CHAPTER **42**

INTRAMEDULLARY NAIL FIXATION IN REARFOOT AND ANKLE ARTHRODESIS PROCEDURES

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Severe ankle and subtalar deformity and pain secondary to destructive processes continues to be a difficult dilemma for foot and ankle surgeons. Attempts at conservative bracing and off-loading of the severely deformed foot and ankle are the initial treatment options. However, as the problems persist and worsen, surgical intervention becomes imminent. This article describes the use of the Biomet® intramedullary nail for the fixation of tibiocalcaneal and tibiotalocalcaneal arthrodeses. The nail is used as a salvage procedure for the patient with severe pain and/or deformity of the ankle and subtalar joints. The authors have found the intramedullary nail to be a good option for the aforementioned patients, affording the patient the opportunity to obtain and maintain a plantigrade foot.

The intramedullary (IM) nail has been in use for over a century. Initially used for long bone fracture management, it has today become a more accepted form of fixation used in lower extremity surgery. As its popularity has increased, numerous companies have developed and modified their own IM ankle arthrodesis nails. Biomet® (Warsaw, IN) has developed one version of the nail, which the authors successfully use, secondary to its compression capability and posterior-to-anterior screw, which increases stability and decreases rotational forces. Patients undergoing tibiocalcaneal or tibiotalocalcaneal arthrodesis have severe ankle and subtalar arthritis, instability of the rearfoot and ankle, and/or severe deformity secondary to processes like Charcot neuroarthropathy. Many of them are one step from an ankle or below the knee amputation.

The benefit of this device in a salvage-type arthrodesis procedure of the rearfoot and ankle lies in its ability to provide a stable, pain-free, and plantigrade foot. The authors realize that the final outcomes in these difficult cases have many potential complications. In these patients, the possibility of a plantigrade foot largely outweighs the possible complications. Minimally, the procedure will delay an ankle or below the knee amputation.

HISTORIC OVERVIEW

One of the earliest descriptions of the concept of intramedullary nail fixation of bones was published by Nicolaysen in 1897.[1] However, it was not until 10 years later that Lambotte[2] reported on the use of IM nails for the treatment of femoral fractures. In 1916, Groves was the first to use IM nails on a routine basis for the treatment of femoral, tibial and humeral fractures and described the insertion of the nails utilizing radiographic visualization.[1] Kuntscher developed a fondness for the procedure as a result of the perceived simplicity and seemingly minimal invasiveness of the surgery, which he felt limited periosteal destruction and prevented delayed wound healing.[1]

As time progressed numerous IM nails were developed in varying shapes and designs; these included the Kuntscher "V" shaped, Rush "diamond" shaped, Hansen and Street "solid, triangular" shaped, Lottes "I-beam", and the Schneider "four-flanged" nail.[2-4] Of additional interest is the fact that historically IM nails came in one length with varying size diameters. The nails were cut to length in the operating room using a sterile bench vice and hacksaw.[3] Today the nails are available in varying lengths, and diameters.

Throughout the 1950s, the Association for the Study of Osteosynthesis (AO) noted that nails lacked anti-rotation and compression properties.[5] Accordingly, the evolution of nails saw further changes in design. Initially the cross sectional design changed.[2,5,6] Design shapes included clover-leafs for increased strength, fluting to oppose bending and shearing, and slotting for a more flexible nail and easier insertion. The rotational concerns led many surgeons to attempt to counter the rotation by placing plates across the fracture site or by simply placing a second nail across the site. It was not until the advent of the interlocking screws that the concept of compression gained acceptance.[6]

Ankle arthrodesis is a common surgical procedure that has used numerous forms of fixation over the years[7,8] including multiple screws, plates, external fixators, and sometimes no fixation at all. Adams was the first to report on the use of an IM nail for ankle arthrodesis in 1948.[9] He used an IM nail for a revisional ankle arthrodesis procedure that had previously failed using a transfibular approach. He described a three-flange nail inserted through the calcaneus, talus and tibia that resulted in eventual bony effusion. In an article by Watson-Jones et al in 1950, brief mention of ankle fusions employing IM nails was made.[1] Specifically, the authors directed attention to the simultaneous treatment of the damaged subtalar joint with this method of ankle fusion. Interestingly, a crude diagram appeared in this article illustrating the use of "two interlocking pins." It appears to have been the first description of such a concept. This concept of interlocking or compression nail techniques was further described by Kaessman et al, Klemm, Shevis, and Zankowki in the 1960s.[5] In 1975, Huckstep produced a four-sided compression nail that employed a proximal screw and nut for fracture compression.[5]

Over time several additional nails were designed with interlocking screws. Differences in the distance from the interlocking screws to the end of the nail and the direction of the proximal interlocking screw were seen. In 1988 Brumback et al described the Russell-Taylor interlocking nail as "static interlocking fixation."[10,11] Prior to the advent of interlocking screws, IM fixation nail techniques were considered dynamic in nature allowing for axial loading at the site of the fracture. Many physicians felt that the axial loading was needed to achieve bony union.[1,10-12] Brumback described utilization of the nail alone or with a proximal or distal interlocking screw for dynamic compression of stable transverse fractures. In cases where a more comminuted fracture was present a proximal and distal interlocking screw was employed to obtain static interlocking fixation. A 98% fusion rate was reported with this technique. This finding was in contradiction to the prevailing notion of the time that the use of static interlocking screws might possibly impede fusion.[6,11,13]

During the 1970s IM nail research focused on the disruption of the periosteal blood flow secondary to medullary reaming.[5,13-15] The reaming was noted to increase pressure within the medullary cavity by pushing bone marrow into intracortical canals and, in turn, blocking circulation. It was determined that reduction of intramedullary pressure by the creation of several metaphyseal defects or "inventing tubes" decreased the intracortical vascular damage. Regardless of the separate metaphyseal defects, the presence of external bone callous was noted at 3 to 4 weeks postoperatively bridging the fracture site, allowing for revascularization of the cortex. Franklin et al described the treatment of broken nails in an article in 1988.[16] They reported that IM nails without interlocking screws broke at the site of the fracture, non-union, or osteotomy, while nails with interlocking screws appeared to fracture at the hole sites for the insertion of the interlocking screws.

Although IM nails were originally developed for fixation of long bone fractures, current nail designs have found a niche in rearfoot and ankle arthrodesing procedures, especially for those with a salvage type of problem. IM nails are most commonly employed with stabilization of the tibiotalar and talocalcaneal articulations. Continued advances in technology and materials, coupled with an increased understanding of the factors governing fusions of the ankle and subtalar joint complex together are likely to enhance final surgical outcomes. IM nails are likely to continue to see increased utilization for stabilization arthrodesis procedures of the ankle and subtalar joint complexes. They are particularly beneficial for salvage arthrodesis of these joints. The technique can be combined with more distal fusions (i.e. midtarsal joints, Lisfranc joints)

INDICATIONS FOR TIBIOTALOCALCANEAL ARTHRODESIS

Tibiotalocalcaneal arthrodesis is typically used as an end-stage procedure for patients who exhibit symptoms of painful arthritis with or without concomitant deformity or instability of the rearfoot and ankle. The procedure has been advocated for the management of numerous severe ankle and rearfoot deformities (Table 1). In general, these deformities can be divided into two major categories. The first category includes patients who are diagnosed with severe, disabling arthritis of both the subtalar and ankle joint complexes. The majority of patients in this category are diagnosed with rheumatic diseases such as rheumatoid arthritis, osteoarthritis, post-traumatic arthritis, and avascular necrosis of the talus.

The second category of patients includes thoses who exhibit severe deformity of the rearfoot and/or ankle with resultant instability upon weight-bearing. Most of the patients in this category have advanced neuroarthropathy. Also included in this category are patients with a fixed equinovarus deformity of the foot and ankle secondary to an underlying neuromuscular disorder and patients with severe peritalar dislocation and ankle valgus as a result of end-stage tibialis posterior tendon dysfunction.

It should be emphasized that the procedure is intended for patients with disease, deformity and/or instability of both the ankle and subtalar joint complexes. Varying combinations of disease can coexist, such as degenerative joint disease of the ankle with chronic lateral subtalar joint (peritalar) dislocation. In other cases the same process can affect both joints (ie. post-traumatic arthritis, AVN, etc.). In some patients, although one joint might normally be preserved, it is more prudent to stabilize both. In these cases loss of motion of a joint that would have normally been preserved will have minimal consequences to the patient.

Table 1

COMMON CONDITIONS TREATED WITH TIBIOTALOCALCANEAL ARTHRODESIS

- Failed Triple Arthrodesis
- AVN of Talus
- Neuroarthropathy
- Inflammatory Arthritis
- Paraplegia With Fixed Equinovarus Deformity of the Foot
- Failed Total Ankle Arthroplasty
- Failed Tibiotalar Arthrodesis
- Failed ORIF of Ankle Fracture With STJ DJD
- Severe DJD of Ankle Secondary to Prior Pilon Fracture With STJ DJD
- DJD of Ankle With STJ Coalition

Tibiotalocalcaneal arthrodesis has been performed using a number of different fixation techniques including internal fixation with pins, cancellous screws, plates and screws, intramedullary nails, and external fixation utilizing a variety of devices. Each of these fixation techniques have their own advantages and disadvantages with respect to the technical ease of insertion/application, ability to maintain rearfoot alignment, fusion rates and complication rates. However, the selection of the type of fixation device to be used must also take into account the nature of the deformity being treated and the quality and quantity of the bone that is present to accept the fixation devices.

While simultaneous fusion of the ankle and subtalar joints can be achieved with other forms of fixation, IM nail fixation may have increased advantages. All other forms of hardware (fixation) are either removed or fail when the fusion itself fails. With IM nail fixation the rigidity and stability achieved are unsurpassed and often result in relatively asymptomatic bone healing complications if they occur.

In high-risk fusion patients IM nail fixation may be indicated and is likely to provide unsurpassed stability to the ankle and rearfoot. High-risk fusion patients include those with chronic nicotine consumption, known peripheral neuropathy, AVN patients, and those patients with underlying poor bone stock due to a disease process such as diabetes or rheumatoid arthritis.

Patients with severe instability and deformity secondary to neuroarthropathy often present the biggest technical challenges when performing tibiotalocalcaneal arthrodesis. As a result of the Charcot disease process, a significant alteration in the normal bony architecture results in malalignment of the rearfoot and/or ankle, and leads to abnormal bony prominences and ulceration. In addition, the clinical picture may be complicated by an underlying infection. In these patients, tibiotalocalcaneal arthrodesis is performed as an alternative to either a Syme's or below-the-knee amputation.

In patients with severe neuroarthropathy, radiographs of the affected extremity often do not clearly delineate the extent of bony destruction due to an increase in the soft tissue density and superimposition of the misaligned rearfoot structures. The talus and calcaneus are often severely fragmented, and collapse of the talar body is not uncommon. In these patients, a CT scan is an excellent tool for evaluating both the quality and quantity of bone. This will give the surgeon a good idea of what types of fixation will be acceptable for the procedure.

The authors favor the IM nail device as fixation of choice for tibiotalocalcaneal arthrodesis in patients with unbraceable neuroarthropathy of the rearfoot and ankle. We have found that this device provides a rigid, plantigrade foot even in the absence of union of the subtalar and/or ankle joint(s). In cases where the talus has undergone significant destruction or precludes the reduction of the hindfoot deformity, a talectomy is performed and the bone is morselized and used as bone graft to fill all defects. Additional allogeneic bone graft is used as needed to reestablish both the height and alignment of the limb.

A variety of IM nails are currently available. Although each of these devices shares common design features, there are subtle differences that may affect the overall construct of the fusion sites. We favor the Biomet® nail for IM fixation of tibiotalocalcaneal and tibiocalcaneal arthrodesis. The Biomet® nail and its associated components are constructed of titanium and the design features two proximal locking screws and three distal locking screws. One of the three distal locking screws can be inserted from posterior to anterior through the body of the calcaneus and into the cuboid or navicular if desired. This may provide additional stability of the midtarsal joint if desired or serve as fixation for fusion of this joint. In some cases only one distal transverse screw can be inserted due to extensive loss of the talar body, rendering the posterior screw very effective. In a small number of patients, particularly those who have a concomitant talectomy, it may be very difficult to nearly impossible to insert a screw from side to side without a significant portion of the nail protruding beyond the plantar aspect of the calcaneus. The implication of this is obvious.

To our knowledge, only the Biomet® nail can impart significant compression through the device itself at the arthrodesis site. This is particularly advantageous in patients with severely compromised bones as is seen in patients with severe Charcot neuroarthropathy or AVN of the talus. A comparison of the features of the currently available nails is found in Table 2. Some manufacturers continue to redesign their nail, making them more attractive for tibiotalocalcaneal arthrodesis.

SURGICAL TECHNIQUE AND CONSIDERATIONS

There are several approaches to insertion of IM nails for rearfoot and ankle arthrodesis. In patients with significant degenerative changes requiring joint resection, a lateral incisional approach is recommended. The incision is placed over the distal aspect of the fibula and continues distally onto the lateral aspect of the foot. Particular care should be taken to avoid damage to the sural nerve traversing the lateral inferior border of the foot and ankle. The deep fascia, capsular, and periosteal tissues are incised and reflected giving excellent exposure to both the ankle and subtalar joints. The fibula can be left intact or, not uncommonly, is transected several centimeters above the tibial plafond and excised in total. The excised fibula may be morselized and used as autogenous bone graft to fill defects within the joint; wedges of bone can also be created. Less commonly, the resected fibula is left whole and used as an on-lay graft. If the fibula is removed, but not utilized as bone graft, it should be processed and saved in the hospital's bone bank for future use in the event revisional surgery becomes necessary.

The ankle and subtalar joints are resected. The authors frequently use an aggressive curettage technique although reciprocal planing of the joints is certainly acceptable as well. If desired, an ancillary medial incision can be made to facilitate joint resection, although this is generally not necessary. In other cases where severe bone destruction has taken place and the normal architectural configuration of the bones are severely distorted, if not all together destroyed, resection of the joints is performed on a limited basis. This is commonly seen in the diabetic neuropathic foot where neuroarthropathy is present. In these cases, complete ankle and/or subtalar joint dislocations are not uncommon and special attention and focus is required to release the deforming tendon and ligamentous structures in order to successfully relocate the joint complexes. Extirpation of the talus may become necessary to allow for relocation, with the removed talus becoming utilized as bone graft as needed (Figure 1). In patients with Charcot neuroarthropathy, definitive arthrodesis is desirable but neither expected nor anticipated. The goal of surgery in these patients is to achieve absolute stability of the limb, thus precluding the need for an amputation of the foot or leg segment.

Once proper alignment and position have been

Table 2

COMPARATIVE SUMMARY OF NAIL DEVICES

Nail Companies	**Biomet** **Ankle Arthrodesis Nail**	**Depuy AIM®** **Supracondylar Nail**	**Richards** **Revision™ Nail**
Materials	Titanium	Titanium	Stainless Steel
Nail Sizes	Diameters 10, 11, 12 mm Length 15 and 18 cm	Diameters 10 and 12 mm Length 15-30 cm (5 mm increments)	Diameters 11, 12, 13 mm Lengths 15,18, and 21 cm
Number of Proximal Transverse Screw Holes	2	2	3
Proximal Anchor Screw Size and Drill	5.0 Fully Threaded Cortical 20 - 110 mm (5mm increments) 4.3 Calibrated Drill and guide	4.5 Fully Threaded Cortical 28 - 52 mm (4 mm increments) 5.3 mm Drill Guide 3.8 mm Drill	5.0 mm or 5.0/6.4 mm Step Screws 20 - 90 mm (5mm increments) 3.5, 4.0, and 8.0 mm Drills 3.2 mm Guide Pin (Osteoporotic Bone)
Number of Distal Transverse Screw Holes	2	2	3
Distal Anchor Screw Size and Drill	5.0 Fully Threaded Cortical 20 - 110 mm increase by 5mm	6.5 Fully Threaded Cortical 50 - 90 mm Increase by 5 mm 5.3 mm Drill Guide 5.3 mm Drill	5.0 mm or 5.0/6.4 mm Step Screws 20 - 90 mm Increase by 5mm Note: Same Drill and Guide as Proximal Screws
Number of Distal Posterior Screw Holes	1	None	None
Distal Posterior to Anterior Anchor Screw Size and Drill	(Transcalcaneal Locking Screw) Note: increases torsional rigidity 5.0 Fully Threaded Titanium 20 - 110 mm increase by 5mm	N/A	N/A
Direction of Insertion of Locking Screws	Medial to Lateral OR Lateral to Medial OR Combination	Lateral to Medial OR Medial to Lateral	Lateral to Medial OR Medial to Lateral
Drill Guide, Reamer, and Guide Pin for Nail	2.4 mm x 9î Steinmann Pin 7.0 Cannulated Drill 3.2 Ball Tip Guide Wire 8.0 - 20.0 mm Cannulated Reamers (Flexible and Nonflexible)	3.2 mm x 14î Guide Pin 12 mm Entry Reamer (non-flexible)	3.2 mm x 15" Threaded Tip Ball Tip Guide Wire Available 9 mm Cannulated Reamer (Non-flexible)
Recommended Reaming	18-20 cm into Tibial Canal no greater than Distal 1/3 Tibial Shaft. 0.5mm Greater than Actual Nail Diameter	0.5 - 1 mm Greater than Nail Diameter	0.5 mm Smaller than Nail
Compression Options	Compression Nut with 3/4" End Wrench (15 mm Compression Possible)	Options: Unilateral Femoral Distractor Tapping Jig with Mallet	None Specified
End Cap	Yes	Yes	No

Figure 1. Exposure of the lateral aspect of the foot and ankle for extirpation of the talus in a patient with severe Charcot arthropathy. Talus is shown being excised from the foot for tibiocalcaneal arthrodesis.

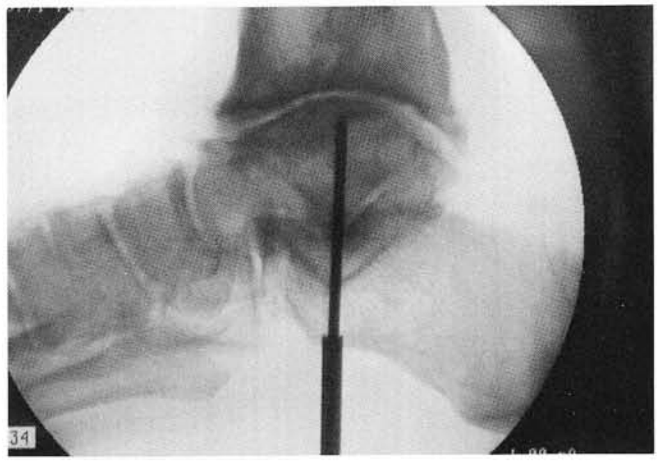

Figure 2A. Intraoperative fluoroscopic picture of the initial guide pin insertion. A protector sleeve overlies the pin to protect the critical neurovascular structures in the area.

achieved the process of nail insertion begins. Primary emphasis is placed on accurate placement of the guide pin. This can only be achieved by the use of intraoperative fluoroscopy to visualize the ankle joint from an anterior-posterior direction as well as a medial-lateral direction. The goal is determine the point of entry in the plantar aspect of the heel that will allow placement of the nail within the center of the medullary canal of the tibia. As a general guideline, the entry point of the guide pin can be estimated by drawing lines bisecting the frontal plane bisection of the medial and lateral malleoli and the longitudinal axis of the second toe to the center aspect of the plantar heel. The intersection of these two lines can be used to estimate the entry point of the guide pin. The process of defining the point of entry of the guide pin is quite tedious and can take as long as 15-20 minutes. The importance of this step in the procedure cannot be over-emphasized as it is this step that will determine the final end product with regard to placement of the nail.

Once the point of entry has been tentatively identified, a traverse incision is made on the plantar aspect of the foot measuring 2-3 cm in length. The authors do not recommend performing the procedure through a small incision as the risk to the neurovascular structures, most notably the lateral plantar nerve, is greatly increased. Blunt dissection technique is used to go through the subcutaneous tissues to the level of the plantar fascia. The plantar fascia is then incised and the blunt dissection continues to the plantar aspect of the calcaneous. As much blunt dissection as possible is used to minimize risk of damage the neurovascular structures.

Figure 2B. Introduction of the ball tip guide wire into the medullary canal of the tibia to guide the cannulated drills and reamers. The exact location of placement has been determined under fluoroscopic visualization.

Next, the skin and subcutaneous tissues are retracted and the guide pin is inserted under fluoroscopic imaging (Figure 2A). A drill guide is inserted over the guide pin and the cannulated drill is then inserted and advanced from the plantar aspect of the calcaneus through the talus and into the tibia. At this point the guide pin is removed and a ball-tipped guide wire is inserted in its place (Figure 2B). The hole is then progressively enlarged using a series of reamers of increasing size. Reaming is continued until some resistance is felt as the reamer begins to intermittently contact the cortical wall of the medullary canal; this phenomenon is referred to as "chatter."

Figure 3. Insertion of the nail with the outrigger assembly attached which will guide insertion of the proximal and distal locking screws.

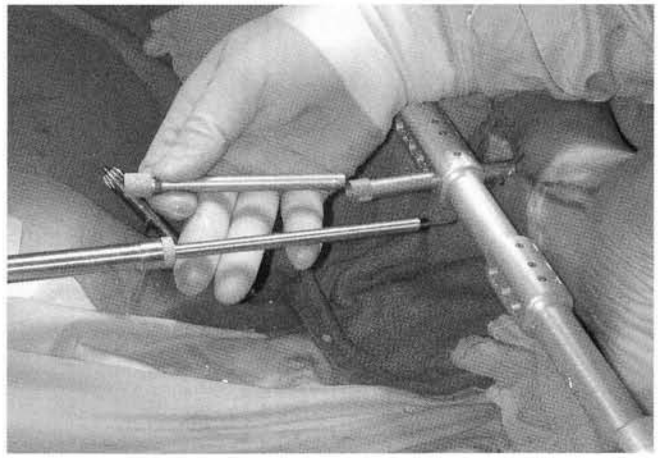

Figure 4. Introduction of the bushing and guide tube into the outrigger assembly. Drilling of the proximal aspect of the tibia, countersinking and insertion of the proximal locking screws will be performed through the guide tube and bushing unit.

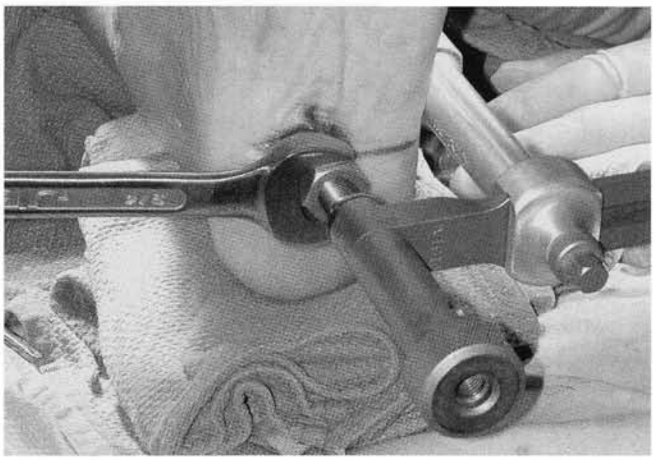

Figure 5. Utilization of the wrench to achieve compression of the fusion site. The wrench is shown on the compression nut which will apply pressure to the plantar aspect of the calcaneus.

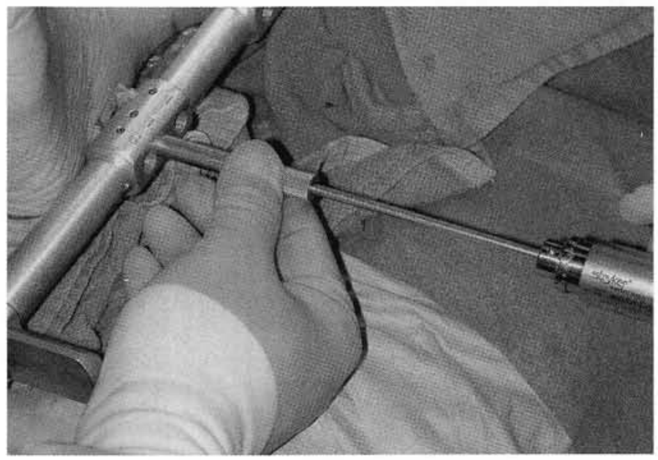

Figure 6. Drilling for the insertion of the distal locking screws through the lateral incision using the same guide tube and bushing unit shown in figure 4. One or two screws can be inserted from lateral to medial through the talus and calcaneus.

The appropriate sized nail (both length and diameter) is determined preoperatively by utilizing a template that is provided by the manufacturer of the nail. The final decision, however, is made intra-operatively. The outrigger assembly is attached to the appropriate sized nail and the nail is then inserted from the plantar aspect of the foot under fluoroscopic visualization (Figure 3). The nail is advanced until it has been countersunk a few millimeters from the plantar surface of the calcaneus. An attempt is made to place the nail in such a position that at least one or two distal transverse locking screws can be inserted into the calcaneus, talus, or both.

While the proximal anchor screws can be inserted through a medial or lateral incision our recommendation is to do so through a medial incision overlying the medial cortex of the tibia. This eliminates the need for excessive dissection of the soft tissues overlying the anterior lateral aspect of the leg which are encountered when using a proximal lateral approach for the insertion of the proximal anchor screws; the anterior tibial artery, nerve and veins lie within this area. Depending on the device employed, a minimum of two proximal anchor screws are inserted. The outrigger device will ensure the proper placement of the drill holes (Figure 4). Following the insertion of the proximal screws, compression with the Biomet® nail is achieved by tightening the compression nut (Figure 5).

The distal screws are inserted next. When possible, the authors insert two screws from a distal lateral approach; one through the talus and the other through the calcaneus. Again, the outrigger assembly will ensure proper placement of these screws (Figure 6). Typically, the distal screws are placed into the talus and calcaneus. Unfortunately, due to extensive bone destruction it may not be possible to insert two screws distally from the lateral approach. In these cases, the authors attempt to insert at least one distal screw.

Finally, a posterior to anterior screw is inserted when additional stability is needed or we are unable to successfully secure the pin distally with two transverse locking screws. This posterior to anterior screw may also be used to stabilize the midtarsal joint with or without fusion (Figure 7). The most stable construct seems to be achieved when two distal screws are inserted laterally and one screw is inserted from a posterior approach. We have been impressed with the stable construct that can be created. In essence we have found that rigid internal compression fixation is achieved.

The fusion sites are then examined and assessed. An implantable bone stimulator is inserted

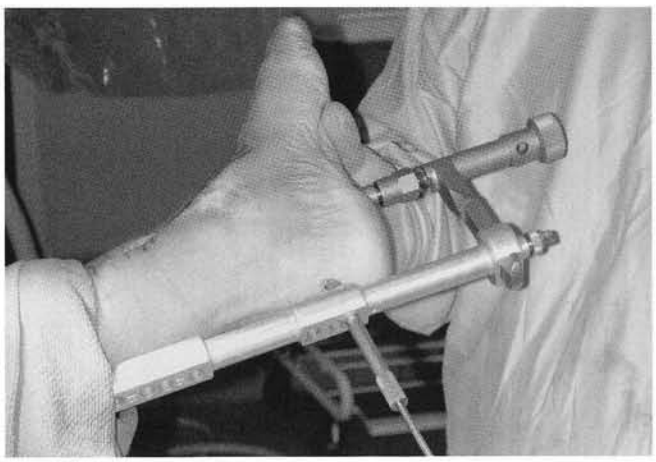

Figure 7. Insertion of posterior locking screw through the calcaneus. This screw can be used to stabilize the midtarsal joint when driven into either the navicular or more commonly the cuboid.

Figure 8. Morcelized autogenous corticocancellous chips created from the partial resection of the distal fibular malleolus. The same technique can be done with an extirpated talus when performing tibiocalcaneal fusion.

Figure 9A. Lateral radiograph 5 months postoperatively employing two proximal locking screws, two transverse distal locking screws, and one posterior screw. An excellent clinical and radiographic fusion was achieved.

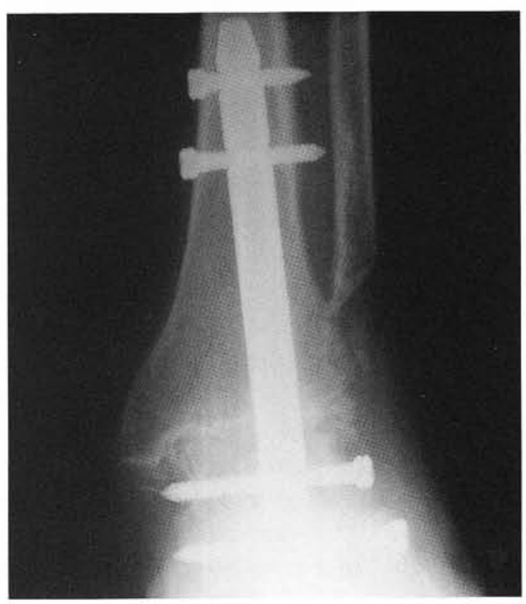

Figure 9B. AP radiograph of the same patient demonstrating solid fusion of the ankle portion of a tibiotalocalcaneal arthrodesis. All four transverse locking screws are readily visualized.

in higher risk patients. Defects are filled with autogenous and/or allogeneic bone graft material (Figure 8). The wounds are irrigated aggressively with normal sterile saline. The periosteal, capsular and deep fascial tissues are reapproximated with heavy absorbable synthetic sutures. The subcutaneous tissues and skin are closed with a suture material of choice. Staples are frequently used. A surgical drain is inserted if significant post-operative bleeding is anticipated.

POSTOPERATIVE MANAGEMENT

Patients are initially placed in a Jones compression bandage. The first major dressing change is performed one-week postoperatively. At that time, patients are placed in a short-leg Jones compression cast that will be worn for a minimum period of 8 weeks. Although many authors recommend early partial or full weightbearing, we feel that weight-bearing can only be detrimental during the initial 4-6 weeks of the healing process.

Serial radiographs are obtained at 4 to 5 week intervals. When radiographic consolidation is seen and correlates with the overall clinical picture, limited weightbearing without ambulation is begun. This is generally begun around 8-12 weeks post-operatively. Progressive increased weight bearing and full ambulation is permitted over the course of the next 4 to 5 weeks. By week 16, patients are generally fully ambulatory and the cast is removed. If necessary, they are placed in a removable cast boot type of device.

It is important to monitor these patients on a 3 to 4 month basis for at least the first year (Figures 9A, 9B). During this time loosening of the screws with or without migration of the screws may occur necessitating the need for screw removal or replacement. Patients should also be monitored for the development of pathologic fractures of the tibia.

COMPLICATIONS

Although an effective method of stabilization, the use of IM nails for tibiocalcaneal and tibiotalocalcaneal arthrodesis is not without its potential complications. Infection, both deep and superficial, can occur.[3,11,17-22] Treatment for superficial infection entails local wound care and oral antibiotics. In the cases of deep infection involving the medullary canal, the nail may need to be removed and a below-the-knee amputation might result.[11,20,21] At minimum, all infected bone would need to be resected and intravenous antibiotics initiated. Nonunion, delayed unions, and pseudoarthroses may also occur.[3,19,23,24] The rate of nonunion for the IM nail arthrodesis has reached as high as 15% in the literature.[23] In an article by Moore et al, the rate of pseudoarthrosis reached 26%.[19] It is important to note that in many cases the pseudoarthrosis is asymptomatic and is therefore more of a radiographic finding and not necessarily a clinical concern.

Complications directly related to the nail itself involve heel pain, nail breakage, and tibial stress risers. Heel pain may result from the prominence of the nail itself, or from pressure on the surrounding nerves, namely the lateral plantar nerve.[18,19,25,26] This can result in paresthesias or numbness along the nerve distribution. Treatment for heel pain usually consists of heel cushioning and neurolysis in recalcitrant cases of nerve entrapment. Although nail breakage has been mainly studied in femoral nails, recent studies have focused on the problem of tibial nail breakage.[11,16,19] These studies indicate that in the majority of cases, tibial nails were likely to break at the site of the fracture or nonunion.[16,19] In cases of failure, the broken tibial nails were removed using open procedures unless the fracture/fusion was already healed, in which case the nail was left in place. Infrequently, the interlocking screws themselves might break.[16,18] The authors have recently had some isolated cases of "backing out" of the distal interlocking screws, treated with surgical reinsertion of the distal screws, with use of longer screws in select circumstances.

Other studies have shown an increase in tibial cortical hypertrophy postoperatively at sites of the proximal interlocking screws or the proximal extent of the nail itself. These findings are consistent with increased stress risers at these locations.[2,3,18,22] Consistent with these findings is the development of stress fractures at these sites, treated with immobilization.[22]

Limb length discrepancy can be a potential problem in the tibiotalocalcaneal and tibiocalcaneal arthrodesis patient secondary to cartilage resection and possible talectomy. This is more of a concern in the patient with a Charcot type deformity secondary to the possibility of abnormal pressure forces on the joints of both feet. In the Charcot patient, any increased or abnormal pressure distribution can result in further breakdown of the rearfoot/ankle complexes. For this reason, bracing of both extremities postoperatively, with attempted correction of the limb length discrepancy, is extremely important to equalize pressure gradients over both feet and ankles.

Although a remote possibility, a complication that deserves mention is fat embolism.[5,27] This occurrence is more commonly noted with the femoral nailing. However, any procedure that involves extensive medullary reaming can result in extrusion of fat into the surrounding circulation, as shown in animal and clinical studies. Although potential complications associated with the IM nail are disastrous, the potential advantages of the nail, namely a plantigrade foot type capable of weightbearing, outweigh the potential complications.

SUMMARY

Tibiotalocalcaneal and tibiocalcaneal arthrodesis is a major surgical procedure that is more often than not a very challenging and frustrating to the surgeon dedicated to reconstructive surgery of the foot and ankle. It is a salvage procedure whose outcome is difficult to predict. IM nail fixation is one technique that is used in patients at higher risk for bone healing complications. Although most IM nails provide excellent stability, the Biomet® nail offers not only stability but compression as well. The distal posterior to anterior screw provides an additional point of stability to the construct. Our experience to date has been a very positive one and we strongly encourage its use in high-risk rearfoot and ankle arthrodesis cases.

REFERENCES

1. Watson-Jones R, Adams JC, Bonnin JG, et al. Medullary Nailing of fractures after fifty years. *J Bone Joint Surg Br* 1950;32:694-729.
2. Pavlik A. A femoral intramedullary nail. *J Bone Joint Surg Am* 1957;39:1059-75.
3. Sage FP. The second decade of experience with the Kuntscher medullary nail in the femur. *Clin Orthop Rel Res* 1968;60:77-85.
4. Vesley DG. 30 years of experience with intramedullary fixation for fractures of the femur. *Clin Orthop Rel Res* 1968;60:3-4.
5. Aginsky J, Reis ND. The present state of medullary nailing of the femur: biomechanical limitations and problems of blood supply to the fracture due to reaming. *Injury* 1979;11: 190-6.
6. Inhofe PD. Biomechanical considerations in intramedullary fixation of lower-extremity fracture. *Orthop Rev* 1992:945-52.
7. Ratliff AHC. Compression arthrodesis of the ankle. *J Bone Joint Surg Br* 1959;41:524-34.
8. Charnley J. Compression arthrodesis of the ankle and shoulder. *J Bone Joint Surg Br* 1951;33:180-91.
9. Adams JC. Arthrodesis of the ankle joint, experiences with the transfibular approach. *J Bone Joint Surg* 1948;30:506-11.
10. Brumback RJ, Reilly JP, Poka A, et al. Intramedullary nailing of femoral shaft fractures, part I: decision-making errors with interlocking fixation. *J Bone Joint Surg Am* 1988;70: 1441-52.
11. Brumback RJ, Reilly JP, Poka A, et al. Intramedullary nailing of femoral shaft fractures. Part II: Fracture-healing with static interlocking fixation. *J Bone Joint Surg AmM* 1988;70:1453-62.
12. Rush LV. Dynamic intramedullary fracture-fixation of the femur, reflection on the use of the round rod after 30 years. *Clin Orthop Rel Res* 1968;60:21-7.
13. Kessler SB, Hallfeldt KK, Perren SM, et al. The effects of reaming and intramedullary nailing on fracture healing. *Clin Orthop Rel Res* 1986;212:18-25.
14. Sturmer KM. Measurements of intramedullary pressure in an animal experiment and propositions to reduce the pressure increase. Original research from Universitatsklinikum Abteilung fur Unfallchirurgie: S7-S21.
15. Danckwardt-Lilliestrom G, Lorenzi L, Olerud S. Intracortical circulation after intramedullary reaming with reduction of pressure in the medullary cavity, a microangiographic study on the rabbit tibia. *J Bone Joint Surg Am* 1970;521390-4.
16. Franklin JL, Winquist RA, Benirschke SK, et al. Broken intramedullary nails. *J Bone Joint Surg Am* 1988;70:1463-71.
17. Fujimori J, Yoshino S, Koiwa M, et al. Ankle arthrodesis in rheumatoid arthritis using an intramedullary nail with fins. *Foot Ankle Int* 1999;20:485-90.
18. Kile TA, Donnelly RE, Gehrke JC, et al. Tibiocalcaneal arthrodesis with an intramedullary device. *Foot Ankle Int* 1994;15:669-73.
19. Moore TJ, Prince R, Pochatko D, et al. Retrograde intramedullary nailing for ankle arthrodesis. *Foot Ankle Int* 1995;16:433-6.
20. Carlsson AS, Montgomery F, Besjakov J. Arthrodesis of the ankle secondary to replacement. *Foot Ankle Int* 1998;19:240-5.
21. Pinzur MS, Kelikian A. Charcot ankle fusion with a retrograde locked intramedullary nail. *Foot Ankle Int* 1997;18:699-704.
22. Thordarson DB, Chang D. Stress fractures and tibial cortical hypertrophy after tibiocalcaneal arthrodesis with an intramedullary nail. *Foot Ankle Int* 1999;20:497-500.
23. Berend ME, Glisson RR, Nunley JA. A biomechanical comparison of intramedullary nail and crossed lag screw fixation for tibiocalcaneal arthrodesis. *Foot Ankle Int* 1997;18:639-43.
24. Russotti GM, Johnson KA, Cass Jr. Tibiocalcaneal arthrodesis for arthritis and deformity of the hind part of the foot. *J Bone Joint Surg Am* 1988;70:1304-7.
25. Pochatko DJ, Smith JW, Philips RA, et al. Anatomic structures at risk: combined subtalar and ankle arthrodesis with a retrograde intramedullary rod. *Foot Ankle Int* 1995;16:542-7.
26. Stephenson KA, Kile TA, Graves SC. Estimating the insertion site during retrograde intramedullary tibiocalcaneal arthrodesis. *Foot Ankle Int* 1996;17:781-2.
27. Wolinsky P, Tejwani N, Richmond JH , et al. Controversies in intramedullary nailing of femoral shaft fractures. *J Bone Joint Surg Am* 2001;83:1404-14.