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Original Article

Bone Transport with the Ilizarov External Fixator for Tibial Shaft Gap Non-Union: A Prospective Observational Study

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ABSTRACT

Background: Tibial shaft gap non-union is a complex reconstructive condition that may be accompanied by infection, segmental bone loss, deformity, limb shortening, and functional impairment. Bone transport using the Ilizarov external fixator allows gradual reconstruction of the defect while providing stable fixation. **Objective:** To evaluate union, radiological and functional outcomes, infection control, external fixation parameters, and complications following Ilizarov bone transport for tibial shaft gap non-union. **Methods & Materials:** This concurrent descriptive observational study included 30 patients with infected or aseptic tibial shaft gap non-union treated at the National Institute of Traumatology and Orthopaedic Rehabilitation (NITOR), Dhaka, Bangladesh, from July 2023 to March 2026. Radical debridement, metaphyseal corticotomy, circular Ilizarov fixation, and gradual bone transport were performed. Bone and functional outcomes were assessed using the Association for the Study and Application of the Method of Ilizarov criteria, while complications were categorized according to the Paley classification. Data were analysed descriptively. **Results:** The mean age was 34.7 ± 10.2 years, and 24 (80.0%) patients were male. The mean bone defect was 4.8 cm, while infected non-union was present in 18 (60.0%) patients. Union was achieved in 28 (93.3%) patients. The mean external fixation time was 10.2 months, the mean external fixation index was 1.4 months/cm, and the mean bone transport time was 76.4 days. Excellent or good bone outcomes were achieved in 26 (86.7%) patients, while excellent or good functional outcomes were achieved in 24 (80.0%). Primary infection eradication was achieved in 16 of 18 infected cases (88.9%), and final infection control was achieved in all infected patients after additional treatment. Superficial pin-tract infection occurred in 16 (53.3%), docking-site non-union requiring intervention in 4 (13.3%), knee flexion contracture in 6 (20.0%), and ankle stiffness in 8 (26.7%). No amputation was required. **Conclusion:** Ilizarov bone transport provided a high rate of union, satisfactory bone and functional outcomes, and effective limb preservation in tibial shaft gap non-union. Nevertheless, prolonged treatment and frequent manageable complications remained important limitations of the procedure.

Keywords: *Bone Transport; Ilizarov External Fixator; Tibial Non-Union; Segmental Bone Defect; Distraction Osteogenesis*

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INTRODUCTION

Among the most difficult reconstructive problems in orthopaedic trauma, tibial shaft gap non-union may involve segmental bone loss, infection, deformity, limb shortening, soft-tissue compromise, and impaired joint function. In the systematic review by Tian et al., a pooled tibial-fracture non-union prevalence of 6.8% was estimated, while high-energy injury, open fracture, severe Gustilo–Anderson grade, middle or distal tibial location, complex fracture configuration, and infection were identified as important associated factors [1]. In a broader meta-analysis of surgically managed diaphyseal fractures, infection was associated with the greatest increase in non-union risk, followed by open injury, fracture complexity, smoking, diabetes, and obesity [2]. Once infection and segmental bone loss are established, mechanical stability, viable bone, soft-tissue coverage, microbial control, and function must be addressed together. Under the fracture-related infection framework, sinus or fistula formation, purulent drainage, and microbiological or histological confirmation have been recognized as confirmatory findings, whereas inflammatory markers and imaging are considered supportive rather than independently diagnostic [3]. Accordingly, debridement, deep-tissue sampling, restoration of stability, dead-space management, soft-tissue coverage, and culture-directed antimicrobial treatment have been recommended [4]. For tibial segmental defects, several reconstructive options have been used, including cancellous bone grafting, vascularized fibular transfer, the induced membrane technique, acute shortening with subsequent lengthening, and distraction osteogenesis. In the pooled analysis by Bezstarosti et al., the tibia accounted for 82% of 1,530 fracture-related infection cases with critical-sized defects, while healing without infection was achieved after the initial protocol in 83% and after additional treatment in 94% [5]. In the meta-analysis by Wakefield et al., pooled union rates of 94.6% for distraction osteogenesis and 88.0% for the induced membrane technique were reported for infected tibial non-unions with segmental bone loss, although no statistically conclusive superiority was established [6]. Accordingly, treatment selection remains dependent on defect characteristics, infection status, soft-tissue condition, limb alignment, expertise, and patient tolerance. Through the Ilizarov method, stable circular external fixation is combined with corticotomy and gradual transport of a vascularized bone segment, allowing regenerate formation while the defect is bridged. In the review by Aktuglu et al., 27 studies involving 619 patients were summarized, with a mean union rate of 90.2%, a mean external fixation duration of 10.75 months, and excellent or good bone and functional outcomes in 88.8% and 82.6%, respectively [7]. In the meta-analysis by Zhang et al., an infection-free rate of approximately 96% was estimated, while more previous operations and longer external fixation were associated with residual bone or functional sequelae [8]. Within South Asian evidence, union was achieved in 98.2% of 56 patients treated for infected tibial non-union, although pin-tract infection occurred in nearly half and treatment was prolonged [9]. More recently, excellent or good Association for the Study and Application of the Method of Ilizarov bone outcomes were reported in 85.7% of patients with defects of at least 5 cm, while larger defects were associated with greater knee, ankle, and docking-site morbidity [10]. Despite favorable union rates, prolonged frame dependence and repeated interventions remain important limitations. In the docking-site analysis by Feng et al., delayed union, axial deviation, and soft-tissue incarceration were documented among 103 patients, with larger and distal-third defects showing greater risk [11]. In another recent series, healing was achieved after bifocal or trifocal transport, although additional procedures remained frequent [12]. Even after radiological healing, functional recovery and return to work were shown to vary, while temporary deterioration in physical and mental health during transport and consolidation was documented by Wang et al [13,14]. Against this background, prospective outcome data from Bangladesh remain limited. Therefore, the present study was conducted to evaluate union, radiological and functional outcomes, infection control, external fixation parameters, and complications following Ilizarov bone transport for tibial shaft gap non-union.

METHODS & MATERIALS

This prospective observational study was conducted at the Ilizarov, Deformity Correction and Reconstruction Unit (Pink Unit-II), National Institute of Traumatology and Orthopaedic Rehabilitation, Dhaka, Bangladesh, from July 2023 to March 2026. Ethical approval and informed consent were obtained. Thirty patients (age 16–60 years) with tibial shaft gap non-union (≥2 cm), infected or aseptic, were included; exclusions were pathological/non-neoplastic lesions, severe vascular disease, uncontrolled diabetes, metabolic bone disease, intra-articular extension, or non-compliance. All patients underwent clinical, radiological, and laboratory assessment (CBC, ESR, CRP), with microbiological cultures when infection was suspected. Surgery involved radical debridement to healthy bone, low-energy corticotomy, and application of a circular Ilizarov frame. Bone transport was performed after a latency period at 1 mm/day (adjusted radiographically), with regular monitoring of regenerate and alignment. Docking-site compression was applied, with additional procedures (refreshment, soft-tissue clearance, or bone grafting) as required. Postoperatively, culture-directed antibiotics, pin-site care, early weight-bearing, and physiotherapy were instituted. Patients were followed weekly during distraction and monthly during consolidation. Frame removal was based on radiological consolidation (≥3 cortices), docking union, and clinical stability, followed by orthosis and rehabilitation. Primary outcome was bone union; secondary outcomes included external fixation time/index, transport time, limb-length discrepancy, joint motion, infection control, complications, and amputation. Union was defined radiologically and clinically. Bone and functional outcomes were graded using Paley's ASAMI criteria, and complications were classified as problems, obstacles, or true complications [15,16]. Data were analyzed descriptively using means, ranges, and proportions; no inferential statistics were applied.

RESULTS

Among the 30 patients, 24 (80.0%) were male and 6 (20.0%) were female. The mean age was 34.7 ± 10.2 years (range 18–55). Road traffic accidents were the most common mechanism of injury (73.3%). The mean time from injury to presentation was 14.8 months, and patients had undergone a mean of 2.4 prior surgical procedures. Infected non-union was present in 60.0% of cases. The mean bone-defect length was 4.8 cm, and the mean baseline limb-length discrepancy was 3.2 cm (*Table I*).

Table I
Baseline demographic characteristics.

Category	Variable	RESULT
Age	Mean ± SD	34.7 ± 10.2
	Range	18–55
Sex	Male	24 (80.0)
	Female	6 (20.0)
Injury mechanism	Road traffic accident	22 (73.3)
	Fall from height	6 (20.0)
	Sports injury	2 (6.7)
Clinical timeline	Time to presentation (months), mean	14.8
	Range	6–36
	Previous surgeries, mean	2.4
	Range	1–5
Defect characteristics	Bone-defect length (cm), mean	4.8
	Range	2–9
	Limb-length discrepancy (cm), mean	3.2
	Range	1–6
Non-union type	Infected	18 (60.0)
	Aseptic	12 (40.0)

SD: standard deviation.

Among the 18 infected non-union cases, *Staphylococcus aureus* was the most frequently isolated organism (55.6%). *Pseudomonas aeruginosa* and polymicrobial infections were equally distributed (22.2% each) (*Table II*).

Table II
Microbiological profile of infected non-union cases.

Category	Organism	n (%)
Monomicrobial	Staphylococcus aureus	10 (55.6)
	Pseudomonas aeruginosa	4 (22.2)
Polymicrobial	Mixed growth	4 (22.2)

Bone union was achieved in 93.3% of patients. Docking-site problems occurred in 13.3% and required additional procedures. The mean external fixation time was 10.2 months, and the mean external fixation index was 1.4 months/cm. The mean bone transport time was 76.4 days. Final limb-length discrepancy was minimal (0.8 cm). No amputations were performed (*Table III*).

Table III
Union and radiological outcomes.

Outcome domain	Parameter	RESULT
Union status	Union achieved	28 (93.3)
	Persistent non-union	2 (6.7)
Docking site	Non-union requiring intervention	4 (13.3)
Fixation duration	External fixation time (months), mean	10.2
	Range	6–16
Efficiency	External fixation index (months/cm), mean	1.4
	Range	0.9–2.1
Transport	Bone transport time (days), mean	76.4
	Range	45–130
Alignment	Final limb-length discrepancy (cm), mean	0.8
Major outcome	Amputation	0 (0.0)

Most patients achieved excellent or good outcomes. Bone results were favorable in 86.7% of cases, while functional outcomes were favorable in 80.0% (*Table IV*).

Table IV
Comparison of ASAMI outcomes.

Outcome grade	Bone outcomes n (%)	Functional outcomes n (%)
Excellent	18 (60.0)	14 (46.7)
Good	8 (26.7)	10 (33.3)
Fair	2 (6.7)	4 (13.3)
Poor	2 (6.7)	2 (6.7)
Failure	0 (0.0)	0 (0.0)
Combined (Excellent + Good)	26 (86.7)	24 (80.0)

Mean knee range of motion was 108.5°. Joint stiffness was observed in a subset of patients. Infection control was achieved in all infected cases after staged management, with no recurrence (*Table V*).

Table V
Functional and infection-related outcomes.

Domain	Variable	RESULT
Knee function	Range of motion (°), mean	108.5
	Range	85–135
	Flexion contracture >10°	6 (20.0)
Ankle function	Dorsiflexion <10°	8 (26.7)
Infection control (n=18)	Eradication after primary treatment	16 (88.9)
	Persistent infection requiring surgery	2 (11.1)
	Final infection control achieved	18 (100.0)
	Recurrence	0 (0.0)

Complications were reorganized into three structured tiers: problems, obstacles, and true complications. Problems were most frequent and mainly minor soft-tissue or pin-related issues. True complications were rare (*Table VI*).

Table VI
Complications structured by Paley classification.

Category	Subcategory	Complication	n (%)
Problems	Soft tissue	Leg swelling	22 (73.3)
	Infection	Superficial pin-tract infection	16 (53.3)
	Mechanical	Pin loosening	8 (26.7)
	Soft tissue	Pin-site hypergranulation	6 (20.0)
Obstacles	Bone healing	Docking-site non-union	4 (13.3)
	Hardware	Broken wires	4 (13.3)
	Alignment	Axis deviation	2 (6.7)
	Soft tissue	Interposition at docking site	2 (6.7)
True complications	Deformity	Residual deformity >7°	2 (6.7)
	Length	Residual discrepancy >2.5 cm	2 (6.7)
	Infection	Persistent deep infection	2 (6.7)
	Major outcome	Amputation	0 (0.0)

Note: Multiple complications could occur in the same patient; therefore, percentages are not mutually exclusive.

Figure 1 Anteroposterior and Lateral Radiographs of the Right Tibia and Fibula

Anteroposterior (left) and lateral (right) radiographs of the right lower extremity demonstrate severe lower leg deformity characterized by profound anterior angular bowing of the tibia and fibula, nonunion/pseudarthrosis, and marked shortening. There is significant bony resorption at the pseudarthrosis site, bone mineral loss, severe soft tissue contracture, and secondary equinovarus deformation of the foot, findings characteristic of congenital pseudarthrosis of the tibia (CPT) or advanced neurofibromatosis-associated tibial bowing. (*Figure 1*).

Figure 2 Radiographic Assessment of Reconstructed Right Tibia and Fibula

Anteroposterior (AP) and lateral radiographs of the right lower leg demonstrate extensive bony remodeling along the tibia and fibula, featuring central tibial diaphyseal strut/vascularized fibular graft fusion alongside prominent proximal and distal metaphyseal-diaphyseal bridging calluses, joint alignment maintenance at the knee, and distal tibiotalar articular preservation (*Figure 2*).

DISCUSSION

In the present prospective observational study, bone transport with the Ilizarov external fixator was associated with union in 28 of 30 patients, giving a union rate of 93.3%. Excellent or good Association for the Study and Application of the Method of Ilizarov bone and functional outcomes were recorded in 86.7% and 80.0%, respectively, while no amputation was required. Satisfactory osseous reconstruction and limb preservation were therefore achieved in most patients, although treatment was prolonged and accompanied by frequent pin-related, soft-tissue, and joint complications. With respect to union, the present result was consistent with the wider evidence. In the meta-analysis by Wakefield et al. (2024), a pooled union rate of 94.6% was reported for distraction osteogenesis in infected tibial non-union with segmental bone loss. Similarly, union in 95.0% was reported by Mohd-Yusof et al., while 98.2% was reported in the South Asian study by Bakhsh et al [9,13]. In contrast, a mean union rate of approximately 90% was summarized across heterogeneous studies by Aktuglu et al [7]. Within this context, the current rate falls within the expected range for Ilizarov bone transport. Because both infected and aseptic non-unions were included in the present cohort, comparison with infection-only cohorts should remain cautious. Regarding the ASAMI results, excellent or good bone outcomes were achieved in 86.7%, compared with pooled estimates of 89% reported by Wakefield et al., 83.9% reported by Bakhsh et al., and 90.0% reported by Mohd-Yusof et al [6,9,13]. Excellent or good functional outcomes were achieved in 80.0%, which was close to the 82.1% reported by Bakhsh et al., but lower than the 87% pooled estimate reported by Wakefield et al. and the 90.0% reported by Mohd-Yusof et al [6,9,13]. Within the present study, favourable bone outcomes exceeded favourable functional outcomes by 6.7 percentage points. Radiological union therefore did not uniformly correspond with complete functional recovery, particularly where joint restriction or gait-related limitations persisted. Regarding treatment duration, the mean external fixation time was 10.2 months, closely approximating the 9.3 months reported by Bakhsh et al. and the approximately 10.7 months summarized by Aktuglu et al [7,9]. The mean external fixation index was 1.4 months/cm, identical to that reported by Bakhsh et al. Bone transport required a mean of 76.4 days, compared with 70.1 days in that study [9]. These findings indicate that successful reconstruction requires prolonged frame dependence, repeated follow-up, and sustained adherence to distraction, pin-site care, weight-bearing instructions, and physiotherapy. Among the 18 infected cases, primary eradication was achieved in 16, or 88.9%. In the meta-analysis by Wakefield et al., infection elimination of 93% was reported, while an overall infection-free rate of 96% and an external-fixator subgroup rate of 97% were reported by Zhang et al [6,8]. The lower primary eradication rate in the present study may reflect chronic infection, previous surgery, microbial factors, or the need for repeat debridement. After additional surgery, infection control was achieved in all 18 patients, with no recurrence documented. However, primary-treatment success and final infection control represent different endpoints and should be reported separately. In the study by Yalikun et al., recurrence was documented in 11.4% over a mean follow-up of 37.5 months, while Pseudomonas aeruginosa, bone exposure, and multiple previous operations were associated with recurrence [17]. Accordingly, the absence of recurrence in the present cohort should be interpreted in relation to the available follow-up. At the docking site, non-union requiring refreshment or bone grafting occurred in four patients, or 13.3%, while persistent non-union remained in two, or 6.7%. In the study by Feng et al., delayed docking-site union was reported in 21.4% and established docking-site non-union in 3.9% of 103 patients [18]. The present intervention rate was below their delayed-union rate but above their final non-union rate. These endpoints are not equivalent because the current category included patients requiring intervention who later achieved union. Nevertheless, the findings indicate that arrival of the transported segment at the docking site does not always ensure spontaneous union. Regarding joint movement, knee flexion contracture greater than 10° occurred in 20.0%, while ankle dorsiflexion below 10° occurred in 26.7%. In the meta-analysis by Wakefield et al., a pooled adjacent-joint stiffness rate of 26% was reported, closely corresponding to the present ankle finding [6]. Because definitions of stiffness vary across studies, precise comparisons with individual cohorts remain difficult. Even so, the findings support early weight-bearing, regular knee and ankle exercises, and continued rehabilitation during distraction and consolidation. During treatment, complications were frequent but predominantly manageable. Superficial pin-tract infection occurred in 53.3%, between the 48.2% reported by Bakhsh et al. and the pooled 60% reported by Wakefield et al. In the 199-patient analysis by Feng et al., pin-tract infection was reported in 61.3%, axial deviation in 43.2%, and delayed union in 25.1% [6,9,11]. By comparison, axial deviation occurred in 6.7% of the present patients, although pin loosening, broken wires, and swelling remained common. Residual deformity greater than 7° and residual limb-length discrepancy greater than 2.5 cm were each observed in 6.7%. No amputation was performed, consistent with Mohd-Yusof et al., although one amputation was reported by Bakhsh et al [9,13]. Overall, high union and limb-retention rates were achieved, but only through prolonged treatment and active management of frequent complications.

LIMITATIONS

This study was limited by its relatively small sample size, single-centre setting, and absence of a comparison group. In addition, the inclusion of both infected and aseptic non-unions introduced clinical heterogeneity, while the available follow-up may not have captured all late infection recurrences, refractures, or functional deterioration.

CONCLUSION

Bone transport with the Ilizarov external fixator was associated with a high rate of union and favourable bone and functional outcomes in patients with tibial shaft gap non-union. Substantial correction of limb-length discrepancy and final infection control were achieved, while no amputation was required. However, prolonged external fixation, pin-related problems, docking-site non-union, and joint stiffness remained important treatment burdens. Careful patient selection, radical debridement, stable frame construction, close radiological monitoring, and sustained rehabilitation are therefore required to achieve satisfactory limb reconstruction.

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CONFLICT OF INTEREST

None declared.

ETHICAL APPROVAL

The study was approved by the Institutional Ethics Committee.

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