The Journal of Orthopaedics Trauma Surgery & Related Research

© J ORTHOP TRAUMA SURG REL RES 4 (12) 2008
Original article

The results of treatment of Stage II posterior tibial tendon rupture with flexor digitorum longus tendon transfer and calcaneal osteotomy

THANOS BADEKAS
Athineon Hospital, Foot and Ankle Disorders Department, Athens, Greece

Address for correspondence/Adres do korespondencji:
Thanos Badekas MD
6, Kesarias str, 11527
Athens, Greece

Statistic

Word count	5916
Tables	0
Figures	0
References	63

Received: 25.07.2008
Accepted: 02.09.2008
Published: 01.10.2008

Summary
In a retrospective study we reviewed our results of treatment of stage II posterior tibial tendon rupture in 129 patients for whom surgery was performed between 1990 and 1997. During this period of time, 148 patients were treated with surgery following failure of non-surgical methods of treatment. The 129 patients (117 female, 12 male) with an average age of 53 years (range, 34-75 years) had been symptomatic for an average of 2.8 years (range, 0.5-7 years). The indication for surgery was the presence of foot pain, which was refractory to shoe modifications, orthoses and brace support. All patients had a painful flexible flatfoot without a fixed forefoot supination deformity. The surgery performed included a medial translational osteotomy of the calcaneus and transfer of the flexor digitorum longus tendon into the navicular. There were additional surgeries performed in 49 patients including repair of a tear of the spring ligament, talonavicular capsule or deltoid ligament (45), lengthening of the Achilles tendon (26), correction of hallux valgus deformity (5), and arthrodesis of the first tarsometatarsal joint (4). 129 patients were examined, radiographs obtained, and isokinetic evaluation of both feet and lower limbs performed with the Kin/Com apparatus at a mean of 4.6 years following surgery (range, 3-8 years). The AOFAS hindfoot scale was used to evaluate each patient, although due to the time elapsed from the initiation of treatment, preoperative AOFAS scores were not retrospectively determined. The mean AOFAS score at the time of the follow up examination was 79 points (range, 54-93). There were 7 significant complications in 6 patients including: significant progressive hindfoot valgus deformity in 1 patient treated with a triple arthrodesis; overcorrection of the hindfoot in 2 patients necessitating revision with a lateral closing wedge calcaneus osteotomy; 3 patients with symptomatic sural neuritis, and 1 patient with weakness of the gastrocnemius resulting from overlengthening of the Achilles tendon. Isokinetic inversion and plantar flexion power and strength was compared with the contralateral limb for 121 patients, and was noted to be symmetric in 95, mildly weak in 18, and moderately weak in 8. Motion of the subtalar joint was normal in 44%, slightly decreased in 51%, and moderately decreased in 5% of patients. Anteroposterior and lateral radiographs were evaluated for the talonavicular coverage angle, talus 1st metatarsal angle, talocalcaneal angle, and the height of the medial cuneiform to the floor. For 4 of these 5 parameters evaluated, the correction obtained was statistically significant ($p<0.05$). 123 patients were entirely satisfied, 4 partially satisfied, and 2 were dissatisfied with the outcome of the procedure. Most patients experienced pain relief (97%), an improvement of function (94%), noted an improvement in the arch of the foot (87%), and were able to wear shoes comfortably without resorting to shoe modifications or orthotic arch support (84%). In conclusion, the surgical correction of Stage II posterior tibial tendon rupture with medial translational calcaneus osteotomy and flexor digitorum longus tendon transfer to the navicular yielded excellent results with minimal complications, and a high patient satisfaction rate.
Key words: foot, posterior tibial muscle insufficiency, flexible flatfoot, tibial tendon rupture, tendon transfer

INTRODUCTION

In the adult loss of function of the posterior tibial tendon (PTT) results to a progressive collapse of the medial longitudinal arch of the foot and therefore causes, adult acquired flatfoot deformity.

Electromyographic studies suggest that the primary support of the medial longitudinal arch is ligamentous rather than muscular. The principal function of the posterior tibial muscle appears to be to invert the subtalar joint during the heel rise phase of the gait cycle. This helps lock the transverse tarsal joint so that weight of the body can be transferred along the lateral aspect of the foot onto the first metatarsal head. When the (PTT) being ruptured the transverse tarsal joint does not lock with heel rise. This leads to prolonged calcaneal eversion and forefoot pronation. Tension on the medial-plantar side of the transverse tarsal joint is transferred to local soft tissue. Eventually this causes rupture and resultant flatfoot deformity. This followed by progressive valgus deformity of the calcaneus, plntarflexion of the talus, abduction of the fore part of the foot, and pronation deformity of the foot.

According to Johnson and Strom modified by Myerson classification system of the posterior tibial tendon dysfunction, in stage II the (PTT) is torn, the limb is weak and the patient is unable to perform a single heel rise on the affected side. The midfoot pronates and the forefoot abducts at the transverse tarsal joint, there is valgus angulation of the heel, the subtalar joint, however remains flexible.

The treatment of an acquired flatfoot deformity due to a ruptured (PTT) is usually through a surgical reconstruction. Conservative modalities have place in patients who are poor surgical candidates, can alleviate the symptoms and give some pain relief but cannot control the deformity. For stage II rupture of the (PTT) the conservative treatment includes shoe modifications, a foam rubber-soled shoe to which a L-inch medial heel and sole wedge is added, tilts the foot into neutral varus valgus alignment and takes the strained off the tendon. An medial arch support orthotic device is helpful also in this stage, however a rigid insole sometimes is not well tolerated, in our series an insole made of a combination of hard and soft density plastizote, Pelite, and leather is more comfortable and better tolerated. A short articulated AFO (ankle foot orthosis), or a rigid (AFO), or a leather lace-up Arizona brace might be helpful for elderly patients who have relatively sedentary life. The effect of cortisone injections into the sinus tarsi, and the anti-inflammatory/analgesic drugs is controversial. They can offer temporary symptomatic relief only but also they mask symptoms sufficiently so that an additional rupture occurs through overuse.

In our study all the patients that underwent surgical treatment with flexor digitorum tendon transfer and calcaneal osteotomy for stage II (PTT) rupture failed previous conservative treatment.

MATERIAL AND METHODS

Patient population. Over an eight-year period (1990 to 1997), we treated 412 patients with posterior tibial tendon (PTT) rupture. This group included patients with all four stages of PTT rupture. (*Myerson ref, JBJS),* of whom 163 had a Stage II deformity. This was defined according to the Johnson and Strom modified by Myerson classification system that was published in JBJS journal on May 1996, and we already mentioned before in the introduction.

Each of the 163 patients were offered non-surgical treatment which was initiated for 148 patients, and surgery performed more promptly for seventeen patients**,** who had already received adequate non-surgical care. Twenty-nine patients improved with non-surgical treatment, leaving 134 patients who formed the basis for this retrospective review. All the patients had received various non-surgical treatments prior to referral, including a 6mm medial heel and sole wedge for 36 patients, a rigid orthotic arch support in 48, a firm accommodative orthotic arch support in 20, a hinged polypropylene ankle foot orthosis in 26, and a stirrup brace used for 33 patients. From 163 patients the 52 (32%) used a combination of these devices. The most common combination was a stirrup brace with a medial arch support insole, 31 patients from the 52 (59%).

Activity modification was recommended for each patient, and in addition to shoe wear and orthotic treatments, non-steroidal anti-inflammatory medication was prescribed for 48 patients who could tolerate this medication, and if tenosynovitis was present. Patients were recommended to modify their activities by limiting the number of hours which they were ambulatory, and standing for prolonged periods of time, and to modify athletic activities in activities that they don't load so much the lower extremities. They advised to use always when they walk their orthosis device. Tenosynovitis was present if swelling, warmth and edema around the tendon was present. Physical therapy was prescribed for 23 patients, and focused upon plantar flexion and inversion strengthening exercises, and decreasing inflammation using ultrasound and electrical stimulation. We did not use oral nor locally injected corticosteroids, although 18 of the patients had received prior treatment with corticosteroid injection, including seven patients with two or more injections. The mean duration of the conservative treatments, which we initiated, was (4 1/2 months, range from 1to 13 months). This data includes 102 patients. The other patient group includes 59 patients who underwent conservative elsewhere and then referred to our institution. The mean duration of conservative treatment on this patient population in our institution was limited (1 1/2 months, range from 0 to 3 1/2 months. Prior to referral in our institution they had conservative treatment for a mean duration of 7 months, range from 2 to 23 months.

The non-surgical treatments we provided were moderately successful for 95 of the 134 patients although

symptoms persisted to some extent for all the 117 patients for whom we provided these treatments. Nine patients treated with an ankle-foot orthosis were markedly improved, however once the use of the brace was discontinued, symptoms promptly returned, and each of these patients preferred the option of surgery to continued brace immobilization. In addition to the seventeen patients for whom surgery was performed more promptly, the remaining 117 patients did not improve sufficiently with non-surgical treatments, and reconstruction was performed with flexor digitorum longus tendon transfer combined with medial translational calcaneal osteotomy. Of these 134 patients who were treated with surgery, we obtained adequate follow-up for 129 patients. One patient was deceased, two were unwilling to participate in this study, and we were unable to contact the remaining two patients. These 129 patients (117 female, 12 male) with an average age of 53 years (range, 34-75 years) had been symptomatic for an average of 2.8 years (range, 0.5-7 years) prior to surgery. The average body weight at the time of the surgery was 183 pounds (range from 105 pounds to 246). The average height at the time of the last clinical study examination was 5 inches and 4 feet (range from 4 inches and 9 feet to 6.0). Average body mass index height/weight 54/183=0.295.

For one hundred and seventeen (117) of the 129 patients the etiology of the tendon rupture was considered to be non specific idiopathic primary degenerative tendinosis, and 12 patients had underlying systemic pathology, including ten with a seronegative inflammatory disease, one patient with Marfan syndrome, and one with Ehlers-Danlos syndrome. Although we treated patients with rheumatoid arthritis who had deformities suggestive of posterior tibial tendon rupture, due to the variable presentation of their deformities and pathology, they were excluded from this study. The mean age of the twelve patients with systemic disease was 41 (range, 34 to 51) and 10 out of 12 were women, while the mean age of the patients with degenerative tendinosis was 55 (range, 39 to 75). Any additional foot and ankle pathology was noted. The indication for surgery was the presence of foot pain, which was refractory to shoe modifications, orthoses and brace support. All patients had a painful flexible flatfoot without a fixed forefoot supination deformity, or if forefoot supination was present, this was less than ten degrees. Clinically we can identify the fixed forefoot supination by holding the subtalar joint reduced in neutral position and radiographically with the Coleman block test. Also prior to the operation the patients were being examined for Achilles tendon contracture. We assessed the ankle dorsiflexion with the subtalar joint in neutral position and with the knee first in extension and then in flexion.

Operative procedure. The patient is placed in the lateral decubitus position on a beanbag. The incision begins superior to the calcaneus and posterior to the peroneal tendons and sural nerve. The incision curves gently in a distal and inferior direction, ending at the plantar edge of the calcaneus. The lateral aspect of the calcaneus is exposed and a transverse calcaneal osteotomy is performed with an oscillating saw blade in line with the skin incision. Care is taken to remain approximately 1cm posterior to the posterior process of the talus to avoid violating the articular surface of the posterior facet at its posterior proximity.

The osteotomy is at a right angle to the lateral border of the calcaneus and is inclined posteriorly approximately 45% to the plantar surface of the hindfoot. No wedge is removed from the calcaneus, and no attempt is made to tilt the tuberosity into varus. A toothless lamina spreader is placed in the osteotomy site and the medial soft tissue attachments to the calcaneus are relaxed by spreading the lamina spreader. The lamina spreader is withdrawn, and the posterior calcaneal tuberosity is then translated medially by 10mm and fixed with a 7-mm cancellous lag screw. Care is taken to prevent the posterior tuberosity from sliding proximally. The screw is inserted from posterior, lateral and inferior to anterior, medial and superior. The lateral incision is then closed, the beanbag is deflated, and the patient is turned supine.

The tendon transfer is performed through a posteromedial incision in the line of the PTT. The flexor retinaculum is opened and the ruptured PTT is inspected.

Operative findings. The operative findings vary according to the underlying systemic pathology of the (PTT). The 10 patients, who had seronegative inflammatory disease, had a proliferative synovial membrane that adheres to the tendon. In these patients, the tendon was found to be attenuated and to contain longitudinal fissures, and a chronic non-specific infiltrate is noted histologically.

In the major group with the patients who had degenerative rupture of the tendon, the tendon sheath was edematous and thickened. Fibrous adhesions usually were present and often extended posteriorly from the inner (medial) aspect of the tendon. The degenerative tear was commonly present one to two centimeters distal to the medial malleolus. Partial or complete rupture of the tendon occurred approximately two centimeters proximal to the tubercle of the navicular. In most cases, the scared tendon was adhered to the tendon sheath. Longitudinal fissures commonly were found in the posterior aspect of the tendon that lies in proximity to the deeper soft tissues and tendon sheath.

Of the 129 patients 48 had complete disruption of the PTT without any visible presence of the tendon either proximally or distally; 39 had complete rupture of the tendon but without any elasticity of the proximal tendon upon testing it's excursion; 23 had complete rupture of the tendon but with maintenance of some elasticity of the tendon proximally; 11 had grossly visible longitudinal fissuring and attritional intrasubstance tears but without any elasticity of the proximal tendon; and 8 had in addition to edema and tenosynovitis, intratendinous degen-

eration on the deep aspect of the tendon but the tendon kept it's elasticity.

Additionally we had operative findings from the adjaced soft tissues on the medial aspect of the foot that contributes to the severity of the unilateral flatfoot deformity.

We recorded 38 spring ligaments tears, 11 of them were associated with a torn talonavicular capsule, and 7 deltoid ligament tears.

The tendon is either advanced or used for a side-to-side tenodesis. If no functional excursion of the musculotendinous unit occurs when the proximal tendon remnant is pulled, the transected end is left free behind the medial malleolus. The tendon sheath of the flexor digitorum longus (FDL) tendon is then opened and exposed beneath the arch of the foot where it crosses superficial to the flexor hallucis longus tendon at the level of the naviculocuneiform joint; plantar retraction of the abductor hallucis brevis muscle belly improves exposure. Care is taken to avoid injury to the plantar vessels and nerve in close proximity. A tenodesis of the stump of the FDL to the flexor hallucis longus tendon is unnecessary if the FDL is transected proximal to the interconnection of these two tendons. A 4.5-mm drill hole is made in the navicular 1cm lateral to its medial border and the tendon is passed through the drill hole from plantar to dorsal. Before suture of the tendon transfer, with the foot held inverted and slightly plantarflexed, the capsule of the talonavicular joint is plicated by excising a vertical ellipse approximately 6 to 8 mm in diameter. The FDL tendon is then secured in this position to the adjacent periosteum. If the stump is long enough, additional strength of repair is achieved by suturing the tendon back on itself. The tension on the tendon is set halfway between its position at rest and maximum excursion, with the foot held in maximum inversion and slight plantarflexion. There were additional surgeries performed in 49 patients including repair of a tear of the spring ligament, talonavicular capsule or deltoid ligament (45), lengthening of the Achilles tendon (26), correction of hallux valgus deformity (5), and arthrodesis of the first tarsometatarsal joint (4). When we determined clinically, as we described previously that tendon Achilles lengthening (TAL) needed to be done, first we proceed with the (TAL) and we continued with the main course of the operative procedure. We use the three-cut percutaneus (TAL). The surgeon grips the heel between his thumb and his index finger and inserts the knife vertically; a small (11 number blade) knife is used. The knife blade is inserted into the center of the tendon first just proximal to its insertion onto the calcaneus. The knife is then rotated to the medial side and pressed against the index finger, the medial half of the tendon is cut. A second cut is being made medially with the same way at the junction between the gastrocnemious muscle and the tendon. Midway between the two incisions, a lateral hemisection is made. The knee is then extended and the ankle dorsiflexed by a slow firm pressure. With the three-step cut, the tendon gives or lengthens more gradually and distinct slide is often not palpable. The dorsiflexion force should not be excessively applied or the tendon will rupture suddenly, producing too much lengthening.

Postoperative treatments. During the first four years of this study, fifty-two patients were immobilized in equinus and varus for 4 weeks, and then a more plantigrade position was assumed in a cast or removable boot over the subsequent 4 weeks. Bearing of weight was not permitted for 6 weeks, followed by weight bearing as tolerated. During the latter part of this study, the remaining seventy seven patients were allowed to commence range of motion exercises at two weeks, a cast was not used, and weight bearing was permitted commencing at two weeks in a walker boot with the foot positioned in slight inversion, and ten degrees of equinus. Once out of the boot, all patients wore a stirrup ankle brace for an additional four weeks, during which time strengthening exercises either in a supervised physical therapy program or at home were performed. Walking, cycling and other strengthening exercises were commenced at 3 months, and other sports activities were permitted by 4 months, provided the patients were able to perform repetitive heel rises without pain.

Each of the 129 patients in this study was examined at a mean of 5.2 years following surgery (range, 3-8 years), and examined in a systematic manner, with objective and subjective criteria used for determining the outcome of treatment. The AOFAS hindfoot scale and the Short Form Health Survey SF-36 was used to evaluate patient satisfaction and hindfoot function of each patient although scores were not assigned retrospectively. Although preoperative scores were available for a limited number of patients, it has been demonstrated that assigning AOFAS scores to patients retrospectively are not valid. (ref. *Michael Brage*). We determined the level of patient satisfaction, their functional status using a questionnaire and clinical examination, their work habits, recreational ability, level and intensity of their postoperative pain, walking endurance, and if the use of any supportive devices, braces or orthoses.

Radiographic assessment was performed using standardized weight bearing anteroposterior and lateral radiographs. On the anteroposterior view, the parameters studied were the talus first metatarsal angle and the talonavicular coverage angle. On the lateral radiograph the talus first metatarsal angle and the height of the plantar cortex of the medial cuneiform to the floor was measured and compared with the preoperative radiographs. We compared in addition, the post-operative radiographs taken at three months with those taken at the final follow up examination to determine if there was loss of correction over time.

The isokinetic strength of one hundred and twenty one patients was evaluated using a dynamometer designed for torque measurements of concentric and eccentric muscle action (Kinetic Communicator [KinCom]) The isokinet-

ic inversion and plantar flexion power and strength was compared with the controlateral limb. We were uncertain as to whether the transferred FDL would contract, fulfilling the function of the PTT in plantar flexion and inversion. We therefore performed electromyographic (EMG) studies of the FDL tendon transfers in selected (5) patients prior to studying the isokinetic strength with the KinCom apparatus. For these patients, the surgically treated foot was compared using EMG with the opposite foot to compare the inversion strengths, noting that the FDL transfer was firing in plantar flexion and inversion in the prior position of the PTT. This we used to compare the FDL tendon transfer with the controlateral foot to give an objective measurement of inversion and plantarflexion concentric and eccentric muscle power and strength.

Results of treatment. Of the 129 patients who were included in the study 118 were entirely satisfied with the outcome of the surgical treatment, and indicated that they would undergo a similar procedure again. Of the eleven patients who were not satisfied, five had ruptures associated with systemic disease: (3 had seronegative inflammatory disease, 1 Marfan syndrome, and 1 Enlers-Danlos syndrome).

Walking and activities. With respect to prolonged walking and activities, 107 patients experienced no pain nor discomfort and were not in any way limited; 11 patients experienced mild pain or discomfort on an intermittent basis which did not limit their activities, 7 patients noted similar limitations with activities which they had experienced prior to surgery, and 4 patients felt that they were worse off with respect to activities and ambulation than they had been prior to surgery. Nine patients resumed recreational jogging, including three patients who returned to competitive long distance running completing the marathon distance. The majority of patients experienced pain relief (97%), and improvement of function (87%). When we evaluated pain relief and return to function, 95% of patients reported a noticeable improvement at a mean of seven months (range, 3-9 months) following surgery, but that this improvement continued for a mean of an additional five months (range, 2-11 months). The mean duration of improvement noted until the patients reached a functional plateau following surgery was fourteen months (range, 9-18 months). The recreational interests and activities improved dramatically in 115 patients (87%), remained the same for 10 patients (9%), and worsened in 4 patients *(*4%) became worst. Although we attempted to note a change in work status, this was not easy to define, since the majority of these patients had fairly sedentary work styles prior to surgery. Of the 129 patients (73) 56% had a full time or part time job, and for (48) of these patients (65%), their employment and work activities remained the same, 20 patients (28%) changed their work activity noting a decrease in their work activities, and 5 patients (7%) noted a marked improvement in their ability to work.

AOFAS score. The arch of the foot was noted to improve by 115 patients (87%), 10 patients (9%) felt that had been mild improvement, and 4 patients (4%) felt that the arch of the foot had flattened. Shoe wear was not limited nor restricted in any manner for 109 patients (84%), and who did not require any shoe modification; thirteen patients (12%) felt more comfortable in a stiff soled shoe, and five patients (4%) routinely used a more rigid supportive shoe. Twenty-seven patients used a soft accommodative orthotic arch support, and nine patients used more rigid orthotic support for routine activities. Two of the patients continued to wear a hinged foot an ankle orthosis and eventually both of them were treated with triple arthrodesis.

The AOFAS hindfoot scale was used to evaluate each patient, although pre-operative scores were not assigned retrospectively. The mean AOFAS score at the time of the follow up examination was 79 points (range, 54-93). In this examination we paid particular attention to the patient's ability to stand unsupported on one foot and repetitively perform a single heel rise, noting that patients (89%) were able to perform this function. Seven patients were able to perform a single heel rise although not repetitively, and eight were unable to perform any single heel rise. We noted the patients walking in a corridor 20m in length, and found that 117 (91%) of the patients had normal gait, 9 patients (7%) had slight changes to the cadence of gait, and 3 patients (2%) demonstrated an obvious antalgic gait. These findings, which we noted, corresponded to the patient's reported observations of their ambulation.

SF-36 Health survey. In our study we used also the short form health survey SF-36, as an outcome assessment method in order to determine the effectiveness of this particular surgical procedure, in patients physical status and general satisfaction. We used the Physical and Mental Component Summary scales (PCS, MCS) that this survey includes. We found 118 patients that completed the SF-36 forms preoperatively and these patients completed another short form health survey SF-36 postoperatively together the other evaluations according to the standard protocol of this study. This outcome assessment method in order to be valid requires minimum two-year follow-up and our study meets this requirement. The preoperative patient population stratified into three groups. Mean PCS 32 +/- std dev. (9.4). Low function group PCS=< 19, middle function group 20=<PCS=<38,and high function group PCS>=39. According to the SF-36 survey pre and postoperatively we had marked improvement in Physical Scales after the FDL tendon and the calcaneus osteotomy. The low and middle functioning groups had dramatic improvement of physical health after the operation. In the high functioning group the operation was less effective at improving physical health. In the

last group we had also three parameters that play role in that less satisfactory result. The gender male (13% vs 7%), the undergoing additional procedures (31% vs 23%), the age percentage of patients under the age of 45 was 74% in the high functioning group to 54% of the patient population under the age of 45 in the less functioning groups. In conclusion this particular procedure appears to be more effective in quality of life of patients with PCS scores <39, SF-36 Health survey, we carefully need to manage the expectations of high functioning group, particularly the younger males and patients when additional procedures needed to be done.

Radiographic measurements. The majority of the patients demonstrated radiographic improvement in the parameters measured postoperatively and is very interesting to notice that the substantial majority 92% retain this improvement in this long term follow up study in an average 6.1 years period of time. The radiographic measurements which we studied were: on the anteroposterior projection the talonavicular coverage and the talo-metatarsal angles, and on the lateral projection, the talus-first-metatarsal angle and the height of the medial cuneiform to the floor (Figure). On the anteroposterior projection, there was improvement in the talonavicular coverage and the talo-metatarsal angles. Statistical analysis was performed using an analysis of variance, (P=0.017). The anteroposterior talometatarsal angle improved from a preoperative mean value of 25^0 (range 0^0 to 49^0) to a postoperative mean value of 6^0 (range, -11^0 to 28^0), a mean improvement of 21^0, (P=0.018) The mean anteroposterior talonavicular coverage angle was 37^0 preoperatively (range, 7^0 to 57^0) with a mean postoperative improvement of 16^0 (range, 0^0 to 45^0) in this parameter. We had 5 patients who showed a slight deterioration of the anteroposterior talonavicular coverage angle. These are patients who had a markedly deformed foot, severe valgus and external rotation deformity of the foot. We noticed in the latest radiographs of the long-term study a mean deterioration of the anteroposterior talonavicular coverage angle of 6^0 (range 4^0 to 9^0) in mean 5.8 years follow up time of these patients. On the lateral projection the mean talus-first-metatarsal angle of -27^0 preoperatively (range, -45^0- to -9^0) improved to a mean value of -12^0 (range, -33^0 to 0^0) postoperatively, a mean improvement of 12^0. The height of the medial cuneiform to the floor increased from a mean preoperative value of 7mm (range, 0 to 16mm) to a mean postoperative value of 19mm (range 12 to 30mm). 5 patients, whose preoperative deformities were the most severe, showed no improvement in the medial cuneiform to floor distance and had maximum deformity also at the naviculocuneiform joint. Six patients showed demonstrated deterioration of the height of the medial cuneiform to floor distance of a mean of 8mm (range 12 to 5mm) in a mean 5.2 years follow up time, of the above-mentioned patients 4 were over 270 pounds and 2 had underlying systemic pathology. On an individual basis the value that showed a consistent and grossly noticeable improvement after the surgery was the height of the medial arch as judged from the distance of the medial cuneiform to the floor.

Isokinetic function. Using the KinCom apparatus, we examined the eccentric and the concentric muscle power and strength of the invertors and plantarflexors of both feet in 121 patients. The remaining eight patients could either not comply with the instructions for use of the apparatus, or could not be scheduled for the examination. Isokinetic inversion strength was noted to be symmetric in 91 patients, mildly weak in 22, and moderately weak in 9. Plantarflexion isokinetic power was noted to be symmetric in 95 patients, mildly weak in 18, and moderately weak in 8.

Subtalar joint motion. It is difficult to determine subtalar joint motion because the muscles that control subtalar joint motion are exactly the same with the muscles that control the ankle joint motion. Although holding the heel firmly in the palm of one hand and passively supinate and pronate the rest of the foot with the other hand, we can grossly assess the pronation and supination.

Motion of the subtalar joint was normal in 44%, slightly decreased in 51%, and moderately decreased in 5% of the patients.

Complications. There were 7 severe complications in 6 patients. One patient developed progressive hindfoot valgus deformity one year following surgery, and was treated with a triple arthrodesis. The deformity in two was overcorrected, resulting in heel varus, with lateral foot pain, and a sense of ankle instability. It was not possible to determine whether the varus position of the heel was due to a malunion of the calcaneal osteotomy or over-tightening of the FDL tendon transfer. These two patients were treated at 18 and 22 months with a lateral closing wedge calcaneus osteotomy. Three patients experienced symptomatic sural neuritis; of these, one underwent transection of the neuroma and burial of the stump in the peroneus brevis muscle, and the remaining two were treated with local desensitization physical therapy modalities, which were successful in alleviating the sensitivity, although the numbness persisted. One patient had weakness and severe calf muscle atrophy resulting from overlengthening of the Achilles tendon, which resolved only partially with physical therapy and strengthening exercises. There were five patients who experienced numbness (3 transient, 2 permanent) in the distribution of the medial plantar nerve. Four patients initially experienced lateral foot pain under the fifth metatarsal and cuboid, however these symptoms abated seven to eleven months after the operation for all four patients. There were no patients who developed a deep wound infections, however five were treated for superficial cellulites following surgery, which resolved with oral antibiotic therapy and topical wound care.

DISCUSSION

The acquired flatfoot deformity that develops in association with tears of the tibialis posterior tendon indicates the importance of this muscle-tendon unit as a dynamic stabilizer of the medial arch of the foot. During gait, inversion of the hindfoot is produced, which locks Chopart's joint. This allows the powerful gastrosoleus complex to act through the foot at the level of the metatarsals heads. The synergistic nature of the function of the tibialis posterior and gastrosoleus muscles deserves special emphasis. Failure of both, results to abnormal gait and flatfoot deformity. With loss of the posterior tibialis tendon, the gastrosoloeus force acts at the talonavicular joint. Downward and medial pressure of the talar head stretches the calcaneonavicular ligaments. The plantar ligaments placed medially that unite the tarsus and metatarsus are comparatively much weaker than those on the lateral side. Heel strike creates a subtalar valgus that stretches the structures of the medial arch. Eventually the passive structures of the longitudinal arch give way under continued dynamic insult and a flatfoot deformity results.

This type of operation affects both the deforming factors of flatfoot deformity, the (PTT) tear and the abnormal action of the gastrosoleus muscle, with the additional benefit that preserves the hindfoot and midfoot motion.

As we previously mentioned patients that sustain (PTT) tear stage II with subsequent pes planovalgus deformity experiences a shift of the gastrosoleus muscle complex lateral to the subtalar axis; therefore contraction of the tendoachilles accentuates the heel valgus. Gleigh is credited as the originator of a calcaneal osteotomy with medial and plantar-based wedge to structurally improve the medial longitudinal arch. Koutsogiannis later described a medial displacement calcaneal osteotomy allows for translation of the gastrosoleus complex medial to the subtalar axis, thereby acting as a stronger heel invertor, relieving the stresses of the calcaneonavicular ligaments and of the talonavicular joint. Additionally, the medialized heel may provide additional support to the medial longitudinal arch.

The use of calcaneal osteotomy improves the talo-first metatarsal angle, the talonavicular coverage and the medial cuneiform height in our patients undergoing PTT reconstruction/substitution with FDL tendon transfer. In our series we had improvement of the anteroposterior and lateral talo-fist metatarsal angles 21 and 12 degrees respectively. The talonavicular coverage angle improved 16 degrees and the medial cuneiform-floor height improved 19mm. That shows also that the medial displacement calcaneus osteotomy contributes in the restoration of the medial arch of the foot. In conclusion the medial displacement calcaneus osteotomy is a relatively simple procedure that offers static and dynamic stabilization of the medial arch of the foot, reinforces the FDL tendon transfer as the gastrosoleus complex is transferred medially and has resulted in overall improvement in the radiographic parameters studied, which has not been the experience with the tendon transfer alone.

Goldner first described Reconstruction of the PTT for correction of an acquired flatfoot in 1974. Mann and Specht in 1982 presented early results of reconstruction/substitution of the PTT using the FDL secured through a navicular drill hole. The rationale behind the reconstruction/substitution technique is to use an in phase tendon (FDL) to substitute for the dysfunctional PTT. The stronger, stouter FHL is not used because of its important function in maintaining stability of the first ray and medial column. Simple side to side anastomosis or augmentation involves potentially degenerated or torn dysfunctional PTT as part of the construct, and therefore would be inherently weaker compared to the PTT reconstruction/substitution using the FDL tendon. Spring ligament and talonavicular capsule attenuation implicated in the formation of progressive planovalgus deformity, and therefore their repair/imbricationis an integral part of the reconstructive procedure.

In our study the long-term results of this procedure are more than encouraging. The number of the patients that involved in this retrospective study (129), the relatively long term mean follow-up (4.6 years), and the variety of the subjective and objective being used and assessed can lead us to more secure conclusions about the usefulness of the method, in treating stage II rupture of the PTT in conjunction with acquired flatfoot deformity.

Summarizing the results the American Foot and Ankle Society (AOFAS) score improved to a postoperative mean of 79 points at the time of the last follow-up examination, lower from the AOFAS score (84) that Myerson and Corrigan reported in 1996 in a series of 32 patients with a mean follow-up of 2.5 years, and slightly lower also from the AOFAS score (82.8) that Pomeroy and Manoli reported in 1997 in a series of 20 cases of stage II PTT insufficiency treated with heel cord lengthening, FDL tendon transfer to the medial cuneiform and calcaneus osteotomy, with a mean follow-up of 17.5 months.

The SF-36 Health Survey outcome assessment form we performed pre and postoperatively gave us interesting results. Although the low and middle functioning patient groups had dramatic improvement of their physical health, in the high functioning group the procedure was less effective especially in the male, elderly, and undergoing additional procedures patient population. Patient education in this particular group should encourage more reasonable expectations of outcome. Although we had patient that used to be Marathon runner, discontinued due to PTT rupture, and after the surgical intervention started again to run the Marathon.

The majority of the patients (97%) experienced pain relief, and 91% were entirely satisfied with the outcome of the surgical treatment. Shoewear was not limited nor restricted in any manner in the 84% of the patient population.

In this study except the multiple subjective findings we have the first objective report of outcome of this particular procedure, in terms of functional evaluation. Using the Kinetic Communicator (KIN/KOM) apparatus we assessed the eccentric and the concentric muscle power and strength of the invertors and plantarflexors on both feet in 121patients. The results were extremely encouraging, the isokinetic inversion strength was symmetric in 91 patients and the plantarflexion isokinetic power was symmetric in 95 patients.

Two other results, which are very interesting to, mentioned are: First the subtalar joint motion, which in our series is normal in 44% and slightly decreased in 51% of the patient population. This decrease is much less than for patients with lateral column lengthening fusion, probably lateral column lengthening osteotomy, and certainly for subtalar arthrodesis. Second the extremely low rate of complications, 7 severe complications in six patients in a series of 129 patients with a mean follow-up 5.8 years.

CONCLUSIONS

Restoration of medial dynamic support by FDL tendon transfer in stage-II PTT rupture has been shown to reduce symptomatology, but has not been shown to correct the deformity. The medial displacement calcaneus osteotomy reduces the deformity valgus thrust at heel strike. By medially shifting the Achilles, its action is converted from a deforming force to a synergist working with the FDL on the tarsal kinematic chain to aid tarsal inversion. Surgical correction of the stage-II PTT rupture should attempt to maintain to maintain flexibility of the foot, to restoring motor function, to reducing the deforming forces, give pain relief, and improving the medial longitudinal arch of the foot. The combined procedure of FDL tendon transfer and translational osteotomy of the calcaneus can well achieve these objectives.

References

1. *Anderson, A. F., and Fowler, S.B.: Anterior calcaneal osteotomy for symptomatic juvenile pes planus. Foot and Ankle, 4:274-283, 1984.*
2. *Anzel, S. H.; Covey, K. W.; Weiner, A. D.; and Lipscomb, P. R.: Disruption of muscles and tendons. An analysis of 1,014 cases. Surgery, 45:406-414, 1959.*
3. *Astion, D. J.; Deland, J. T.; Otis, J. C.; and Hogle, S.: Motion of the hindfoot after selected fusions. Read at the Annual Meeting of the American Orthopaedic Foot and Ankle Society, Orlando, Florida, Feb. 19, 1995.*
4. *Badani, K.; Gabriel, R. A.; and Wagner, F. W., Jr.: Surgical correction of adult flatfoot deformity by lateral column lengthening and medial soft tissue augmentation. Read at the Annual Summer Meeting of the American Orthopaedic Foot and Ankle Society, Vail, Colorado, July 21, 1995.*
5. *Bono, J. V., and Jacobs, R. L.: Triple arthrodesis through a single lateral approach: a cadaveric experiment. Foot and Ankle, 13:408-412, 1992.*
6. *Chao, W.; Lee, T. H.; Hecht, P. J.; and Wapner, K. L.: Conservative management of posterior tibial tendon rupture. Qrthop. Trans., 18:1030, 1994-1995.*
7. *Clain, M. R., and Baxter, D. E.: Simultaneous calcaneocuboid and talonavicular fusion. Long-term follow-up study. J. Bone and Joint Surg., 76-B(1): 133-136, 1994.*
8. *Conti, S.; Michelson, J.; and Jahss, M.: Clinical significance of magnetic resonance imaging in preoperative planning for reconstruction of posterior tibial tendon ruptures. Foot and Ankle, 13:208-214, 1992.*
9. *Cooper, P. S.; Nowack, M.; and Schear, J.: Calcaneocuboid joint pressures with the Evans lateral column lengthening procedure. Read at the Annual Meeting of the American Orthopaedic Foot and Ankle Society, Atlanta, Georgia, Feb. 25, 1996.*
10. *Deland, J. T.; Amoczky, S. P.; and Thompson, F. M.: Adult acquired flatfoot deformity at the talonavicular joint: reconstruction of the spring ligament in an in vitro model. Foot and Ankle, 13:327-332, 1992.*
11. *Elbar, J. E.; Thomas, W. H.; Weinfeld, M. S.; and Potter, T. A.: Talonavicular arthrodesis for rheumatoid arthritis of the hindfoot. Orthop. din. North America, T. 821-826, 1976.*
12. *Evans, D.: Calcaneo-valgus deformity. J. Bone and Joint Surg., 57-B(3): 270-278, 1975.*
13. *Fairbank, A.; Myerson, M. S.; Fortin, P.; and Yu-Yahiro, J.: The effect of calcaneal osteotomy on contact characteristics of the tibio-talar joint. Foot, 5:137-142, 1995.*
14. *Fogel, G. R.; Katoh, Y.; Rand, J. A.; and Chao, E. Y. S.: Talonavicular arthrodesis for isolated arthrosis. 9.5-year results and gait analysis. Foot and Ankle, 3:105-113, 1982.*
15. *Erey, C.; Shereff, M.; and Greenidge, N.: Vascularity of the posterior tibial tendon. J. Bone and Joint Surg., 72-A: 884-888, July 1990.*
16. *Funk, D. A.; Cass, J. R.; and Johnson, K. A.: Acquired adult flat foot secondary to posterior tibial-tendon pathology. J. Bone and Joint Surg., 68-A: 95-102, Jan. 1986.*
17. *Gleich, A.: Beitrag zur operativen Plattfussbehandlung. Arch. klin. Chir., 46:358-362, 1893.*
18. *Goldner, J. L.; Keats, P. K.; Bassett, F. H., Ill; and Clippinger, F. W.: Progressive talipes equinovalgus due to trauma or degeneration of the posterior tibial tendon and medial plantar ligaments. Orthop. Clin. North America, 5:39-51, 1974.*
19. *Graves, S. C.; Mann, R. A.; and Graves, K. 0.: Triple arthrodesis in older adults. Results after long-term follow-up. J. Bone and Joint Surg., 75-A: 355-362, March 1993.*
20. *Harper, M. C.: Deltoid ligament: an anatomical evaluation of function. Foot and Ankle, 8:19-22, 1987.*
21. *Holmes, G. B., Jr., and Mann, R. A.; Possible epidemiological factors associated with rupture of the posterior tibial tendon. Foot and Ankle, 13:70-79, 1992.*
22. *Horton, G. A., and OIney. B. W.: Triple arthrodesis with lateral column lengthening for treatment of severe planovalgus deformity. Foot and Ankle Internal., 16:395-400, 1995.*
23. *Jahss, M. H.: Spontaneous rupture of the tibialis posterior tendon: clinical findings, tenographic studies, and a new technique of repair. Foot and Ankle, 3:158-166, 1982.*
24. *Jahss, M. H.: Personal communication, 1994.*
25. *Jahss, M. H.; Godsick, P.; and Levin, H.: Quadruple arthrodesis with iliac bone graft. In The Foot and Ankle: a Selection of Papers from the American Orthopaedic Foot Society Meetings, pp. 93-102. Edited by J. E. Bateman and A. W. Trott. New York, Brian C. Decker, 1980.*

26. *Johnson, K. A.: Tibialis posterior tendon rupture. Clin. Orthop., 177:140-147, 1983.*
27. *Johnson, K. A., and Strom, D. E.: Tibialis posterior tendon dysfunction. Clin. Orthop., 239:196-206, 1989.*
28. *Johnson, W. L., and Lester, E. L.: Transposition of the posterior tibial tendon. Clin. Orthop., 245:223-227, 1989.*
29. *Kjaersgaard - Aiidersen, P.; Wethelund, J.-O.; Helinig, P.; and Soballe, K.: Stabilizing effect of the tibiocalcaneal fascicle of the deltoid ligament on hindfoot joint movements: an experimental study. Foot and Ankle, 10:30-35, 1989.*
30. *Kodros, S. A.; Patel, M. V.; Ali, R. M.; Trevino, S. G.; and Baxter, D. E.: The effect of various transverse tarsal joint arthrodeses on subtalar motion: a cadaveric study. Read at the Annual Meeting of the American Orthopaedic Foot and Ankle Society, Orlando, Florida, Feb.19, 1995.*
31. *Koutsogiannis, E.: Treatment of mobile flat foot by displacement osteotomy of the calcaneus. J. Bone and Joint Surg., 53-B(1): 96-100, 1971.*
32. *Lahr, D. D., and Shereff, M. J.: Reconstruction for posterior tibial tendon insufficiency. Read at the Annual Summer Meeting of the American Orthopaedic Foot and Ankle Society, Vail, Colorado, July 19, 1995.*
33. *Lord, J. P.: Correction of extreme flatfoot. Value of osteotomy of os calcis and inward displacement of posterior fragment (Gleich operation). J. Am. Med. Assn., 81:1502-1507, 1923.*
34. *McGarvey, W. C., and Braly, W. G.: Bone graft in hindfoot arthrodesis: allograft versus autograft. Read at the Combined Meeting of the American, British, and European Foot and Ankle Surgeons (COMFAS), Dublin, Ireland, Aug. 27, 1995.*
35. *Mann, R. A.: Acquired flatfoot in adults. Clin. Orthop., 181:46-51, 1983.*
36. *Mann, R. A., and Thompson, E. M.: Rupture of the posterior tibial tendon causing flat foot. Surgical treatment. J. Bone and Joint Surg., 67-A: 556-561, April 1985.*
37. *Monto, R. R.; Moorman, C. X, III; Mallon, W. J.; and Nunley, J. A., II: Rupture of the posterior tibial tendon associated with closed ankle fracture. Foot and Ankle, 11:400-403, 1991.*
38. *Myerson, M. S.: Acquired flatfoot in the adult. Adv. Orthop. Surg., 2:155-165, 1989.*
39. *Myerson, M.: Posterior tibial tendon insufficiency. In Current Therapy in Foot and Ankle Surgery, pp. 123-135. Edited by M. Myerson. St. Louis, Mosby-Year Book, 1993.*
40. *Myerson, M. S.; Roland, C. M.; and Allon, S. M.: Regional anesthesia for foot and ankle surgery. Foot and Ankle, 13:282-288, 1992.*
41. *Myerson, M.; Solomon, G.; and Shereff, M.: Posterior tibial tendon dysfunction: its association with seronegative inflammatory disease. Foot and Ankle, 9:219-225, 1989.*
42. *Myerson, M. S.; Corrigan, J.; Thompson, F.; and Schon, L. C.: Tendon transfer combined with calcaneal osteotomy for treatment of posterior tibial tendon insufficiency: a radiological investigation. Foot and Ankle Internal., 16:712-718, 1995.*
43. *Myerson, M. S.; Pell, R.; Schon, L. C.; and Haddad, S.: The clinical results of triple arthrodesis. Unpublished data.*
44. *Nayak, R. K., and Cotterill, C. P.: Osteotomy of the calcaneum for symptomatic idiopathic valgus heel. Foot, 2:111-116, 1992.*
45. *Ouzounian, T. J., and Myerson, M. S.: Dislocation of the posterior tibial tendon. Foot and Ankle, 13:215-219, 1992.*
46. *Phillips, G. E.: A review of elongation of os calcis for flat feet. J. Bone and Joint Surg., 65-B(1): 15-18, 1983.*
47. *Resnick, R. B.; Jahss, M. H.; Choueka, J.; Kummer, F.; Hersch, J. C.; and Okereke, E.: Deltoidi ligament forces after tibialis posterior tendon rupture: effects of triple arthrodesis and calcaneal displacement osteotomies. Foot and Ankle Internal., 16:14-20, 1995.*
48. *Rose, G. K.: Pes planus. In Disorders of the Foot and Ankle: Medical and Surgical Management, edited by M. H. Jahss. Ed. 2, vol. 1, pp. 892-920. Philadelphia, W. B. Saunders, 1991.*
49. *Rosenberg, Z. S.; Cheung, Y.; Jahss, M. H.; Noto, A. M.; Norman, A.; and Leeds, N. E.: Rupture of posterior tibial tendon: CT and MR imaging with surgical correlation. Radiology, 169:229-235, 1988.*
50. *Rosenberg, Z. S.; Jahss, M. H.; Noto, A. M.; Shereff, M. J.; Cheung, Y.; Frey, C. C.; and Norman, A.: Rupture of the posterior tibial tendon: CT and surgical findings. Radiology, 167:489-493, 1988.*
51. *Saltzman, C. L., and Brown, T. D.: Effects of a medial/lateral displacement calcaneal osteotomy on the contact stresses in the ankle joint. Read at the Annual Summer Meeting of the American Orthopaedic Foot and Ankle Society, Vail, Colorado, July 22, 1995.*
52. *Sammarco, G. J.: Technique of triple arthrodesis in treatment of symptomatic pes planus. Orthopedics, 11:1607-1610, 1988.*
53. *Sands, A.; Grujic, L.; Sangeorzan, B.; and Hansen, S. T., Jr.: Lateral column lengthening through the calcaneo-cuboid joint: an alternative to triple arthrodesis for correction of flatfoot. Read at the Annual Meeting of the American Orthopaedic Foot and Ankle Society, Orlando, Florida, Feb. 19, 1995.*
54. *Sangeorzan, B. J.; Mosca, V.; and Hansen, S. T., Jr.: Effect of calcaneal lengthening on relationships among the hindfoot, midfoot, and forefoot. Foot and Ankle, 14:136-141, 1993.*
55. *Sangeorzan, B. J.; Smith, D.; Veith, R.; and Hansen, S. T., Jr.: Triple arthrodesis using internal fixation in treatment of adult foot disorders. Clin. Orthop., 294:299-307, 1993.*
56. *Sarrafian, S. K.: Anatomy of the Foot and Ankle: Descriptive, Topographic, Functional. Ed. 2. Philadelphia, J. B. Lippincott, 1993.*
57. *Saxby, T., and Myerson, M.: Calcaneus osteotomy. In Current Therapy in Foot and Ankle Surgery, pp. 159-162. Edited by M. Myerson. St. Louis, Mosby-Year Book, 1993.*
58. *Stormont, D. M.; Morrey, B. F.; An, K. N.; and Cass, J. R.: Stability of the loaded ankle. Relation between articular restraint and primary and secondary static restraints. Am. J. Sports Med., 13:295-300, 1985.*
59. *Teasdall, R. D., and Johnson, K. A.: Surgical treatment of stage I posterior tibial tendon dysfunction. Foot and Ankle Internal, 15:646-648, 1994.*
60. *Thoren, K.; Ljung, P.; Pettersson, H.; Rydholm, U.; and Aspenberg, P.: Comparison of talonavicular dowel arthrodesis utilizing autogenous bone versus defatted bank bone. Foot and Ankle, 14:125-128, 1993.*
61. *Vogler, H. W.: Triple arthrodesis as a salvage for end-stage flatfoot. Clin. Podiat. Med. and Surg., 6:591-604, 1989.*
62. *Wapner, K. L.; Hecht, P. J.; Shea, J. R.; and Allardyce, T. J.: Anatomy of second muscular layer of the foot: considerations for tendon selection in transfer for Achilles and posterior tibial tendon reconstruction. Foot and Ankle Internal., 15:420-423, 1994.*
63. *Welton, E. A., and Rose, G. K.: Posterior tibial tendon pathology: the foot at risk and its treatment by os calcis osteotomy. Foot, 3/4:168-174, 1993.*