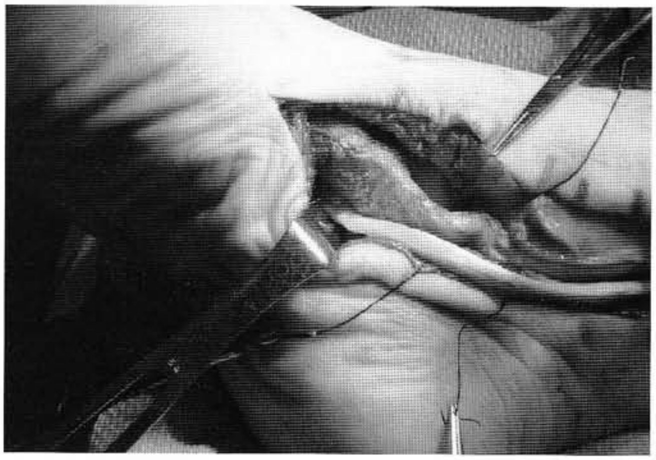

Figure 7. Visualization of the FDL tendon into the plantar aspect of the foot deep to the navicular tuberosity. The Master Knot of Henry is just distal to the visualized point.

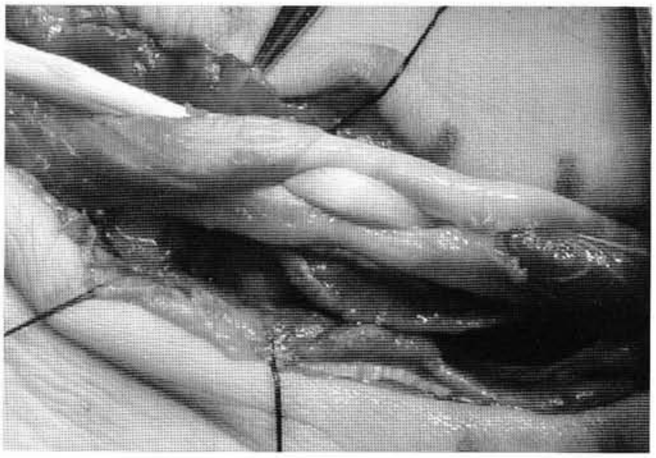

Figure 8. FDL tendon interwoven through a series of small slits in the PT tendon. Following complete interweaving and appropriate distal tension on the FDL, the anastamosis is secured with a combination of absorbable and nonabsorbable sutures.

the peroneus longus. This in turn might be more effective to stabilize the medial column and thus the midtarsal and subtalar joints.

The original surgical incisions must be extended distally to the level of the first metatarsocuneiform joint to visualize the insertion of the TA tendon (Figure 10). The actual insertion of the TA will not be disturbed. A second ancillary incision is made over the TA in the anterior aspect of the leg just lateral to the tibial crest, which is readily palpated and visualized (Figure 11). The length of TA tendon needed to repair the ruptured PT tendon determines the precise location of this incision. An umbilical tape is used to simulate the transfer and determine the length of tendon required for the repair. An extra centimeter or so is recommended to ensure adequate length (Figure 12).

The incision is carried down to the deep fascia and paratenon, which are incised and reflected. There are no neurovascular structures of concern at this level making the dissection and exposure of the TA simple and efficient. Using a small hemostat, the entire TA tendon is bluntly separated from the muscle belly and the medial one-half of the tendon secured with heavy 0 polyester suture (Figure 13). A long double stranded suture tag (5-10 cm.) is left to facilitate transfer. The medial one-half of the tendon is transected. A long tendon passer or more frequently uterine packing forceps are inserted from the distal insertion, up the tendon sheath to the proximal anterior leg incision. The suture strands are grasped and pulled distally through the sheath and the entire tendon complex pulled distally effectively splitting the TA tendon into halves (Figure 14). The distal insertion is not com-

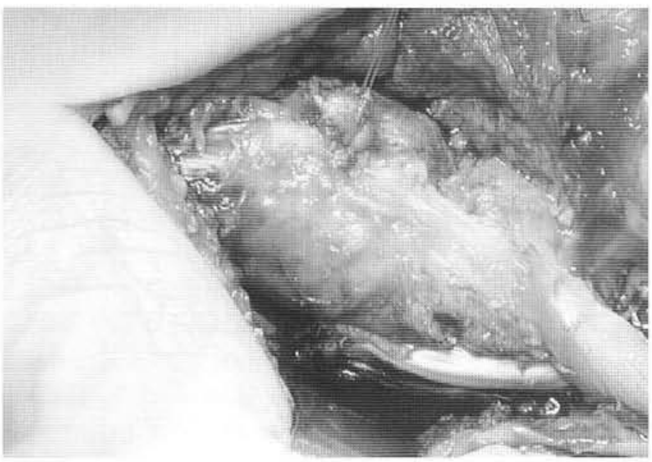

Figure 9. The distal stump of the FDL tendon has been secured to the navicular tuberosity plantarly with heavy gauge suture. A tendon anchor device can also be employed.

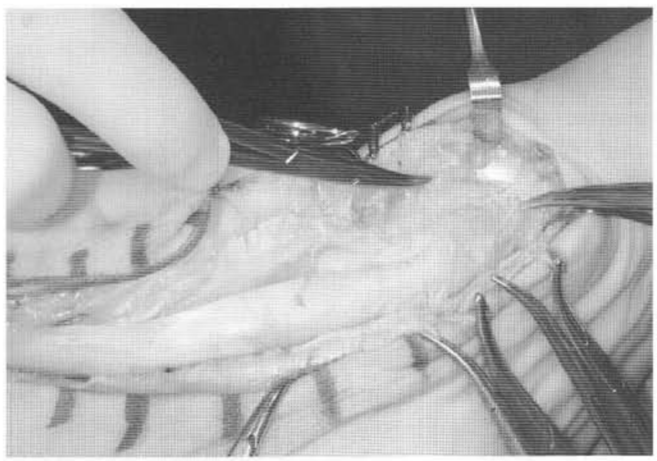

Figure 10. Exposure of the TA tendon at the level of its insertion into the medial cuneiform. A small incision has been made through the deep fascia covering the tendon to allow passage of a tendon passer or uterine packing forceps to retrieve the tendon proximally in the leg without the need for a large skin incision.

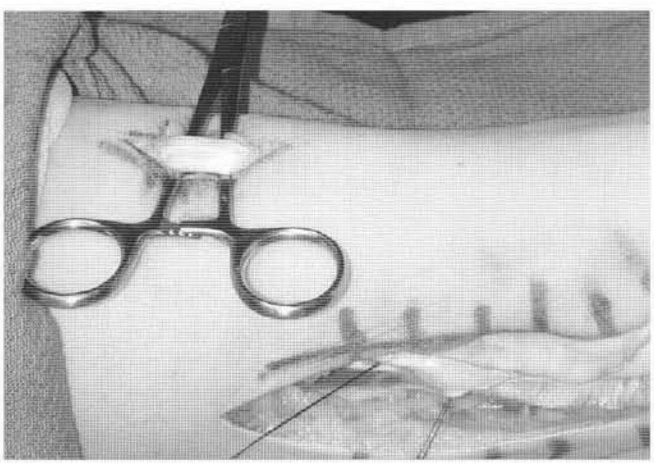

Figure 11. Surgical exposure of the TA tendon proximally in the leg. Only a small incision is required to harvest the tendon proximally. The deep fascia has been incised and reflected.

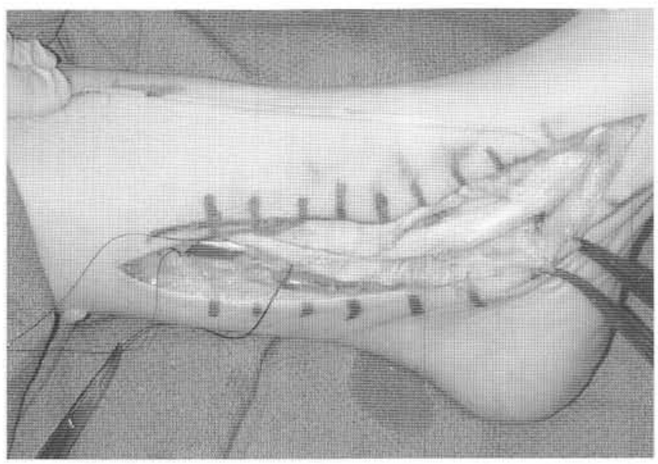

Figure 12. Umbilical tape being used to simulate the amount of length of the TA tendon desired for transfer to ensure complete coverage of all areas of diseased PT tendon. It is desirable to attach the TA into normal appearing PT tendon following transfer.

promised. The withdrawn tendon is used to repair the PT rupture. Several options exist for the repair.

While the tendon can be passed through the navicular tuberosity or anchored with a tendon anchor device, we have not found this to be necessary. We create a subperiosteal tunnel from the insertion of the TA at the medial cuneiform to the navicular tuberosity at the insertion of the PT tendon (Figure 15). The TA is passed through the subperiosteal tunnel and sutured to the PT tendon at its insertion point with heavy absorbable or non-absorbable suture while placing proximal tension on the tendon with the medial column maximally plantarflexed. This technique stabilizes the medial column similar to the Young's tenosuspension procedure commonly done as an adjunct in flexible flatfoot reconstruction. The remaining length of the TA tendon is then used to reinforce and repair the PT tendon. As previously described it can be interwoven through a series of small stab incisions, secured in a side-to-side anastamosis fashion or fed down a central defect of the tendon in a "hot dog and bun" manner. The technique employed depends on the type and extent of rupture and the anatomic configuration of the tendon following debridement and initial repair.

The wound is irrigated aggressively. The deep fascia and flexor retinaculum are repaired with 2-0 absorbable suture of choice in a continuous interlocking stitch (Figure 16). The subcutaneous layer is re-approximated with 3-0 or 4-0 synthetic absorbable sutures and the skin typically with 5-0 synthetic absorbable suture in a subcuticular manner. The incision is reinforced with wound closure strips. A dry sterile dressing is applied and

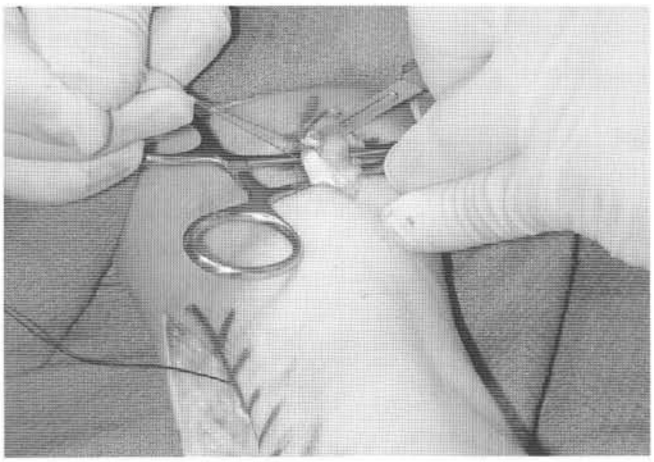

Figure 13. One half of the TA tendon tagged with heavy suture material, which will be used to pull the tendon through from proximal to distal. One half of the tendon retains complete integrity. Following securing of the tendon with the suture, the tendon is transected.

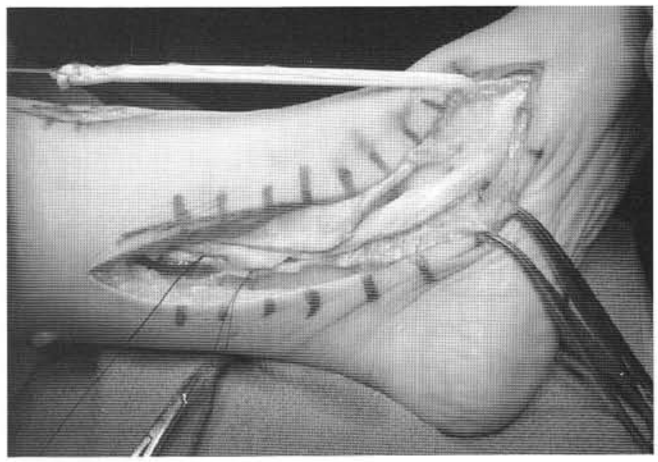

Figure 14. The TA tendon has now been harvested. The distal insertion has been preserved. The tendon is now ready to be used to repair and augment the PT tendon.

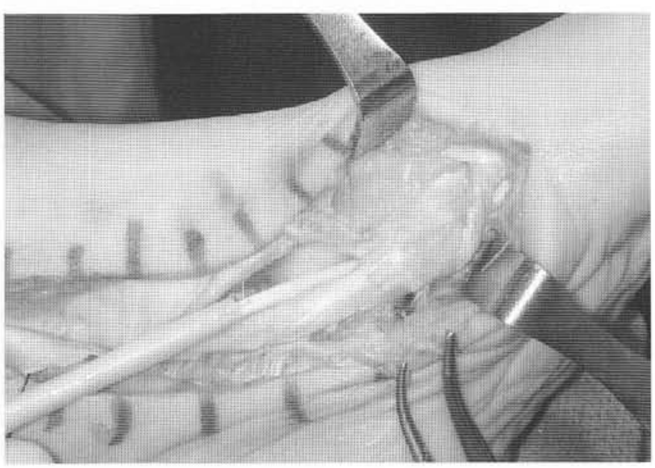

Figure 15. Passage of the TA tendon through a subperiosteal channel deep to the PT tendon at its insertion into the navicular tuberosity. The preservation of the distal insertion allows proximal traction on the rerouted TA tendon to enhance stability of the medial column.

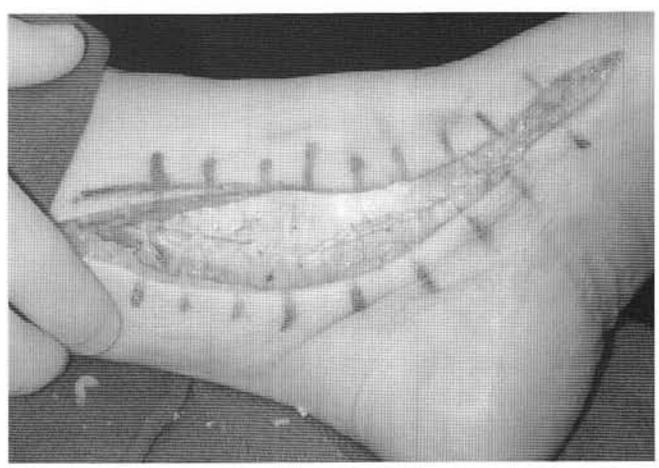

Figure 16. Closure of the deep fascia and flexor retinaculum over the repaired PT tendon complex. Closure is the same for both TA and FDL tendon augmentation techniques. Only one compartment is closed. Both the tendons are now contained within a single compartment.

the foot placed in a short leg Jones compression bandage or, more commonly, a cast with the foot held in neutral to slightly supinated position.

POSTOPERATIVE MANAGEMENT

The postoperative course depends on whether other major osseous procedures have been performed but typically consists of a short leg cast for 6-7 weeks; the first 4 weeks are non-weightbearing, the fifth week weightbearing without ambulation and the final week(s) with full weightbearing and ambulation as tolerated. A short leg removable walking cast brace may be employed for an additional 3-4 weeks. Physical therapy is instituted to assist with resolution of edema and strengthen the PT tendon. An appropriate custom orthotic device or brace is prescribed as needed.

DISCUSSION

The purpose of this paper is to provide the reader with a detailed description of the various surgical techniques that the senior author and others have employed for many years when repairing ruptures of the PT tendon. It is hoped that the detailed description will enhance the surgical techniques of surgeons who perform surgical repairs of PTTD. The surgical pearls described have proven very effective over the years. In most cases symptoms of pain are greatly reduced or eliminated altogether providing a good functional result. Position of the foot is generally not altered by these procedures alone. Downey[53] has indicated that the FDL transfer, although a smaller tendon, has consistently resolved symptoms associated with PTTD despite the continued loss of arch height in the foot postoperatively.

A variety of ancillary procedures may be performed if soft tissue repair alone is deemed inadequate. The specific procedure(s) performed will vary and is/are dependent on a number of factors including the nature and extent of the tendon rupture itself, the degree of pronatory changes in the foot in comparison to the contralateral foot, the functional demands expected postoperatively, the degree of degenerative changes in the major tarsal joints, as well as the patients overall health status and the experiences of the surgeon to list a few. Possible procedures include various calcaneal osteotomies, the most common one being a medial displacement osteotomy and/or medial column osteotomy or fusion; single, double or even triple joint arthrodesis alone or in combination with gastrocnemius recession or tendoachilles lengthening. Numerous approaches have been described and advocated over the years reinforcing that no single procedure or combination of procedures has been shown to be effective in all cases.

Clear clinical and/or radiographic guidelines and criteria for any single procedure or combination of procedures are lacking. While there are several classifications and staging schemes described in the literature, the senior author has not found one to be superior over the others. Rather each classification has been found to offer different criteria that deserve careful thought and consideration when selecting a most appropriate approach for a given patient. A thorough discussion with each patient is essential in order for the patient to have realistic expectations and a realistic outcome. The senior author feels there is considerable art and science to the management of this sometimes very difficult clinical problem. Continued critical evaluation and assessment of individual outcomes has been the most influencing aspect altering the senior author's own philosophy and beliefs about the disease entity of PTTD/rupture. We continue to maintain an open mind about the most effective and predictable method of treatment whether it is conservative or surgical. One routine approach to all cases only invites inevitable failure. Continued research is needed to further understand the pathophysiology of this distinct clinical entity and to better define criteria for successful management. We hope that the reader finds the information contained in this article helpful in refining surgical technique as one way to improve upon the surgical management of PTTD.

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