Outcomes in Open Tibia Fractures: Relationship between Delay in Treatment and Infection

Monti Khatod, MD, Michael J. Botte, MD, David B. Hoyt, MD, R. Scott Meyer, MD, Jeffrey M. Smith, and Wayne H. Akeson, MD

Background: **Emergent irrigation and debridement has been accepted as a mainstay of open fracture treatment. The purpose of this study was to evaluate the infectious outcome of open tibia fractures relative to the time from injury to operative irrigation and debridement.**

Methods: **One hundred seventy-eight patients with 191 consecutive fractures were retrospectively reviewed. Of these, 103 patients with 106 fractures were available for this study, with an average follow-up of 10.23 months.**

Results: **Results revealed 21.7% type I fractures, 43.4% type II fractures, 16.0% type IIIa fractures, 11.3% type IIIb fractures, and 7.5% type IIIc fractures. Of all fracture types, 22.6% became infected and 5.7% went on to have osteomyelitis. The average time to treatment was not significantly different in infected versus noninfected fractures across fracture types. No infection occurred when the time to surgery was within 2 hours; however, no significant increase in infection was discovered with respect to patients treated after 6 hours compared with those treated within 6 hours.**

Conclusion: **The results support the Gustilo grading system of open fractures as a significant prognostic indicator for infectious complication. We continue to support the emergent treatment of open tibia fractures.**

Key Words: **Fracture, Tibia, Open, Infection, Timing, Treatment.**

J Trauma. 2003;55:949–954.

Among the most common and devastating complications of an open fracture is infection, which has a reported incidence of 3% to 40%.[1–16] The tibia is the most frequent site of an open fracture, with incidences ranging from 49.4% to 63.2%. This is attributable in part to the relatively thin soft-tissue covering along its anteromedial surface.[5,13,17,18] The tibia is not only more susceptible to open fractures but subsequently more susceptible to infection, with a reported infection rate 10 to 20 times higher than open fractures in other areas.[11] Factors contributing to tibial osteomyelitis are a relative lack of muscle covering, the tendency for the tibia to become widely exposed in open fractures, and a lack of anastomotic blood supply in the lower leg.

Protocols for open tibial fracture management are well established.[9,11,19–21] It is generally accepted that emergent care with irrigation and antibiotics will minimize infections. Traditionally, a “6-hour rule” has developed, in which trauma victims triaged within 6 hours are felt to have significantly less morbidity and mortality than those seen after 6 hours.[1,22,23] The 6-hour rule as used in the treatment of open fractures, however, seems to have few clinical data to support it as a significant reference point for the development of infection. Although urgency in the definitive management of these injuries cannot be questioned, many studies do not specifically address the relationship between timing of treatment of open fractures and infectious outcome. A shorter time period to treatment may possibly decrease infection rate. Conversely, the specific detrimental effects of a delay longer than 6 hours are not adequately established, and recent studies seem to be conflicting. Kindsfater and Jonassen, who reviewed 47 patients with Gustilo type II and III fractures, found a significant increase in infections if irrigation and debridement were delayed longer than 5 hours.[23] However, Patzakis and Wilkins’ review of 1,104 patients and Bednar and Parikh’s review of 82 patients revealed no significant increase in infections with late irrigation and debridement of an open fracture wound.[1,13] The purpose of this study was to retrospectively examine the effects of elapsed time before operative treatment on the rate of infectious outcome in open tibia fractures.

PATIENTS AND METHODS

The medical records of 178 consecutive patients with 191 open tibia fractures admitted to the University of California at San Diego Medical Center (UCSDMC) from July 29, 1988, to August 2, 1995, were reviewed. Of these, 19 patients with 21 fractures died from multiple injuries not related to their open fractures. Fifty-six patients with 64 fractures were lost to follow-up or transferred to another institution before wound closure or completion of treatment. This left for review 103 patients with 106 fractures, with an average follow-up of 10.23 months (range, 2–67 months). All

Submitted for publication May 6, 2001.

Accepted for publication August 5, 2003.

From the Departments of Orthopaedics (M.K., M.J.B., R.S.M., J.M.S., W.H.A.) and General Surgery, Division of Traumatology (D.B.H.), University of California at San Diego, School of Medicine, and San Diego Veteran’s Affairs Medical Center (M.J.B., R.S.M., J.M.S., W.H.A.), La Jolla, California.

Address for reprints: Monti Khatod, MD, 10 Columbus Square, Suite 4, Boston, MA 02116; email: mkhato@caregroup.harvard.edu.

DOI: 10.1097/01.TA.0000092685.80435.63

patients were treated by orthopedic residents along with a UCSDMC orthopedic staff member. There was no formal study protocol, and treatment was performed by existing community standards as follows:

1. Emergent evaluation of the patient for life-threatening injury by the trauma surgical team or emergency department physician.
2. Appropriate tetanus and antibiotic prophylaxis. All but one patient received cefazolin. Gentamicin was routinely added for additional gram-negative coverage for type II and III fractures. For farm injuries or marine wounds, penicillin was also added. Antibiosis was continued for 48 to 72 hours and perioperatively for subsequent procedures at the discretion of the staff physician.
3. After initial stabilization, the patient underwent emergent irrigation and debridement, which included surgical extension of wounds, sharp debridement of devitalized and/or contaminated soft tissue and bone, and pulse lavage irrigation with an average of 8.4 L of sterile saline solution.
4. Fracture stabilization ensued with primary amputation, casting, external fixation, intramedullary rod placement, and plate-and-screw fixation as the stabilization techniques used acutely.
5. Wounds were left open. Re-debridement and irrigation was performed as indicated. Coverage was obtained by delayed primary closure, skin grafting, or flap closure.

The open fractures were graded by the operating surgeon according to the classification system set forth by Gustilo and Anderson[5] and Gustilo et al.[6] Time from injury to irrigation and debridement was determined by historical data. Infection was initially diagnosed by clinical examination and was then confirmed by positive cultures. Simple pin-track infections were excluded. Other exclusion criteria included lack of follow-up or transfer of a patient to another facility. Patients were followed to wound or fracture healing. If complete wound healing was obtained and patients were subsequently lost to follow-up, they were included in the results. Results are reported on the basis of all 178 patients for epidemiologic data. Infectious outcome data are derived only from those 103 patients with adequate wound or fracture follow-up. Two statistical analyses were performed on the available date. A χ^2 test was used to identify a difference in infectious outcome between those patients treated within 6 hours as compared with those treated at greater than 6 hours. Second, an unpaired t test was used to determine whether a difference in operative time existed between infected and noninfected cases across fracture types.

RESULTS

One hundred ninety-one fractures from 178 patients were retrospectively reviewed, with an average patient age of 34 years (range, 6–90 years). There were 138 (77.5%) male patients and 40 (22.5%) female patients. Fracture types included 41 (22.0%) type I fractures, 75 (40.3%) type II fractures, 28 (15.1%) type IIIa fractures, 26 (14.0%) type IIIb fractures, 16 (8.6%) type IIIc fractures, and 5 of unrecorded type.

Of the 191 fractures, 54 involved only one anatomic area of the tibia, whereas 137 fractures extended beyond one area or were segmental in nature. A fracture including the tibial plateau with intra-articular extension was seen in 19 (9.9%), the proximal metaphysis was involved in 29 (15.2%), the proximal one third of the diaphysis was involved in 51 (26.7%), the middle one third of the diaphysis was involved in 89 (46.6%), the distal one third of the diaphysis was involved in 75 (39.3%), the distal metaphysis was involved in 36 (18.8%), and a fracture involving the tibial plafond was seen in 29 (15.2%) (Table 1).

Table 1 Localization of Open Fractures on the Tibia as a Percentage of Total Fractures[a]

Site of Open Fracture on Tibia	Percentage of Total Fractures
Tibial plateau	9.9
Proximal metaphysis	15.2
Proximal one third of diaphysis	26.7
Middle one third of diaphysis	46.6
Distal one third of diaphysis	39.3
Distal metaphysis	18.8
Pilon fracture	15.2

[a] One fracture may occupy multiple sites on the tibia. Each value represents the percentage of total fractures with that specific site involved.

The cause of injury was divided into street related, gunshot wound, or farming/marine injury. Of the 191 fractures, 164 (87.2%) were street related. Thirty-three (23.7%) were caused by motor vehicle collisions, 29 (20.9%) were caused by motorcycle collisions, 59 (42.4%) were caused by pedestrian versus motor vehicle collisions, 18 (12.9%) were caused by some other bicycle or fall type accident, and 25 were recorded as street related with unknown mechanism. Fourteen (7.4%) were gunshot victims and 10 (5.3%) were farming/marine type injuries (Table 2). Three of the 191 had no recorded mechanism of injury.

One hundred three patients with 106 fractures had adequate follow-up to wound or fracture healing. Of the 106 fractures, 23 (21.7%) type I fractures, 46 (43.4%) type II

Table 2 Cause of Injury

Cause of the Injury	Percentage of Total Fractures
Street-related wounds	87.2
Motor Vehicle collision	23.7
Motorcycle collision	20.9
Pedestrian vs. automobile	42.4
Bicycle, fall, or other	12.9
Gunshot injury	7.4
Farming or marine injury	5.3

Table 3 Breakdown of the Gustilo Type of Injury as Dictated in the Operative Report

Fracture Type	Percentage of Total Fractures
I	21.7
II	43.4
IIIa	16.0
IIIb	11.3
IIIc	7.5

fractures, 17 (16.0%) type IIIa fractures, 12 (11.3%) type IIIb fractures, and 8 (7.5%) type IIIc fractures were evaluated for infection (Table 3).

The overall rate of soft-tissue wound infection in open tibia fractures followed to union or onset of infection was 22.6%. The overall rate of osteomyelitis across fracture types was 5.7%. Of the type I fractures, two (8.7%) developed soft-tissue infection and one (4.3%) developed osteomyelitis. Of the type II fractures, five (10.9%) developed soft-tissue infection and one (2.2%) developed osteomyelitis. Of the type IIIa fractures, four (23.5%) developed soft-tissue infection and none developed osteomyelitis. Of the type IIIb fractures, eight (66.7%) developed soft-tissue infection and two (16.7%) developed osteomyelitis. Of the type IIIc fractures, five (62.5%) developed soft-tissue infection and two (25.0%) developed osteomyelitis (Table 4). Increased rate of infection with increasing Gustilo type was found to be statistically significant, with a value of $p < 0.0001$ when analyzed with the χ^2 test for trend.

There was no significant increase in time to treatment in those patients with infectious outcomes relative to those without infectious outcomes across fracture types (Fig. 1). A χ^2 analysis revealed no difference in overall infectious outcome with initial irrigation and debridement performed within 6 hours versus after 6 hours.

The average time to irrigation and debridement was 9.0 hours for infected type I fractures versus 6.5 hours for noninfected type I fractures (Fig. 2); 5.0 hours for infected type II fractures versus 10.0 hours for noninfected type II fractures (Fig. 3); 6.2 hours for infected type IIIa fractures versus 10.4 hours for noninfected type IIIa fractures (Fig. 4); 4.7 hours for infected type IIIb fractures versus 5.5 hours for noninfected type IIIb fractures (Fig. 5); and 3.5 hours for infected type IIIc fractures versus 3.8 hours for noninfected type IIIc fractures (Fig. 6). The time from injury to initial irrigation and debridement between infected and noninfected fractures proved to have no significant difference in any fracture type when analyzed with an unpaired *t* test. Of note, no infections in any fracture type occurred if the initial operative treatment began within 2 hours of the injury.

Table 4 Rate of Infectious Outcome as a Function of Gustilo Type

Fracture Type	Infected (%)	Osteomyelitis (%)
All types	22.6	5.7
I	8.7	4.3
II	10.9	2.2
IIIa	23.5	None
IIIb	66.7	16.7
IIIc	62.5	25.0

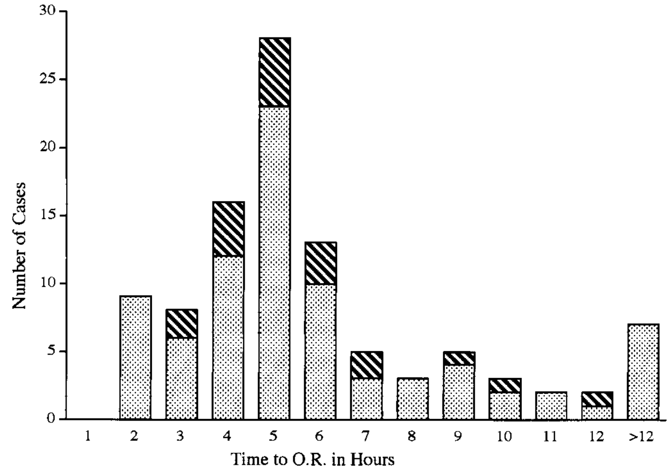

Fig. 1. *Histogram depicting the total number of noninfected cases (*dots*) relative to the total number of infected cases (*cross-hatching*) as a function of time from injury to operative therapy.*

Bony stabilization was performed by multiple methods. Among patients with eventual infection, 1 was casted, 16 were treated with external fixation, 4 underwent open reduction with plate-and-screw fixation, 4 underwent intramedullary fixation, and 3 underwent immediate amputation. This is compared with patients in whom infection did not develop with adequate follow-up: 13 were casted, 24 were treated with external fixation, 11 underwent open reduction with plate-and-screw fixation, 35 underwent intramedullary fixation, and 1 underwent immediate amputation. When broken

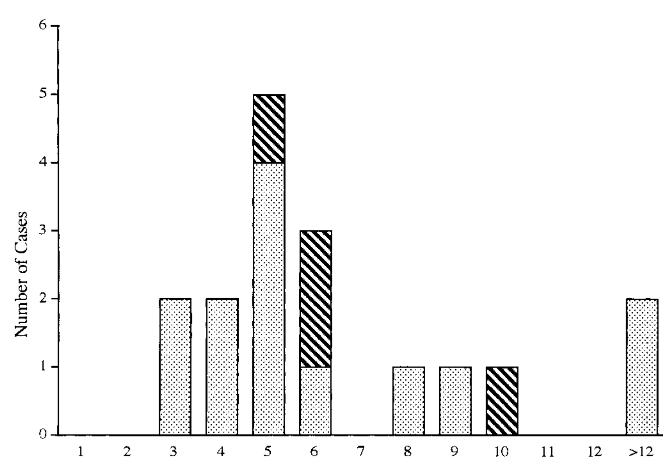

Fig. 2. *Histogram depicting Gustilo type I fractures, with noninfected cases (*dots*) and infected cases (*cross-hatching*), as a function of time from injury to operative therapy.*

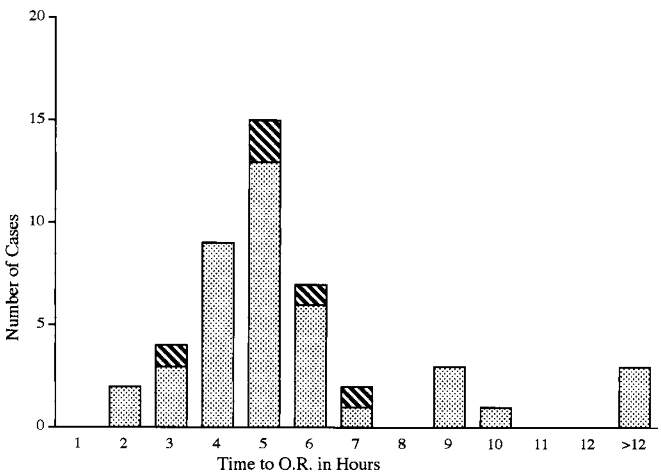

Fig. 3. *Histogram depicting Gustilo type II fractures, with noninfected cases (*dots*) and infected cases (*cross-hatching*), as a function of time from injury to operative therapy.*

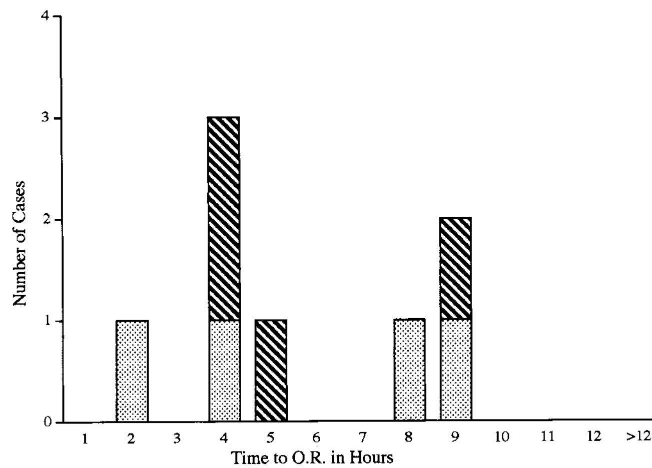

Fig. 5. *Histogram depicting Gustilo type IIIb fractures, with noninfected cases (*dots*) and infected cases (*cross-hatching*), as a function of time from injury to operative therapy.*

down by fracture type, the majority of type I and II fractures underwent intramedullary fixation, whereas external fixation predominated in the type IIIa, type IIIb, and type IIIc fractures. This is representative of the customary fixation methods used at the time of data collection. Culture results in the infected patients revealed 12 (27.9% of positive cultures) positive for *Staphylococcus aureus*; 6 (14.0%) positive for *Acinetobacter anitratus*; 5 (11.6%) positive for *Enterobacter faecalis*; 4 (9.3%) positive for *Pseudomonas aeruginosa*; 2 (4.7%) each positive for *Staphylococcus epidermidis*, *Serratia marcescens*, and *Proteus morganii*; and 1 (2.3%) each positive for methicillin-resistant *S. aureus*, *Peptostreptococcus anaerobius*, *Klebsiella pneumoniae*, *Actinomyces odontolyticus*, *Branhamella catarrhalis*, *Propionibacter acnes*, group B *Streptococcus*, *Enterobacter cloacae*, mucormycosis, diphtheroids, and *Corynebacterium* (Table 5).

DISCUSSION

This article attempts to address the effect that time to operative irrigation and debridement has on the infectious outcome of open tibial fractures. Variables such as concurrent medical comorbidities, history of tobacco use, method of stabilization, and timing of soft-tissue coverage were not subdivided in the analysis. Another concern with this article is the overall low rate of follow-up and relatively short follow-up. This is indicative of the patient population seen with these types of injuries at our institution. Because of its retrospective nature, a community standard protocol was used in the treatment of these injuries. No formal protocol for operative debridement, fracture fixation, wound, or antibiotic coverage was implemented within the study.

These multiple covariables and high rate of loss to follow-up may mask the true significance time plays in the

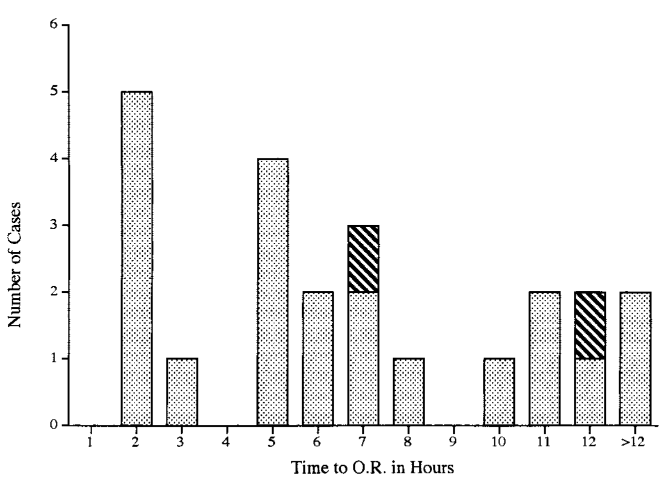

Fig. 4. *Histogram depicting Gustilo type IIIa fractures, with noninfected cases (*dots*) and infected cases (*cross-hatching*), as a function of time from injury to operative therapy.*

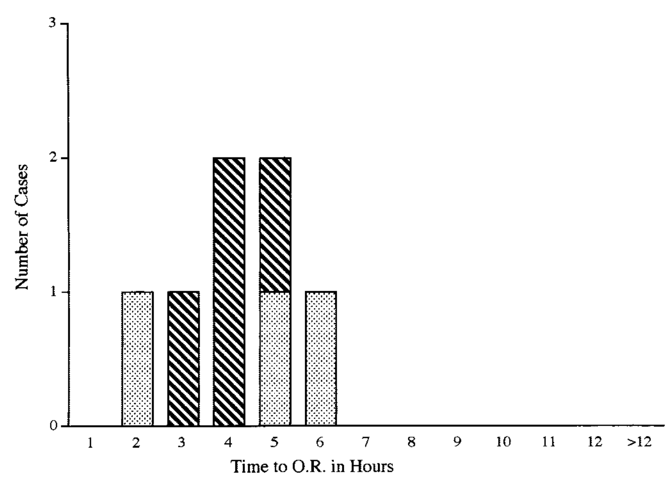

Fig. 6. *Histogram depicting Gustilo type IIIc fractures, with noninfected cases (*dots*) and infected cases (*cross-hatching*), as a function of time from injury to operative therapy.*

Table 5 Breakdown of the Most Common Organisms Cultured, with Rates Reflective of All Positive Cultures

Infecting Organism	Percentage of the Positive Cultures
Staphylococcus aureus	27.9
Acinetobacter anitratus	14.0
Enterobacter faecalis	11.6
Pseudomonas aeruginosa	9.3
Staphylococcus epidermidis	4.7
Serratia marcescens	4.7
Proteus morganii	4.7
Methicillin-resistant *S. aureus*	2.3
Peptostreptococcus anaerobius	2.3
Klebsiella pneumoniae	2.3
Actinomyces odontolyticus	2.3
Branhamella catarrhalis	2.3
Propionobacter acnes	2.3
Group B *Streptococcus*	2.3
Enterobacter cloacae	2.3
Mucormycosis	2.3
Diphtheroids	2.3
Corynebacterium	2.3

treatment of these injuries. Of note, however, is the lack of infection in any fracture type when treatment was initiated within 2 hours of the injury.

Many studies identify controversies in the management of open fractures.[9,19,20,24] The management protocols all, however, include emergent operative irrigation and debridement as a necessity in treatment. The majority of the literature does not find a correlation between timeliness of care for open fractures and rate of infectious outcome.[1,4,10,13,18] The use of 6 hours as the cutoff for emergent treatment seems to be based more on historical precedence than on scientific evidence.[1,22,23] Only one study has found a statistical difference in infectious complication when time from injury to debridement was less than 5 hours.[23]

We chose to use the Gustilo and Anderson classification system for open tibia fractures. This is the most commonly used classification system in our institution. Brumback and Jones, however, have shown an overall interobserver agreement of only 60% (range, 42%–94%) when surgeons viewed video presentations of the history, physical examination, radiographs, and operative debridement of the wound in 13 open fractures.[25] The Gustilo and Anderson open fracture grading system was also found to be statistically significant as a prognostic indicator for infectious outcome. These findings support the Gustilo and Anderson classification system.

Research on the time-dependence and the count-dependence in microbial infection by Williams and Meynell revealed the importance of contamination load and time for bacteria to multiply in an inoculated wound.[26] Pathologic bacteria do not suddenly become infectious at a particular time but have a rate of birth, growth, and death. These bacteria need to be eradicated before they cause disease. More virulent strains with higher initial inoculation loads lead to a rapid increase in bacterial count in vitro. The diameter of infectious necrosis in surgical wounds will grow within hours after inoculation with bacteria.[27] Decreased oxygen tension in traumatic wounds also increases susceptibility to infection, thereby heightening the urgency in treatment of a traumatic wound. The tibia has a relatively poor blood supply, increasing its risk because of lowered oxygen tension.[5,13,17,18] This in vitro study on bacterial proliferation and pathogenicity, in addition to the anatomic limitations of the tibia, push strongly for the continued emergent management of open tibial fractures.

A definitive correlation between time to operative treatment of open fractures and infectious outcome cannot be found in the majority of the literature; however, a prospective study has yet to be conducted. It is our contention that no 6-hour rule should exist, but rather all open fractures should be treated emergently until such a study exists.

CONCLUSION

The findings at UCSDMC show no significant increase in infection with respect to time from injury to initial operative management of the patient. Closer evaluation of the data, however, reveals that no infection occurred when the time from injury to initial operative debridement was within 2 hours. The findings have supported the Gustilo grading system of open fractures as a significant prognostic indicator for infectious complication. Every reviewed protocol for the management of an open fracture includes emergent surgical irrigation and debridement as a primary objective.[9,11,19–21] Factors such as fixation device, antibiotic coverage, wound coverage, medical comorbidities, and type of contamination were not subdivided and may therefore mask the relative importance of time as a risk factor for infection. Knowledge of bacterial multiplication and pathogenicity and host defense mechanisms and wound healing has led to the treatment of open fractures as orthopedic emergencies. This study suffers from its retrospective nature. A well-designed prospective collection of data on a large number of open tibia fractures is needed to more conclusively test our hypothesis. We currently continue to support the emergent treatment of open fractures despite the lack of statistical significance in our results.

ACKNOWLEDGMENT

We thank Jeffrey Katz, MD, of the Robert Brigham Arthritis and Musculoskeletal Clinical Research Center, Brigham and Women's Hospital, and the Clinical Research Unit, New England Baptist Bone and Joint Institute, for advice on statistical analysis.

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