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Original Article

Clinical Outcomes of Ilizarov Ring Fixation in Infected Nonunion of Tibial Fractures: A Prospective Study

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ABSTRACT

Background- Infected non-union of tibial fractures is a difficult orthopaedic condition characterized by persistent infection, failure of fracture healing, deformity and functional disability. The Ilizarov ring fixator offers simultaneous infection control, stable fixation, deformity correction and bone regeneration. This study evaluated its effectiveness in the management of infected non-union of tibial fractures.

Methodology- A prospective hospital-based study was conducted on 27 adult patients with infected non-union of tibial fractures treated using the Ilizarov ring fixator. Patients were assessed clinically and radiologically for bony union, eradication of infection, deformity correction, limb function and complications. Outcomes were evaluated using the ASAMI bone and functional scoring system.

Results- The mean age was 43.11±7.12 years, with male predominance (85.2%). Road traffic accidents accounted for 88.9% of injuries and mid-shaft tibia was the commonest fracture site (40.7%). Staphylococcus aureus was the most frequently isolated organism (44.4%). Bone grafting and corticotomy were required in 77.8% and 55.6% of patients, respectively. Successful bony union with eradication of infection was achieved in 92.6% of cases. Excellent and good ASAMI bone results were observed in 59.3% and 37.0% of patients, respectively. Overall treatment outcome was good in 55.5%, excellent in 22.3%, fair in 18.5% and poor in 3.7%. Pin tract infection was the commonest complication, predominantly mild to moderate.

Conclusion- The Ilizarov ring fixator is an effective limb-salvage technique for infected tibial non-union, providing high rates of union, reliable infection control, satisfactory functional recovery and acceptable complication rates. It remains an excellent treatment option for complex infected tibial non-unions.

Keywords: Ilizarov ring fixator; Infected non-union; Tibial fracture; ASAMI score; External fixation; Bone union; Limb salvage.

INTRODUCTION

Infected non-union of the tibia is one of the most challenging complications in orthopaedic trauma, characterized by the coexistence of failed fracture healing, persistent infection, and mechanical instability.[1] The tibia is particularly prone to non-union because of its subcutaneous location, limited soft tissue coverage, and relatively poor blood supply.[2] Tibial shaft fractures account for approximately 4–6% of all fractures and commonly result from high-energy trauma such as road traffic accidents.[3] The incidence of non-union ranges from 2–10% in closed fractures and is considerably higher in open injuries, with the prevalence in India reported to be approximately 6–7%.[4,5]

Non-union is defined by the United States Food and Drug Administration (FDA) as a fracture that persists for at least nine months without progressive healing for three consecutive months.[6] Infected non-union is frequently associated with chronic osteomyelitis, bone loss, deformity, limb shortening, and joint stiffness, resulting in substantial functional impairment.[7] Bacterial biofilm formation further compromises fracture healing by promoting persistent infection and impairing osteogenesis despite antimicrobial therapy.[8]

The management of infected tibial non-union remains challenging and typically requires radical debridement, infection control, restoration of mechanical stability, and biological stimulation of bone healing.[9] Conventional treatment methods often require multiple procedures and may be associated with persistent infection, recurrent non-union, or inadequate functional recovery.[10]

The Ilizarov technique, developed by Gavriil Ilizarov, is based on the principles of distraction osteogenesis and the law of tension-stress, allowing simultaneous eradication of infection, stable fixation, deformity correction, limb length restoration, and management of bone defects through bone transport.[11] Clinical studies have demonstrated high rates of fracture union and effective infection control, often exceeding 90%, with the added advantages of early weight-bearing and improved functional outcomes.[12]

Therefore, the present prospective study was undertaken to evaluate the effectiveness of the Ilizarov ring fixator in the management of infected non-union of tibial fractures, with emphasis on bony union, infection control, functional outcome, deformity correction, limb length restoration, and treatment-related complications.

MATERIALS AND METHODS

Study Design and Setting

This hospital-based prospective study was conducted in the Department of Orthopaedics, S.P. Medical College and Associated Group of Hospitals, Bikaner, Rajasthan, India, after obtaining approval from the Institutional Ethics Committee. The study was carried out over a period of three months.

Study Population

Adult patients presenting with infected non-union of tibial fractures to the Department of Orthopaedics were screened for eligibility. Patients aged 18–65 years with infected tibial non-union who consented to participate and completed the scheduled postoperative follow-up were included in the study. Patients with severe tibial nerve injury, peripheral vascular disease, psychiatric illness affecting compliance, senile dementia, or anticipated poor cooperation were excluded.

Sample Size

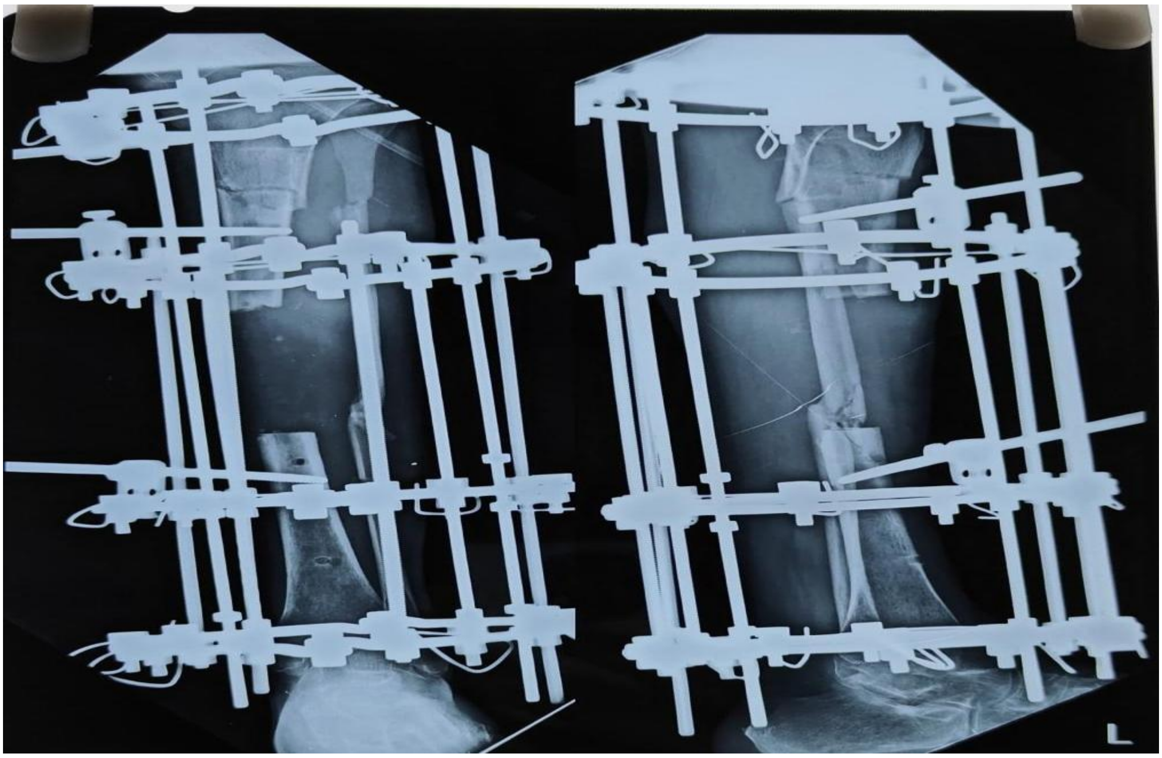
The sample size was calculated using an expected union rate of 93.3% reported by Mankar *et al.* with a 95% confidence level, 10% absolute precision, and α error of 0.05. The minimum calculated sample size was 24, which was increased to 27 after accounting for an anticipated 10% loss to follow-up. Consecutive sampling was used for patient recruitment.

Preoperative Evaluation

All patients underwent detailed clinical, radiological, and laboratory evaluation. Clinical assessment included history of injury, previous surgical procedures, duration of non-union, and evidence of infection. Standard anteroposterior and lateral radiographs were obtained to evaluate fracture configuration, alignment, bone loss, and non-union characteristics. Laboratory investigations included complete blood count, erythrocyte sedimentation rate, C-reactive protein, renal and liver function tests, and serological screening. Samples obtained from wound discharge or sinus tracts were sent for culture and antimicrobial susceptibility testing to guide targeted antibiotic therapy.

Surgical Procedure

All patients underwent radical debridement of infected and necrotic tissues followed by stabilization using the Ilizarov ring fixator. Frame configuration was individualized according to fracture morphology, bone loss, and soft-tissue status.



Circular rings were applied with tensioned trans-osseous wires and Schanz screws inserted through established safe anatomical corridors under fluoroscopic guidance. Fracture reduction, restoration of limb alignment, and frame stability were confirmed intraoperatively. Compression, distraction, or bone transport was performed when indicated to achieve union and address bone defects or limb length discrepancy. Foot extension was added selectively in distal tibial fractures requiring additional ankle stabilization.

Postoperative Management

Targeted antibiotic therapy was administered according to culture and sensitivity reports. Patients were encouraged to begin early joint mobilization and progressive weight-bearing as tolerated. Standardized pin-site care was performed throughout treatment. In patients undergoing distraction osteogenesis, distraction was initiated after a latency period of 5–7 days at a rate of 1 mm/day in divided increments. Regular physiotherapy was prescribed to preserve knee and ankle range of motion and facilitate functional recovery.

Follow-up

Patients were reviewed every two weeks initially and subsequently at monthly intervals until fracture union. Clinical evaluation included assessment of pain, construct stability, pin-site condition, gait, joint mobility, recurrence of infection, and complications. Serial anteroposterior and lateral radiographs were obtained to assess regenerate formation, fracture union, alignment, and consolidation. The Ilizarov fixator was removed after confirmation of both clinical and radiological union.

Outcome Measures

The primary outcome was successful fracture union with eradication of infection. Secondary outcomes included deformity correction, limb length restoration, complications, and functional recovery. Bone and functional outcomes were assessed using the Association for the Study and Application of the Method of Ilizarov (ASAMI) criteria. Bone results were graded according to union, infection, residual deformity, and limb length discrepancy, whereas functional outcomes were evaluated based on pain, gait, joint stiffness, return to daily activities, and overall limb function.

RESULTS

A total of 27 patients with infected non-union of tibial fractures were included in the study.

Demographic and Clinical Characteristics

The mean age of the study population was 43.11 ± 7.12 years. The highest proportion of patients belonged to the <30 years (25.9%) and 31–40 years (25.9%) age groups, followed by those aged >60 years (22.2%). Male patients predominated, accounting for 85.0% of the study population, whereas females constituted 15.0%. (Table 1)

Table 1 Demographic and Baseline Characteristics (n = 27)

Variable	Category	n (%)
Age group (years)	<30	7 (25.9)
	31–40	7 (25.9)
	41–50	3 (11.1)
	51–60	4 (14.8)
	>60	6 (22.2)
Mean age (years)	Mean ± SD	**43.11 ± 7.12**
Gender	Male	23 (85.2)
	Female	4 (14.8)

Road traffic accidents were the most common mechanism of injury, accounting for 88.9% of cases, while 11.1% sustained injuries following falls from height. The mid-shaft of the tibia was the most frequently involved fracture site (40.7%), followed by the distal tibia (33.3%), proximal tibia (22.2%), and segmental fractures (3.7%). (Fig 1)

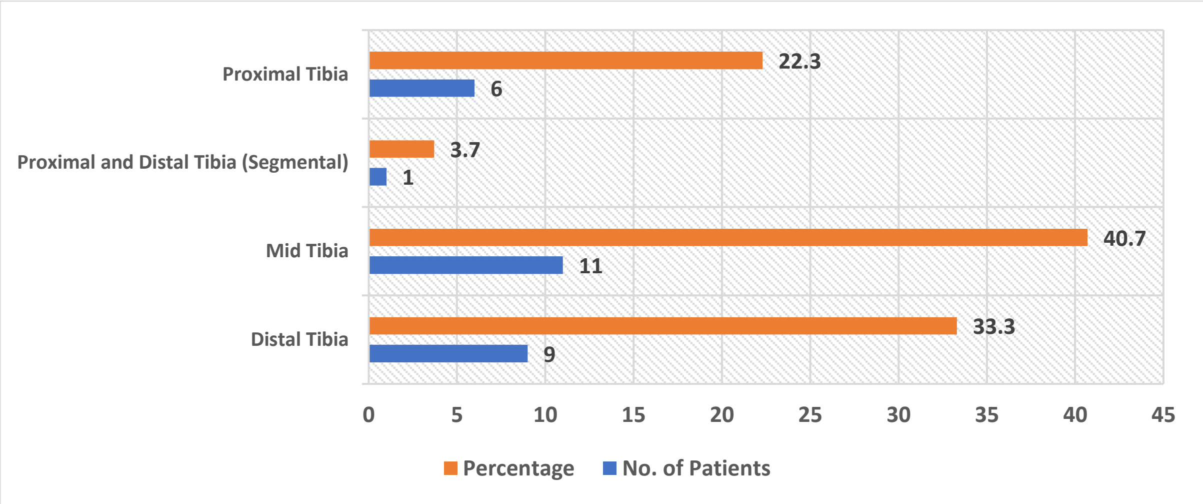


Fig 1 Distribution of fracture sites among patients with infected non-union of the tibia (n = 27)

Microbiological Profile

Microbiological culture identified Staphylococcus aureus as the predominant pathogen, isolated in 44.4% of patients. Pseudomonas aeruginosa was isolated in 18.5%, Escherichia coli in 11.1%, and Klebsiella species in 7.4% of cases, whereas 18.5% of cultures showed no bacterial growth. (Fig. 2)

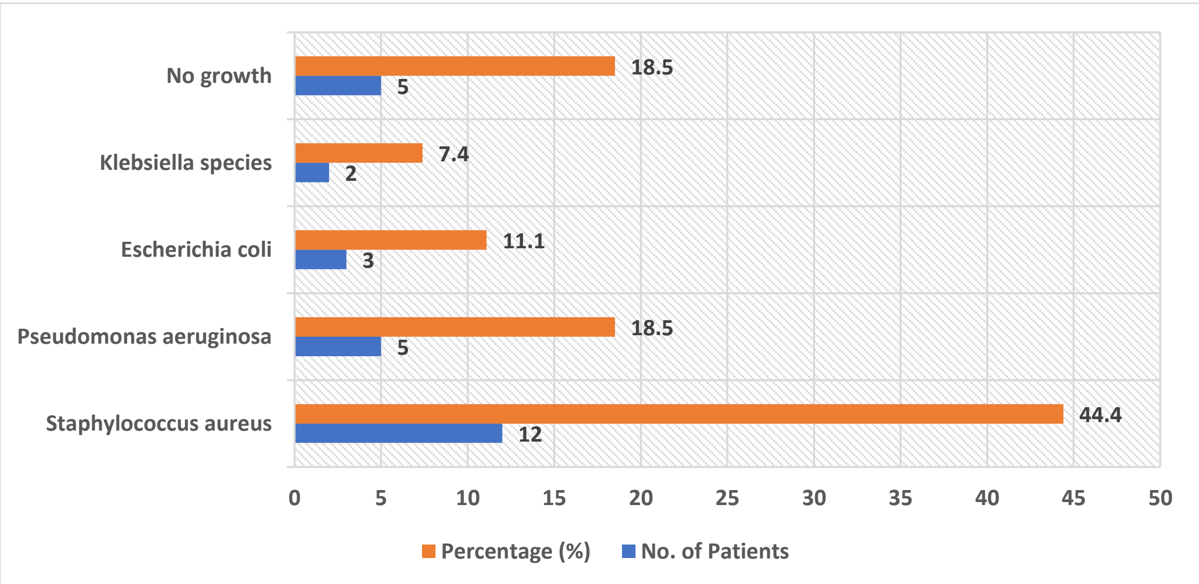


Fig. 2 Distribution of microorganisms isolated from patients with infected tibial non-union (n = 27).

Operative Characteristics
Bone grafting was performed in 75.0% of patients, while 25.0% did not require grafting. Corticotomy was undertaken in 55.5% of cases (Table 2). Wire-related complications requiring wire replacement occurred in 40.7% of patients, whereas 59.3% did not require wire change.

Table 2 Operative Details (n = 27)

Variable	Category	n (%)
Bone grafting	Yes	21 (77.8)
	No	6 (22.2)
Corticotomy	Yes	15 (55.5)
	No	12 (44.5)

According to the Moore–Dahl classification, pin-site infection was graded as Grade 3 in 37.0% of patients, followed by Grade 2 (29.6%), Grade 4 (14.8%), Grade 5 (14.8%), and Grade 1 (7.4%).

Radiological Outcomes
Successful fracture union without persistent infection was achieved in 25 of 27 patients (92.6%), whereas 2 patients (7.4%) had persistent non-union. Residual deformity of <7° was observed in 59.3% of patients, while 40.7% had deformity greater than 7°. According to the ASAMI bone criteria, 59.3% of patients achieved excellent results, 37.0% had good results, and 3.7% had poor outcomes. (Table 3)

Table 3 Radiological Outcomes (ASAMI Bone Results) (n = 27)

Variable	Category	n (%)
Union status	Union without infection	25 (92.6)
	Non-union	2 (7.4)
Residual deformity	<7°	16 (59.3)
	≥7°	11 (40.7)
ASAMI bone result	Excellent	16 (59.3)
	Good	10 (37.0)
	Poor	1 (3.7)

Functional Outcomes
Limp was absent in 63.0% of patients, whereas 37.0% demonstrated a residual limp. Knee range of motion reached 130° in 55.5% of patients, 110° in 29.6%, and 100° in 14.9%. Ankle stiffness of 20° was observed in 55.5% of patients, while 44.5% had 10° of ankle stiffness.

Overall functional outcome assessment demonstrated good results in 55.5% of patients, excellent in 22.3%, fair in 18.5%, and poor in 3.7%. (Fig. 3)

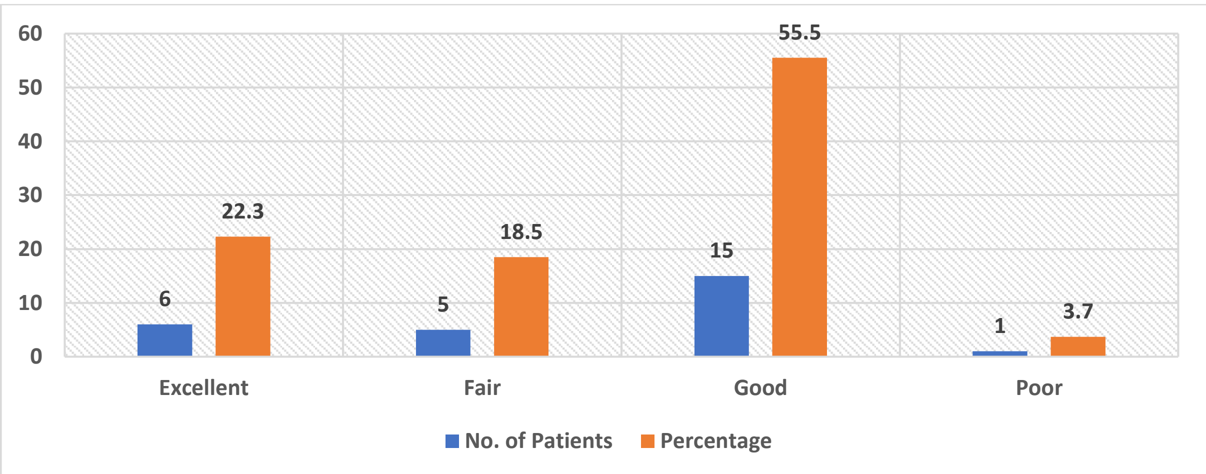


Fig. 3 Functional outcomes in patients treated with the Ilizarov ring fixator (n = 27).

DISCUSSION
Infected non-union of the tibia remains one of the most challenging conditions in orthopaedic trauma because of the coexistence of infection, instability, bone loss, and soft tissue compromise. The Ilizarov ring fixator has gained widespread

acceptance for managing these complex cases by providing stable fixation, facilitating infection control, and promoting bone regeneration through distraction osteogenesis. The present prospective study evaluated the effectiveness of the Ilizarov technique in achieving fracture union, eradicating infection, correcting deformity, and restoring limb function.

The mean age of patients in the present study was 43.11 ± 7.12 years, with the majority belonging to the younger and middle-aged population. This finding is comparable to those reported by Mankar et al.[12] and Gundavarapu et al.[13], who observed that infected tibial non-union predominantly affects individuals in the third and fourth decades of life. The predominance of male patients (85.2%) is also consistent with previous studies by Wani et al.[14], Kumar et al.[15], and Mankar et al.[12], reflecting the greater exposure of males to high-energy trauma and occupational hazards.

Road traffic accidents accounted for 88.9% of injuries, making them the leading cause of infected tibial non-union in the present study. Similar observations have been reported by Sen et al.[18] and Sahu et al.[17], emphasizing the strong association between high-energy trauma, open fractures, and subsequent infection. The mid-shaft of the tibia was the most frequently affected site, consistent with previous reports, which may be explained by the subcutaneous location and relatively poor soft tissue coverage of the tibial shaft.[19-21]

Microbiological analysis demonstrated that *Staphylococcus aureus* was the predominant pathogen (44.4%), followed by *Pseudomonas aeruginosa* (18.5%). These findings are comparable with those reported by Trampuz and Zimmerli[22] and Yin et al.[23], who also identified *S. aureus* as the most common organism responsible for infected non-union.45,78 The presence of gram-negative organisms and culture-negative cases further highlights the polymicrobial nature of chronic osteomyelitis and underscores the importance of meticulous debridement combined with culture-directed antibiotic therapy.

Bone grafting was required in 77.8% of patients, reflecting the high prevalence of bone defects following radical debridement. Corticotomy was performed in more than half of the patients, emphasizing its importance in eliminating infected and necrotic bone. These findings support previous studies that identified adequate debridement as a critical prerequisite for successful eradication of infection and fracture healing.[24,25]

The principal finding of the present study was the high rate of union without persistent infection (92.6%). This outcome is comparable with the union rates reported by Dendrinos et al.[26], Sen et al.[18], and Yin et al.[23], all of whom reported union rates exceeding 90% following Ilizarov fixation. The excellent union achieved in our study can be attributed to stable circular fixation, preservation of blood supply, and the biological effects of distraction osteogenesis, which together create an optimal environment for fracture healing even in infected cases.

Radiological outcomes were also encouraging. Most patients achieved acceptable alignment, with 59.3% demonstrating residual deformity of less than 7°, while ASAMI bone assessment showed excellent or good results in 96.3% of patients. These findings are consistent with previous reports by Paley et al.[27], Catagni et al.[28], and Marsh et al.[21], confirming the ability of the Ilizarov technique to achieve reliable correction of deformity while maintaining fracture stability.

Functional recovery was similarly favorable, with the majority of patients achieving good or excellent ASAMI functional outcomes. Although a proportion of patients experienced residual limp and ankle stiffness, these complications have been commonly reported following prolonged treatment with external fixation and extensive soft tissue injury.[14,17] Early mobilization, weight-bearing, and supervised physiotherapy likely contributed to the satisfactory functional recovery observed in the present study.

Pin-site infection was the most frequent complication but was predominantly mild to moderate in severity and managed successfully with local pin care and antibiotics. Wire replacement was required in 40.7% of patients but did not adversely affect final union. Similar complication profiles have been reported in previous studies, suggesting that these issues are generally manageable and do not compromise the overall success of Ilizarov treatment.[20,29]

CONCLUSION

The present study demonstrates that the Ilizarov ring fixator is an effective treatment modality for infected non-union of tibial fractures, achieving a high rate of fracture union with successful infection control. The technique also provided satisfactory deformity correction and favorable functional outcomes with acceptable and manageable complications. Despite the limitations of a relatively small sample size and short follow-up, the findings support the Ilizarov method as a reliable limb-salvage procedure for managing complex infected tibial non-unions. Further multicenter studies with larger sample sizes and longer follow-up are warranted to validate these findings.

DECLARATIONS

Funding: None.

Conflict of Interest: The authors declare no conflict of interest.
Ethical Approval: The study was conducted in accordance with applicable ethical standards and approved by the appropriate ethics committee where required.
Informed Consent: Informed consent was obtained from all participants involved in the study where applicable.
Author Contributions: All authors contributed to the study conception, design, data collection, analysis, manuscript preparation, and approved the final version of the manuscript.
Data Availability: Data supporting the findings of this study are available from the corresponding author upon reasonable request.

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