

Temporary External Fixation Is Safe in a Combat Environment

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Background: External fixation has been used extensively during recent wars as a damage control measure for fractures in coalition forces being evacuated. We hypothesize that external fixation is a safe and effective initial stabilization procedure for combat-related open fractures.

Methods: Records on 55 consecutive type III tibia fractures between March 2003 and September 2007 were reviewed. We stratified the complications related to external fixation as major, potential, and minor complications. We defined major complications as neurovascular injury, mechanical failure, septic joint, and pin tract osteomyelitis. Potential complications were defined as pins within 1 inch of the fracture, pin overpenetration (≥ 26 mm), pin without cortical purchase, and intracapsular pin placement. Minor complications were defined as pin tract infections, addition of pins or bars, and pin overpenetration (9–25 mm). “Successful application” was defined as the absence of major or potential complications.

Results: We recorded no major complications. There were 12 of 53 (22.6%) constructs and 21 of 228 (9.2%) pins inserted with potential complications. We detected minor complications in 27 of 53 (50.9%) constructs and 35 of 228 (15.3%) pins inserted; 41 of 53 (77.4%) constructs had no major or potential complications.

Conclusions: Treatment of combat-related open tibia fractures with external fixation was 77% successful in our series. We recorded no major complications but demonstrated the possibility for technical improvement in one of the five constructs with potential complications. Despite the recorded potential and minor complications, external fixation is safe and effective as a temporary damage control in open fractures sustained in combat.

Key Words: External fixation, Damage control, Open fractures, Combat.

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External fixation is used to expeditiously stabilize extremity and pelvic injuries, protect neurovascular repairs, stabilize the soft-tissue envelope, minimize posttraumatic systemic complications,¹ and possibly decrease infection rates with

fracture stabilization.² In addition to providing stability for long bone injuries, external fixation provides wound access for dressing changes, repeat debridement and irrigation procedures, and compartment monitoring.

In austere combat environments, the challenge is to stabilize the injured extremity while minimizing complications. The goal is transportation to a higher echelon of care rather than focusing on providing a device capable of achieving bony union. The alternatives to external fixation in the combat environment for high-energy extremity injuries are splinting or skeletal traction. The main disadvantages of splint immobilization and traction are less relative stability compared with properly applied external fixation.³ Skeletal traction and splint immobilization preclude access to soft tissues for monitoring and wound care, are less amenable for operational medicine,⁴ can moisten and loosen, collect wound drainage, and can be more cumbersome when required to stabilize across the knee and hip joints. The features of military evacuation flights make traction, which is lost and unsupervised, inadequate for bony stabilization.⁵ Successful application of external fixation in the damage control scenario entails stabilizing the extremity while minimizing complications. Many of the facilities in theater lack the resources common to most healthcare facilities in the United States, including parts, power, and fluoroscopy. In addition, these polytraumatized patients frequently undergo simultaneous surgery on the chest or abdomen.⁶

Several authors have reported on the successful use of external fixation of type II or III tibia fractures,^{7,8} but few studies have evaluated the safety of application. A recent publication by Clasper and Phillips consisted of 15 constructs in 14 patients with an overall complication rate of 86.7%; 67% had instability and 33% had pin loosening. The authors caution that external fixation seems to have “limited benefit in the context of military injuries.”⁹ On the contrary, other publications have demonstrated reasonable success with the use of external fixation in combat injuries but lacked a critical review of the early complications.^{7,8,10} The lack of major or potential complications can be used to predict safety of external fixation application. We hypothesized that temporary external fixation can be performed in a combat environment without major complications.

METHODS

After institutional review board approval, we reviewed a series of combat-related Gustilo and Anderson type III open tibia fractures initially treated with temporary external fixation in a combat environment. The patients were evacuated to

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a single institution between March 2003 and June 2007. Patients were included if external fixation was placed in the theater of operations and maintained until arrival at our institution. Electronic medical records, operative logs, the Joint Theater Trauma Registry, and sequential radiographs from theater through the definitive treatment facility were reviewed. Mechanism of injury, injury characteristics, time to external fixation placement, complications from application, number of construct revisions, characteristics of revisions, presence of osteomyelitis, and deep infection were recorded. No data were available to identify the number of constructs placed under fluoroscopic guidance. The Gustilo and Anderson classification system and the Orthopaedic Trauma Association (AO) classification system were used to describe soft-tissue injury and fracture severity.¹¹⁻¹³ Complications were stratified into major, potential, and minor categories. Major complications consisted of neurovascular injury because of frame application,¹⁴ mechanical frame failure as evident by pin, clamp, or bar breakage,¹⁴ pin tract osteomyelitis,¹⁵ and septic arthritis because of intra-articular pin placement.¹⁶ Potential complications included pins within 1 inch of the fracture site,¹⁷ loss of fracture reduction,⁹ deep pin overpenetration ≥ 26 mm,¹⁸ soft-tissue pin placement (no cortical purchase), and intra-articular pin placement defined as pins within 14 mm of the tibial plateau^{19,20} or 10 mm of the tibial plafond.²⁰ Minor complications included pin tract infection defined as infection necessitating pin removal,^{11,21,22} shallow overpenetration between 9 mm and 25 mm, and instability of the frame requiring addition of a bar or pin.⁹

Clear definitions of pin overpenetration have not been described previously. The first thread of a Hoffmann II 5-mm half-pin (Stryker Howmedica Osteonics, Rutherford, NJ) is 6 mm from the tip of the pin. We allowed for an additional pin penetration of <3 mm (less than three threads) as our upper limit of acceptable penetration. Therefore, any cortical penetration ≥ 9 mm, we defined as shallow overpenetration. We defined cortical penetration >26 mm as deep overpenetration. These definitions are consistent with Topp et al., who described a “prominent” pin as greater than two threads protruding from the far cortex. This publication evaluated the same external fixator used in our study placed without fluoroscopy in cadavers and found a 13-mm mean overpenetration rate with a mean distance to the neurovascular structures of 10.2 mm.¹⁸ We accepted 100% of this mean overpenetration as our definition of deep overpenetration.

We defined “successful application” of the temporary external fixator as the absence of major or potential complications at latest follow-up. Although previous publications consider events such as pin tract infections “problems” or “obstacles” instead of complications,²³ we chose to categorize these as minor complications to have a higher level of scrutiny in our study.

Osteomyelitis was defined as positive bone culture and those treated for presumptive osteomyelitis with 6 weeks of intravenous antibiotics. Deep-wound infection was defined as positive deep-wound cultures without positive bone cultures. Categorical data were analyzed with two-sided Fisher’s exact test. Continuous data were analyzed with Student’s *t* test with

Wilcoxon signed-rank test for groups of two and Kruskal-Wallis for groups of three. Analysis was performed using SPSS version 16.0 (SPSS Inc., Chicago, IL). Significance was set at $p = 0.05$.

RESULTS

During the period reviewed, 45 consecutive patients with 55 Gustilo and Anderson type III open tibia fractures were treated at our institution. Forty-three patients and 53 type III open tibias were included, 91% were men, and 9% were women. The average age of the patients was 27 years, ranging from 19 years to 45 years. Two patients were excluded from analysis because one external fixator was converted to internal fixation and the other was a circular external fixator before arrival at our institution. All patients were treated with the Hoffmann II external fixation device (Stryker Howmedica Osteonics) applied in the theater of combat operations. The majority of fractures were middle third, Gustilo-Anderson type IIIB, and OTA type C. One fracture was stabilized on the day after injury, whereas all others were stabilized on the day of injury. Patients were treated in temporary external fixation for an average of 30 days (range, 5–135 days). Average follow-up was 2.2 years (range, 8 months to 5 years). No major complications were recorded.

Construct Complications

Potential complications occurred in 12 of 53 (22.6%) of the fixators (Fig. 1). Minor complications occurred in 50.9% (27 of 53) of the constructs (Fig. 2). Eight constructs had both potential and minor complications.

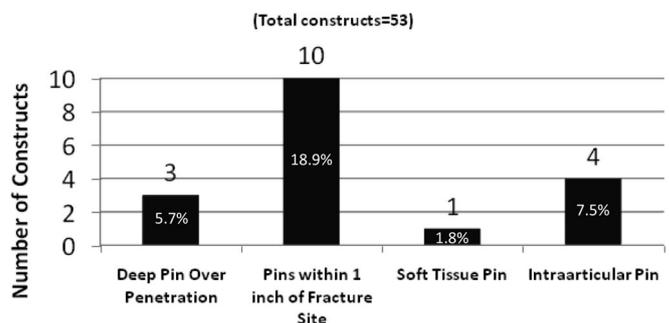


Figure 1. Potential construct complications.

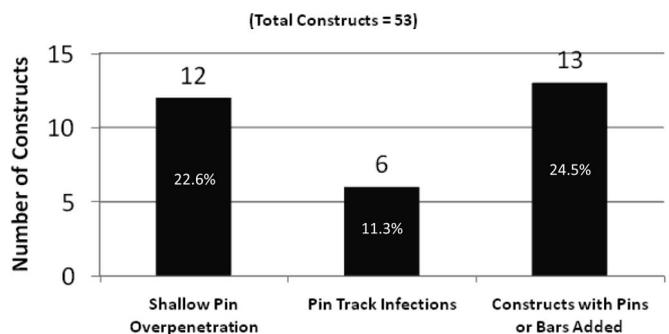


Figure 2. Minor construct complications.

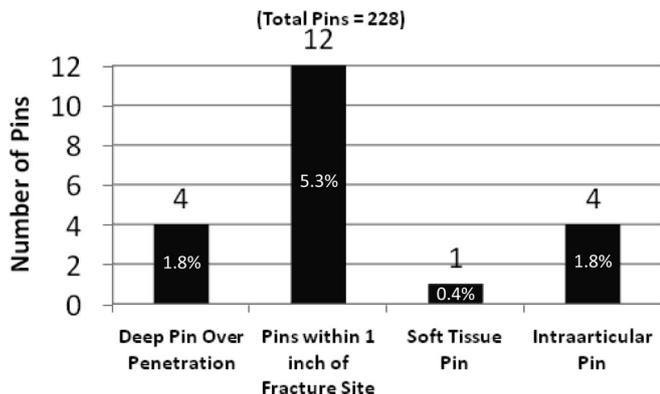


Figure 3. Potential pin complications.

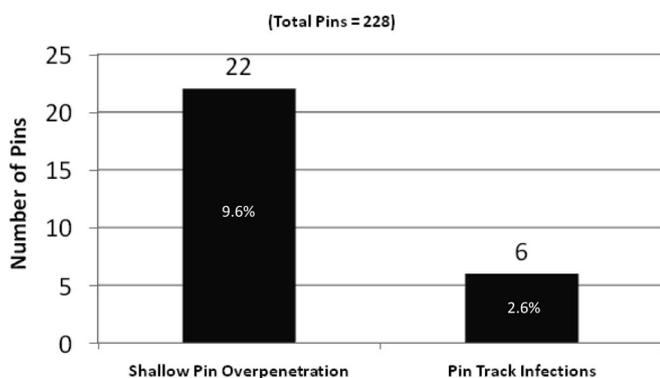


Figure 4. Minor pin complications.

Pin Complications

Potential complications occurred in 21 of 228 (9.2%) of pins inserted (Fig. 3). Minor complications occurred in 28 of 228 (12.2%) of the pins inserted (Fig. 4). Two of the pin tract infections were cultured, but no relation was found with subsequent deep infection of the fracture site.

There were no cases of pin tract osteomyelitis, but eight (15.1%) cases of osteomyelitis were found at the fracture site in this cohort. An additional 22 tibias (41.5%) were clinically diagnosed and treated for osteomyelitis at the fracture site without a positive bone culture. There were also two soft-tissue infections in this cohort.

Our analysis showed no association with the location of the fracture, Gustilo and Anderson classification, and OTA fracture classification and the presence of potential and minor complications. There was no statistical relationship between osteomyelitis and deep infection in the presence of potential and minor complications. Minor complications and osteomyelitis showed a trend at $p = 0.075$ (Table 1). According to our previously defined criteria, we found that 77.4% of the constructs had a “successful application” (Fig. 5).

DISCUSSION

Initial treatment of these fractures in far-forward facilities focuses on damage control with goals of controlling hemorrhage, restoring limb perfusion, soft-tissue debridement, and achieving bony stability without disrupting resus-

TABLE 1. Statistical Analysis

Variable 1	Variable 2	<i>p</i>
Location of fracture	Presence of minor complications	0.195
	Presence of potential complications	0.714
G and A classification	Presence of minor complications	0.398
	Presence of potential complications	0.86
OTA classification	Presence of minor complications	0.79
	Presence of potential complications	0.53
Osteomyelitis	Presence of minor complications	0.075
	Presence of potential complications	0.775
Deep infection	Presence of minor complications	0.659
	Presence of potential complications	0.513

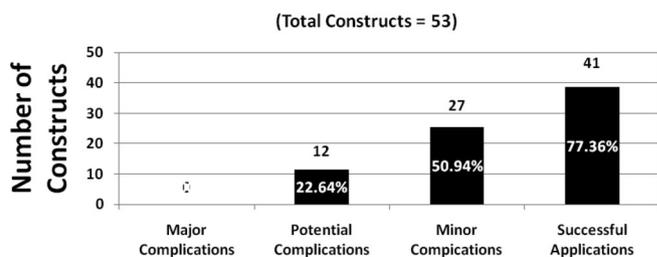


Figure 5. Complications summary.

citation of the patient.²⁴ Precise fracture reduction, wound closure, and a definitive rigid construct are not expected at this level of care.³ Temporary external fixation has been generally accepted by US forces in overseas contingency operations with limited data on its safety and efficacy when placed in a combat environment. To our knowledge, Clasper and Phillips have provided the only critical analysis of the external fixator in its current role. This publication highlighted legitimate safety concerns with the widespread use of temporary external fixation in combat injuries. However, the two main weaknesses of that study are its small sample size and its vague definitions of the categories of complications.⁹

We stratified complications into major, potential, and minor to assess the safety of external fixation. Successful application (absence of major or potential complications) occurred in 77% of the constructs evaluated in our series despite application occurrence in an austere combat environment.

Furthermore, we recorded no neurovascular injuries during external fixation application, which is consistent with Burny’s prior report of no neurovascular injuries after 1,421 tibia fractures treated with an external fixation device.¹⁴ Dwyer, after studying pin insertion in cadaver specimens, noted that vessels are usually pushed to the side as the pin penetrates the soft tissue.²⁵ It is proposed that vascular injury occurs by vessel wall erosion over a period of weeks because of proximity of a pin.¹⁷ Topp et al. evaluated external fixator pin placement in cadaver specimens without fluoroscopy recording a 1.3% neurovascular injury rate.¹⁸ Catastrophic failure of an external fixator device was not recorded in our review. It is an unlikely major complication because of limited time (average, 30 days) in the frame, use of only new hardware, and unlikely ambulatory status of the patients during evacuation. Previous

reports of pin or bar breakage were remedied by only allowing single use of the equipment.²⁶

We did identify the possibility for technical improvement in application in 22.6% of the constructs as represented by our potential complication category. The most common potential complication in our study was a pin within 1 inch of the fracture site, placing undue risk for propagation and infecting fracture hematoma.¹⁷ All the constructs with potential complications were modified at our institution. None were noted to progress to clinical complications preventing them from proceeding to their definitive procedure; however, these potential complications highlight the need for continued vigilance with predeployment training and experience in fracture surgery.

Pin tract infections are the most common complication encountered with external fixation. Rates up to 100% have been reported.²⁷ Pin tract infections showed no significant difference with the number of days in constructs, ranging from 5 days to 135 days. Hammer et al.¹⁰ reported that the incidence of pin tract infection may be due to over treatment of the pin sites. With regard to infectious complications, further study is warranted to determine the true relationship with “minor” pin tract infections and ultimate deep infection. The rate of osteomyelitis in our series is consistent with previous publications. Posttraumatic long bone osteomyelitis infection rates have ranged from 16% to 50%.^{7,28,29} More specifically, deep infection (7.7–24%) and osteomyelitis (2–56%) rates have been reported in type III tibia fractures treated with external fixation, although no specific definition of infection was explained.^{22,30–32} It is possible that our higher rate of reported osteomyelitis is inflated because 22 of the 30 infected tibias were treated presumptively for osteomyelitis without a positive bone culture. The trend between osteomyelitis and minor complications may exist, because this technical error does not result in failure; therefore, constructs with shallow penetration remain unchanged. Prospective evaluation of pin tract infections with genotypic mapping of infectious organisms is warranted to establish any true relationship between pin tract infections and contamination of the fracture site and subsequent internal fixation.

There are several limitations in this study. It is a retrospective study containing the inherent drawbacks of the study design. We were unable to clinically assess each construct because our evaluation was solely based on radiographs and clinical records. The study only evaluated external fixation of open tibia fractures, and the data cannot be directly extrapolated to other anatomic locations. Furthermore, there is no control group of patients treated without temporary external fixation to compare functional or clinical outcomes.

Despite our limitations, we determined that temporary external fixation had a 77.4% rate of successful application when used in the Global War on Terror. In conclusion, temporary external fixation can be performed in a combat environment without major complications.

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DISCUSSION

Dr. Jon Clasper (United Kingdom): First, I would like to thank ATACCC for the opportunity to discuss this article. This is an interesting and relevant article in an area where opinion is strong but where there is little evidence and controlled trials are unlikely to be possible.

First, I would like the authors to tell us a bit more about the patients. It is described as damage control, implying these were sick patients with multiple injuries. I would fully support the use of external fixation, but the range of Injury Severity Score suggests that some may have isolated injuries. In this case, I would not agree the use of external fixation, particularly in resource limited forward surgery, is always indicated, and may have contributed to the technical errors.

They have only studied tibial fractures—this is not a criticism, as these are the most common and problematic fractures; but I would caution people not to blindly apply these results to all fractures. In particular, femoral shaft fractures are more difficult to control and have a higher pin tract infection. It is likely they would have found a higher complication rate as documented by other authors. An unstable Ex Fix on a femur is worse than traction in my experience.

As it is approximately 25% were unstable, as manifest by the addition of bars and pins, despite these being described as minor complications. Approximately 20% had pins too close to the fracture site and 5% were in the joint. Given the overpenetrated pins, there seems to be a technical error in 50% to 60% of frames.

Can I ask the authors: were the frames put on under X-ray control?; if not, then is this truly safe? How do the authors suggest that we improve this issue that seems to have affected half their patients?

In terms of the final outcome, approximately 55% of the patients developed deep infection. This is high but may reflect the nature of the injury rather than anything else. We

are not told how many patients still had unhealed fractures, and therefore, this may well rise. We are not told how many were converted to an IM device, and these seem to be associated, in the literature, with a significant late infection rate, to the point that some authors state that they will no longer convert these patients to an IM device; therefore, the Ex Fix has affected the final management and outcome of the patient. I would like to ask the authors what form of definitive fixation was used and whether they can say that this high infection rate was not related to the initial stabilization.

My final question to the authors is whether they believe that all open fractures in the combat environment should be stabilized initially with Ex Fix as suggested by some authors. In a recent review of UK casualties, 45% did not get an Ex Fix, and it did not increase the infection rate. Certain areas such as the upper limb can be difficult to Ex Fix but easy to splint, and this does not compromise later internal fixation. Proximal femoral fractures can be managed with a bridging frame, but these have a high complication rate and are not comfortable, and in my experience, they are worse than skeletal traction.

Thank you.

Dr. Daniel R. Possley (US Army Institute of Surgical Research, Fort Sam Houston, TX): We first want to thank Dr. Clasper and all the reviewers for contributing their thoughtful critiques of our article. Your comments have strengthened our article. Since the review of our original manuscript, we have changed the title as this is a mixed group of patients. Some are patients with multiple injuries, whereas others have isolated injuries. The study only evaluated external fixation of open tibia fractures, so the data cannot be directly extrapolated to other anatomic locations. Furthermore, there is no control group of patients treated without temporary external fixation to compare the functional or clinical outcomes. There are a variety of injuries that may benefit from external fixation in a combat environment. Because this intervention has been used with such widespread use for the first time in this conflict, we felt that a safety analysis was warranted. The term “error” implies a consequence or adverse outcome for the patient. Although technical improvement seems possible in 58% of frames, we were unable to link these to consequences or adverse outcomes. Because of the retrospective nature of the study, we were unable to determine the reason for addition of bars and pins en route to the continental United States. We are also unable to tell from the records whether frames were put on under X-ray control.

Assessment of how these fractures were converted to definitive fixation is an important topic. Because of a variety of internal and external fixation with numbers too small, we are unable to derive scientific conclusions for that data.