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Avoiding Complications in the Treatment of Pronation-External Rotation Ankle Fractures, Syndesmotic Injuries, and Talar Neck Fractures

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Abstract

Fractures of the foot and ankle are common injuries that often are successfully treated nonsurgically; however, some injuries require surgical intervention. To restore anatomy and avoid the need for additional surgery, surgeons must pay attention to detail and understand common, avoidable complications. The surgeon should have an understanding of the pathologic characteristics of three common injuries of the foot and ankle as well as the potential complications and their prevention.

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Almost 2% of the general population will sustain an ankle fracture during their lifetime.[1] These fractures are so common that their treatment seems routine, leading to a certain disregard for their seriousness and potential complications. In an effort to provide guidelines for treatment, investigators have developed classification schemes such as the Lauge-Hansen system,[2] a two-part system based on the mechanism of injury. In this scheme, the first word denotes the position of the foot at the time of injury and the second, the direction of the deforming force. There are four basic injury patterns in this system: supination-external rotation, seen in 40% to 75% of cases; supination-adduction, seen in 10% to 20%; pronation-abduction, seen in 5% to 21%; and pronation-external rotation, seen in 7% to 19%.

Pronation-External Rotation Ankle Fractures

Introduction and Pathologic Findings

The pronation-external rotation pattern, one of the least common injuries but arguably the one most likely to be treated poorly, occurs when an external rotation force is applied to a pronated foot. The injury begins medially and, depending on the amount of force exerted on the ankle, progresses toward the fibula and the tibiofibular ligaments. There are four described stages. Initially, stage 1 produces a rupture of the deltoid ligament or an avulsion of the medial malleolus. A disruption of the anterior-inferior tibiofibular ligament occurs in stage 2, and a diaphyseal fracture of the fibula occurs in stage 3. Stage 3 is identified on the basis of the pathognomonic fibular fracture patterns, described as a spiral or oblique fracture occurring

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Figure 1 AP radiograph of a pronation-external rotation injury. Note the diaphyseal fibular fracture, the medial malleolar fracture, and widening of the syndesmosis.

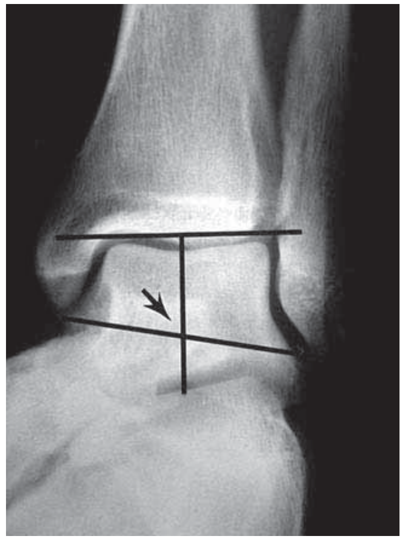

Figure 2 The talocrural angle (arrow) is determined by drawing a line perpendicular to the plafond, which intersects a line connecting the tips of the malleoli.

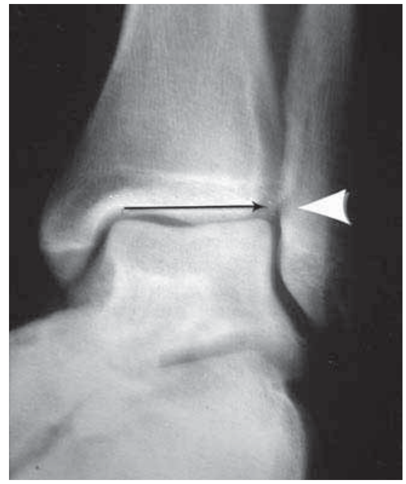

Figure 3 The Shenton line is drawn from the Wagstaffe tubercle (*white arrowhead*) on the fibula toward the medial malleolus. If the fibula is of adequate anatomic length, the line should pass through the tibial plafond (*black arrow*).

proximal to the plafond and continuing from anterior-proximal to posterior-distal. Continued force leads to stage 4, which is a failure of the posterior-inferior tibiofibular ligament or a fracture of the posterior malleolus.

The importance of this supra-articular fibular fracture is the potential for failure of the entire ligamentous connection between the tibia and fibula. In such a situation, radiographs frequently demonstrate, in addition to the fractures of the medial malleolus and the fibula, a diastasis or dislocation of the syndesmosis (Figure 1). Because as little as 1 mm of lateral talar displacement can decrease the contact area of the ankle joint by more than 40%, it is important to restore normal anatomy.[3,4] A combination of lateral talar displacement with persistent external rotation and fibular shortening ultimately contributes to early degenerative arthritis of the ankle.[5] Obtaining an anatomic reduction of the ankle with nonsurgical techniques is difficult. To avoid these complications, open surgical reduction and fixation usually are required. The key to obtaining an anatomic reduction of the mortise is to first obtain an adequate reduction of the lateral malleolus,[6,7] then obtain a reduction of the medial malleolus, and finally repair any remaining osseous and soft-tissue injuries.

Radiographic Evaluation

Routine radiographic studies of the ankle, consisting of AP, mortise, and lateral plain radiographs, are the mainstay of imaging of ankle injuries. A critical analysis of these three plain radiographs should identify any shortening of the fibula, widening of the joint space, or malrotation of the fibula. A persistently widened medial clear space seen on radiographs often is an indication that fibular length has not been adequately restored. Three measurements are used to ascertain whether the correct fibular length has been restored: the talocrural angle,[8] the tibiofibular (or Shenton) line,[9] and the circle sign.[10] The talocrural angle is created by a line drawn perpendicular to the tibial plafond intersecting a line drawn from the tips of the medial and lateral malleoli; the normal angle ranges from 79° to 87° (Figure 2). The tibiofibular line, which should intersect the distal (Wagstaffe) tubercle of the fibula, is drawn parallel to and through the subchondral bone of the tibial plafond (Figure 3). The circle sign is an unbroken curve between the lateral process of the talus and the recess in the distal tip of the lateral malleolus (Figure 4). Radiographs to evaluate syndesmotic widening are discussed in the next section.

Factors Producing Malreduction of Pronation-External Rotation Injuries

Three of the most common causes of persistent malreduction of pronation-

Figure 4 The circle sign is seen on the mortise radiograph and should be an unbroken curve connecting the recess in the distal tip of the fibula and the lateral process of the talus when the fibula is of adequate anatomic length.

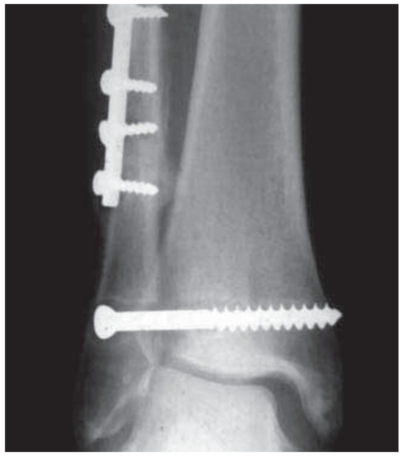

Figure 5 Radiograph of an inadequately reduced pronation-external rotation injury, demonstrating a shortened fibula with widening of the medial clear space. A syndesmotic screw was added in an attempt to "squeeze" the tibia and fibula together to reduce the mortise, which cannot be done until fibular length has been restored.

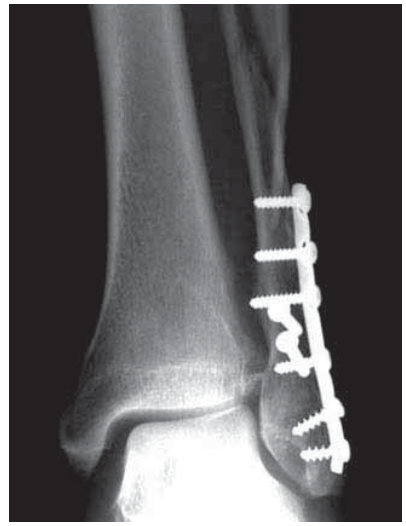

Figure 6 Postoperative radiograph demonstrating malreduction of the ankle mortise. The implant is too short and should be revised so that the fixation extends past the proximal fragments of the fibula.

external rotation injuries are inadequate restoration of fibular length, persistent external rotation of the fibula, and inadequate fixation of the fibula.

A widened medial clear space usually indicates continuing lateral talar subluxation. This often is due to a shortened fibula. To correct the lateral talar shift, the talus needs to be "pushed" toward the medial malleolus. This is achieved by lengthening the fibula. The most common mistake when trying to reduce the size of the medial clear space is to "squeeze" the tibia and fibula together with bone clamps or syndesmotic screws (Figure 5). This maneuver does not reduce the mortise, and a widened medial clear space persists. The anatomic length of the fibula needs to be restored with a distraction technique. When adequate fibular length is achieved, the mortise will be reduced, and the widening of the medial clear space will disappear.

Once adequate fibular length has been achieved, it is important to identify any persistent malrotation of the fibula. To correct malrotation, it is important to remember that the articular surface of the fibula articulates with the lateral border of the talus.[11] If there is any question regarding rotation, the dissection should be extended distally to expose the lateral malleolus and ensure that it articulates with the talus. Once proper length and rotation are verified, definitive fixation of the fibula can be applied.

The third common mistake is inadequate fixation. This is a mechanical problem caused by a plate that is either too short to provide adequate fixation or too malleable to hold the reduction of the fibula. Both situations can result in failure of the fixation (Figure 6). The fracture forces with this injury are unlike those seen with the more common supination-external rotation fracture. The fibular fracture of the pronation-external rotation injury is in the hard diaphyseal bone rather than the soft metaphyseal region, and the associated ligamentous injuries prevent neutralization of the forces across the fracture with a short malleable plate. The solution is the use of longer, stouter 3.5-mm plates (LCP Metaphyseal Plate; Synthes, Paoli, PA). The attraction of these plates is that they are available in lengths of up to 242 mm, allowing at least three screws to be placed proximal to the fracture; have a lower profile so they can be better contoured to the distal metaphyseal bone; and provide a sturdier proximal portion to stabilize the diaphyseal injury.

Syndesmotic Injuries of the Ankle

Introduction and Pathologic Findings

The syndesmosis complex is made up of an osseous component—the

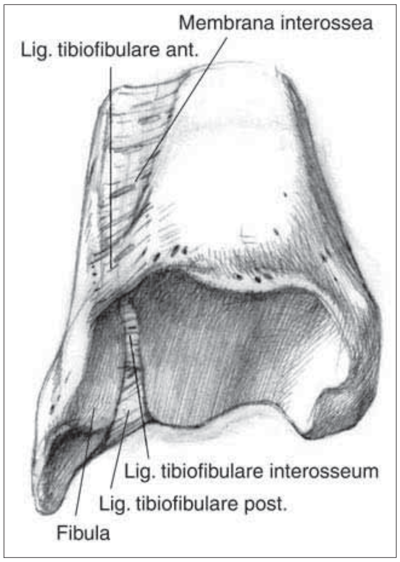

Figure 7 Drawing depicting the components of the syndesmotic complex. (Reproduced with permission from Grass R, Zwipp H: Syndesmosenplastik bei chronischer Insuffizienz des distalen tibiofibularen Syndesmosenkomplexes. *Operat Orthop Traumatol* 2003;15:208-225.)

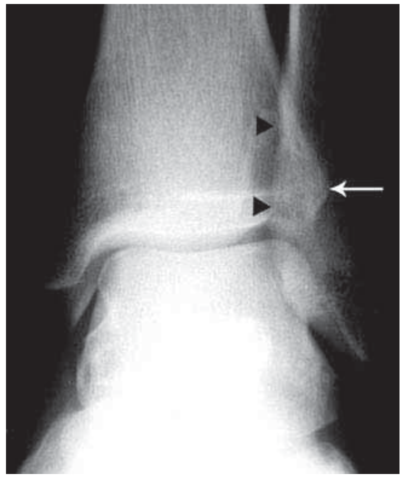

Figure 8 On an AP radiograph, tibiofibular overlap should be measured from the medial edge of the fibula (arrowheads) to the lateral border of the tibia (arrow), and it should exceed 6 mm.

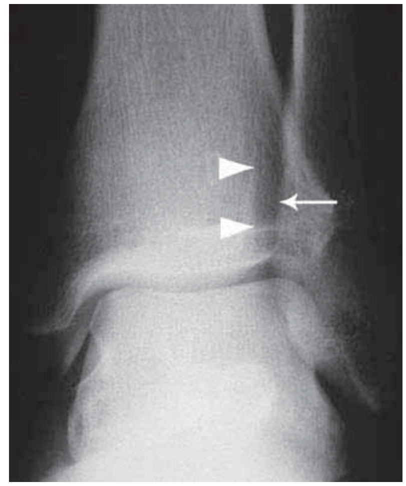

Figure 9 The tibiofibular clear space should be measured on the AP radiograph from the medial border of the fibula (arrow) to the lateral border of the tibial incisura (arrowheads).

fibular shaft (the lateral malleolus articulating with the recessed area of the tibia [the tibial incisura])—and four soft-tissue restraints, consisting of the anterior-inferior tibiofibular ligament, the posterior tibiofibular ligament, the interosseous ligament, and the interosseous membrane (Figure 7). These four ligaments stabilize the syndesmosis by preventing lateral displacement of the fibula. The anterior tibiofibular ligament provides 35% of the syndesmotic strength; the posterior ligament, 40%; and the interosseous ligament, 22%.[12] When the syndesmosis is disrupted, it alters the normal gliding and rotational motion between the talar dome and the distal part of the tibia. In a study quantifying the amount of diastasis produced by sectioning of these ligaments, a complete disruption of all four ligaments produced an average of 7.3 mm of tibiofibular diastasis.[12] When the soft-tissue restraints were individually divided, a loss of the anterior tibiofibular ligament produced 2.3 mm of diastasis, a loss of the posterior tibiofibular ligament produced 2.8 mm, and every 2 cm of sectioned interosseous ligament produced an additional 0.5 mm of diastasis.[12]

Radiographic Evaluation

Plain radiographs are used as the initial means of screening for a syndesmotic injury. The radiographs are either static or dynamic studies. Static radiographs are made without any stress applied to the ankle, whereas dynamic radiographs are made with an applied stress. Three measurements used to evaluate the syndesmosis are the tibiofibular overlap, the tibiofibular clear space, and the medial clear space.[13-15] Tibiofibular overlap is best measured 1 cm proximal to the joint on an AP radiograph. There should be more than 6 mm of overlap between the medial border of the fibula and the lateral border of the tibia (the anterior tubercle of the incisura; Figure 8). The tibiofibular clear space is one of the most sensitive indicators of syndesmotic injuries and is measured on the AP view. At 1 cm proximal to the ankle joint, widening is demonstrated by a distance of more than 6 mm between the medial border of the fibula and the medial cortical density of the tibia (the posterior tubercle of the incisura; Figure 9). Finally, the medial clear space should measure less than 4 mm; however, to detect subtle changes, this measurement may need to be compared with that in the contralateral extremity. If, after the performance of these studies, there is still a question about whether there is a syndesmotic injury, comparison radiographs of the contralateral extremity or CT can help to detect a subtle diastasis.

The two dynamic evaluations used to evaluate the integrity of the syndesmosis are the Cotton test and the modified Cotton test.[16,17] The

Cotton test, which has been attributed to F.J. Cotton, often is performed intraoperatively. It is done by grasping the distal part of the fibula and pulling it laterally. When the syndesmosis is compromised, the syndesmosis or the mortise or both are widened. The modified Cotton test also is intraoperatively done by obtaining a lateral radiograph of the ankle while pushing or pulling the fibula in the sagittal plane. Again, evaluation of the contralateral extremity may be necessary to identify subtle differences. Because the fibula often displaces posteriorly and laterally, the modified Cotton test may be more valuable than the Cotton test, but both should be done.

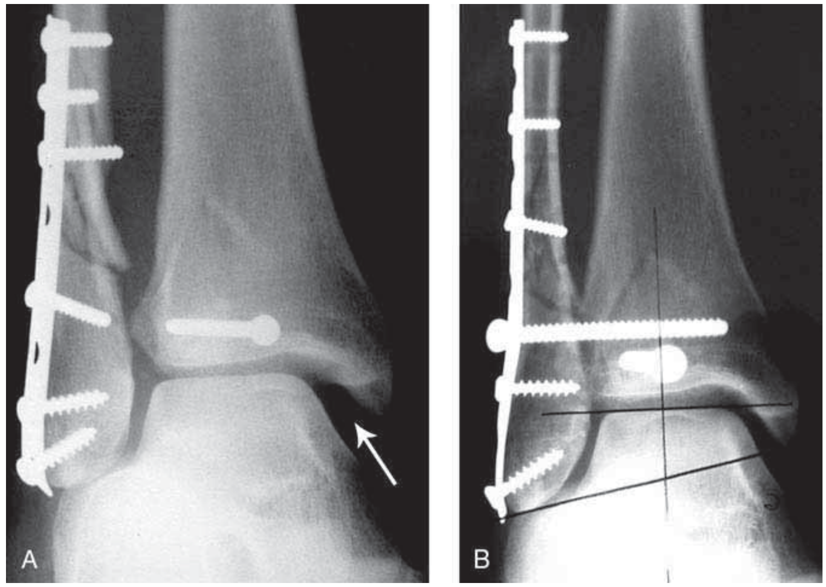

Figure 10 **A,** Mortise radiograph demonstrating malreduction of the ankle. The fibula is shortened, producing widening of the medial clear space (*arrow*) and widening of the syndesmosis. **B,** Following revision of the fixation, the fibula is now of adequate anatomic length. Use of a longer plate resulted in a reduction of the mortise and syndesmosis.

Factors Producing Malreduction of the Syndesmosis

Three common reasons why the syndesmosis cannot be anatomically reduced are malreduction of one or both malleoli, osseous or soft-tissue interposition, and malreduction of the fibula within the tibial incisura.

Malreduction of the malleoli will affect the syndesmosis, especially if substantial external rotation and shortening of the fibula remain (Figure 10). This occurs more often in association with comminuted fractures of the fibula because correct alignment of the fibula is difficult to achieve. Persistent external rotation does not allow the fibula to lie within the boundaries of the incisura. It is a mistake to accept a malreduction just because it is within the "acceptable" range for treatment of these injuries. Such malrotation ultimately affects the rotation and gliding motion of the ankle. The solution is to revise the fixation of the fibula to correct both malrotation and shortening.

Both osseous or soft-tissue interposition and malreduction of the fibula within the incisura are strictly mechanical issues. After fixation of the malleoli, dynamic and static radiographs often demonstrate persistent widening of the syndesmosis. As is the case with pronation-external rotation injuries, the mistake is trying to "squeeze" the tibia and fibula together with a bone clamp. Too often, a closed reduction is done, and the tibiofibular relationship is deemed adequate on the basis of intraoperative static radiographs, even when the reduction is not anatomic. This is often a result of an inadequate radiographic assessment of the syndesmosis. When a closed manipulation does not produce an anatomic reduction, the solution is open reduction of the syndesmosis (Figure 11). The approach uses the fibular incision, with the dissection directed anterior to the fibula and onto the tibia. A lamina spreader can be used to separate the tibia and fibula and allow removal of debris from the incisura. The incisura should be carefully examined to confirm that all blocks to reduction have been removed, allowing reduction of the fibula into its correct anatomic position. When this is confirmed radiographically, the fibula is securely fixed to the tibia.

Fractures of the Talar Neck

Introduction and Pathologic Findings

The talus contributes to the motion of the subtalar, tibiotalar, and transverse tarsal joints and plays a major role in the entire function of the foot and ankle. Approximately 50% of all talar fractures occur through the neck, the portion of the talus that is weakest and has the smallest cross-sectional area. These fractures are produced by hyperdorsiflexion of the foot, an axial load on the plantar surface of the fixed talus, or a direct blow.[18] The most common clas-


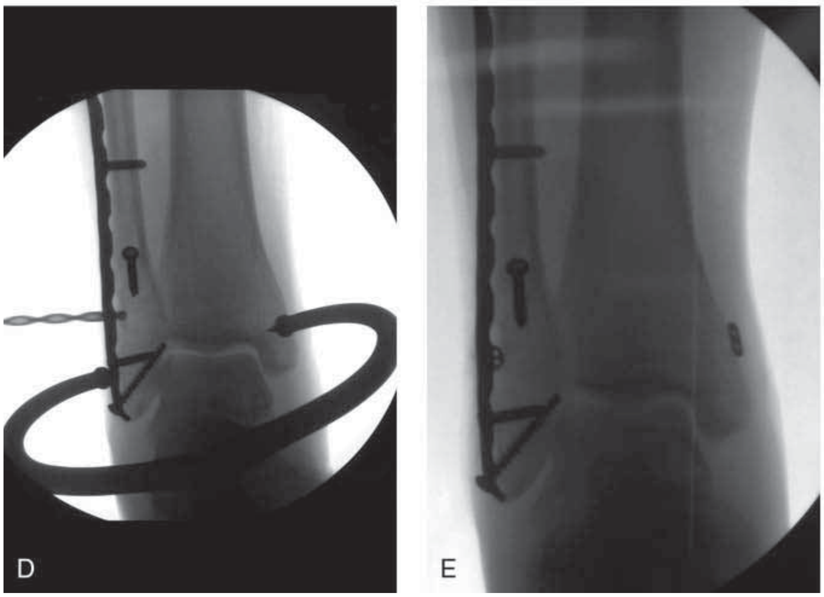

Figure 11 **A,** Intraoperative radiograph demonstrating some persistent widening of the syndesmosis after fixation of the fibula. **B,** Intraoperative photograph demonstrating how the syndesmosis is approached by dissecting anterior to the fibula. **C,** When the syndesmosis has been identified, a lamina spreader is placed between the tibia and fibula to facilitate removal of any loose osseous or soft-tissue structures within the incisura. **D,** Once the loose fragments have been removed, a bone clamp is used to reduce the fibula back into the incisura. An attempt should be made to place the bone clamp along the intermalleolar line and parallel to the line of syndesmosis fixation. **E,** The reduction is completed with suture (TightRope, Arthrex, Naples, FL) fixation. The radiograph demonstrates reduction of the syndesmosis.

sification system for fractures of the talar neck is that of Hawkins,[19] who described four distinct fracture patterns. The type I pattern is a nondisplaced fracture. Type II is a displaced fracture with a dislocation or subluxation of the subtalar joint. Type III is a fracture in which the talar body is displaced from both the subtalar and the tibiotalar joint. Type IV, originally described by Canale, is a fracture associated with subluxation or dislocation of the talonavicular joint.[20]

The problems associated with fractures of the neck of the talus are necrosis of the talar body, posttraumatic arthritis, and malunions and nonunions, resulting in the loss of ankle and subtalar motion. The causes of these complications are an interruption of the blood supply to the talar body, direct chondral damage produced at the time of the injury, malalignment of the fracture, excessive motion at the fracture site, and prolonged immobilization of the injured foot and ankle. As a general rule, as the severity of the injury increases, so do the complication rates. However, the two complications over which surgeons have the least control are necrosis of the bone and the development of posttraumatic arthritis. Current studies[21] have demonstrated that historical rates of necrosis are inaccurate. The incidence of posttraumatic arthritis is higher than that of osteonecrosis, and the timing of fixation does not seem to affect either of these two complications. However, even when an anatomic reduction has been achieved, osteonecrosis is still seen with 40% of type II fractures and 40% to 65% of type III fractures.[21]

Malunions and nonunions are usually caused by surgeon error. Although union rates are between 88% and 94%,[21] most malreductions occur as a result of inadequate reduction or insufficient methods of fixation. Malunion often produces varus malalignment of the hindfoot and shortening and deformity of the medial column (adduction of the midfoot and forefoot), with or without a cavus foot deformity. This deformity limits motion of the subtalar joint and decreases ankle dorsiflexion.[22,23]

Radiographic Evaluation

Plain AP, oblique, and lateral radiographs of the ankle and foot are used to identify fractures and displacement of the talar neck. In addition, the Canale view provides a direct AP view of the talar neck (Figure 12). This radiograph is made by placing the ankle into equinus and rotating the foot into 15° of pronation while the x-ray tube is angled 75° from the horizontal plane.[20] CT scans can also be extremely helpful for assessing comminution and displacement of the fracture as well as providing images of the ankle, subtalar, and transverse tarsal joints.

Factors Producing Malreduction of the Talar Neck

Four common reasons for malreduction of talar neck fractures are poor visualization of the fracture during reduction, medial compression of comminuted fractures, inadequate fixation, and early weight bearing by the patient.

Inadequate visualization of the fracture is an avoidable surgical error. Using percutaneous screws to stabilize the fracture because some or all of the displacement appears to have been corrected with a closed reduction technique is an error that should be avoided (Figure 13). Too often, there is residual malreduction that has not been corrected with the closed reduction and is not fully appreciated on fluoroscopic images. Inadequate preoperative planning (usually because preoperative CT scans were not ordered or were inadequately reviewed) or acceptance of "very little step-off" will result in a less-than-anatomic reduction of the fracture. The solution is an open reduction, with a two-incision approach, to verify an anatomic reduction of both the neck and the subtalar joint.[24] This two-incision approach consists of a medial incision that begins at the anterior border of the medial malleolus and extends toward the navicular tuberosity, just dorsal to the posterior tibial tendon, and an anterolateral incision that begins at the Chaput tubercle on the tibia and extends toward the bases of the third and fourth metatarsals.[25]

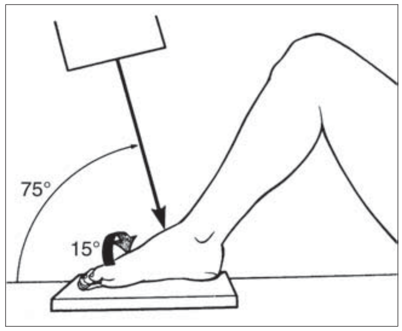

Figure 12 The position of the foot and the angle of the x-ray beam needed to produce a Canale radiograph of the talus. (Reproduced with permission from Heckman JD: Fractures of the talus, in Bucholz RW, Heckman JD (eds): *Rockwood and Green's Fractures in Adults*, ed 5. Philadelphia, PA, Lippincott Williams & Wilkins, 2001, vol 2, p 2097.)

Figure 13 Percutaneous fixation resulting in malreduction of a talar fracture.

Another cause of malreduction is medial compression of a comminuted fracture. Comminution of the talar neck makes it difficult to judge the proper length of the neck, especially the medial column. Although descriptions of standard techniques include a recommendation for the use of a lag screw, this compresses the medial side of the neck, leading to a malreduction. The solutions are to obtain adequate visualization, use a bone graft when there is loss of bone, use a transfixion (noncompression) screw technique to avoid compression, and consider adding a small plate and screw fixation to prevent medial collapse[26] (Figure 14).

Weight bearing before the fracture is healed and inadequate fixation are two of the prime reasons for failures. Often, a closed reduction improves the alignment of the fragments. The surgeon then wants to "hold" this position by stabilizing the fracture with pins. The mistake is that pins alone cannot maintain an adequate reduction of the fracture. This type of fixation allows gaps and motion to persist, increasing the risk of nonunion and osteonecrosis (Figure 15). The solution, after a formal open reduction technique, is to use screw and screw-plate combinations to maintain the reduction until healing has occurred.

Postoperative Care

Early weight bearing is avoided following all three of these injuries by applying a short leg, non–weight-bearing cast, which is worn until the sutures are removed (at 2 to 3 weeks). The patient then wears a cam-walker boot, begins range-of-motion and strengthening exercises, and maintains no weight bearing for the first 3 months after surgery.

Figure 14 **A,** Lateral radiograph of a comminuted fracture of the talar neck. Compression of this fracture will result in malreduction of the hindfoot. **B,** Postoperative radiographs demonstrating the use of a transfixion screw technique augmented with a small plate to maintain the correct length of the talus.

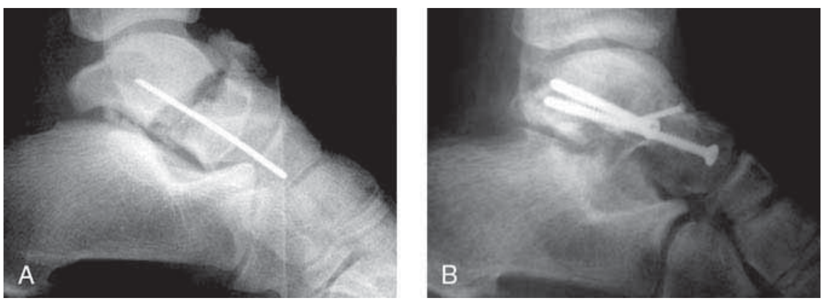

Figure 15 **A,** Radiograph made after pin fixation of a talar neck fracture, demonstrating shortening and angular malalignment of the neck. **B**, Revision with the use of screw fixation allowed the length of the talus to be restored.

Summary

Pronation-external rotation ankle fractures, syndesmotic injuries, and talar neck fractures are common conditions seen by most orthopaedic surgeons. Adequate preoperative evaluations, sufficient visualization of the pathological characteristics, and good surgical techniques should decrease the rates of complications associated with the management of these injuries.

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