# The Adult Acquired Flatfoot Deformity: A Treatment Algorithm

*Troy Watson, MD*

**Abstract:** The presentation of an adult with acquired flatfoot deformity is highly variable with a wide range of foot deformities. There remains much controversy in the treatment of the flexible deformities that are moderate to severe. If conservative treatment fails, surgery is often recommended to prevent progression of the deformity and continued pain. This article presents clinical and radiographic parameters in an algorithmic approach to the surgical management.

**Key Words:** adult acquired flatfoot, posterior tibial tendon dysfunction, algorithm, flexible flatfoot

(*Tech Foot & Ankle* 2012;11: 102–111)

There are few conditions in foot and ankle surgery that elicit as much controversy and discussion as the adult acquired flatfoot deformity. As our understanding of the underlying pathology has evolved, so to have the procedures we use to treat the deformity. Although many of the conservative treatment options remain the same, surgical options have evolved over time and today there are a myriad of surgical procedures to consider when correcting the acquired flatfoot deformity. Increasingly, I find it inadequate to treat the flexible flatfoot deformity with simply a medializing calcaneal osteotomy (MCO) and a flexor digitorum longus (FDL) transfer to the navicular.

The adult acquired flatfoot deformity typically presents with flattening of the medial longitudinal arch leading to insufficiency of the medial ankle and hindfoot structures. Most commonly this is associated with posterior tibial tendon dysfunction (PTTD). In what follows, the author reviews the significant clinical features, the diagnostic workup, and treatment options for this difficult-to-treat problem. As procedures and techniques have evolved, new avenues for improved deformity correction and potentially improved clinical outcomes are explored. Surgeons must have a concise algorithm for correcting deformity in this disease based on sound mechanical principles and an awareness of what works best in their hands.

## CLINICAL FINDINGS

A thorough history is typically elicited before the physical examination. A history of diabetes, trauma, duration and location of symptoms, previous treatment, and any family history of inflammatory arthropathies is explored with the patient.

The decision making begins in the office with the clinician examining the patient. The patient should be wearing shorts or able to roll the pant legs above the knee and the shoes and socks removed. With the patient in the standing position and facing the clinician, the knee is checked for genu valgus, which can lead to an increased load on the medial ankle and development of a planovalgus foot deformity. It is important that the patient stand with both knees facing forward as they often will internally rotate the affected extremity to have the appearance that the affected foot is facing forward. The ankle and foot is also observed in this position for any angular deformities, forefoot abduction, and subfibular impingement.

The patient is then turned 180 degrees to face away from the clinician. In this position, the hindfoot valgus is measured using a goniometer to quantitate the severity of deformity. Looking at the medial ankle, swelling overlying the medial ankle can be best observed and easily compared with the contralateral extremity. With the patient standing and the patella facing directly forward, the clinician observes associated forefoot abduction with the too-many-toes sign. To assess residual strength and integrity of the posterior tibial tendon (PTT), the patient is asked to perform a double-leg heel raise looking specifically for asymmetric hindfoot inversion. Lack of symmetry indicates that the affected PTT is incompetent to invert the subtalar joint. Next, the patient is asked to complete a single-leg heel raise on the affected side noting that inability to do so is consistent with PTTD. Care must be taken to avoid patients assisting themselves with their hands or arms during this test to assure an accurate test.

Sitting examination should include range of motion testing of the ankle, subtalar, and midfoot joints, especially those of the medial column. Ankle motion should be full and symmetric when compared with the contralateral ankle. Ankle motion should be examined in subtalar neutral with the knee both flexed and extended, allowing the practitioner to differentiate between gastronemius and Achilles tendon contracture, which is usually present with a valgus hindfoot (Silverskjold test). Having the patient circumduct the foot in the seated position in comparison with the opposite extremity often elicits subtle differences in subtalar range of motion that a patient may sense and the clinician observes. This may be an indication of early subtalar joint arthrosis if a decrease in motion is noted. Quantitative measurements of subtalar joint range of motion are best done using a goniometer with the patient placed in the prone position and the knee flexed to 90 degrees.

Palpation over the medial ankle and along the PTT may elicit pain, swelling, and tenosynovitis along the course of the tendon. Often a boggy sponge-like feel is noted with palpation along the course of the PTT indicating fluid within the sheath and tenosynovitis. Often pain is a major component over the medial ankle and PTT but in long-standing cases, pain dissipates over the medial ankle and becomes more prominent over the lateral ankle and hindfoot, often secondary to subtalar joint arthrosis or subfibular impingement. Palpation over the sinus tarsi and along the peroneal tendons may reveal tenderness and should be assessed. Callus formation overlying the abducted talar head may be noted.

From the Foot and Ankle Institute, Desert Orthopaedics Center, Las Vegas, NV.

Dr Watson received nothing for writing this paper and it is not directly linked to any manufacturer of implants.

The author declares no conflict of interest.

Address correspondence and reprint requests to Troy Watson, MD, Foot and Ankle Institute, Desert Orthopaedics Center, 2800 Desert Road Inn, Suite 100, Las Vegas, NV 89121. E-mail: feetmd@mac.com.

The last aspect of the seated examination involves an attempt at reduction of the flatfoot deformity. The heel is reduced to a subtalar neutral position and the severity of forefoot varus is observed. A line is drawn along the plantar aspect of the metatarsal heads should be perpendicular to a line drawn down the long axis of the tibia and calcaneus. In long-standing cases of PTTD, the patient's hindfoot assumes a valgus position and the forefoot develops a compensatory varus deformity. This forefoot varus can be flexible and easily reducible to a neutral position or in long-standing cases, it may become fixed in nature. In addition, hypermobility of the first metatarsal-cuneiform joint should be ruled out as this, if present, may be an indication for medial column stabilization when treating the adult acquired flatfoot.

## CLINICAL STAGING

PTTD is a continuum process with patients presenting at differing stages and severity of deformity. In its earliest stages, patients may simply present with pain over the medial ankle and no deformity or late presenting cases may have no pain medially, but significant pain over the lateral hindfoot joints indicating progression to arthrosis.

Johnson and Strom[1] described 3 stages of PTTD with Myerson[2] adding an additional stage IV. Staging of the disease process allows the clinician to begin the thought process of treatment options. As this is a progressive disease process, without clinical intervention, a patient will typically continue to advance through the stages of PTTD. Thus, staging a patient is an excellent starting point for a treatment algorithm in the treatment of the adult acquired flatfoot (Table 1).

In stage I, patients have tenosynovitis of the PTT and typically complain of medial ankle pain but have no significant deformity present. The length of the tendon is preserved and, as a result of this, the strength of the tendon is maintained and the patient demonstrates a normal single-heel and double-heel raise test. In addition, no hindfoot valgus, forefoot abduction, or other deformity is present. This remains a rare stage for presentation.

With stage II disease, the foot begins to develop a hindfoot valgus deformity as the PTT degenerates and elongates. In the past, stage II has been subdivided into a IIa and a IIb deformity, but it may be more logical and fitting to subdivide this stage into a IIa (mild), a IIb (moderate), and a IIc (severe) category. In the early stage II or stage IIa, pain and swelling is noted over the medial ankle and there is evidence of early flatfoot deformity. There may be some forefoot abduction evident by the appearance of the too-many-toes sign. These patients can typically perform a single-limb heel raise, but they do so with some pain. The heel will typically invert past the midline with a double-limb heel raise. With the patient in the seated position, the hindfoot valgus can be corrected to neutral and the forefoot abduction usually corrects quite easily. There is minimal compensatory forefoot varus. As the disease process continues to advance further deformity is noted. The stage IIb patient presents with moderate heel valgus (< 15 degrees), may not be able to invert the heel past the midline although some inversion is seen, and can usually perform a single-heel raise but with difficulty and pain. In the late stage II or stage IIc, pain migrates laterally as the calcaneus abuts the fibula creating subfibular impingement. With the PTT becoming increasingly dysfunctional, the heel typically will not translate into inversion as the patient performs a double-limb heel raise. In addition, these patients will not be able to perform a single-limb heel raise. The hindfoot valgus (> 15 degrees) and forefoot abduction become more pronounced in stage IIc as does the flatfoot deformity and collapse. Often times, with the heel reduced to subtalar neutral, the compensatory forefoot varus present may be significant and difficult to passively reduce to neutral. Forefoot varus >10 degrees greater than the contralateral side is considered significant.

Stage III progresses to a rigid deformity meaning the calcaneus is no longer easily reducible to neutral and the forefoot abduction can no longer be passively reduced.

**TABLE 1.** The Stages of Adult Acquired Flatfoot Deformity

| | | Radiographs | |
|---|---|---|---|
| **Stages** | **Deformity** | **Anteroposterior** | **Lateral** |
| I | Pain and swelling along PTT; no deformity | No findings | May see some preexisting flatfoot |
| IIa | Mild flatfoot deformity, heel valgus <5 degrees, inverts past the midline, able to perform single-heel raise, minimal forefoot abduction | < 25% talar head uncoverage | < 10 degrees of collapse of the talar-first metatarsal angle |
| IIb | Moderate flatfoot deformity, heel valgus <15 degrees, may demonstrate inability to invert heel past the midline, difficulty with single-limb heel raise | Talar head uncoverage of between 25% and 40% | 10-20 degrees of collapse at the talar-first metatarsal angle |
| IIc | Severe flatfoot but remains flexible, heel valgus >15, inability to invert past midline, inability to perform a single limb-heel raise, lateral subfibular impingement, severe abduction deformity | Talar head uncoverage >40% | > 20 degrees of collapse at the talar-first metatarsal angle |
| III | Fixed flatfoot deformity; may be able to reduce heel valgus but residual forefoot varus uncorrectable | Arthritic changes at the talonavicular and calcaneocuboid joints may be seen; deformity typically as described for the stage IIc | Arthritic changes noted at triple hindfoot joints will be variable; deformity typically as described for the stage IIc |
| IVa | Flexible ankle valgus with underlying flatfoot foot deformity | Evaluate ankle film for severity of deformity and note minimal arthritic change; may utilize fluoroscopy to evaluate flexibility of the deformity | No significant ankle arthritis noted |
| IVb | Fixed ankle valgus deformity with flatfoot deformity | Evaluate ankle for severity of deformity and arthritis | Evaluate ankle for subluxation, joint space narrowing, osteophytes |

In addition, there may be a rigid forefoot varus deformity present. Pain now is mostly localized to the arthritic hindfoot joints, especially the subtalar joint. Once again, these patients cannot perform a single-limb heel raise and the calcaneus does not invert with the double-limb heel raise. These patients may also present with midfoot collapse and arthritic changes of the midfoot, especially the medial column.

Stage IV was added by Myerson and is essentially a stage III with a valgus deformity of the ankle joint secondary to eccentric loads placed across the deltoid ligament with a long-standing valgus hindfoot deformity. Early stage IV may present with pain over the lateral aspect of the ankle joint as the foot deformity leads to lateral compartment thinning of the articular cartilage without significant deformity. As most clinicians would agree, this remains one of the most difficult treatment dilemmas in foot and ankle orthopedics.

## DIAGNOSTIC IMAGING

There is no established radiography protocol in the workup of patients with PTTD. Weight-bearing views of the foot and ankle are recommended at the initial office visit. Non–weight-bearing views are of little utility as they fail to accurately define the deformity present. The ankle films are reviewed for ankle deformity and arthritis. There are many described lines, angles, and other measurements that have been defined in the literature to assess the adult acquired flatfoot. Many of these defined measurements are of little use to the clinician as they show low intraobserver and interobserver correlation.

Younger et al[3] reviewed several radiographic parameters looking specifically for those measurements that accurately define a flatfoot deformity and allow the surgeon to assess his postoperative correction. Furthermore, they looked for those radiographic measurements that were most reproducible. On the weight-bearing lateral radiograph the talar-first metatarsal angle, the calcaneal pitch angle and the medial cuneiform-fifth metatarsal height differed significantly between the symptomatic flatfoot patient group and the control group. Of these, the talar-first metatarsal angle was determined to be the most discriminating and statistically significant radiographic parameter in patients who had symptomatic flatfoot. This measurement also showed good correlation between readings (intraobserver and interobserver) making this a fairly reproducible radiographic parameter. On the anteroposterior (AP) radiograph, they measured talar-first metatarsal angle, talonavicular coverage angle, calcaneal-fifth metatarsal angle, and the talar head uncoverage distance. They found the talar head uncoverage distance to be the most statistically significant value but with a lower intraobserver and interobserver reliability.

Perhaps a more simplistic means of describing abduction deformity of the foot radiographically is to measure the amount of talonavicular uncoverage as a percentage, for example, 30% uncoverage of the talar head. The author finds this to be a quick and useful means of defining the flatfoot deformity on the AP radiograph and in the decision-making algorithm. In fact, Deland[4] uses this radiographic parameter to differentiate between stage IIa and stage IIb. A mild flatfoot deformity is defined as one with minimal abduction deformity through the midfoot and $<30\%$ talar head uncoverage on the standing AP radiograph, with the more advanced stage IIb showing $>30\%$ uncoverage on the AP radiograph. Furthermore, Vora et al[5] demonstrated in a flatfoot model in the laboratory that the flexible stage II flatfoot required division into a mild and severe category when recommending surgical procedures. The authors concluded that while the less severe acquired flexible flatfoot might be appropriately treated with a combined MCO and FDL transfer, the more severe deformity might require additional procedure for adequate correction. Despite these many radiographic measurements, the intraoperative correction of deformity is best performed using a sequential algorithmic plan.

In addition to the diagnostic imaging outlined above, magnetic resonance imaging (MRI) and computed tomography (CT) may also play a role in the diagnostic workup of a patient presenting with an adult acquired flatfoot. CT scans are most helpful in evaluating the late stage IIb or early stage III where the surgeon is uncertain as to which treatment pathway to follow. The CT scan may allow for better assessment of the hindfoot joints looking specifically for arthritic changes. Subfibular impingement is also accurately assessed with CT. MRI can be a useful adjunct to the workup helping to confirm the diagnosis and evaluate the severity of pathology in the tendon as well as the spring ligament complex. I have also found MRI useful to further educate my patients on the disease process and the potential need for surgical intervention.

## OTHER DIAGNOSTIC MODALITIES

Use of differential injections can help the clinician through the treatment algorithm for patients presenting with PTTD. It is sometimes difficult, especially in younger patients, to assess the degree of subtalar or talonavicular joint arthrosis. At times these joints may seem somewhat normal by the weight-bearing films obtained in the office. The use of a selective injection may help the clinician differentiate the amount of the patient's discomfort that is attributable to a degenerative joint. The author will often recommend a differential injection into the subtalar joint and then base part of the decision to move forward with a triple arthrodesis versus a joint sparring reconstruction on the outcome and temporary pain relief achieved.

In office, ultrasound may offer some advantages in the diagnostic workup over CT and MRI. Many practitioners now have these units within their office. Ultrasound has been recognized as an inexpensive imaging modality for evaluating tendon disorders in the foot and ankle. Chen and Liang[6] studied the use of ultrasound for diagnosing the mild cases of PTTD. The researchers suggest that ultrasound may be superior to MRI based on speed, convenience, low cost, and its dynamic nature. They also caution the surgeon that an experienced sonographer is necessary to accurately interpret the images.

## NONOPERATIVE TREATMENT

After the initial presentation, most patients will be treated with conservative modalities targeted at decreasing inflammation around the PTT and decreasing pain. Immobilization in a walker boot or cast can be a most effective treatment for the acutely inflamed tendon. After a period of 4 to 6 weeks, the patient with a mild to moderate flexible flatfoot deformity is advanced into an orthosis with a medial heel wedge, which is fabricated for bilateral feet. For more severe deformities, a short articulated ankle-foot orthosis or an Arizona brace may be trialed. Physical therapy can be used once the inflammatory phase has subsided. A program stressing strengthening and stretching of the Achilles tendon, inversion ankle exercises, and modalities may be helpful for the symptomatic patient. Alvarez et al[7] showed the efficacy of a concentrated physical therapy program combined with a foot orthosis or a short articulated ankle-foot orthosis in treatment of the symptomatic

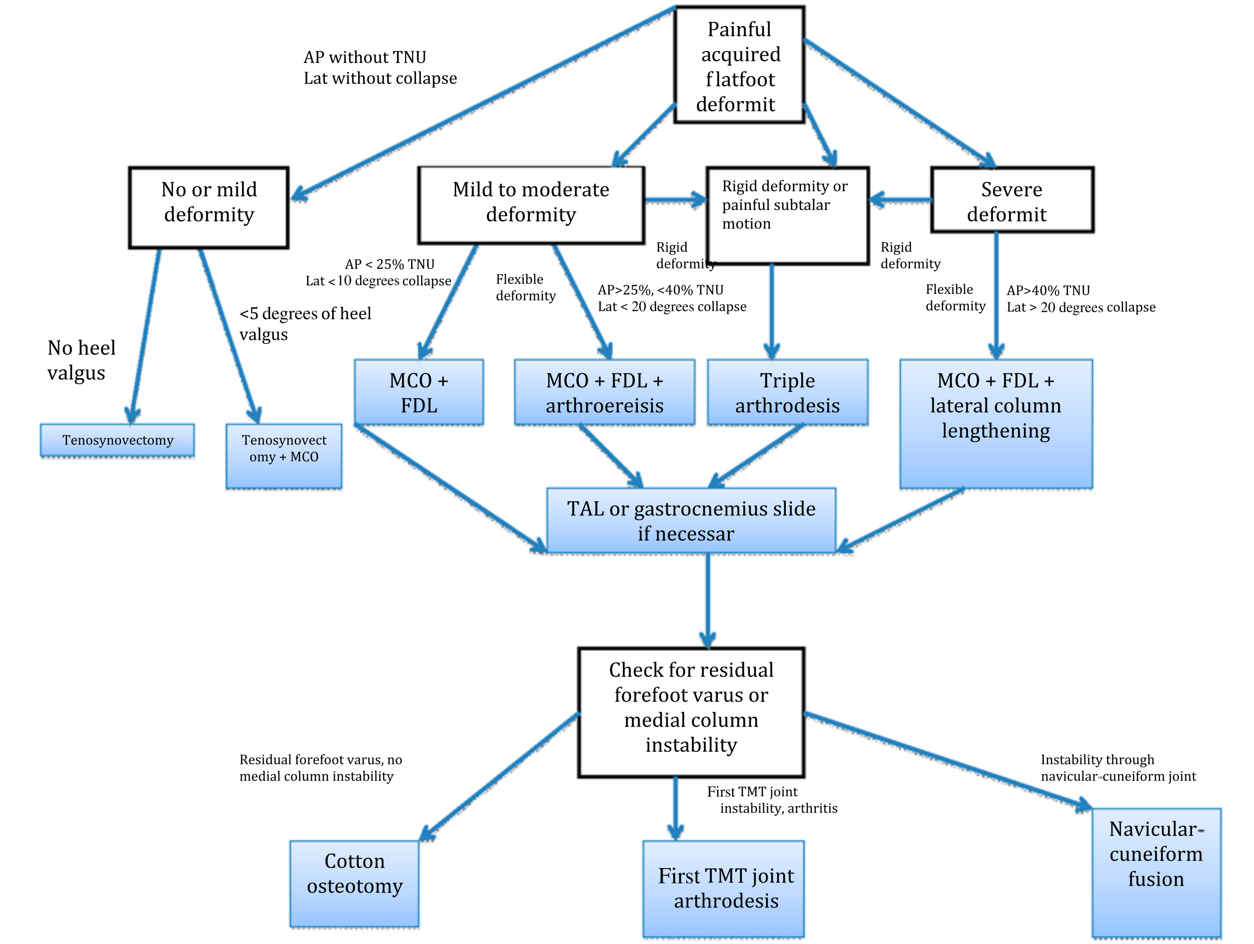



FIGURE 1. Algorithm for the adult acquired flatfoot deformity. AP, anteroposterior; FDL, flexor digitorum longus; MCO, medializing calcaneal osteotomy; TAL, Tendo-Achilles Lengthing; TMT, tarsometatarsal; TNU, talonavicular uncoverage.

PTTD patient. Eighty-three percent of their patients had successful subjective and functional outcomes and 89% reported satisfaction with their result. When conservative treatments fail to improve symptoms or deformity progression is noted, operative intervention is considered.

## OPERATIVE TREATMENT

### Stage I PTTD

When conservative modalities have failed to improve the symptoms of tensynovitis along the course of the PTT, then surgery may be indicated. This is a rare presentation and surgical intervention typically consists of debridement of the tendon and repair of any longitudinal split tears noted. In the event of more advanced tendinosis, other procedures may be required such as FDL transfer (Fig. 1).

A thigh tourniquet is applied before incision. The incision is then made along the course of the PTT and the tendon sheath opened. All synovitis within the tendon sheath should be removed, the tendon inspected and repaired if necessary and the tendon sheath reapproximated. Postoperatively, patients are placed into a splint for 10 to 14 days and then transferred to a walker boot for an additional 4 weeks. Physical therapy should be instituted early to prevent tendon adhesions and scar tissue formation.

### Stage II PTTD

Most of the controversy surrounding the adult acquired flatfoot is seen with the surgical management of the stage II deformity. The stage II or flexible flatfoot deformity has a wide variety in its presentation and thus we can conclude that not all stage II disease is equivalent. In fact recently, stage IIa and stage IIb has been defined to differentiate a mild and a more severe case of the flexible flatfoot. Further division into a IIa, a IIb, and a IIc group with each category representing a progression of the disease process and therefore requiring advancing surgical procedures. In addition, it may be helpful to categorize flatfoot in such a manner to provide surgeons with a clearer picture when defining outcomes as a result of surgical intervention.

In this scenario, the stage IIa disease presents with a mild flexible flatfoot deformity as defined by the clinical and radiographic examination. These patients have <5 degrees of hindfoot valgus, invert past the midline with the double-heel raise, have <25% talonavicular joint uncoverage on the AP radiograph and <10 degrees of collapse of talar-first metatarsal angle on the lateral radiograph. The surgical approach to this patient typically consists of an MCO and an FDL tendon


FIGURE 2. A–E, Preoperative and postoperative weight-bearing radiographs of type IIa posterior tibial tendon dysfunction treated with medializing calcaneal osteotomy and a flexor digitorum longus tendon transfer. Note approximately 1 cm of medial translation of the calcaneus on the heel axial view.

transfer to the navicular (Fig. 2). The medial heel slide corrects the heel valgus and also decreases strain over the medial ankle structures.[8] Other options for the stage IIa patient include an arthroereisis implant with an FDL tendon transfer medial, avoiding an MCO. However, for this stage of presentation, the surgeon should weigh the potential benefits of avoiding a calcaneal osteotomy versus the risk of potential pain in the sinus tarsi from the implant. It is best to reserve the arthroereisis implant for the more advanced deformity (IIb) as discussed later. It is the researchers' opinion that the diseased PTT should be resected distally leaving only 1 cm of tendon attached to the navicular to aid in secure fixation of the FDL tendon transfer. In addition, if tendon excursion remains intact, transfer or tenodesis of the PTT to the FDL proximal to the medial malleolus may maintain the use of the PTT muscle belly. A tight heel cord, if present, should be recognized after the MCO is completed and corrected with a lengthening procedure. It is rare that additional procedures are necessary in this early stage II presentation.

The stage IIb foot shows some advancement of the flatfoot deformity and a worsening clinical presentation. Namely, we see moderate heel valgus but not > 15 degrees, the hindfoot is now no longer able to invert past the midline with the double-heel raise, there is between 25% and 40% uncoverage of the talonavicular joint on the AP, and the lateral radiograph shows increased collapse of the talo-first metatarsal angle between 10 and 20 degrees. As shown in the laboratory model of Vora et al,[5] the increasing deformity in the flatfoot requires additional surgical procedures to adequately correct the foot position. In their "severe" group, the arch collapse (talar-first metatarsal angle) measured an average of 14.8 degrees and these did poorly with an MCO and FDL transfer alone. The researchers suggest that the more "severe" deformity requires additional procedures and suggest the addition of a subtalar arthroereisis implant to further correct the increase in deformity. Thus, the stage IIb patient as defined above typically will be treated with an MCO, subtalar arthroereisis implant and an FDL tendon transfer. The spring ligament should be inspected intraoperatively and repaired if attenuated or torn (Fig. 3). Most of these patients will also require a heel cord lengthening procedure. Lastly, the medial column should be examined closely for instability and addressed if present. Failure to correct residual medial column deformity is the chief reason for treatment failures in stage IIb deformity. Options include a first metatarsal-cuneiform plantarflexion fusion, a medial cuneiform opening wedge osteotomy (Cotton), or a navicular-cuneiform fusion. If instability is noted at the first tarsometatarsal joint or arthritis and pain is noted in this location preoperatively, than the addition of a plantarflexion fusion through this joint is indicated to provide a stable medial column. More commonly, after the MCO and subtalar arthroereisis implant is placed, the forefoot may supinate or have residual fixed varus requiring a Cotton osteotomy to correct the first ray position and restore the tripod of the foot. This cuneiform osteotomy is easy to perform, reliable, and has a high union rate. Lastly, if the location of the collapse of the longitudinal arch on the weight-bearing lateral radiograph is at the navicular-cuneiform joint, a stabilization procedure of this joint should be considered.


FIGURE 3. A–D, Preoperative and postoperative weight-bearing radiographs of type IIb posterior tibial tendon dysfunction treated with a medializing calcaneal osteotomy, subtalar arthroereisis, flexor digitorum longus tendon transfer, and Tendo-Achilles Lengthing Procedures are performed in that order with the lateral work being completed before externally rotating the leg for the tendon transfer.

Although subtalar arthroereisis has provided us with an excellent and powerful adjunct in the correction of the flexible flatfoot, further research will help define its use for this indication. Although the author and others performing this procedure have reported a 30% to 40% removal rate of the metallic implant due to residual pain in the sinus tarsi, the use of a biosorb implant may eliminate this complication. After switching to a biosorb implant, the author has noted no cases requiring implant removal. In cases where the metallic implant was removed after 6 months or so, no collapse or loss of correction was noted on subsequent radiographs.

Stage IIc demonstrates continued deformity with increasing heel valgus to >15 degrees, subfibular impingement, inability to invert the heel past the midline with the double-heel raise, >40% uncoverage at the talonavicular joint on the AP radiograph and significant loss of arch height as noted with increasing deformity >20 degrees through the talo-first metatarsal angle on the lateral radiograph. This more severe deformity is not correctable by the previously described procedures for the type IIb deformity. The author has not found subtalar arthroereisis combined with the MCO and FDL tendon transfer to be adequate in the correction of the flexible flatfoot when talonavicular uncoverage is over 40% and the talo-first metatarsal angle on the lateral film is >20 degrees. In these cases, the lateral column lengthening procedure is performed in place of subtalar arthroereisis and in combination with the other procedures described for the treatment of the type IIb flatfoot (Fig. 4). Lateral column procedures are designed to specifically improve a flatfoot deformity. The lateral column procedures correct the deformity in 3 planes by adducting the forefoot around the talar head, plantarflexing the midfoot, and derotating the hindfoot out of valgus. Lateral column lengthening procedures may be performed through the anterior portion of the calcaneus or through the calcaneocuboid joint. Calcaneocuboid distraction arthrodesis has a high rate of nonunion[9] and results in a higher incidence of lateral column pain when compared with lengthening done through the calcaneus.[10] These authors also showed that lateral column lengthening is not a benign procedure with some postoperative complications seen including lateral column foot pain, fifth metatarsal stress fractures, nonunion and significant stiffness.

## Stage III PTTD

In the stage III adult acquired flatfoot, the deformity becomes less flexible and more rigid to the point where passive reduction of the foot is no longer possible. In the stage III disease, a triple arthrodesis is necessary with intraoperative correction of the deformity. The author prefers a single lateral incision technique for correction and fixation, although a 2-incision technique may allow better access to the talonavicular joint but potentially higher nonunion rates. The foot is aligned by first correcting the substantial heel valgus, while rotating the talus back on top of the calcaneus. The subtalar joint is then provisionally fixed with guide wires and AP and lateral radiograph are obtained to assess concentric reduction of the talus, and restoration of the talo-first metatarsal angle on


FIGURE 4. A–D, Preoperative and postoperative weight-bearing radiographs of type IIc posterior tibial tendon dysfunction treated with a medializing calcaneal osteotomy, lateral column lengthening, and flexor digitorum longus tendon transfer. Residual forefoot varus noted after completion of the lateral column lengthening was addressed with a Cotton osteotomy to restore the tripod of the foot.

the AP and lateral views. After successful reduction of the subtalar joint and restoration of heel valgus to < 5 degrees, the forefoot is derotated correcting any residual forefoot varus and provisional fixation is placed across the talonavicular joint. The author prefers screw fixation at the subtalar and talonavicular joints, with compression staples placed laterally at the calcaneocuboid and talonavicular joints. A first metatarsal-cuneiform fusion is added for an unstable first ray. Achilles tendon contracture can be corrected with either a gastrocnemius slide or a triple hemisection technique of the Achilles tendon.

## Stage IV PTTD

Little has been published concerning the treatment of the stage IV flatfoot deformity and thankfully this remains a rare presentation. In fact, Myerson reported the incidence of the flexible stage IV cases to represent only 2.3% of all patients treated for PTTD over an 11-year period.[11] The stage IV disease has been further subclassified into a stage IVa where the tibiotalar joint is passively correctable and a stage IVb where the tibiotalar joint is rigid and not passively correctable.[12] Decision making in stage IV cases is then dependent on the clinicians ability to passively correct the tibiotalar angular deformity and the severity of arthritis present at this joint (Fig. 5). If the deformity is passively correctible (stage IVa) confirmed with fluoroscopy in the office, then the deltoid ligament is reconstructed in combination with a flatfoot reconstruction (usually a triple arthrodesis, but not always). The flatfoot reconstruction is typically performed first followed by the deltoid ligament reconstruction. Allograft reconstructions are preferred to use of suture anchors to reconstruct the anterior portion of the deltoid ligament. The lateral ligaments should be tested under fluoroscopy as well and repaired with suture anchors if deemed necessary at the time of the reconstruction. It is critical to position the foot in a plantigrade position or risk failure of the ligament repair in the joint sparring scenario. If the ankle deformity is not correctable (stage IVb) and/or has significant arthritic changes, then a tibiotalocalcaneal fusion or a pantalar fusion is required.

## SUMMARY

In all stages of PTTD and the adult flatfoot, nonsurgical management with immobilization followed by shoewear modifications, orthotics, bracing options, physical therapy, and anti-inflammatories should be trialed before considering operative intervention. Progressive deformity and/or pain in the foot are primary indications for operative treatment. Although preoperative planning is helpful, an intraoperative algorithmic approach to correcting stage II deformity is necessary so that the surgeon is confident that all foot deformity has been corrected before leaving the operating room. Rarely is surgical management necessary in the stage I PTTD. Stage II disease is best divided into three separate subcategories noting the continuum of disease process. The stage IIa can typically be


FIGURE 5. A–G, Preoperative and 2-year postoperative weight-bearing radiographs of stage IVa PTTD. Note stress view (C) reducing the valgus angular deformity. A triple arthrodesis was performed due to the severe deformity and inability to passively reduce the foot preoperatively. Once the triple arthrodesis was completed, a Tendo-Achilles Lengthing was performed. An open repair of the deltoid was performed due to the minor angular deformity utilizing suture anchors. The patient is currently asymptomatic at the ankle. It may be preferable to perform an allograft reconstruction of the deltoid.

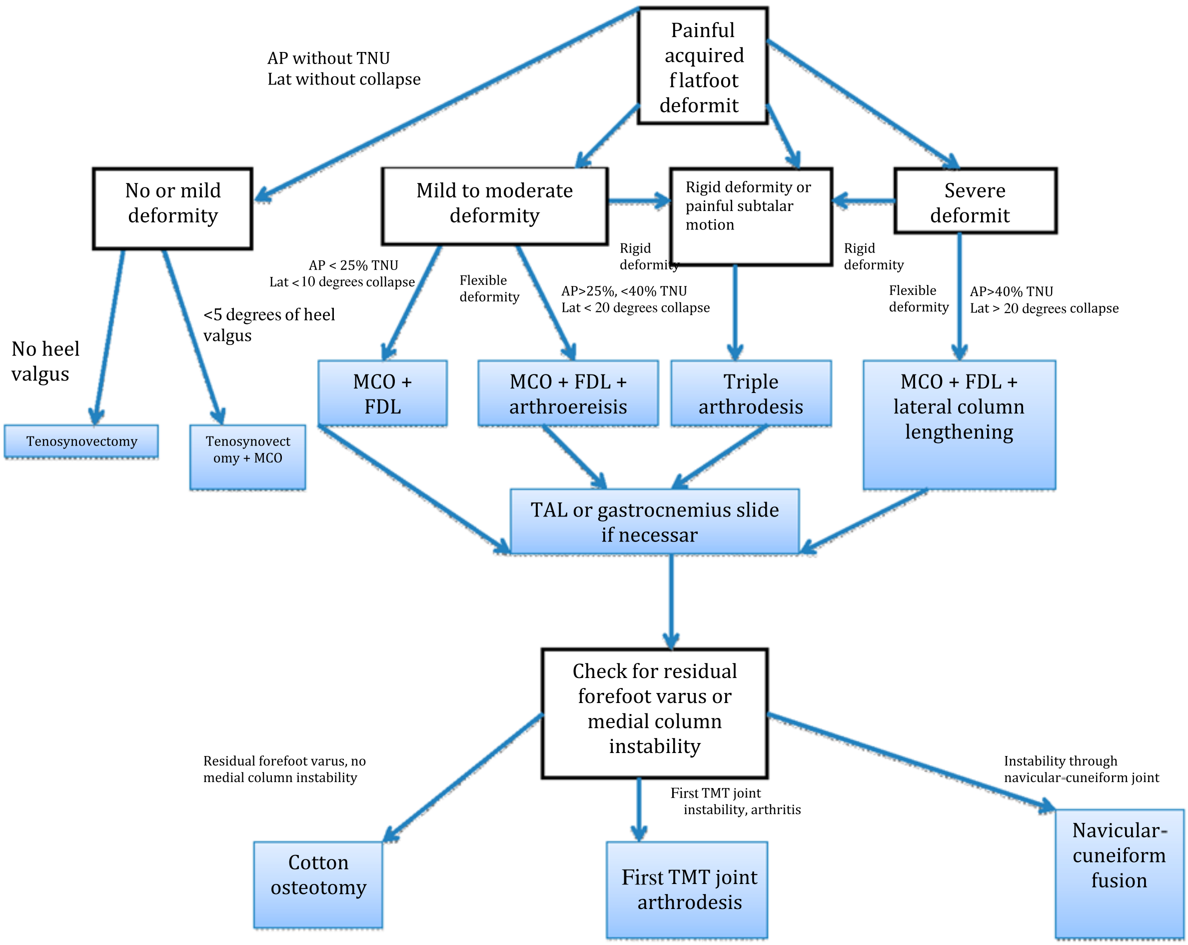
corrected with an MCO and an FDL tendon transfer and the stage IIb requiring the addition of a subtalar arthroereisis. The subtalar arthroereisis implant has emerged as a potentially beneficial augment that may bridge the gap between the treatment for the mild and more severe cases requiring a lateral column lengthening. As the foot progresses into additional valgus and forefoot abduction in the stage IIc, a lateral column lengthening is usually combined with an MCO and the FDL transfer. Additional procedures as previously described may be helpful in further correcting residual forefoot varus or an unstable medial column. Triple arthrodesis remains the treatment of choice for stage III with particular emphasis placed on correcting the foot to a plantigrade position as residual deformity is not well tolerated in these patients and may lead to a poor outcome. Finally, the stage IV disease is recognized as a challenging problem with treatment options dependent on the rigidity of the ankle deformity. Long-term studies will help define the long-term outcome for ligamentous repair at the level of the ankle when combined with flatfoot reconstruction.

## REFERENCES


1. Johnson KA, Strom DE. Tibialis posterior tendon dysfunction. *Clin Orthop Relat Res*. 1989;239:196–206.
2. Myerson MS. Adult acquired flatfoot deformity: treatment of dysfunction of the posterior tibial tendon. *Instr Course Lect*. 1997; 46:393–405.
3. Younger AS, Sawatzky B, Dryden P. Radiographic assessment of adult flatfoot. *Foot Ankle Int*. 2005;26:820–825.
4. Deland JT. Adult-acquired flatfoot deformity. *J Am Acad Orthop Surg*. 2008;16:399–406.
5. Vora AM, Tien TR, Parks BG, et al. Correction of moderate and severe acquired flexible flatfoot with medializing calcaneal osteotomy and flexor digitorum longus transfer. *J Bone Joint Surg Am*. 2006;88: 1726–1734.
6. Chen YJ, Liang SC. Diagnostic efficacy of ultrasonography in stage I posterior tibial tendon dysfunction: sonographic-surgical correlation. *J Ultrasound Med*. 1997;16:417–423.
7. Alvarez RG, Marini A, Schmitt C, et al. Stage I and II posterior tibial tendon dysfunction treated by a structured nonoperative management protocol: an orthosis and exercise program. *Foot Ankle Int*. 2006;27: 2–8.
8. Otis JC, Deland JT, Kenneally S, et al. Medial arch strain after medial displacement calcaneal osteotomy: an in vitro study. *Foot Ankle Int*. 1999;20:222–226.
9. Wong YS, Conti SF. Osteolysis of structural autograft after calcaneocuboid distraction arthrodesis for stage II posterior tibial tendon dysfunction. *Foot Ankle Int*. 2002;23:521–529.
10. Thomas RL, Wells BC, Garrison RL, et al. Preliminary results comparing two methods of lateral column lengthening. *Foot Ankle Int*. 2001;22:107–190.
11. Bluman E, Myerson M. Stage IV posterior tibial tendon rupture. *Foot Ankle Clin N Am*. 2007;12:341–362.
12. Blueman E, Title C, Myerson M. Posterior tibial tendon rupture: a refined classification system. *Foot Ankle Clin*. 2006;12:233–249.

## APPENDIX

Watson T. The Adult Acquired Flatfoot Deformity: A Treatment Algorithm. *Tech Foot Ankle Surg*. 2012;11:102–111.




**ALGORITHM.** Algorithm for the adult acquired flatfoot deformity. AP, anteroposterior; FDL, flexor digitorum longus; MCO, medializing calcaneal osteotomy; TAL, Tendo-Achilles Lengthing; TMT, tarsometatarsal; TNU, talonavicular uncoverage.