Talus Fractures: Evaluation and Treatment

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Abstract

Fractures of the talus are uncommon. The relative infrequency of these injuries in part accounts for the lack of useful and objective data to guide treatment. The integrity of the talus is critical to normal function of the ankle, subtalar, and transverse tarsal joints. Injuries to the head, neck, or body of the talus can interfere with normal coupled motion of these joints and result in permanent pain, loss of motion, and deformity. Outcomes vary widely and are related to the degree of initial fracture displacement. Nondisplaced fractures have a favorable outcome in most cases. Failure to recognize fracture displacement (even when minimal) can lead to undertreatment and poor outcomes. The accuracy of closed reduction of displaced talar neck fractures can be very difficult to assess. Operative treatment should, therefore, be considered for all displaced fractures. Osteonecrosis and malunion are common complications, and prompt and accurate reduction minimizes their incidence and severity. The use of titanium screws for fixation permits magnetic resonance imaging, which may allow earlier assessment of osteonecrosis; however, further investigation is necessary to determine the clinical utility of this information. Unrecognized medial talar neck comminution can lead to varus malunion and a supination deformity with decreased range of motion of the subtalar joint. Combined anteromedial and anterolateral exposure of talar neck fractures can help ensure anatomic reduction. Posttraumatic hindfoot arthrosis has been reported to occur in more than 90% of patients with displaced talus fractures. Salvage can be difficult and often necessitates extended arthrodesis procedures.

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Major fractures and dislocations of the talus and peritalar joints are uncommon. However, fractures of the talus rank second in frequency (after calcaneal fractures) of all tarsal bone injuries. The incidence of fractures of the talus ranges from 0.1% to 0.85% of all fractures.[1]

Talus fractures most commonly occur when a person falls from a height or sustains some other type of forced dorsiflexion injury to the foot or ankle. The anatomic configuration of the injury is important because of both the function of the talus and its relationship to the tenuous blood supply. The classification of these fractures is based on their anatomic location within the talus (i.e., head, body, or neck). Each type has unique features that affect both diagnosis and treatment.

Anatomy

The talus is the second largest tarsal bone, with more than one half of its surface covered by articular cartilage. The superior aspect of the body is widest anteriorly and therefore fits more securely within the ankle mortise when it is in dorsiflexion. The articular medial wall is straight, while the lateral articular wall curves posteriorly, such that they meet at the posterior tubercle. The neck of the talus is oriented medially approximately 10 to 44 degrees with reference to the axis of the body of the talus and is the most vulnerable area of the bone after injury. In the sagittal plane, the neck deviates plantarward between 5 and 50 degrees.

The talus has no muscle or tendinous attachments and is supported solely by the joint capsules, ligaments, and synovial tissues. Ligaments that provide stability and allow motion bind the talus to the tibia, fibula, calcaneus, and navicular. The tendon of the flexor hallucis longus lies within a groove on the posterior talar tubercle and is held by a retinacular ligament. The spring (calcaneonavicular) ligament lies inferior to the talar head and acts like a sling to suspend the head.

Inferiorly, the posterior, middle, and anterior facets correspond to the articular facets of the calcaneus. Between the posterior and middle

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facets is a transverse groove, which, with a similar groove on the dorsum of the calcaneus, forms the dorsal canal that exits laterally into a cone-shaped space, the tarsal sinus. The tarsal canal is located just below and behind the tip of the medial malleolus. These two anatomic regions form a funnel: the tarsal sinus is the cone, and the tarsal canal is the tube. Because blood vessels reach the talus through the surrounding soft tissues, injury resulting in capsular disruption may be complicated by vascular compromise of the talus.

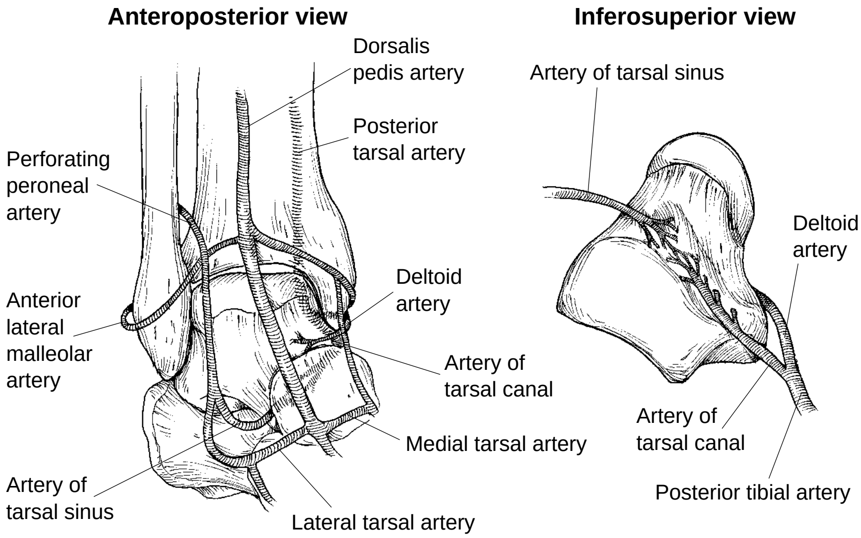


Figure 1 Blood supply to the talus.

Blood Supply

Wildenauer was the first to correctly describe in detail the blood supply to the talus. His findings were confirmed by Haliburton et al[2] through gross dissection and microscopic studies on cadaver limbs. In 1970, Mulfinger and Trueta[3] provided the most complete description of the intraosseous and extraosseous arterial circulation.

Only two fifths of the talus can be perforated by vessels; the other three fifths is covered by cartilage. The extraosseous blood supply of the talus comes from three main arteries and their branches (Fig. 1). These arteries, in order of significance, are the posterior tibial, the anterior tibial, and the perforating peroneal arteries. In addition, the artery of the tarsal canal (a branch of the posterior tibial artery) and the artery of the tarsal sinus (a branch of the perforating peroneal artery) are two discrete vessels that form an anastomotic sling inferior to the talus from which branches arise and enter the talar neck area.

The main supply to the talus is through the artery of the tarsal canal, which gives off an additional branch that penetrates the deltoid ligament and supplies the medial talar wall. The main artery gives branches to the inferior talar neck, thereby supplying most of the talar body. Therefore, most of the talar body is supplied by branches of the artery of the tarsal canal. The head and neck are supplied by the dorsalis pedis artery and the artery of the tarsal sinus. The posterior part of the talus is supplied by branches of the posterior tibial artery via calcaneal branches that enter through the posterior tubercle.

Extensive intraosseous anastomoses are present throughout the talus and are responsible for the survival of the talus in severe injuries. Preservation of at least one of the three major extraosseous sources can potentially allow adequate circulation via anastomotic channels. Initial fracture displacement, timing of reduction, and soft-tissue handling at the time of surgery are all factors that can potentially affect the integrity of the talar blood supply.

Fractures of the Talar Head

Fractures of the talar head are rare and often difficult to visualize on routine radiographs. It is not uncommon, therefore, for fractures of the talar head to go unrecognized. Coltart,[4] in his review of 228 talar injuries, reported only a 5% incidence of talar head fracture. Most of these injuries were secondary to flying accidents. Kenwright and Taylor[5] reviewed 58 talar injuries and found a 3% incidence of talar head injury, whereas Pennal[6] reported a 10% incidence among all fracture-dislocations involving the talus.

According to Coltart,[4] the mechanism of injury consists of the application of a sudden dorsiflexion force on a fully plantar-flexed foot, which thereby imparts a compressive force through the talar head. Another mechanism is thought to be hyperdorsiflexion, resulting in compression of the talar head against the anterior tibial edge. Impaction fractures of the talar head can also occur in association with subtalar dislocations. Patients usually give a history of a fall and complain of pain in the talonavicular joint region. Swelling and ecchymosis may be present, along with pain on palpation of the talonavicular joint. Depending on the size and degree of displacement of the fracture fragment, routine radiographs may not identify the fracture; therefore, computed tomography (CT) may be needed to define the extent of the injury.

Initial treatment of nondisplaced fractures and those involving a very small amount of articular surface includes immobilization in a short leg cast for 6 weeks, as well as rest, ice, and elevation. If the fragment causes instability of the talonavicular joint or is displaced, causing articular incongruency, open reduction and internal fixation should be considered. Typically, a medial approach to the talonavicular joint is used, carefully avoiding the posterior tibial tendinous attachment to the navicular. Dissection must also proceed cautiously over the anterior aspect of the talar head to avoid disruption of the blood supply to the head. Small-fragment subchondral cancellous lag screws or bioabsorbable pins can be utilized to fix the head fracture. With more severe impaction injuries, bone grafting is occasionally necessary to maintain the articular reduction.

Postoperatively, weight bearing is not allowed for 6 to 8 weeks. Early range-of-motion exercises can be initiated if the fixation is stable and the patient is reliable. Rapid healing usually ensues with a low incidence of osteonecrosis because of the abundant blood supply to the talar head. The prognosis is good as long as severe comminution is not present and anatomic reduction is obtained.

Not uncommonly, these injuries go unrecognized, which leads to loss of medial-column support and talonavicular joint instability. Small nonunited head fragments that are symptomatic and cause limitation of joint range of motion can be excised. Nonunions involving a larger portion of the articular surface should be treated on the basis of the overall integrity of the joint surface. Severe posttraumatic arthrosis may necessitate talonavicular joint arthrodesis. Due to the coupled motion of the hindfoot joints, fusion of the talonavicular joint essentially eliminates motion at the subtalar and calcaneocuboid joints and should be considered a salvage procedure.

Fractures of the Talar Neck

Talar neck fractures account for approximately 50% of all talar fractures. In 1919, Anderson reported 18 cases of fracture-dislocation of the talus and coined the term "aviator's astragalus." He was the first to emphasize that forced dorsiflexion of the foot was the predominant mechanism of injury.

Fractures occur when the narrow neck of the talus, with its less dense trabecular bone, strikes the stronger anterior tibial crest. As forces progress, disruption occurs through the interosseous talocalcaneal ligament and the ligamentous complex of the posterior ankle and subtalar joints, leading to eventual subluxation or dislocation of the body from the subtalar and tibiotalar articulations (Fig. 2). With forced supination of the hindfoot, the neck can encounter the medial malleolus, leading to medial neck comminution and rotatory displacement of the head.

In the laboratory, it is difficult to produce talar neck fractures with forced dorsiflexion alone. Peterson et al[7] experimentally produced these fractures only after eliminating ankle

A B C

Figure 2 **A,** Preoperative lateral radiograph shows a displaced fracture of the talar neck. **B,** Canale view demonstrates anteromedial and anterolateral lag-screw placement. **C,** Postoperative lateral radiograph shows reduction of the talar neck and subtalar joint.

joint motion by vertical compression through the calcaneus, forcing the talus against the anterior tibia. They felt that these forces could be reproduced in an extended leg if the triceps surae was contracted.

In a study by Hawkins,[8] 15 of 57 patients (26%) had associated fractures of the medial malleolus. Canale and Kelly[9] found that 11 of 71 patients (15%) with fractures of the talar neck had associated fractures of the medial and lateral malleoli (10 and 1, respectively). This level of incidence of malleolar fractures supports the concept that in addition to dorsiflexion, rotational forces contribute to displacement of a talar neck fracture.

Displaced talar neck fractures often occur as a result of high-energy injuries. Hawkins[8] reported that 64% of patients had other fractures, and 21% had open fractures.

Classification

Hawkins,[8] in his classic paper, described a classification system that could be correlated with prognosis. He classified fractures into groups I to III. In 1978, Canale and Kelly[9] reported on the long-term results in their series of talus fractures. They referred to the three different Hawkins groups as "types" and included a type IV not previously described. The terms "group" and "type" have since been used interchangeably in the literature.[10] The classification for fractures of the neck of the talus is based on the radiographic appearance at the time of injury (Fig. 3).

Type I fractures of the neck of the talus are nondisplaced. Any displacement is significant and precludes classification as a type I fracture. The fracture line enters the subtalar joint between the middle and posterior facets. The talus remains anatomically positioned within the ankle and subtalar joints. Theoretically, only one of the three major blood supply sources is disrupted—the one entering through the anterolateral portion of the neck. True type I fractures may be difficult to see on conventional radiographs, and CT or magnetic resonance (MR) imaging may be necessary for confirmation. Fractures with clear displacement of even 1 to 2 mm should be considered type II fractures rather than type I.

Type II fractures combine a fracture of the talar neck with subluxation or dislocation of the subtalar joint. In 10 of the 24 cases reported by Hawkins,[8] the posterior facet of the body of the talus was dislocated posteriorly; in most of the remaining cases there was a medial subtalar joint dislocation, with the foot and calcaneus displaced medially. Two of the main sources of blood supply to the talus are injured—the vessels entering the neck and proceeding proximally to the body and the vessels entering the foramina in the sinus tarsi and tarsal canal. The third source of blood supply, entering through the foramina on the medial surface of the body, is usually spared, but can be injured.

Type III injuries are characterized by a fracture of the neck with displacement of the body of the talus from the subtalar and ankle joints. Hawkins[8] identified 27 of these fractures and found that the body of the talus extruded posteriorly and medially and was located between the posterior surface of the tibia and the Achilles tendon, where it can compress adjacent tibial neurovascular structures. The body of the talus may rotate within the ankle mortise; however, the head of the talus remains aligned with the navicular. All three sources of blood supply to the talus are usually disrupted with this injury. Over half of type III injuries are open, and many have associated neurovascular and/or skin compromise.

In type IV injuries, the fracture of the talar neck is associated with dislocation of the body from the ankle

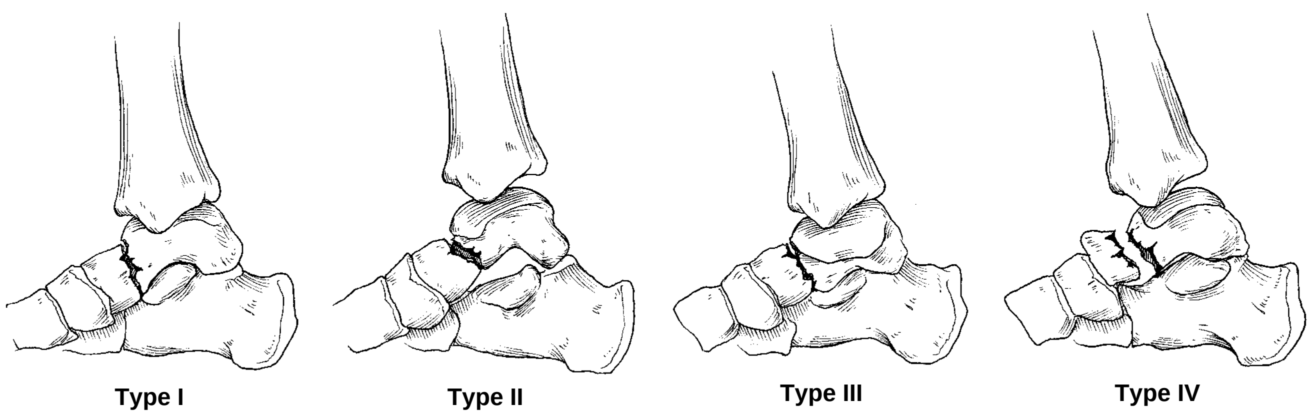


Figure 3 Classification of talar neck fractures.[8,9]

and subtalar joints with additional dislocation or subluxation of the head of the talus from the talonavicular joint. In the series of Canale and Kelly,[9] 3 of 71 talar fractures (4%) were type IV injuries, all of which had unsatisfactory results.

Clinical and Radiologic Evaluation

Patients with talar neck fractures present with significant swelling of the hindfoot and midfoot. Gross deformity may be present, depending on the displacement of the fracture and any associated subtalar and ankle joint subluxation or dislocation.

A history of a fall from a height or a forced loading injury (e.g., a motor-vehicle collision) may be elicited. A talus fracture may be only part of the total spectrum of the patient's injuries, and a general trauma survey should be included in each patient's evaluation. Particular attention should also be directed to the thoracolumbar spine, because spine fractures have been found in association with talar neck and body fractures. Focused evaluation of the involved foot should include an assessment of the neurovascular status as well as the integrity of the skin over the fracture site. Displaced talar neck fractures often lead to significant stretching of the dorsal soft tissues. Prompt reduction is mandatory to avoid skin necrosis. With fracture-dislocations, posterior displacement of the body leads to bowstringing of the flexor tendons and neurovascular bundle. Patients can present with flexion of the toes and tibial nerve dysesthesias. As many as 50% of type III Hawkins fractures present as open injuries, with a subsequent infection rate as high as 38%.[11] Hence, an open fracture must be treated with urgency.

Radiographic evaluation consists initially of anteroposterior (AP), lateral, and oblique views of the foot and ankle. This allows classification of the fracture and an assessment of associated injuries. The special oblique view of the talar neck described by Canale and Kelly[9] (Fig. 4) provides the best evaluation of talar neck angulation and shortening, which is not appreciable on routine radiographs. This view should be obtained to assess initial displacement of all talar neck fractures before embarking on an operative reduction. Computed tomography is invaluable for preoperatively assessing talar body injuries with regard to fracture pattern, degree of comminution, and the presence of loose fragments in the sinus tarsi. The typical CT protocol involves 2-mm-thick sections in the axial and semicoronal planes with sagittal reconstructions.

Treatment

The goal of treatment of talar neck fractures is anatomic reduction, which requires attention to proper rotation, length, and angulation of the neck. Biomechanical studies on cadavers have shown why precisely reducing talar neck fractures leads to better outcomes. In one cadaveric study, displacements by as little as 2 mm were found to alter the contact characteristics of the subtalar joint, with dorsal and medial or varus displacement causing the greatest change. The weight-bearing load pathway changed, and contact stress was decreased in the anterior and middle facets but was more localized in the posterior facet.[12] In another study, varus alignment was created by removing a medially based wedge of bone from the talar neck. This resulted in inability to evert the hindfoot, and the altered foot position was characterized by internal rotation of the calcaneus, heel varus, and forefoot adduction.[13] The altered hindfoot mechanics with a talar neck fracture may be one factor that leads to subtalar posttraumatic arthrosis. For these reasons, open reduction and internal fixation is recommended for displaced fractures.

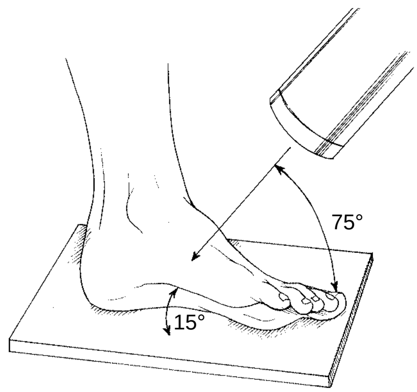


Figure 4 Radiographic positioning for the oblique view of the talar neck, as described by Canale and Kelly.[9]

Type I Fractures

Truly nondisplaced fractures of the talar neck can be treated successfully by cast immobilization. Care must be taken to obtain appropriate radiographs, including a Canale view, to ensure that there is no displacement or malrotation. A cast is applied, and weight bearing is not allowed for 6 to 8 weeks or until osseous trabeculation is seen on follow-up radiographs. Nonoperative treatment necessitates frequent radiographic follow-up to make certain that the fracture does not displace during treatment.

Type II Fractures

Initial management of displaced talar neck fractures should involve prompt reduction to minimize soft-tissue compromise. This can often be performed in the emergency room. However, repeated forceful reduction attempts should be avoided. The foot is plantar-flexed, bringing the head in line with the body. The heel can then be manipulated into either inversion or eversion, depending on whether the subtalar component of the displacement is medial or lateral.

Anatomic reduction of this fracture is difficult to obtain by closed means. Rotational alignment of the talar neck is very difficult to judge on plain radiographs. Even minimal residual displacement can adversely affect subtalar joint mechanics and is therefore unacceptable.[12] Even if closed reduction is successful in obtaining an anatomic reduction, immobilization in significant plantar-flexion is typically necessary to maintain position. For these reasons, operative treatment of all type II fractures has been recommended.[10]

Numerous surgical approaches have been described for talar neck fractures. The medial approach allows easy access to the talar neck and is commonly used. An incision just medial to the tibialis anterior starting at the navicular tuberosity exposes the neck and can be extended proximally to facilitate fixation of a malleolar fracture or to perform a malleolar osteotomy. Surgical exposure can contribute to circulatory compromise of the talus. Care must be taken to avoid stripping of the dorsal neck vessels and to preserve the deltoid branches entering at the level of the deep deltoid ligament.

The disadvantage of the medial approach is that the exposure is less extensile than that which can be achieved along the lateral aspect of the neck. This limited exposure makes judging rotation and medial neck shortening difficult. Medial neck comminution or impaction can be underestimated; if either condition is present, compression-screw fixation of the medial neck will result in shortening and varus malalignment. In these circumstances, a separate lateral exposure allows a more accurate assessment of reduction and better fixation.

The anterolateral approach lateral to the common extensor digitorum longus–peroneus tertius tendon sheath provides exposure to the stronger lateral talar neck. A wide-enough skin bridge must exist between the two incisions, and stripping of the dorsal talar neck must be avoided.

Once the fracture has been reduced, it is provisionally stabilized with Kirschner wires. Two screws (one medial and one lateral) are inserted from a point just off the articular surface of the head and directed posteriorly into the body (Fig. 2, B). Lag screws can be used unless there is significant neck comminution that would result in neck shortening or malalignment when the fracture is compressed. Bone graft is occasionally necessary to make up for large impaction defects of the medial talar neck (Fig. 5, A).

Another alternative for screw placement is the posterolateral approach described by Trillat et al.[14] An incision is made lateral to the heel cord in the interval between the flexor hallucis longus and peroneal muscles (Fig. 5, B). This allows safe access to the entire posterior talar process. Care must be taken during exposure to avoid injury to the peroneal artery and its branches. Most commonly, the posterolateral exposure is used in combination with an initial anteromedial or anterolateral approach for provisional fracture reduction and stabilization with Kirschner wires under image intensification. The patient is then positioned prone or on one side, and a posterolateral approach is used for placement of cannulated screws for final fracture fixation. Alternatively, if anatomic reduction can be accomplished with closed manipulation, posterior-to-anterior screw fixation can be used through a single posterior approach.

Posterior-to-anterior screw placement provides superior mechanical strength compared with insertion

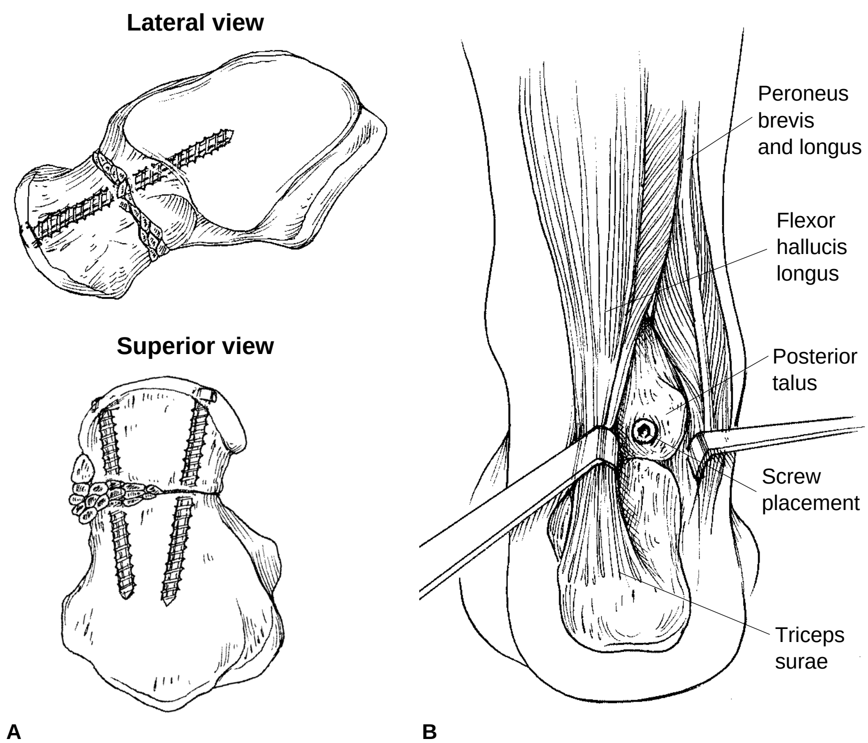


Figure 5 **A,** Placement of bone graft into an impaction defect in the medial talar neck. **B,** Posterolateral exposure of the talus as described by Trillat et al.[14]

from anterior to posterior.[15] Sanders[10] has suggested that screws can be placed on either side of the flexor hallucis groove and directed anteromedially. On the basis of their findings in a cadaveric study, Ebraheim et al[16] suggested that the best point of insertion for anterior-to-posterior screws is the lateral tubercle of the posterior process.

Pitfalls of posterior-to-anterior screw fixation include penetration of the subtalar joint or lateral trochlear surface, injury to the flexor hallucis longus tendon, and restriction of ankle plantar-flexion due to screw-head impingement. These potential problems can be minimized by placement of smaller-diameter countersunk screws directed along the talar axis.

Several types of screws have been used, including solid-core stainless steel small-fragment lag screws. Cannulated screws offer the potential advantage of easier insertion. Titanium screws have the advantage of compatibility with MR imaging, allowing early assessment of osteonecrosis.[17]

Bioabsorbable implants have several theoretical advantages, but experience is limited with these devices. They are not easily visible on radiographs, resorb over time, and can be placed through articular surfaces. These are most often used in fractures of the talar body but may be helpful as supplemental fixation of talar neck fractures.[10,18]

Screws placed from the talar head into the body may interfere with talonavicular joint function if the screw head is prominent and near the joint. This often necessitates countersinking the screw head. Headless lag screws have been shown to have mechanical properties comparable to those of small-fragment compression screws.[19] They have the theoretical advantage of not interfering with talonavicular joint function when placed through the talar head.

The timing of operative treatment of type II fractures remains controversial. There are no data to suggest that emergent treatment of type II fractures improves outcome, but most would agree that they should be treated with all possible expediency.

Type III Fractures

Type III fractures, which are characterized by displacement of the talar body from the ankle and subtalar joints, pose a treatment challenge. Urgent open reduction is mandated to relieve compression from the displaced body on the neurovascular bundle and skin medially and to minimize the occurrence of osteonecrosis. Many of these injuries have an associated medial malleolar fracture, which facilitates exposure. When the malleolus is intact, medial malleolar osteotomy is often required to allow repositioning of the talar body. Careful attention to the soft tissues around the deltoid ligament and medial surface of the talus is necessary, as these may contain the only remaining intact blood supply. A femoral distractor or external fixator may be applied for distraction of the calcaneus from the tibia to help extricate the body fragment. A percutaneous pin may be placed in the talus to toggle the body back into its anatomic position. Fracture stabilization can be carried out as described for type II fractures.

Because nearly half of these fractures are open, meticulous irrigation and debridement is mandated on an urgent basis. Open type III injuries are devastating and typically associated with significant long-term functional impairment.[20] In cases of severe open injury with extrusion of the talar body, a dilemma exists as to whether to save and reinsert the talar body or to discard it.[10] Marsh et al[11] reported on the largest series of open severe talus injuries. In 12 of 18 cases, the talus was totally or partially extruded through the wound. Deep infection developed in 38% of the patients despite contemporary open fracture management. The occurrence of deep infection was the major factor contributing to poor results. There was a 71% failure rate in patients in whom an infection developed. In cases of contaminated wounds when the talar body is totally extruded and completely devoid of soft-tissue attachment, consideration should be given to discarding the body fragment and planning a staged reconstruction.

Type IV Fractures

Type IV injuries are treated in a manner similar to type III injuries, with urgent open reduction and internal fixation. The talar body and head fragments are reduced and rigidly fixed. Stability of the talonavicular joint is then assessed; if it is unstable, consideration should be given to pinning the talonavicular joint. The significance of this injury is that osteonecrosis of both the talar body and the head fragment is possible.[10] As with type III injuries, urgent treatment is of paramount importance.

Postoperative Care

Provided stable fixation has been achieved, early range of motion is begun once the wounds are healed. With comminuted fractures and those with significant instability of the ankle, subtalar, or talonavicular joint, consideration should be given to cast immobilization until provisional healing has taken place (4 to 6 weeks). Weight bearing is delayed until there is convincing evidence of healing, which may take several months.

Complications

The reports of the incidence of complications vary widely (Table 1). There is, however, a consistent

Table 1
Complications Following Talar Neck Fractures*

Fracture Type	Osteonecrosis	Degenerative Joint Disease	Malunion
Type I	0%-13%	0%-30%	0%-10%
Type II	20%-50%	40%-90%	0%-25%
Type III/IV	8%-100%	70%-100%	18%-27%

* Range of cited incidence values in references 1, 4, 5, 6, 8, 9, 11, 23, 25, and 26.

trend for the incidence of complications to increase with the Hawkins stage.

Fractures of the Talar Body

Talar body fractures occur less frequently than fractures of the talar neck.[13] Because fractures of the talar body involve both the ankle joint and the posterior facet of the subtalar joint, accurate reconstruction of a congruent articular surface is required.

Evaluation and Classification

It is sometimes difficult to differentiate vertical fractures of the talar body from talar neck fractures. Inokuchi et al[21] suggest that the diagnosis can be accurately predicted on the basis of the location of the inferior fracture line in relation to the lateral process. Fractures in which the inferior fracture line propagates in front of the lateral process are considered talar neck fractures. Fractures in which the inferior fracture line propagates behind the lateral process involve the posterior facet of the subtalar joint and are therefore considered talar body fractures.

Plain radiographs often underestimate the extent of articular injury. Computed tomography is necessary to define the fracture pattern, amount of comminution, and extent of joint involvement.

Talar body fractures have been classified by Sneppen et al[22] on the basis of anatomic location, as follows: type A, transchondral or osteochondral; type B, coronal shear; type C, sagittal shear; type D, posterior tubercle; type E, lateral process; and type F, crush fractures. Boyd and Knight[23] also proposed a classification system for shearing injuries of the talar body. In their classification system, body fractures are differentiated according to associated dislocation of the subtalar or talocrural joint. As with talar neck fractures, talar body fractures with associated dislocation have a higher incidence of osteonecrosis. In the simplest sense, talar body fractures can be divided into three groups: group I are proper or cleavage fractures (horizontal, sagittal, shear, or coronal); group II, talar process or tubercle fractures; and group III, compression or impaction fractures (Fig. 6).

Treatment of Talar Process and Tubercle Fractures

The extent of joint involvement and the degree of comminution should be considered when treating fractures of the talar process or tubercle. These injuries are often missed or neglected; this can lead to significant disability, because such fractures can involve a substantial portion of the ankle and subtalar articular surface. In general, nondisplaced process or tubercle fractures can be treated with casting and maintenance of non-weight-bearing status. For displaced fractures with significant articular involvement, consideration should be given to operative fixation (Fig. 7). Not uncommonly, however, the extent of comminution precludes operative fixation, and fragments can only be either excised or managed nonoperatively (Fig. 8).

Treatment of Cleavage and Compression Fractures

Displaced cleavage and crush fractures of the talar body are optimally treated with anatomic reduction and internal fixation. Because these fractures occur beneath the ankle, a mortise, medial, or lateral malleolar osteotomy is often necessary to gain exposure to the fracture.[16] Once the fracture has been exposed, temporary Kirschner-wire fixation is used before final fracture stabilization with screws. Bioab-

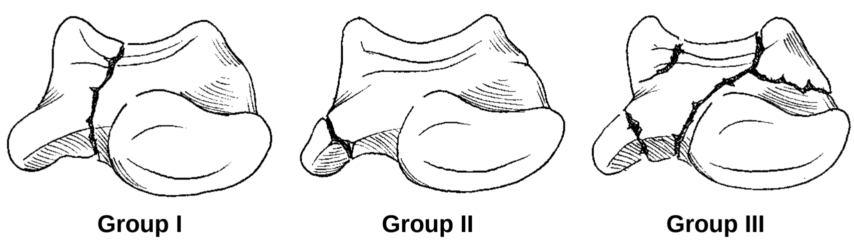


Figure 6 Talar body fractures. Group I are fractures of the body proper or cleavage fractures (horizontal, sagittal [shown], shear, or coronal). Group II are talar process or tubercle fractures (lateral talar-process fracture shown). Group III are compression or impaction fractures of the articular surface of the body.

A B C

Figure 7 Preoperative CT scan **(A)** and lateral radiograph **(B)** showing a displaced posteromedial talar tubercle fracture (arrows). **C,** Radiograph obtained after lag-screw fixation.

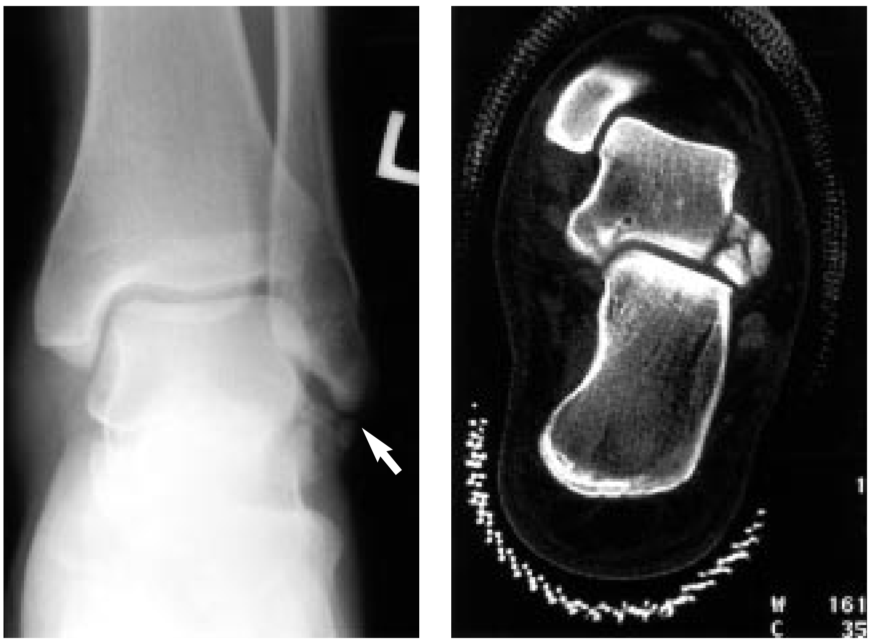
sorbable pins or subarticular screws can be helpful (Fig. 9). Severe injuries with significant impaction of the cancellous bone of the talus may require bone grafting (Fig. 10).

Results

Differences in treatment methods among reported series and the small numbers of patients make it difficult to make valid inferences regarding the outcome of talus fractures. Contemporary management with open reduction and internal fixation of all displaced fractures has led to improved clinical results. Canale and Kelly[9] reported only 59% good or excellent results in a series of 71 fractures followed for an average of 12.7 years. More than half of the patients with type II fractures in that series were treated with closed reduction and casting. Many of these fractures were complicated by varus malalignment and subsequent arthrosis. Low et al[24] reported good or excellent results in 18 of 22 patients who underwent open reduction and internal fixation for displaced talar neck fractures. Other authors have reported comparable clinical results, as well as diminished osteonecrosis and arthrosis, with operative treatment of all displaced fractures.[25,26]

Complications and Salvage

Osteonecrosis, malunion, and arthrosis are the most commonly reported complications after talus



A B

Figure 8 Plain radiograph **(A)** and CT scan **(B)** demonstrate a comminuted lateral talar-process fracture (arrow), which was subsequently treated by excision of fragments.

Figure 9 **A,** AP radiograph of a talar body fracture. **B,** CT reconstruction shows the talar neck component of the fracture (arrows). Postoperative AP **(C)** and lateral **(D)** radiographs. Medial malleolar osteotomy was required for fracture exposure. Headless subarticular screws were used for fracture fixation.

fracture. Nonunion occurs infrequently.

Osteonecrosis

Osteonecrosis is a frequent complication of talar neck and body fractures and dislocations. Hawkins[8] reported no osteonecrosis in 6 type I fractures, whereas Canale and Kelly[9] reported a 13% incidence in 15 type I fractures. Hawkins reported a 42% incidence in 24 type II fractures and a 91% incidence in 27 type III fractures.

Osteonecrosis is not always easily recognized. Hawkins[8] stated that the time to recognize its presence is within 6 to 8 weeks; however, it may first be observed on radiographs at any time from 4 weeks to 6 months after fracture-dislocation. It usually presents as relative opacity of the involved bone caused by osteopenia of the neighboring bones of the foot secondary to disuse and cessation of weight bearing.

The Hawkins sign (evidence of preserved vascularity of the talus) is seen 6 to 8 weeks after the injury. It consists of patchy subchondral osteopenia on the AP and mortise views of the ankle and is useful as an objective prognostic sign. The presence of the Hawkins sign is a reliable indicator that osteonecrosis is unlikely. The absence of the Hawkins sign, however, is not as reliable in predicting the development of osteonecrosis.[9] A film of the normal side, taken at the same exposure, should be available for comparison.

Magnetic resonance imaging is very sensitive for detecting osteonecrosis and estimating the amount of talar involvement. Adipocyte viability produces strong T1-weighted images. With avascularity of bone, death of marrow adipocytes occurs early.[27] This alters the appearance of fat signals on the T1-weighted image. It does not appear that MR imaging is helpful in assessing osteonecrosis until at least 3 weeks after the time of injury, and false-negative MR images have been reported.[16,28] The role of MR imaging in the follow-up of both nonoperatively and operatively treated talus fractures has yet to be determined.

Initial treatment for osteonecrosis is conservative. It is important to note that a talus fracture can heal despite the development of osteonecrosis. The main determinant for progressing the patient's weight-bearing status on the injured extremity is the presence of fracture healing. Once radiographic evidence of healing has been demonstrated, the patient may be allowed to bear weight.

It may take up to 36 months for revascularization of the talus to occur; therefore, prolongation of non-weight-bearing status until the risk of collapse no longer exists is not practical. There is no definite evidence to suggest that weight bearing on an avascular talus will contribute to collapse. Hawkins[8] stated that collapse of the talus occurred despite maintenance of enforced non-weight-bearing status for several years.

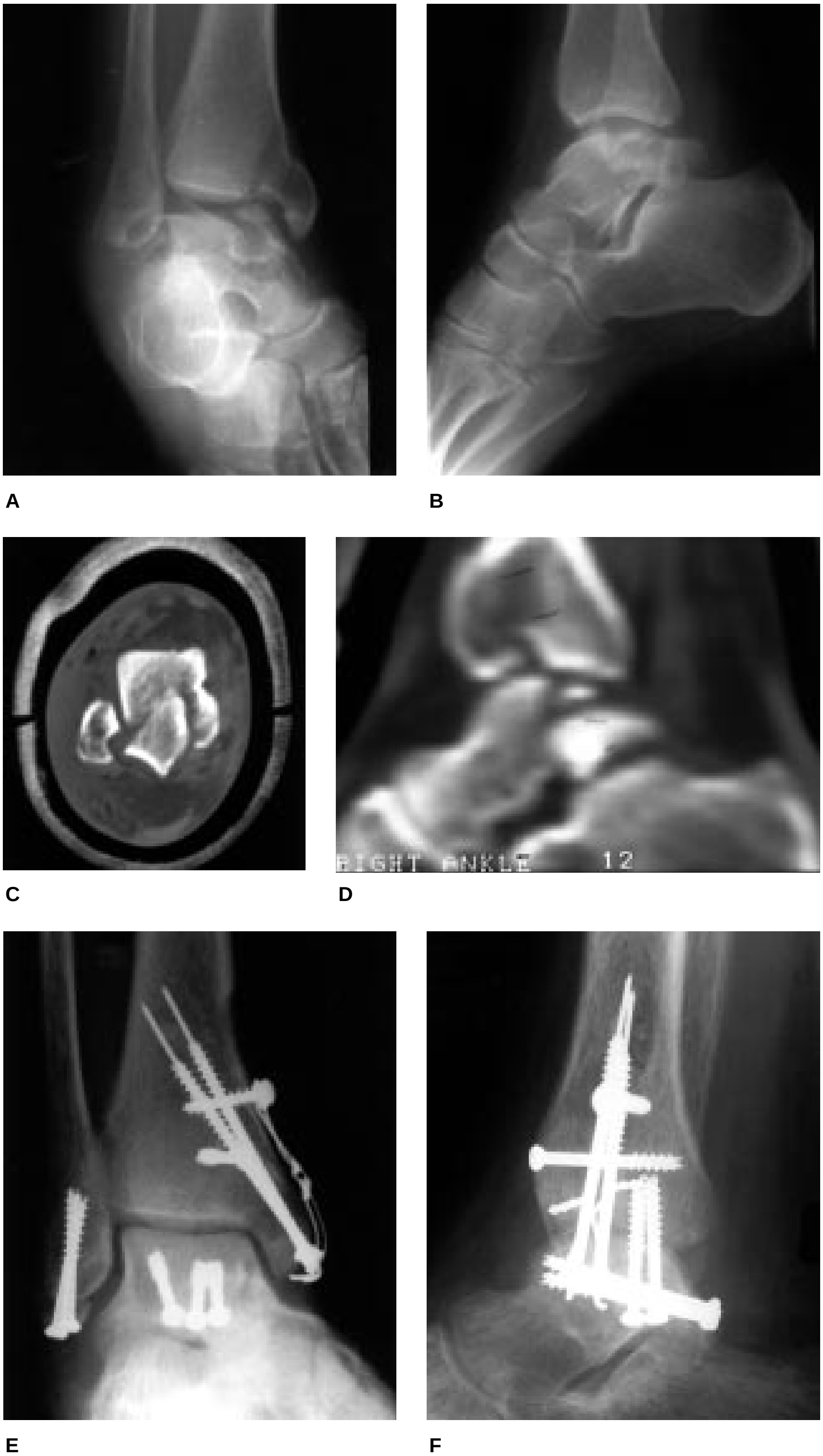


Figure 10 AP **(A)** and lateral **(B)** plain radiographs show an impacted talar-body fracture. Axial CT image **(C)** and sagittal CT reconstruction **(D)**. AP **(E)** and lateral **(F)** radiographs obtained after operative fixation. The medial malleolar fracture facilitated exposure to the talar body. The impacted articular segment was elevated and bone-grafted.

Patients with pain and evidence of osteonecrosis may be offered an off-loading orthosis, such as a patellar tendon–bearing brace, which may limit symptoms. However, these types of orthotic devices have not been shown to prevent collapse of the talar dome in the presence of osteonecrosis. It should be noted that osteonecrosis of the talus is not always symptomatic, and patients may function quite satisfactorily without discomfort despite having radiographic findings of osteonecrosis. Surgical salvage is indicated only for patients with intractable symptoms after nonoperative treatment.

Operative treatment of osteonecrosis after a talus fracture depends on the location and extent of necrosis and the degree of accompanying arthrosis of the ankle and subtalar joints. Patchy osteonecrosis with isolated involvement of one joint is approached differently than total body necrosis and collapse. In cases of limited osteonecrosis with arthrosis, arthrodesis of the involved joint is an effective means of eliminating pain. It is important that any dead bone adjacent to the fusion interface be removed to ensure successful union. Bone graft is necessary to fill any defect created by removal of the necrotic bone. In cases of isolated lateral dome involvement, the fibula can be used as a strut graft.

Operative salvage in cases of total body osteonecrosis and collapse is a challenge. Talectomy alone has been used in such cases with only minimal success.[8,9] Hawkins[8] reported on 6 patients evaluated an average of 6 years after talectomy. All patients had problems related to pain or shortening of the limb. To address some of the problems with talectomy alone, a Blair-type fusion has been suggested.[10] This involves resection of the necrotic talar body fragment and fusion of the talar head to the anterior distal tibia. This has the potential advantages of limiting the amount of limb shortening and preserving some hindfoot motion. This technique can result in a painless plantigrade foot, but potential problems include high rates of nonunion at the tibiotalar junction and late collapse.[10]

Alternatively, the defect created by removal of the talar body can be spanned with tricortical graft between the distal tibia and the calcaneus in conjunction with fusion of the talar head and anterior distal tibia. This preserves limb length and limits the risk of late collapse between the tibia and the calcaneus (Fig. 11). Another option that has been recently reported is to leave the necrotic talar body in place and span from the tibia to the calcaneus with bone graft. Kitaoka et al[29] reported union in 13 of 16 patients treated with this technique.

Nonunion and Malunion

Nonunion is the least frequent complication of talar neck fracture. In a review of the world literature up to 1985,[30] the reported incidence was 2.5%. The differentiation of a nonunion from a delayed union is somewhat arbitrary. Consolidation across the site of a type III talar neck fracture may take as long as 8 months.[30] Treatment of nonunion is dependent on the presence of coexisting problems, such as arthrosis, osteonecrosis, and infection, and is injury-specific. Consideration should be given to arthrodesis when nonunion is associated with advanced hindfoot arthrosis.

Malunion after inaccurate reduction of talar neck fractures has a reported incidence as high as 32%, with varus malunion occurring most frequently.[9,10] It is difficult to assess the accuracy of reduction on plain radiographs; therefore, malunion is probably more common than reported. Canale and Kelly[9] found that varus malunion occurred most frequently in Hawkins type II fractures that had been treated in a closed manner. Type III fractures were more likely to be treated operatively, and the incidence of malunion was less in this group. The authors stressed the importance of obtaining adequate radiographs, particularly the specialized oblique view that allows assessment of neck alignment.

Because treatment of talar neck malunion is difficult, preventing this complication is important. It has been recommended that minimally displaced fractures of the talar neck can be treated with casting,[8,9] but acceptable amounts of displacement have been variably defined. Canale and Kelly[9] suggested that 5 mm of

A B C

Figure 11 AP **(A)** and lateral **(B)** plain radiographs demonstrate osteonecrosis of the entire talar body. **C,** Lateral postoperative radiograph shows tibiocalcaneal arthrodesis with intramedullary nail fixation. The necrotic talar body was removed.

displacement and 5 degrees of angulation or varus are acceptable. Sangeorzan et al[12] studied the effect of malalignment of the talar neck on the contact characteristics of the subtalar joint. Displacement by 2 mm resulted in changes in the subtalar contact characteristics. These small displacements are likely critical and can lead to altered subtalar joint mechanics and arthrosis. Therefore, displaced fractures should be accurately reduced and internally fixed. With any medial comminution, a two-incision approach may provide the best chance for accurate fracture reduction.

Patients with varus malunion walk with the foot internally rotated and often complain of excessive weight bearing on the lateral border of the foot. Initial management consists of footwear modification and use of inserts intended to cushion the lateral overload.

Surgical treatment of talar neck malunion is dependent on the status of the ankle, subtalar, and talonavicular joints. Long-standing varus malunion with significant arthrosis and loss of hindfoot motion can be salvaged with arthrodesis to obtain a plantigrade foot. At the time of arthrodesis, the malpositioning of the foot should be corrected. Patients with varus malunion typically have a shortened medial column of the foot. Correction of the deformity involves lengthening of the medial column or shortening of the lateral column of the foot in conjunction with derotation of the forefoot. Occasionally, joint function is preserved, and correction of the varus deformity with talar neck osteotomy is possible. Monroe and Manoli[31] reported a successful outcome after talar neck osteotomy and insertion of a tricortical bone graft to restore medial neck length.

Dorsal malunion can occur when the body is not properly derotated during reduction and the head fragment remains dorsal to the body. This can lead to symptomatic impingement of the dorsal surface of the talus on the distal tibia and restriction of ankle dorsiflexion. In the absence of significant arthrosis, resection of the dorsal prominence of the talar neck may relieve symptoms.

Skin Necrosis and Infection

Deep infection and skin slough are probably the most dreaded complications of severe talar fractures. Displaced fractures can lead to excessive tension on the dorsal skin and subsequent necrosis. Extensive soft-tissue loss can increase the chance of infection and often necessitates flap coverage. Prompt reduction will help minimize this potentially disastrous complication (Fig. 12). Acute, deep infection, such as septic arthritis, should be treated aggressively with serial debridement and attempted wound closure or coverage and prolonged antibiotic therapy.[20] Chronic deep infection with bone involvement typically requires removal of the infected bone and hardware. Antibiotic-impregnated bone-cement spacers can be used to fill large defects, and staged reconstruction can be considered after the infection has been eradicated.

Posttraumatic Arthrosis

Subtalar and tibiotalar arthrosis with limited range of motion is a frequent residuum of severe talar injuries. Arthrosis can result from articular damage at the time of injury or from abnormal joint mechanics, as is seen with talar neck malunion. The exact incidence of arthrosis for each fracture type is unknown. In a study of displaced talar neck fractures, Sanders[10] reported that the incidence of arthrosis varied from 47% to over 90%. Arthrosis is often not symptomatic and is, therefore, probably more common than has been reported. As with osteonecrosis, the presence of arthrosis does not preclude a satisfactory outcome.

Arthrodesis may be considered for symptomatic arthritic joints if bracing and lifestyle modification do not provide sufficient relief. It is

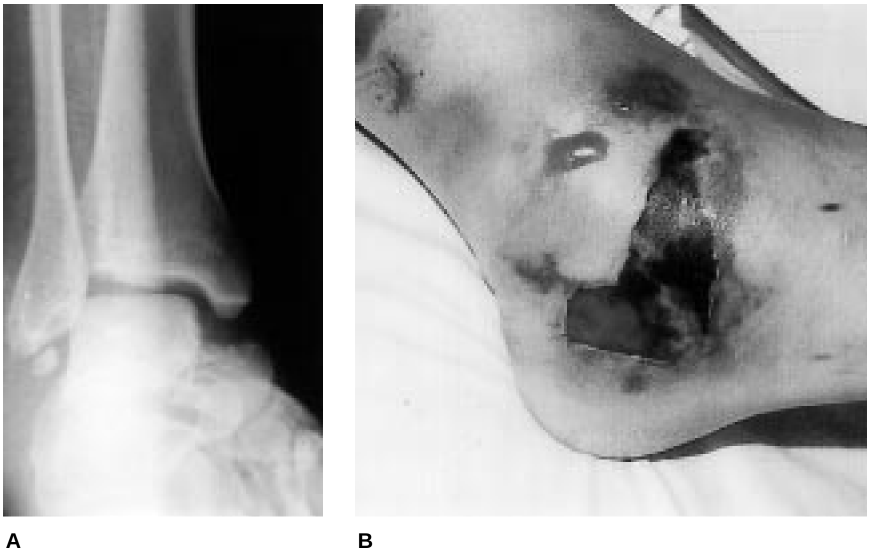


Figure 12 **A,** AP plain radiograph shows a Hawkins type III fracture. **B,** Injury was left unreduced for 48 hours, which resulted in full-thickness skin loss that necessitated free-vascularized-flap and skin-graft coverage.

important not to underestimate the possibility of osteonecrosis in patients with arthritis subsequent to talar injuries. The presence of focal osteonecrosis may not be apparent on plain radiographs, and conventional arthrodesis techniques may fail if large areas of necrotic bone are not appropriately treated with bone grafting.

Summary

Talus fractures often present as complex injuries. Optimal diagnosis and management require a thorough understanding of the osseous anatomy and the vascular supply of the talus. Fractures with significant displacement or associated dislocation require urgent reduction to afford the best outcome. Using a combination of anteromedial and anterolateral incisions for fracture exposure facilitates anatomic reduction. Severe talar injuries with significant initial displacement remain problematic, and even aggressive management does not always lead to a satisfactory outcome.

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