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Original Research Article

FUNCTIONAL ANALYSIS OF DISTAL TIBIA FRACTURES TREATED WITH HYBRID EXTERNAL FIXATOR: A PROSPECTIVE STUDY

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ABSTRACT

Background: Distal tibial fractures are challenging injuries associated with significant soft tissue compromise and variable outcomes. Hybrid external fixation has emerged as a viable alternative, particularly in open and comminuted fractures.

Materials and Methods: A prospective study was conducted at the Department of Orthopaedics, Narayana Medical College and Hospital, Nellore from May 2024 to February 2026. Twenty patients aged 18 years and above with distal tibial fractures (AO types A, B, and C) were treated with hybrid external fixation. Functional outcomes were assessed using the AOFAS Ankle–Hindfoot Score and Ovadia–Beals scoring system at 6 weeks, 3 months, 6 months, and 12 months.

Results: The mean age was 40.5 years with a male predominance (70%). Road traffic accidents were the most common mechanism of injury (60%). The mean time to radiological union was 17.5 ± 2.54 weeks. AOFAS scores improved progressively from 54.25 ± 6.05 at 6 weeks to 85.70 ± 8.26 at 12 months. Ovadia–Beals objective assessment showed excellent results in 55% and good results in 20% of patients. The complication rate was 40%, with pin tract infection and ankle stiffness each accounting for 15%.

Conclusion: Hybrid external fixation provides reliable radiological union and good functional recovery in distal tibial fractures. It is particularly suitable for open and comminuted fractures with compromised soft tissues, offering early mobilization with acceptable complication rates.

Keywords: Distal tibia fracture; Hybrid external fixator; AOFAS score; Ovadia–Beals; Pilon fracture; Open fracture.

INTRODUCTION

Fractures of the distal tibia represent a challenging subset of lower extremity injuries owing to their complex anatomy, tenuous blood supply, and frequent association with significant soft tissue compromise. The distal tibia is subcutaneous along its anteromedial surface and is therefore particularly susceptible to fracture blisters, swelling, and open wounds following high-energy trauma. These factors substantially increase the risk of wound complications, infection, delayed union, and non-union, especially when extensive surgical dissection is undertaken.

Distal tibial fractures may be extra-articular or intra-articular; intra-articular variants—commonly termed pilon fractures—require precise restoration of joint congruity, alignment, and stability to prevent post-traumatic arthritis and long-term functional impairment. High-energy mechanisms, predominantly road traffic accidents, tend to produce comminuted and open fractures, while low-energy falls produce less complex patterns that nonetheless demand careful management.

Conventional treatment strategies include conservative casting, open reduction and internal fixation (ORIF) with plates and screws, intramedullary nailing, and external fixation. Although plating offers accurate anatomical

reduction, it carries an elevated risk of soft tissue complications in the setting of severe swelling or open injuries. Intramedullary nailing is useful in selected extra-articular fractures but is less applicable to intra-articular or very distal segments.

Hybrid external fixation—combining circular ring fixation with tensioned wires in the metaphysis and monolateral half-pin fixation in the diaphysis—has emerged as an effective alternative, particularly when soft tissues are compromised. This construct provides stable fixation with minimal additional soft tissue trauma, allows early ankle mobilization, preserves periosteal blood supply, and can be applied in contaminated open wounds while permitting staged soft tissue coverage.

Standardised scoring systems such as the AOFAS Ankle–Hindfoot Score and the Ovadia–Beals scoring system are widely employed for functional outcome assessment. Despite the increasing adoption of hybrid fixation, considerable variability exists in reported functional outcomes, complication rates, and recovery timelines. The present study aims to provide a detailed functional and radiological analysis of distal tibial fractures managed with hybrid external fixation.

Aims and Objectives

Aim: To evaluate the functional and radiological outcomes of distal tibial fractures managed with hybrid external fixation, with emphasis on fracture union, restoration of function, and associated complications.

The specific objectives were:

1. To assess functional outcome using the AOFAS Ankle–Hindfoot Score and Ovadia–Beals scoring system.
2. To evaluate time to radiological union.
3. To analyse the complication profile, including pin tract infection, ankle stiffness, delayed union, and malunion.
4. To study the relationship between fracture type (AO/OTA and Gustilo–Anderson classifications) and clinical outcome.
5. To assess the effect of soft tissue status (open vs. closed fractures) on union time and functional recovery.
6. To evaluate the efficacy of hybrid fixation in maintaining fracture alignment and facilitating early mobilization.

MATERIALS AND METHODS

Study Design and Setting: This prospective observational study was conducted in the Department of Orthopaedics, Narayana Medical College and Hospital, Nellore, Andhra Pradesh, India, from May 2024 to February 2026. Ethical approval was obtained from the Institutional Ethics Committee. Written informed consent was obtained from all participants prior to enrolment.

Patient Selection

Inclusion Criteria

Patients aged 18 years or above with distal tibial fractures involving the distal 5 cm of the tibia (AO/OTA types A, B, and C), including both open and closed injuries.

Exclusion Criteria

Skeletally immature patients and those unwilling to accept external fixation.

Preoperative Assessment: All patients underwent standard preoperative evaluation including detailed history, physical examination, and radiographic assessment (anteroposterior, lateral, and mortise views). Computed tomography was performed where intra-articular extension was suspected. Fractures were classified according to the AO/OTA classification system; open fractures were additionally graded using the Gustilo–Anderson classification. Routine haematological investigations, ECG, chest radiograph, and screening for HIV and HBsAg were performed.

Surgical Technique: All procedures were performed under spinal anaesthesia in the operating theatre under fluoroscopic guidance. Open fractures were managed with immediate debridement and copious irrigation with normal saline, followed by administration of intravenous third-generation cephalosporins and aminoglycosides, and tetanus prophylaxis.

The hybrid external fixator construct comprised a 5/8 Ilizarov ring positioned perpendicular to the mechanical axis of the distal tibia, approximately 1–2 cm proximal to the ankle joint. Two tensioned olive wires (1.8 mm) were inserted through safe anatomical corridors in the metaphysis and tensioned to 90–110 kg. Two to three Schanz pins (4.5 mm) were inserted into the tibial diaphysis and connected to the ring via connecting rods and clamps. Fracture reduction was achieved by closed means under fluoroscopic control, with limited open reduction where necessary for intra-articular fractures. Supplementary K-wires or lag screws were used when required.

Postoperative Protocol: Limb elevation was maintained for 48–72 hours. Early ankle range-of-motion exercises were commenced as tolerated. Partial weight-bearing was initiated once pain subsided and radiological stability was confirmed. Pin-site care was performed regularly. Follow-up radiographs were obtained at 4-weekly intervals until union. Fracture union was defined as the presence of bridging callus on at least three cortices on anteroposterior and lateral views. Fixator removal was performed after confirmation of union and a period of pain-free partial weight-bearing. Thereafter, a posterior slab was applied for two weeks, followed by full weight-bearing with an ankle splint, which was discontinued upon restoration of pain-free range of motion.

Outcome Assessment: Functional outcomes were evaluated using two validated instruments: (1) the AOFAS Ankle–Hindfoot Score, assessed at 6 weeks, 3 months, 6 months, and 12 months postoperatively;

and (2) the Ovadia–Beals scoring system (objective and subjective components) at final follow-up.

Statistical Analysis: Data were expressed as mean ± standard deviation (SD), frequency, and percentage. Continuous variables were compared using the independent samples t-test; non-normally distributed data were analysed using the Mann–Whitney U test. Categorical variables were compared using the Pearson chi-square test. A p-value < 0.05 was considered statistically significant. All analyses were performed using IBM SPSS Statistics version 25.0 (IBM Corp., Armonk, NY, USA).

RESULTS

Demographic Profile: Twenty patients (14 males, 6 females; male-to-female ratio 2.3:1) were enrolled. The mean age was 40.5 years (range: 27–60 years). Road traffic accidents were the predominant mechanism of injury (12 patients, 60%), followed by falls (6 patients, 30%) and sports-related injuries (2 patients, 10%).

Fracture Classification: Of the 20 fractures, 11 (55%) were extra-articular and 9 (45%) were intra-articular. Twelve fractures (60%) were closed and 8 (40%) were open. Among open fractures, 2 were Gustilo–Anderson Type I, 4 were Type II, and 2 were Type IIIA. A significant association was observed between open fracture grade and intra-articular involvement; all Type II and Type IIIA open fractures had intra-articular extension, whereas Type I open fractures were exclusively extra-articular.

According to the AO/OTA classification, Type 44A fractures were most common (11 patients, 55%), followed by Type 44B (7 patients, 35%) and Type 44C (2 patients, 10%).

Table 1: Age distribution of study participants

Age Group (years)	No. of Patients	Percentage (%)
25–29	3	15
30–34	3	15
35–39	4	20
40–44	3	15
45–49	3	15
50–54	2	10
55–60	2	10
Total	20	100

Table 2: AO/OTA fracture classification

AO/OTA Type	No. of Patients	Percentage (%)
44A	11	55
44B	7	35
44C	2	10
Total	20	100

Table 3: Distribution of fracture type by open/closed status (Gustilo–Anderson classification)

Fracture Status	Extra-articular	Intra-articular	Total
Closed	9	3	12
Type I Open	2	0	2
Type II Open	0	4	4
Type IIIA Open	0	2	2
Total	11	9	20

Surgical Timing: The mean interval between injury and surgery was 2.25 ± 0.91 days (range: 1–4 days) for closed fractures. Open fractures were managed operatively at a mean of 24.9 hours (range: 8–72 hours) following injury.

Radiological Union: The mean time to radiological union in the overall study cohort was 17.5 ± 2.54 weeks (range: 14–22 weeks). A progressive increase in union time was observed with increasing Gustilo–Anderson grade [Table 4]. Type IIIA open fractures demonstrated the longest mean union time at 22 weeks.

Table 4: Mean radiological union time by fracture type

Fracture Type	Mean Union Time (weeks)
Closed	16.08
Type I Open	17.00
Type II Open	19.75
Type IIIA Open	22.00
Overall	17.50 ± 2.54

Functional Outcome – AOFAS Ankle–Hindfoot Score: Serial AOFAS scores demonstrated consistent and statistically significant improvement across follow-up intervals [Table 5]. At 6 weeks, the mean score was 54.25 ± 6.05. By 12 months, the

mean score had risen to 85.70 ± 8.26, reflecting substantial functional recovery.

Table 5: AOFAS Ankle–Hindfoot Score at serial follow-up intervals

Follow-up	Mean Score	Minimum	Maximum	SD
6 weeks	54.25	44	63	6.05
3 months	69.35	57	80	6.95
6 months	80.10	65	92	8.36
12 months	85.70	70	96	8.26

Functional Outcome – Ovadia–Beals Scoring System: On objective assessment, 11 patients (55%) achieved excellent results, 4 (20%) good, 4 (20%) fair, and 1 (5%) poor. Subjective assessment yielded excellent results in 9 patients (45%), good in 5 (25%), fair in 5 (25%), and poor in 1 (5%).

Table 6: Ovadia–Beals functional outcome (objective and subjective)

Outcome	Objective n (%)	Subjective n (%)
Excellent	11 (55%)	9 (45%)
Good	4 (20%)	5 (25%)
Fair	4 (20%)	5 (25%)
Poor	1 (5%)	1 (5%)
Total	20 (100%)	20 (100%)

Complications: Twelve patients (60%) experienced no complications. Among those who did, pin tract infection and ankle stiffness were equally the most frequent (3 patients each; 15%). Delayed union and malunion were each recorded in 1 patient (5%). All complications were managed conservatively without requiring revision surgery. The overall complication rate was 40%.

Table 7: Complication profile

Complication	No. of Patients	Percentage (%)
None	12	60
Pin tract infection	3	15
Ankle stiffness	3	15
Delayed union	1	5
Malunion	1	5
Total	20	100

DISCUSSION

The present prospective study evaluated radiological and functional outcomes of distal tibial fractures treated with hybrid external fixation in 20 patients. Our findings indicate that hybrid external fixation provides reliable fracture union, progressive functional recovery, and a manageable complication profile.

Demographic Profile: The mean age of 40.5 years with male predominance (70%) is consistent with published literature describing ankle and distal tibial fractures as injuries predominantly affecting young and middle-aged males engaged in outdoor occupational and recreational activities. Road traffic accidents were the leading mechanism (60%), reflecting the epidemiological profile of fractures in developing countries and corroborating the findings of Court-Brown et al.

Fracture Pattern and Classification: Extra-articular fractures (55%) were slightly more prevalent, and AO/OTA type 44A fractures were most common (55%), followed by 44B (35%) and 44C (10%). This distribution is comparable to that reported by Michelson et al. A clear association was noted between open fracture grade and intra-articular involvement—all Type II and IIIA fractures extended into the joint surface, consistent with the higher energy imparted by the causative mechanism.

Radiological Union: The overall mean union time of 17.5 weeks is comparable to the 16–20 weeks previously reported by Hughes et al. for surgically managed ankle fractures. A progressive increase in union time with ascending Gustilo grade was observed—closed fractures united at 16.08 weeks versus 22 weeks for Type IIIA injuries—consistent with the biological consequences of periosteal stripping, soft tissue devascularisation, and contamination documented by Burwell and Charnley. Gopinath et al. (2022, 2023) reported union at 12–14 weeks in their hybrid fixation series of 20 patients each, while Raina et al. (2021) achieved radiological consolidation in all 23 patients with compound extra-articular pilon fractures. Our slightly longer mean union time may reflect the higher proportion of intra-articular and higher-grade open fractures in our cohort.

Functional Outcomes: Progressive improvement in AOFAS scores from 54.25 at 6 weeks to 85.70 at 12 months reflects gradual restoration of ankle biomechanics facilitated by early mobilization and physiotherapy-assisted rehabilitation. A final mean score of 85.7 is consistent with good functional outcome and is comparable to results reported by Egol et al. and Bhandari et al. following operative fixation of ankle fractures.

Ovadia–Beals objective and subjective assessments further corroborate these findings, with 75% of

patients achieving good-to-excellent objective outcomes. Vejaya Kumar et al. (2023) reported AOFAS-based excellent outcomes in 82.4% of distal tibial fractures managed with hybrid fixation, and Rathod and Tailor (2019) noted excellent results in approximately 50% of patients at six months using Ovadia–Beals criteria, with additional cases classified as good or fair—findings broadly consistent with our results.

Complications: The 40% complication rate, with pin tract infection and ankle stiffness each occurring in 15% of patients, is within the range reported in the literature. Raina et al. (2021) similarly identified pin site infections and ankle stiffness as the most frequent complications in their series of compound pilon fractures. Schepers et al. have characterised stiffness and superficial infection as common but manageable sequelae of ankle fracture surgery. No patient in our series required revision surgery, reflecting adequate perioperative and postoperative management.

The low incidence of severe complications can be attributed to early operative intervention (mean 2.25 days), meticulous surgical technique with adherence to safe pin insertion corridors, and structured postoperative care including regular pin-site dressings and supervised ankle mobilization.

Limitations: Limitations of the present study include the relatively small sample size, single-centre design, absence of a comparative control group, and a follow-up period of 12 months which may not capture late complications such as post-traumatic arthritis. Future multicentre randomised controlled trials with longer follow-up are warranted to consolidate these findings.

CONCLUSION

Hybrid external fixation provides reliable radiological union and satisfactory functional outcomes in distal tibial fractures, including open and comminuted injuries with compromised soft tissues. The technique facilitates early ankle mobilization, minimises additional soft tissue trauma, and yields acceptable complication rates when combined with meticulous perioperative care. AOFAS scores demonstrated significant progressive improvement over 12 months, with the majority of patients achieving good-to-excellent outcomes on both objective and subjective Ovadia–Beals assessment. Union time increased predictably with severity of open injury. These results support hybrid external fixation as a reliable primary treatment modality for distal tibial fractures, particularly in resource-limited settings and in patients with high-grade open injuries.

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