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Original Article

External Fixation as Primary and Definitive Treatment for Tibial Diaphyseal Fractures: Experience from Misurata Central Hospital, Libya

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ABSTRACT

This retrospective study evaluates the effectiveness of unilateral external fixators as a primary and definitive treatment for complex tibial diaphyseal fractures (TDFs) at Misurata Central Hospital, Libya. The study included 56 patients with TDFs, specifically focusing on open fractures (Gustilo type III), fractures with severe soft tissue injuries, and those in multiply injured patients. Our findings indicate that unilateral external fixation provides a viable and effective solution for these challenging cases. Union was achieved in open fractures within an average of 27 weeks and in closed fractures within 22 weeks. While complications such as nonunions (8 cases), delayed unions (5 cases), malunions (1 case), pin track infections (13 cases), and osteomyelitis (1 case) were observed, the external fixator served as a definitive treatment in 82.14% of cases. Reoperations were necessary in 17 patients. This study supports the use of unilateral external fixators as a primary and definitive treatment option for complicated tibial shaft fractures, emphasizing that reoperation or a change in fixation method should be considered primarily in instances of delayed callus formation.

Introduction

External fixation has experienced a significant resurgence in contemporary trauma management, largely attributed to its role in damage control strategies for multiply injured patients and its utility in managing soft tissue complications prior to internal fixation [1,2,3]. Advancements in the design of external fixators and bone pins have broadened their indications, establishing external fixation as a legitimate and effective definitive treatment alternative for trauma surgeons [4]. The applications of external fixation can be broadly categorized into three primary functions: Temporary or Emergency Stabilization: Used for patients with limb- or life-threatening injuries, providing immediate stability.

Definitive Fracture Treatment: Serving as the primary and final method for fracture stabilization. Limb Reconstruction Surgery: Employed in deformity correction, limb lengthening, and the treatment of non-unions and osteomyelitis. While intramedullary (IM) nailing is generally considered the gold standard for closed diaphyseal tibial fractures, considerable debate persists regarding the optimal management of complex cases, including Gustilo type III open fractures, tibial shaft fractures with severe soft tissue injuries, and fractures in polytraumatized patients [5]. The choice between angle-stable (locking) plate fixation, primary IM nailing, primary external fixation followed by conversion to IM nailing, or definitive external fixation remains a critical clinical decision [6].

Historically, external fixation was widely used in the early 20th century, then saw a decline with the advent of internal fixation devices. Its popularity resurged in the 1980s, though challenges and questions regarding its application persisted [7]. Furthermore, ongoing discussions have focused on optimizing frame design and understanding the biomechanical characteristics of various fixators to improve outcomes [8]. This retrospective study, conducted at Misurata Central Hospital between August 2016 and November 2017, aims to evaluate the results and effectiveness of unilateral external fixators (specifically HOFFMAN2 or Orthofix systems) as a primary and definitive treatment for high-risk tibial diaphyseal fractures, addressing the aforementioned complexities.

The external fixator functions as an exoskeleton, providing structural support to the fractured, deficient, or deformed endoskeleton (bone). The biomechanical principles underlying external fixation allow for controlled manipulation through the exoskeleton, which, in turn, produces parallel effects on the endoskeleton, facilitating fracture reduction and stabilization [9].

Contemporary external fixator systems are generally categorized into two main types: unilateral and circular. The stability conferred by an external fixator is primarily influenced by three critical variables [10]: Bone-Pin Interface: The quality and integrity of the interface between the bone and the fixation pins are paramount for load transfer and stability. Components of the Fixator: The design, material, and rigidity of the fixator components (e.g., clamps, rods) directly impact the overall construct stability. Fixator Configuration: The manner in which the fixator is assembled on the inserted bone pins, including the number, placement, and orientation of pins and connecting rods, significantly affects its biomechanical performance.

Furthermore, the fracture pattern itself plays a crucial role in determining stability. Stresses at the bone-pin interface and the fixator's ability to maintain its hold depend heavily on contact area and fracture-line morphology [11] [12] [13]. This

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concept of shared stability is fundamental, allowing clinicians to make biomechanically informed adjustments to the external fixator. This approach moves beyond the simplistic application of a 'standard' anteromedial unilateral fixator for all tibial fracture types, enabling a more tailored and effective treatment strategy. Figure 1 illustrates an anteromedial approach to applying an external fixator (Hoffman 2). Shared stability is fundamental, allowing clinicians to make biomechanically informed adjustments to the external fixator. This approach moves beyond the simplistic application of a 'standard' anteromedial unilateral fixator for all tibial fracture types, enabling a more tailored and effective treatment strategy. Figure 1 illustrates an anteromedial approach in the application of an external fixator (Hoffman 2).

Figure 1. illustrates an anteromedial approach in the application of an external fixator (Hoffman 2).

Patients and Methods

This retrospective study included 56 patients (56 tibial shaft fractures) treated with unilateral external fixators at Misurata Central Hospital. The patients were followed by the authors over the last decade. The external fixators utilized were either Orthofix or Hoffman 2 systems.

Inclusion Criteria

The application of external fixators was based on the following inclusion criteria:
Soft tissue injuries and closed fractures (10 fractures).
Gustilo type III open fractures (39 cases).
Fractures in multiply injured patients with closed fractures (7 cases).

Patient Demographics and Injury Characteristics

The mean age of the patients at the time of injury was 32 years (range: 21–47 years). The cohort comprised 48 male and 8 female patients. The etiology of the injuries varied: Gunshot injuries: 36 patients
Motor vehicle accidents: 16 patients
Falls from a height: 4 patients
The mean time from injury to surgical intervention was 12 hours.

Fracture Classification

Fracture patterns were categorized according to the AO/ASIF classification system:
Type A (simple) fractures: 6 cases
Type B (wedge) fractures: 8 cases
Type C (comminuted) fractures: 42 cases

Surgical Technique and Postoperative Management

All surgical procedures were performed on a radiolucent table, with intraoperative fracture reduction confirmed using fluoroscopy. The primary surgical objective was to achieve anatomical closed reduction, incorporating axial and side-to-side compression. Open fractures received primary soft tissue coverage for exposed vessels, nerves, tendons, and bone. Autologous iliac bone grafting was employed in cases of nonunion. Postoperatively, patients were encouraged to initiate early movement of the knee and ankle joints, along with muscular exercises. Axial dynamization and loading protocols were individualized. Early dynamization was permitted exclusively for transverse or short oblique fractures. Generally, partial weight-bearing was initiated within 8 weeks, progressing to full weight-bearing within 3 to 4 months.
Clinical and radiographic evaluations were conducted monthly, commencing one month postoperatively. (Figure 2) displays a Gustilo type IIIB open fracture of the left tibia, treated with a unilateral external fixator.

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Figure 2. A Gustilo type IIIB open fracture of the left tibia, treated with a unilateral external fixator.

Results

Medical records of all 56 patients were analyzed, with an average follow-up period ranging from 8 to 15 months. The mean operative time was 30 minutes, excluding the time dedicated to irrigation and soft tissue debridement. Treatment outcomes were evaluated based on six key criteria.

Time to Union

Fracture union was defined as normal healing within 6 months, delayed union between 6 and 8 months, and nonunion as the absence of healing after 8 months. The mean time to fracture union for the 39 open fractures that did not require a change in fixation method or bone graft was 27 weeks (range: 22–34 weeks; median: 30 weeks). For the 17 closed fractures, the mean union time was 22 weeks (range: 16–33 weeks; median: 25 weeks). A total of 8 nonunions and 5 delayed unions were observed. (Figure 3) illustrates an AP & lateral view of a 24-year-old man with a Gustilo type IIIB open fracture at 15 weeks, showing signs of union.

Table 1. Mean and Median Time to Fracture Union (Weeks)

Fracture Type	Number of Fractures	Mean Time to Union (Weeks)	Range (Weeks)	Median Time (Weeks)
Open	39	27	22–34	30
Closed	17	22	16–33	25

Final Alignment

Malunion was defined by specific criteria: varus or valgus malalignment of ≥5 degrees, anterior or posterior angulation of ≥10 degrees, shortening of ≥1 cm, or rotational malalignment of ≥10 degrees when compared to the contralateral limb. At the latest follow-up, one case of malunion was identified, presenting with a tibial shortening of approximately 1.5 cm.

Pin Track Infection and Deep Infection

Pin track infection is a recognized complication of external fixation. This study recorded 13 cases of pin track infections. One case of osteomyelitis was observed, exclusively in open fractures. Eight cases of pin infections were successfully managed with antibiotics, while in 5 patients, pin replacement was necessary. The osteomyelitis case required intravenous antibiotic treatment combined with debridement of necrotic tissue, leading to eventual resolution of all

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infections. (Figure 4) shows AP & lateral views of an open fracture of the left leg involving both bones (Gustilo-Anderson type IIIB), with changes due to pin track infection.

Figure 3. illustrates an AP & lateral view of a 24-year-old man with a Gustilo type IIIB open fracture at 15 weeks, showing signs of union.

Figure 4. Shows AP & lateral views of a open fracture of the left leg involving both bones (Gustilo-Anderson type IIIB), with changes due to pin track infection.

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Final Ranges of Motion of the Knee and Ankle Joint and Pain

At the latest follow-up, no patients reported restriction in the range of motion of their knee or ankle joints, and none complained of pain.

Reoperations

Severe open tibial fractures frequently necessitate repeat procedures, such as soft-tissue coverage, bone grafting, or exchange nailing, to achieve union. All procedures requiring general or spinal anesthesia directly related to the tibial fracture treatment were included. Reoperation was performed in 17 fractures. The reasons for reoperation included 8 nonunions, 2 out of 5 delayed unions, 1 osteomyelitis, 1 malunion, and 5 pin revisions due to infection or loosening. Bone graft alone was used for 2 delayed unions. In 2 cases (one osteomyelitis, one malunion with shortening), the external fixator was converted to open reduction internal fixation (plate + screws + bone graft). For 8 nonunion cases, an intramedullary nail was used, and in 5 cases, only 1 or 2 half-pins were changed. In total, the fixation method or device was changed in 10 fractures (17.85%). All reoperated fractures achieved union within a mean time of 3 months (range: 3–5 months; median: 4 months). Figure 5 depicts an AP & lateral view of a closed fracture of the left tibia in a 22-year-old male, showing signs of nonunion after 8 months, with subsequent conversion to intramedullary nailing.

Table 2. Causes for Reoperations

Cause of Reoperation	Number of Cases
Nonunions	8
Delayed Unions	2
Osteomyelitis	1
Malunions	1
Pin Revisions	5

Table 3 Type of Operations Performed in Cases Requiring Reoperation with or without Change of Fixation Methods

Type of Operation	Number of Cases
Change of device by IM Nailing (nonunion)	8
Bone Graft Alone (for delayed unions)	2
Change of 1 or 2 Half-Pins (for infection/loosening)	5
Change of device by ORIF (for osteomyelitis and malunion)	2

Figure 5. depicts an AP & lateral view of a closed fracture of the left tibia in a 22-year-old male, showing signs of nonunion after 8 months, with subsequent conversion to intramedullary nailing.

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Other Complications

Fat embolism was diagnosed in two young patients. Deep Venous Thrombosis (DVT) was clinically suspected in 12 patients, but confirmed by Doppler ultrasonography in only 5 patients.

Discussion

The annual incidence of open long bone fractures is estimated at 11.5 per 100,000 persons, with approximately 40% occurring in the lower limb, predominantly in the tibial diaphysis [14]. Open tibial fractures are generally more severe than upper limb fractures due to extensive soft-tissue damage and frequent associated musculoskeletal injuries. High-energy trauma often leads to open femoral fractures, commonly observed in polytrauma patients [15].

Various classification systems have been developed to grade the severity of initial injuries and provide prognostic insights for optimal management [16-21]. The Gustilo and Anderson classification system remains the most widely used, categorizing open fractures into three increasing severity groups based on wound size, contamination, and soft-tissue injury extent [22]. A significant limitation of the original classification was the broad spectrum of injuries within the Type III category, leading to variable prognoses. Consequently, Gustilo et al. reclassified Type III injuries into three subgroups in 1984, based on bone exposure, soft-tissue coverage requirements, and the need for vascular repair [23]. While this revised system gained widespread acceptance [24], its interobserver reliability has been challenged, even among experienced orthopedic surgeons, as demonstrated by Brumback and Jones [25,26].

Our findings align with the broader literature on external fixation for open tibial fractures. A review of 13 papers focusing on external fixation for open tibial fractures [27-30] revealed that 536 open tibial fractures were treated with external fixation, with 82% being Grade III injuries. The timing of soft-tissue coverage for Grade III open fractures, as reported in nine studies involving 405 fractures treated with external fixation [27-33], indicated delays exceeding 72 hours. Despite these delays, union was achieved in 94% of cases within a mean of 37 weeks. This underscores that severe open tibial fractures often necessitate repeated procedures, including soft-tissue coverage, bone grafting, or exchange nailing, to achieve union. Therefore, union timelines derived from closed fracture treatments are not directly applicable to these complex cases.

The overall incidence of delayed union (healing after six months) was 24% across eight studies with complete follow-up on 392 open tibial fractures [28-37]. The implant failure rate was low, with only four (2.7%) failures reported in four papers describing 149 open tibial fractures [38,39]. However, a substantial proportion (68.5%) of the 536 fractures required at least one additional operation before union. The malunion rate with external fixation was reported to be up to 20% in 458 fractures [27-31,36]. The incidence of deep infection was 16.2% [27-30], with 4.2% developing chronic osteomyelitis [27-29,31,35,37]. Pin-track infection rates were as high as 32.2% [27-29,31, 32,36].

Despite continuous advancements in surgical techniques, the optimal treatment for complex tibial shaft fractures, including Type III open fractures, those with severe soft tissue injuries, threatened compartment syndrome, and fractures in multiply injured patients, remains a subject of ongoing debate [40]. Significant challenges related to infection, malunion, and nonunion persist. While emergency irrigation and soft-tissue debridement are universally accepted as cornerstones of initial care for open fractures, consensus on the best method for achieving and maintaining tibial alignment and stability is lacking [29]. Intramedullary nails (IM), external fixation, external fixation followed by IM nailing, and plates have all been proposed, often yielding suboptimal results [41,42,32,33,43]. Recent years have seen increased interest in managing open fractures, even Type IIIB, with reamed or unreamed nails [39]. However, concerns exist that immediate intramedullary nailing may elevate the risk of septic complications, nonunion, and pulmonary dysfunction. Consequently, a staged management approach involving initial external fixation followed by delayed reamed IM nailing has been advocated, particularly for Type III open fractures and polytrauma patients [27] [44]. The application of external fixation followed by conversion to an IM nail has both proponents and detractors [29] [30] [31]. Crucially, the risk factors for infection and nonunion in this sequence of fixation are not well-defined, and the optimal timing for converting an external fixator to an IM nail remains an unanswered question [32] [43]. A primary concern is establishing an appropriate interval between pin removal and nailing to allow the host's defense mechanisms to eradicate any residual bacteria from the pin sites. A systematic review of 96 studies further highlights these complexities [38].

Conclusion

Our study at Misurata Central Hospital demonstrates that unilateral external fixators serve as a viable and effective primary and definitive treatment option for complex tibial diaphyseal fractures, particularly in cases involving severe soft tissue injuries, Gustilo type III open fractures, and multiply injured patients. While complications such as pin track infections, delayed unions, and nonunions were observed, the majority of cases achieved union, and the external fixator was definitively used in a high percentage of patients. The decision for reoperation or a change in fixation method should be primarily guided by evidence of delayed callus formation. Continued research is warranted to further refine treatment protocols and optimize outcomes for these challenging injuries.

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