Open Fractures of the Calcaneus: Soft-Tissue Injury Determines Outcome

By Keith A. Heier, MD, Anthony F. Infante, DO, Arthur K. Walling, MD, and Roy W. Sanders, MD

Investigation performed at Tampa General Hospital, Tampa, Florida

Background: Studies of open calcaneal fractures have been limited and have not analyzed results according to wound location, severity of soft-tissue disruption, fracture type, or treatment method. In this study, results were evaluated on the basis of the hypothesis that early surgical intervention was indicated.

Methods: Between 1989 and 1997, 503 calcaneal fractures were treated at our institution, and forty-three of these fractures, in forty-two patients, were open (8.5%). According to the Gustilo classification there were nine type-I, eight type-II, twelve type-IIIA, and thirteen type-IIIB open fractures as well as one type-IIIC open fracture. All fractures were treated according to the same protocol, consisting of intravenous administration of antibiotics chosen on the basis of the wound type, irrigation and débridement in the operating room, temporary wound coverage, and initial stabilization of the limb. Definitive final fixation was performed after the wound was clean, and soft-tissue swelling was minimal. The final follow-up examinations were performed at a minimum of two years after treatment. Clinical results were graded with use of the AOFAS (American Orthopaedic Foot and Ankle Society) score.

Results: An infection developed at the sites of 37% of the forty-three fractures, with osteomyelitis developing at the sites of 19%. Seven of the nine type-I open fractures were treated with open reduction and internal fixation or with primary fusion, with no major complications and a good-to-excellent short-term result. Three of the eight type-II open fractures were complicated by an infection. Three of the twelve type-IIIA open fractures and ten of the thirteen type-IIIB open fractures were complicated by an infection. Six of the infections associated with a type-IIIB open fracture progressed to osteomyelitis, and three of those cases led to an amputation. Overall, thirteen (50%) of the twenty-six type-III open fractures were complicated by an infection, with osteomyelitis occurring in seven (27%). Thirty-three patients with a total of thirty-four open calcaneal fractures were available for follow-up at a minimum of two years, and an average of fifty-five months. The average AOFAS hindfoot score for the twenty-seven patients who had not undergone amputation was 71 points.

Conclusions: Open calcaneal fractures have a high propensity for deep infection despite the use of an aggressive treatment protocol to prevent it. It appears that type-I and type-II open fractures associated with a medial wound can be treated with open reduction and internal fixation. Type-II fractures associated with a wound in another location should be treated with limited or no internal fixation. Type-III open fractures, and especially type-IIIB open fractures, require extensive débridement and prompt soft-tissue coverage as soon as possible. Early internal fixation should be avoided in this subgroup because of the high rates of osteomyelitis and subsequent amputation.

Level of Evidence: Prognostic study, Level II-1 (retrospective study). See Instructions to Authors for a complete description of levels of evidence.

Many studies have shown that open reduction and internal fixation is the preferred treatment for closed calcaneal fractures[1-7]. Although intra-articular fractures require an anatomic reduction with stable internal fixation to maximize the chances of good joint function[4], there is uncertainty about whether open fractures should be treated with open reduction and internal fixation. Previous studies have shown that treatment of open ankle fractures with immediate open reduction and internal fixation and delayed wound closure has excellent results, with less impairment, shorter hospital stays, and better functional outcomes than those following nonoperative treatment and with infection rates similar to those associated with nonoperative treatment[8,9]. Gustilo[10] also showed that fracture stability preserves soft-tissue integrity, decreases the risk of wound infection, and allows early joint and muscle function.

A review of the literature revealed that most studies on open fractures have focused on long-bone injuries and have excluded calcaneal fractures[10-14]. There have been only isolated reports on the treatment of open calcaneal fractures, and the authors have not analyzed the results according to the location of the wound, severity of soft-tissue disruption, type of calcaneal fracture, or definitive treatment. Those studies have demonstrated that, compared with closed calcaneal fractures, open calcaneal fractures are associated with worse results of treatment, with higher rates of infection[1,3-6,15-17].

The purpose of this study was to determine the prevalence and results of treatment of open calcaneal fractures seen at a large level-one trauma center. A treatment protocol was developed and applied to all patients with an open calcaneal fracture. Our hypothesis was that aggressive débridement and fracture stabilization would minimize the rate of soft-tissue infection, subsequent calcaneal osteomyelitis, and limb amputation.

Methods

Classifications

The open fractures were graded according to the classification of Gustilo et al.[13,18]. In this paper, the Gustilo classifications are labeled with Roman numerals (type I, II, IIIA, IIIB, or IIIC; see Appendix). Type-I fractures are associated with a clean wound of <1 cm in length. Type-II fractures involve soft-tissue disruption of <10 cm without periosteal stripping. Type-III fractures involve extensive soft-tissue destruction and are divided into A, B, and C subtypes. Type-IIIA fractures are associated with soft-tissue destruction with adequate osseous coverage. Type-IIIB fractures are associated with periosteal stripping and require a vascularized tissue transfer for soft-tissue coverage. Type-IIIC fractures are associated with a vascular injury that requires repair. Because of the difficulty in applying the Gustilo system to the foot and ankle, wounds were also classified according to their location: medial, lateral, plantar, posterior, and extensive (involving more than one location).

Preoperative computed axial tomographic scans were made for all patients, and all intra-articular calcaneal fractures were classified according to the computed tomography classification described by Sanders et al.[4]. In this paper, fracture comminution is referred to as type 1, 2, 3, or 4. Nondisplaced intra-articular fractures are classified as type 1, irrespective of the number of fracture lines. Type-2 fractures are two-part fractures of the posterior facet. Type-3 fractures are three-part intra-articular fractures and typically feature a depressed articular fragment. Type-4 fractures have at least four intra-articular parts and are usually highly comminuted. In the Appendix, extra-articular fractures are listed as type 0.

Treatment Protocol

All fractures were treated according to a protocol that included immediate intravenous administration of antibiotics, chosen on the basis of the wound type, in the emergency room; débridement combined with irrigation with at least 9 L of normal saline solution in the operating room; temporary wound coverage with Epigard (Parke-Davis, Detroit, Michigan) as needed; and stabilization of the limb by external fixation or a padded splint.

Intravenous antibiotics, consisting of a first-generation cephalosporin (cefazolin, 1 g/8 hr) for type-I and II open fractures and a combination of a first-generation cephalosporin and an aminoglycoside (gentamicin, 3 to 5 mg/kg/day in three equal doses) for type-III fractures, were administered while the patient had an open wound and for seventy-two hours after the definitive procedure. Penicillin (4,000,000 units/6 hr) was added to cover for clostridia in patients with a heavily contaminated wound. When soft-tissue coverage was required, it was performed once the wound was clean, and it consisted of delayed closure, application of a split-thickness skin graft, or rotational or vascularized tissue transfer.

When the patient had a severe soft-tissue injury, external fixation was used to span the ankle/subtalar joint. Although the location of the pins and wires varied depending on the soft-tissue wounds, a hybrid construct was used with thin wires or a medial half-pin in the calcaneus and two or three half-pins in the tibia. Internal fixation, when indicated, was performed after the wound was clean and when soft-tissue swelling was minimal. Indications for internal fixation varied according to the degree of soft-tissue disruption. If the other injuries permitted treatment of the calcaneus within three weeks and the soft tissue was adequate to cover the implants and bone, intra-articular fractures with >2 mm of displacement of the articular surface were fixed with a calcaneal plate and screws, as has been previously described[4]. The approach was altered depending on the wound location and severity. Fractures were often manipulated through the open wound to obtain better alignment, and limited lag-screw fixation was performed at the time of the final wound closure if the fracture permitted it.

Postoperative Treatment

Although the postoperative regimen differed for each patient because of variations in the fracture and soft-tissue problems, the overall goal of treatment was to close the wound as soon as possible and to stabilize the fracture with either closed or open methods. Three to four months were generally required to permit adequate fracture consolidation before walking was allowed. Patients who underwent open reduction and internal fixation with closure of the soft-tissue defect at the time of the definitive procedure had three months of non-weight-bearing activity, with a range of motion of the subtalar and ankle joints permitted once soft-tissue healing was deemed to be adequate.

Clinical Evaluation

Long-term follow-up was performed with use of the American Orthopaedic Foot and Ankle Society (AOFAS) Hindfoot Score[19]. The AOFAS score assigns 40 points for pain, 50 points for function, and 10 points for alignment. In addition, the examiner focused on evaluating the calcaneal wounds and on any history of an infection or any residual infection. Wound com-

plications were divided into those involving delayed healing and those involving infection. Superficial infection was defined as postoperative wound breakdown and erythema that resolved with local wound care and a short course of oral or intravenous antibiotics (less than one week). Patients with deep infection had persistent erythema and drainage that required surgical irrigation and débridement and resolved within six weeks. Osteomyelitis was diagnosed on the basis of a positive bone and indium or magnetic resonance imaging scan, or positive bone cultures.

Radiographic Evaluation

All patients were evaluated with three radiographic views of the calcaneus (axial, lateral, and Broden views). The radiographs were assessed for evidence of fracture-healing and osteomyelitis. Fractures and fusions were considered to be healed when a normal trabecular pattern was identified across at least 50% of the fracture or joint on two different views.

Statistical Analysis

All hypothesis tests were conducted with use of two-sided generalized Fisher exact tests with a 5% type-1 error.

Results

Injury Data

Between January 1, 1989, and June 30, 1997, 503 calcaneal fractures in 463 patients were treated at our institution; forty-three fractures (8.5%) in forty-two patients were open*. Thirty-four fractures were intra-articular, and nine were extra-articular. Medical records for all forty-two patients (forty-three fractures) treated during the eight-year study period were reviewed. Of the forty-two patients, thirty-three (79%) with a total of thirty-four fractures returned for clinical and radiographic follow-up at an average of fifty-five months (range, twenty-four to 121 months). Eight patients were lost to follow-up, and one patient died of unrelated causes. All forty-two patients for whom the following injury and hospital data were obtained were followed for at least three months. The clinical and radiographic follow-up data presented in this study apply only to fractures followed for more than two years. A comprehensive listing of the data on all forty-three fractures can be found in the Appendix.

There were twenty-eight male and fourteen female patients, and they had an average age of forty years (range, nineteen to seventy-eight years). The mechanisms of injury included nineteen automobile accidents, six motorcycle accidents, eight falls, two injuries sustained in a parachute jump, three boating accidents, one crush injury, one gunshot wound, two lawnmower injuries, and one explosion. The patients had often sustained multiple injuries (average, four additional injuries; range, zero to ten additional injuries). According to the classification of open wounds described by Gustilo et al.[13,18], there were nine type-I, eight type-II, twelve type-IIIA, and thirteen type-IIIB fractures as well as one type-IIIC fracture. There were nineteen medial, five lateral, three plantar, two posterior, and fourteen extensive wounds. According to the classification described by Sanders et al.[4], there were two type-1, five type-2, nine type-3, eighteen type-4, and nine extra-articular (type-0) fractures.

*This study was retrospective by design. All data were obtained from either the patient's private office medical records or radiology jacket. These files contained not only a complete record of follow-up visits and radiographs, but also a complete duplicate of all hospital admissions data, both radiographic and with respect to records documentation. Upon accepting care by the physicians at our private facility, patients agree to sign the Authorization to Use Patient Medical Information for Medical Research form, which gives us permission to use their data for research purposes. All patients in this study signed these forms. As a result, approval was not sought from the hospital institutional review board, as neither files nor radiographs from that institution were used.

Hospital Data

An average of four surgical procedures (range, one to eleven) related to the open calcaneal fracture were performed. The open wounds were usually covered in a delayed fashion, at an average of 10.6 days (range, zero to forty-one days). Soft-tissue coverage consisted of three primary closures, twenty-five delayed closures, five split-thickness skin grafts, two rotational flaps, and six free tissue transfers. During the initial hospitalization, three patients required an early below-the-knee amputation and one required an above-the-knee amputation because of infection and problems with wound coverage. The above-the-knee amputation and one of the below-the-knee amputations were performed acutely because of severe soft-tissue and bone loss from the tibia and calcaneus. In addition, one below-the-knee amputation was performed after a flap that had been used to cover a type-IIIB calcaneal fracture failed, and another was done in a patient who had a penetrating calcaneal injury for which reconstruction was not possible because of loss of the heel pad.

Fourteen fractures were treated nonoperatively, and the remaining twenty-nine fractures were treated with some form of internal or external fixation or arthrodesis. The average time between presentation at the hospital and fixation was 7.3 days (range, zero to fifty-one days) after presentation at the hospital. Definitive treatment during the initial hospitalization consisted of open reduction and internal fixation with a plate and screws for nine fractures, primary subtalar or triple arthrodeses for eleven, limited fixation for eight, and external fixation for one. The average hospital stay was twenty-three days (range, three to 109 days).

Gustilo et al.[13,18] Classification

Type I

Seven of the nine type-I fractures involved a small medial puncture wound from the spike of the medial calcaneal wall near the sustentaculum tali. The remaining two fractures presented with a single small lateral and plantar wound. Although these injuries varied with regard to Sanders fracture type, they tended to have simpler fracture patterns. Five fractures were treated with open reduction and internal fixation, whereas two Sanders type-4 fractures were treated with a primary subtalar fusion. There were no major complications, and all patients had a good to excellent result.

Type II

Of the eight type-II open fractures, three were treated with in-

ternal fixation or fusion. A superficial infection developed at the site of one of these three fractures, and osteomyelitis developed at the site of another. A deep infection developed at the site of one other fracture, not treated with fixation. Thus, the overall infection rate was three of eight fractures.

Type III

Patients with a type-III open fracture had a significantly higher rate of infection compared with patients with a type-I or II fracture ($p < 0.02$).

Type IIIA

There were twelve type-IIIA open fractures, and three of them were extra-articular. Compared with the type-I and II open fractures, the nine intra-articular fractures included a higher overall number of comminuted fractures: one fracture was type 2, two were type 3, and six were type 4. There was one superficial infection (associated with a medial wound), one deep infection (associated with a posterior wound), and one case of osteomyelitis (associated with a medial wound) in these twelve patients, for an infection rate of three of twelve fractures.

Type IIIB

An infection developed following treatment of ten of the thirteen type-IIIB open fractures. Osteomyelitis developed in six patients, and six patients ultimately required an amputation. Three amputations were performed acutely because of osteomyelitis, and one was performed acutely because of deep infection. The two remaining amputations were performed after the initial hospital stay; one was done because of continued wound drainage and the other, because of a poorly functioning heel pad.

Type IIIC

One patient had a type-IIIC wound and an extra-articular calcaneal fracture. This wound was treated with a latissimus dorsi transfer, and an infection did not develop.

Soft-Tissue Injury

Penetrating Injury

Because of the complexity of these soft-tissue wounds, the data were first analyzed according to the injury pattern. Seven open calcaneal fractures were the result of penetrating trauma: two were lawnmower injuries, three were boat propeller injuries, one was a shotgun wound, and one was sustained in an explosion. An infection developed in six of the seven patients. There was one superficial infection, three deep infections, and two cases of osteomyelitis. Two patients had an early amputation because of severe soft-tissue loss and uncontrolled infection.

Wound Location

The wound was classified as being in one of three locations: medial, other (lateral, plantar, or posterior), or extensive.

Medial: There were nineteen medial wounds. No infection developed at the site of any of the seven type-I open fractures associated with a medial wound, even though the amount of comminution varied. Four type-II open fractures were associated with a medial wound, and two were complicated by an infection. Of the eight type-III open fractures associated with a medial wound, one was complicated by osteomyelitis and two, by a superficial wound infection. Importantly, no patients with an open fracture and only a medial wound had an amputation.

Other (lateral, plantar, or posterior): Five fractures were associated with a lateral wound. One of these fractures was type I, one was type II, one was type IIIA, and two were type IIIB. Both type-IIIB fractures resulted in an amputation because of severe, unreconstructible soft-tissue loss. Three fractures, all of which were extra-articular, were associated with a plantar wound. A superficial wound infection developed at the site of one of these fractures, which had been treated with limited internal fixation to diminish pressure on the posterior soft tissue by a prominent tuberosity; the infection resolved with oral administration of antibiotics. Two type-IIIA fractures were associated with a posterior heel wound. Both fractures were treated with limited internal fixation to reattach the insertion of the Achilles tendon. A deep infection developed at the site of one of those fractures; it resolved after additional débridement.

Extensive: Fourteen fractures were associated with extensive soft-tissue disruption (a combination of medial, lateral, posterior, plantar, and anterior wounds). Two deep infections and six of the eight cases of osteomyelitis occurred in association with these complex fractures; four resulted in an amputation. When compared with type-I and II open fractures, type-III open fractures with a wound in a non-medial location were associated with significantly increased rates of both infection ($p < 0.014$) and amputation ($p < 0.003$).

Fracture Patterns

Excluding the extra-articular fractures, the percentage of type-4 comminuted fractures increased as the severity of the wound increased: 25% of the type-I fractures, 33% of the type-II fractures, 66% of the type-IIIA fractures, and 73% of the type-IIIB fractures had type-4 comminution. With the numbers available, there was no significant relationship between fracture comminution and the presence of infection.

Internal Fixation

Nine fractures were treated with open reduction and internal fixation with a laterally based plate and screws to stabilize the calcaneus. One type-IIIA fracture was complicated by a superficial wound infection, and one type-II fracture was complicated by osteomyelitis. Open reduction and internal fixation was not performed for any type-IIIB fracture.

Eleven fractures were treated with a primary subtalar or triple arthrodesis in order to stabilize the hindfoot. One patient (Case 34) initially had limited fixation but underwent a subtalar fusion at two years postinjury. Ten of the eleven fractures had a type-4 pattern. Three fractures (two type IIIB and

TABLE I Complications (Number) After Treatment of Open Calcaneal Fractures

Gustilo[13,18] Type of Fracture	No. of Fractures	Wound Infection	Osteomyelitis	Split-Thickness Skin Graft/Flap	Amputation
I	9	0	0	0/0	0
II	8	2	1	2/0	0
IIIA	12	2	1	2/0	0
IIIB	13	4	6	1/7	6
IIIC	1	0	0	0/1	0

one type IIIA) were complicated by osteomyelitis after treatment, and one of them subsequently required a below-the-knee amputation.

With the numbers available, there was no significant association between the use of internal fixation and the development of infection ($p < 0.5$).

Osteomyelitis

Osteomyelitis, as diagnosed on the basis of a positive culture of a bone biopsy specimen, developed at the sites of eight of the forty-three fractures despite multiple débridements and aggressive soft-tissue coverage. Seven (27%) of the twenty-six type-III fractures were complicated by osteomyelitis, and six of the seven were type IIIB. Three of the cases of osteomyelitis necessitated an amputation, whereas the other five cases resolved after intravenous administration of antibiotics and additional débridements. Patients with deep infection or osteomyelitis were more likely to require an amputation ($p < 0.04$).

Late Problems

All fractures were seen to be healed on radiographs within five months after the index procedure. The sites of all primary subtalar arthrodeses healed. The sites of six triple arthrodeses healed, and one required a revision of the subtalar joint because of a nonunion. Sixteen fractures (37%) were complicated by infection: four of the infections were superficial, four were deep, and eight were osteomyelitis. The infection rate for the type-III fractures was 50% (thirteen of twenty-six). The complications related to infections are listed in Table I. There were five below-the-knee amputations and one above-the-knee amputation. All six amputations were in patients with a type-IIIB injury.

No late cases of osteomyelitis were diagnosed after the first six months. Two patients had a below-the-knee amputation at three and four months after the injury because of failure of the soft-tissue procedure that could not be treated with reconstruction and because of continued wound drainage. The fixation was removed from the sites of nine fractures over the study period. A calcaneal malunion that required a late subtalar arthrodesis because of posttraumatic arthritis and continued hindfoot pain developed at the sites of four fractures that had not been initially treated with open reduction and internal fixation. An infection did not develop at the site of any of these fractures.

AOFAS Hindfoot Score

The average AOFAS hindfoot score was 71 points (range, 17 to 100 points) for twenty-seven patients. The six patients who had had a below-the-knee or an above-the-knee amputation were not included in this analysis because questions pertaining to foot and ankle pain, range of motion, and function were not applicable. The average AOFAS score was 83 points for the patients with a Gustilo type-I injury, 78 points for those with type-II, and 57 points for those with type-III.

Discussion

Recent studies on open fractures have demonstrated infection rates ranging from 7% to 16%[11,12,14]. Dellinger et al.[12] noted an increased infection rate in association with lower extremity fractures, higher-grade open fractures, and open fractures that had been treated with open reduction and internal fixation. The infection rate for the type-IIIB open fractures in their study was 58%. Our findings are similar with respect to the association between infection and the type-III open fractures. We found an overall infection rate of 37% for all open fractures, which highlights the fact that the open calcaneal fracture must be evaluated as a distinct injury, primarily because of limited soft-tissue coverage.

Infection rates and clinical results differ vastly between open ankle fractures and open calcaneal fractures. Dellinger et al.[12] found a 15% infection rate for open ankle fractures. Two reports on the treatment of open ankle fractures recommended early open reduction and internal fixation to obtain the most favorable results. In a study of thirty-eight open ankle fractures, Franklin et al.[9] found no correlation between soft-tissue injury and infection. They reported one deep infection, five superficial infections, and no cases of osteomyelitis. No infections developed in association with the sixteen type-IIIA open fractures in their study. The study by Bray et al.[8] confirmed this low infection rate in association with ankle fractures treated with open reduction and internal fixation (6.6%) or closed means (6.3%). The results for the type-III fractures were no worse than those for the type-I fractures in their study.

Siebert et al.[20] reported the results of treatment of thirty-six open intra-articular calcaneal fractures. The rate of open fractures was 10.7% in their series compared with 8.5% in ours. The mechanisms of injury and types of open fractures were similar between the two studies, with a preponderance of

type-III open fractures in both. Osteomyelitis developed following treatment of 60% of the type-III open fractures in the study by Siebert et al. compared with 27% in ours. The main difference between the two reports appears to be that the fractures were not treated with a standard protocol in the study by Siebert et al. since twenty-nine of the thirty-six fractures were initially treated at another facility. In our study, all patients were treated at the same facility, which allowed standardization of treatment. Early and aggressive irrigation, débridement, and stabilization probably prevented our complication rate from being even higher, and the importance of that protocol cannot be overemphasized.

The degree of soft-tissue injury in association with the open calcaneal fracture therefore appears to be the most important variable in determining the outcome in these cases. When the results of open and closed calcaneal fractures are compared, it is clear that these two injuries must be treated differently. In the present study, 79% of the intra-articular fractures were type 3 or 4, whereas other studies from our own institution have documented only a 25% to 30% rate of type-3 or 4 fractures[1,4]. Most investigators who have studied closed calcaneal fractures have advocated open reduction and internal fixation as the best method to obtain good clinical results[1-6,17]. In studies of closed calcaneal fractures treated with open reduction and internal fixation, the infection rate has ranged between 1.9%[6] and 2.7%[1]. In the present study, of open calcaneal fractures, the infection rate was 33% (three of nine) after open reduction and internal fixation and 27% (three of eleven) after primary fusion. The results after fixation of type-I and II fractures associated with a medial wound were significantly better than those after fixation of the same types associated with a non-medial wound. In our study, the results for the type-I injuries were routinely good, whereas those for the type-IIIB injuries were uniformly poor. These two types of fractures are readily distinguishable. Recommendations are harder to make with type-II and type-IIIA fractures[21]. We did not find an association between the degree of comminution and the rate of infection. However, we concluded that, while simpler fracture patterns associated with less extensive wounds may be treated surgically within a window of opportunity (typically within twenty-one days), treatment of comminuted fractures associated with more complex wounds should be delayed until the soft-tissue injury can be appropriately managed. This may require late treatment of a calcaneal malunion, or a triple arthrodesis, but that is preferable to the development of an early infection, possibly leading to an amputation.

While the published literature suggests that open long-bone fractures are best treated with early stabilization, this approach should not be used for open calcaneal fractures. We have modified our treatment regimen as a result of this study. Early intravenous administration of antibiotics and multiple débridements with early soft-tissue coverage must be employed without exception.

All type-I open fractures and those type-II open fractures associated with a medial wound can be treated with open reduction and internal fixation (plate and screw fixation), with results similar to those of treatment of closed fractures. The outcomes after treatment of type-II and IIIA open fractures range from fair to poor, and it is difficult to make specific treatment recommendations for these two groups because of the variability within them. We presently recommend either external fixation or the use of limited percutaneous lag-screw fixation for type-II non-medial fractures and all type-IIIA fractures. Patients with a type-IIIB open fracture and those in whom the fracture was the result of penetrating trauma often have a poor outcome and a protracted treatment course that requires multiple operations. In addition to thorough débridements and intravenous antibiotics, we recommend the use of external fixation to stabilize the fracture and to allow the soft tissues to heal. Limited percutaneous screw fixation may be used in selected cases, but we now caution against the use of internal fixation (open reduction and internal fixation or primary subtalar fusion) for type-IIIB injuries. Delayed or late reconstruction for any resulting malunion seems to be a wise alternative. These patients need to be counseled about the high risks of infection, osteomyelitis, and subsequent fusions and the possibility of amputation.

Appendix

eA A table showing the patient demographic and treatment data is available with the electronic versions of this article, on our web site at www.jbjs.org (go to the article citation and click on "Supplementary Material") and on our quarterly CD-ROM (call our subscription department, at 781-449-9780, to order the CD-ROM). ■

Keith A. Heier, MD
Metrocrest Orthopedics, 4780 Josey Lane, Carrollton, TX 75010. E-mail address: kaheier@aol.com

Anthony F. Infante, DO
Arthur K. Walling, MD
Roy W. Sanders, MD
Florida Orthopedic Institute, 4 Columbia Drive, Tampa, FL 33606.

The authors did not receive grants or outside funding in support of their research or preparation of this manuscript. They did not receive payments or other benefits or a commitment or agreement to provide such benefits from a commercial entity. No commercial entity paid or directed, or agreed to pay or direct, any benefits to any research fund, foundation, educational institution, or other charitable or nonprofit organization with which the authors are affiliated or associated.

References

1. **Bezes H, Massart P, Delvaux D, Fourquet JP, Tazi F.** The operative treatment of intraarticular calcaneal fractures. Indications, technique, and results in 257 cases. *Clin Orthop.* 1993;290:55-9.
2. **Letournel E.** Open treatment of acute calcaneal fractures. *Clin Orthop.* 1993; 290:60-7.
3. **Paley D, Hall H.** Intra-articular fractures of the calcaneus. A critical analysis of

results and prognostic factors. *J Bone Joint Surg Am.* 1993;75:342-54.

4. **Sanders R, Fortin P, DiPasquale T, Walling A.** Operative treatment in 120 displaced intraarticular calcaneal fractures. Results using a prognostic computed tomography scan classification. *Clin Orthop.* 1993;290:87-95.
5. **Sanders R.** Displaced intra-articular fractures of the calcaneus. *J Bone Joint Surg Am.* 2000;82:225-50.
6. **Zwipp H, Tscherne H, Thermann H, Weber T.** Osteosynthesis of displaced intraarticular fractures of the calcaneus. Results in 123 cases. *Clin Orthop.* 1993;290:76-86.
7. **Sanders R.** Intra-articular fractures of the calcaneus: present state of the art. *J Orthop Trauma.* 1992;6:252-65.
8. **Bray TJ, Endicott M, Capra SE.** Treatment of open ankle fractures. Immediate internal fixation versus closed immobilization and delayed fixation. *Clin Orthop.* 1989;240:47-52.
9. **Franklin JL, Johnson KD, Hansen ST Jr.** Immediate internal fixation of open ankle fractures. Report of thirty-eight cases treated with a standard protocol. *J Bone Joint Surg Am.* 1984;66:1349-56.
10. **Gustilo RB.** Current concepts in the management of open fractures. *Instr Course Lect.* 1987;36:359-66.
11. **Chapman MW, Mahoney M.** The role of early internal fixation in the management of open fractures. *Clin Orthop.* 1979;138:120-31.
12. **Dellinger EP, Miller SD, Wertz MJ, Grypina M, Droppert B, Anderson PA.** Risk of infection after open fracture of the arm or leg. *Arch Surg.* 1988; 123:1320-7.
13. **Gustilo RB, Anderson JT.** Prevention of infection in the treatment of one thousand and twenty-five open fractures of long bones: retrospective and prospective analyses. *J Bone Joint Surg Am.* 1976;58:453-8.
14. **Rittmann WW, Schibli M, Matter P, Allgower M.** Open fractures. Long-term results in 200 consecutive cases. *Clin Orthop.* 1979;138:132-40.
15. **Myerson M, Quill GE Jr.** Late complications of fractures of the calcaneus. *J Bone Joint Surg Am.* 1993;75:331-41.
16. **Thermann H, Krettek C, Hufner T, Schratt HE, Albrecht K, Tscherne H.** Management of calcaneal fractures in adults. Conservative versus operative treatment. *Clin Orthop.* 1998;353:107-24.
17. **Levin SL, Nunley JA.** The management of soft-tissue problems associated with calcaneal fractures. *Clin Orthop.* 1993;290:151-6.
18. **Gustilo RB, Mendoza RM, Williams DN.** Problems in the management of type III (severe) open fractures: a new classification of type III open fractures. *J Trauma.* 1984;24:742-6.
19. **Kitaoka HB, Alexander IJ, Adelaar RS, Nunley JA, Myerson MS, Sanders M.** Clinical rating systems for the ankle-hindfoot, midfoot, hallux, and lesser toes. *Foot Ankle Int.* 1994;15:349-53.
20. **Siebert CH, Hansen M, Wolter D.** Follow-up evaluation of open intra-articular fractures of the calcaneus. *Arch Orthop Trauma Surg.* 1998; 117:442-7.
21. **Horn BD, Rettig ME.** Interobserver reliability in the Gustilo and Anderson classification of open fractures. *J Orthop Trauma.* 1993;7;357-60.