

ORIGINAL ARTICLE

Clinical and Functional Outcome of Ilizarov External Fixation in the Management of Infected Tibial Nonunion

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ABSTRACT

Background: Infected tibial nonunion is a difficult complication characterized by persistent infection, bone loss, deformity, instability, and impaired limb function. Ilizarov external fixation offers simultaneous infection control, stable fixation, bone transport, deformity correction, and functional restoration. **Aim of the study:** The study aims to evaluate the clinical and functional outcomes of Ilizarov external fixation in the management of infected tibial nonunion. **Methods & Materials:** This descriptive observational study included 40 consecutive adults with infected tibial nonunion treated with Ilizarov external fixation at the National Institute of Traumatology and Orthopedic Rehabilitation (NITOR), Dhaka, Bangladesh, from July 2024 to June 2025. All patients underwent debridement, with acute docking, corticotomy, bone transport, or bone grafting performed as required. Clinical and radiological follow-up assessed union, eradication of infection, ASAMI bone and functional outcomes, weight-bearing status, deformity, limb-length discrepancy, and complications. Data were analyzed using SPSS and summarized as mean $\pm$ SD, frequencies, and percentages. **Results:** Among 40 patients, the mean age was 39.6 ± 10.8 years; 82.5% were male, 67.5% sustained road traffic injuries, and 77.5% had open fractures. Bone defects were present in 72.5%, while *Staphylococcus aureus* was isolated in 45.0%. Following Ilizarov treatment, radiological union was achieved in 90.0%, eradication of infection in 87.5%, and overall treatment success in 85.0%. Excellent-to-good ASAMI bone and functional outcomes were observed in 82.5% and 77.5% of cases, respectively. Pin-tract infection was the most frequent complication, occurring in 37.5% of cases. **Conclusion:** Overall, Ilizarov external fixation achieved high rates of bone union, eradication of infection, and favorable functional recovery in infected tibial nonunion, with mostly manageable complications. The technique appears to be an effective limb-reconstruction option for complex cases with bone loss, deformity, and chronic infection.

Keywords: Infected tibial nonunion; Ilizarov external fixation; Bone union; Infection eradication; Functional outcome.

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INTRODUCTION

Globally, tibial fractures represent a major component of musculoskeletal trauma, particularly after high-energy road traffic injuries, falls, and occupational accidents. Because the tibia has limited anteromedial soft-tissue coverage and relatively vulnerable blood supply, open tibial fractures are particularly susceptible to contamination, soft-tissue injury, fracture-related infection, delayed healing, and subsequent nonunion [1,2]. Approximately 15% of tibial fractures are open injuries, while open tibial shaft fractures constitute a substantial proportion of all open long-bone fractures [1]. Once

infection and nonunion coexist, treatment becomes considerably more challenging because mechanical instability, devitalized bone, compromised soft tissues, deformity, limb shortening, and persistent infection may occur simultaneously [3,4]. Within low- and middle-income countries, these problems are particularly important because high-energy trauma remains common and timely access to specialized orthopaedic reconstruction may be limited. In Bangladesh, road traffic injuries represent an important cause of hospitalization and disability; among hospitalized road-traffic-injury patients studied in Dhaka, lower-limb injuries were among the most

frequently documented injury patterns [5]. Moreover, evidence from a major Bangladeshi trauma centre demonstrated that motor vehicle accidents accounted for 72.2% of open tibial fractures, while postoperative cultures revealed a considerable burden of infection and multidrug-resistant organisms [6]. Consequently, infected tibial nonunion may create a particularly substantial clinical and socioeconomic burden in settings where patients are commonly young, economically active adults and prolonged treatment can disrupt employment and family responsibilities. Clinically, management requires eradication of infection while simultaneously restoring skeletal stability, achieving bone union, correcting deformity and limb-length discrepancy, and recovering useful limb function. Although conventional approaches include repeated debridement, antibiotic-loaded cement, cancellous bone grafting, vascularized bone transfer, internal fixation, and the Masquelet induced-membrane technique, each has limitations when extensive infection, bone loss, deformity, or poor soft-tissue conditions are present [7,8]. In contrast, Ilizarov circular external fixation provides stable fixation while permitting compression, distraction osteogenesis, bone transport, deformity correction, and progressive weight bearing without retaining internal hardware within an infected area [3,9,10]. Encouraging clinical outcomes have consequently been reported. Across several contemporary series, Ilizarov treatment has produced high union rates and favorable ASAMI bone and functional outcomes in infected tibial nonunion [3,9,11]. More recently, satisfactory limb salvage, infection control, and functional recovery have also been reported in complex distal and proximal tibial nonunions [12,13]. Nevertheless, prolonged external fixation, pin-tract infection, joint stiffness, residual deformity, docking-site problems, and patient discomfort remain important concerns [9,14]. Comparative evidence also remains heterogeneous; recent systematic and scoping reviews have emphasized the predominance of observational studies, small cohorts, differing defect sizes, variable techniques, and limited high-quality prospective evidence [8,15]. Despite the clinical relevance of infected tibial nonunion in trauma-heavy, resource-constrained settings, locally generated evidence evaluating both anatomical healing and functional recovery remains limited in Bangladesh. Therefore, assessment of Ilizarov treatment under local clinical circumstances is necessary to clarify its effectiveness, complications, and potential role in limb reconstruction. Accordingly, this study aimed to evaluate the clinical and functional outcomes of Ilizarov external fixation in the management of infected tibial nonunion, with particular emphasis on bone union, eradication of infection, ASAMI bone and functional outcomes, weight-bearing recovery, residual deformity, limb-length discrepancy, and treatment-related complications.

METHODS & MATERIALS

Between July 2024 to June 2025, a prospective observational study was conducted in the Department of Orthopaedic Surgery, National Institute of Traumatology and Orthopedic Rehabilitation (NITOR), Dhaka, Bangladesh. In accordance with predefined eligibility criteria, 40 consecutive patients with infected tibial nonunion who underwent Ilizarov external fixation were enrolled. Patients aged ≥ 18 years with established infected tibial nonunion, persistent or recurrent infection, and radiological evidence of nonunion were included. Those with pathological fractures, severe peripheral vascular disease, malignancy, major neurovascular injury, or inadequate follow-up were excluded. After admission, demographic characteristics, injury history, previous surgical procedures, duration and site of nonunion, fracture type, presence of a discharging sinus, bone defect, and relevant comorbidities were recorded using a structured data-collection form. Before surgery, routine hematological and biochemical investigations, radiographs, and microbiological cultures from deep tissue or infected sites were obtained where appropriate. Under suitable anesthesia, thorough debridement of all infected and devitalized soft tissue and bone was performed until viable tissue was achieved. Depending on the size of the bone defect and limb condition, acute docking, corticotomy, bone transport, or additional bone grafting was performed. Subsequently, a circular Ilizarov frame was applied to achieve stable fixation, deformity correction, and restoration of limb length. Following surgery, culture-directed antibiotics, regular pin-site care, physiotherapy, and progressive weight bearing were provided according to clinical tolerance. During follow-up, patients were assessed clinically and radiologically at regular intervals until union or completion of treatment. Primary outcomes included radiological union, time to union, eradication of infection, and bone and functional outcomes according to the Association for the Study and Application of the Method of Ilizarov criteria. Secondary outcomes included limb-length discrepancy, residual deformity, weight-bearing status, duration of external fixation, and treatment-related complications. After data collection, analyses were performed using SPSS (V. 26.0). Continuous variables were expressed as mean $\pm$ standard deviation, while categorical variables were presented as frequencies and percentages. Before enrollment, ethical approval was obtained from the institutional ethics committee, and written informed consent was obtained from all participants.

RESULTS

Among the 40 participants, the mean age was 39.6 ± 10.8 years, with males comprising 82.5% of the study population. Rural residents accounted for 65.0%, while 42.5% were smokers. Previous surgery for the tibial fracture had been performed in 85.0% of cases, and the mean duration of nonunion was 15.2 ± 7.4 months (*Table 1*).

Table I: Demographic and baseline clinical characteristics of the study participants (n=40).

Variables	Categories	n (%)
Age (years)	Mean $\pm$ SD	39.6 $\pm$ 10.8
Age group	≤ 30 years	8 (20.0)
	31–40 years	15 (37.5)
	41–50 years	11 (27.5)
	>50 years	6 (15.0)
Sex	Male	33 (82.5)
	Female	7 (17.5)
Residence	Urban	14 (35.0)
	Rural	26 (65.0)
Smoking status	Smoker	17 (42.5)
	Non-smoker	23 (57.5)
Diabetes mellitus	Present	7 (17.5)
	Absent	33 (82.5)
Duration of nonunion (months)	Mean $\pm$ SD	15.2 $\pm$ 7.4
Previous surgery for tibial fracture	Yes	34 (85.0)
	No	6 (15.0)
Number of previous operations	Mean $\pm$ SD	2.1 $\pm$ 1.0

Regarding injury characteristics, road traffic accidents accounted for 67.5% of cases, and 77.5% had initially sustained an open fracture. Involvement of the middle third of the tibia was the most common (55.0%), and atrophic nonunion accounted for 60.0% of cases. Bone defects were present in

72.5%, with a mean defect length of 3.6 $\pm$ 1.8 cm, and *Staphylococcus aureus* was the predominant organism at 45.0% (Table II).

Table II: Injury, nonunion, and infection-related characteristics of the study participants (n=40).

Variables	Categories	n (%)
Mechanism of initial injury	Road traffic accident	27 (67.5)
	Fall from height	9 (22.5)
	Other causes	4 (10.0)
Affected side	Right	23 (57.5)
	Left	17 (42.5)
Site of tibial nonunion	Proximal third	6 (15.0)
	Middle third	22 (55.0)
	Distal third	12 (30.0)
Original fracture type	Open	31 (77.5)
	Closed	9 (22.5)
Type of nonunion	Atrophic	24 (60.0)
	Oligotrophic	10 (25.0)
	Hypertrophic	6 (15.0)
Bone defect	Present	29 (72.5)
	Absent	11 (27.5)
Bone defect length (cm)	Mean $\pm$ SD	3.6 $\pm$ 1.8
Active discharging sinus	Present	27 (67.5)
	Absent	13 (32.5)
Microbiological culture	<i>Staphylococcus aureus</i>	18 (45.0)
	<i>Pseudomonas aeruginosa</i>	5 (12.5)
	<i>Klebsiella</i> spp.	3 (7.5)
	<i>Escherichia coli</i>	2 (5.0)
	Other organisms	2 (5.0)
	Culture negative	10 (25.0)

During Ilizarov management, radical debridement was performed in all patients, whereas bone transport and corticotomy were required in 60.0% and 75.0% of patients, respectively. Additional bone grafting was needed in 20.0%.

The mean duration of Ilizarov fixation was 8.7 $\pm$ 2.4 months, and full weight bearing was achieved after a mean of 5.8 $\pm$ 2.1 weeks (Table III).

Table III: Operative and Ilizarov treatment characteristics of the study participants (n=40).

Variables	Categories	n (%)
Radical debridement	Performed	40 (100.0)
Acute docking	Yes	12 (30.0)
	No	28 (70.0)
Bone transport	Yes	24 (60.0)
	No	16 (40.0)
Corticotomy	Yes	30 (75.0)
	No	10 (25.0)
Additional bone grafting	Required	8 (20.0)
	Not required	32 (80.0)
Duration of Ilizarov fixation (months)	Mean $\pm$ SD	8.7 $\pm$ 2.4
External fixation index (months/cm)	Mean $\pm$ SD	1.9 $\pm$ 0.6
Time to full weight bearing (weeks)	Mean $\pm$ SD	5.8 $\pm$ 2.1
Hospital stay (days)	Mean $\pm$ SD	12.6 $\pm$ 5.4
Follow-up duration (months)	Mean $\pm$ SD	18.4 $\pm$ 6.2

Following treatment, radiological union was achieved in 90.0% of patients after a mean of 9.4 $\pm$ 2.6 months. Complete eradication of infection was documented in 87.5%, and 77.5%

regained full weight-bearing without support. Overall treatment success was achieved in 85.0% of cases (*Table IV*).

Table IV: Clinical and radiological outcomes following Ilizarov external fixation (n=40).

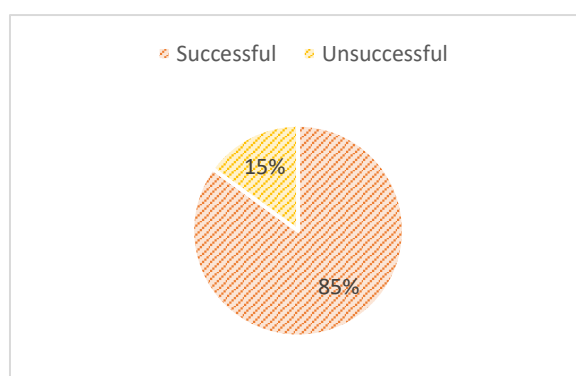
Outcome variables	Categories	n (%)
Radiological union	Achieved	36 (90.0)
	Not achieved	4 (10.0)
Time to union (months)	Mean $\pm$ SD	9.4 $\pm$ 2.6
Infection status at final follow-up	Complete eradication	35 (87.5)
	Persistent/recurrent infection	5 (12.5)
Discharging sinus at final follow-up	Present	4 (10.0)
	Absent	36 (90.0)
Limb-length discrepancy	$\leq$ 1 cm	32 (80.0)
	$>$ 1 cm	8 (20.0)
Residual deformity	None/mild	34 (85.0)
	Significant	6 (15.0)
Final weight-bearing status	Full without support	31 (77.5)
	Full with support	6 (15.0)
	Partial/non-weight bearing	3 (7.5)
Overall treatment outcome	Successful	34 (85.0)
	Unsuccessful	6 (15.0)

According to the ASAMI criteria, excellent and good bone outcomes were observed in 47.5% and 35.0% of patients, respectively, yielding a combined excellent-to-good bone outcome of 82.5%. For functional outcome, 37.5% achieved an

excellent result, and 40.0% achieved a good result, producing a combined favorable functional outcome of 77.5% (*Table V*).

Table V: Bone and functional outcomes according to ASAMI criteria (n=40).

ASAMI outcome	Excellent	Good	Fair	Poor
Bone result	19 (47.5)	14 (35.0)	4 (10.0)	3 (7.5)
Functional result	15 (37.5)	16 (40.0)	6 (15.0)	3 (7.5)


Figure 1: Overall treatment outcome (n=40).

Among the observed complications, pin-tract infection was the most frequent, affecting 37.5% of patients. Joint stiffness occurred in 27.5%, limb-length discrepancy greater than 1 cm in 20.0%, and delayed union at the docking site in 17.5%.

Persistent or recurrent infection was found in 12.5%, whereas neurovascular complications and refracture were uncommon, each occurring in 2.5% (*Table VI*).

Table VI: Complications associated with Ilizarov external fixation (n=40).

Complications	n (%)
Pin-tract infection	15 (37.5)
Pin loosening	4 (10.0)
Wire breakage	2 (5.0)
Joint stiffness	11 (27.5)
Ankle stiffness	9 (22.5)
Knee stiffness	4 (10.0)
Residual angular deformity	6 (15.0)
Limb-length discrepancy >1 cm	8 (20.0)
Delayed union at docking site	7 (17.5)
Persistent/recurrent infection	5 (12.5)
Neurovascular complication	1 (2.5)
Refracture after frame removal	1 (2.5)
Additional surgical procedure required	9 (22.5)

DISCUSSION

In this study, Ilizarov external fixation resulted in favorable clinical and functional outcomes in 40 patients with infected tibial nonunion. Radiological union was achieved in 90.0%, complete eradication of infection in 87.5%, and overall treatment success in 85.0%. Such findings support the continued value of Ilizarov reconstruction for complex infected tibial nonunion, particularly when bone loss, deformity, previous surgery, and chronic infection coexist. Regarding bony healing, the 90.0% union rate was comparable with several recent reports. In the study by Abuomira et al., consolidation following the initial procedure was achieved in 89.0% of tibial nonunions treated with circular-frame distraction osteogenesis [16]. Similarly, approximately 92.3% of patients achieved union in the series by Eralp et al. [17]. In the study by McNally et al., initial union was achieved in 86.1%, rising to 96.2% with monofocal distraction and 93.8% with bifocal compression-distraction [18]. Furthermore, bone transport resulted in 92% union in the randomized study by Rohilla et al. [19]. Higher rates were reported by Fahad et al. (approximately 96.1%) and by Chalak et al. (100%) [3,20]. Differences may be attributable to variations in bone-defect size, nonunion location, infection severity, docking-site management, operative technique, and follow-up duration. Concerning infection control, complete eradication was achieved in 87.5% of the present cases. By comparison, infection was eradicated in 96.2% of patients in the series reported by McNally et al., while complete arrest of infection was reported among patients with infected distal tibial nonunion treated with specialized Ilizarov protocols [12,18]. The comparatively lower rate in the current study may reflect its substantial baseline disease burden, as 67.5% had active discharging sinuses, 72.5% had bone defects, and 85.0% had undergone previous surgery. Nevertheless, excellent or good radiological outcomes occurred in 96.1% of patients in the study by Testa et al., supporting the effectiveness of aggressive infection control combined with stable Ilizarov fixation [9]. The mean Ilizarov fixation period was 8.7 ± 2.4 months. A shorter mean external fixation duration of approximately 6.5 months was reported by Eralp et al., whereas Szelerski et al. documented a mean stabilization period of 7.9 months [21]. Conversely, Chalak et al. reported an average fixation duration of 11.43 months with a mean defect of 7.17 cm [17,20]. Among patients requiring extensive transport, fixation durations exceeding 13 months have also been described [22]. The

relatively shorter duration observed here was likely related to the smaller mean bone defect of 3.6 ± 1.8 cm, illustrating how larger reconstruction distances generally prolong frame dependence. According to ASAMI criteria, excellent-to-good bone and functional outcomes were achieved in 82.5% and 77.5%, respectively. In comparison, excellent-to-good bone outcomes were reported in 75.0% of cases and functional outcomes in 85.0% of cases by Meleppuram and Ibrahim [23]. In the study by Testa et al., excellent-to-good bone results were achieved in 96.1%, while functional results were 84.6% [9]. Within Bangladesh, the study by Kamruzzaman et al. reported excellent-to-good bone and functional results of 90.0% and 85.0%, respectively [24]. Meanwhile, a large multicenter study by Xie et al. found excellent-to-good bone and functional results of 77% and 74%, respectively [25]. These variations probably reflect differences in joint stiffness, pain, muscle wasting, soft-tissue injury, defect magnitude, and rehabilitation intensity. Adjunctive biological strategies have also been investigated, with the study by Rollo et al. suggesting potential benefits from teriparatide combined with Ilizarov treatment [26]. Regarding complications, pin-tract infection was the most frequent problem, affecting 37.5% of patients. This was remarkably close to the 40.0% reported in the Bangladeshi study by Kamruzzaman et al., but higher than the 17.6% observed by Fahad et al. [3,24]. Joint stiffness occurred in 27.5%, while limb-length discrepancy greater than 1 cm occurred in 20.0%. Recent evidence similarly identifies pin-site infection, stiffness, residual deformity, docking-site difficulties, and prolonged treatment burden as important limitations of circular fixation [12,22,25]. Clinically, these findings indicate that successful Ilizarov treatment should be judged not only by union but also by eradication of infection, limb alignment, length restoration, weight-bearing capacity, and functional recovery. In Bangladesh and comparable resource-constrained settings, Ilizarov fixation remains particularly valuable because it can simultaneously address infection, bone loss, deformity, and limb-length discrepancy without relying on complex internal implants. Nevertheless, prolonged treatment and frequent minor complications require meticulous debridement, stable frame construction, regular pin-site care, early joint mobilization, progressive weight-bearing, close radiological surveillance, and sustained rehabilitation.

LIMITATIONS

The study was limited by its small sample size, single-centre design, and observational nature. Variations in disease severity and treatment methods may have influenced the outcomes. The follow-up period may also have been insufficient to assess long-term complications. Larger multicentre studies with longer follow-up are recommended.

CONCLUSION

Ilizarov external fixation demonstrated favorable clinical, radiological, and functional outcomes in the management of infected tibial nonunion. Most patients achieved successful bony union, eradication of infection, satisfactory limb alignment, and restoration of weight-bearing capacity. According to the ASAMI criteria, the majority attained excellent-to-good bone and functional results. Although complications such as pin-tract infection, joint stiffness, limb-length discrepancy, and delayed union at the docking site were relatively common, serious complications were infrequent. Overall, the findings indicate that the Ilizarov technique is an effective limb-reconstruction method for managing complex infected tibial nonunion with associated bone loss, chronic infection, deformity, and prior surgical treatment.

RECOMMENDATIONS

For optimal outcomes, Ilizarov external fixation should be considered in carefully selected patients with infected tibial nonunion, particularly when infection, bone loss, deformity, or limb-length discrepancy is present. During treatment, meticulous debridement, appropriate frame application, regular pin-site care, early rehabilitation, and close follow-up should be ensured to minimize complications and improve functional recovery. Further multicenter studies with larger sample sizes and longer follow-up periods are warranted to validate these findings.

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CONFLICT OF INTEREST

None declared.

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