Open calcaneal fractures are uncommon, but potentially devastating traumatic hindfoot injuries. Compound fractures comprise 3%-6% of all os calcis fractures. Published series are limited in number; they generally consist of multiply injured patients referred to regional trauma centers. A wide continuum of injury patterns have been documented with an equal array of treatments and outcomes. Although the initial, emergent treatment of an open fracture-disruption has become fairly standardized, subsequent treatment addressing the injury’s osseochondral component remains controversial. A thorough review of the available literature assists in establishing a knowledge base on this devastating hindfoot injury. A treatment protocol is proposed to provide a basis for future treatment advances.

**LITERATURE REVIEW**

Few published reports detail the treatment and outcomes following compound calcaneal fractures. Furthermore, a critical review of the few published series demonstrates therapeutic interventions, timings, complications, and outcomes.

Siebert et al reported 36 open calcaneal fractures managed over a 5-year period. In this series, a majority of the patients were referred after initial care was provided elsewhere. Specifically, in 29 of 36 fractures, the initial intervention was not dictated by the authors. The overall complication rate was remarkably high—>60% of patients developed wound complications. Nine of 17 patients with Gustilo III type wounds developed osteomyelitis or joint sepsis. Five limbs were amputated for uncontrolled infection; 1 limb required joint arthrodesis. Severe functional deficits and chronic pain resulted in most patients. After documenting the poor outcomes and high complication rate, the authors recommend that management of the soft tissue disruption and avoidance of infection should be the initial treatment focus, rather than fracture stabilization.

Aldridge et al reported 19 open os calcis fractures treated over a 10-year period. In this series, 17 fractures underwent some form of internal fixation, yet the overall complication rate was only 11%. The number of days to internal fixation averaged 7 days post-injury (range: 0-22 days). One patient required a below-the-knee amputation. Four free flaps were performed. At 26-month follow-up, 737
the average American Orthopedic Foot and Ankle Society hindfoot score was 82 points. In accordance with Siebert et al, the authors concluded that these open injuries be initially managed with aggressive wound care followed by delayed fracture stabilization.

Heier et al reported 43 fractures treated over a 9-year period. Various forms of stabilization were undertaken in approximately 70% of cases. Approximately 25% underwent a primary arthrodesis. Six limbs were amputated. Eight flaps and 5 split-thickness skin grafts were performed. All 8 Gustilo I type injuries fared well. Overall, a 37% infection rate was reported. Furthermore, in Gustilo IIIb wounds, 11 complications developed in 12 patients. Therefore, complication rates appeared to correlate to the severity of the soft-tissue injury. The authors concluded that patients with high-grade open calcaneal fractures be informed of the likelihood of chronic debilitating pain and dysfunction. They should be forewarned that an amputation may be necessary, especially if significant complications arose.

Lawrence and Grau reported 48 open fractures treated over a 7-year period. The ratio of blunt to penetrating trauma was 7:1. Of the blunt trauma patients, >90% sustained multiple orthopedic and non-orthopedic injuries. Two below-the-knee amputations were performed as primary intervention. Of patients with open calcaneus fractures, 23% sustained a local neurovascular injury and >40% sustained concomitant ipsilateral foot and ankle fractures. In this series, 42% underwent some form of internal fixation. Five wounds required free flap coverage. The overall complication rate was approximately 5%. Unfortunately, long-term functional outcomes were not discussed.

**DISCUSSION**

The orthopedic literature remains controversial regarding the optimal management of compound calcaneal fractures. Nonetheless, considerable insight into the injury can be derived from the limited number of reported series. Isolated open calcaneal fractures are relatively rare and appear to be associated with multiple-injured patients with high-energy injuries (Figure 1). Commonly, patient resuscitation is necessary prior to management of musculoskeletal injuries. Following hemodynamic stabilization, a thorough wound evaluation and detailed neurovascular assessment of the limb are necessary (Figure 2). Hindfoot radiographs and computed tomography are recommended to assess fracture comminution and displacement.

The fundamental tenets of open fracture care remain the cornerstone of initial management for these hindfoot fracture-
disruptions. Tetanus prophylaxis is administered, if indicated. Emergent serial irrigation and debridement is performed and repeated every 48 hours until a stable, clean wound results. Antibiotic coverage with cefazolin and gentamycin is appropriate in most instances; however, contaminated wounds resulting from marine or barnyard injuries are best managed with triple antibiotic coverage until culture-based sensitivities are available.

In a majority of instances, the traumatic wound can be closed primarily or secondarily. Closure by secondary intent is appropriate if viable wound edges are not opposable and no exposed osseous or neurovascular structures are present. In this instance, local wound care is instituted. A recent addition to nonsurgical options is the vacuum-assisted closure, a treatment modality that promotes secondary wound healing by augmenting the rapid in-growth of granulation tissue. In severely disrupted wounds, a free microvascular tissue transfer may be necessary, especially in exposed bony or neurovascular elements. In such instances, internal fixation of the osseochondral injury should be performed prior to the free tissue transfer procedure.

Means to stratify injury severity have not been established. By default, the Gustilo-Anderson7 and Sanders classification9 schemes have been applied, either singularly or in combination, by most clinicians to describe the injury patterns. Neither scheme, unfortunately, is intended for this purpose. Overall, the severity of the soft-tissue disruption and fracture subtypes appear to parallel the prognosis, outcome, and complication rates.

**TREATMENT SUGGESTIONS**

Distinct treatment phases need to be defined, as the timing of treatment may be as important as the treatment type. As highlighted by several series,3,5 overzealous attempts at fracture stabilization frequently result in wound difficulties, infection, or both. On the other hand, delays >3 weeks may be hampered by early fracture healing. Delineation of specific phases is intended to guide the timing of intervention for these complex injuries.

The University of Kentucky hospital’s experience with open os calcis fracture management has been reported previously.6 Considerable value exists in dividing treatment into three phases—acute, subacute, and reconstructive (Table). The acute phase comprises the initial 10 days following injury; the subacute follows the acute and extends to day 21; the reconstructive stage begins at 3 weeks and continues indefinitely.

During the acute phase, the priority of the initial treatment is soft-tissue management. Meticulous but aggressive debridement of devitalized tissues with wound irrigation is a critical component of care—this appears to minimize the risk of complications such as deep infection. Occasionally, after open fracture care has been successfully completed, no further operative care is necessary, except for fracture immobilization until healing. However, this is a rare occurrence. During the acute stage, due to traumatized soft-tissue envelope, traditional forms of plate and screw osteosynthesis are best avoided. However, osseous stabilization with minimal internal fixation, such as Kirschner wires, percutaneous cannulated screws, or application of an external fixator, appears to be valuable while invoking a minimal increased risk of infection.6 However, these techniques are generally undertaken on severely disrupted fractures where anatomic reduction of the articular surface is not possible (Figure 3). The fixation is used to circumvent superior or migration of the tuberosity fragment due to the unbridled effect of the Achilles tendon.

Formal plate and screw osteosynthesis is probably best reserved for the subacute phase. This time period follows stabilization of the scant soft-tissue envelope, but proceeds prior to bony consolidation. Fracture subtypes amenable to reconstruction were found in >60% of a large series of open os calcis fractures (Figures 4 and 5).10 Therefore, many tongue-type, one-, two-, and three-part fractures of the posterior facet may be appropriate for delayed reconstruction in the subacute phase (Figures 6 and 7).

The third, or reconstructive, phase extends beyond the critical 3-week “fracture repair” period; therefore, open reduc-

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**TABLE**

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<thead>
<tr>
<th>Phases</th>
<th>Days</th>
<th>Treatment</th>
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<tbody>
<tr>
<td>Acute</td>
<td>0-10</td>
<td>Open fracture care (mandatory) Minimal internal fixation techniques in appropriate fractures</td>
</tr>
<tr>
<td>Subacute</td>
<td>11-20</td>
<td>Minimal internal fixation or plate and screw osteosynthesis in appropriate fractures</td>
</tr>
<tr>
<td>Reconstruction</td>
<td>≥21</td>
<td>Arthrodesis combined with other forms of reconstructive procedures</td>
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</tbody>
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*Note. Amputation is a potential treatment option in any phase.*
tion and internal fixation of a comminuted calcaneal fracture with a disrupted subtalar joint should not be attempted in this phase. Open reduction and internal fixation of the body of the os calcis combined with arthrodesis is recommended.9 Additionally, fractures with non-reconstructible (≥4-part) fractures of the posterior facet are probably best treated during this phase with a subtalar arthrodesis (Figure 8). Arthrodesis may be undertaken with minimal risk during this phase, as the soft-tissue condition has stabilized, the risk of infection is no longer a concern, and consolidation of multiple tuberosity fracture fragments has begun, facilitating a “compression” arthrodesis of the subtalar joint.

As recommended by Heier et al,5 all patients should be forewarned that extensive and protracted series of staged surgical procedures may be necessary. They should understand that chronic pain and ambulatory dysfunction are relatively common, especially with high-grade injuries. Unfortunately, disastrous outcomes may result despite appropriate treatment.

The exact role of limb amputation for high-grade open calcaneal fractures remains controversial. Sound clinical judgment is necessary to predict whether a series of complex reconstructive procedures will likely result in a more functional outcome than amputation. This procedure may be necessary in any of the three treatment phases. Circumstances such as severe fracture comminution with articular damage, combined with adjacent ipsilateral foot and ankle injuries, neurovascular defects, advanced age, severe patient compliance issues, or severe systemic medical comorbidities may favor ablative surgery.

SUMMARY

Open calcaneal fractures can be managed with an array of treatment techniques and result in a wide range of outcomes. Due to the fracture’s relative obscurity, the optimal form of intervention remains controversial. Consequently, treatment for these hindfoot fracture-disruptions continues to evolve. Timing of intervention may be a key factor in decreasing complication rates.

The goals of open calcaneal fracture management include timely healing of the soft-tissue envelope without infection and maintenance of bony alignment. Unfortunately, restoration of joint congruence may be impossible. Unsatisfactory outcomes may result from neurogenic pain, infection, malunion, arthrosis, and bony impingement. Future advancements in treatment are anticipated and will depend on an improved understanding of this devastating orthopedic injury.
REFERENCES


