Acute Calcaneal Fractures: Treatment Options and Results

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Abstract

The treatment of choice for acute displaced intra-articular calcaneal fractures remains controversial. The authors present a brief historical review of treatment options and results, coupled with the biomechanical rationale for open reduction and internal fixation. Their current management protocol and surgical technique are outlined, along with preliminary functional results at an average follow-up of 2.5 years.

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The calcaneus is the most commonly fractured tarsal bone. Despite the orthopaedic community's length of experience with this injury, treatment remains a source of controversy. Historically, the treatment of acute calcaneal fractures has been largely dissatisfying due to the marginal functional results. In 1916 Cotton and Henderson, writing on the basis of their experience with conservative treatment, stated that "the man who breaks his heel bone is done." This view was reiterated by Conn, who in 1926 reported that "calcaneus fractures are serious and disabling injuries in which the end results continue to be incredibly bad." In 1942 Bankart's experience was summarized when he wrote, "the results of crush fractures of the os calcis are rotten."[1]

The search for improved results has provided a strong impetus for the development of alternative treatment methods. Historically, a wide spectrum of treatment options have been advocated. Elevation, compression, and early range-of-motion exercises without reduction were supported by Rowe et al.[2] Gissane and Bohler advocated closed manipulative reduction by means of percutaneous pins placed in the tibia and calcaneus, followed by casting.[3] Gallie[4] and Hall and Pennal[5] reported their results with primary arthrodesis as the treatment of choice for severely comminuted os calcis fractures. Recently, open reduction with rigid internal fixation has gained increasing support.

The lack of consensus regarding the most appropriate treatment of calcaneal fractures has resulted in part because the association between classification and treatment has not been consistent. Clearly, a meaningful classification scheme must include information relative to pattern of injury, prognosis, and treatment. Several authors have proposed schemes based on fracture configuration and the degree of involvement of the posterior facet,[1,6-8] but the prognostic value of these schemes has been variable. Consequently, there is no single method of classification that has gained universal acceptance or that reliably addresses these issues.

For the purpose of data collection, we use the classification system described by Letournel.[6] This system is based on the premise that all displaced calcaneal fractures have one fracture line in common, the separation fracture (the primary fracture line). This fracture line runs obliquely anterior to posterior, breaking the calcaneus into two pieces through the sinus tarsi or the posterior facet, and always lies behind the interosseous ligament. An essential feature of this fracture line is that it creates a fragment (the sustentaculum tali) that remains attached to the talus by the interosseous ligament. The simplest displaced fractures end with this line and are considered two-part fractures (Fig. 1). These are extremely rare injuries, as the associated trauma usually creates secondary fracture lines that extend throughout the remainder of the calcaneus.

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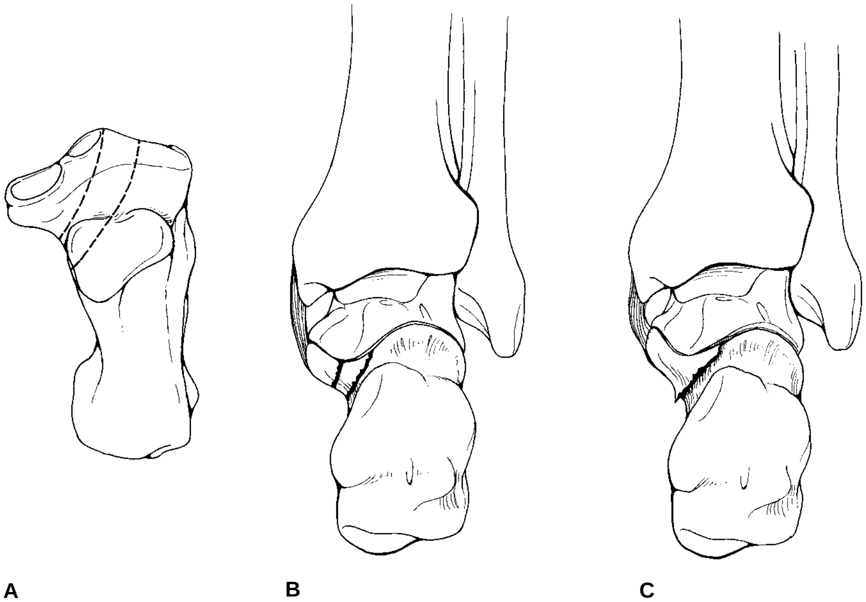


Fig. 1 Constant separation fracture line. **A,** Fracture runs through the sinus tarsi behind the interosseous ligament. **B,** Fracture intersects the thalamus (posterior facet). **C,** Two-fragment fracture without displacement (exceptional).

In a simple three-part fracture, there is an additional fracture line through the posterior facet. If this fracture line involves only the posterior facet without extension into the tuberosity, it is considered an impaction fracture or a joint-depression fracture (Fig. 2). In a tongue-type fracture, the fracture line continues posteriorly to include the posterior facet and exits through the posterior aspect of the tuberosity (Fig. 3). In the simplest fractures, the inferior cortex of the calcaneus remains intact, thereby preserving the general morphologic features of the bone.

Complex fractures result in four or more fragments. These include the two basic fragments from the primary fracture line and the posterior facet fragment in combination with other fragments created by secondary fracture lines that extend through the inferior cortex and the anterior process of the calcaneus. These fractures disrupt the whole morphologic structure of the bone and are associated with severe disruption of the lateral cortex caused by violent impaction of the posterior facet (Fig. 4).

Although we use Letournel's classification system for descriptive purposes, we do not consider this system comprehensive enough to serve as the only basis for a decision to proceed with operative intervention. We believe an important criterion is restoration of biomechanical function.

Biomechanical Rationale for Open Reduction

An evaluation of normal hindfoot function provides the most compelling evidence in support of anatomic reduction of calcaneal fractures. Because the majority of calcaneal fractures involve the talocalcaneal articulation, a good understanding of subtalar joint function is important in comprehending the rationale for anatomic reduction. Further support for anatomic restoration comes from an understanding of the relationship between normal calcaneal morphology and hindfoot function during normal gait.

Subtalar Joint Function

One important function of the subtalar joint is its action as a torque converter producing a cushioning effect on the foot. During normal gait, between the phases of "heel strike" and "foot flat," the subtalar joint converts the normal internal

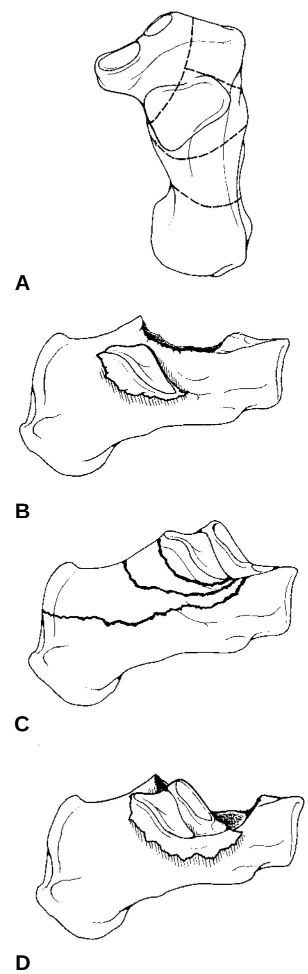
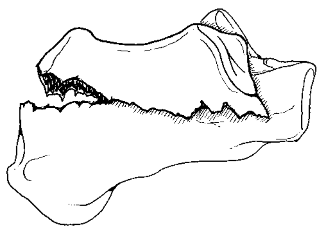


Fig. 2 Three-fragment fractures. **A,** Impaction of the thalamus; the various fracture lines are seen from above. **B,** Horizontal impaction of the thalamus. **C,** Possible fracture lines of a vertical impaction. **D,** Vertical impaction of the thalamus.



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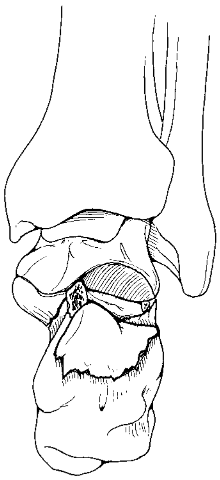


B

Fig. 3 Tongue-type fracture vertical impaction of the thalamus. **A,** Lateral view. **B,** Axial view of the tongue.

rotation of the tibia into pronation of the foot by increasing the talocalcaneal angle (producing hindfoot valgus) and unlocking the transverse tarsal joints. This torque conversion results in a softening of the arch, allowing shock absorption because the arch functions as a leaf spring (Fig. 5). Between the phases of "foot flat" and "toe off," normal external rotation of the tibia causes convergence of the talocalcaneal angle (producing hindfoot varus), which locks the transverse tarsal joints and creates a more rigid platform for push-off.[9,10]

The second important function of the subtalar joint is to allow the foot to adapt to uneven surfaces through inversion and eversion. These actions protect the tibiotalar joint, where motion is normally limited to the sagittal plane. Without free subtalar inversion and eversion, the tibiotalar joint is exposed to unusually high stresses out of its normal plane of motion. Long-term studies of subtalar and triple arthrodeses have shown that significant degenerative changes occur in the ankle when the subtalar joint is unable to cushion and protect the ankle from medial and lateral tilt stresses.[11]

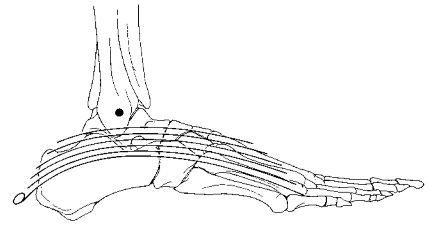
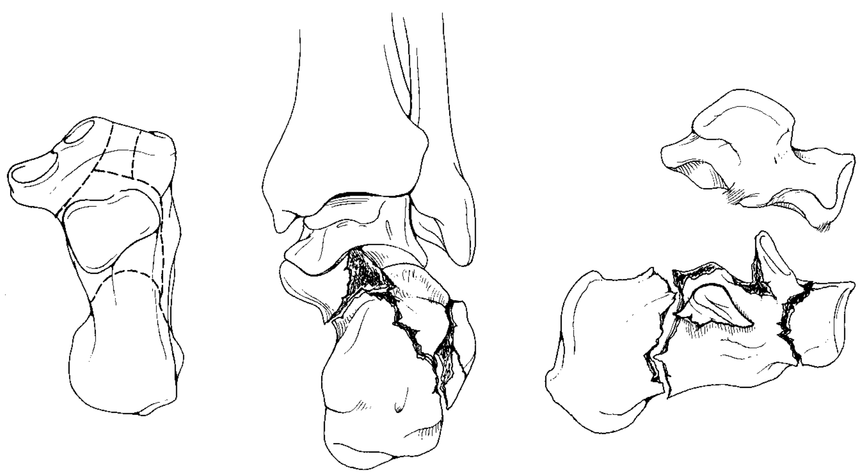


Fig. 5 The osseous and ligamentous structures of the foot soften the arch when the tibia is internally rotated and locked onto the dome of the talus. Pronation occurs at the beginning of the weight-bearing portion of the gait cycle as the foot strikes the ground and accepts body weight. The foot rotates laterally under and in front of the talus, and as a result the arch of the foot functions as a leaf spring.



A B C

Fig. 4 Complex calcaneal fractures comprising four fragments or more. **A,** Fracture lines on the upper aspect of the bone. **B,** Axial view of fracture. **C,** Lateral view of a complex fracture.

Calcaneal Function

Normal calcaneal morphology contributes to three principal functions of normal gait, which are variably disrupted dependent on the fracture pattern:

1. The normal calcaneus provides a lever arm to increase the power of the gastrosoleus mechanism. This lever arm is extended through the midfoot and forefoot by normal subtalar supination with simultaneous locking of the transverse tarsal articulations. To maximize the efficiency of its lever-arm function, the calcaneus must provide a fulcrum in the midbody of the talus, and it must interact normally with its motor, the gastrosoleus muscle. High-energy calcaneal fractures markedly disrupt these anatomic relationships and have a profound effect on hindfoot function. The gastrosoleus muscle is functionally weakened when the subtalar joint is disrupted and the tuberosity of the calcaneus is displaced proximally.

2. Normal calcaneal structure provides a foundation for body

weight transmitted through the tibia, ankle, and subtalar joints. The normal vertical-support function of the calcaneus is dependent on its normal alignment beneath the weight-bearing line of the tibia to prevent eccentric weight distribution in the foot. Lateral displacement of the calcaneus may result in fibular or peroneal impingement. In addition, eccentric weight-bearing may cause a valgus tilt of the hindfoot, resulting in increased stresses on medial soft-tissue structures (deltoid ligament and posterior tibialis muscle). Medial displacement of the body of the os calcis results in varus alignment, causing increased compressive forces on the medial aspect of the ankle and increased tension on the lateral soft-tissue structures (lateral ligaments and peroneal muscles). This deformity may predispose to lateral ankle sprain and eventually lead to varus tilting of the talus and secondary ankle arthrosis. Direct vertical collapse of the calcaneus results in impaction of the talus into the body of the calcaneus. The talus then assumes a more dorsiflexed position in the ankle mortise, which can result in anterior ankle impingement, decreased ankle dorsiflexion, and accelerated arthrosis.

3. Normal calcaneal anatomy provides structural support for the maintenance of normal lateral column length, which affects abduction and adduction of the midfoot and forefoot. In addition, lateral support indirectly assists in supination of the foot to provide strong push-off during gait. When the anterior process of the calcaneus is fractured, often there is shortening and loss of lateral column length. As a result, the midfoot and forefoot are forced into abduction through Chopart's joint, the naviculocuneiform joint, or Lisfranc's joint. Abduction leads to increased tension on the posterior tibial tendon and may lead to lateral peritalar subluxation or frank dislocation with posterior tibial tendon rupture. As the calcaneus continues to migrate laterally, there may be talocalcaneal impingement in the sinus tarsi. This degree of malalignment causes severe compromise in the vertical-support function of the calcaneus.

Criteria and Goals for Surgery

The important relationships between the calcaneus and normal hindfoot function underlie the biomechanical rationale for the surgical restoration of normal calcaneal anatomy. Absolute indications for operative fixation have not been determined and will vary among orthopaedists. The important criteria we consider in our decision to pursue operative intervention include: (1) the degree of distortion in the relationship between the posterior facet and the middle and anterior facets, which may contribute to the development of restricted subtalar motion; (2) the amount of displacement within the posterior facet; (3) the amount of lateralization of the tuberosity; and (4) the degree of widening of the foot and other factors such as displacement of the tuberosity and / or calcaneocuboid joints.

The goal of surgery should be to restore normal calcaneal morphology and regain the normal height, width, length, and longitudinal axis of the calcaneus, with stable anatomic reconstruction of all joint surfaces to allow early motion. Calcaneal body fractures that do not change the weight-bearing surface of the foot or alter normal hindfoot mechanics usually receive closed treatment. In a simple fracture pattern with only a primary fracture line extending through the posterior facet, 2 mm of displacement may be tolerated and closed reduction can be used. We believe that fractures with displacement of 3 mm or more should be treated with open reduction and internal fixation. We believe there is no fracture too comminuted for reduction, because the salvage for a severely comminuted, malunited fracture is usually more difficult than the initial fracture surgery.

We try to reconstruct all fractures within 10 days from the time of injury if soft-tissue conditions are favorable. Reduction becomes very difficult after 3 weeks.

Preoperative Evaluation and Treatment

Displaced intra-articular fractures of the calcaneus are the result of high-energy axial-loading injuries. Consequently, the damage to the surrounding soft-tissue envelope may be extensive, resulting in significant swelling. Fracture-blister formation is common. To minimize soft-tissue compromise during the preoperative period, the foot should be elevated to the level of the heart and immediately splinted with the ankle in neutral position. Surgical timing is dependent on the condition of the soft tissues. Swelling should be decreased such that tissue turgor allows skin wrinkling in response to gentle pressure. Fracture blisters should be debrided and allowed to epithelialize prior to surgical reconstruction.

Understanding the fracture pattern is dependent on the appropriate radiographic evaluation. Preoperative lateral and axial plain films are essential for the preliminary investigation of the fracture type. In addition, transverse (parallel to the plantar surface) and coronal (perpendicular to the posterior facet) computed tomographic (CT) scans should be obtained to evaluate the fracture pattern and degree of comminution. The CT scans should be evaluated to determine the degree of widening of the heel and the amount of hindfoot varus, calcaneocuboid disruption, anterior process injury, and posterior facet involvement. We have found no real advantage to three-dimensional CT scans in preoperative planning.

Operative Technique

The goal of surgery is anatomic reduction of the calcaneus and rigid internal fixation so that early motion can proceed. Restoration of the articular surfaces, overall shape, and alignment of the calcaneus is critical to achieve successful functional results.

Historically, the specific surgical approach for reduction has been the source of controversy in the treatment of these injuries. The medial approach has been advocated by McReynolds.[12] The benefits of this approach include good visualization of the sustentaculum tali and the ability to control varus and valgus alignment. The disadvantages include poor visualization of the posterior facet and lateral wall and the lack of exposure of the calcaneocuboid articulation.

The lateral approach to the calcaneus has been favored by Palmer[13] and Letournel[6] and has been modified by Benirschke.[14] This approach is our method of choice for treating displaced intra-articular calcaneal fractures. The advantages include excellent exposure of the tuberosity, posterior facet, lateral wall, and calcaneocuboid articulation. Reduction of the sustentaculum to the tuberosity through the lateral approach is performed indirectly.

Stephenson[15] advocates a combined lateral and medial approach to difficult fractures. This method offers the advantages of both approaches; however it requires substantial soft-tissue stripping and disruption of the calcaneal blood supply.

To perform a lateral approach, the patient is placed on the operating table in the true lateral position. The extremity is exsanguinated, and a pneumatic tourniquet is used for hemostasis. After identification of the important superficial landmarks, including the fibula, the Achilles tendon, and the base of the fifth metatarsal, a J-shaped (left side) or L-shaped (right side) incision is made laterally (Fig. 6) with care to avoid injury to the sural nerve. The incision should extend directly to bone plantar to the peroneal tendons to allow the development of a full-thickness periosteal-cutaneous flap. The calcaneofibular ligament and peroneal tendon sheaths are sharply dissected off the lateral wall of the calcaneus and maintained within the flap. Progressive dorsally directed dissection results in a full view of the tuberosity, subtalar joint, and anterior process. Two small K wires can be placed into the lateral aspect of the talus to serve as soft-tissue retractors of the flap. Distal extension of the incision with dissection over the peroneal tendons may be necessary to fully visualize the calcaneocuboid joint.

Once adequate exposure has been obtained, the blown-out portion of the lateral wall is removed and marked to preserve its orientation. The posterior facet is then disimpacted from the body of the calcaneus and inspected to document the extent of comminution and articular cartilage disruption. If the posterior facet is comminuted, it should be anatomically reconstructed on the back table using 0.045-inch K wires. We have found that many intra-articular fractures have associated extension into the anterior process. In this situation, the first step is to reduce the sustentacular fragment to the anterior process at the critical angle of Gissane. This reduction is provisionally held with 0.045-inch K wires.

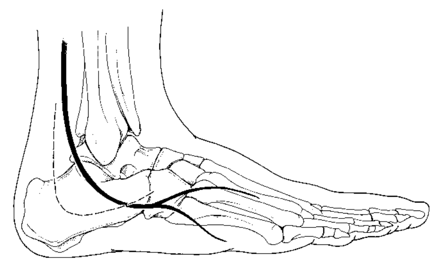


Fig. 6 Surgical approach (dashed line). Sural nerve (solid lines) is shown just above it within the elevated periosteal-cutaneous flap.

Next, attention is turned to reducing the posterior facet to the anterior process–sustentaculum complex. Again, K wires are used for provisional fixation. The tuberosity is then indirectly reduced to the sustentacular complex and the medial wall with the use of a 4.0- or 5.0-mm Schanz pin introduced laterally into the tuberosity. The Schanz pin is used to manipulate the tuberosity and secure anatomic alignment in the varus-valgus planes (Fig. 7). This reduction is provisionally held with 0.062-inch K wires directed axially.

Alignment and reduction are then confirmed with intraoperative lateral and axial radiographs. Bone defects are filled with cancellous graft. The lateral wall is replaced, and a 3.5- or 2.7-mm reconstruction plate is contoured to span from the tuberosity to the anterior process laterally. The plate is fixed with 3.5- or 2.7-mm screws. Two additional 3.5-mm thalamic lag screws are placed beneath the articular surface of the posterior facet to maintain the reduction of the posterior facet to the sustentacular fragment (Fig. 8). Additional fixation of the posterior tuberosity is often necessary if a tongue component exists. This is best accomplished with a small or medium cervical H plate placed under the reconstruction plate and extending over the dorsal aspect of

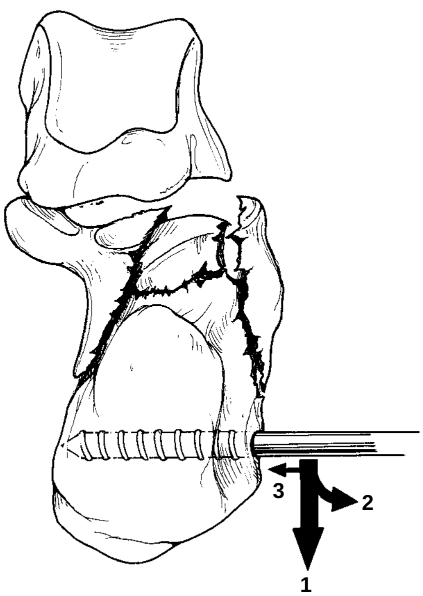


Fig. 7 A 4.0- or 5.0-mm Schanz pin is placed laterally in the tuberosity fragment. Vectors of manipulation, all with reference to the sustentacular fragment, are as follows: 1, restoration of height; 2, valgus alignment; 3, medial translation. Medial wall reduction is indirect.

the tuberosity. All provisional fixation is then removed. In areas not suited for screw fixation, such as the anterior process at the critical angle of Gissane, K wires are left in, impacted next to the plate.

The wound is closed over a ⅛-inch suction drain brought out dorsolaterally through the skin overlying the sinus tarsi. The drain is routinely removed 48 hours after the operation. The periosteal-cutaneous flap is closed as a single layer using 2-0 Vicryl in an inverted, interrupted fashion. The skin is closed using a 3-0 nylon horizontal stitch to minimize tension on the edge of the flap.

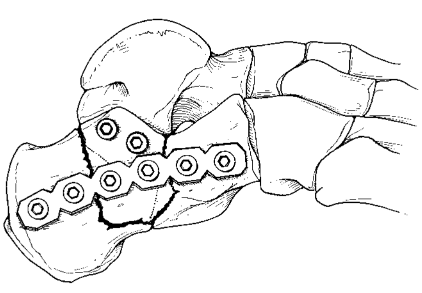


Fig. 8 Lateral view of reconstruction performed with use of a 3.5-mm reconstruction plate extending from the tuberosity to the anterior process, with two separate lag screws to stabilize the posterior facet.

Postoperative Care

Initially, the leg is splinted with the ankle in neutral position for 72 hours and then placed in a removable aluminum splint with a sheepskin lining. When the incision is dry (3 to 5 days), an active ankle and subtalar range-of-motion exercise program is begun. The exercise program also includes passive stretching of all toes to avoid the development of flexion contractures. Sutures are removed at 3 weeks, and patients avoid weight-bearing for 12 weeks postoperatively. Patients are fitted with support stockings to control edema and are encouraged to continue their use for 6 months. Hardware is usually removed at 1 year, depending on symptoms and patient preference.

Results of Treatment

Literature Review

It is difficult to interpret the comparative results of various treatment modalities advocated in the past. Studies have been done on patient populations with different countries of origin, using numerous fracture classification systems to describe injuries treated with various surgical approaches. To date, there have been no prospective studies.

Letournel[6] used a lateral approach to gain stable anatomic reduction and fixation in 99 patients with intra-articular calcaneal fractures. His results at 2-year follow-up were good or very good in 56% of cases, fair in 33%, and bad in 11%. The patients with good and very good results had no functional disability or only occasional pain while walking on uneven surfaces. Forty-seven percent had useful subtalar motion following open reduction and internal fixation. There were three infections (3%) and six technical failures (6%).

Sanders et al[8] used a combination of the lateral and modified lateral approach and correlated their operative results in 120 patients with a new classification system based on the CT evaluation of associated comminution at the posterior facet of the calcaneus. They found that the clinical results deteriorated with increasing comminution of the posterior facet. Seventy-three percent of patients with mild to moderate comminution had excellent or good clinical results, while only 9% of patients with severe comminution of the posterior facet had good to excellent results. Reported complications included two cases of infection leading to osteomyelitis. Eighteen percent of patients developed peroneal tendinitis, which responded to plate removal, and 12 patients had variable symptoms related to sural neuromata.

Tscherne and Zwipp[16] used a combination of medial, lateral, and bilateral approaches in their treatment of 157 displaced calcaneal fractures. They developed a fracture-classification scoring system based on the number of fracture fragments, the degree of joint involvement and soft-tissue injury, and the presence of associated foot fractures, which they considered predictive of clinical outcome following open reduction and internal fixation. Using their scoring system, they reported an inverse relationship between fracture severity and clinical outcome following surgery. Complications included wound margin necrosis in 8.5% of cases, hematomas requiring decompression in 2.6%, and a deep infection in 2.0%. These complications developed independent of which operative approach was used.

Authors' Results

We have yet to fully analyze the long-term functional results of our treatment protocol, but we have conducted a preliminary review of over 100 displaced intra-articular calcaneal fractures treated with open reduction and internal fixation through a lateral approach. To date, our results have been encouraging, but our preliminary experience has not been subjected to rigorous analysis. The ongoing functional assessment is currently at an average follow-up of more than 2 years. Patients are evaluated to determine their level of physical activity and limitations in activities of daily living. In addition, data on pain-medication requirements and work status are being collected.

Our most recent surveillance indicates that the majority of patients (65%) are limited only in their ability to participate in vigorous activities and sports. Over 50% of patients are able to walk comfortably on any surface. Sixty percent report no need for medications to control discomfort. Forty percent of patients have been unable to return to their previous employment due to functional limitations caused by the calcaneal fracture. Approximately 70% of patients have been completely satisfied with their surgical outcome to date.

Our preliminary evaluation of morbidity reveals that skin loss at the wound margin is the most common complication and occurs in approximately 10% of patients. This problem responds well to daily dressing changes on an outpatient basis. The incidence of superficial wound infection has been less than 2%, and deep infection requiring hardware removal has yet to be encountered. Approximately 20% of patients have peroneal tendinitis necessitating hardware removal. To determine the longer-term functional results and incidence of morbidity, we will be conducting a rigorous analysis of our data.

Summary

We have found that there is a steep learning curve associated with the demanding surgical technique necessary for the successful reconstruction of acute calcaneal fractures. Familiarity with the surgical technique and the demand for meticulous handling of soft tissues during this approach are critical factors in achieving a successful result and avoiding postoperative complications. There are a number of pitfalls during the approach to these fractures that can frustrate the inexperienced surgeon and lead to poor results, such as inability to achieve adequate reduction to secure fixation.

Although a number of patients are left with functional limitations following open reduction and fixation of calcaneal fractures, the majority of limitations are modest when compared with the previously reported results of conservative treatment. These improved results come from our ability to surgically restore the articular surfaces of the subtalar joint and overall calcaneal morphology, upon which normal biomechanics and hindfoot function depend. Unfortunately, the disruption of articular cartilage is a variable over which we have no control but which clearly has an impact on the functional outcome. Although the final determination of the treatment of choice for these difficult fractures will depend on well-controlled randomized clinical trials, we believe that reconstruction of normal calcaneal anatomy should be the goal when treating these potentially devastating injuries.

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