Tibiotalocalcaneal Arthrodesis

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ABSTRACT

The purpose of this multicenter retrospective study of 55 patients (56 ankles) who underwent simultaneous tibiotalocalcaneal arthrodesis with eevere disease involving the ankle and subtalar joints was to determine improvement of pain and function. The surgical Indications included osteoarthritis, posttraumatic injury, failed previous surgery, talar avascular necrosis, osteoarthritis, and rheumatoid arthritis involving the ankle and subtalar joints. The average age at the time of the operation was 53 years. The average time of follow-up was 26 months after the operation. Fusion was achieved in 49 ankles, with an average time of fusion of 18 weeks. Forty-eight of the 55 patients were satisfied with the procedure. The average leg length discrepancy was 1.4 cm. The average amount of dorsiflexion was 2 degrees and planter flexion was 5 degrees. Following surgery, 42 patients complained of pain, 40 patients required Shoe modification or an orthotic device, and 34 patients had a limp. Fourteen patients described their activity as unlimited. Based on the AOFAS evaluation, the patients scored an average of 66 on the ankle-hind foot scale following surgery. The mo6t common complications were nonunion (8 ankles) and wound Infection (6 ankles). This study demonstrates that tibiotalocalcaneal arthrodesis is an effective salvage procedure for patients with disease both Involving the ankle and subtalar joints.

INTRODUCTION

Patients with disease involvement of both the ankle and subtalar joints can have symptoms of pain, deformity, and limited ambulatory capacity on the affected limb. Treatment options are limited; rtonope measures may help decrease some of the symp but much of pain and deformity remain. Surgical ment is aimed at obtaning a painless, brace plantigrade foot, and tibiotalocalcaneal arthro offers an effective surgical treatment. This metho< discussed by Russotti and Johnson[1] in 1988 a not commonly performed. It has been reported quently, with the largest series being 30 cases" '" and most series involve Charcot foot problems purpose of this study was to determine the frequ Of this procedure and report on the clinical results use of the AOFAS evaluation for the ankle-hindfc

MATERIALS AND METHODS

Between 1991 and 1998, tibiotalocalce arthrodesis was performed by 9 surgeons at respective 9 Institutions on 55 patents (56 ankle which 30 patients were women (31 ankles) an were men (25 ankles). The average age ot the pat at the time of surgery was 53 years (range, 19 I years).

The indications for surgery were severe arth and associated deformity and pain involving both ankle and subtalar joints from one of the follo: posttraumatic injury (14 ankles), failed previous gery (12 ankles), osteoarthritis (11 ankles), nvas necrosis of the talus (7 ankles), rheumatoid arthri ankles), failed total ankle replacement (2 ant Charcot-Marie-Tooth disease (2 ankles), and Ch. foot (2 ankles). All patients had failed nonsur treatment.

All patients were interviewed and underwent p cal and radiographic examination. The average fo up time was 26 months after the time of oper, (range, 12 to 168 months). The physical examin. involved evaluation ot the limb for tenderness, j lion, and range of motion. The position of the foot assessed in the standing position with a hand

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goniometer. Weight-bearing radiographs were taken of the operated ankle in the anteroposterior, lateral and mortise planes, and of the foot in the anteroposterior and oblique planes. Fusion was determined by radiographic consolidation at the arthrodesis site.

The American Orthopaedic Foot and Ankle Society Clinical Mating System Ankle-Hind Foot Scale was used for evaluation. This includes subjective and objective factors into numerical scales to describe function, alignment, and pain.

SURGICAL TECHNIQUE

An intramedullary rod was used in 37 procedures, screws in 17 procedures, an external fixator in one procedure, and a plate and screws in one procedure. Autogenous bone grafting was utilized in 42 cases, and allograft in one case.

In most cases, the intramedullary fixation device was used. A transfibular approach is utilized between the sural nerve and the lateral branch of the superficial peroneal nerve, similar to the method described for ankle fusion." The articular cartilage was removed from the tibiotalar joint with a saggital saw. Frequently, a small medial incision was used to remove the medial malleolus. Next, the articular surface was removed from the subtalar joint. Any deformity involving the ankle or hindfoot was corrected with the saw cuts. The hind foot was placed in approximately 5 degrees of valgus with neutral dorsi-plantar flexion. The amount of external rotation was equal to the contralateral foot, approximately 5 to 10 degrees. If there was extensive bone loss, iliac crest bone graft was utilized.

When an intramedullary rod was used, a small transverse incision was made on the plantar aspect of the heel at the level of the distal and middle third of the heel pad. A guide wire was placed through the calcaneus, talus, and into the tibia, and the position was confirmed with image intensification. Reaming was accomplished over the guide pin, and then the rod was placed in a retrograde fashion. The interlocking screws were drilled and filled. The wound was closed in layers over a drain, and a bulky compression dressing with splints was placed.

The drain was removed after 24 hours. The dressing and sutures were removed 10 to 14 days following surgery. A short leg cast was placed, and nonweight-bearing was continued for a total of 3 months, following which progressive weight-bearing was begun in a short leg walking cast. The extremity was protected with a cast until clinical and radiographic healing was satisfactory.

RESULTS

Fusion was achieved clinically and radiographically in 47 patients (48 ankles), with an average time to fusion of 19 weeks (range, 12 to 65 weeks). These patients had no motion at the arthrodesis site and consolidation was seen radiographically. The average time of immobilization was 20 weeks.

Forty-eight of the 55 patients were satisfied with the procedure. Seven patients were not satisfied with the results, because of nonunion of the ankle arthrodesis in 5 patients, residual severe pain in one, and limited activity level in one. Two patients complained of severe pain, 7 of moderate, 33 of mild, and 13 had no pain.

Nine patients use an AFO, of which 2 had anterior tibial pain from a stress reaction to the rod. Thirty-one patients require some form of shoe modification. Must of the modifications consisted of a soft insert or orthotic device. Forty-one patients had limited activity, of which 2 used a wheelchair, and one was house bound. The remaining 14 patients described their activity as unlimited.

The average leg length discrepancy was 1.4 cm as measured with blocks. The average position of fusion was 3 degrees of valgus. The average range of motion of dorsiflexion was 2 degrees, and plantar flexion was 5 degrees, which took plate through the distal tarsal joints. Wearing shoes, 35 patients had a flatfoot gait and limped.

The AOFAS ankle/hind foot score is based on pain (40% of the total score of 100 points), function (28%), motion (22%), end alignment (10%). The average postoperative ankle-hind foot scale was 66.

COMPLICATIONS

Thirty-eight ankles healed without complications. There was nonunion of the ankle arthrodesis in 8 patients, superficial wound infection in 5, and there was one case of each of the following complications: deep wound infection (in one case involving a nonunion), skin necrosis, sural neuroma, suture granuloma, delayed union of the ankle arthrodesis, and stress tracture. Of the 8 cases with nonunion, 3 had fixation with screws and 5 had fixation with an intramedullary rod. Additional surgery was required in 16 patients, which included hardware removal in 11 cases, revision for nonunion in 2, and one case of each of the following: removal of a bone growth stimulator, placement of autograft for a nonunion, and resection of a postoperative aural neuroma. The patients with the superficial infections healed with antibiotics and local wound care. The patient with the

deep infection was treated with antibiotics and wet to dry dressings. The patient with the stress fracture healed after 1 month.

DISCUSSION

Arthrosis involving both the ankle and subtalar joint is one of the most difficult problems facing the orthopaedic foot and ankle surgeon. Patients complain of moderate to severe pain, deformity, and disability. The goal of tibiotalocalcaneai arthrodesis is to alleviate pain and provide a stable plantigrade foot for ambulation. Often, bracing this type of deformity is not possible because of the severe deformity. In cases of failed ankle arthrodesis, failed total ankle replacement, and avascular necrosis of the talus, pain and instability progress. It would be preferable to avoid performing a fusion of both joints because of the significant loss of motion.6 Following a pantalar arthrodesis, dorsiflexion is decreased 63% and plantar flexion 82%, which results in a significant increase in the amount of stress placed on the surrounding joints. However, arthrodesis of only the ankle joint when the subtalar joint is arthritic will likely result in residual symptoms in the subtalar joint.

Tibiotalocalcaneai arthrodesis has been reported infrequently[1,9,10,11,12,13] until recently and generally show good results. The aim of this study was to obtain data 1rom multiple institutions to evaluate the frequency of the use of this procedure (56 cases from 9 orthopaedic foot and ankle practices), and determine the clinical outcome of this procedure. The AOFAS ankle/hindfoot score was used to provide a value from a system that is widely utilized. To our knowledge, this is the largest reported series of tibiotalocalcaneai arthrodesis.

Tibiotalocalcaneai arthrodesis has been described by Johnson[13] to treat severe pain and deformity involving the hind part of the foot and ankle. Johnson initially reported on this procedure using multiple internal screws or an external fixator. The indications were failed arthrodesis of the ankle, failed total ankle arthroplasty, osteonecrosis of the talus, infra-articular fracture at the ankle that was un-united or malaligned, and neuropathy involving both joints. Satisfactory results were obtained in 75 per cent of 21 patients, and fusion was achieved in 18 patients.

Johnson later devised an intramedullary fixation device (Revision Nail, Smith & Nephew Richards Inc., Memphis, TN) for this procedure to improve on the stability of the fixation, and would avoid complications associated with external fixation devices. Kile4 reporting on using this intramedullary fixation device obtained 87% satisfactory result in 30 patients, and fusion was complete in 26 patients. Twenty-six

patients felt that the operation had been worthwhile There was 1 superficial skin slough, 2 deep infection 1 prominent plantarward rod, and one death fro pneumonia. There were 2 patients with stress rea tions at the proximal end of the nail that healed w immobilization.

In a similar report by Moore et al.[6], retrogra intramedullary redding was evaluated retrospectiv in 19 ankle arthrodesis in 16 patients. The procedu was done as a salvage procedure in each patient significant posttraumatic arthrosis and bone loss. cc comitant subtalar arthrosis, and severe osteoper Union occured in 14 ankles. The complications w nonunion in 5 ankles, one deep infection, and one b ken rod. Thirteen of the 16 patients were ambulate and 9 used an AFO or shoe modification.

This study only had one patient with a Charcot jt of the 51 ankles. In contrast, Pinzur and Kelikia reported on 20 patients (21 ankles) with severe neu pathic (Charcot) ankle deformities who were trea with a retrograde locked intramedullary nail. Ninet ot the 21 ankles went on to fusion at an average of months. In ten of the patients, the talus was retain There were 6 patients who developed late postope tfve wound infections, of which, 3 required remova the nail. One patient with an infection elected to unr go an ankle disarticulation. The authors stated t use of the retrograde locked intramedullary nail is excellent method of obtaining ankle fusion in Charcot patient.

Papa et al." reported on 2 cases of tibiotalo caneal arthrodesis for intractable diabetic neuropa arthropathy of the foot and ankle. One patient ha partial wound slough, but fused in 4 to 5 months. T preferred internal fixation for their patient popula who are prone to infection. In another study by P. et al.[10], 13 patients underwent tibiotalocalcaneai fus for posttraumatic osteoarthrosis of the ankle and r foot. They included patients who underwent pant, arthrodesis, and the results were not separated from each type of fusion. Eighty-one percent w much improved, but 95% had residual pain. Ove the union rate was 86%, and the mean time to fus was 14 weeks. The mean amount of shortening 1.5 cm. There were 3 nonunions (pantalar and li talocaicaneal). The authors found that their nonur rate was low, considering that extended arthrode was performed. They concluded that ft is a com[and technically demanding procedure but a reas able alternative to amputation.

Felix and Kitaoka[7] report the result of 26 ar arthrodeses performed for rheumatoid arthritis or patients. In their series, tibiotalocalcaneai arthrod was performed in 12 ankles. They did not distingi

results of the ankle arthrodesis from the tibiotalocalcaneai arthrodesis patients. Fixation was achieved with external fixation or internal fixation with multiple screws. Nearly all patients were satisfied, and union was achieved in 96%. Their union and complication rate were found to be comparable with rates for arthrodesis for posttraumatic and degenerative arthritis. The authors concluded that for the treatment of rheumatoid arthritis, arthrodesis provides more reliable long term function, and remains the standard of treatment. They also emphasize that patients be educated that they will not have a normal joint function and will continue to have limitations.

Rigid internal fixation with good bony apposition is important for successful fusion. Biomechanical analysis of hindfoot fixation using an intramedullary rod was compared to three cross-cannulated screws[3]. The intramedullary rod with one distal screw inserted provided more stiffness to the hindfoot. We prefer the use of the intramedullary rod when possible. External fixation may be used if the bone stock is insufficient. Autogenous corticocancellous bone graft may be necessary with severe bone deficits.

The time to fusion in this study, 19 weeks, is prolonged as compared to ankle arthrodesis (138 weeks)[1]. This is not surprising because the patients in this study had more severe disease. In a retrospective study on arthrodesis of 81 ankles by Mann and Rongsiad[7], there were 10 nonunions, (12%). The average postoperative score for ankle-hindfoot on the AOFAS evaluation was 74 points, and the rate of the patient satisfaction was 65 (89%) of the 73 patients. In our study, the AOFAS clinical rating system score was consistent with expectations of improved pain and function but with some residual limitations. Many of these patients have co-morbidities that further limit function, such as rheumatoid arthritis. Also, with extensive disease there is usually soft-tissue problems trial affect healing and symptoms.

The scores obtained in this study will be helpful to compare to longer follow-up studies for this procedure. In addition, these values may be used to compare to other procedures involving the ankle and subtalar joints, for example, combined total ankle replacement and subtalar arthrodesis.

The position of the tibiotalocalcaneai arthrodesis is extremely important as with other fusions of the foot and ankle. The optimum position is neutral flexion and 5 degrees of valgus, and 5 to 10 degrees of external rotation.[1] The final result of fusion is dependent on the bony cuts and quality of the bone stock. It is not uncommon for bone affected by chronic disease such as posttraumatic arthritis or rheumatoid arthritis to have some shifting or settling during the healing

process. Rigid Internal fixation may help to avoid this situation. The average amount of shortening of the operated limb was 1.4 cm, and was tolerable for most of the patients. Most did not require a heel lift.

The most common complications with arthrodesis of the foot and ankle are infection, skin slough, neuroma, nonunion, or malunion.[6] The postoperative complication is higher for tibiotalocalcaneai arthrodesis because of previous operations, loss of adequate bone stock, and co-morbidities. The incidence of nonunion in this study is similar to other reports of this procedure. The incidence of infection was slightly higher than seen with ankle fusions. This probably is caused by already compromised soft tissue of the foot and ankle that limits healing capacity. Thus, it is important to evaluate the patientis vascular status and note the risk of complications.

CONCLUSION

Tibiotalocalcaneai arthrodesis is a salvage operation to treat a difficult problem; normal function is not expected with arthrodesis of these two major joints. However, it can be concluded that it is a good treatment option to improve pain and function. As stated by previous studies, we emphasize that patients must be informed that they will not have a normal joint and will continue to have limitations.

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Tendon Fixation in Flexor Hallucis Longus Transfer: A Biomechanical Study Comparing a Traditional Technique Versus Biobasorbable Interference Screw Fixation

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■ ABSTRACT

Augmentation of the Achilles mechanism utilizing the flexor hallucis longus (FHL) tendon transfer to the calcaneus is a well-described procedure. Traditional methods for this procedure require suturing the tendon onto itself after passing it through an osseous tunnel. Tendon fixation techniques that reduce dissection and thus operative time while allowing adequate fixation would be advantageous in reducing patient morbidity from the aforementioned extended operative times. The authors suggest a new technique for transfer of the FHL to the calcaneus as a treatment of chronic Achilles tendon insufficiency. The objective of this fresh cadaver study is to compare the tendon fixation pullout strength of a traditional tendon transfer technique versus bioabsorbable interference screw fixation and, subsequently, propose a less invasive but stronger and more efficient technique for FHL transfer and fixation. Clinical implications suggest more reliable fixation that may allow faster rehabilitation after the procedure. Ten cadaver foot and ankle matched pairs were used after undergoing bone densitometry. A specimen from each cadaver pair had the flexor hallucis longus tendon sutured to itself with #1 Ticron suture (Ethicon) after being pulled through an osseous tunnel. These 10 specimens were assigned to group A. In the contralateral ankle specimen, the flexor hallucis longus tendon was placed into a 6.5-mm osseous drill hole and fixed with a ? x 25-mm bioabsorbable interference screw. These

comprised group B. Mechanical testing of pulloui strength was then performed; pulloui strength and mode of failure were recorded during this testing. Tendon fixation in group A averaged 127.6 N, and group B 170.28 N. By paired 2-tailed Student *t* test, the differences between each matched pair were statistically significant (P = 0.04529). In group A, failure occurred most often at the bone tunnel (6 of 10) and tendon midsubstance (4 out of 10). Failures at the tendon midsubstance were not included in the data analysis. All Group B failures occurred at the tendon/screw interface. According to the results of our study, the bioabsorbable interference screw fixation technique was found to resist significantly higher pulloui forces than the traditional approach to flexor hallucis longus transfer. The authors feel that the interference screw technique is technically easier while having the capacity to resist higher loads, subsequent to clinical testing, it could prove a superior method of flexor hallucis longus transfer for chronic Achilles tendon rupture or tendinopathy.
Keywords: flexor hallucis longus transfer, bioabsorbable screw, interference screw

• BACKGROUND/HISTORICAL PERSPECTIVE

The treatment of chronic Achilles tendon rupture and tendinopathy is challenging for the general orthopedic surgeon as well as the foot and ankle subspecialist. Numerous surgical procedures have been proposed to address the reconstruction of chronic Achilles tendon rupture and tendinopathy.[1–5,13,14,15,17] Of these, transfer of the flexor hallucis longus (FHL) tendon has become

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a viable option and has numerous benefits.[6] The close proximity of the FHL to the Achilles tendon complex facilitates its transfer with minimal risk for neurovascular injury. The FHL is one of the strongest plantar flexors, second only to the gastrocnemius–soleus complex. The axis of contractile force of the FHL fires in phase with the gastrocnemius–soleus complex. Finally, transfer of the FHL tendon has the least impact on the biomechanics of the foot and ankle us well as gait.

Hansen[3] and Wapner el al[7] have eloquently described the technique of flexor hallucis longus tendon transfer. Wapner recommends tendon harvest by way of a 2-incision technique, passing the tendon through an osseous tunnel in the calcaneus and tenodesing it to itself. Potential complications with this method include technical difficulty with graft harvest, inadequate length of tendon for tenodesis, and wound breakdown and/or posteromedial incisions.

To avoid these potential complications, we propose a technique in which fixation of the FHL tendon is achieved in an osseous tunnel of the calcaneus with an interference-fit screw. We feel that this method would allow less dissection, avoid violation of the plantar surface of the foot, and decrease the chance of fracture through the osseous tunnel.

The success of bioabsorbable interference screw fixation of tendon transfers has been well documented in the knee.[3,16] In addition, we have reported interference screw fixation in tendon transfers in the foot.[8,13] We present a biomechanical study comparing interference screw fixation with traditional tenodesis of the flexor hallucis longus tendon transfer for the treatment of chronic Achilles tendon rupture and tendinopathy.

■ MATERIALS AND METHODS

Ten pairs of feet and ankles from fresh cadaveric specimens were obtained for evaluation. Although no case histories were available for review, examination of each specimen revealed no obvious abnormalities or evidence of trauma. Criteria for inclusion were lower leg specimens with intact flexor hallucis longus insertions, no flexor hallucis longus tendinopathy, and minimal osteoporosis of the calcaneus. All specimens underwent bone densitometric evaluation utilizing a Hologic QDR 4000 DEXA Scanner before manipulation to document variation in specimen bone quality.

Ten feet were randomly assigned to group A and their counterparts to group B. Group A represented feet in which a traditional flexor hallucis longus tendon transfer involving tenodesis using #1 Ticron after passage through an osseous tunnel in the calcaneus was performed. Croup B was the experimental group, in which interference fixation was used to secure the flexor hallucis longus tendon in the osseous tunnel of the calcaneus.

Specimens were thawed to room temperature for 24 hours. In all specimens assigned to groups A and B, a longitudinal incision was made just medial to the Achilles tendon from the musculotendinous junction to approximately 2 cm distal to the insertion of the Achilles tendon on the calcaneus. After retraction of the posterior tibial neurovascular bundle medially, the deep posterior compartment fascia was incised longitudinally to expose the flexor hallucis longus muscle belly. In specimens assigned to group A, a second longitudinal incision was made along the medial border of the foot. With the abductor hallucis, flexor hallucis brevis, and medial plantar neurovascular bundle retracted plantar, the tendons of the flexor hallucis longus and flexor digitorum longus were isolated. The flexor hallucis longus tendon was harvested distal to the knot of Henry and pulled through to the proximal wound. In group B specimens, FHL harvest was performed through the same posterior incision planned for fixation of the tendon transfer. The FHL was transected in the fibroosseous tunnel, just beneath the sustentaculum tali. The fibrous raphe, if preserved, prevents errant procurement of the tibial nerve.

In group A, a transverse 6.5-mm drill hole was created in the calcaneus approximately 1 cm distal and 1 cm anterior to the Achilles tendon insertion. The flexor hallucis longus tendon was then passed from medial to lateral and tenodesed to itself using a #1 Ticron suture (Figs. 1–5).

In group B specimens, a vertical 6.5-mm drill hole was created in the calcaneus approximately 1 cm medial and 5 mm anterior to the Achilles tendon in the superior aspect of the calcaneus. This drill hole was full thickness through the calcaneus to allow for tendon transfer through the calcaneus and out through the heel pad. The flexor hallucis longus tendon was then passed through this osseous tunnel and out the plantar heel pad. With tension applied to the tendon via a pullout suture, a 7 × 25-mm bioabsorbable interference screw was secured next to the tendon within the osseous tunnel (Figs 6–9).

' Each specimen was fixated via a smooth transverse metatarsal shaft Steinmann pin (3/64) through the midshaft portion of the first, second, and third metatarsals and a smooth transcalcaneal Steinmann pin (3/64) through the body of the calcaneus to allow for attachment to the MTS device (MTS Machine Testing System 810). The free portion of the flexor hallucis longus tendon was attached to the load cell using a freeze clamp. Following secure fixation, each specimen was sequentially loaded to determine ultimate yield strength and mode of failure. The specimens were loaded physiologically; that is, the tension was applied vertically on the tendon and perpendicular to the screw, rather than in-line tension parallel to
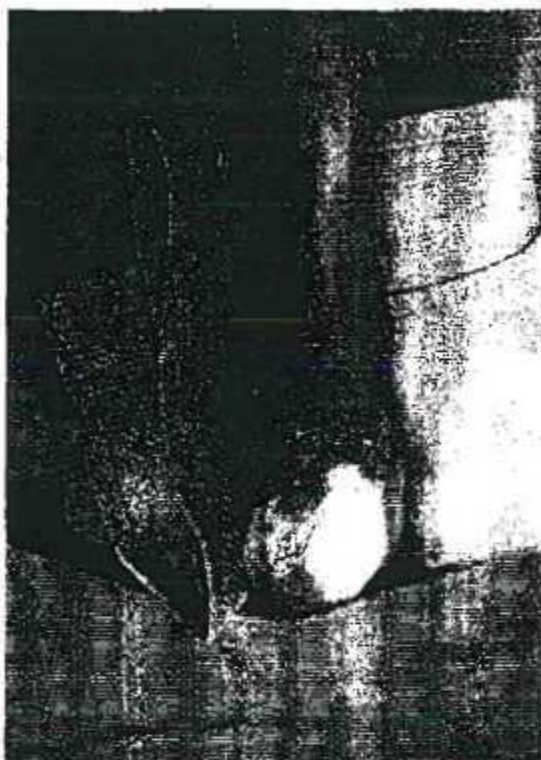
FIGURE 1. Planned incision for FHL transfer.

the screw. Tensile testing of each specimen using the computer-controlled, servo-hydraulic materials' tester was performed at a uniform rate of 1 mm/s. Testing was concluded when failure of fixation or tendon rupture occurred.

The bioabsorbable interference screws used in the study are composed of 82% L-lactic acid and 18% glycolic acid (Arthrotek, Warsaw, IN). The size of the screw used for interference fit in the calcaneus was 7 x 25 mm. This screw is amorphous with uniform degradation throughout its substance. The copolymer ratio allows retention of original strength for an average of 6 to 8 weeks.

- **INDICATIONS
  AND CONTRAINDICATIONS**

Plexor hallucis tendon transfer is indicated when residual Achilles tendon tissue is deemed inadequate, necessitating augmentation.

Preoperative Planning
Flexor hallucis tendon function should be assessed to ensure that its function is not compromised. The extent of Achilles disease should be assessed clinically and with imaging studies. Substantial Achilles disease should

prompt the surgeon to be prepared for an FHL tendon transfer/augmentation.

Surgical Procedure
Based on the results of this study and a clinical desire for the senior authors to minimize trauma from surgical dissection as well as to maximize efficiency of this procedure, some modifications have been implemented to arrive at the final proposed surgical method

The procedure is currently performed through 1 incision. This is typically placed just medial to the midline for noninsertional Achilles problems but may be shifted to directly midline for insertional pathology in an effort to better access the diseased portion of the tendon.[19] Regardless of whether the pathology lies al the insertion or the more classic "watershed" region of the tendon, extensive debridement is necessary to excise all diseased tissue for rapid symptom palliation. Debridement should take place through the substance of the Achilles tendon itself, and no residual or suspect tissue should be preserved.

The FHL may now be harvested through this split in the tendon. The muscle belly is most easily identified after the fascial covering is incised. The body of the muscle is used to trace its course into the region of the tarsal

FIGURE 2. Midline Achilles tendon-splitting Incision is made full thickness through the tendon.

FIGURE 3. The retrocalcaneal bursa is visualized through the tendon.

tunnel where it becomes tendinous. Care should be taken to avoid careless identification of presumed tendon alone, without meticulous inspection, as the shiny whitish yellow tubular appearance of the tibial nerve can be deceptive to the unassuming surgeon. We often spend a moment dissecting the neurovascular structures to accurately identify and isolate them from harm's way before proceeding with the FHL harvest. Once revealed, the FHL tendon should be tracked into its fibroosseous tunnel directly beneath the sustentaculum tali and freed of any adhesions. Now, with the ankle in maximal equinus and the hallux plantarflexed, the tendon may be transected with either tenotomy scissors or, more preferably, a sharp scalpel with the blade beveled toward the calcaneus to ensure safely of the neurovascular bundle. One caveat here is that the temptation to harvest a longer tendon with a blind pass of a tendon stripper should be avoided because this may result in an injury to one or more of the plantar branches of the tibial nerve.

Once the tendon is harvested, a whip stitch is performed in its free end. The surgeon should he aware that the amount of tendinous remnant on the harvested end of the muscle is much shorter than that described for the 2-incision technique; however, this is uniformly adequate

to provide enough tendon for passage and fixation into the calcaneus below.

A tunnel is created just anterior (5–10 mm) to the Achilles insertion in the central body of the calcaneus. In cases of insensional tendinopathy, a generous resection of the posterolateral prominence, or Haglund deformity, is necessary; but this has not presented a problem with positioning or fixation. The tunnel is drilled using the same diameter reamer as the planned implant (most often 7 mm).

The tendon is passed in one of several ways. Several systems are available to attempt to prevent plantar cortical penetration, and these require exact measurement of desired tendon length before the passage of the tendon. More traditionally, the plantar cortex is penetrated, and a Beith pin is passed through the plantar foot. The sutures are pulled through the plantar skin until a sufficient amount of tendon has passed into the tunnel. The appropriate amount of tendon passage is based on the ultimate tensioning of the tendon transfer. For this, we routinely include both feet in the sterile field to use the normal contralateral side as a reference of normal resting tension. Alternatively, one may choose to arbitrarily position

FIGURE 4. The FHL tendon and tibial nerve (medial or to the right) tie parallel and in close proximity to one another, separated by a fibroosseous sheath.
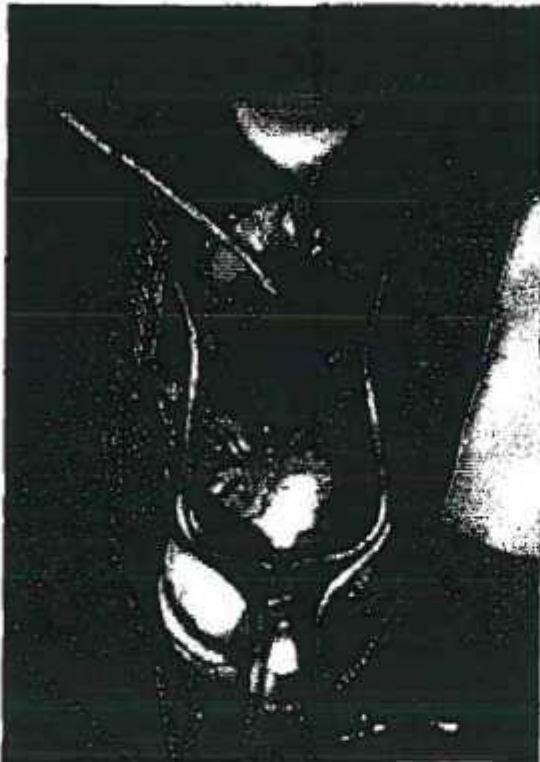
FIGURE s. Due lo anatomic proximity and concern over injury, the tibial nerve is routinely Identified.

the foot in 15–20 degrees of equinus and tension at this level.

Once tensioning is optimized, the interference screw is placed. Should solid purchase not be obtained, the implant may be removed safely and without fear of tendon rupture and replaced with a larger-diameter screw. Tension should be tested, and the foot should come to at least neutral (Fig. 10,11).

Closure is performed by first providing a side-to-side tenodesis of the remaining Achilles and its gastroc-soleus muscle belly to the new Achilles anchor, the FHL transfer (Pig. 12). This serves 2 presumed purposes. First, push-off power is maximized by incorporating the strong gastroc–soleus complex into the new heel cord. Second, the ample blood supply from the rich vascular network in the FHL muscle belly provides a source of nutrition and oxygenation to the previously injured Achilles remnant. Careful closure is performed with separate layers of paratenon, if still present (not often), subcutaneous fat, and skin.

• POSTOPERATIVE MANAGEMENT

The patient is immobilized in an equinus splint at 15–20 degrees for 2 weeks. He or she is then placed into a boot or cast with a 2-inch heel lift and allowed to gently touch down for another 2 weeks. After 1 month, patients are instructed on gentle active/assisted range of motion and advancement of weightbenring to full as tolerated. Over the next 2–3 months, the amount of the heel lift is decrementally removed until a painless, plantigrade foot is achieved. Physical therapy for strengthening is begun at the 2-month point.

• RESULTS

The results of bone mineral density studies of the paired cadaveric specimens were as follows: average bone mineral density for the traditional tendon fixation technique specimens was 0.32095 g/cm^2; the average bone mineral density for the bioabsorbable interference screw technique was 0.33536 g/cm^2. A repeatability study was performed on each cadaver specimen utilizing the DEXA scanning technique. Results of this study revealed a coefficient of variation of 2.4%. A Student t test revealed no statistical difference between cadaveric matched specimen pair results ($P = 0.2870$).

The average pulloui strength of the traditional group was 127.6 N (median 121.4 N, standard deviation 9,3 N);

FIGURE 6. The FHL is harvested through the posterior incision with great care taken lo avoid injuring the nerve, which lies just outside or medial to the fibroosseous tunnel

FIGURE 7. A bony tunnel is reamed to the size of the screw to be used.

the average pullout strength of the bioabsorbable interference screw specimens was 170.28 N (median 164.7 N, standard deviation 8.6 N) (Fig 10). With the data obtained, a paired 2-tailed Student *t* test was performed showing a statistically significant difference between bioabsorbable interference screw fixation and traditional tenodesis techniques (0.04529) All specimens were included in the study.

Of specimens in group A, 6 of 10 failures occurred at the bone-tendon interface, and 4 out of 10 occurred in the mid substance area of the tendon. Data included for analysis were all traditional failures at the site of transfer; the failures at the midsubstance area of the tendon were not included in data analysis because they did not make it to failure at the surgical site. All specimens in group B were loaded to failure with all failures occurring at the bone-tendon interface.

• POSSIBLE CONCERNS AND FUTURE *Ot* TECHNIQUE

Tendon transfer for the treatment of chronic Achilles rupture and tendinopathy is an evolving concept. The outcome of several different studies[7, 9-11] has shown the efficacy of flexor hallucis longus transfer for Achilles

tendon pathology. The biomechanical and anatomic advantages of flexor hallucis longus have been documented by numerous studies.[7,9,12,17] The flexor hallucis longus is a stronger plantar flexor compared with the flexor hallucis longus and peroneus brevis; its axis of contractile force more closely reproduces that of the Achilles tendon; it fires in phase with the gastrocnemius–soleus complex, its anatomic proximity avoids the neurovascular bundle; and its original function is the same as that of the Achilles tendon (plantarflexion).

The use of interference screw fixation for tendon transfer has been well documented in ligament reconstruction in the knee.[3,16] Its use in tendon transfer fixation in the foot and ankle is a new concept. The potential benefits for bioabsorbable screw fixation are also well known. The long-term benefit of bioabsorbable screw fixation is complete resorption over a period of six months. This optimized the environment for ingrowth of bone at the bone–tendon interface. Further, slow resorption of the bioabsorbable screw serves to slowly increase physiologic tensile forces at the bone–tendon interface to stimulate tendon–bone healing. Finally, use of bioabsorbable materials reduces the potential complications seen with metallic fixation. These include host reaction to foreign body and potential problems with magnetic resonance

FIGURE 8. A Krakow locking suture is used to secure the FHL to be brought into the tunnel.

FIGURE 9. Tendon pulled through bony tunnel with tension equal to that of the contralateral leg.

FIGURE 11. Completed FHL transfer with interference screw fixation.

imaging if future imaging of the fool and ankle complex is required.

In the present study, the strength of the interference screw fixation (group B) was superior to that of traditional suture tenodesis (group A) in all specimens. It may be argued that the innate tendon strength of each individual cadaveric specimen may have affected the

FIGURE 10. Interference screw fixation.

overall outcome of the present study. By using matched cadaveric specimen pairs, it is assumed that this will reduce the effect of intercadaver variability. Further, bone mineral density did not significantly affect pulloui strength between matched-pair results. In addition, it may be argued that the angle of distraction on the tendon by the material testing system may not be similar to physiologic forces and thus, may have affected the outcome. However, this was a constant variable throughout specimen evaluation. Finally, to minimize screw variability all screws were used from the same production lot from a single manufacturer.

• **CONCLUSION**

The present study focuses on improving a previously described surgical technique' to address the treatment of chronic Achilles tendon rupture and tendinopathy. The reduction in surgical time, avoidance of a secondary incision, decrease in surgical dissection, and increase in initial repair strength show this technique to be a viable surgical option. The increase in physiologic tensile loading at the bone-tendon interface during screw resorption may increase the strength of transfer over time.

FIGURE 12. A side-to-side FHL muscle belly to Achilles remnant tenodesis is performed. In theory, this provides vascularity from muscle belly to Achilles remnant and, in turn, power from the Achilles to the new tendon insertion.

Clinical studies utilizing this technique are ongoing and will serve to support or refute this addition to a previously successful surgical reconstruction.

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