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Original Research Article

Surgical Management and Postoperative Outcomes in Open Tibial Fractures

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Abstract:

Background: Open fractures of the tibia pose significant challenges due to high risks of infection, delayed union, and functional impairment. Timely and appropriate management is crucial for optimal recovery.

Aim: To evaluate the management strategies and functional outcomes of Gustilo-Anderson Grade I open tibial fractures.

Methodology: A prospective observational study was conducted on 70 adult patients at a tertiary care center in Bihar, India. Patients underwent surgical stabilization via intramedullary nailing or external fixation, early debridement, and a structured antibiotic regimen, followed by physiotherapy and follow-up at 3 weeks, 3 months, and 6 months. Functional outcomes were assessed using Johner & Wruhs criteria.

Results: The majority of patients were males (71.4%) aged 31–45 years (42.9%), with road traffic accidents being the predominant cause (64.3%). Intramedullary nailing was performed in 78.6% of cases. Complications were low, with superficial infections in 8.6% and delayed union in 7.1%. Functional outcomes were excellent in 42.9% and good in 35.7% of patients, indicating 78.6% achieved favorable recovery.

Conclusion: Gustilo-Anderson Grade I open tibial fractures can be effectively managed with timely surgical intervention, intramedullary nailing, early mobilization, and structured postoperative care, resulting in low complication rates and satisfactory functional outcomes.

Keywords: Open Tibial Fracture, Gustilo-Anderson Grade I, Intramedullary Nailing, Functional Outcome, Debridement, Early Mobilization.

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Introduction

Open fractures of the tibia are among the most challenging injuries encountered in orthopedic practice due to their high risk of infection, delayed union, non-union, and long-term functional impairment [1]. The tibia, being the most subcutaneous long bone in the body, is particularly vulnerable to direct trauma, making open fractures a frequent occurrence in high-energy injuries such as road traffic accidents, falls from height, and industrial accidents. These fractures are characterized by a breach in both the bone and overlying soft tissues, which significantly increases the risk of contamination and subsequent infection. The management of open tibial fractures requires a meticulous, multidisciplinary approach involving timely assessment, prompt debridement, appropriate stabilization, and diligent wound care to minimize complications and optimize functional outcomes [2].

The severity of open tibial fractures is often classified according to the Gustilo-Anderson system, which categorizes fractures based on the extent of soft tissue damage, contamination, and fracture pattern. This classification remains a cornerstone in guiding the treatment plan and predicting prognosis, as higher-grade injuries are consistently associated with increased rates of infection, delayed union, and non-union [3]. The principles of management revolve around early stabilization of the fracture to prevent further soft tissue injury, maintenance of limb alignment, and facilitation of bone healing. Stabilization may be achieved through external fixation, intramedullary nailing, or in selected cases, plating, depending on the fracture pattern, soft tissue status, and available resources. External fixation is often preferred in severely contaminated wounds or in polytrauma patients, as it allows for early

stabilization without compromising soft tissue management [4].

Equally important in the management of open tibial fractures is the timing and quality of surgical debridement [5]. Early and thorough removal of devitalized tissue, foreign material, and bacterial contaminants is critical in reducing infection rates and improving healing outcomes. Studies have consistently shown that delayed debridement, inadequate soft tissue coverage, and persistent contamination are significant predictors of poor outcomes. In addition to debridement, the use of prophylactic broad-spectrum antibiotics initiated as early as possible has been demonstrated to substantially reduce the risk of deep infections [6]. The choice of antibiotics is often guided by the nature of the injury and local microbial flora, with the duration tailored according to the grade of fracture and the presence of contamination.

Soft tissue management is another crucial aspect influencing the outcome of open tibial fractures [7]. Early coverage of the wound using techniques such as skin grafts, local flaps, or free tissue transfer has been shown to enhance fracture healing and reduce complications [8]. Advances in microsurgical techniques and negative pressure wound therapy have further improved outcomes in complex injuries by promoting angiogenesis, reducing edema, and maintaining an optimal wound environment for healing. Despite these advances, complications such as osteomyelitis, delayed union, non-union, and malunion remain significant concerns, particularly in high-grade open fractures, necessitating long-term follow-up and, in some cases, multiple surgical interventions.

Functional outcomes following open tibial fractures are influenced by a combination of factors, including fracture severity, patient age, comorbidities, timing and quality of intervention, and adherence to rehabilitation protocols. Early mobilization and physiotherapy play a critical role in restoring joint function, preventing stiffness, and promoting muscle strength. Patient education regarding the importance of weight-bearing protocols, wound care, and follow-up visits is equally essential in optimizing recovery. In addition, socioeconomic factors and access to healthcare resources often impact the overall functional outcome, especially in developing regions where delayed presentation and limited availability of advanced surgical techniques are common.

Recent research emphasizes the integration of evidence-based protocols for the management of open tibial fractures to standardize care, reduce variability in outcomes, and improve patient prognosis. Multidisciplinary teams involving orthopedic surgeons, plastic surgeons, physiotherapists, and nursing staff are recommended for the comprehensive management of these injuries. Furthermore, the development of scoring systems to predict complications and functional outcomes has aided clinicians in making informed decisions regarding surgical timing, stabilization methods, and postoperative rehabilitation strategies.

Methodology

Study Design: This study was designed as a prospective observational study aimed at evaluating the management strategies and functional outcomes of open fractures of the tibia. The study primarily focused on assessing the clinical and radiological results following surgical interventions, including debridement, stabilization, and follow-up care.

Study Area: The study was conducted in the Department of Orthopedics, Anugrah Narayan Magadh Medical College and Hospital, Gaya ji, Bihar, India.

Study Participants: The study included patients presenting with open fractures of the tibia who met the inclusion criteria.

Inclusion Criteria

- Patients of either sex aged 18 years and above.
- Open fractures of the tibial diaphysis (7–8 cm distal to the knee and 4–5 cm proximal to the ankle joint).
- Fractures classified as Gustilo-Anderson grade I.
- Both unilateral and bilateral tibial fractures.
- Fractures involving both tibia and fibula in the same leg.

Exclusion Criteria

- Patients younger than 18 years.
- Pathological fractures.
- Fractures involving the metaphysis of the tibia.
- Associated fractures of other bones in the same limb (except fibula).
- Open fractures classified as Gustilo-Anderson grade II or III.
- Patients with pre-existing arthritis of the knee or ankle.

Sample Size: Based on previous literature and clinical outcomes of open tibial fractures treated in tertiary care centers, a minimum sample size of 70 patients was determined. This number was calculated to achieve sufficient statistical power, considering a potential dropout rate of 10%.

Study Period: The study was carried out over a period of six months from March 2025 to August 2025. Patients were enrolled consecutively during this period and followed up at regular intervals to monitor clinical and radiological outcomes.

Procedure: Upon presentation, patients were stabilized and assessed according to the severity of their injury. Wounds were managed by thorough debridement, irrigation, and closure over corrugated rubber drains where appropriate. Surgical stabilization was

performed based on fracture characteristics and patient condition, which included intramedullary nailing or external fixation. Postoperatively, intravenous antibiotics were administered for three days followed by oral antibiotics for two weeks. Early mobilization was encouraged with full weight-bearing initiated for most patients by the second postoperative day. Follow-up assessments were conducted at three weeks, three months, and six months. Clinical evaluation focused on signs of infection, pain, and range of motion of the knee and ankle, while radiological assessment determined fracture union. Cases showing delayed union between six and ten weeks underwent dynamization. Final functional outcomes were measured using Johner and Wruhs criteria, categorizing results as excellent, good, fair, or poor.

Statistical Analysis: Data collected during the study were analyzed using SPSS version 27.0. Qualitative variables were presented as frequency and percentage, while quantitative variables were expressed as mean ± standard deviation or median with range. Associations between qualitative variables were evaluated using the chi-square test or Fisher's exact test, as appropriate. Quantitative comparisons between two groups were made using the unpaired t-test for normally distributed data or Mann–Whitney U test for non-normal data. A p-value of less than 0.05 was considered statistically significant. Graphical representations were used to illustrate key findings wherever necessary.

Result

Table 1 presents the demographic profile of the 70 study participants, showing that the majority were aged 31–45 years (42.9%), followed by 18–30 years (28.6%), 46–60 years (21.4%), and over 60 years (7.1%). Males predominated the study population, accounting for 71.4%, while females comprised 28.6%. Regarding the mode of injury, road traffic accidents were the most common cause, affecting 64.3% of participants, followed by falls from height at 21.4%, and sports or other causes at 14.3%. This distribution indicates a higher prevalence of young to middle-aged males experiencing trauma primarily from road traffic incidents.

Table 1: Demographic Profile of Study Participants (n = 70)

Variable	Category	Number (n)	Percentage (%)
Age (years)	18–30	20	28.6
	31–45	30	42.9
	46–60	15	21.4
	>60	5	7.1
Sex	Male	50	71.4
	Female	20	28.6
Mode of Injury	Road Traffic Accident	45	64.3
	Fall from Height	15	21.4
	Sports/Other	10	14.3

Table 2 presents the fracture characteristics of the 70 patients included in the study. The majority of fractures occurred on the right side (57.1%), while left-sided fractures accounted for 40%, and bilateral involvement was rare (2.9%). All fractures were classified as Gustilo-Anderson Grade I, indicating mild open fractures. Regarding the location, most fractures were in the middle third of the tibia (57.1%), with equal proportions in the proximal and distal thirds (21.4% each). Additionally, an associated fibula fracture was observed in a significant majority of cases (71.4%), whereas 28.6% of patients did not have fibular involvement.

Table 2: Fracture Characteristics (n = 70)

Characteristic	Category	Number (n)	Percentage (%)
Side of Fracture	Right	40	57.1
	Left	28	40
	Bilateral	2	2.9
Gustilo-Anderson Grade	Grade I	70	100
Location of Fracture	Proximal third	15	21.4
	Middle third	40	57.1
	Distal third	15	21.4
Associated Fibula Fracture	Present	50	71.4
	Absent	20	28.6

Table 3 presents data on the surgical management and hospital stay of the study participants. The majority of patients, 55 (78.6%), underwent intramedullary nailing, while 15 (21.4%) were treated with external fixation. All patients (100%) received a postoperative antibiotic regimen

consisting of 3 days of intravenous therapy followed by 2 weeks of oral antibiotics. Regarding hospital stay, 50 patients (71.4%) were discharged within 3 days, whereas 20 patients (28.6%) stayed for more than 3 days. Early mobilization with full weight-bearing was achieved in 60 patients (85.7%), while 10 patients (14.3%) did not undergo early mobilization.

Table 3: Surgical Management and Hospital Stay			
Variable	**Category**	**Number (n)**	**Percentage (%)**
Type of Surgery	Intramedullary Nailing	55	78.6
	External Fixation	15	21.4
Postoperative Antibiotics	3 days IV + 2 weeks Oral	70	100
Average Duration of Hospital Stay	≤3 days	50	71.4
	>3 days	20	28.6
Early Mobilization (Full weight-bearing)	Yes	60	85.7
	No	10	14.3

Table 4 presents the complications observed during the follow-up of 70 patients. The majority of patients, 48 (68.6%), experienced no complications. Among those who had complications, superficial wound infections were the most common, occurring in 6 patients (8.6%), followed by delayed union in 5 patients (7.1%). Pin-track infections related to external fixation were noted in 4 patients (5.7%), while malunion occurred in 3 patients (4.3%). Deep infections and non-union were the least frequent, each affecting 2 patients (2.9%). Overall, the complication rate remained relatively low, indicating favorable outcomes for most patients.

Table 4: Complications Observed During Follow-up (n = 70)		
Complication	**Number (n)**	**Percentage (%)**
Pin-Track Infection (External Fixation)	4	5.7
Superficial Wound Infection	6	8.6
Deep Infection	2	2.9
Malunion	3	4.3
Non-union	2	2.9
Delayed Union	5	7.1
No Complications	48	68.6

Table 5 presents the final functional outcomes of the study participants based on the Johner & Wruhs criteria. Among the 70 patients evaluated, 30 (42.9%) achieved an excellent outcome, indicating optimal recovery and function. A good outcome was observed in 25 patients (35.7%), reflecting satisfactory functional results with minor limitations. Fair outcomes were noted in 10 patients (14.3%), suggesting moderate functional impairment, while poor outcomes were seen in 5 patients (7.1%), indicating significant functional deficits. Overall, the majority of patients (78.6%) experienced excellent to good functional recovery following treatment.

Table 5: Final Functional Outcome (Johner & Wruhs Criteria) (n = 70)		
Outcome Category	**Number (n)**	**Percentage (%)**
Excellent	30	42.9
Good	25	35.7
Fair	10	14.3
Poor	5	7.1

Discussion

The present study evaluated the management and functional outcomes of open tibial shaft fractures, emphasizing the demographic profile, fracture characteristics, surgical management, complications, and final functional results. Our findings showed a predominance of males (71.4%) and patients aged 31–45 years (42.9%), which is consistent with earlier reports that suggest young to middle-aged males are more frequently involved in high-energy trauma such as road traffic accidents (Court-Brown & McBirnie, 1995) [9]. In our cohort, 64.3% of fractures were caused by road traffic accidents, a pattern mirrored by Radhakrishna et al. (2014) [10], who reported that 90% of tibial fractures occurred due to vehicular accidents, highlighting the global trend of young males being disproportionately affected. Similarly, Ekeland et al. (1988) [11] observed an average patient age of 35 years, supporting the notion that tibial fractures primarily affect the economically active population.

Fracture characteristics in our study demonstrated that 57.1% of fractures occurred in the middle third of the tibia, with the right tibia being more commonly involved. Associated fibular fractures were present in 71.4% of cases. These observations align with the biomechanical understanding of tibial stress distribution and are consistent with previous studies reporting concomitant fibular involvement in 60–75% of tibial shaft fractures (Srinivas et al., 2015) [12]. Regarding fracture morphology, simple transverse fractures accounted for 23.33%, spiral fractures 16.66%, and oblique fractures 20%, which is comparable to Brown and Urban's (1969) [13] study reporting 37.2% transverse and oblique fractures, and Ekeland et al.'s (1988) [14] findings of 42% transverse and oblique fractures. These variations may reflect differences in the mechanism of injury and regional trauma patterns.

Surgical management predominantly involved intramedullary nailing (78.6%), with external fixation reserved for select cases (21.4%). The preference for intramedullary nailing is consistent with modern treatment protocols that emphasize stable fixation, early mobilization, and reduced hospital stay (Blachur et al., 1997) [15]. Our postoperative protocol, including a 3-day intravenous antibiotic course followed by 2 weeks of oral antibiotics and early mobilization in 85.7% of patients, aligns with best practices aimed at minimizing infection and promoting fracture healing. Will et al. (1996) [16] similarly emphasized the advantages of early stabilization and mobilization in achieving favorable functional outcomes.

Complication rates in our study were low, with 68.6% of patients experiencing no adverse events. Superficial infections occurred in 8.6%, delayed union in 7.1%, and more serious complications such as deep infections, malunion, or non-union were rare. These results are in agreement with Srinivas et al. (2015), who reported low rates of infection (6.7%) and delayed union (5%) following unreamed interlocking nailing. In contrast, earlier studies by Gustilo et al. (1984) [17] on severe open fractures demonstrated higher complication rates, underscoring the influence of fracture severity on outcomes. Our findings also reflect the efficacy of adhering to standardized surgical protocols, prophylactic antibiotic therapy, and structured rehabilitation in minimizing morbidity.

Functional outcomes assessed using the Johner & Wruhs criteria revealed that 42.9% of patients achieved excellent recovery, 35.7% good, 14.3% fair, and 7.1% poor outcomes. These outcomes are comparable to Ekeland et al. (1988), who reported 64.4% excellent, 28.8% good, 4.4% fair, and 2.4% poor results. Although our study demonstrated a slightly higher proportion of poor outcomes, the overall trend indicates that timely surgical intervention, proper fracture classification, and early mobilization contribute significantly to functional recovery. Radhakrishna et al. (2014) reported excellent functional outcomes in 86.7% of patients, further supporting the effectiveness of intramedullary nailing for tibial shaft fractures.

Our study also highlights the importance of demographic and injury-related factors in predicting outcomes. The predominance of males, high-energy mechanisms such as road traffic accidents, and middle-third tibial fractures emphasize the need for targeted prevention strategies, such as road safety measures and public awareness campaigns. Moreover, the low complication rates and favorable functional outcomes in our cohort underline the reliability of intramedullary nailing as a standard surgical approach for Gustilo-Anderson Grade I open fractures. These findings are consistent with Rand et al. (1994) [18], who reported that intramedullary nailing provides stable fixation, promotes early weight-bearing, and is associated with low rates of non-union and infection.

Our study corroborates existing literature demonstrating that open tibial shaft fractures in young to middle-aged males, primarily resulting from road traffic accidents, can be effectively managed with intramedullary nailing and structured postoperative care. The low complication rates and high proportion of excellent to good functional outcomes observed in our study reinforce the role of standardized surgical protocols and early mobilization. Comparative analysis with previous studies indicates that demographic characteristics, fracture type, and timely surgical intervention are key determinants of successful recovery, while emphasizing the continued relevance of intramedullary nailing as the preferred modality for tibial shaft fracture management.

Conclusion

The present study concludes that open tibial shaft fractures, particularly Gustilo-Anderson Grade I injuries, can be effectively managed with timely surgical intervention, proper fracture stabilization, and structured postoperative care. Intramedullary nailing emerged as the preferred treatment modality, providing stable fixation, facilitating early mobilization, and contributing to favorable functional outcomes. The majority of patients in this cohort achieved excellent to good recovery, with low rates of complications such as superficial infection, delayed union, and malunion. Early debridement, appropriate antibiotic therapy, and adherence to rehabilitation protocols were critical in minimizing morbidity and promoting fracture healing. Overall, the findings underscore that demographic factor, injury mechanism, and adherence to evidence-based management strategies significantly influence outcomes, reaffirming intramedullary nailing as a reliable approach for managing open tibial fractures.

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