Section: Orthopaedics

Original Research Article

FUNCTIONAL OUTCOME OF NON-UNION OF LONG BONES TREATED BY LIMB RECONSTRUCTION SYSTEM AUGMENTED WITH EXTERNAL FIXATOR

Sudhakar. R.[1], G.Venkatesh[2], Sathiyamoorthi P.[3]

[1]Assistant Professor, Department of Orthopaedics, Government Tiruvannamalai Medical College and Hospital, Tamilnadu, India.
[2]Assistant Professor, Department of Orthopaedics, Government Tiruvannamalai Medical College and Hospital, Tamilnadu, India.
[3]Senior Assistant Surgeon, Department of Orthopaedics, Government Hospital, Bhavani, Tamilnadu, India.

Received : 05/02/2026
Received in revised form : 28/03/2026
Accepted : 15/04/2026

Keywords:
Bone Lengthening; External Fixators; Fracture Healing; Fracture Nonunion; Osteomyelitis; Tibial Fractures.

Corresponding Author:
Dr. Sathiyamoorthi P.,
Email: sathiyamoorthydr@gmail.com

DOI: 10.47009/jamp.2026.8.2.170

Source of Support: Nil,
Conflict of Interest: None declared

Int J Acad Med Pharm
2026; 8 (2); 929-933

ABSTRACT

Background: Infected non-union of long bones is challenging due to infection, bone loss, and deformity. Limb Reconstruction System, augmented with AO external fixation, provides stability and supports bone healing. **Aims and objectives:** The study aims to analyse the prospective and retrospective outcomes of treatment of infected non-union of long bones with or without gap treated by using the Limb Reconstruction System augmented with AO External fixators (Biplanar). **Materials and Methods:** A retrospective and prospective study was conducted at the Institute of Orthopaedics and Traumatology, Madras Medical College, Rajiv Gandhi Government General Hospital, Chennai. Thirty patients with infected non-union of long bones treated with Limb Reconstruction System augmented with AO external fixator were included and followed for clinical and functional outcomes. **Results:** Most patients were in the 20–29 years and 30–39 years age groups, with 10 cases (33.3%) each. The femur was the most commonly affected bone in 16 cases (53.3%), followed by the tibia in 12 cases (40%). Draining infected non-union was more common, seen in the femur in 10 cases (35.7%) and tibia in 8 cases (28.6%). External fixation was the most frequent previous stabilisation method in the femur, 14 cases (87.5%) and tibia, 9 cases (75%). According to ASAMI criteria, good bone results were observed in 25 cases (83.3%), while excellent results were seen in 3 cases (10%). Functional outcomes were good in 23 cases (76.7%), with excellent outcomes in 4 cases (13.3%). **Conclusion:** Limb reconstruction system augmented with AO external fixation provides stable fixation and helps achieve satisfactory bone union and functional recovery in infected non-union of long bones.

INTRODUCTION

Fracture healing is a complicated biological phenomenon characterized by tissue regeneration and recovery of bone stability. However, in some instances, fractures can fail to heal due to a series of conditions; in such cases, a phenomenon called non-unions emerges. As per the FDA's definition, non-unions are characterized by lack of radiological progression of healing in a period of three months followed by persistence of fractures for nine months.[1] However, this timeline should be interpreted carefully in long bones such as the femur and tibia, where healing may be prolonged due to biomechanical and biological factors; therefore, clinical judgment is important before diagnosing non-union, within the first six months following injury.[1]

Long bone non-unions continue to pose serious problems following orthopedic trauma with a frequency of occurrence between 2% to 15% depending on the fracture and the type of treatment applied. This complication poses much higher chances in cases of open fractures than closed fractures because of tissue damage and poor blood supply.[2] Open fractures have been found to suffer from impairment of osteogenesis due to lack of blood supply and bacteria colonization, while closed fractures tend to have a problem of non-union mainly due to mechanical issues or biological problems such as insufficient vascularity. At the cell level, failure in vascularisation, osteogenic cells activities, and inflammation hinder proper bone fracture healing process, hence, leading to non-union.[2]

Non-union of infection is a relatively complicated scenario where an existing infection prevents the

ISSN (O): 2687-5365; ISSN (P): 2753-6556

bone from mending. The infection causes the breakdown of bone tissue, resulting in the creation of dead bone tissue (sequestra) along with the development of biofilm around bacteria.[3,4] In clinical conditions, infected non-union usually occurs in combination with sinus drainage and soft tissue involvement. According to researches, 50-60 % of infected non-unions have sinus drainage, which represents chronic osteomyelitis.[3,4] Progressive bone destruction and vascular compromise may result in deformity, bone loss, limb length discrepancy, and joint stiffness, ultimately causing significant functional disability and prolonged treatment duration.[3,4]

Several treatment methods have been used to manage infected non-union of long bones. Internal fixation is usually avoided when infection is present because metallic implants may maintain bacterial colonisation. External fixation provides stable mechanical support while allowing access for wound care and infection control. According to orthopaedic principles, external fixators are widely used in infected non-unions because they stabilise the fracture and permit gradual correction of deformity or limb shortening.[5]

Distraction osteogenesis is a technique that allows regeneration of bone by gradual mechanical distraction. This method can correct bone defects, limb shortening and deformity while stimulating new bone formation. The Limb Reconstruction System (LRS) is a monolateral external fixation device designed for bone transport and limb lengthening procedures. Several studies have reported that LRS provides stable fixation and satisfactory clinical results in infected non-union of long bones.[6,7] However, single-plane fixation may provide limited stability in large bones such as the femur, and augmentation with an additional AO external fixator can improve stability through a biplanar construct.[8,9]

Despite advances in reconstruction techniques, limited studies evaluate the functional outcome of infected non-union of long bones treated with Limb Reconstruction System augmented with AO external fixator in a biplanar configuration, particularly in patients with or without a bone gap. Evaluation of clinical and functional results after this treatment method is necessary to understand its effectiveness in restoring bone union and limb function.

Aims and objectives

The study aims to analyse the prospective and retrospective outcomes of treatment of infected non-union of long bones with or without gap treated by using the Limb Reconstruction System augmented with AO External fixators (Biplanar).

MATERIALS AND METHODS

This retrospective and prospective study included 30 patients aged 17–55 years (mean age 35 years) treated at the Institute of Orthopaedics and Traumatology, Madras Medical College, Rajiv Gandhi Government General Hospital, Chennai, between May 2016 and September 2018. Approval was obtained from the institutional ethics committee, and written informed consent was obtained from all patients before treatment.

Inclusion and Exclusion Criteria

Patients aged 17–55 years with clinically and radiologically confirmed infected non-union of long bones (femur, tibia, humerus, or ulna), with or without bone gap, who were treated using Limb Reconstruction System augmented with AO external fixator and were available for follow-up, were included.

Patients with non-infected non-union, pathological fractures due to tumour or metabolic bone disease, severe systemic illness making them unfit for surgery, age below 17 years or above 55 years, and those lost to follow-up or with incomplete records were excluded.

Methods

Data were collected from 30 male patients with infected non-union of long bones. The cases were classified according to AO classification into infected quiescent non-draining non-union (4 cases), infected active non-draining non-union (6 cases), and infected draining non-union (18 cases). Non-draining cases were defined as wounds without pus discharge for at least three months. Infection was identified by clinical features such as warmth, redness, sinus formation, and fever. The bones involved included the femur in 16 patients, the tibia in 12 patients, the ulna in 1 patient, and the humerus in 1 patient. Among femur cases, 2 occurred after plating, and 14 followed open fractures that were initially stabilised with external fixation. Among tibia cases, 2 developed after ORIF for closed fractures and 10 followed open fractures treated initially with external fixation. In the series, 4 patients developed infected non-union after previous surgical procedures, and 2 patients developed infection after improper treatment of open fractures by native bone setters. Twenty-four cases were Grade III B open fractures according to the Gustilo-Anderson classification and were initially managed with external fixation. Follow-up ranged from 6 to 24 months with a mean of 12 months.

Clinical data were obtained from patient history, physical examination, laboratory investigations, and radiological evaluation. Laboratory tests included erythrocyte sedimentation rate, C-reactive protein, total and differential leukocyte count, and pus culture with sensitivity. Radiological assessment was performed using standard anteroposterior, lateral, and oblique X-ray views. Joint stiffness was noted in some cases, with knee stiffness in 8 femur cases and ankle stiffness in 6 tibial cases.

Data were analysed using SPSS v29. Data were presented as frequencies and percentages.

ISSN (O): 2687-5365; ISSN (P): 2753-6556

RESULTS

Most patients belonged to the 20–29 years and 30–39 years age groups, with 10 cases (33.3%) each. The 40–49 years age group included 6 cases (20%), while patients above 50 years accounted for 4 cases (13.3%). The least number of cases was observed in the 10–19 years age group with 2 cases (6.7%). [Table 1]

Table 1: Age-wise distribution

Age group (years)	N (%)
10–19	2 (6.7%)
20–29	10 (33.3%)
30–39	10 (33.3%)
40–49	6 (20%)
>50	4 (13.3%)

Among the 30 patients included in the study, the femur was the most commonly involved bone, seen in 16 cases (53.3%). Tibial involvement was observed in 12 cases (40%). Non-union of the ulna and humerus was less frequent, with 1 case each (3.3%). [Table 2]

Table 2: Distribution of infected non-union according to the bone involved

Bone involved	N (%)
Femur	16 (53.3%)
Tibia	12 (40%)
Ulna	1 (3.3%)
Humerus	1 (3.3%)

In the femur, draining non-union was present in 10 cases (35.7%), while non-draining non-union was seen in 6 cases (21.4%). In the tibia, draining non-union was noted in 8 cases (28.6%) and non-draining non-union in 4 cases (14.3%). [Table 3]

Table 3: Distribution of draining and non-draining infected non-union by bone involved

Bone	Draining non-union	Non-draining non-union
Femur	10 (35.7%)	6 (21.4%)
Tibia	8 (28.6%)	4 (14.3%)

External fixation was the most common previous method of stabilisation, observed in 14 femur cases (87.5%) and 9 tibia cases (75%). Plating was noted in 2 femur cases (12.5%) and 2 tibia cases (16.7%), while nailing was recorded in 1 tibia case (8.3%) and none in femur cases. [Table 4]

Table 4: Distribution of previous fixation methods by bone involved

Bone	Plating	Nailing	External fixator
Femur	2 (12.5%)	0	14 (87.5%)
Tibia	2 (16.7%)	1 (8.3%)	9 (75%)

Most patients showed good bone results (25 cases; 83.3%), whereas excellent bone results were observed in 3 cases (10%) and fair results in 3 cases (10%). Functional results were predominantly good in 23 cases (76.7%), with excellent outcomes in 4 cases (13.3%) and fair outcomes in 4 cases (13.3%). [Table 5]

Table 5: Distribution of bone and functional outcomes according to ASAMI criteria

Variable	Category	N (%)
Bone results	Excellent	3 (10%)
	Good	25 (83.3%)
	Fair	3 (10%)
Functional results	Excellent	4 (13.3%)
	Good	23 (76.7%)
	Fair	4 (13.3%)

DISCUSSION

This study shows that most patients were young adults in the third and fourth decades. The femur was the most frequently affected bone. Draining an infected non-union was more common. External fixation was the usual prior stabilisation method. Bone and functional outcomes were predominantly good according to ASAMI criteria following limb reconstruction system treatment in most patients.

In our study, most patients belonged to the third and fourth decades of life, with fewer cases observed in younger and older age groups. Similarly, Shevate et al. found that most patients were in the 20–40 years age group, with 12 cases (66.7%), while 6 cases

ISSN (O): 2687-5365; ISSN (P): 2753-6556

(33.3%) were in the 40–60 years age group.10 Balagani found that the most commonly affected age groups were 41–50 years and 61–70 years, each accounting for 25% of the cases.[11] These studies support our findings, as infected non-union commonly affects active adult age groups due to higher exposure to trauma, road traffic accidents, and occupational injuries in early and middle adulthood.

Our study shows that the femur was the most commonly affected bone, followed by the tibia, while upper limb bones such as the ulna and humerus were rarely involved. Likewise, Kumar et al. reported that the femur was the most commonly affected bone, reported in 16 cases (53.33%), followed by the tibia in 11 cases (36.67%), and the humerus in 3 cases (10%) among patients with infected non-union.[4] Patra et al. found that the tibia was the most commonly affected bone, reported in 19 cases, followed by the femur in 7 cases, and the humerus in 1 case, among patients with infected non-union.[7] These findings support our study as long bones like the femur and tibia sustain high-energy trauma frequently, making them more prone to fractures, infection, and subsequent non-union compared with upper limb bones.

In our study, draining infected non-union was more frequently observed than non-draining non-union in both femur and tibia among the studied cases. Similarly, Gupta et al. found that a draining sinus was observed in 10 patients (55.6%), indicating that a majority of infected non-union cases presented with draining infection at the fracture site.[12] Meselhy et al. show that all patients initially presented with discharging sinus at the infected non-union site, with increased discharge during the first three weeks, which gradually decreased and disappeared within 5–8 weeks during treatment. Additionally, a persistent discharging sinus was noted in 1 patient (5.9%) at follow-up.[13] These studies support our findings, as infected non-union commonly presents with draining sinus due to chronic infection, sequestrum formation, and persistent inflammatory response at the fracture site in long bones.

In this study, external fixation was the most common previous stabilisation method. Most patients achieved good bone outcomes according to ASAMI criteria, while only a few showed excellent or fair results. Aligning with our findings, Naidu reported that among femur cases, external fixation was used in 6 patients, plating in 4 patients, and intramedullary nailing in 5 patients. In tibial cases, external fixation was used in 2 patients, and nailing in 4 patients, while plating was not reported. In humerus cases, plating was performed in 3 patients and external fixation was not used.[14] Bakhsh et al. found that according to ASAMI criteria, excellent bone results were observed in 37 patients (66%), good results in 10 patients (17.85%), fair results in 6 patients (10.71%), and poor results in 3 patients (5.35%) among patients treated for infected non-union.[15]

Hameed et al. show that according to ASAMI criteria, excellent bone results were observed in 28 patients (50.9%), good results in 16 patients (29%), fair results in 7 patients (12.7%), and poor results in 3 patients (5.4%) among patients treated with the Ilizarov method for infected non-union.[16] These studies support our findings as external fixation provides stable fixation in infected non-union, allowing infection control and bone healing, resulting in predominantly good bone outcomes according to ASAMI criteria.

Our study shows that functional outcomes were predominantly good, with fewer patients demonstrating excellent or fair outcomes following treatment of infected non-union cases. Similarly, Aksoy et al. reported that functional outcomes were mainly good, seen in 23 cases (76.7%). Excellent functional results were observed in 4 cases (13.3%), while fair results were noted in 4 cases (13.3%).[17] Dake et al. found that, according to ASAMI functional outcome criteria, excellent functional results were observed in 10 patients, good results in 7 patients, fair results in 8 patients, and poor results in 5 patients among the 30 patients treated with the limb reconstruction system for infected non-union.18 These studies support our findings as effective infection control, stable fixation, and limb reconstruction improve joint mobility, reduce pain, and restore limb function, resulting in predominantly good functional outcomes after treatment.

Limitations

The study involved a small sample from a single institution, which limits generalizability. The follow-up duration was relatively short. Lack of a comparison group and possible selection bias may influence outcomes. Variation in injury severity and previous treatments could also affect the results.

CONCLUSION

In this study of 30 patients with infected non-union of long bones, treatment using the limb reconstruction system augmented with AO external fixation was associated with predominantly good bone and functional outcomes as per ASAMI criteria. The technique allowed management of infected non-union with acceptable rates of union and functional recovery within the limitations of this study. However, due to the small sample size, lack of a control group, and descriptive nature of analysis, definitive conclusions regarding superiority or causality cannot be established. Further studies with larger sample sizes, longer follow-up, and comparative analysis are required to validate these findings.

Acknowledgement

I would like to express my sincere gratitude to my guide and mentors for their valuable guidance and constant support throughout this study. I also thank my colleagues and the staff of the Institute of Orthopaedics and Traumatology, Madras Medical College, Rajiv Gandhi Government General

ISSN (O): 2687-5365; ISSN (P): 2753-6556

Hospital, Chennai, for their assistance and cooperation during the study period.

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ISSN (O): 2687-5365; ISSN (P): 2753-6556