CHAPTER 17

TRIPLE ARTHRODESIS FOR ADULT ACQUIRED FLATFOOT

Alan R. Catanzariti, DPM
Brian T. Dix, DPM
Phillip E. Richardson, DPM
Robert W. Mendicino, DPM

INTRODUCTION

Triple arthrodesis for adult acquired flatfoot is typically indicated in stage III and stage IV deformities (1-4). These patients often have end-stage arthritis and significant deformity that is nonreducible. The authors also consider triple arthrodesis when there has been a failed joint-sparing procedure or a failed arthrodesis of an isolated tri-tarsal joint to address stage II adult acquired flatfoot. The goals of surgery include resolution of symptoms, realignment, and sound arthrodesis.

Acceptable outcomes following triple arthrodesis in stage III adult acquired flatfoot are based on the surgeon's ability to obtain a plantigrade foot that will support the ankle in optimal alignment. Therefore, realignment becomes the most important factor relative to good results. A well-aligned triple arthrodesis will result in normal physiologic contact pressures throughout the ankle and prevent medial soft tissue attenuation and ensuing degenerative changes. A triple arthrodesis with residual valgus deformity predisposes the ankle to attenuation of medial soft tissue constraints and subsequent valgus deformity as well as degenerative joint disease.

Preoperative imaging should include weightbearing radiographs of the foot and ankle, hindfoot alignment/long-leg calcaneal axial radiographs and advanced imaging. Weightbearing radiographs of the ankle are necessary to evaluate the presence of valgus deformity and degenerative changes. Long-leg calcaneal axial and hindfoot alignment views provide information regarding frontal alignment. The authors sometimes consider magnetic resonance imaging (MRI) to evaluate the ankle arthritis that might be equivocal on standard radiographs. Additionally, when the foot deformity is rather severe, and the ankle is congruent on an anterioposterior (AP) radiograph, the authors obtain an MRI to evaluate the deltoid ligament. In those situations where the deltoid ligament is attenuated on MRI, we will consider a medial displacement osteotomy to offload the deltoid ligament as well as deltoid repair as adjunct procedures.

There are a number of ancillary procedures that are necessary in order to obtain a plantigrade foot. Posterior muscle group lengthening either in the form of an Achilles tendon lengthening or gastrocnemius recession is invariably required in stage III adult acquired flatfoot. The authors utilize gastrocnemius recession in the majority of cases. However, following realignment of a severe deformity, an Achilles tendon lengthening may be necessary to obtain adequate length and restore sagittal plane position.

Medial displacement osteotomy of the calcaneus has been mentioned earlier as an adjunct procedure to address ankle valgus or medial soft tissue attenuation (Figure 1). Resnick et al have shown that a triple arthrodesis in combination with a medial displacement osteotomy of the calcaneus will reduce deltoid ligament forces by 56% (5). Song et al have also suggested that medializing the calcaneus following triple arthrodesis would protect the deltoid complex (6).

The authors will consider medial column stabilization either in the form of naviculocuneiform arthrodesis or first tarsometatarsal arthrodesis, when medial column instability is identified following triple arthrodesis for stage III adult acquired flatfoot (Figure 2). Insufficiency of the medial column can result in a functional varus. Failure to address medial column instability can result in a lateral column overload when patients begin weightbearing with subsequent fifth metatarsal base bursitis or fifth metatarsal head callosities.

Harvesting of regional bone graft and/or bone marrow aspirate is a part of virtually every triple arthrodesis. Cancellous bone is often harvested from the calcaneus utilizing 6-8 mm trephines through small lateral incisions (Figure 3). Bone marrow aspirate is obtained from the calcaneus prior to tourniquet inflation. The cancellous bone is packed into arthrodesis sites. The extra-articular areas along the under surface of the talus and the dorsal surface of the calcaneus are decorticated. The bone marrow aspirate is mixed with bioactive glass and then packed into this extra-articular area.

Figure 1A. Anterioposterior radiograph of flatfoot deformity.

Figure 1B. Anterioposterior radiograph of the ankle demonstrating valgus deformity.

Figure 1C. Postoperative radiograph of triple arthrodesis combined with medial displacement osteotomy to address valgus deformity of the ankle.

Figure 1D. Postoperative radiograph.

Figure 2A. Preoperative anterio-posterior radiograph.

Figure 2B. Postoperative radiograph of triple arthrodesis with naviculocuneiform arthrodesis to address medial column instability.

Figure 2C. Posoperative radiograph.

Transfer of peroneus brevis to peroneus longus tendon is performed when the deformity is rather severe (Figure 4). Severe contracture of the peroneus brevis tendon can sometimes make it difficult to obtain complete realignment. As an alternative, the authors sometime transect both tendons.

Figure 3A. Harvesting of small, cancellous bone graft.

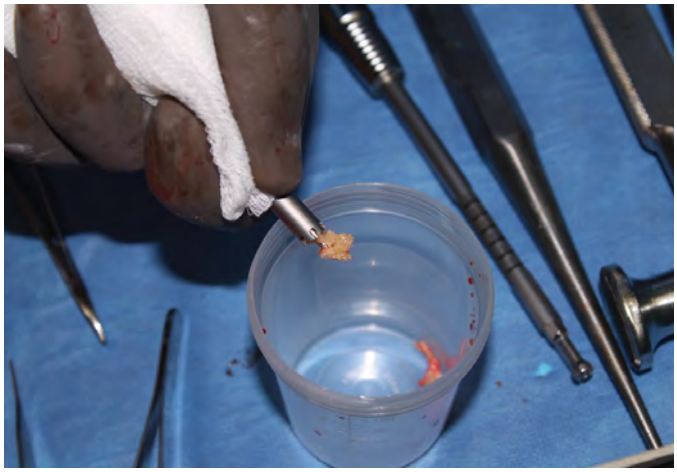

Figure 3B. Harvesting bone graft.

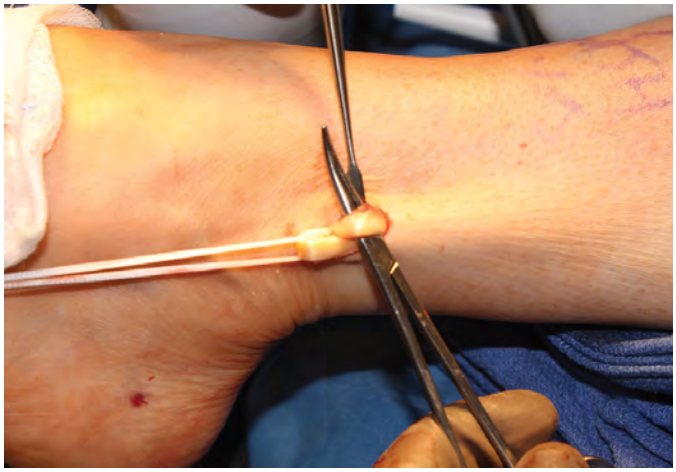

Figure 4A. Transfer of the peroneus brevis to longus tendon to eliminate abductory pull and contracture of the peroneus brevis tendon.

Figure 4B. Tendon transfer.

SURGICAL TECHNIQUE FOR TRIPLE ARTHRODESIS

Subtalar and Calcaneocuboid Dissection

Triple arthrodesis is usually performed under general anesthesia: however, these procedures may also be performed with spinal anesthesia depending on the patient's comorbidities and overall medical status. The patient is positioned supine with a bump placed under the ipsilateral hip to internally rotate the foot and ankle. The patient's heel should be located just distal to the end of the operating room table to allow access to the posterior calcaneus for delivery of fixation and to permit easier manipulation of the extremity during intraoperative imaging. The extremity is elevated on several stacks of towels or a bump to facilitate use of retractors and to enhance imaging during the procedure. The authors typically utilize a thigh tourniquet, which is released after osteosynthesis has been achieved.

Triple arthrodesis is typically performed through a combination of medial and lateral incisions. The lateral incision extends from the tip of the lateral malleolus and courses distally to the fourth metatarsal base (Figure 5). This incision is dorsal to the peroneal tendons and sural nerve. Care is taken to maintain hemostasis with cauterization or ligation of the venous structures within this area. A lightly moistened saline-sponge may be used for planal dissection down to fascia. The peroneal tendons are then mobilized with Metzenbaum scissors and retracted inferior (Figure 6).

Dissection is then carried down to the level of the deep fascia and the extensor digitorum brevis muscle belly. An inverted T-shaped incision is performed with the base of incision along the inferior aspect of the muscle belly, extending proximally along the lateral capsule of the talocalcaneal joint. The vertical arm of the incision is within the sinus tarsi. A second vertical incision is then placed parallel within the sinus tarsi and the contents of the sinus tarsi are thoroughly evacuated (Figure 7). This enhances visualization and access to the subtalar joint. Dissection is then carried proximal along the lateral talocalcaneal joint where the calcaneofibular ligament is incised to

Figure 5. Lateral incision for triple arthrodesis. Incision begins just proximal to the tip of the malleolus and extends distally to the fourth metatarsal base.

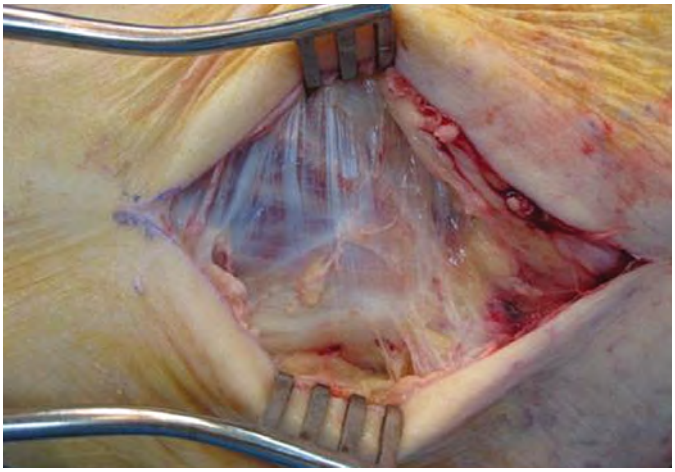

Figure 6A. The fascia covering the extensor digitorum muscle belly. The peroneal tendons are inferior and the sinus tarsi is proximal.

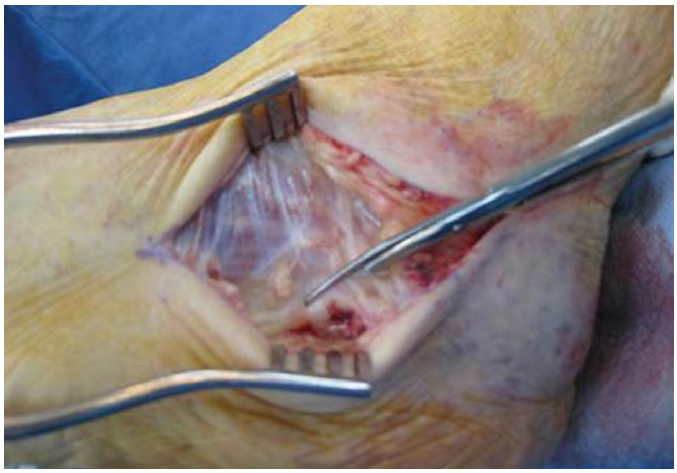

Figure 6B. Peroneal tendon sheath being incised with Metzenbaum scissors.

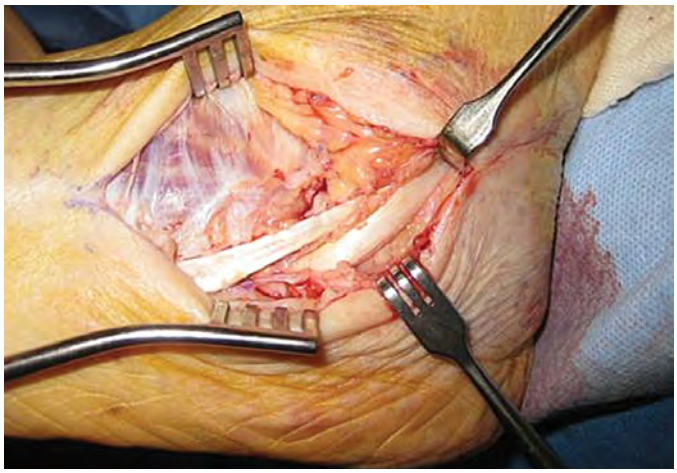

Figure 6C. Exposure of the peroneal tendons for inferior retraction.

facilitate access to the subtalar joint (Figure 8). The lateral talocalcaneal ligaments and calcaneofibular ligament are often contracted in long-standing adult acquired flatfoot. Releasing these periarticular structures will enhance mobilization of the subtalar joint and therefore, permit easier access and realignment.

Subtalar Joint and Calcaneocuboid Joint Preparation

A lamina spreader with teeth is placed within the sinus tarsi, which provides access to the subtalar joint (Figure 9). Alternatively, pin-distractors can also be used. The cartilage of the posterior and middle facet is thoroughly removed with the use of narrow, straight, and curved osteotomes. This process is often tedious but essential. Straight and angled curettes are also beneficial when debriding cartilage from the middle facet of the subtalar joint. Cartilage debris should then be completely removed from within the joint. The authors often "walk the lamina spreaders" throughout the various areas of the subtalar joint in order to gain access to the entire joint (Figures 10, 11).

The articular cartilage debris is then thoroughly removed from the subtalar joint region prior to preparing the subchondral plate. The lateral aspect of the talonavicular joint may be visualized from the lateral incision and partially prepared before accessing this joint from the medial incision. The subchondral plates of both the talus and calcaneus are first fenestrated with a 2.5 mm drill and then methodically broken using a straight, narrow osteotome. A small distractor can initially be used to access the subtalar joint when the lamina spreader is too large (Figure 12). The goal of joint preparation is to develop a healthy cancellous substrate that will go on to primary union. A lamina spreader with teeth is placed within the calcaneocuboid joint and the same technique is used for cartilage removal and joint preparation as described above (Figure 13).

Talonavicular Joint Dissection and Preparation

The second incision of the triple arthrodesis is located medial. This incision begins within the medial gutter of the ankle joint and extends distally to the base of the first

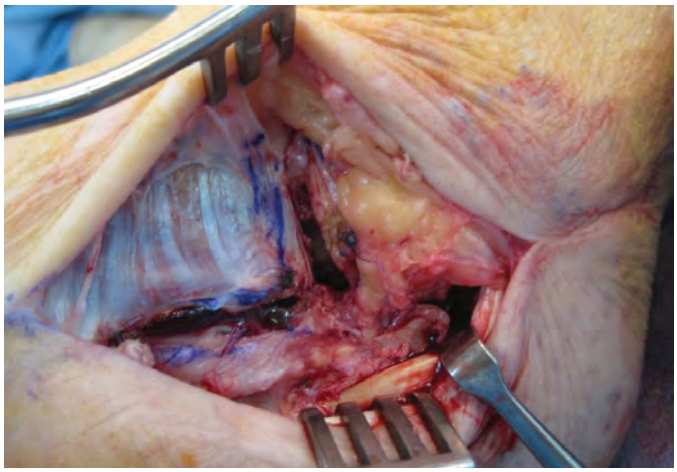

Figure 7. Inverted-T incision with the vertical within the sinus tarsi and the horizontal arm along the inferior aspect of the extensor digitorum longus muscle belly and the lateral talocalcaneal joint. Note the soft tissue resection within the sinus tarsi.

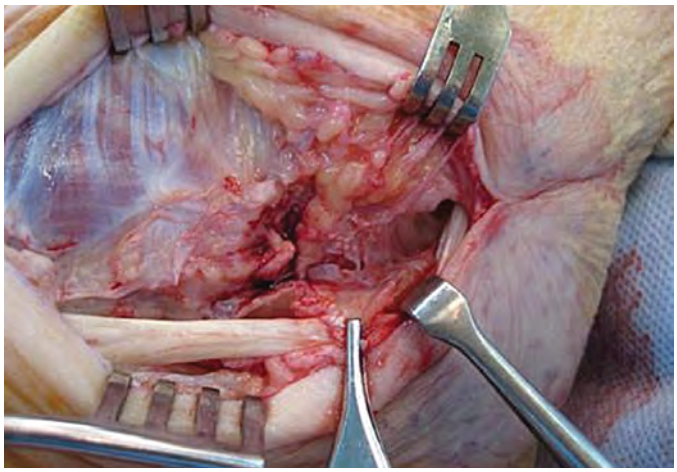

Figure 8A. Intact calcaneofibular ligament.

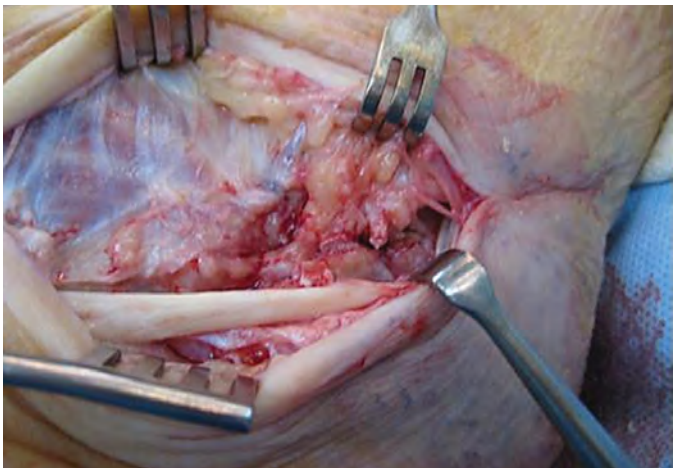

Figure 8B. Lateral talocalcaneal joint following transaction of the calcaneofibular ligament.

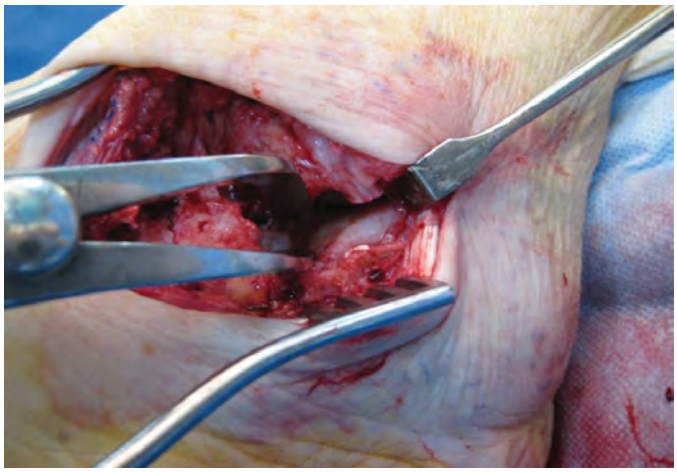

Figure 9. Lamina spreader within the sinus tarsi exposing the posterior facet of the subtalar joint.

metatarsal (Figure 14). This incision provides access to the talonavicular joint and can be extended distally to incorporate the naviculocuneiform and/or first tarsometatarsal joint if necessary. There are often a large number of vessels in this area, which require ligation, especially within the distal portion of the ankle capsule. A sponge can be used for planal dissection down to the level of deep fascia. The tibialis anterior tendon is located within the dorsal aspect of the wound and the tibialis posterior tendon within the inferior aspect of the wound. The deep fascia and periosteum should then be incised between these two tendons and all dissection performed in a subperiostal manner (Figure 15). Dissection must be extended both inferior and dorsal in order to obtain adequate exposure.

A lamina spreader or small pin distractor is then utilized to open the talonavicular joint. The cartilage is removed utilizing a combination of narrow, straight, and curved osteotomes. All cartilage debris should be thoroughly removed from the talonavicular joint. A 2.5 mm drill and a narrow osteotome are then utilized to break the subchondral plates in a methodical fashion (Figure 17).

Realignment/Positioning and Fixation

The subtalar joint is the first joint to be realigned. Realignment is based on clinical and radiographic assessment. The calcaneus is placed vertical to the lower leg with the subtalar joint in neutral position. This position is confirmed with an intraoperative axial image, which should demonstrate the calcaneus parallel to the tibia (Figure 18). Lateral radiographs should demonstrate restoration of the calcaneal inclination angle (Figure 19). Fixation is accomplished with percutaneous large diameter cannulated screws. The authors prefer two-point fixation. The first guide pin is placed from the inferior aspect of the calcaneus into the talus. A helpful tip is to have the surgeon palpate the distal aspect of the anterior tibial crest with the fingers of the nondominant hand, aiming the guidewire towards this point of reference, while confirming the wire's course

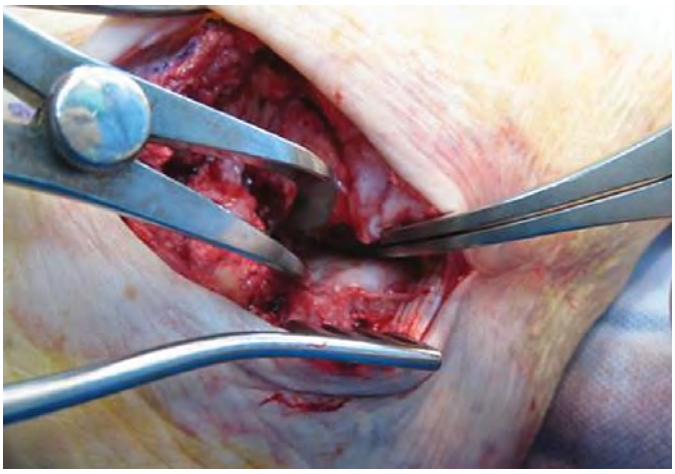

Figure 10A. "Walking the lamina spreaders" through various areas of the subtalar joint to expose articular surface for cartilage debridement and joint preparation.

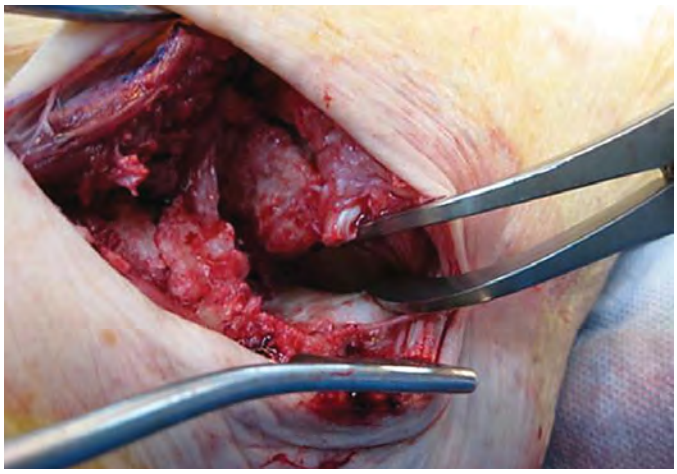

Figure 10B.

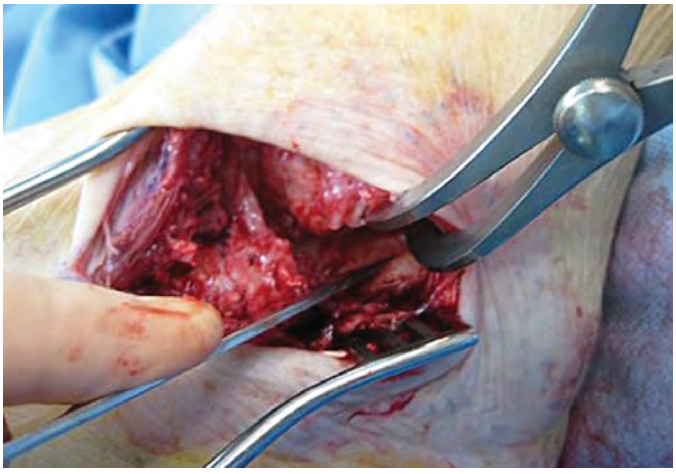

Figure 11A. Small straight osteotome being utilized to remove the cartilage from within the subtalar joint.

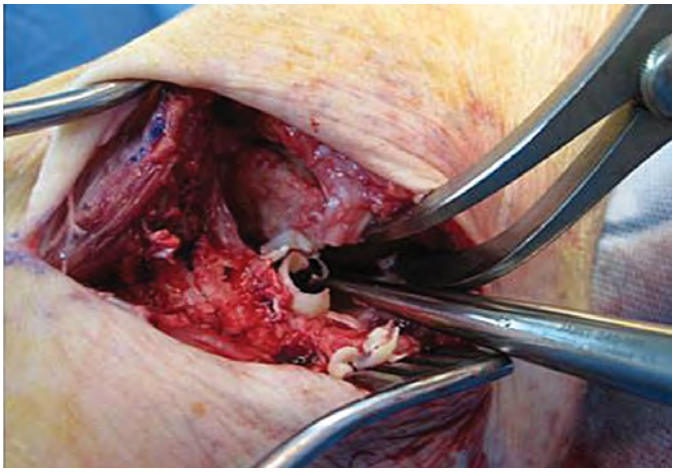

Figure 11B. Subtalar joint cartilage can also be removed with the use of straight and angled curettes. This is especially useful for the middle facet.

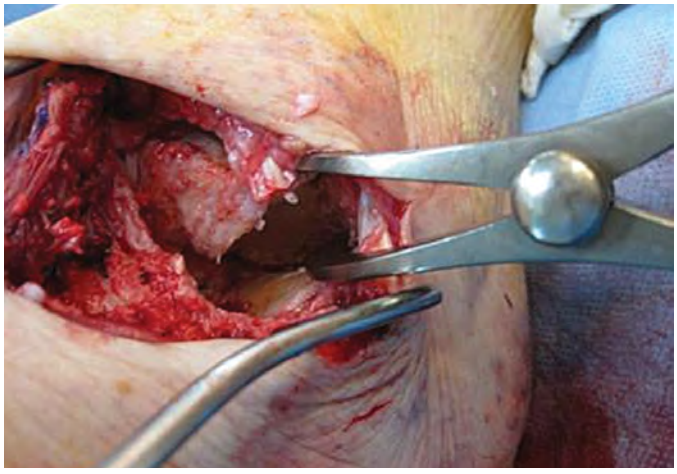

Figure 11C. Intraoperative picture of the subtalar joint following cartilage removal.

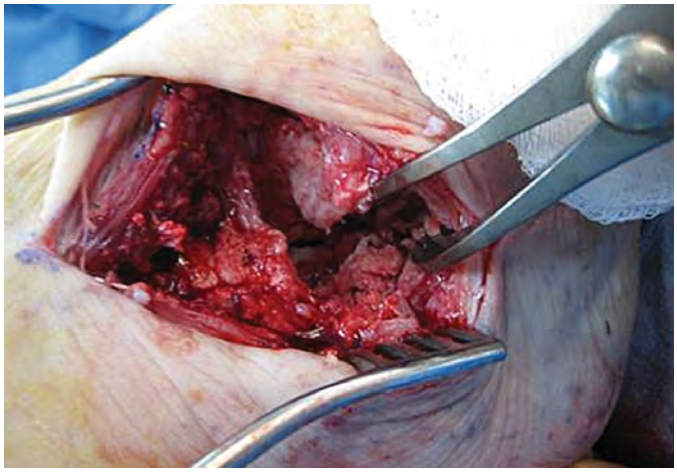

Figure 11D. Methodical breaking of the subchondral plate to enhance arthrodesis.

Figure12A. Initial use of a minidistractor to expose the subtalar joint when the lamina spreader is too large.

Figure 12B. Laminar spreader has now been inserted.

Figure 12C. Subchondral plate preparation with the use of small ostetomes.

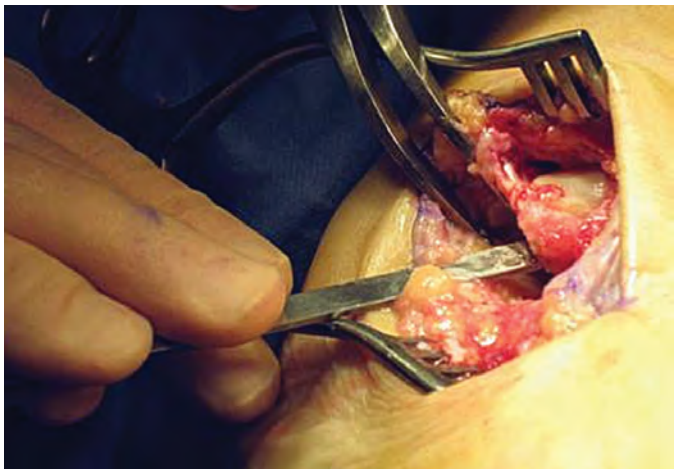

Figure 12D. Subchondral plate preparation with the use of small osteotomes.

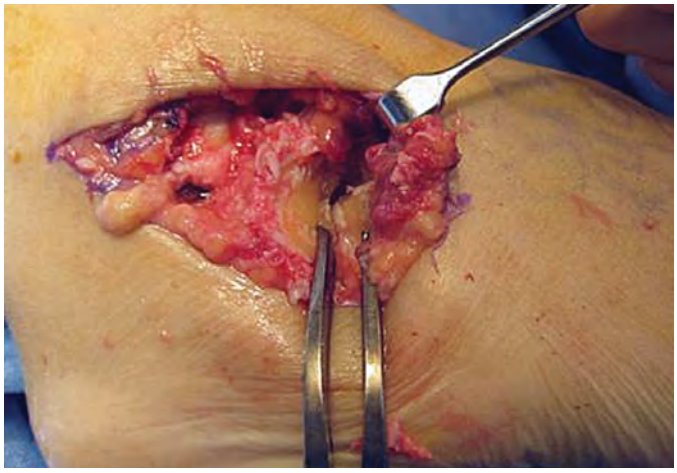

Figure 13A. Calcaneocuboid joint following cartilage removal.

Figure 13B. Calcaneocuboid joint following methodical breaking of the subchondral plate.

Figure 14. Medial incision for a triple arthrodesis. This incision begins within the medial gutter of the ankle and extends toward the first metatarsal base.

Figure 15A. The tibialis anterior tendon is located along the dorsal aspect and tibialis posterior tendons along the inferior aspect of the wound.

Figure 15B. The deep fascia/periosteal incision is made between the two tendons with care taken to ligate vessels along the most distal aspect of the ankle joint capsule.

Figure 16A. Exposure of the talonavicular joint.

Figure 16B. Talonavicular joint following cartilage removal.

Figure 16C. Talonavicular joint following methodical breaking of the subchondral plate to enhance arthrodesis.

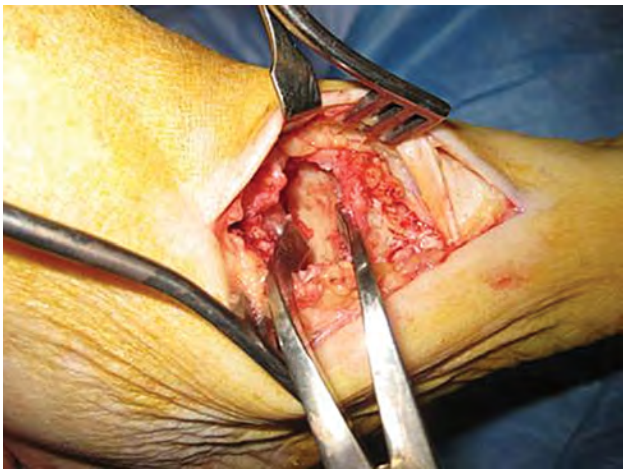

Figure 17A. The talonavicular joint following the cartilage removal.

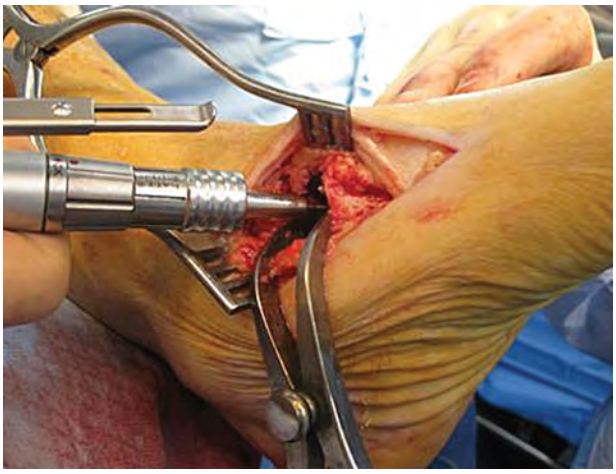

Figure 17B. A Surgairtome with rotary sidecutter burr being used to prepare the talonavicular joint.

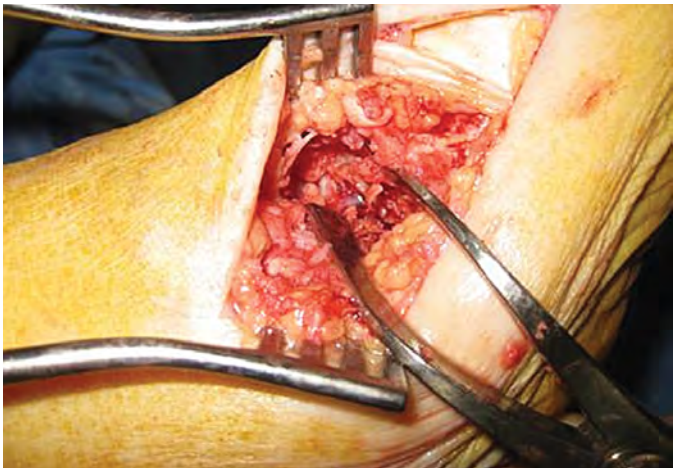

Figure 17C. The bone paste is left within the talonavicular joint to enhance arthrodesis.

Figure 18A. Maximum pronation during positioning of the subtalar joint prior to provisional fixation.

Figure 18B. Maximum supination.

Figure 18C. Neutral position.

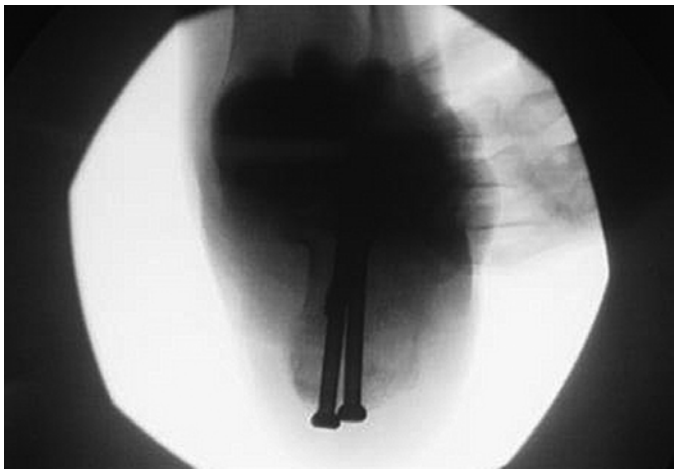

Figure 18D. Axial image showing relationship of the calcaneous to the tibia.

Figure 19A. Preoperative lateral view of stage 3 PTTD.

Figure 19B. Intraoperative lateral image demonstrating restoration of calcaneal inclination and provisional pin fixation.

Figure 20A. The fingers of the nondominant hand are placed along the distal aspect of the anterior tibial crest. This will serve as a target for placement of guide pins.

Figure 20B. Lateral intraoperative image showing guide pin placement.

with fluoroscopy on the lateral view (Figure 20). A second guide pin should then be placed in a similar direction. An AP image of the ankle should be obtained prior to screw delivery to ensure that the pins do not invade the ankle joint (Figure 21). Screw length is measured and confirmed on a lateral image. The large diameter screws are then delivered over the guide pins (Figure 22).

The talonavicular joint is the second joint to be addressed. Realignment is obtained by adducting the forefoot on the hindfoot and rotating the medial column in a plantar direction. The forefoot should parallel the hindfoot in the frontal and transverse planes. An AP image should demonstrate the talar head to be completely covered by the navicular and the talus-first metatarsal angle reduced to zero. A lateral image should also demonstrate the talus-

Figure 21. Anterior-posterior image of the ankle demonstrating guide pins located within the talus.

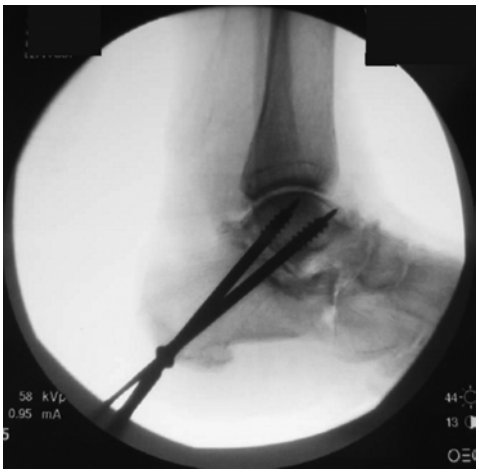

Figure 22. Lateral image following delivery of the large-diameter screws over guide pins.

first metatarsal angle to be zero, indicating sagittal plane realignment. The authors typically utilize smaller diameter screws in this joint. A guide pin is then inserted from the inferior aspect of the navicular tuberosity into the head and neck of the talus. This is performed under image intensification on a lateral view and an AP image should be obtained to confirm adequate placement within the talus (Figure 23).

A second pin is then placed from the dorsal aspect of the distal navicular into the midsubstance of the talus. This pin should be in the lateral aspect of the joint. This should be performed under lateral image intensification and then confirmed on an AP image. Measurements are then taken and cannulated screws are delivered over the guide pins (Figure 24).

There is little positioning required for the calcaneocuboid joint as its position has been secured by positioning and fixation of the subtalar joint and talonavicular joint. Fixation can be accomplished with two small diameter cannulated screws placed in various constructs (Figure 25). Alternatives include the use of one large diameter screw in an axial fashion placed from either distal to proximal or proximal to distal and staple fixation (Figure 26).

Hemostasis and Closure

The pneumatic thigh tourniquet is released and hemostasis achieved following osteosynthesis. Any small defects can then be packed with bone graft. The authors will often decorticate the undersurface of the talus and dorsal aspect of the calcaneus. This area is then packed with a combination of bone graft and bone graft substitute that provide osteoinduction. A closed suction drain is placed and closure performed. A popliteal nerve block is performed to aid in postoperative pain management.

POSTOPERATIVE MANAGEMENT

Patients with a risk of deep vein thrombosis receive prophylactic anticoagulation during the initial postoperative immobilization period. The patient will remain non-weightbearing for 6-8 weeks or until osseous consolidation is noted on serial radiographs. The patient is then transitioned into a walking fracture boot and progresses from partial weightbearing to full weightbearing over the span of 2-3 weeks, with eventual return to standard foot gear. Residual postoperative edema is managed with compression stockings upon transition into the walking boot. Depending on the patient's progress and length of recovery, physical therapy may be beneficial in promoting a more comfortable and expeditious return to activity. We especially consider physical therapy if the posterior muscle group was lengthened in an elderly person.

COMPLICATIONS

Complications following triple arthrodesis include nonunion, malunion/malposition, anterior or lateral impingement, fixation problems, loss of correction, and progressive degenerative joint disease of the ankle. The incidence of nonunion following triple arthrodesis for adult acquired flatfoot is relatively low when compared to those patients undergoing triple arthrodesis for post-traumatic arthritis. Adequate joint preparation, two-point fixation and adequate non-weightbearing until consolidation are important factors relative to prevention of nonunion. Unfortunately, nonunion is often associated with malunion and this requires revisional surgery. Malposition can be avoided by meticulous intraoperative positioning, utilizing both clinical and radiographic confirmation. Lateral impingement is often the result of inadequate realignment

Figure 23A. The initial guide pin for fixation of the talonavicular joint is delivered just inferior to the navicular tuberosity.

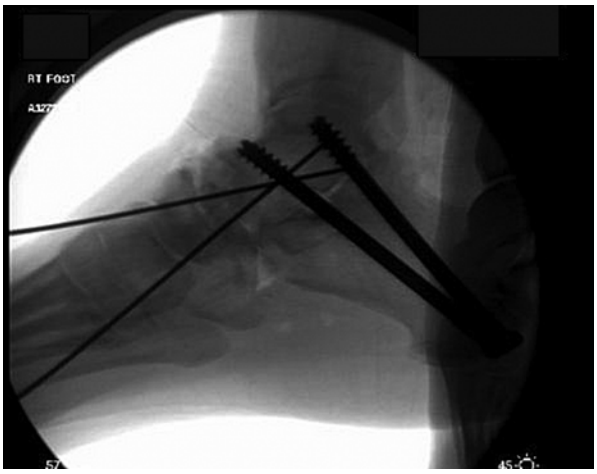

Figure 23B. Lateral image confirming guide pin placement. Notice restoration of the talus-first metatarsal angle.

Figure 23C. Anterioposterior image confirming guide pin placement, noticed complete coverage of the talar head.

Figure 24A. Intraoperative picture showing guide pin placement within the talonavicular joint.

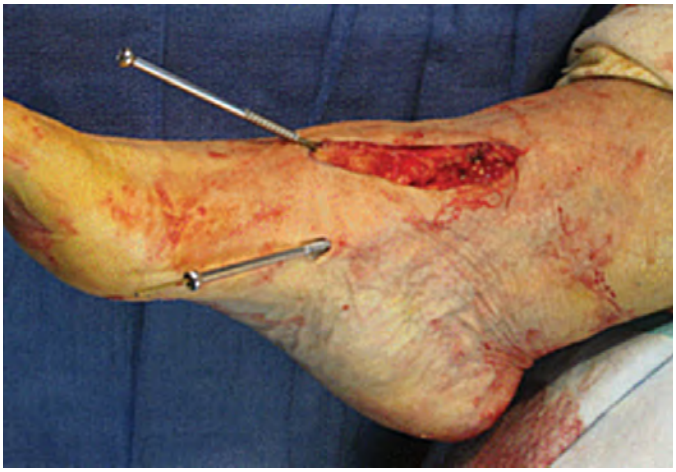

Figure 24B. Delivery of small-diameter screws over guide pins.

Figure 24C. Anterioposterior image following screw delivery.

Figure 24D. Lateral image following screw delivery.

Figure 25A. Intraoperative image demonstrating guide pin placement for calcaneocuboid joint.

Figure 25B. Small diameter screw delivery over guide pins.

Figure 25C. Anterioposterior radiograph confirming screw placement.

Figure 25D. Lateral image confirming small diameter screw placement.

of a severe valgus deformity. Anterior impingement is secondary to overcorrection when reducing the talonavicular joint, which can result in a horizontal talus and subsequent decrease in ankle joint range of motion. Ankle joint arthritis is not uncommon following triple arthrodesis. However, most ankle arthritis is asymptomatic. Pell et al demonstrated that patient satisfaction was not correlated with the degree of deformity or ankle arthritis following triple arthrodesis. Rather, patient satisfaction was correlated with postoperative alignment (7).

Figure 26A. Intraoperative image demonstrating guide pin placement of large diameter screw fixating the calcaneocuboid joint.

Figure 26B. Anterioposterior image confirming guide pin placement.

Figure 26C. Lateral radiograph showing axial-placed large-diameter screw for the calcaneocuboid joint.

SUMMARY

Triple arthrodesis for adult acquired flatfoot results in universally good outcomes. Patients typically demonstrate decreased symptoms and an improved level of function. This procedure has proven to be quite predictable. Results are enhanced with adequate preparation of joint surfaces, bone graft/bone graft substitutes, two-point fixation of all tri-tarsal joints, a vertical heel position and extra-articular arthrodesis. Adequate realignment is the most critical factor relative to outcome.

REFERENCES

1. Fortin PT, Walling AK. Triple Arthrodesis. Clin Orthop Relat Res 1999;365:91-9.
2. Bennett GL, Graham CE, Mauldin DM. Triple arthrodesis in adults. Foot Ankle 1991;12:138-43.
3. Bednarz PA, Monroe MT, Manoli A. Triple arthrodesis in adults. Foot Ankle Int 1999;20:356-63.
4. Catanzariti AR, Mendicino RW, Maskill MP. Posterior tibial tendon dysfunction. In: Southerland JT. McGlamry's Comprehensive Textbook of Foot and Ankle Surgery. Philadelphia: Lippincott Williams & Wilkins; 2012. p. 636-69.
5. Resnick RB, Jahss MH, Choueka J, Kummer F, Hersch JC, Okereke E. Deltoid ligament forces after tibialis posterior tendon rupture: effects of triple arthrodesis and calcaneal displacement osteotomies. Foot Ankle Int 1995;16:314.5
6. Song, SJ, Lee S, O'Malley MJ, Otis JC, Sung IH, Deland JT. Deltoid ligament strain after correction of acquired flatfoot deformity by triple arthrodesis. Foot Ankle Int 2000;21:573-7.
7. Pell RF, Myerson MS, Schon LC. Clinical outcome after primary triple arthrodesis. J Bone Joint Surg Am 2000;82:47-57.