ISSN 0973-2063 (online) 0973-8894 (print)

Bioinformation 22(8): 5319-5324 (2026)

BIOINFORMATION
Discovery at the interface of physical and biological sciences

BIOMEDICAL INFORMATICS

www.bioinformation.net
Volume 22(8)

Research Article

Received August 1, 2026; Revised August 31, 2026; Accepted August 31, 2026, Published August 31, 2026

DOI: 10.6026/973206300225319

SJIF 2026 (Scientific Journal Impact Factor for 2026) = 8.478
2022 Impact Factor (2023 Clarivate Inc. release) is 1.9

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Edited by P Kangueane
Citation: Kumar *et al.* Bioinformation 22(8): 5319-5324 (2026)

Ilizarov ring fixation outcome in infected tibial non-union: A report

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ISSN 0973-2063 (online) 0973-8894 (print)

Bioinformation 22(8): 5319-5324 (2026)

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Abstract:
Infected non-union of tibial fractures, particularly following open injuries, remains challenging and the Ilizarov technique permits simultaneous infection control and bone reconstruction. In this prospective study of 32 patients followed for 9 months, treatment outcomes were assessed using the Association for the Study and Application of Methods of Ilizarov (ASAMI) criteria. Radiological outcomes were excellent or good in 87.7% of patients, while functional outcomes were excellent or good in 81.3%; complications occurred in 56.2%, with joint stiffness, pain, limb-length discrepancy and reinfection being the most frequent. Severe open fractures, positive cultures and the need for additional procedures were significantly associated with complications. The Ilizarov ring fixator therefore provides an effective limb-reconstruction strategy for infected tibial non-union, although complication rates remain substantial and may adversely affect functional recovery.

Keywords: Infected non-union tibia; Ilizarov ring fixator; association for the study and application of methods of ilizarov (ASAMI) criteria

Background:
Infected non-union of the tibia presents a formidable challenge in the field of orthopedic surgery, especially in developing countries where healthcare resources are limited and the incidence of trauma-related injuries is high **[1].** The tibia, being a subcutaneous bone, is particularly vulnerable to injuries from road traffic accidents, falls and other traumatic events. The reported incidence rate for tibial shaft fractures is 16.9 per 100,000 per year, with a significant proportion of these progressing to non-union, especially in cases of open fractures **[2]**. Non-union rates for tibial fractures range from 3% to 11% and the infection rate in proximal tibial fractures can be as high as 12.9% in open fractures **[3]**. These infected non-unions result in complications such as persistent infection, bone loss, deformity, joint stiffness and substantial functional disability, posing a significant burden on patients and healthcare systems alike, Therefore, it is of interest to report on the Outcome of Ilizarov Ring Fixator in Infected Non-Union of Tibia **[4].** Traditional treatments for infected non-unions involve extensive and often sequential procedures. These include debridement of necrotic tissue, antibiotic bead placement, papineau open cancellous grafting, tibiofibular synostosis and free tissue transfers **[5]**. While these interventions aim to manage infection and promote bone healing, they frequently require multiple surgeries, resulting in significant scarring, joint stiffness and prolonged rehabilitation periods. This cascade of interventions often leads to suboptimal limb function and considerable patient morbidity **[6].** The Ilizarov method, developed by Gavriil Ilizarov, has revolutionized the treatment of complex orthopedic conditions, particularly infected non-unions of the tibia **[7]**. This technique utilizes a circular external fixator composed of percutaneously inserted tensioned wires, forming a stable and versatile frame. The method's key component, corticotomy, enhances vascularity and facilitates bone regeneration through a process known as distraction osteogenesis **[7]**. Bone transport techniques employed in this method enable the progressive filling of bone defects, thereby eradicating infection and promoting robust fracture union **[8]**. The Ilizarov fixator offers several advantages over conventional treatments. It provides stable fixation that allows for early weight-bearing and joint mobilization, essential for maintaining articular function and preventing stiffness. The method's ability to simultaneously address infection control and bone defect reconstruction sets it apart **[9]**. Radical debridement of infected tissues, followed by bone transport, allows for effective management of infection while promoting bone healing and restoring limb length and alignment. This integrative approach reduces the need for additional bone grafting procedures and minimizes complications associated with prolonged immobilization **[10].** Clinical studies have consistently demonstrated the efficacy of the Ilizarov technique in managing infected non-unions of the tibia. Research indicates that the method not only achieves high rates of bone union and infection resolution but also significantly improves functional outcomes. Patients treated with the Ilizarov fixator experience fewer surgeries, reduced hospital stays and quicker rehabilitation compared to those undergoing conventional treatments **[11]**, Furthermore, the technique's adaptability to various clinical scenarios, including cases with significant soft tissue defects and previous fixation failures, underscores its versatility and effectiveness **[12].** The success of the Ilizarov method lies in its holistic approach to fracture management. By providing mechanical stability, enhancing biological healing processes and enabling early mobilization, it addresses the multifaceted challenges of infected non-unions comprehensively. This technique has become a cornerstone in orthopedic practice, offering a viable solution for patients suffering from this debilitating condition and significantly improving their quality of life **[13].** The Ilizarov ring fixator represents a groundbreaking advancement in the treatment of infected non-unions of the tibia. Its ability to integrate infection control with bone reconstruction, coupled with its stability and early mobilization benefits, makes it a superior alternative to

conventional treatments **[14].** As numerous studies and clinical experiences accumulates, the Ilizarov method continues to affirm its role as a transformative approach in orthopedic surgery, offering hope and improved outcomes for patients with this challenging condition **[15].** Therefore, it is of interest to evaluate the clinical and radiological outcomes of the Ilizarov ring fixator in the management of infected tibial non-union and to identify factors associated with complications and treatment outcomes.

Methodology:

This was a single-center, clinical interventional study conducted among patients admitted to the Orthopaedics department M.L.N. Medical College, Prayagraj. The study was carried out according to the principles of the Helsinki Declaration. The study included patients diagnosed with infected non-union of the tibia that had persisted for at least nine months, regardless of the presence or absence of bone defects. Patients were excluded if they had non-union of the tibia without evidence of infection or if the infection had been present for less than nine months at the time of diagnosis.

Study methodology:

Spinal anaesthesia was administered to all patients. All existing implants were removed, followed by surgical debridement guided by previous scars. Debridement involved cleaning the fractured bone ends until punctate hemorrhage was observed. During each operation, samples of soft tissue, pus and/or biofilm were obtained for culture and sensitivity tests. The Ilizarov frame was pre-constructed based on clinical and radiological results using three to five rings. It was secured to the patient's bone using 1.8 mm bayonet tip trans-osseous wires and 6 mm tapered Schanz screws to maintain alignment stability. Bayonet tip wires were chosen to minimize thermal necrosis. A reference wire parallel to the knee joint line was passed through and attached to the proximal ring at the level of the fibular head. A distal reference trans-fibular wire was inserted perpendicular to the ankle joint and secured to the distal ring to maintain frontal plane alignment. To correct sagittal plane recurvatum deformity, folded towels were placed under the middle component between the ring and the leg. A Schanz pin was inserted into the middle ring on the medial tibial surface to maintain alignment in both frontal and sagittal planes. Another wire was inserted from the tibia to the head of the fibula through the proximal ring. Two Schanz pins were inserted into the proximal ring at the medial and lateral borders of the patellar tendon with Rancho cubes to maintain a ninety-degree crossing angle. Two Schanz pins were inserted across the medial tibial surface on each side of the middle ring, positioned in the center ring. The distal tibial ring was modified with two wires and one Schanz screw. Schanz screws were used over the medial tibial surface instead of wires to avoid muscle trans-fixation and restrict normal muscle excursion. The fixation span of the ring was adjusted using Rancho cubes of varying sizes to match the bone fragment length. All fixation components were placed securely within the tibial passageways. After removing connecting rods, a one-centimeter incision was made above the tibial shin for corticotomy. The periosteum on the medial and lateral surfaces was elevated. The cortex above the tibial shin was drilled using a 4.5 mm diameter drill bit, creating multiple holes on the front, middle and posterior bone surfaces. The holes were connected using a 10 mm osteotome, followed by corticotomy. Successful completion of corticotomy was confirmed by piece translation, after which rods were inserted between the rings. When a gap of less than 4 centimeters was identified, acute docking was attempted, followed by corticotomy distraction (**Figure 1 and Figure 2**). Distraction typically started on the seventh post-operative day, initially set at 0.25 mm four times daily. Distraction rate was adjusted based on regeneration progression observed in follow-up X-rays. Patients with acute docking received additional compression at a rate of 0.25 mm per day for seven days. Patients were instructed to bear weight and walk with assistance from walkers starting from the first post-operative day. Initially, broad-spectrum antibiotics were prescribed, adjusted based on intraoperative microbiology and culture sensitivity results. Patients were discharged two weeks after suture removal, instructed on pin tract and distraction care. They were followed up routinely every two weeks during distraction and monthly thereafter. Monthly X-rays were taken until complete distraction, followed by biweekly X-rays. After radiological evidence of fracture union and regenerate consolidation, the Ilizarov frame was dynamized. Patients were strongly encouraged to bear full weight for an additional four weeks to reduce stress and achieve better consolidation. The frame was eventually removed inside the outpatient department after careful evaluation.

Evaluation:

Following frame removal, all results were evaluated using criteria established by the Association for the Study and Application of the Method of Ilizarov (ASAMI). Union was considered successful if bridge callus was observed on at least three cortices, dynamization was painless and there were no abnormal movements at the union site (**Figure 3**).

Results:

The present study was carried out to assess the radiological and functional outcome of infected non-union tibial fractures managed using Ilizarov ring fixator. For this purpose, a prospective interventional study was planned in which a total of 32 cases fulfilling the eligibility criteria were enrolled. In the present study, age of study population ranged from 22 to 50 years. Maximum number of cases (n=14; 43.8%) were aged between 21 and 30 years followed by 31-40 years (n=11; 34.4%) and 41-50 years (n=7; 21.9%) respectively. Mean age of patients was 33.25±7.87 years. Majority of patients were males (n=28; 87.5%). There were 4 (12.5%) females. Sex-ratio (M:F) of study population was 7. Road traffic accident (n=24; 75%) was the most common mode of injury followed by fall from height (n=5; 15.6%) and assault (n=3; 9.4%) respectively and Right side (n=17; 53.1%) was more commonly involved than the left side (n=15; 46.9%) (**Table 1**). Of all the 32 cases, 10 (31.3%) had Open 3A type fracture followed by Open 3B (n=8; 25.0%), Open 2 (n=7;

21.9%), Open 1 (n=5; 15.6%) and Closed (n=2; 6.3%) fracture respectively debridement with Ilizarov ring fixator (n=14; 43.8%) was the most common procedure followed by Ilizarov ring fixator only (n=10; 31.3%) and debridement, Ilizarov ring fixator with corticotomy (n=8; 25%) respectively (**Table 2**). A total of 26/32 (81.2%) cases were culture positive. Among different pathogens, *Staphylococcus aureus* (n=12; 37.5%) was the most common followed by *Escherichia coli* (n=4; 12.5%), *Pseudomonas aeruginosa* (n=3; 9.4%), *Klebsiella spp*. and *Proteus mirabilis* (n=2; 6.3% each) respectively. There was one case each in whom *Enterococcus, Streptococcus* and MRSA were isolated (**Table 3**). **Table 4** presents a statistically significant association between the presence of complications and both radiological and functional outcomes in patients with infected tibial non-unions. Among patients without complications (n=14), the majority achieved excellent radiological outcomes (92.9%) compared to only 27.8% in those with complications (n=18), with the difference being statistically significant (χ^2 = 13.669, p = 0.003). Conversely, poorer radiological outcomes (good, fair and poor) were more frequent among those with complications. Similarly, functional outcomes showed an even stronger association: 92.9% of patients without complications had excellent functional recovery, compared to only 5.6% among those with complications. In contrast, the incidence of good, fair and poor functional outcomes was significantly higher in the complication group. This difference was highly significant (χ^2 = 24.502, p < 0.001), indicating that the presence of complications adversely impacts both radiological healing and functional recovery.

Table 1: Demographic profile of study participants

Age Group	Category	No. of patients	Percentage
	21-30 Years	14	43.8
	31-40 Years	11	34.4
	41-50 Years	7	21.9
Mean age ± SD (Range)		33.25±7.87 (22-50)	
Gender.	Male	28	87.5
	Female	4	12.5
Mode of Injury	Road traffic accident	24	75.0
	Fall from height	5	15.6
	Assault	3	9.4
Side involved	Left	15	46.9
	Right	17	53.1

Table 2: Distribution of cases according to Fracture Type (Classification) and procedure done

Type of Fracture	No. of patients	Percentage
Closed	2	6.3
Open 1	5	15.6
Open 2	7	21.9
Open 3A	10	31.3
Open 3B	8	25.0
Procedure done	**No. of patients**	**Percentage**
Debridement with Ilizarov ring fixator	14	43.8
Ilizarov ring fixator only	10	31.3
Debridement, Ilizarov ring fixator with corticotomy	8	25.0

Table 3: Distribution of cases according to culture sensitivity

S.N	Culture Sensitivity	No. of patients	Percentage
1.	**Culture negative**	6	18.8
2.	**Culture positive**	26	81.3
	Staphylococcus aureus	12	37.5
	Escherichia coli	4	12.5
	Pseudomonas aeruginosa	3	9.4
	Klebsiella sp.	2	6.3
	Proteus mirabilis	2	6.3
	Others (one each *Enterococcus, Streptococcus* and MRSA)	3	9.4

Table 4: Association of complications with radiological and functional outcomes

SN	Outcome	No Complications (n=14)		Complications (n=18)		Statistical significance	
		No.	%	No.	%	χ^2	'p'
I. Radiological outcome							
1.	Excellent	13	92.9	5	27.8	13.669	0.003
2.	Good	1	7.1	9	50.0		
3.	Fair	0	0.0	3	16.7		
4.	Poor	0	0.0	1	5.6		
II. Functional outcome							
1.	Excellent	13	92.9	1	5.6	24.502	<0.001
2.	Good	1	7.1	11	61.1		
3.	Fair	0	0.0	4	22.2		
4.	Poor	0	0.0	2	11.1		

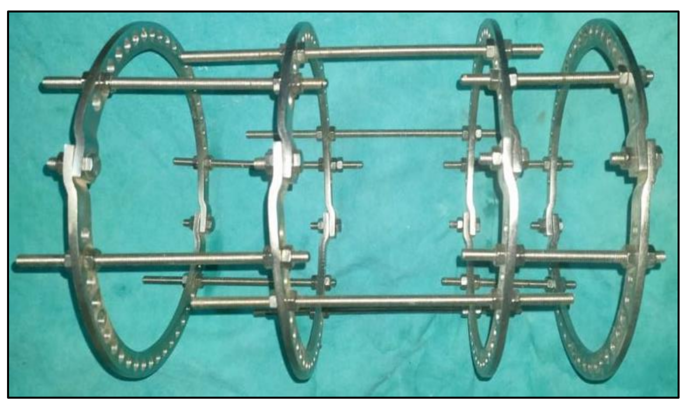

Figure 1: Ilizarov ring assembly

Figure 2: Instruments used in Ilizarov ring fixation

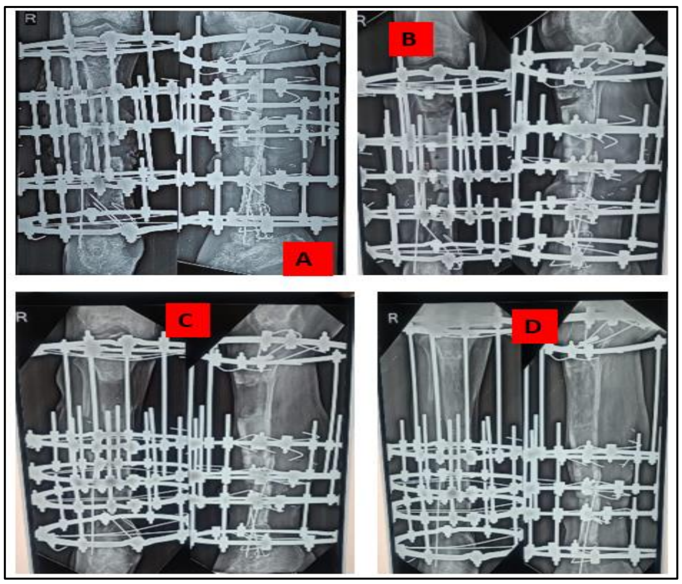

Figure 3: (A) Ilizarov ring fixation with corticotomy was performed for the infected non-united tibial fracture following appropriate debridement and preparation of the non-union site. (B) At 1-month follow-up, the Ilizarov frame was well maintained, with satisfactory alignment and early evidence of regenerate formation at the corticotomy site. (C) At 3-month follow-up, progressive bone transport was observed with continued regenerate formation and maintained axial alignment of the tibia. (D) At 5-month follow-up, approximately 8 cm of bone transport had been achieved, with good-quality regenerate formation, satisfactory alignment and evidence of solid union at the docking/non-union site.

Discussion:

The present prospective interventional study evaluated the radiological and functional outcomes of infected tibial non-unions treated using the Ilizarov ring fixator in 32 patients. The demographic analysis revealed that the majority of patients were young adult males, with a mean age of 33.25 years and 87.5% being male. This demographic distribution is consistent with findings by Anandasivam *et al.* **[2]** and Munk *et al.* **[3],** who noted that young males are more susceptible to high-energy trauma, particularly road traffic accidents (RTAs)-the most common mechanism of injury in our study (75%). The right lower limb was more frequently involved (53.1%), reflecting patterns seen in lower limb trauma literature **[2].** Fracture classification **(Table 2**) showed that over half the patients (56.3%) sustained Gustilo-Anderson Type 3A and 3B open fractures. These severe injuries are known to be at higher risk of infection and non-union due to extensive soft tissue damage, as emphasized by Chaudhary **[1]** and Aktuglu *et al.* **[10]**. Only 6.3% had closed fractures, further underscoring the challenging nature of this cohort. The most common surgical intervention was debridement with Ilizarov ring fixator (43.8%), followed by Ilizarov alone (31.3%) and Ilizarov with corticotomy (25%). These combinations reflect standard approaches for managing infection and bone defects and are supported by Li *et al.* **[12]** and Xie *et al.* **[9],** who advocate the use of corticotomy or bone transport in complex cases. Culture sensitivity analysis (**Table 3)** revealed that 81.3% of patients were culture-positive, with *Staphylococcus aureus* being the most commonly isolated pathogen (37.5%). This aligns with microbiological trends noted by Testa *et al.* **[8]** and Fahad *et al.* **[16]**, where *S. aureus* predominated among isolates in infected non-unions. Other pathogens such as *E. coli*, *Pseudomonas aeruginosa*, *Klebsiella* and *Proteus* were also reported, indicating polymicrobial flora commonly associated with chronic osteomyelitis. Culture-negative results in 18.8% of cases could be attributed to prior empirical antibiotic use or biofilm-associated infections that evade standard detection methods **[6].** Radiological and functional outcomes were significantly influenced by complications (**Table 4**). Among patients without complications, 92.9% achieved excellent outcomes in both domains, compared to only 27.8% (radiological) and 5.6% (functional) among those with complications, with results being statistically significant ($p = 0.003$ and <0.001, respectively). These findings are in concordance with Chalak *et al.* **[17]** and Hameed *et al.* **[18]**, who reported similar outcome deterioration in patients who developed complications during the course of Ilizarov treatment. The most common complications in the present study were joint stiffness, followed by pin tract infection and reinfection. These complications are consistent with previous reports by Meleppuram and Ibrahim **[19],** who highlighted that prolonged external fixation and insufficient post-operative physiotherapy contribute to such sequelae. Fahad *et al.* **[16]** also documented similar complications and emphasized the need for proactive physiotherapy and pin site care. Despite the complications, the Ilizarov technique showed high efficacy in achieving bone union, with outcomes comparable to those reported by Mankar *et al.* **[20],** Hameed *et al.* **[18]** and Ramos *et al.* **[21]**. This technique's success lies in its ability to provide stable fixation, promote osteogenesis and allow for gradual deformity correction, making it suitable even in infected and bone-deficient environments **[9, 11].** Differences in reported success rates across studies-such as 60% excellent outcomes by Meleppuram and Ibrahim **[19]** versus 90% reported by Chalak *et al.* **[17]** can be attributed to variations in patient profiles, fracture severity and surgical expertise. Our study had a substantial number of Type 3 fractures (56.3%), requiring combined debridement and corticotomy, which may explain some variability in outcomes. High-volume centers with dedicated Ilizarov teams, like that of Chalak *et al.* **[17]**, often report better outcomes due to more standardized care. Moreover, the role of rehabilitation is critical in functional recovery. In our study, the subgroup without complications attained excellent outcomes in 92.9% of cases, affirming the importance of uninterrupted physiotherapy and follow-up care. Khan *et al.* **[22]** and Ramos *et al.* **[21]** also emphasized the necessity of structured rehabilitation to optimize joint function post-fixator removal. Beyond technical factors, socioeconomic and psychological variables also influence treatment adherence and recovery. Madhusudhan *et al.* **[23]** reported that patients from lower socioeconomic strata often experience delays in treatment and poor follow-up, resulting in less favorable outcomes. Aspects such as patient motivation, nutritional status and support systems are pivotal in ensuring treatment success and preventing re-infection or failure. Evaluation variability between studies due to different scoring systems-such as ASAMI, KOOS, or SF-36-also contributes to the inconsistency in reported functional outcomes **[14]**. For instance, ASAMI, commonly used in Ilizarov literature, places more emphasis on bony consolidation and alignment than quality-of-life metrics.

Conclusion:

The Ilizarov ring fixator provides favorable radiological and functional outcomes in most patients with infected tibial non-union. Complications remain common, particularly in severe injuries, culture-positive cases and those requiring corticotomy. Thus, careful patient selection and individualized treatment planning improves outcomes, while larger studies are needed to validate these findings.

Advancement to knowledge:

This study shows that the Ilizarov ring fixator can achieve favorable radiological and functional outcomes in infected tibial non-union while addressing infection and bone reconstruction simultaneously. The findings also highlight severe initial injury, positive microbiological cultures and the requirement for additional procedures as important predictors of complications.

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