Ankle Arthrodesis: Indications and Techniques

Nicholas A. Abidi, MD, Gary S. Gruen, MD, and Stephen F. Conti, MD

Abstract

Patients with ankle arthritis and deformity can experience severe pain and functional disability. Those patients who do not respond to nonoperative treatment modalities are candidates for ankle arthrodesis, provided pathologic changes in the subtalar region can be ruled out. Several techniques are available for performing the procedure; the most successful combine an open approach with compression and internal fixation. The foot must be positioned with regard to overall limb alignment and in the optimal position for function. A nonunion rate as high as 40% has been reported. Osteonecrosis of the talus and smoking are known risk factors for nonunion. When good surgical technique is used in carefully selected patients, ankle arthrodesis can be a reliable procedure for the relief of functionally disabling ankle arthritis, deformity, and pain.

J Am Acad Orthop Surg 2000;8:200-209

The ankle joint consists of a highly constrained articulation of the talus with the tibial plafond and the distal fibula. With weight bearing, congruity between the sulcus of the talus and the tibial plafond provides stability in the sagittal plane in a normal ankle joint. Torn or detached ligaments around the ankle joint, however, allow abnormal coronal-plane instability with weight bearing.

The deep deltoid ligament carries the primary blood supply to the medial aspect of the body of the talus from the posterior tibial artery. Therefore, at least on a theoretical basis, an effort should be made to preserve the deltoid ligament during surgical procedures on or about the ankle joint.

Damage to the ankle joint from trauma or disease can result in progressive loss of the tibiotalar articular cartilage surface, with resulting inflammation, synovitis, osteophyte formation, progressive loss of ankle-joint motion, weight-bearing pain, and functional disability. A variety of techniques for ankle arthrodesis have been described over the years as surgical measures to relieve the pain and functional disability associated with a damaged ankle joint.[1-14]

Treatment of the Symptomatic Ankle Joint

Nonoperative treatment of a symptomatic degenerative ankle joint includes the use of shoe inserts or shoe modifications. A shoe with a cushioned heel and a stiff, rocker-bottom sole usually helps patients with less severe ankle-joint damage.[15] If more support is needed, the use of a molded ankle-foot orthosis or a double-upright type of brace attached to the patient's shoe can be used. Such a brace tends to decrease joint inflammation and pain by restricting ankle-joint motion. Some patients are helped by supporting the arthritic ankle joint in a walking cast for 6 weeks. The use of a walking cast has also been suggested as a trial device to evaluate patient acceptance and degree of pain relief prior to performing an ankle arthrodesis.[15]

Nonsteroidal anti-inflammatory drugs can be helpful in relieving ankle pain. If long-term use is expected, patients should be screened for contraindications, and appropriate blood and urine studies should be performed. Intra-articular injections of corticosteroid-anesthetic combinations can be used to decrease joint pain and inflammation, but the injections should be at least 3 months apart.

Arthroscopic ankle-joint debridement may temporarily relieve the symptoms of early arthritis. This technique permits direct visualization of intra-articular and intracapsular structures, thus allowing accu-

Dr. Abidi is Assistant Professor of Orthopaedic Surgery, Jefferson Medical College, Thomas Jefferson University, and Chief, Division of Orthopaedic Foot and Ankle Surgery, Rothman Institute, Philadelphia. Dr. Gruen is Associate Professor and Chief, Division of Orthopaedic Trauma Surgery, University of Pittsburgh Medical Center, Pittsburgh. Dr. Conti is Associate Professor and Chief, Division of Foot and Ankle Surgery, University of Pittsburgh Medical Center.

Reprint requests: Dr. Gruen, Department of Orthopaedic Surgery, University of Pittsburgh Medical Center, Suite 911 Kaufmann Building, 3471 Fifth Avenue, Pittsburgh, PA 15213.

rate diagnostic evaluation and the opportunity for immediate therapeutic intervention. Removal of loose osteochondral fragments or impinging osteophytes by arthrotomy or arthroscopy can provide effective relief of pain.[16] Several large series have documented a high incidence of impinging spurs in football players (up to 45%)[17] and in dancers (up to 59.3%).[18] Because this entity is frequently encountered in athletes, it has been referred to as "athlete's ankle" and "footballer's ankle."[17] The suspected mechanism consists of extreme ankle dorsiflexion with resultant anterior joint impingement and posterior joint distraction. It is theorized that repetitive anterior ankle impingement causes anterior subperiosteal hemorrhages and subsequent sclerotic bone growth.

Periarticular osteotomy and syndesmotic reconstruction for malunited ankle fractures is a treatment alternative for patients who do not demonstrate joint-space collapse on weight-bearing radiographs. Symmetry of the tibiotalar joint space must be maintained, and the seating of the fibula in the incisura fibularis of the tibia must be evaluated. The two findings most often cited as indicators of abnormal relationships are (1) diminished overlap of the distal fibula and anterior aspect of the tibia and (2) excessive widening of the tibiofibular clear space. A significant and frequent component of ankle fracture malunion is rotation and shortening of the fibula.[19] Ankle malalignment secondary to malreduction or impingement results in shifting of the talus, persistent instability, and valgus tilt. As little as 1 mm of lateral talar displacement has been demonstrated to alter tibiotalar contact by as much as 40%.[20] With the loss of joint congruity, damage to the cartilage surface occurs progressively over time.

Factors that determine whether ankle reconstruction is a viable option include the condition of the articular cartilage at the time of revision and the quality of fracture reduction. Other variables, such as length of time from injury to the reconstructive procedure and the age of the patient at time of presentation, have not been shown to influence outcome. Anatomic reconstruction of a malunited ankle joint will prevent further progression of ankle arthritis, even in the presence of early disease.[21] Furthermore, precise restoration of ankle-joint anatomic relationships is critical to a successful outcome. In one series,[22] good to excellent results were achieved in 85% of patients after reconstruction of ankle malunions. Factors associated with favorable patient outcome included position of the talus in the mortise, stability of the syndesmosis, correct length of the fibula, and quality of the joint surface at the time of reconstruction.

Clinical results support the concept that late reconstruction of a malunited ankle provides pain relief and improved patient function.[19,21,23-25] Reconstruction most frequently involves fibular or tibial osteotomy, but may be combined with syndesmotic stabilization as well.

Indications for Arthrodesis

The principal indication for ankle arthrodesis is persistent ankle-joint pain and stiffness that is functionally disabling to the patient and is not alleviated by nonoperative treatment methods. This may be the result of previous fracture, infection, osteonecrosis, or arthritis.

Radiographic changes in the ankle joint are best assessed on weight-bearing standing anteroposterior (Fig. 1, A), lateral (Fig. 1, B), and mortise views. Computed

A B

Figure 1 Weight-bearing anteroposterior **(A)** and lateral **(B)** radiographs of the ankle show complete joint-space collapse, valgus malalignment, and an old medial malleolar fracture.

tomography, alone or in combination with arthrography, can be useful for assessing joint-surface defects, degenerative joint changes, and the location of osteophytes. The bones of the subtalar complex (the talocalcaneal, talonavicular, and calcaneocuboid joints) should be in normal alignment and without arthritic changes. A bone scan or selective joint injections can help to determine whether joints other than the tibiotalar joint have degenerative changes. Following a successful ankle arthrodesis, it has been shown that motion in the subtalar complex increases by an average of 11 degrees during the first year.[6]

Surgical Techniques

Selection of the surgical technique should be based on the underlying disorder. As a general rule, external fixators are preferred for patients undergoing arthrodesis for a preexisting septic joint and for those with severe osteopenia. Arthroscopic arthrodesis or the "mini-open" arthrodesis should be used only for patients with minimal deformity. Open arthrodesis is appropriate for patients with significant ankle deformity and foot and ankle malalignment.

Regardless of the surgical technique chosen, the optimal postoperative position of the affected foot and ankle joint is the same.[26] The foot should be externally rotated 20 to 30 degrees relative to the tibia,[27] with the ankle joint in neutral flexion (0 degrees), 5 to 10 degrees of external rotation, and slight valgus (5 degrees). This position provides the best extremity alignment and accommodation of hip and knee motion. Fusion of the ankle in plantar-flexion results in genu recurvatum when placing the foot flat on the floor and subsequent laxity of the medial collateral ligament of the knee, which develops from the externally rotated gait that patients adopt to avoid "rolling over" a plantar-flexed foot.[26]

External Fixation

Before Charnley's report in 1951 on the results obtained with a compression arthrodesis technique involving use of an external fixator, ankle arthrodesis was associated with high rates of failure because of nonunion.[2] The Charnley method combined open surgical debridement of the ankle-joint cartilage with the application of an external fixator by placing one pin through the tibia and another through the neck of the talus, with connecting bars running between the two pins. Compression across the arthrodesis site relies on an intact Achilles tendon functioning as a tension band. Patients are allowed to bear weight on the treated ankle during the first 8 weeks after surgery. After removal of the external fixator, patients are immobilized in a plaster walking cast for an additional 4 weeks.

The Calandruccio external fixator makes use of a triangular configuration to achieve stability and compression across the tibiotalar joint,[4] which provides added resistance to torsional forces at the ankle joint. After surgical removal of the ankle-joint articular cartilage, fixation pins are placed through the tibia, through the neck and body of the talus, and, occasionally, into the calcaneus. The fusion site is then buttressed with bimalleolar onlay bone grafts. This external fixator technique does not require an intact Achilles tendon to serve as a tension band.

A simplified alternative method of external fixation with the use of a unilateral frame was reported in 1994.[13] This method appears to provide adequate resistance to both dorsiflexion and plantar-flexion forces at the tibiotalar joint. The unilateral external fixator pins are placed into the medial aspect of the tibia, the calcaneus, and the neck of the talus and are of larger diameter than those used with the Calandruccio device. Compression can be exerted across the arthrodesis site by adding a compression device to the external fixator apparatus prior to placement on the patient.

Arthroscopic Arthrodesis

The intra-articular portion of an ankle fusion can be done with an arthroscope, but this technique should be limited to patients with arthritic ankles with minimal deformity, because it is difficult to correct ankle deformity arthroscopically.[8] For this technique, arthroscopy is performed through two or, occasionally, three portals. One portal is medial to the tibialis anterior tendon, and the other is lateral to the extensor digitorum longus tendon. A third portal can be placed lateral to the peroneus tertius tendon and can then be used to remove debris generated during articular-surface denuding.

The joint space is widened with a noninvasive distractor or a unilateral external fixator. A 4.5-mm bur and curettes are used to denude the articular surfaces. After preparation, compression of the joint surfaces can be obtained with either internal or external fixation. Preferably, two cannulated screws are placed across the tibia into the talus. The first screw runs from the lateral aspect of the tibia into the neck of the talus. The second screw runs from the medial malleolus into the lateral aspect of the talus. Patients are kept in non-weight-bearing status for 5 weeks postoperatively and then are allowed to bear weight progressively until joint fusion is demonstrated radiographically.

In an attempt to achieve the advantages of both the open and arthroscopic techniques, a "mini-

open" technique was reported in 1996.[11] This technique decreases reliance on regular arthroscopic techniques in favor of using enlarged arthroscopic portals for exposure and removal of articular cartilage. Curettes and osteotomes are used to denude the joint surfaces. This technique reportedly decreases the amount of soft-tissue stripping required in the more standard open techniques and is reported to be associated with quicker radiographic fusion rates.

Open Arthrodesis

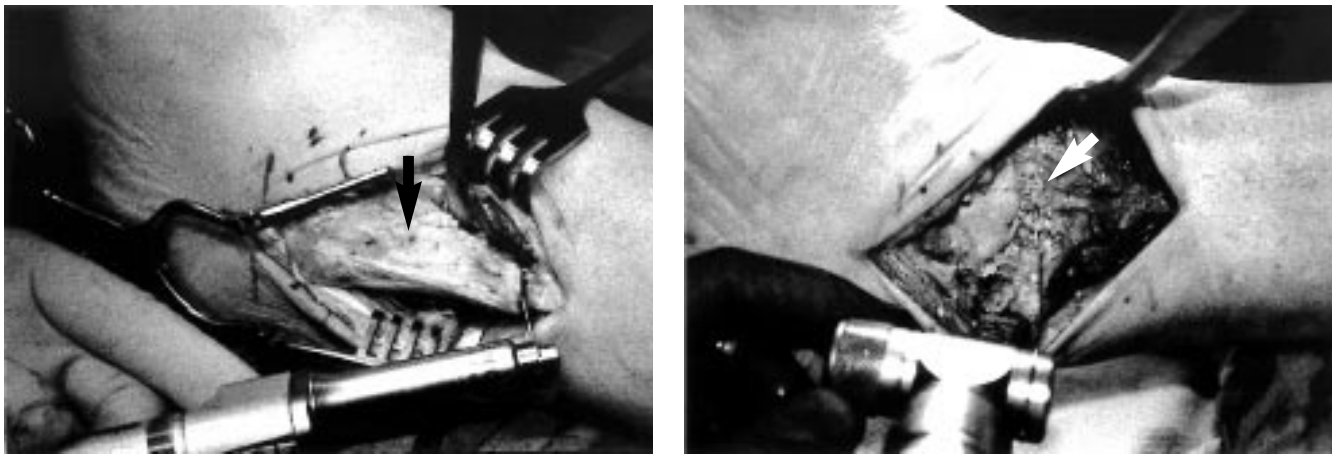
The open ankle arthrodesis is performed through a two-incision transfibular exposure. This technique can be used for any patient but is particularly useful for patients with severe ankle-joint deformity. Its benefits are better visualization of the joint and improved access for bone resection, correction of deformity, and screw placement. Its drawbacks are the large incisions and the amount of soft-tissue stripping required.

The first incision is made directly over the fibula, and the second incision is made along the anterior third of the medial malleolus. Both exposures are carried out carefully to maintain full-thickness flaps and to identify and protect tendons and neurovascular structures. After the distal 10 cm of the fibula has been exposed, the superior peroneal retinaculum is incised posteriorly, and the peroneal tendons are mobilized while protecting the sural and superficial peroneal nerves.

A small acetabular reamer can be used to morselize the fibula for bone graft material prior to its removal. A micro-oscillating saw is used to make an oblique osteotomy 10 cm from the fibular tip (Fig. 2, A). The remaining fibular fragment can then be excised. Alternatively, the distal fibular soft-tissue attachment can be preserved if the fibula has not been morselized. The medial half of the fibula is cut away, and the remaining fibula is turned down and away from the arthrodesis site. The blood supply is maintained because of the remaining ligamentous attachments. The outer half of the fibula is secured to the tibia and the talus with two 3.5-mm screws later during the procedure. This lateral buttress gives additional lateral stability to the arthrodesis site and assists in preventing lateral drifting of the talus.

Sharp dissection is used through the lateral incision to elevate the scarred ankle capsule from the joint both anteriorly and posteriorly, thus allowing the vital structures on both sides of the ankle joint to be protected by retractors. Soft-tissue protection is provided through the medial incision by a retractor. A large oscillating saw is used to make a cut perpendicular to the tibial shaft at the level of the apex of the dome of the articular surface, allowing removal of the tibial plafond (Fig. 2, B). An attempt should be made to preserve the medial malleolus so as to provide an area of solid fixation for the lateral-to-medial screw and to preserve the medial blood supply to the talus through the deltoid ligament.[28]

After removal of the distal tibial articular surface, the talus is positioned so that the forefoot is in 5 to 10 degrees of external rotation and the hindfoot is in 5 degrees of valgus, with neutral dorsiflexion and displacement so that the posterior margins of the talus and tibia are flush. The foot must be aligned



A B

Figure 2 **A,** Through the lateral incision, the fibula is osteotomized 10 cm proximal to the tip with a micro-oscillating saw. The arrow marks the distal fibula. **B,** Through the lateral approach, the distal articular surface of the tibia is removed at a 90-degree angle to the tibial shaft with an oscillating saw. The arrow marks the distal tibia.

with regard to the entire limb. A cut through the dome of the talus is then made parallel to the distal tibia, resecting approximately 5 mm of the talus. Alternatively, the joint surfaces can be prepared with curettes and osteotomes. The remaining joint surfaces are inspected carefully for residual cartilage and sclerotic bone. All joint surfaces are drilled or curetted until bleeding bone is noted. The fibula may be used as a strut graft or as crushed cancellous autograft to fill deep defects if it has been morselized.

The talus is apposed flush to the distal tibia. After the surface congruency and joint position have been checked, the joint position is secured with two guide pins for large (7.0- to 7.3-mm) cannulated screws. The first pin is started at the posterolateral corner of the tibia and is placed across the joint and into the neck of the talus. The second guide pin is placed from the medial malleolus into the lateral aspect of the talus. Alternatively, the second pin may be placed from the lateral process of the talus into the medial cortex of the tibia. Pin placement and bone apposition are checked under fluoroscopy (Fig. 3, A and B). Care must be taken that the pins do not violate the subtalar joint.

Once pin placement and bone apposition have been found to be satisfactory, short threaded cannulated screws with washers are placed into the bone (Fig. 3, C and D). The wounds are closed with a two-layer technique, taking care to protect the adjacent nerves. The extremity is placed in a bulky cast padding and a plaster splint dressing, which is maintained for 2 weeks. A non-weight-bearing short leg cast is then applied, and weight bearing is not permitted until evidence of arthrodesis is observed on the follow-up radiographs, which usually occurs 8 to 12 weeks postoperatively.

The arthrodesis technique must be modified for patients with compromised soft tissues, with nonunions after previous arthrodesis attempts, or with neuropathic ankle joints. Patients with symptomatic nonunions, osteonecrosis of the talus, or Charcot arthropathy frequently require substantial debridement of devitalized bone from the talus. Bone grafting can be used in these patients to regain some of the lost height, but often tibiotalocalcaneal arthrodesis is required to achieve a successful fusion. More rigid internal fixation is a part of almost all fusion techniques used in these difficult situations.

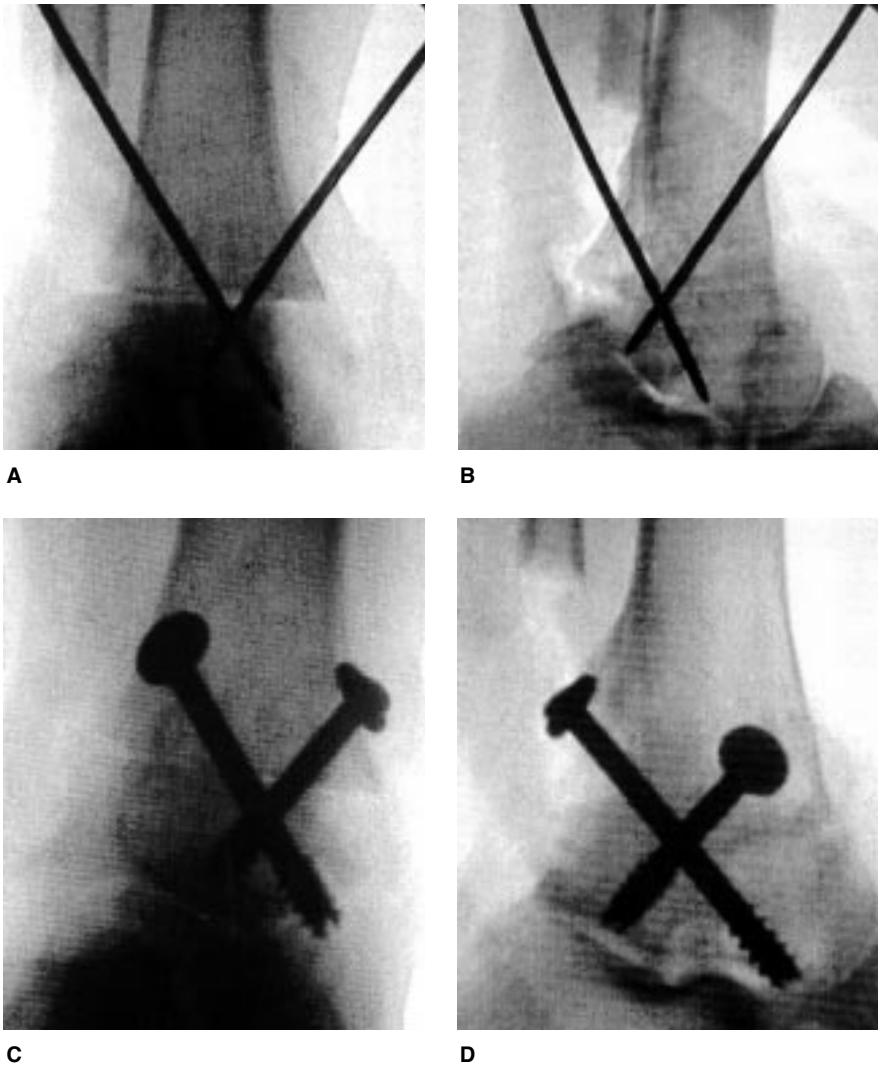


Figure 3 Anteroposterior **(A)** and lateral **(B)** images obtained during fluoroscopy of the ankle joint with guide pins in place confirm surface apposition. Anteroposterior **(C)** and lateral **(D)** views obtained after screw placement demonstrate that there is no penetration of the subtalar joint space.

A technique for tibiotalocalcaneal arthrodesis with the use of an angled blade-plate inserted through a posterior approach was reported in 1991.[29] This technique was proposed for use in patients with persistent ankle-joint nonunion. With the patient in the prone position, the Achilles tendon is osteotomized at its insertion into the calcaneus and displaced cephalad with its attached bone block (Fig. 4).

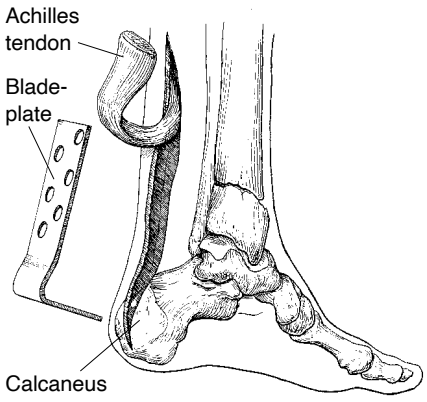


Figure 4 The posterior approach (with the patient in the prone position) for blade-plate insertion directly through the bed of the Achilles tendon for the patient with pre-existing anterior or lateral soft-tissue compromise who requires arthrodesis. (Reproduced with permission from Gruen GS, Mears DC: Arthrodesis of the ankle and subtalar joints. *Clin Orthop* 1991;268:15-20.)

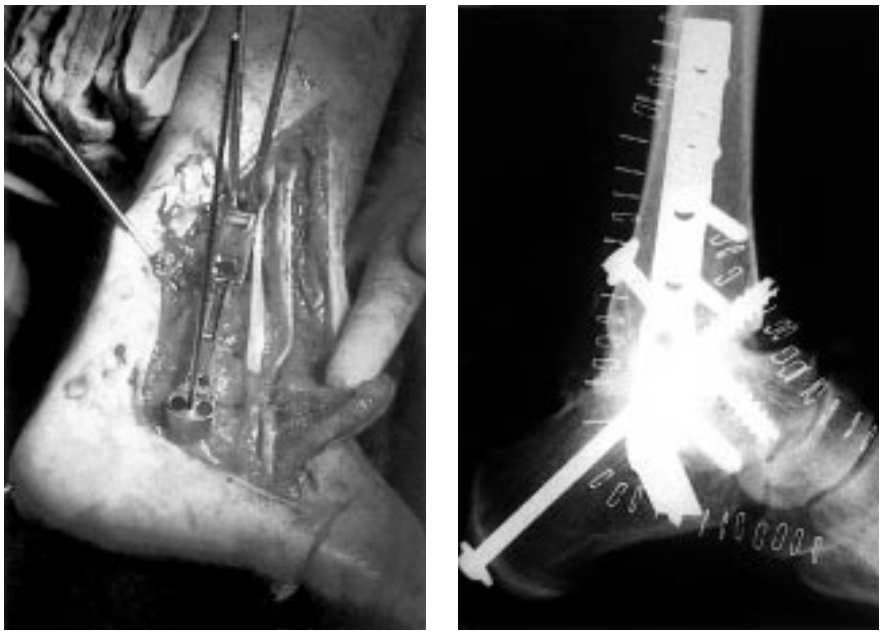
After ankle-joint exposure, articular cartilage is removed from the joint surfaces. The nonunion site is curetted until viable bone is seen. Autologous cancellous bone graft, harvested from the proximal tibial metaphysis or iliac crest, is packed into the nonunion site and the denuded joint. After proper joint alignment has been achieved, a 95-degree 50-mm five-hole blade-plate is seated into an appropriate slot prepared in the surface of the posterior calcaneus. After application of the tension device to the free end of the plate, the screws are inserted into the plate, and the Achilles tendon is reattached to the calcaneus with a 6.5-mm cancellous screw and ligamentous washer. A short windowed leg cast with a rocker bottom is applied on the third postoperative day, and touch-down gait is allowed for the next 6 to 8 weeks, progressing to weight bearing as tolerated. The total cast-immobilization time after this procedure averages 12 to 16 weeks.

The results with use of a compression arthrodesis technique for tibiocalcaneal arthrodesis in seven patients with nonbraceable neuropathic ankle joints were reported in 1994.[30] A cannulated humeral blade-plate was placed into the tibia and calcaneus through a lateral approach for rigid fixation, augmented by an external compression device and large cancellous screws (Fig. 5). The seven patients in this series progressed to solid fusion in an average of 5.2 months. All became ambulatory in a lined, molded bivalve ankle-foot arthrosis without the use of an ancillary device.

Mechanical difficulties reported with blade-plate techniques include difficulty in placing the foot and ankle in the optimal functional position and difficulty associated with accurate placement of the blade-plate into a small talus and calcaneus. The use of a retrograde intramedullary nail has been described for patients with soft-tissue compromise, failed prior arthrodesis, or diabetic neuropathy.[31,32] The drawbacks of retrograde nail fixation include the risk of neurologic and vascular injury during nail insertion (Fig. 6, A),[33] difficulty in providing compression across the arthrodesis site, placement of screws in the osteoporotic talus and calcaneus (Fig. 6, B), and stress fracture of the tibia after operation.[34]

Results

Ankle arthrodesis, which was originally a surgical treatment for tuberculosis of the ankle joint, continues to find use in patients functionally disabled by ankle-joint destruction due to a variety of causes. Several scoring systems now are available to provide standardized methods of evaluating and comparing functional results both before and after operative treatment as well as between the various techniques available for ankle arthrodesis. The American Orthopaedic Foot and



A B

Figure 5 **A,** Intraoperative lateral view of a tibiotalocalcaneal arthrodesis with placement of a 90-degree blade-plate guide and large cancellous-screw guide pins prior to blade-plate impaction. **B,** Lateral radiograph obtained after insertion of lateral blade-plate.

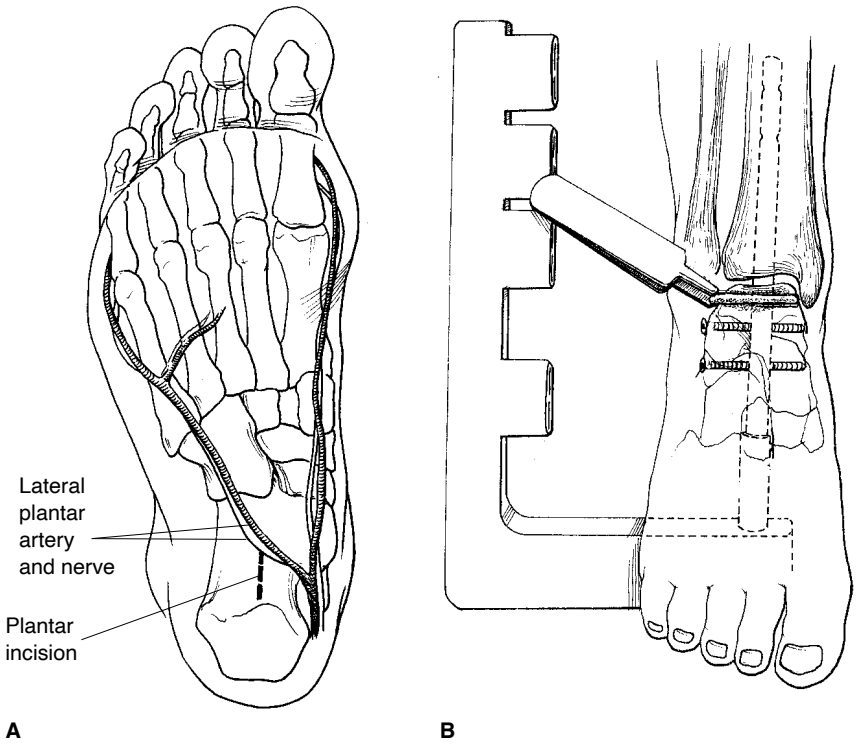


Figure 6 **A,** Plantar retrograde nail insertion site at the junction of the calcaneal body and the sustentaculum, adjacent to the lateral plantar neurovascular bundle. **B,** Retrograde nail insertion, with placement of one screw into the talus and one screw into the calcaneus, accompanied by insertion of bone graft at the tibiotalar arthrodesis site and impaction of the construct before screw placement into the tibia. (Reproduced with permission from Paul Cooper, MD, and DePuy ACE Medical Company, El Segundo, Calif.)

Ankle Society has published a 100-point scoring system for the evaluation of ankle and hindfoot pain and function (Table 1).[35] The most recent scoring system introduced for assessing patients with osteoarthritis of the ankle is the "Ankle Osteoarthritis Scale," which is based on a visual analog scale completed by the patient.[36] Unfortunately, neither has yet been used to assess the functional results in a large series of patients with ankle arthrodesis.

Prior to 1979, the results obtained with ankle arthrodesis were generally graded as good if arthrodesis was achieved or poor if nonunion resulted. In 1959 Ratliff reported retrospectively on 59 patients who had undergone compression arthrodesis of the ankle with a Charnley external fixator 1 to 9 years previously. The outcome was graded as excellent in 61% of the patients, good in 18%, fair in 19%, and poor in 2%. Six patients had a limp, and 2 had persistent pain because of unrecognized subtalar arthritis. A high rate of complications related to pin-track infections was noted in this series of patients.

An early scoring system for assessment of patient function and gait after ankle arthrodesis was published by Mazur et al[37] in 1979. This system is based on a maximum possible score of 90 points. The patients who were evaluated in that report had an average preoperative score of 40 points and an average postoperative score of 80 points, reflecting an improvement in patient function after ankle arthrodesis.

The same system was used by Scranton[12] in 1985 to evaluate internal compression in arthrodesis of the ankle. Scranton used a T plate medially for compression of the ankle arthrodesis site. His patients achieved functional improvement from an average preoperative score of 47 points to an average postoperative score of 82 points. A similar study reporting the use of an anterior tension-band plate showed an average postoperative score of only 70 points, suggesting that this technique may not be as successful as others.[7]

In 1991, Malarkey and Binski[14] reported the results in 12 patients who had undergone ankle arthrodesis with use of the Calandruccio-frame external fixator and bimalleolar onlay grafting. Eleven patients achieved a solid osseous union. Eight patients were available for evaluation; the results in 6 were rated as good or excellent, and those in the other 2 were rated as poor (1 patient with nonunion and 1 patient not rated because of underlying disease that limited ambulation).

In 1991, Myerson and Quill[18] evaluated the results obtained with arthroscopic ankle arthrodesis compared with conventional open arthrodesis performed with use of 6.5- and 7.0-mm screws. Joint fusion was achieved an average of 8.7 weeks after arthroscopic arthrodesis, compared with an average of 14.5 weeks after arthrodesis with conventional internal fixation. However, the patients who underwent arthroscopic arthrodesis had arthritic ankles with only minimal deformity, whereas those for whom the open technique was chosen had more severe deformities.

The results of arthrodesis in patients who require revision are more difficult to evaluate because of the small number of patients in reported series. In one study,[29] five patients underwent revision arthrodesis for nonunion in which an angled blade-

Table 1
American Foot and Ankle Society Clinical Ankle-Hindfoot Rating Scale*

Criterion	Points	Total Possible Points
Pain		40
None	40	
Mild, occasional	30	
Moderate, daily	20	
Severe, almost always present	0	
Function		50
Activity limitations, support requirement		
No limitations, no support	10	
No limitation of daily activities, limitation of recreational activities, no support	7	
Limited daily and recreational activities, cane use	4	
Severe limitations of daily and recreational activities; use of walker, crutches, wheelchair, brace	0	
Maximum walking distance, blocks		
Greater than 6	5	
4 to 6	4	
1 to 3	2	
Less than 1	0	
Walking surfaces		
No difficulty on any surface	5	
Some difficulty on uneven terrain, stairs, inclines, ladders	3	
Severe difficulty on uneven terrain, stairs, inclines, ladders	0	
Gait abnormality		
None, slight	8	
Obvious	4	
Marked	0	
Sagittal motion (flexion plus extension)		
Normal or mild restriction (30° or more)	8	
Moderate restriction (15° to 29°)	4	
Severe restriction (less than 15°)	0	
Hindfoot motion (inversion plus eversion)		
Normal or mild restriction (75% to 100% of normal)	6	
Moderate restriction (25% to 74% of normal)	3	
Marked restriction (less than 25% of normal)	0	
Ankle-hindfoot stability (anteroposterior, varus-valgus)		
Stable	8	
Definitely unstable	0	
Alignment		10
Good, plantigrade foot, ankle-hindfoot well aligned	10	
Fair, plantigrade foot, some degree of ankle-hindfoot malalignment observed, no symptoms	5	
Poor, nonplantigrade foot, severe malalignment, symptoms	0	
		100

* Adapted with permission from Kitaoka HB, Alexander IJ, Adelaar RS, Nunley JA, Myerson MS, Sanders M: Clinical rating systems for the ankle-hindfoot, midfoot, hallux, and lesser toes. *Foot Ankle Int* 1994;15:349-353.

plate was inserted through a posterior approach for tibiotalar, tibiotalocalcaneal, or tibiocalcaneal arthrodesis. All five progressed to solid ankle fusion after 16 weeks. On a modified Boston Children's Hospital rating scale, the average preoperative rating of the five patients was 13 points (of a possible 50 points), and the average postoperative rating was 44 points. Three patients subjectively rated their result as excellent, and two rated it good.

The use of a combined open-compression arthrodesis technique in a subsequent report dealing with nonbraceable neuropathic ankle joints resulted in solid fusion in all seven patients at an average of 5.2 months.[31] All became ambulatory in a lined, molded bivalve ankle-foot arthrosis without the use of an ancillary device.

Risk Factors for Nonunion

Ankle arthrodesis is a technically difficult surgical procedure that is frequently associated with complications. Patients being considered for ankle arthrodesis should be screened carefully for identifiable risk factors. Even in series combining an open approach with internal fixation, compression, and bone grafting, the most frequently encountered complication associated with ankle arthrodesis was nonunion.

In one study, Frey et al[38] reviewed 78 ankle arthrodeses to identify factors that might predispose patients to nonunion. Complications occurred in 44 (56%) of the 78 patients at an average follow-up interval of 4 years. These included 32 nonunions (41%), 7 infections (9%), 2 nerve injuries (3%), 2 malunions (3%), and 2 wound problems (3%). Risk factors associated with nonunion in this series included a severe fracture, an open injury, local infection, evidence of osteonecrosis of the talus, and coexisting major

medical problems. Factors not associated with nonunion included patient age, past history of undergoing a subtalar or triple arthrodesis, and the surgical arthrodesis technique selected. A prior diagnosis of a combined plafond-talus fracture led to the worst prognosis, followed by Hawkins II or III talar fractures. Large-fragment screw fixation led to higher fusion rates, possibly because less soft-tissue stripping was required for screw fixation compared with plating or possibly because these screws provide better compression at the arthrodesis site.

Nonunion after ankle arthrodesis has also been associated with smoking.[39] In patients without other risk factors, the risk of nonunion in smokers has been estimated to be 16 times the risk of nonunion in nonsmokers. The effects of nicotine on the peripheral circulation and the effects of hydrogen cyanide and carbon monoxide on the oxygen-carrying capacity of hemoglobin have been cited as possible causes of the high rate of nonunion in smokers. The period of smoking cessation prior to ankle surgery necessary to clear the toxic effects from the patient has not been established, but 1 week has been empirically suggested.[40]

A careful attempt should be made to try to learn the reason for nonunion in patients in whom revision surgery is contemplated. This should include a complete workup to rule out local infection and to attempt to identify associated risk factors that might compromise a successful outcome.

Summary

A thorough history and physical examination will help to determine which form of treatment will provide pain relief and improved function in a patient with advanced ankle arthritis. If nonoperative treatment measures fail, operative intervention should be considered. Careful examination of all lower-extremity joints, limb alignment, and the relationship of the hindfoot to the forefoot, as well as gait appraisal, should be carried out preoperatively. A plantigrade foot position can be obtained by placing the heel in 5 to 7 degrees of valgus, externally rotating the ankle by 5 to 10 degrees, and displacing the talus posteriorly. Appropriate positioning of the foot during arthrodesis helps to avoid altering the patient's gait significantly and also helps to preserve hip and knee function.

Several surgical techniques for performing ankle arthrodesis are available. External fixators are recommended for fixation in patients undergoing arthrodesis because of a preexisting septic joint or osteopenia. Arthroscopic arthrodesis or the "mini-open" arthrodesis can be considered for patients with minimal deformity. Open arthrodesis is advisable for patients with significant ankle deformity and foot and ankle malalignment. Nonunion of ankle arthrodeses can occur in up to 40% of patients. Smoking cessation, awareness and control of known risk factors such as metabolic diseases and osteonecrosis, careful preoperative planning, and meticulous operative technique all contribute to a successful outcome.

Acknowledgment: The authors would like to thank John J. Gartland, MD, for his assistance in the preparation of this manuscript.

References

1. Barr JS, Record EE: Arthrodesis of the ankle joint: Indications, operative technic and clinical experience. *N Engl J Med* 1953;248:53-56.
2. Charnley J: Compression arthrodesis of the ankle and shoulder. *J Bone Joint Surg Br* 1951;33:180-191.
3. Holt ES, Hansen ST, Mayo KA, Sangeorzan BJ: Ankle arthrodesis using internal screw fixation. *Clin Orthop* 1991;268:21-28.
4. Malarkey RF, Binski JC: Ankle arthrodesis with the Calandruccio frame and bimalleolar onlay grafting. *Clin Orthop* 1991;268:44-48.
5. Mann RA, Van Manen JW, Wapner K, Martin J: Ankle fusion. *Clin Orthop* 1991;268:49-55.
6. Morgan CD, Henke JA, Bailey RW, Kaufer H: Long-term results of tibiotalar arthrodesis. *J Bone Joint Surg Am* 1985;67:546-550.
7. Mears DC, Gordon RG, Kann SE, Kann JN: Ankle arthrodesis with an anterior tension plate. *Clin Orthop* 1991;268:70-77.
8. Myerson MS, Quill G: Ankle arthrodesis: A comparison of an arthroscopic and an open method of treatment. *Clin Orthop* 1991;268:84-95.
9. Ratliff AHC: Compression arthrodesis of the ankle. *J Bone Joint Surg Br* 1959; 41:524-534.
10. Newman A: Ankle fusion with the Hoffmann external fixation device. *Foot Ankle* 1980;1:102-109.
11. Paremain GD, Miller SD, Myerson MS: Ankle arthrodesis: Results after the miniarthrotomy technique. *Foot Ankle Int* 1996;17:247-252.
12. Scranton PE Jr: Use of internal compression in arthrodesis of the ankle. *J Bone Joint Surg Am* 1985;67:550-555.
13. Thordarson DB, Markolf KL, Cracchiolo A III: External fixation in arthrodesis of the ankle: A biomechanical study comparing a unilateral frame with a modified transfixion frame. *J Bone Joint Surg Am* 1994;76: 1541-1544.
14. Wang GJ, Shen WJ, McLaughlin RE, Stamp WG: Transfibular compression arthrodesis of the ankle joint. *Clin Orthop* 1993;289:223-227.
15. Scranton PE Jr: An overview of ankle arthrodesis. *Clin Orthop* 1991;268:96-101.
16. Scranton PE Jr, McDermott JE: Anterior tibiotalar spurs: A comparison of open versus arthroscopic debridement. *Foot Ankle* 1992;13:125-129.

17. McMurray TP: Footballer's ankle. *J Bone Joint Surg Br* 1950;32:68-69.
18. Stoller SM, Hekmat F, Kleiger B: A comparative study of the frequency of anterior impingement exostoses of the ankle in dancers and nondancers. *Foot Ankle* 1984;4:201-203.
19. Weber BG: Lengthening osteotomy of the fibula to correct a widened mortice of the ankle after fracture. *Int Orthop* 1981;4:289-293.
20. Ramsey PL, Hamilton W: Changes in tibiotalar area of contact caused by lateral talar shift. *J Bone Joint Surg Am* 1976;58:356-357.
21. Marti RK, Raaymakers EL, Nolte PA: Malunited ankle fractures: The late results of reconstruction. *J Bone Joint Surg Br* 1990;72:709-713.
22. Rosen H: Reconstructive procedures about the ankle joint, in Jahss MH (ed): *Disorders of the Foot and Ankle: Medical and Surgical Management*, 2nd ed. Philadelphia: WB Saunders, 1991, vol 3, pp 2593-2613.
23. Offierski CM, Graham JD, Hall JH, Harris WR, Schatzker JL: Late revision of fibular malunion in ankle fractures. *Clin Orthop* 1982;171:145-149.
24. Weber BG, Simpson LA: Corrective lengthening osteotomy of the fibula. *Clin Orthop* 1985;199:61-67.
25. Yablon IG, Leach RE: Reconstruction of malunited fractures of the lateral malleolus. *J Bone Joint Surg Am* 1989;71:521-527.
26. Buck P, Morrey BF, Chao EYS: The optimum position of arthrodesis of the ankle: A gait study of the knee and ankle. *J Bone Joint Surg Am* 1987;69:1052-1062.
27. Mann RA: Biomechanical approach to the treatment of foot problems. *Foot Ankle* 1982;2:205-212.
28. Mann RA, Rongstad KM: Arthrodesis of the ankle: A critical analysis. *Foot Ankle Int* 1998;19:3-9.
29. Gruen GS, Mears DC: Arthrodesis of the ankle and subtalar joints. *Clin Orthop* 1991;268:15-20.
30. Alvarez RG, Barbour TM, Perkins TD: Tibiocalcaneal arthrodesis for nonbraceable neuropathic ankle deformity. *Foot Ankle Int* 1994;15:354-359.
31. Pinzur MS, Kelikian A: Charcot ankle fusion with a retrograde locked intramedullary nail. *Foot Ankle Int* 1997;18:699-704.
32. Kile TA, Donnelly RE, Gehrke JC, Werner ME, Johnson KA: Tibiotalocalcaneal arthrodesis with an intramedullary device. *Foot Ankle Int* 1994;15:669-673.
33. Flock TJ, Ishikawa S, Hecht PJ, Wapner KL: Heel anatomy for retrograde tibiotalocalcaneal roddings: A roentgenographic and anatomic analysis. *Foot Ankle Int* 1997;18:233-235.
34. Lidor C, Ferris LR, Hall R, Alexander IJ, Nunley JA: Stress fracture of the tibia after arthrodesis of the ankle or the hindfoot. *J Bone Joint Surg Am* 1997;79:558-564.
35. Kitaoka HB, Alexander IJ, Adelaar RS, Nunley JA, Myerson MS, Sanders M: Clinical rating systems for the ankle-hindfoot, midfoot, hallux, and lesser toes. *Foot Ankle Int* 1994;15:349-353.
36. Domsic RT, Saltzman CL: Ankle Osteoarthritis Scale. *Foot Ankle Int* 1998;19:466-471.
37. Mazur JM, Schwartz E, Simon SR: Ankle arthrodesis: Long-term follow-up with gait analysis. *J Bone Joint Surg Am* 1979;61:964-975.
38. Frey C, Halikus NM, Vu-Rose T, Ebramzadeh E: A review of ankle arthrodesis: Predisposing factors to nonunion. *Foot Ankle Int* 1994;15:581-584.
39. Cobb TK, Gabrielsen TA, Campbell DC II, Wallrichs SL, Ilstrup DM: Cigarette smoking and nonunion after ankle arthrodesis. *Foot Ankle Int* 1994;15:64-67.
40. Lind J, Kramhoft M, Bodtker S: The influence of smoking on complications after primary amputations of the lower extremity. *Clin Orthop* 1991;267:211-217.