The Operative Reduction of Intra-articular Calcaneal Fractures

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In the past the evaluation of treatment modalities of calcaneal fractures has been fraught with the lack of well-designed, randomized clinical studies. As a result, surgeons treating these injuries were typically polarized when deciding between a surgical or nonsurgical approach to management. Among the many technical reasons for the frank dichotomy of treatment preferences were the difficulty in anatomical restoration, the relatively poor surgical access to the calcaneus, the limited internal fixation devices available for stabilization, and the difficulty in comprehensive radiographic imaging. Furthermore, the lack of complete understanding of the mechanism of sequential bony failure complicated the surgical exercise. The lack of standardized protocols for surgical treatment also lended to the controversy.

In recent years the technical difficulty has diminished due to advances in surgical exposure, fixation devices, radiographic imaging, and understanding of the mechanism of injury. Consequently, the frequency of operative reduction of intra-articular calcaneal fractures has increased in recent years. As surgeons gained experience with these fractures, the indications and goals of operative reduction have become clear.

Certainly the treatment goals of any articular fracture are anatomic reduction of articular surfaces, restoration of normal bony contours, and attainment of bony union. Many calcaneal fractures have severe articular damage and are so fragmented that they defy reconstruction in even the most skilled hands (Fig. 1). Nevertheless, restoration of normal height of the calcaneus, narrowing of the heel via decompression of the lateral wall expansion, and remodeling of the calcaneus may offer distinct biomechanical advantages in spite of the quality of the articular surfaces.[1] This argument can also be applied to situations in which the ability to achieve rigid fixation is compromised due to decreased bone stock, but there is significant widening and flattening of the heel.[1]

The specific indications for open reduction of an intra-articular calcaneal fracture depend upon the age of the patient, occupation, activity level, general health status, ability of the surgeon, and the type of fracture. None of these factors can be considered to be an absolute determinant for the type of treatment rendered. Young, active, healthy patients with manual types of occupations may derive more benefit from surgical restoration than the inactive, sedentary individual. Although advancing age is not an absolute contraindication to surgical intervention, one must be aware of the physiologic barriers that may adversely affect the result. Bone stock is likely to be compromised, especially in women. There is also a loss of resilience of the soft tissues with advancing age.[2]

Regardless of the specific individual factors, there is no absolute formula to aid in the decision of operative vs. nonoperative care. Clearly, one must decide based on informed patient participation, patient expectations, attendant risks, and the overall assessment of the ability of the surgeon to achieve specific goals. As the technique becomes more refined and each surgeon attains more experience, the criteria may become more refined in the future.

MECHANISM OF INJURY

The mechanism of injury for the intra-articular calcaneal fracture has been poorly understood in the past. Inconsistent and erroneous descriptions in the literature[2,3] have unfortunately persisted and pervaded the thinking of even the most thoughtful foot and ankle surgeons. These erroneous concepts may have hampered the surgeon's ability to restore anatomy. As with many fractures of the foot and ankle, it is important to neutralize the forces which tend to disrupt the reconstruction. This can only be accomplished with a complete understanding of the pathologic physical forces responsible

Figure 1. Severely flattened and displaced calcaneal fracture. There is an associated talonavicular joint dislocation.

Figure 2a. Lateral view of two-part calcaneal fracture. Note the primary fracture is posterior to the critical angle.

Figure 2b. Lateral tomogram of same patient confirming the location of the primary fracture line.

Figure 3. Axial view demonstrating the "overlap" of the sustentaculum on the rotated tuber fragment.

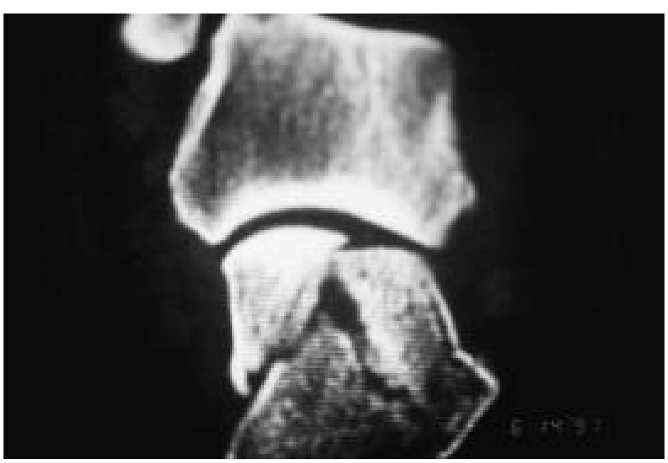

Figure 4. Axial CT scan of three-part calcaneal fracture showing the sagittal split in the posterior facet.

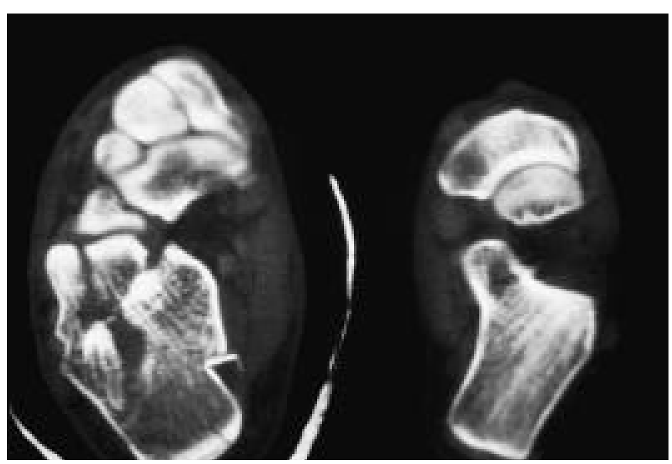

Figure 5. CT scan showing a five-part fracture with visualization of all five major fragments.

for bony failure of the calcaneus so that the appropriate maneuvers for bone fragment mobilization and stabilization are employed.

A better understanding of the mechanism of injury has been appreciated and made possible by the widespread use of computed tomography scanning and direct intraoperative observation of fracture patterns. The preoperative CT scan is likened to a road map which accurately predicts the degree of displacement and comminution and the orientation of the fracture lines to the cardinal body planes. Furthermore, with the centralization of trauma care to a few hospitals, it has enabled several surgeons to operate on large series of patients.

It becomes clear after one examines large numbers of fractures that no two fractures are exactly alike. However, there are some common features that reinforce the most commonly accepted mechanism of injury. Predictable osseous failure patterns further substantiate the sequential mode of osseous failure. The work of Sanders et al., Tscherne and Zwipp, and Letournel[4-7] has correlated the severity of injury with the degree of comminution of the calcaneus and a deteriorating prognosis. Further experimental models with load frames will likely validate this clinical reproduction of the mechanism.

In order to explain and accept the mechanism of injury, one needs to assume that when the foot impacts the ground, the forces are concentrated at the sustentaculum tali, possibly as a result of reflexive varus posturing by the patient in a vertical fall. But as the force from the incumbent body weight increases, a shearing type mechanism occurs at the sustentaculum tali which cleaves off the sustentaculum from the rest of the calcaneal body. The sustentacular fragment may contain all or a portion of the posterior facet, but there are basically two major fragments. The fracture line runs from proximal medial to distal lateral. Almost invariably this primary fracture line exits the lateral side of the calcaneus posterior to the critical angle of Gissane. In the past it was perceived that the lateral process of the talus serves to propagate the fracture by wedging into the angle of Gissane. Although this anatomic area may become comminuted, it is clear that the primary fracture line is well removed from the critical angle (Fig. 2).

Since the sustentacular fragment is firmly secured to the talus by its medial ligamentous complex, the achilles tendon pulls the "free" body fragment into equinus. Due to the obliquity of the primary fracture line, the sagittal plane tilt of the body fragment creates the illusion of overlapping of the sustentaculum on the tuber. It must be realized that the sustentaculum stays in its normal anatomic location and the rotation of the main fragment is the actual displacement. This is the two-part fracture described by Zwipp and Tscherne[5,6] and the Type I by Sanders (Fig. 3).[4]

As forces continue, the lateral aspect of the posterior facet now becomes detached from the rest of the tuber fragment. There are now three distinct

Figure 6. Preoperative photograph of patient with resolving edema. Note the presence of skin lines in spite of persistent ecchymosis.

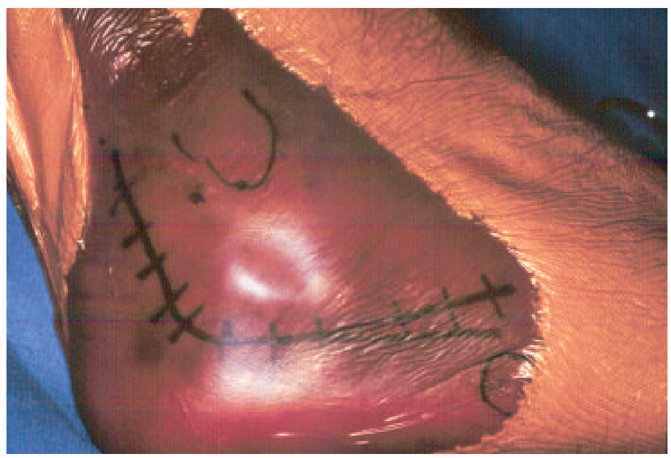

Figure 7a. Intraoperative photograph of right foot with the proposed incision. The contour of the lateral malleolus is also outlined.

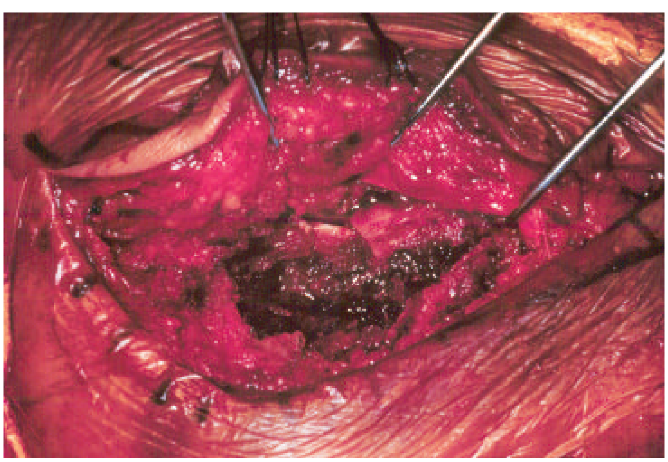

Figure 7b. Note the elevation of the full thickness flap. The three self-retaining Kirschner wires are in place.

Figure 8. Photograph of the comminuted posterior facet. It was completely devoid of all soft tissue components.

major fragments: (1) the sustentacular fragment; (2) the tuber fragment attached to the achilles tendon; and (3) the lateral aspect of the posterior facet. This latter piece can comprise the portion of the posterior facet left behind from the initial shearing fracture, or can further comminute into two or more pieces. This is known as the three-part fracture of Zwipp and Tscherne[5,6] (Fig. 4) or type II by Sanders.[4] If further comminution of this fragment is observed, it would be classified as a type III or IV by Sanders depending on the number of fragments.

The free lateral articular fragment is now driven inferiorly into the substance of the calcaneal body–a procedure which can result in cleavage of the sustentacular fragment into an additional two or three fragments. If the sustentacular fragment results in two pieces, there is a four-part fracture: (1) the sustentacular fragment; (2) the tuber fragment attached to the achilles tendon; (3) the lateral aspect of the posterior facet; and (4) the anterior portion of the calcaneal body containing all or part of the calcaneocuboid joint. If the sustentacular fragment results in three pieces, there is a five-part fracture: (1) the sustentacular fragment; (2) the tuber fragment attached to the achilles tendon; (3) the lateral aspect of the posterior facet; (4) the anterior portion of the calcaneal body containing all or part of the calcaneocuboid joint; and (5) the remaining portion of the calcaneocuboid joint or the lateral wall (Fig. 5).

One must remember that there are usually many more than five fragments to the comminuted intra-articular calcaneal fracture. However, these other pieces are often too numerous to count and occur far less consistently than the five main fragments that may result. Furthermore, the lack of consistency and their size make these fragments relatively unimportant in the scheme of reconstruction.

TECHNIQUE OF OPEN REDUCTION

Ideally the operative reduction of a calcaneal fracture should be performed as soon as the injury occurs before severe swelling takes place. Immediate surgical intervention decompresses the engorged anatomic compartments and may lessen the degree of skin compromise. Unfortunately, this is seldom possible in most busy hospitals. It is impractical to operate with the urgency of any open fracture. With this in mind, unless surgery can be done immediately, it is preferable to wait three to seven days after the injury to allow for a reduction of swelling and stabilization of the soft tissue envelope. The reappearance of skin wrinkles in the foot usually indicates significant reduction in the pedal edema and is a good temporal landmark for the procedure. In some cases swelling is not severe, and this waiting interval may not be necessary. When a crush injury is involved, it is better to overestimate the period of delay rather than to operate expediently, as soft tissue damage may manifest latently (Fig. 6).

Until surgery is feasible, proper preoperative care of the patient can reduce the tendency for postoperative wound complications. The injured extremity should be wrapped with compressive dressings and a plaster splint until the time of operative intervention. Strict elevation is essential in decreasing the postinjury edema. It is often difficult to convince the patient who is not hospitalized to comply with this activity. Hospital utilization practices preclude this activity on an inpatient basis unless the patient has multiple injuries.

In spite of meticulous preventive preoperative care, some patients will develop fracture blisters which may encroach upon the proposed surgical incision. One must then resolve the dilemma of whether to wait until resolution of the blister and re-epithelization of the skin, or to proceed with the operation in spite of the blisters. After a two-week grace period, the ability to obtain bony fragment mobilization and anatomic reduction is hampered. After a three-week postinjury delay, it may be severely compromised.

EXTENDED LATERAL APPROACH

For most cases of comminuted intra-articular fracture, the extended lateral approach is favored. The patient is positioned in the supine attitude, and bony prominences are well padded. A bolster is used to elevate the ipsilateral hip, tilting the pelvis approximately 30° from the operating table. The patient is

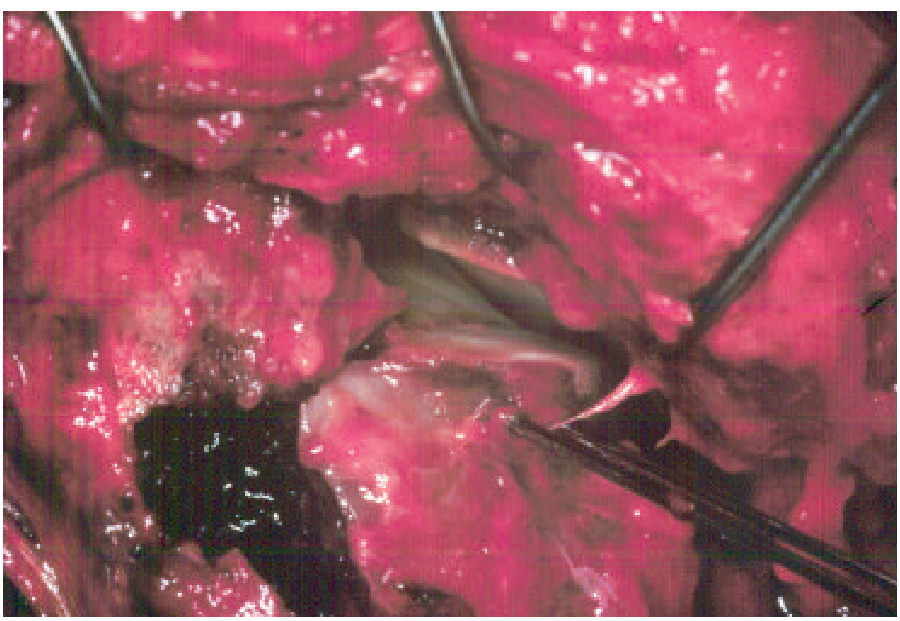

Figure 9. Intraoperative photograph of the posterior facet and the anatomic reduction being maintained with K-wires.

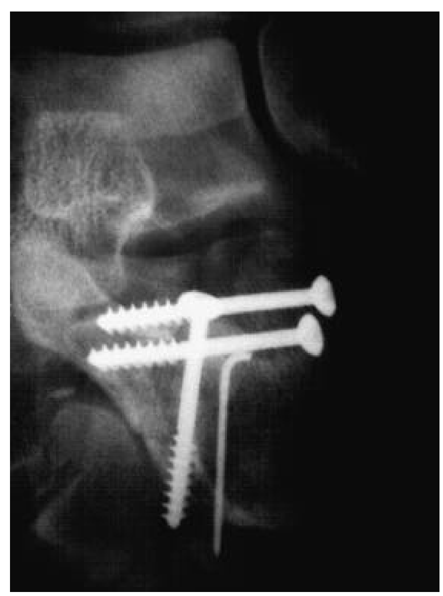

Figure 10. Intraoperative radiograph of the posterior facet and re-establishment of the medial cortical contour.

securely anchored to the operating surface to allow for the airplane position. The advantage of the modified supine position over the lateral position favored by Sanders[4] and Bernirschke[8] is its versatility in adopting the medial approach if needed. There is no argument that the lateral position is preferable if it is unequivocal that the medial approach will not be used.

The requirement for bone graft is infrequent, but when necessary, autogenous bone should be utilized. Therefore the iliac crest is prepared and draped. Tourniquet control is not mandatory but highly recommended at mid-thigh level. The principles of tourniquet utilization should be followed, but in most cases the bulk of the operation is completed in one 90- to 120-min session of ischemia.

In the past, surgical exposure to the calcaneus has been difficult due to the use of traditional incisional approaches to the bone. The calcaneus is flanked on either side by an array of tendons and medially by the neurovascular bundle. The extended lateral approach provides complete accessibility to the lateral wall and allows for superb visualization of the major pathology. The incision is fashioned as a full thickness flap so that all of the soft tissue structures on the lateral aspect of the calcaneus are elevated in a single layer off of the bony structures. This includes the sural nerve, peroneal tendons, calcaneofibular ligament, and extensor digitorum brevis. In a right foot, the incision resembles an *L* and in a left foot, it resembles a *J*.

The incision begins over the posterior triangle halfway between the achilles tendon and peroneal tendons. It courses inferiorly to a point halfway between the plantar heel and the tip of the lateral malleolus and then makes a very sharp curve anteriorly so that a "rounded right angle" is made. The incision is carried distally to the calcaneocuboid joint (Fig. 7). The incision directly over the calcaneus is made directly to bone, recognizing that the soft tissue structures should be conveniently positioned superior to the incision line. A full thickness flap is developed, with care taken to dissect all of the soft tissue off of the underlying bone. It is helpful to place some nonabsorbable sutures at and on either side of the apex of the flap and use them for retraction rather than subject the precarious flap to manual or self-retaining retractors (Fig. 7). Once the flap is elevated, three 0.062-in K-wires are inserted into the talus, the cuboid, and the fibula respectively to serve as self-retaining retractors for the balance of the procedure.

The lateral wall is gently retracted, and the lateral fragment of the posterior facet will be observed impacted into the substance of the body. If completely detached, the fragment or fragments are retrieved from the wound for later assembly on the back table, even if there are multiple components. If there is a substantial periosteal pedicle, an attempt at preservation is made (Fig. 8). It is best to disimpact the facet by using an elevator and applying a simultaneous elevating and anterior translation force. A 5.0-mm Shantz pin is now inserted into the tuber fragment in order to control its position and aid in reduction to the stable sustentacular fragment. It is important to anchor the pin in good dense bone because significant forces may be applied in order to mobilize the tuber fragment and counteract the pull of the achilles tendon. The best location of bone for this purpose is just anterior to the attachment of the achilles tendon either perpendicular or parallel to the lateral wall of the calcaneus. The former is favored when the modified supine approach is utilized so that there is no interference of the operating table with the pin.

The posterior facet is then reconstructed either on the back table if comminuted, or directly to the sustentaculum if not. Anatomic reduction is achieved under direct vision. Temporary fixation with guide pins for the 4.0-mm or 3.5-mm cannulated screws is preferable (Fig. 9). If cannulated screws are not to be utilized, 2.0-mm K-wires are utilized for later introduction of 4.0-mm cancellous or cortical screws in the same "drill hole." At least two pins are placed for temporary fixation so that reduction is not compromised during the insertion of the screws.

With manipulation of the Shantz screw, the tuber fragment is derotated, medially displaced, and taken out of varus. This should allow for anatomic restoration of the tuber to the stable sustentacular fragment. Careful inspection of all fracture and anatomic margins will ensure anatomicity. A frequent point of difficulty arises by failure to pull the tuber fragment out of equinus far enough to re-establish the proper calcaneal inclination.

Once proper orientation of the calcaneal tuber is attained, the position can be maintained with heavy caliber pins driven from the tuber through the subtalar joint into the talus or into the sustantaculum tali. Large caliber pins are necessary to resist any loss of reduction as a consequence of the achilles tendon forces.

Next, the anterior column is addressed. If there is a sagittal split of the calcaneocuboid joint, it is temporarily fixed with K-wires or guide pins (for cannulated screws). If there is no such split, the anterior fragment is

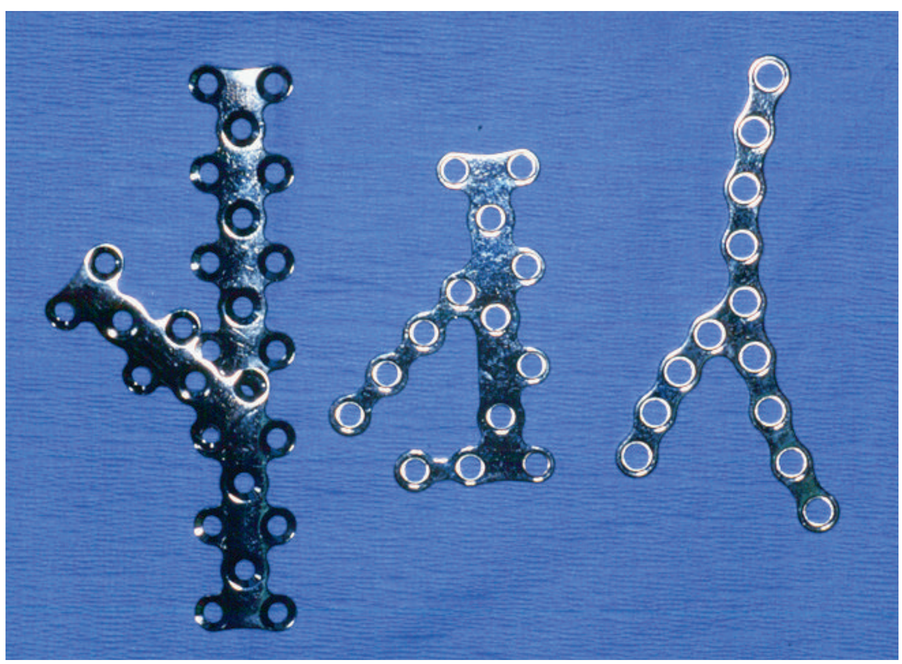

Figure 11. Three of the more commonly used plate configurations. Left: stacked multiple H-plates; center: Sanders plate; right: Y-plate of Letournel.

positioned to the sustentacular fragment and maintained with K-wires. Again, careful inspection of anatomical borders and fracture margins will assure anatomic restoration. In many instances, the articular surface fragments will be relatively well aligned to the calcaneocuboid joint, but there will be some sagittal plane migration of the more proximal end of the anterior column. This latter displacement is often difficult to restore.

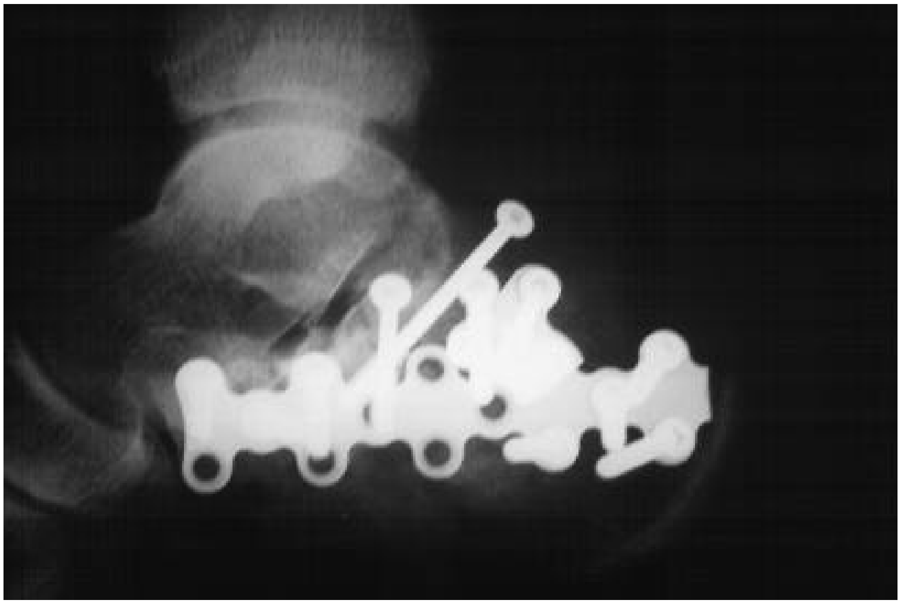

Figure 12a. Lateral postoperative radiograph showing stabilization with stacked multiple H-plates and intrafragmentary screws.

When the entire construct has been temporarily fixated, intraoperative X-rays are taken with Broden, axial, and lateral views for accuracy of reduction. Unless there is a tremendous void in the cancellous bone stock, bone graft is not necessary. The lateral wall is replaced and permanent fixation is delivered (Fig. 10). Where possible, compression screws should be utilized to effect interfragmentary compression of the posterior facet and the calcaneocuboid sagittal split.

The entire construct is buttressed by a choice of plates. Multiple fragment plates, H-plates, reconstruction plates, the Y-plate of Letournel, and the new Sanders plate all allow for stabilization of the entire construct (Fig. 11). The chosen plate must be able to span all of the major cleavage planes and be able to counteract those forces which would tend to disrupt the reconstruction. These forces include the achilles ten-

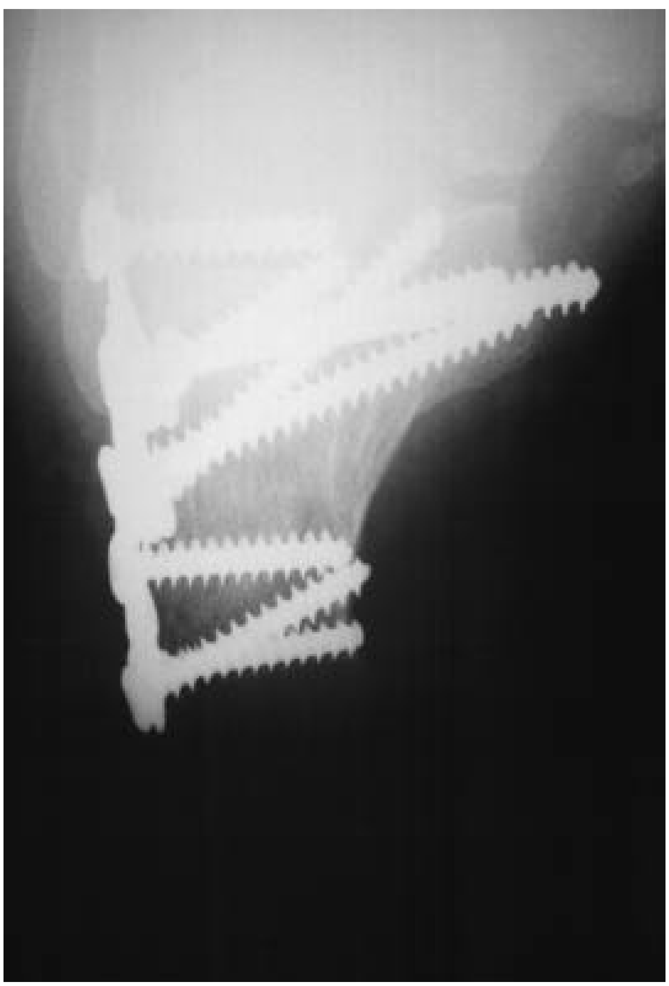

Figure 12b. Postoperative axial view of different patient showing proper orientation of screws to medial cortex.

Figure 12c. Postoperative Broden view showing reduction of posterior facet and placement of screws.

don, the natural tendencies for the lateral aspect of the posterior facet to tilt anteriorly and the anterior column to dorsiflex. For those reasons, I favor either the Sanders plate or multiple-stacked H-plates oriented at 60° to one another. Both the latter arrangement and the reconstruction plates tend to be a bit bulky, but surprisingly the increased lateral width is seldom a postoperative problem (Fig. 11).

The plate should be attached in some fashion to the stable medial sustentacular fragment. This attachment to the medial sustentacular fragment assures that the plate will be secured to the best quality of available bone. Even if the lateral wall fragments are somewhat soft, the strong cortical composition of the medial wall allows for a stable buttress effect by virtue of good purchase of the screw threads in the wall. Generally these plates are secured with fully threaded screws, unless interfragmentary compression is possible through one or more of the plate holes (Fig. 12).

Final X-rays are taken in the operating room to assure proper placement of the hardware and proper alignment. The tourniquet is released prior to closure, and residual bleeding is controlled. The wound is generally closed only with skin sutures or staples. Occasionally, subcutaneous sutures may be used. A small suction drain is typically utilized, and a compressive splint secures the foot in neutral position.

POSTOPERATIVE CARE

Following open reduction and internal fixation, the patient is placed at bed rest for 24 to 48 hours with the leg elevated. Suction drains are removed on the second or third postoperative day.

If rigid internal fixation has been achieved, then active and passive range-of-motion exercises are begun on the second or third postoperative day. It is critical to impress upon the patient the importance of early motion to enhance the probability of a good functional result. Initially, it is often helpful to use oral or parenteral narcotics prior to each therapy session. Patient-controlled analgesia may be instituted to facilitate early range of motion. If available, another party is taught to assist the patient in performance of passive range-of-motion exercises of the subtalar and midtarsal joints with vigor.

Except during physical therapy, the leg is immobilized in a removable short-leg splint or cast. If fixation was tenuous, then only gentle active range-of-motion exercises are permitted early. In some cases multiple transarticular pins preclude mobilization of the joints.

Weight bearing is permitted no sooner than eight weeks postsurgery. It is unrealistic to expect sufficient healing to occur to withstand major weight-bearing forces. It is better to protect the extremity in a short-leg walking cast or splint after the eight-week period of non-weight bearing. Careful radiographic assessment will also guide one's postoperative regimen, but failure from late collapse is quite possible with premature repetitive loading.

RESULTS

Assessment of ultimate patient outcome is best delayed for about a year following surgery. Most patients will not stabilize before this time; in fact, the plateau may not be reached for two years. Careful and honest assessment of postoperative results will enable further refinement of the technique and indications for this challenging fracture.

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