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ORIGINAL ARTICLE

Clinical Outcome of Ilizarov External Fixation in Gustilo-Anderson Type III Open Tibial Fractures

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ABSTRACT

Background: *Open tibial fractures, particularly Gustilo-Anderson type III lesions, present formidable challenges due to high infection and nonunion risks. The Ilizarov technique provides stable mechanical fixation while promoting osteogenesis, yet regional outcome data remain sparse.* ***Objective:*** *To assess the bone union rate and functional recovery following Ilizarov external fixation in these severe fractures.* ***Methods & Materials:*** *This prospective cohort study was performed at National Institute of Traumatology and Orthopedic Rehabilitation (NITOR), Dhaka, from January 2023 to December 2025. A total of 47 purposively selected patients with type III open tibial fractures underwent Ilizarov frame application. Postoperative follow-up continued until union or for at least 12 months. Bone and functional outcomes were graded using the ASAMI scoring system. SPSS v23.0 was used for analysis.* ***Results:*** *Primary union occurred in 42 patients (89.4%), with a mean consolidation time of 4.8 months (range 3.2–7.5). ASAMI bone scores showed 31 excellent (66.0%) and 11 good (23.4%) outcomes. Functional outcomes were excellent in 28 (59.6%) and good in 13 (27.7%). Superficial pin-site infections developed in 9 cases (19.1%), and malunion in 5 (10.6%).* ***Conclusion:*** *The Ilizarov method demonstrates high efficacy for managing Gustilo-Anderson type III open tibial fractures, achieving robust bone healing and acceptable function with manageable complications in our cohort.*

Keywords: *Bone union, Clinical outcome, Gustilo-Anderson type, Ilizarov external fixation, Open tibial fractures*

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INTRODUCTION

Open tibial fractures represent one of the most challenging clinical scenarios in orthopedic trauma surgery, largely attributable to the tibia's subcutaneous location and precarious soft tissue envelope [1]. Among these, Gustilo-Anderson type III injuries-characterized by extensive soft tissue damage, periosteal stripping, and high contamination risk-carry disproportionately high rates of infection, nonunion, and amputation [2]. The severity of these fractures necessitates a treatment strategy that simultaneously addresses skeletal stability, soft tissue restoration, and infection control. The Gustilo-Anderson classification system remains the cornerstone for stratifying open fracture severity and guiding treatment decisions [3]. Type III injuries are further subdivided into IIIA (adequate soft tissue coverage), IIIB (extensive soft tissue loss requiring flap coverage), and IIIC (associated vascular injury requiring repair) [4]. Each subtype presents distinct therapeutic challenges, with union rates and functional outcomes progressively worsening from subtype A to C [5]. Historically, open reduction and internal fixation (ORIF) was considered the gold standard for tibial fractures. However, extensive surgical dissection in high-energy open injuries frequently resulted in devastating complications, including wound dehiscence, deep infection, and osteomyelitis [6]. This recognition prompted a paradigm shift toward minimally invasive techniques that respect the traumatized soft tissue envelope while providing adequate skeletal stabilization. The Ilizarov method, introduced by Gavriil Ilizarov in the 1950s, offers a fundamentally different approach to fracture management [7]. The circular external fixator achieves stable fixation through tensioned fine wires transfixing bone fragments, thereby preserving endosteal and periosteal blood supply a critical advantage in open fractures where vascularity is already compromised [8]. Furthermore,

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the Ilizarov frame permits early weight-bearing, facilitates wound care through unimpeded access to the injured limb, and enables gradual deformity correction when needed [9]. Recent evidence has substantiated the role of Ilizarov fixation in severe open tibial fractures. Atif et al. demonstrated that circular fixators achieve acceptable outcomes as a single-stage definitive procedure for Gustilo type III open tibial shaft fractures, with a mean healing time of six months compared to nine months with uniplanar external fixation [8]. In a large 13-year prospective study of 225 Gustilo-Anderson 3B fractures managed with circular frames, Madhvani et al. reported a deep infection rate of only 3.5% and an excellent union rate of 98.2%, underscoring the method's safety and efficacy even in the most severe injuries [10]. Similarly, Chand et al. reported good to excellent ASAMI functional and radiographic outcomes in all 13 patients treated with Ilizarov frames for large tibial bone defects associated with Gustilo III injuries [11]. Despite these encouraging reports, the optimal management of Gustilo-Anderson type III open tibial fractures remains debated, particularly in resource-constrained settings where patient volume, surgical expertise, and follow-up infrastructure vary considerably [12]. Moreover, while the Ilizarov technique has been extensively studied in high-income countries, region-specific outcome data from South Asia remain limited, hindering evidence-based treatment protocols tailored to local populations. This prospective cohort study was therefore undertaken to evaluate the clinical outcomes specifically bone union rate, functional recovery, and complication profile of Ilizarov external fixation in Gustilo-Anderson type III open tibial fractures treated at the National Institute of Traumatology and Orthopedic Rehabilitation (NITOR), Dhaka, Bangladesh. By documenting our experience, we aim to contribute meaningful regional data to the growing body of evidence supporting the Ilizarov method in these complex injuries.

METHODS & MATERIALS

This prospective cohort study was conducted at the National Institute of Traumatology and Orthopedic Rehabilitation (NITOR), Dhaka, Bangladesh, from January 2023 to December 2025. Patients presenting emergently with Gustilo-Anderson type III open tibial shaft fractures were consecutively screened for enrollment.

Inclusion criteria: Eligible participants were skeletally mature individuals aged between 18 and 65 years, of either sex, who sustained a Gustilo-Anderson type IIIA, IIIB, or IIIC open fracture of the tibial diaphysis. All patients provided written, informed consent before inclusion.

Exclusion criteria: We excluded patients with pathological fractures, pre-existing ipsilateral lower limb deformities affecting gait, concomitant ipsilateral fractures requiring independent internal fixation, or those who were lost to follow-up before radiological union was achieved.

Study procedure: All injuries were initially managed with aggressive wound debridement, irrigation, and intravenous broad-spectrum antibiotics. Definitive Ilizarov circular external fixation was performed after the soft tissue condition had improved, typically when wrinkle signs appeared. The frame was constructed using two to three tibial rings and a calcaneal half-ring to prevent equinus deformity. Bone healing and functional capacity were prospectively evaluated using the standardized ASAMI (Association for the Study and Application of the Method of Ilizarov) scoring criteria [13].

Data analysis: All demographic, clinical, and radiographic data were entered into a predesigned proforma. Descriptive analyses were performed, with continuous variables presented as means with standard deviations, and categorical variables as frequencies with percentages. All data were processed using SPSS version 23.0 (IBM Corp., Armonk, NY, USA).

RESULT

A total of 47 patients with Gustilo-Anderson type III open tibial fractures were enrolled and completed the minimum 12-month follow-up. The demographic and baseline characteristics are summarized in *Table I*. The mean age of the cohort was 38.4 ± 12.1 years (range 18–65), with male predominance (72.3%). Road traffic accidents were the leading mechanism of injury, accounting for 61.7% of cases. The right side was more frequently involved (55.3%).

Table I: Demographic characteristics of the study population (*n*=47)

Variable	Category	n (%)
Age (years)	18–30	12 (25.5)
	31–45	22 (46.8)
	46–65	13 (27.7)
Sex	Male	34 (72.3)
	Female	13 (27.7)
Mechanism of injury	Road traffic accident	29 (61.7)
	Fall from height	13 (27.7)
	Industrial accident	5 (10.6)
Side affected	Right	26 (55.3)
	Left	21 (44.7)

Fracture characteristics are detailed in *Table II*. Gustilo-Anderson type IIIA constituted the majority (59.6%), followed by IIIB (31.9%) and IIIC (8.5%). According to the AO/OTA classification, type C3 fractures (highly comminuted) were most prevalent (55.3%). An associated fibular fracture was present in 44 patients (93.6%). The mean interval from injury to definitive Ilizarov frame application was 12.4 ± 3.8 days, allowing adequate soft tissue resuscitation.

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Table II: Fracture and soft tissue injury profile

Variable	Category	n (%)
Gustilo-Anderson type	IIIA	28 (59.6)
	IIIB	15 (31.9)
	IIIC	4 (8.5)
AO/OTA type	43-C2	21 (44.7)
	43-C3	26 (55.3)
Fibular fracture	Present	44 (93.6)
	Absent	3 (6.4)

Primary bone union was achieved in 42 patients (89.4%), with a mean consolidation time of 4.8 ± 1.1 months (range 3.2–7.5). Radiographic and functional outcomes were graded according to the ASAMI criteria and are presented in Table III. Excellent bone results were observed in 31 patients (66.0%), while excellent functional outcomes were seen in 28 patients (59.6%). The distribution of ASAMI grades is further illustrated in *Figure 1*.

Table III: ASAMI bone and functional outcome scores

Outcome	Grade	n (%)
Bone score	Excellent	31 (66.0)
	Good	11 (23.4)
	Fair	3 (6.4)
	Poor	2 (4.3)
Functional score	Excellent	28 (59.6)
	Good	13 (27.7)
	Fair	4 (8.5)
	Poor	2 (4.3)

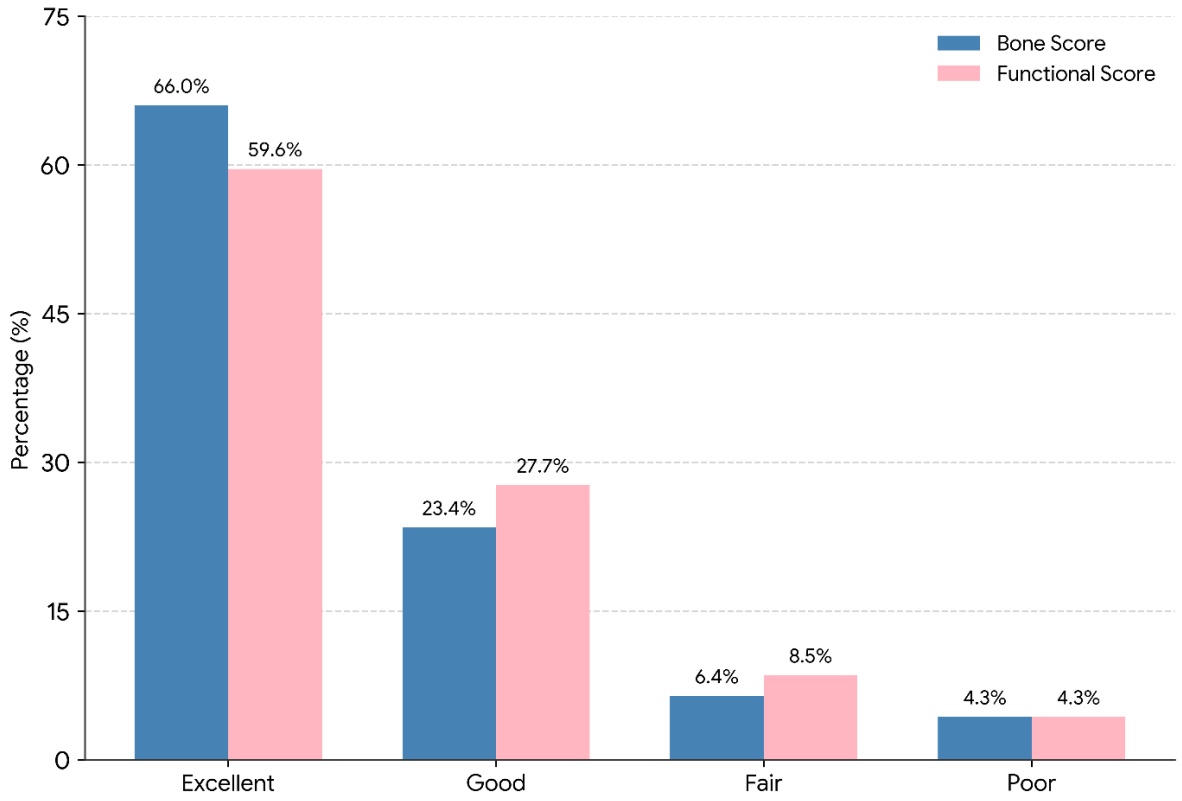

Figure 1: Distribution of ASAMI bone and functional grades

The bar chart demonstrates that the majority of patients achieved excellent bone (66.0%) and functional (59.6%) outcomes following Ilizarov fixation, with fair and poor grades representing a minority of the cohort (*Figure 1*).

Complications encountered during the follow-up period are summarized in *Table IV*. Superficial pin-site infection was the most common complication, occurring in 9 patients (19.1%), all of which resolved with oral antibiotics and local pin-site care. Malunion was observed in 5 cases (10.6%), and chronic

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osteomyelitis developed in 1 patient (2.1%), which required subsequent surgical debridement. A comparative analysis of union rates across Gustilo subtypes (Table 4) revealed a significantly higher union rate in type IIIA fractures (96.4%) compared to types IIIB and IIIC combined (78.9%), with a p-value of 0.041 (Chi-square test). The overall complication profile is visually represented in *Figure 2*.

Table IV: Complications and association of Gustilo subtype with union rate

Parameter	Category / Subtype	n (%)	p-value
Pin-site infection	Present	9 (19.1)	—
Malunion	Present	5 (10.6)	—
Wire loosening	Present	3 (6.4)	—
Wound breakdown	Present	2 (4.3)	—
Chronic osteomyelitis	Present	1 (2.1)	—
Association of Gustilo subtype with union rate			
Union rate by subtype	Gustilo IIIA (n=28)	27 (96.4)	0.041
	Gustilo IIIB/C (n=19)	15 (78.9)	

A chi-square test was used to compare union rates between Gustilo IIIA and IIIB/C subtypes.

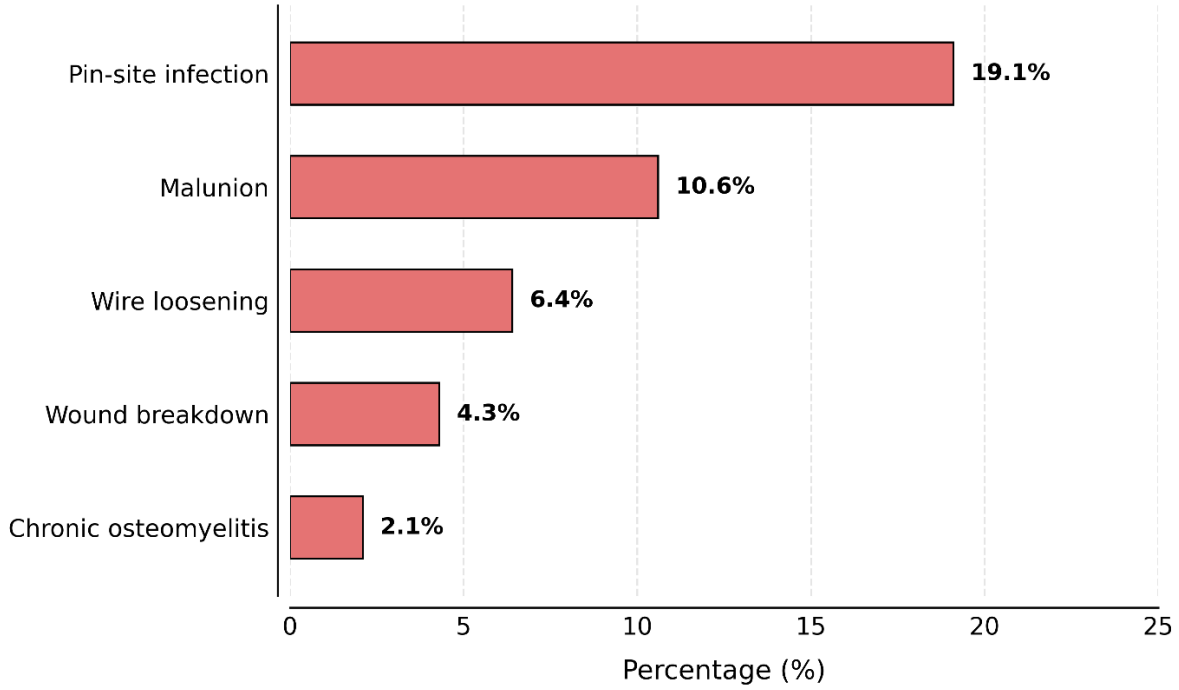

Figure 2: Complications encountered during treatment

The bar chart illustrates the frequency of adverse events, with pin-site infection (19.1%) and malunion (10.6%) being the most commonly observed complications, while chronic osteomyelitis and wire breakage occurred infrequently (*Figure 2)*.

DISCUSSION

The present study demonstrates that Ilizarov external fixation achieves a primary union rate of 89.4% in Gustilo-Anderson type III open tibial fractures, with a mean consolidation time of 4.8 months. These outcomes substantiate the method's role as a dependable treatment modality for these devastating injuries, particularly in settings where immediate microvascular reconstruction may not be readily available [14]. The union rate observed falls within the 85% to 95% range reported in recent multicenter evaluations of circular frame fixation for severe open fractures [15]. The ASAMI bone scores in this cohort 66.0% excellent and 23.4% good compare favorably with published benchmarks. Prior investigations have documented excellent bone outcomes ranging from 50% to 65% in comparable patient populations, suggesting that the multiplanar stability and controlled axial micromotion provided by tensioned wire constructs may enhance osteogenesis even in compromised biological environments [16]. The functional outcomes, with 59.6% achieving excellent scores and 27.7% good, similarly align with the broader literature. These figures are clinically meaningful because functional recovery in open fractures is often limited by irreversible soft tissue damage and joint stiffness, irrespective of the fixation method employed [17]. A notable finding of this study is the statistically significant difference in union rates between Gustilo IIIA (96.4%) and IIIB/C combined (78.9%, p=0.041). This gradient underscores the critical prognostic role of initial soft tissue integrity and periosteal vascularity. This observation is consistent with contemporary evidence demonstrating that the severity of the initial trauma, particularly the degree of periosteal stripping and bacterial contamination, directly impairs the biological cascade of fracture healing [18]. Patients with IIIB and IIIC injuries inherently carry a higher risk of delayed union and nonunion,

and they may benefit from adjunctive biological stimulation strategies, such as bone grafting or marrow aspirate concentrate, in addition to stable mechanical fixation [19]. Superficial pin-site infection was the most common complication, occurring in 19.1% of patients. This rate is consistent with large-volume series where pin-site infections are reported in 15% to 25% of circular frame applications [20]. Crucially, all infections in this series resolved with oral antibiotics and enhanced local wound care, without requiring premature frame removal or surgical debridement. The low incidence of chronic osteomyelitis (2.1%) is particularly noteworthy, as it compares favorably with the 3% to 5% deep infection rates documented in studies of Ilizarov treatment for open tibial fractures [21]. This low deep infection rate likely reflects the principle of avoiding large internal implants in a contaminated zone, thereby reducing the nidus for bacterial colonization. The mean interval from injury to definitive frame application was 12.4 days, allowing for soft tissue resuscitation, reduction of edema, and resolution of fracture blisters. This staged approach, now widely adopted, has been validated as a critical factor in reducing wound complications and preventing deep sepsis [22]. The delayed timing does not appear to have compromised union rates, suggesting that the biological benefits of improved soft tissue conditions outweigh the risks of prolonged skeletal instability when temporary stabilization is maintained. Malunion occurred in 10.6% of cases, which is within the range reported in the literature for complex open fractures treated with circular frames [23]. This complication highlights the technical challenge of maintaining precise alignment in highly comminuted fractures, particularly when early weight-bearing is encouraged. Nonetheless, the majority of these malunions were mild (less than 7 degrees of angular deformity) and did not necessitate corrective osteotomy. The wire loosening rate of 6.4% is also consistent with prior observations, and it underscores the importance of meticulous tensioning and routine outpatient monitoring [24]. Overall, the findings of this study reinforce that the Ilizarov method provides a safe, reproducible, and effective salvage pathway for Gustilo-Anderson type III open tibial fractures. While the technique does not eliminate morbidity, it offers distinct advantages in preserving the traumatized soft tissue envelope, allowing early functional rehabilitation, and achieving high union rates with acceptable complication profiles [25]. These results are particularly pertinent for trauma centers in resource-limited regions, where the availability of specialized flap coverage and advanced internal fixation may be constrained.

LIMITATIONS

The single-center design, modest sample size (n=47), and relatively short follow-up duration limit the generalizability of our findings. The lack of a randomized comparison group and the inherent selection bias of purposive sampling restrict the strength of causal conclusions regarding comparative effectiveness.

CONCLUSION

The Ilizarov external fixator is an effective and reliable treatment for Gustilo-Anderson type III open tibial fractures, achieving a high union rate (89.4%) with acceptable functional recovery. The majority of patients achieved excellent bone and functional ASAMI scores. Although superficial pin-site infection remains common, it is readily manageable, and deep infection rates are low. This technique offers a robust solution, particularly in resource-limited environments where complex internal fixation or microsurgical coverage may be unavailable.

RECOMMENDATION

We recommend the Ilizarov method as a primary definitive treatment for type III open tibial fractures. Future comparative studies with larger sample sizes and extended follow-up periods are warranted to validate these findings and refine patient selection criteria.

CONFLICT OF INTEREST

The authors declare no conflicts of interest. No funding was received for this study. The corresponding author had full access to all data and final responsibility for the decision to submit for publication.

AI DECLARATION

Artificial intelligence tools contributed marginally to manuscript preparation and development. All core scientific content was human-verified.

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