

Limb Salvage in Massive Tibial Gap Nonunion: Outcomes of Tibialization of Fibula Using the Ilizarov Method

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ABSTRACT

Background: Massive tibial gap nonunion presents a formidable limb salvage challenge, with tibialization of the fibula offering a biological reconstruction option. However, outcome data from the Bangladeshi population remain limited. **Objective:** To evaluate the union rate and functional outcomes of tibialization of the fibula using the Ilizarov method for massive tibial gap nonunion. **Methods & Materials:** This prospective observational study was conducted at National Institute of Traumatology and Orthopedic Rehabilitation (NITOR), Dhaka, Bangladesh, Dhaka, from January 2021 to December 2025. A total of 25 patients with massive tibial gap nonunion underwent tibialization of the fibula using the Ilizarov method. Bone union and functional outcomes were assessed using standardized criteria. Data were analyzed using SPSS version 23.0. **Results:** Bony union was achieved in 88.0% of patients (n=22), with a mean time to union of 7.2 ± 2.4 months. Excellent functional outcomes were observed in 60.0% (n=15), good in 24.0% (n=6), and fair/poor in 16.0% (n=4). Pin site infection occurred in 24.0%, and minor complications in 16.0%. **Conclusion:** Tibialization of fibula using the Ilizarov method achieves satisfactory union rates and functional outcomes in massive tibial gap nonunion, with acceptable complication rates. This technique offers a reliable limb salvage option in resource-limited settings where microvascular reconstruction may not be available.

Keywords: Fibula, Ilizarov technique, Limb salvage, Nonunion, tibia, Tibialization

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INTRODUCTION

Massive tibial bone defects, defined as segmental bone loss exceeding 4–5 cm in length, represent one of the most formidable challenges in orthopedic trauma and limb reconstruction surgery [1]. These defects most commonly arise from high-energy open fractures, infected nonunions with sequestrectomy, chronic osteomyelitis, or tumor resection [2]. The management of such defects is complicated by the compromised soft tissue envelope, devascularized bone fragments, persistent infection, and the inherent biological limitations of the tibia as a weight-bearing bone with a tenuous blood supply [3]. Historically, the treatment of massive tibial defects has been associated with high rates of amputation, prolonged disability, and significant socioeconomic burden [4]. Conventional reconstructive options have included vascularized fibular grafting, massive cancellous bone grafting, and, more recently, distraction osteogenesis using the Ilizarov method [5]. However, each of these techniques has distinct limitations: vascularized grafts require

microsurgical expertise and specialized facilities, bone grafting is often insufficient for defects exceeding 6–8 cm, and bone transport can be complicated by prolonged fixator time, docking site nonunion, and regenerate insufficiency [6]. In this context, tibialization of the fibula a technique in which the ipsilateral fibula is gradually transferred medially to fill the tibial defect using the Ilizarov external fixator has emerged as a valuable biological reconstructive strategy [7]. First described in the context of the Huntington procedure, this technique exploits the inherent ability of the fibula to hypertrophy when subjected to weight-bearing loads, effectively transforming it into a weight-bearing tibial substitute [8]. The gradual nature of the transfer, facilitated by the Ilizarov apparatus, allows for simultaneous correction of deformity, limb length discrepancy, and soft tissue adaptation while preserving the vascularity of the fibular segment [9]. A study describing ipsilateral vascularized fibular transport (IVFT) using the Ilizarov fixator system reported successful transport, proximal and

distal union, and hypertrophy of the graft without fracture in all five patients with massive tibial bone loss following open fracture, infected nonunion, or chronic osteomyelitis [10]. More recently, a prospective study of 14 patients with large tibial defects (mean 13.2 cm) treated with gradual medial fibular transfer using Ilizarov external fixators reported union in all patients, with an average fixator time of 32.4 weeks and good functional outcomes at a mean follow-up of 40.5 months [11]. A retrospective cross-sectional study from Ethiopia involving 12 patients with tibial defects averaging 8.96 cm reported bone union in 91.7% of patients, with excellent or good functional and bone healing outcomes in 58.3% and 75% of cases, respectively [12]. A British Limb Reconstruction Society series of 56 patients with big tibial defects (average 18.5 cm) treated by tibialization of fibula reported complete union in all patients, with an average time to union of 8.6 months [13]. Despite these encouraging reports, the application of tibialization of fibula using the Ilizarov method for

massive tibial gap nonunion has not been systematically evaluated in the Bangladeshi population. The technique offers particular promise in resource-limited settings where microvascular reconstruction may be unavailable, and the cost of alternative treatments is prohibitive^[14]. Understanding the union rates, functional outcomes, and complication profiles in this context is essential for guiding clinical decision-making and optimizing patient care. This prospective study was therefore undertaken to evaluate the outcomes of tibialization of the fibula using the Ilizarov method in patients with massive tibial gap nonunion treated at the National Institute of Traumatology and Orthopaedic Rehabilitation (NITOR), Dhaka, Bangladesh.

METHODS & MATERIALS

This prospective observational study was conducted at the National Institute of Traumatology and Orthopaedic Rehabilitation (NITOR), Dhaka, Bangladesh, from January 2021 to December 2025. A total of 25 patients with massive tibial gap nonunion were enrolled in this study.

Inclusion criteria: Patients aged 18 to 65 years, of either sex, with a massive tibial gap nonunion (bone defect ≥ 4 cm) following trauma, infection, or previous surgery, and providing written informed consent were eligible for inclusion.

Exclusion criteria: Patients with active uncontrolled infection, severe peripheral vascular disease, systemic illness precluding surgery, ipsilateral fibular fracture or deficiency, or those unwilling to complete the follow-up protocol were excluded.

Study procedure: After obtaining written informed consent, demographic and baseline clinical data were recorded. All patients underwent tibialization of the fibula using the standard Ilizarov frame construct. Gradual medial fibular transfer was performed at a rate of 1 mm per day until the fibula bridged the tibial defect. Bone union was assessed using standardized radiographic criteria, and functional outcomes were evaluated using the Association for the Study and Application of the Method of Ilizarov (ASAMI) scoring system^[14]. Pin site care was performed according to institutional protocols, and complications were

documented throughout the follow-up period.

Data analysis: Data were entered into a predesigned proforma and analyzed using SPSS version 23.0. Categorical variables were presented as frequencies and percentages, and continuous variables as means with standard deviations. A p-value <0.05 was considered statistically significant.

RESULT

A total of 25 patients with massive tibial gap nonunion underwent tibialization of the fibula using the Ilizarov method and completed the study.

The demographic and clinical characteristics of the study population are summarized in *Table I*. The mean age was 34.8 ± 11.6 years (range 19–58), with a male predominance (80.0%). The mean bone gap size was 7.6 ± 2.4 cm (range 4.2–13.5). Post-traumatic etiology was the most common cause (64.0%), followed by infected nonunion (24.0%). The majority of defects were located in the middle third of the tibia (48.0%).

Table I
Demographic and clinical characteristics of the study population (n=25).

Variable	Category	n (%)
Age (years)	≤ 30	9 (36.0)
	31–45	10 (40.0)
	>45	6 (24.0)
Sex	Male	20 (80.0)
	Female	5 (20.0)
Etiology	Post-traumatic	16 (64.0)
	Infected nonunion	6 (24.0)
	Post-osteomyelitis	3 (12.0)
Defect location	Proximal third	7 (28.0)
	Middle third	12 (48.0)
	Distal third	6 (24.0)
Bone gap size (cm)	Mean $\pm$ SD= 7.6 ± 2.4	

The preoperative and postoperative radiologic parameters are presented in *Table II*. The mean bone gap decreased significantly from 7.6 ± 2.4 cm

preoperatively to 0.8 ± 0.6 cm postoperatively ($p<0.001$), representing a mean correction of 6.8 cm. The mean mechanical axis deviation improved from

18.4 ± 8.2 mm to 6.2 ± 4.8 mm ($p<0.001$). The mean length of the transferred fibular segment was 8.4 ± 2.8 cm.

Table II
Preoperative and postoperative radiologic parameters.

Parameter (Mean $\pm$ SD)	Preoperative	Postoperative	p-value*
Bone gap (cm)	7.6 ± 2.4	0.8 ± 0.6	<0.001
Mechanical axis deviation (mm)	18.4 ± 8.2	6.2 ± 4.8	<0.001
Fibular transfer length (cm)		8.4 ± 2.8	
Time to union (months)		7.2 ± 2.4	

*Paired t-test was used to compare preoperative and postoperative parameters. SD = standard deviation

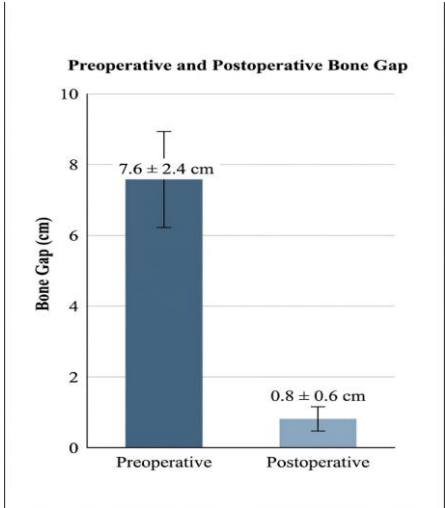


Figure 1 Preoperative and postoperative bone gap.

Figure 1 illustrates the significant reduction in bone gap achieved with tibialization of the fibula using the Ilizarov method.

The functional outcomes assessed using the ASAMI scoring system are presented in Table III. Bony union was achieved in 88.0% of patients (n=22). The mean time to union was 7.2 ± 2.4 months (range 4–14 months). Regarding bone outcomes, excellent results were observed in 56.0%

(n=14), good in 32.0% (n=8), and fair/poor in 12.0% (n=3). Functional outcomes demonstrated excellent results in 60.0% (n=15), good in 24.0% (n=6), and fair/poor in 16.0% (n=4).

Table III
ASAMI bone and functional outcomes.

Outcome	Category	n (%)
Bony union	Achieved	22 (88.0)
	Not achieved	3 (12.0)
ASAMI bone score	Excellent	14 (56.0)
	Good	8 (32.0)
	Fair	2 (8.0)
	Poor	1 (4.0)
ASAMI functional score	Excellent	15 (60.0)
	Good	6 (24.0)
	Fair	3 (12.0)
	Poor	1 (4.0)

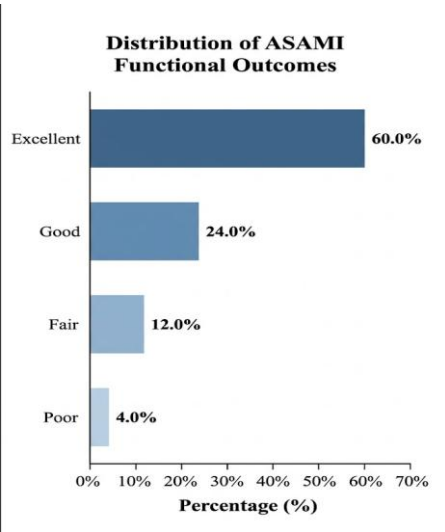


Figure 2 Distribution of ASAMI functional outcomes.

Figure 2 demonstrates the distribution of functional outcomes, with the majority of patients achieving excellent (60.0%) and good (24.0%) results following tibialization of the fibula.

The complications encountered during treatment are presented in Table IV. Pin

site infection was the most common complication, occurring in 24.0% of patients (n=6), all of which resolved with local wound care and oral antibiotics. Minor complications occurred in 16.0% (n=4), including wire loosening (8.0%) and soft tissue irritation (8.0%). Major complications included regenerate fracture

in 4.0% (n=1) and docking site nonunion requiring bone grafting in 8.0% (n=2). No cases of neurovascular injury or amputation were observed. The overall complication rate was 40.0%, with the majority being minor and manageable.

Table IV
Complications encountered during treatment.

Complication	n (%)
Pin site infection	6 (24.0)
Wire loosening	2 (8.0)
Soft tissue irritation	2 (8.0)
Regenerate fracture	1 (4.0)
DSN requiring bone grafting	2 (8.0)
Neurovascular injury	0 (0)
Amputation	0 (0)
Overall complication rate	10 (40.0)

DSN: Docking site nonunion

A representative clinical and radiographic case demonstrating the deformity before treatment and the result after tibialization

of the fibula using the Ilizarov method is shown in Figure 3.

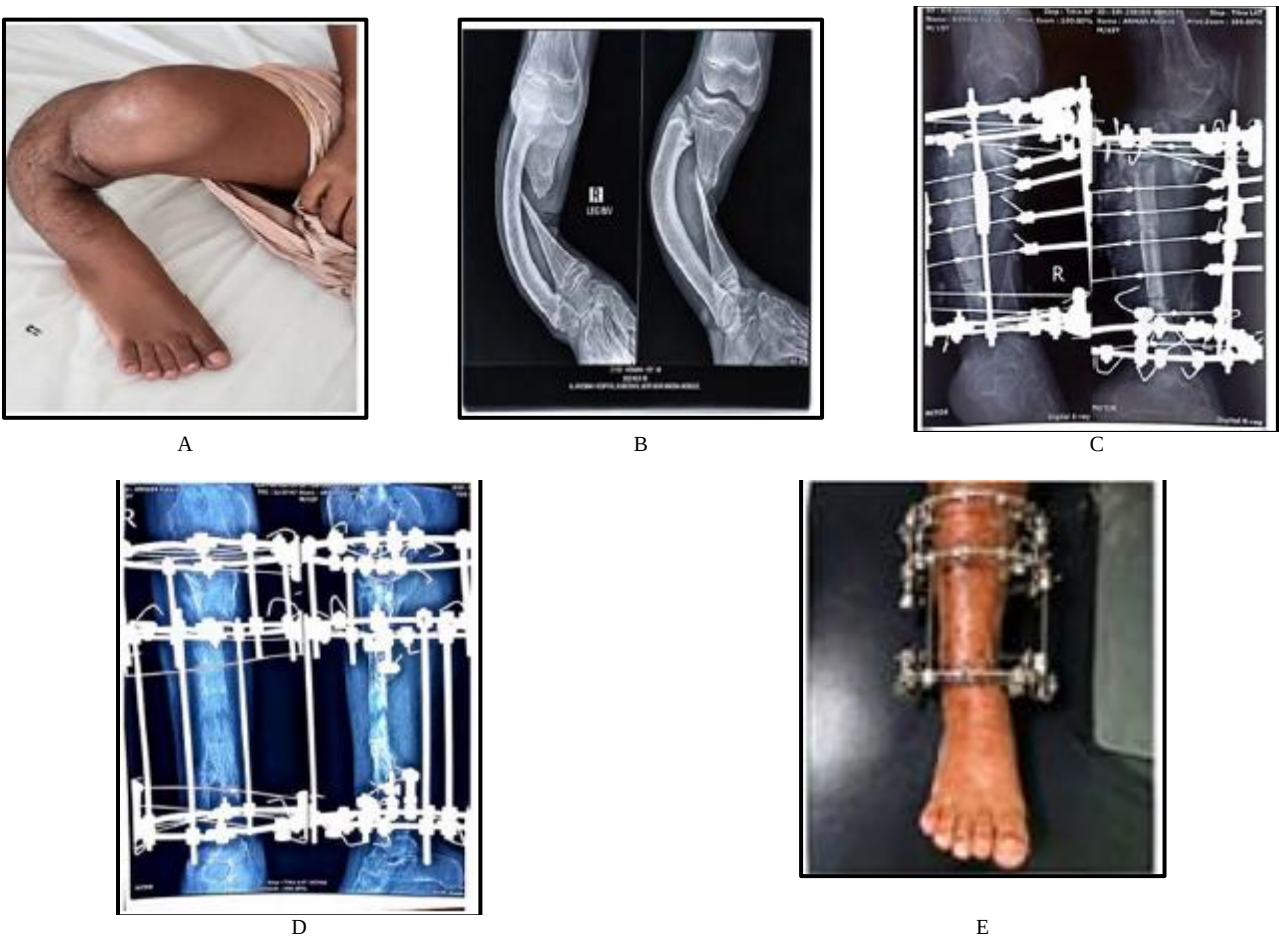


Figure 3 Representative clinical and radiographic case.

Representative clinical and radiographic case (Figure 3). (A) Preoperative clinical photograph of the affected leg showing the deformity; (B) Preoperative radiographs demonstrating the tibial deformity and

bone defect; (C) Postoperative anteroposterior radiograph with the Ilizarov external fixator in situ; (D) Postoperative lateral radiograph with the Ilizarov external fixator in situ; (E) Clinical photograph after

correction demonstrating the corrected limb alignment.

DISCUSSION

This prospective study of 25 patients with massive tibial gap nonunion demonstrates that tibialization of fibula using the Ilizarov method achieves a satisfactory union rate of 88.0% with a mean time to union of 7.2 months. Excellent functional outcomes were observed in 60.0% of patients, with an overall complication rate of 40.0%, the majority being minor and manageable. These results compare favorably with existing literature and underscore the value of this biological reconstructive technique, particularly in resource-limited settings where microvascular reconstruction may not be available [15]. The union rate of 88.0% observed in this study is consistent with the findings of a retrospective cross-sectional study involving 12 patients with tibial defects averaging 8.96 cm, which reported bone union in 91.7% of patients [16]. Similarly, a series of 56 patients with large tibial defects (average 18.5 cm) treated by tibialization of the fibula reported complete union in all patients, with an average time to union of 8.6 months [17]. The mean time to union of 7.2 months in our study compares favorably with these figures and suggests that the gradual fibular transfer technique achieves union within a clinically acceptable timeframe [18]. A prospective study of 14 patients with large tibial defects (mean 13.2 cm) treated with gradual medial fibular transfer using Ilizarov external fixators reported union in all patients, with an average fixator time of 32.4 weeks and good functional outcomes at a mean follow-up of 40.5 months [19]. The mean bone gap of 7.6 cm in our cohort, while smaller than the 13.2 cm reported in that series, still represents a significant reconstructive challenge. The achievement of union in 88.0% of our patients, despite the absence of specialized microvascular facilities, attests to the reliability of the Ilizarov-based tibialization technique [20]. The functional outcomes in this study, with 60.0% excellent and 24.0% good results according to the ASAMI scoring system, are consistent with the broader literature. A study of open segmental tibial bone defects treated with Ilizarov frame reported excellent functional results in six and good in seven cases using the ASAMI scoring system, while bony results were excellent in eight, good in four, and fair in one case [21]. The same study emphasized that good to excellent functional and radiological scores can be expected when the Ilizarov frame is applied with correct principles for simultaneous treatment of large tibial bone and soft tissue defects [21]. The slightly higher excellent bone outcomes in our study (56.0%) compared to the 15% reported in the Ethiopian series may reflect differences in patient selection, defect characteristics, or surgical technique [16]. The complication profile observed in this

study pin site infection in 24.0%, wire loosening in 8.0%, and docking site nonunion requiring bone grafting in 8.0% is consistent with the known risks of Ilizarov-based reconstruction. The Ethiopian series reported an overall complication rate of 0.74 per patient, with pin tract infection being the most common [16]. The same study noted that gradual fibular transfer by Ilizarov external fixator is a reliable technique with good clinical outcomes and few complications [19]. The absence of neurovascular injury or amputation in our cohort reflects the safety of the gradual transfer technique and the importance of meticulous surgical planning and execution [22]. The biological rationale for tibialization of fibula lies in the principle of distraction osteogenesis, which enables gradual transfer of the vascularized fibular segment into the tibial defect while preserving its blood supply [23]. The advantage of ipsilateral vascularised fibular transport (IVFT) is that the fibular segment retains its vascularity without the need for microvascular dissection or anastomoses. Superficial osteal formation of new bone occurs if the tibial periosteal bed is retained, and other procedures such as corticotomy and lengthening can be carried out concurrently [24]. This biological advantage, combined with the mechanical stability provided by the Ilizarov frame, explains the high union rates observed in this and other series [25]. The strengths of this study include its prospective design, which minimizes recall bias and allows for systematic data collection, and the use of standardized outcome measures including the ASAMI scoring system [14]. The inclusion of a relatively homogeneous patient population with well-defined inclusion criteria enhances the internal validity of the findings.

LIMITATIONS

The single-center design, small sample size (n=25), and absence of a control group limit generalizability. Relatively short follow-up may not capture long-term outcomes, including graft hypertrophy and late complications. Unmeasured confounding variables may have influenced the observed outcomes.

CONCLUSION

Tibialization of fibula using the Ilizarov method achieves satisfactory union rates (88.0%) and functional outcomes, with excellent results in 60.0% of patients and a mean time to union of 7.2 months. The technique offers a reliable limb salvage option for massive tibial gap nonunion, with acceptable complication rates, particularly in resource-limited settings where microvascular reconstruction is unavailable.

RECOMMENDATIONS

We recommend tibialization of the fibula using the Ilizarov method for massive tibial gap nonunion, particularly in resource-limited settings. Larger multicenter studies with extended follow-up and comparative designs are warranted to validate these findings and assess long-term outcomes.

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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CONFLICT OF INTEREST

None declared

ETHICAL APPROVAL

The study was approved by the Institutional Ethics Committee

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