ANKLE AND PANTALAR ARTHRODESIS

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In: Foot and Ankle Disorders

Edited by Mark S. Myerson, M.D.

Since reports in the late 19th Century, arthrodesis has been a successful accepted treatment method for painful disorders of the ankle, subtalar, and transverse tarsal joints. While the title of this chapter involves arthrodesis - the intentional fusion of a joint - as a form of reconstruction, this chapter will address not only surgical technique, but nonoperative methods of care as well. We will address the pathophysiology leading to ankle and hindfoot disability, succinctly review the existing literature on the topic of hindfoot and ankle arthrodesis, highlight the pathomechanics involved, and spend considerable time on establishing the diagnosis, indications, and preoperative planning when surgery is indicated. We also will discuss the rehabilitation of the postoperative patient, as well as the management of complications that may arise after ankle and pantalar arthrodesis.

There are more than thirty different viable techniques that have been described in order to achieve successful ankle and hindfoot arthrodesis. It is not the purpose of this chapter to serve as compendium of all the techniques ever described. The author will, rather, attempt to distill into a useful amount of clinically applicable material this vast body of information that the literature and clinical experience provide.

Ankle arthrodesis is defined as surgical fusion of the tibia to the talus. Surgical fusion of the ankle (tibiotalar) and subtalar (talocalcaneal) joints at the same operative sitting is termed tibiotalocalcaneal arthrodesis. Fusion of the talus to all the bones articulating with it (distal tibia, calcaneus, navicular, and cuboid) is termed pantalar arthrodesis. Despite the myriad techniques existing for surgical approach to fusion and implants employed, these techniques all have in common a similar goal: the formation of a solid, pain free arthrodesis in a biomechanically stable and functional position.

Ankle arthrodesis can eliminate pain and improve function in even the most severely disabled
patient when the technique is clinically indicated. This technique is not without its pitfalls and biomechanical alterations of the extremity, however. Even more so, tibiotalocalcaneal and extended pantalar arthrodeses are quite technically demanding, though useful procedures, that may be employed for a variety of indications. These latter procedures, however, should be viewed as salvage techniques to be used for what otherwise would be an extremely disabling or even limb threatening clinical situation.

Indications for ankle arthrodesis include primary or post-traumatic osteoarthrosis, rheumatoid arthritis, and avascular necrosis of the talus. Tibiotalar fusion can also be done for the painful sequelae of septic arthritis and hemophilic arthrosis.

Tibiotalocalcaneal arthrodesis is indicated for any of the reasons just listed and additionally may be employed for the failed total ankle arthroplasty with subtalar intrusion or a failed attempt at ankle fusion with resultant insufficient talar body. Other indications for tibiotalocalcaneal fusion include the severe deformity of untreated clubfoot or neuromuscular disease, Charcot neuroarthropathy, or skeletal defects after tumor reconstruction. Pseudarthrosis of any etiology, as well as fixed or flail ankle and hindfoot deformities due to other causes are also indications for tibiotalocalcaneal arthrodesis.

A pantalar arthrodesis may be employed for any of the reasons listed above that also include significant instability, subluxation, or arthritis involving the ankle, hindfoot and transverse tarsal joints.

Contraindications for performing ankle and hindfoot arthrodesis include the dysvascular extremity or one involved with severe, active infection. Contraindications specific to ankle arthrodesis performed by arthroscopic or mini-arthroscopy techniques and contraindications to closed medullary nailing techniques for tibiotalocalcaneal and pantalar arthrodesis include the presence of moderately severe or severe and fixed deformity of the ankle, hindfoot and distal tibia. Such closed or minimally invasive techniques are contraindicated because of the difficulty in obtaining collinear reduction in satisfactory position and alignment of the tibia and hindfoot employing these techniques. Such significant deformity often requires
an open, realigning, reconstructive procedure often employing osteotomy, talectomy, or resection of appropriate wedges of bone to obtain satisfactory functional position and alignment by arthrodesis.

**ANKLE ARTHRODESIS**

The author has found successful ankle arthrodesis to be one of the most gratifying procedures in terms of pain relief and the patient's improved function when applied to the patient with appropriate indications. Most patients considered candidates for arthrodesis of the ankle have already lost a good deal of motion at this joint, and depending upon how long they have been living with for example arthritic pain of the ankle, often remark very early in their postoperative course after arthrodesis with rigid internal fixation that the preoperative pain has been greatly relieved by the procedure. The key to a successful result when employing ankle arthrodesis for these patients is obtaining and maintaining a solid arthrodesis in the appropriate position. Whether fixed internally or externally, rigid fixation is the key to a successful result and an early relief of the patient's preoperative pain.

Alternatives to arthrodesis include total ankle replacement arthroplasty, but this procedure has proven unrewarding to date. Existing implants, even in the appropriately selected patient, often fail at the bone cement or bone implant interface due to the unique biomechanical stresses applied to the tibiotalar articulation. Resection of adequate amounts of talar body and distal tibial articular surface in order to accommodate existing ankle joint replacements, often adversely affect the motion and mechanics of the joint, as well as leave very little native talus intact. Foot and ankle orthopaedists practicing since the mid-1980's no doubt have removed more failed total ankle replacement prostheses than they have ever implanted.

The appropriate patient for total ankle replacement is one who has excellent bone stock, little deformity, is not overweight, and places little demand on the extremity. Suffice it to say that at the date of publication, the patients appropriate for total ankle replacement arthroplasty are few in number.
Nonoperative management for the patient with isolated tibiotalar arthritis and/or deformity includes the use of oral and occasionally parenteral anti-inflammatory medications, the use of a high-top shoe which restricts ankle and hindfoot motion, or the judicious and infrequent use of intra-articular corticosteroid and local anesthetic injection.

Patients who are not deemed satisfactory candidates for ankle arthrodesis and who still have significantly disabling arthritic or post-traumatic pain from an abnormal tibiotalar joint may be successfully managed nonoperatively with an ankle-foot orthosis. Patients with normal sensation and little deformity and bony prominence may do well with a custom-molded, solid-ankle, polypropylene ankle-foot orthosis. Patients with preservation of some joint space with a limited range of motion that is pain free through a certain arch of motion may benefit from having a uni-directional hinged ankle for the polypropylene ankle-foot orthosis. Other patients with greater deformity, bony prominence or diminished peripheral sensation due to nerve injury or peripheral neuropathy may be shod with an appropriate oxford shoe attached by means of double metal upright bars to a proximal calf sleeve. In severely painful cases, this may be a laced leather or Velcro closure, plastic patellar tendon bearing sleeve. Often such double metal upright ankle-foot orthoses incorporate a drop lock or dial lock hinge medially and laterally. Patients with significant valgus or varus deformity through the ankle and hindfoot may also have applied to their double metal upright AFO a medial or lateral, respectively, T-strap.

These orthoses will serve to limit the amount of weight bearing pain and excursion of the painful joints to which they are applied. These joints have often lost a good deal of the articular cartilage that normally lines the ankle joint. The patients seem to understand that when their cartilage is gone and they are "rubbing bone on bone", holding the joint still by means of these orthoses or even a short leg cast will limit the amount of pain they have because of the arthritic joint. Indeed, the application of a short leg walking cast for three to four weeks' time for the patient with an arthritic ankle may serve a useful diagnostic
and educational tool. If the patient experiences a good deal of pain relief while wearing the cast, one can conclude that most likely they would do well with a successful arthrodesis or an appropriate orthosis as well. Also, during the time that the patient walks with his cast in place, he can gain some perspective on what it might be like to walk with a fused ankle postoperatively.

Patients with primary osteoarthrosis or arthritis secondary to prior ankle trauma will often complain of pain, swelling and stiffness of the distal limb. Almost all of these patients will have a limp due either to their antalgic limb while weight bearing or fixed deformity precluding normal progressive heel-toe gait. Patients with osteoarthrosis or rheumatoid arthritis confined to the ankle will often complain of early morning or start-up stiffness and pain. Patients with intra-articular loose bodies or large abutting anterior tibiotalar osteophytes often complain that their joint catches or locks in position, causing sudden paroxysmal pain. These patients with arthritis localized only to the tibiotalar joint will not necessarily notice any increased difficulty while walking on uneven ground compared to walking on level surfaces. Patients will often remark, however, that if they encounter a stone or other similar object in their path, it may cause great difficulty during the stance phase of gait if the object applies extreme varus or valgus force to their ankle. Patients who have maintained normal subtalar and transverse tarsal joint function will always do better than the patients who have ankle and subtalar or transverse tarsal pathology. The patient with isolated tibiotalar arthritis may be able to function surprisingly well even on uneven ground because of the adaptive and energy absorbing affect of a healthy subtalar joint.

Patients with unstable and very symptomatic ankles, in addition to any tibiotalar arthritic symptoms they may have, will have the added disability of joint laxity. These patients, who have insufficiency of the soft tissue supports of their ankle joint will notice that descending stairs is often more difficult and painful for them than ascending stairs. Similarly, wearing heels is much more difficult for them than ambulating in flats or while barefoot because of the limited lateral support caused by insufficiency of the tibiotalocalcaneal and
tibiotalar ligament complex. I have encountered many patients in my office with significant pes cavovarus of either a familial or neuropathic etiology whose main pain complaint and mechanical disability is the unstable ankle requiring either hindfoot realignment or arthrodesis. These latter patients may avoid the need for tibiotalar arthrodesis if their weight bearing mechanical axis can be improved with a valgus-producing calcaneal osteotomy and ankle ligament reconstruction. The patient with Charcot-Marie-Tooth disease and similar cavovarus foot deformity accompanied by ankle instability, may also require tendon transfer to improve foot eversion power.

If these patients fail the nonoperative options mentioned here, and if indeed their pathology is limited to the tibiotalar joint, then they may be considered acceptable candidates for ankle arthrodesis. It is the patient with daily pain refractory to nonoperative care and/or the one with progressive and disabling non-braceable deformity for whom ankle arthrodesis is indicated.

Preoperative assessment and planning for the ankle arthrodesis patient will occasionally include the use of selective Lidocaine or Marcaine blocks. These blocks are a useful clinical tool in ascertaining the exact anatomic location of the patient's most significant pain. It is often difficult to ascertain whether a patient's pain is due to the ankle joint alone, ankle and subtalar pathology, or even the peroneal tendons in the presence of subfibular impingement. If a diagnostic injection of local anesthetic into the ankle joint only alleviates the majority, if not all of the patient's pain, then successful ankle arthrodesis would be expected to eliminate just as much of this patient's preoperative discomfort. Conversely, if an extra-articular injection within the peroneal tendon sheath alone relieves the patient's pain, then arthrodesis may not be indicated.

In assessing the patient for ankle arthrodesis, it is very important to obtain weight bearing x-rays in at least the AP and lateral projection. I order standing AP and mortise x-rays of the patient's ankle, as well as a standing lateral x-ray of the patient's entire foot. These films are inspected for the presence or
absence of subchondral sclerosis, joint space narrowing or subluxation of the talus within the ankle mortise. The presence or absence of subchondral cysts, osteophytes, talar bone loss, porosity or avascularity of subchondral bone, and any existing hardware is ascertained. We also inspect these films for osteolytic or osteomyelitic processes as well. The status of the transverse tarsal and subtalar joints is also inspected. The angle which the long axis of the tibia makes with the floor is important on review of the standing lateral foot film and is often noted to be in a position of equinus because of large abutting anterior tibiotalar osteophytes. On the standing AP and mortise film, one can appreciate whether the tibiotalar joint remnant is parallel to the floor and deductively infer its relationship to the knee joint line.

In cases of bone loss, suspected neoplasia or infection, or suspected subtalar pathology, computed tomography with both feet and ankles in the gantry at the same time is quite a useful preoperative clinical tool. Magnetic resonance imaging can help greatly in ascertaining the presence or absence of bone marrow edema, soft tissue pathology, synovial proliferation, or tibiotalar avascular necrosis.

Nuclear medicine scans with technetium and indium-labeled white blood cell scans can be useful preoperatively in planning surgery for the indication of osteomyelitis. Extensive work on the topic of arthrodesis of the tibiotalar joint for sepsis has been done by Cierny and others.

The optimal position of the fused ankle in most cases is neutral plantar flexion so that the plantar aspect of the foot is at a right angle to the long axis of the leg, 0 to 5 degrees of hindfoot and ankle valgus, and external rotation symmetric with the contralateral uninvolved side. This usually is about 5 to 10 degrees of external rotation or the position in which the anteromedial crest of the tibia and tibial tubercle line up with the second ray of the normal foot on the ipsilateral side.

The notion of fusing an ankle in 5 to 10 degrees of plantar flexion for the female patient who wishes to wear a heeled shoe postoperatively is not well founded. Not only is it more difficult to obtain the
arthrodesis in this position due to intraoperative and postoperative mechanical concerns, but fusion in slight
equinus often leads to the development of symptomatic transverse tarsal arthrosis. The transverse tarsal
joints after ankle arthrodesis are usually much more supple in plantar flexion from the transverse position
than they are in dorsiflexion. These joints often have very little capacity to dorsiflex beyond the neutral
talonavicular inclination. It has been this author's experience that if the foot is fused perpendicular to the
long axis of the leg, active and passive transverse tarsal joint plantar flexion are much greater than
dorsiflexion. Transverse tarsal motion in the parasagittal plane will often increase and even double its
preoperative value after ankle arthrodesis as the patient ambulates more after cessation of postoperative
casting. I have often been pleasantly surprised at how much motion through the transverse tarsal joint
remains six to twelve months after successful ankle arthrodesis, easily allowing my patients to
accommodate up to a 1 to 1 inch heel height, even if the tibiotalar joint is fused at neutral in the
parasagittal plane (plantar flexion, dorsiflexion x-rays can be included here).

The patient presenting for ankle arthrodesis who also has ipsilateral quadriceps weakness, e.g.
secondary to poliomyelitis or CVA, may constitute a relative indication for ankle arthrodesis in slight
equinus. Floor reaction forces through an ankle fused in equinus will pass anterior to the knee, thus
stabilizing the weak knee in recurvatum. Fusing the ankle in excessive plantar flexion, however, also
contributes to painful recurvatum forces at the normal knee. Fusion in excessive dorsiflexion, while slightly
better tolerated than too much plantar flexion, will often lead to recalcitrant heel pain from the repetitive
impact sustained at heel strike. Excessive dorsiflexion also results in diminished push-off strength.
Postoperative tibiotalar varus malunion is poorly tolerated and often leads to lateral foot pain and callosities
at the fifth metatarsal head and/or base. Such varus-valgus malunion will also lead to ipsilateral knee and
contralateral greater trochanteric discomfort (bursitis).

The patient whose ankle has been fused in too much equinus will often walk with the operated
extremity externally rotated at the hip in order to circumduct the plantar flexed foot. This abnormal gait also highlights the limited dorsiflexion available through the transverse tarsal joints. Fusing the ankle in slight external rotation symmetric with the contralateral uninvolved side allows for a more normal foot progression angle during postoperative gait. At least 75 percent of the author’s patients undergoing ankle arthrodesis for isolated tibiotalar trauma have demonstrated no postoperative limp, even to the trained eye.

It has been recommended in the past that in order to reduce the anterior lever arm of the foot under an arthrodesis site, the talus should be translated posteriorly under the tibia at the time of ankle fusion. Although anterior translation should definitely be avoided, in situ arthrodesis without posterior translation repetitively with successful results has not confirmed the clinical significance of posterior translation of the foot relative to the tibia. The theoretical advantage of translating the foot posteriorly to improve ground clearance and diminish the lever arm of the foot on the arthrodesis site has not proved to be as clinically significant as was indicated in the older literature. (__________)

Arthroscopic Ankle Arthrodesis Surgical Technique

The arthroscopic procedure is performed under general or spinal anesthesia with the patient positioned supine on a radiolucent table in a manner that would facilitate fluoroscopic imaging, appropriate access to the ankle anteriorly and posterolaterally, and the use of internal fixation. Leg holding devices are not always necessary and often are in the way when applied too far distally on the limb. Preoperatively, superficial anatomic landmarks including the tendons and superficial neurovascular structures are all identified. The anteromedial portal located medial to the tibialis anterior tendon and the anterolateral portal, located lateral to the extensor communis digitorum tendon, are usually the only portals necessary for this technique. An accessory lateral portal, located lateral to the peroneus tertius tendon and inferior to the anterolateral portal, may occasionally be used to facilitate removal of articular debris. Because access and visualization are complete with the first two portals mentioned, posterior or anterior central portals are not
necessary and are often quite dangerous.

The initial arthroscopic debridement entails distracting the joint with any of a number of available alternative fixation devices. It is very difficult to quantify the amount and force of distraction required for visualization of any one ankle arthroscopically. Capsular and ligamentous scarring is often quite advanced in the severely arthritic ankle. Severely distorted or malaligned ankles present a relative contraindication to the arthroscopic method of arthrodesis.

As the arthroscopic procedure progresses, the surgeon may take advantage of the viscoelasticity of the surrounding soft tissue structures, facilitating more distraction over time. Care must be taken not to over distract the joint in cases of severe arthrofibrosis and post-traumatic arthritis with soft tissue compromise.

Once articular surface debridement commences, the space available for intra-articular surgery increases, further facilitating posterior access for debridement. The surgeon must avoid the tendency to debride small segments of the tibiotalar surfaces too deeply when the operative field is limited. This can be avoided by the frequent use of intraoperative roentgenograms or fluoroscopy.

A 4 millimeter 30 degree arthroscope can readily be introduced through the arthrotomy portals described. The preferred full radius resector/shaver employed for this initial debridement and synovectomy is a 4_ millimeter device. Smaller shavers and resectors, while requiring less tibiotalar space and distraction, often are tedious and slow in performing the amount of resection necessary to complete arthrodesis.

Once the anterior synovectomy and debridement are completed, there is improved visualization, and cartilage removal from the distal tibial and dorsal talar surface is easier. Cartilage from the medial side of the fibula and the lateral side of the medial malleolus can also be removed. Thorough debridement of the talofibular recess is recommended.
Curettes of various sizes, shapes and angles are helpful in denuding the articular surfaces. Simultaneous large bore cannula suction through an accessory anterolateral portal removes this articular debris. Also, pituitary forceps may be used to extract the larger fragments. Arthroscopy pumps are available in improving visualization and constant irrigation through the scope. High-speed cannulated burs ranging from 4 mm to 5 mm in diameter can be employed to remove cartilage remnants and expose bleeding subchondral bone. To avoid maceration of the skin by frequently switching instruments through the portals, plastic disposable cannulas can be used to protect the skin at the site of the portals.

After debridement of the joint surface is complete, the external fixator distracting device is removed unless it is to be used for compression postoperatively. Compression and rigid fixation are mandatory for a successful arthroscopic ankle arthrodesis and can be provided with either internal or external fixation. If the fixator is to be used for postoperative compression, it is important to place the calcaneal pins in such a manner that the compression force is centered directly under the tibia and talus, thereby avoiding eccentric compressive loading.

External fixation can lead to postoperative stiffness of the subtalar joint if the distal transfixation pins are located in the calcaneus. Often the external fixator construct is bulky and not well tolerated by the patient. Other problems such as pin tract infection, pin loosening, patient compliance with pin care, and impingement of medial fixators against the contralateral limb make external fixation less desirable than internal fixation after arthroscopic ankle arthrodesis.

As mentioned elsewhere in this work, the foot is positioned in neutral dorsiflexion with approximately 5 degrees of hindfoot valgus and appropriate, symmetric external rotation. The preferred method of internal fixation is 6 mm or 7 millimeter cannulated screws. A small 2 cm posterolateral incision can be made between the peroneal and Achilles tendons, 2 cm centimeters proximal to the ankle joint and taking appropriate care to avoid injury to the lesser saphenous vein and sural nerve.
This portal serves as a useful site for introducing the threaded guide wire from the cannulated screw set to position the first screw from the posterolateral tibia obliquely into the head and neck of the talus. This approach is also useful in the case of the small talus. Alternatively, since the arthroscopic technique leaves intact the majority of the ankle mortise and thereby leaves the tibiotalar arthrodesis site relatively stable, crossed screws may provide enough fixation that this posterolateral tibiotalar screw is not necessary.

Another guide wire can be inserted from posteromedial on the tibia 2 to 3 centimeters proximal to the joint line at the supramalleolar flare and directed slightly anterolaterally into the talus. The guide wire for the second screw can be introduced from lateral superiorly on the tibia and directed slightly vertically and medially into the talus. Eccentric loading of the arthrodesis may occur as the first screw is inserted and tightened because the screws are not introduced in parallel fashion. Alternately tightening each screw until compression is obtained can avoid eccentric loading of the arthrodesis site. Other combinations of screw placement are feasible. The first screw can be inserted anteromedial on the tibia and be directed posterolaterally into the talus. The length of this screw is deceptive, however, and one must avoid penetration of the normal subtalar joint. Mobility of the subtalar joint should be checked fluoroscopically and clinically before the case is completed. Permanent roentgenograms of the ankle and subtalar joint in orthogonal planes are recommended, and the surgeon should not rely solely on intraoperative fluoroscopy to ascertain appropriate position, alignment and fixation.

Skin closure is followed by application of a soft bulky dressing incorporating the appropriate splints. Elevation of the extremity is recommended, followed by touch-down weight bearing and short leg cast application as clinically and radiographically indicated. Full weight bearing in a short leg cast commences approximately four to five weeks after the procedure until the arthrodesis is clinically and radiographically united.

This arthroscopic technique was compared with an open tibiotalar arthrodesis technique employing
malleolar ostectomy by Myerson and Quill. Internal fixation with compression across the tibiotalar
arthrodesis site was utilized for both methods using either 6.5 millimeter or 7.0 millimeter cannulated
screws. Arthroscopic arthrodesis was performed in 17 patients, and open arthrotomy with malleolar
ostectomy employed for 16. The mean time to fusion after arthroscopic procedure was 8.7 weeks (range 6
to 14 weeks), compared to 14 weeks with the open technique (8 to 26 weeks; p<0.004).

Each of these techniques carries with it certain advantages and disadvantages. Arthrodesis was
achieved in the arthroscopic group considerably faster than it was for the patients undergoing arthrotomy
and malleolar ostectomy. Theoretically, the arthroscopic technique involves limited exposure and,
therefore, significantly diminished periosteal and capsular stripping. The arthroscopic technique also
preserves the overall contour of the ankle mortise. Patient selection also may contribute to shorter time to
fusion in the arthroscopic group, as those with greater preoperative deformity were included in the
arthrotomy group undergoing ankle arthrodesis.

The arthroscopic technique may also have as its advantage less perioperative morbidity and pain
and a shorter hospital stay. The disadvantages commonly incurred with arthroscopic ankle arthrodesis
include the relatively long time it takes for a surgeon to gain facility with this technique, slightly higher
nonunion rate, sometimes tenuous percutaneous fixation, and the longer operative time associated with
greater fluoroscopic exposure for the surgical team. Again, the arthroscopic technique is relatively
contraindicated in the patients with significant deformity or bone loss requiring large bone graft.

Ankle Arthrodesis: Mini-arthrotomy Surgical Technique

The mini-arthrotomy technique for achieving ankle arthrodesis was initially coined and subscribed
by Miller and Myerson and published in September of 1996. This technique consists of a limited anterior
resection of the tibiotalar joint surfaces employing two small anterior incisions. These authors report a very
high (31 of 32 cases) successful fusion rate with an average time of radiographic arthrodesis at eight
weeks.

This technique employs two 1-centimeter incisions, one anteromedial and one anterolateral, in approximately the same location as the portals used for the arthroscopic technique described above. Patients have this procedure performed while under general, spinal or regional anesthesia with IV sedation. The first incision is medial to the anterior tibial tendon at the level of the ankle joint line, and a second incision is anterolateral to the peroneus tertius tendon placed to avoid the cuticular branches of the superficial peroneal nerve. Curettes, rongeurs and small sharp bone chisels are used in debriding synovium and cartilage from the anterior ankle. A small lamina spreader facilitates visualization of the joint surface to be resected and can be alternated between the two wounds. Removing the teeth of the lamina spreader allows this instrument to be placed between the bones of even very narrow arthrodesis sites. After this initial debridement by hand, the ankle is then irrigated for the final time with saline.

A pneumatic bur generating a bone slurry, which can be collected for later use as an autogenous bone graft, is then placed within the joint to debride any further cartilage and bone to the healthy subchondral level (AM 10 bit, Midas Rex, Fort Worth, Texas). Excessive burring should be avoided, as it may cause necrosis of subchondral bone. Satisfactory resection and debridement of the posterior one-third of the ankle joint is not possible with this technique. Medial and lateral gutters, however, can be easily debrided using the bur. Appropriate ankle position is then obtained, and threaded guide wires from available cannulated screw sets are used to maintain the position (7.0 or 7.3 millimeter screws, Synthes, Paoli, Pennsylvania or 6.8 millimeter screws, Orthopedic Biosystems, Phoenix, Arizona).

Guide wire insertion for at least two and possibly three screws can be oriented as described above for the arthroscopic technique. An additional screw can be placed from the fibula into the talus after lateral gutter debridement in order to enhance stability and fusion rates.

Position, alignment and appropriate depth of the screws and wires are checked intraoperatively.
with the fluoroscope. The bone slurry can then be packed circumferentially around the joint through the two mini-arthrotomies. In order to prevent postoperative leakage of the autogenous bone graft and minimize transient anterior ankle inflammation (often seen by Miller and Myerson at up to four to ten weeks postoperatively), the ankle joint capsule must be closed meticulously. Routine wound closure superficially of the ankle is followed by application of a bulky padded dressing incorporating coaptation and posterior plaster splints.

Patients are discharged in the initial dressing to follow-up in the office in ten to fourteen days' time for wound inspection, suture removal and application of a short leg nonweight bearing cast. If signs of clinical stability and even radiographic early union are present, this cast can be changed six weeks postoperatively to a short leg walking cast until arthrodesis appears solid by clinical and radiographic examination. A posterior heel may be applied to the cast to provide an axial force across the ankle joint with weight bearing.

Early satisfactory results with the mini-arthrotomy technique may also be attributed to the less invasive nature of the procedure compared with open larger arthrotomies and/or transmalleolar approaches. In Miller and Myerson's early reports, 22 of the 32 patients undergoing ankle arthrodesis by means of the mini-arthrotomy technique did so as outpatients incurring sedation and regional ankle block anesthesia. Postoperative radiographs will demonstrate fusion at the anterior two-thirds of the joint, and the clinical significance of partial surface contact healing pattern for long-term stability is as yet undetermined.

Transfibular Approach For Ankle Arthrodesis

The author's preferred method of arthrotomy for arthrodesis of the tibiotalar joint is through a lateral transfibular approach with the patient positioned supine on the operating table. While the patient is under general or spinal anesthesia a well-padded roll is placed under the ipsilateral buttock in order to slightly
internally rotate the involved lower extremity. A thigh tourniquet is used for intraoperative hemostasis.

The author prefers a transfibular approach for ankle arthrodesis because of the ease of exposure, positioning, and obtaining internal fixation. Even very significant preoperative deformity is easily corrected with this approach, employing distal tibial osteotomy, medial malleolar ostectomy, or resection of the appropriate wedges of bone in order to position the foot plantigrade in neutral position for fusion. By removing at least the lateral and sometimes even the medial malleolus using this approach, the patient often experiences greatly improved shoe wear postoperatively. The distal fibula once resected serves as an excellent source of autogenous bone graft material. The transfibular approach may be combined with a small anteromedial arthrotomy for further exposure, but since the author has begun to favor a congruous type of tibiotalar reduction, I usually avoid medial malleolar ostectomy. Often it is a matter of the surgeon's preference whether he resects planar flat surfaces of distal tibia and talar dome for apposition across the arthrodesis site, but this author prefers to resect in a more anatomic fashion the concave distal tibial surface and retain the convex talar dome surface.

The preferred lateral incision is made along the posterolateral border of the distal fibula well anterior to the expected course of the sural nerve, but still posterior to the expected course of the superficial peroneal nerve as it perforates the fascia from the peroneal to the anterior compartment over the distal fibula. This incision is extended distally and curved anteriorly over the sinus tarsi so that the whole tarsal canal and lateral process of the talus can easily be exposed through this same wound.

Next a low beveled fibular ostectomy is done just barely proximal to the level of the ankle joint line. This distal resection of the fibula still affords excellent exposure while keeping the syndesmosis intact. The distal fibula is retained on the back table, where later it will be used to harvest the autogenous bone graft material.

At this point it is very important to expose the anterior tibiotalar capsule and remove any impinging
anterior tibiotalar osteophytes. These osteophytes, if not appropriately resected, will prohibit a successful reduction of the foot in neutral dorsiflexion. The posterior tibiotalar capsular exposure may be somewhat less than is stripped anteriorly.

The author prefers to prepare the tibiotalar arthrodesis site with the use of sharp chisels rather than high-speed spurs, which can cause osteonecrosis of the subchondral bone. I prefer to contour the bone on either side of the arthrodesis site in the appropriate congruous concave-convex fashion as noted above. Enough diseased cartilage and subchondral bone is removed so that the joint can be reduced in a position of 0 dorsiflexion and no more than 3 to 5 degrees of valgus. Leaving the joint in a congruous fashion, if it has not been grossly altered by significant preoperative trauma, affords the surgeon great ease of reducing rotation symmetrically. The anterior medial crest of the tibia and the tibial tubercle should line up with the second ray of the ipsilateral foot.

The next most important part of this step is the insertion of guide wires to facilitate passage of interfragmentary cannulated screws used for internal fixation. I usually insert a guide wire from the posterior portion of the lateral process of the talus in a distal lateral to proximal medial direction across the arthrodesis site and lying just prominent to the tented skin at the medial metaphyseal flare of the tibia. The second guide wire can be inserted quite readily through the lateral wound proximally and anteriorly from the lateral distal tibial tubercle, which had once articulated with the distal fibula before it was removed across the arthrodesis site into the body of the talus distally and more medially. In this fashion the first two guide wires are crossed in the frontal plane and may be either crossed or parallel in the sagittal plane. Lab bench studies have demonstrated that two crossed screws provide better torsional and load rigidity than two parallel screws alone. If the talus is of sufficient size, then a third screw may either be inserted parallel to the first or from posterolateral on the distal tibia directed anteriorly and medially into the head and neck of the talus. Three screws when appropriately inserted and tightened in a sequential fashion can provide
quite a rigid construct with good interfragmentary compression.

Even though the first guide wire was inserted from distal to proximal, I have found that if this wire is brought out through the skin posteromedially on the distal leg and then the screw inserted from proximal medial to distal lateral, excellent countersinking of the head in the distal tibial metaphysis, as well as avoidance of a large bulky head near the lateral subtalar joint can be avoided (I need to re-word this later). It, therefore, is more productive to insert the medial to lateral screws from proximal to distal rather than distal to proximal.

After the guide wires are inserted and their length ascertained, but before the screws are actually drill tapped in placed, it is wise to obtain an intraoperative x-ray in both the AP and lateral projections. This film is used to study not only the position of the ankle that will be achieved at arthrodesis, but also the alignment, fixation and length of the cannulated screws to be inserted.

Counter sinking measuring tapping is then done, followed by insertion of the appropriate 6.5 or 7 millimeter cannulated screw over each of the guide wires (Figure).

A second set of intraoperative radiographs is advised before closing the wound, again checking alignment, position and fixation. One must take great care to check radiographically and clinically that the subtalar joint is free and clear of bone graft and fixation materials. An abundant amount of cancellous bone can usually be harvested from the metaphyseal area of the distal fibula that has been resected. Corticocancellous materials can also be morselized and packed anteriorly, as well as posteriorly and laterally across the arthrodesis site. The surgeon should take care not to have any graft impinging the peroneal tendons, sinus tarsi or subtalar joint before closure.

Usually the extensive nature of the exposure, the abundant amount of bone graft material inserted, and the large leading surfaces of cancellous bone that have been fashioned during this procedure will necessitate the placement of a closed suction drainage tube. The tourniquet is deflated at this point, and
hemostasis obtained. The osteoperiosteal flap remaining after fibular resection in the fascia near the peroneal tendons provides an excellent deep layer of closure. The dermis is closed usually without any tension, and the skin edges apposed as well. The drain is placed to suction, and the appropriate noncircumferential postoperative splints are applied over a bulky bandage.

The patient is in most cases admitted to the hospital for one or two nights postoperatively and discharged in the operative dressing if there are no complications. The patient is followed in the office two weeks postoperatively when the dressing and staples are removed, dressing changed, and a nonweight bearing short leg cast applied. These patients are best kept nonweight bearing for six weeks postoperatively. The subsequent six weeks of the postoperative convalescence can be done in a short leg walking cast. With rigid internal fixation, the patients remark very early in their postoperative recovery that there preoperative pain is gone.

If the ankle is fused in the appropriate position, most patients undergoing this procedure will not require shoe wear modification, brace wear or orthotic usage. The patient who has difficulty with transverse tarsal dorsiflexion, difficulty at the end of the stance phase of gait, or concomitant ipsilateral forefoot pathology may best be managed with a shoe that includes either a SACH heel or rocker bottom over a longitudinal steel shank. External shoe wear adjustments for leg length inequality may be necessary in severe cases.

**TIBIOTALOCALCANEAL AND PANTALAR ARTHRODESIS**

Methods of peritalar fusion published before 1922 were reviewed by Arthur Steinler. On this date Steinler also described his technique for panastragaloid arthrodesis by way of denuding articular cartilage. Other studies in 1936 and in the Spanish literature in 1951 detailed the orthopaedic experience of hundreds of patients followed after panastragaloid arthrodesis for neuromuscular imbalance or flail feet and ankles.

It was recommended in 1938 by Leebolt that the “pantalar” arthrodesis be accomplished in two
stages because of prolonged operating time and the difficulty in obtaining correction of all the deformities simultaneously. It was recommended by that author that the subtalar arthrodesis be performed first, fusing the ankle at a second operative procedure when it was perceived to be easier to obtain the desired final degree of equinus and dorsiflexion. A one-stage operation for pantalar arthrodesis was published by Hunt and Thompson in 1954. Employing this technique, the authors used an anterolateral approach to disarticulate and remove the talus from the hindfoot, subsequently peeling off its articular cartilage, cortex and ligaments on the back table before this denuded talus is replaced in its bed and the patient's wounds closed. This report does not include any data regarding the incidence of talar avascular necrosis following such a procedure. Orthopaedic surgeons' experience in treating numerous patients with knee extensor weakness was reflected in their recommendations that the ankle and hindfoot be fused in 8 to 10 degrees of plantar flexion, thus stabilizing the knee in slight recurvatum during stance.

Many excellent clinical evaluations after pantalar arthrodesis exist, and some provide very long-term follow-up. Many of these authors have concluded that extensive arthrodesis of the ankle and hindfoot is a technically demanding and easily complicated procedure. Current scientific opinion regards pantalar and tibiotalocalcaneal arthrodesis procedures as salvage operations capable of producing satisfactory results when applied by experienced surgeons for the correct indications. Successfully completed, these procedures may provide a reasonable alternative to what otherwise would be severely disabling conditions or even amputation if left untreated. Many authors have concluded that pantalar arthrodesis can provide a much more satisfactory result than can takedown.

**Tibiotalocalcaneal Arthrodesis**

For patients who have arthritis, infection or deformity of not only the tibiotalar, but also the talocalcaneal joint, the surgeon must not only fuse the ankle, but the subtalar joint as well. Adding subtalar arthrodesis to a tibiotalar fusion can be accomplished with a cannulated screw technique (references
Pappa and Myerson, Bone and Joint Journal, 1992). Success has been reported with sliding fibular struts anchored to the tibia, talus and calcaneus. Plates applied laterally to the tibia, talus and calcaneus have also been employed for the fixation and maintenance of the desired position of arthrodesis of the tibia to the talus to the calcaneus.

The author believes, however, that intramedullary nailing is a solid method of fixation for achieving tibiotalocalcaneal arthrodesis. A medullary nail inserted through the plantar aspect of the foot can afford excellent stability and maintain satisfactory position and alignment. This medullary nail is a load sharing device used for internal fixation and not as prone to failure in heavy patients, neuropathic patients, or those with osteopenic bone, as are cannulated screws alone. In the author’s experience patients undergoing intramedullary fixation for tibiotalocalcaneal arthrodesis need not be casted as long or have their activities restricted as severely as patients undergoing similar procedures employing other methods of fixation. Furthermore, the neuropathic patient, even in the presence of an acute Charcot process, can be managed quite readily by medullary fixation with an acceptable complication rate when undergoing ankle and hindfoot arthrodesis.

Gerhart Kuntscher described the method of combined arthrodesis of the ankle and subtalar joints. He performed closed medullary nailing with a conical nail inserted over a guide pin through the sole of the foot.

In 1979, Tomeno presented 45 pantartheses using a variety of fixation techniques, but his infection rate was very high. He obtained an 80 percent consolidation rate. Russotti and Johnson reported in 1988 on 21 tibiotalocalcaneal arthrodeses employing Steinmann pins and external fixation. Radiographic union was achieved at 85 percent with satisfactory results in 75 percent of patients employing a posterior Achilles splitting approach. Pappa and Myerson published a series of 21 pantalar and tibiotalocalcaneal arthrodesis for osteoarthrosis. An 86 percent fusion rate was obtained by these authors employing a
transfibular approach with cannulated screws for fixation.

Kyle, et al, also reported the use of an intramedullary nail for tibiotalocalcaneal fusion. Employing their technique, the patient is positioned prone, and an Achilles splitting approach is employed.

This author prefers to perform tibiotalocalcaneal arthrodesis using an intramedullary nail, placed percutaneously, and combined with arthrotomy and debridement of the diseased surfaces of the ankle and subtalar joints. The nail can be placed transcalcaneally through the talus into the tibia and locked proximally in the tibia from lateral to medial. Impaction can be obtained and lateral to medial, as well as posterior to anterior interlocking screws used distally (Figure). Currently, a number of different ankle fusion nails are being developed and marketed. As early as 1986, experience has been gained with the use of a bowed supracondylar femoral nail inserted retrograde for ankle fusion. Straight end-curve nails are available by different manufacturers. Exciting new fixation options are available that also include posterior to anterior partially and fully threaded distal locking screws. These posterior to anterior distal screws provide much better purchase of the calcaneus in a reliable fashion and, when extended across the transverse tarsal joints, can simplify the method in which a medullary nail can be used not only to achieve tibiotalocalcaneal, but also transverse tarsal (pantalar) fixation and arthrodesis.

Tibiotalocalcaneal Arthrodesis: Surgical Technique

The patient is positioned supine on a radiolucent operating table with a well-padded bump under the ipsilateral buttock to rotate internally the involved extremity. Another pad can be placed under the heel to facilitate cross-table fluoroscopic imaging. General or spinal anesthesia is usually required, and a thigh tourniquet may be used for hemostasis, greatly facilitating the plantar dissection. Intraoperative fluoroscopy is used as indicated.

An anterolateral ankle arthrotomy with an incision carried over the sinus tarsi is used to correct any deformity that may be present across the tibiotalar and/or subtalar joints and to prepare the joint surfaces
by removing what is left of the diseased articular cartilage. These arthrotomies also give the surgeon a site for inserting bone graft as indicated.

A fibular osteotomy or distal fibular ostectomy should be considered at the time of hindfoot fusion if there is significant varus deformity or loss of tibial length relative to the fibula. If fibular osteotomy is not done in these cases, the fibula may actually hold the tibiotalar and talocalcaneal arthrodesis sites distracted postoperatively.

A longitudinally oriented plantar incision is placed just anterior to the weight bearing subcalcaneal heel pad. After the incision is made and carried through dermis sharply, blunt dissection is taken down to the plantar fascia, which is split longitudinally. The intrinsic muscles can be swept aside and the neurovascular bundle identified at the medial portion of the wound. A sharp awl is used to make a plantar calcaneal corticotomy. Alternatively a guide wire and cannulated drill can be used to provide access to the talus and tibial medullary canal after calcaneal corticotomy. The insertion site of either the awl or the cannulated drill bit must be checked intraoperatively with fluoroscopy before proceeding with exposure through the talus of the tibial medullary canal.

A spade-tipped or bulb-tipped guide wire can then be passed through the calcaneus and talus into the distal tibial medullary canal. A series of progressively larger flexible reamers are then passed over the guide wire and used to prepare and enlarge the tibiotalocalcaneal canal. It is wise to ream a full _ to 1 millimeter larger than the anticipated nail's outside diameter in order to avoid serious stress risers and a significant risk for postoperative fracture at the proximal tip of the nail.

The nail is attached to its alignment guide. The nail is slightly internally rotated so that when the screws are inserted from lateral to medial, they will pass into the tibia without impinging the fibula.

The nail is usually readily inserted manually without need for the guide wire and then impacted. The distal aspect of the nail is usually countersunk a few millimeters below the plantar surface of the os
calcis. Fluoroscopy is used to ascertain the appropriate position and make sure that the distal locking screw holes are lined up to provide satisfactory purchase of the talus and calcaneus. Further compression and impaction can be done across the arthrodesis sites after inserting the interlocking screws. The remaining interlocking screws are inserted after compression across the arthrodesis site is obtained. The author rarely uses screws longer than 25 millimeters to gain bicortical purchase of the distal tibia. Lateral to medial locking screws from 35 to 45 millimeters in length may be required to gain adequate purchase of the talus and calcaneus. Posterior to anterior locking screws are usually no longer than 80 millimeters unless the surgeon intends to also fuse the transverse tarsal joints.

**Pantalar Arthrodesis**

The existing literature on pantalar arthrodesis is fairly old, dating to orthopaedic surgeons' experience with treating the sequelae of poliomyelitis and other neuromuscular conditions. These reports would also indicate that the technique of pantalar arthrodesis is one of the months technically demanding and involved procedures encountered in foot and ankle surgery today. Also, these procedures are usually done in the salvage setting for severely disabling or even limb threatening conditions.

Pantalar arthrodesis proved to be a reliable, reproducible surgical procedure for addressing the flail foot and ankle associated with poliomyelitis, paralysis, and tuberculous and bacterial infection in the earlier part of this century. Most early reports of this technique focused, therefore, on achieving a rigid stable hindfoot in satisfactory position, and few if any articles published before the 1950's include recommendations on internal fixation.

To this day, patients with post-traumatic osteoarthrosis involving both the ankle and subtalar joints still pose a difficult therapeutic challenge. Spinal cord injury, longer life expectancy, high-speed motor vehicular trauma and the popularity of sports and active lifestyle, have again focused attention on the foot and ankle. With a better appreciation of lower extremity biomechanics, orthopaedic surgeons are
producing articles on the topic of pantalar arthrodesis on a much more frequent basis today than in the recent past.

Alternatives to pantalar arthrodesis for patients with arthritis or bone deficiency of the ankle and hindfoot include Syme or below-the-knee amputation. Modern articles are detailing the expected functional results in patients who have an arthrodesis of the hindfoot and ankle. Debate continues regarding the relative atrophy of a one-stage versus a two-stage technique in achieving pantalar arthrodesis. For reasons of economics, patient desire for expedient care and an interest in rehabilitating the patient more quickly and returning to a more normal lifestyle, this author prefers a one-stage procedure for pantalar arthrodesis.

A satisfactory pantalar arthrodesis can be achieved using the intramedullary nail for tibiotalocalcaneal arthrodesis and, in turn, linking this fused hindfoot to the midfoot with cannulated screws or bone staples (Figure). Alternatively, a triple arthrodesis of the foot can be performed in standard fashion, and then this construct can be linked to the ankle in the desired position of neutral dorsiflexion-plantar flexion, 3 to 5 degrees of hindfoot valgus, and symmetric external rotation with either a medullary nail or more cannulated screws.

The patient's first and fifth metatarsal heads must strike the ground at the same time in ambulation. If the ankle and hindfoot are fused in too much equinus, the patient will have a tremendous tendency to recurvatum at the knee and have heel off too early in the gait cycle. These patients will often walk with the extremity externally rotated in an effort to vault more easily over the involved foot that is held in equinus.

If the ankle and hindfoot are fused in too much dorsiflexion, the gait will seem more natural and stride length more symmetric with the other uninvolved side. The pressures of weight bearing at heel strike will quickly become uncomfortable, however, and the patient will lack satisfactory push-off. Gellman, et al, have shown that the deficits in dorsiflexion and plantar flexion after isolated ankle arthrodesis are 50.7
percent and 70.3 percent respectively. After tibiotalocalcaneal arthrodesis, however, the dorsiflexion and plantar flexion deficits are only 53 percent and 71.3 percent respectively. Thus, linking the calcaneus to the fused ankle does not cause an appreciable loss of dorsiflexion or plantar flexion. Inversion and eversion, however, undergo a diminution of at least 40 percent greater after tibiotalocalcaneal arthrodesis than with ankle fusion alone.

Pantalar arthrodesis has been noted to cause deficits in dorsiflexion and plantar flexion of 62.8 percent and 82.2 percent, respectively. Inversion and eversion are reduced by 71.7 percent and 67.4 percent, respectively, after pantalar arthrodesis. These values stress the absolute importance of achieving appropriate position in the foot and ankle if the pantalar arthrodesis is to be successful.

Pantalar Arthrodesis: Surgical Technique

When pantalar arthrodesis is performed employing a cannulate screw technique through open arthrotomy as described by Pappa and Myerson, the patient is positioned supine with a well-padded bump underneath the ipsilateral buttock. A pneumatic thigh tourniquet is used, and the ipsilateral iliac crest is prepped, as well as the entire lower extremity from the knee distally. It is also quite helpful to note the contralateral uninvolved lower extremity anatomy to ascertain the appropriate position and rotational alignment. The contralateral limb can be prepped into the field or readily palpable through a thin layer of sterile drapes. An extended lateral approach is made using an incision longitudinally oriented over the distal fibula and curving anteriorly over the sinus tarsi. The cuticular branches of the superficial peroneal nerve and sural nerve are protected throughout the case. A distal fibular ostectomy is performed with an oscillating saw at a level just proximal to the tibiotalar joint. In this fashion wide exposure of the ankle and hindfoot is obtained; yet the proximal fibula is still well anchored to the tibia by the syndesmotic ligaments. The fibula is saved and used later in the case as autogenous bone graft in piecemeal fashion.

A second anteromedial incision can be made midway between the medial malleolus and the tibialis
anterior tendon, protecting the greater saphenous vein and its cuticular nerve. The second incision can be used to resect the medial malleolus if it is prominent, or preferably, to leave the medial malleolus in place and denude the articular cartilage from its medial aspect.

If significant deformity is not present at the level of the ankle joint, a sharp bone chisel can be used and, in a congruous fashion, the articular cartilage and hard subchondral bone can be removed from both sides of the ankle joint, taking appropriate resections of bone as necessary to make the foot plantigrade. Alternatively, as described by Pappa and Myerson, an oscillating saw held perpendicular to the long axis of the tibia could be used to make planar cuts, preserving as much bone stock as possible.

A lamina spreader is helpful when exposing the subtalar and transverse tarsal joints. Chisels, rongeurs and curettes can be used to denude the cartilage from these joints, and appropriate wedges of bone can be removed as necessary to make the foot plantigrade. Final alignment of the hindfoot in 0 to 5 degrees of valgus, 0 to 5 degrees of calcaneus, and external rotation equal to that of the contralateral extremity is desired. In the older orthopaedic literature, a position of 5 to 10 degrees of equinus was recommended at the ankle, but these pantalar arthrodeses were often performed for a flail foot in the presence of quadriceps weakness, in which case plantar flexion lower reaction forces caused recurvatum at the knee to stabilize this joint. In a patient with normal quadriceps function, however, 0 to 5 degrees of calcaneus is more desirable.

Fixation at the arthrodesis sites can be achieved with threaded guide wires, facilitating passage of 6 millimeter or 7 millimeter cannulated screws for permanent fixation. An autogenous bone graft harvested either from the distal fibula or the anterior iliac crest can be tamped into available spaces to insure mechanical support and quicker union.

The author finds it easiest to first fix, from dorsal to plantar with guide pin and cannulated screw, the talocalcaneal joint. Next, taking care to rotate the foot appropriately through the transverse tarsal joint,
a proximal to distal calcaneocuboid screw and a distal to proximal talonavicular screw can be inserted over guide wires.

Next a guide wire is inserted from just anterior to the lateral process of the talus in the sinus tarsi in a distal to proximal and lateral to medial direction across the tibiotalar joint. On the lateral view, this guide wire and subsequent cannulated screw would be passed in the anterior body of the talus, exiting the medial tibia at the supramalleolar level. It is easier to insert the screw, however, over this guide wire from proximal medial to distal lateral, gaining better purchase in the talus with the thread and countersinking the head of the screw in the medial cortex of the metaphyseal tibia.

The last screw can be placed anterolaterally on the distal tibia to posteromedial in the posterior body of the talus. On the lateral radiograph, this screw appears to be parallel over the first tibiotalar screw, and on the anterior-posterior film it appears to cross the medial tibiotalar screw at nearly a right angle (Figure).

After further irrigation and bone grafting, the wounds can be closed in layers over suction drainage tubes, and a bulky dressing reinforced with plaster splints applied. The drains can be removed 24 to 48 hours postoperatively with the patient discharged from the hospital usually within 48 hours from surgery.

At approximately two weeks postoperatively, if no special circumstances exist, the operative bandages and sutures are removed, and a well-padded, well-molded short leg cast is applied. Patients are routinely kept nonweight bearing for at least six weeks, followed by weight bearing to tolerance in a cast for the subsequent six to eight weeks. Clinical and radiographic correlation is used to modify this recommended postoperative regimen. Shoe lifts may be necessary to compensation any limb length discrepancy caused by the shortening inherent in this procedure. Ideally the operated extremity should be approximately _ to 1 centimeter shorter than the contralateral uninvolved limb to allow clearance during the swing phase of the gait cycle.
Most patients can wear regular athletic or walking shoes after a period of adjustment and experimentation and removing the final cast. Some patients, however, will benefit greatly from the application of a rocker sole or single access cushioned heel to the plantar aspect of the shoe on the involved side.

The ankle is the most frequently reported site of pseudarthrosis after a pantalar arthrodesis, followed by the talonavicular joint. The more rigid the fixation and the more the surgeon respects the local vascular anatomy, the less the likelihood of nonunion developing. Malunion is a fairly frequent complication of pantalar arthrodesis because of the great technical demands of performing this procedure. A precise determination of appropriate final alignment is the key. Intraoperative radiographs should be employed in almost every case. Hindfoot valgus is better tolerated than varus, and if the surgeon must error, it should be to the side of valgus. Avoidance of internal rotation and the use of mild posterior subluxation of the talus under the tibia can enhance postoperative gait.

Other complications after pantalar arthrodesis include superficial or deep wound infection, wound slough, malunion and nonunion. Hardware failure and/or prominence can be remedied with subsequent removal after radiographic union is achieved. Cuticular neuromas have been reported, and prevention is the key to minimizing the symptoms here. Patients with normal plantar sensation and arthrodesis in the appropriate position should have minimal incidence of ulceration. Avascular necrosis was reported after pantalar arthrodesis primarily when talectomy and reinsertion of the talus were employed in earlier reports.

Tibiotalocalcaneal and extended pantalar arthrodeses are quite demanding, though useful procedures that may be used for a variety of indications. These procedures should be used as salvage techniques to be used for what otherwise would be extremely disabling or even limb threatening situations and applied for patients with osteoarthrosis, rheumatoid arthritis, neuropathic joint destruction, and paralytic or flail extremities.