A Study on Functional Outcome of Various Modalities in the Management of Distal Tibial Fractures: A Prospective Analytical Study

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Abstract

Background: Distal tibial fractures remain a therapeutic challenge because of a compromised soft tissue envelope, poor bone stock, comminution, and difficulty in achieving rigid fixation. Management strategies range from conservative treatment to intramedullary nailing, plating, and hybrid external fixation, each with its own advantages and limitations depending on fracture pattern, soft tissue condition, and patient factors.

Objective: To evaluate and compare the clinical and functional outcomes of different treatment modalities used in the management of distal tibial fractures.

Methods: This prospective analytical study was conducted in the Department of Orthopaedics, Saraswathi Institute of Medical Sciences, Hapur, from March 2024 to February 2026, after institutional ethical approval and written informed consent. Forty-eight patients aged 15–64 years with AO type 43-A distal tibial fractures, including open Gustilo–Anderson type 1, 2, 3A, and 3B injuries, were enrolled and allocated to four treatment groups of 12 patients each: Group I – conservative management, Group II – intramedullary nailing, Group III – hybrid external fixation, and Group IV – plate osteosynthesis. Patients were followed up clinically and radiologically at regular intervals, and functional outcome was assessed at six months using the American Orthopaedic Foot and Ankle Society (AOFAS) ankle–hindfoot score. Data were analysed using ANOVA, with $p < 0.05$ considered statistically significant.

Results: The majority of patients were male (32; 66.7%), and the highest incidence was in the 25–34 year age group (15; 31.3%). Road traffic accidents were the most common mode of injury (28; 58.3%), and AO type A3 was the most frequent fracture pattern (22; 45.8%); 35.4% of fractures were open and 64.6% closed. The mean duration of follow-up was 7.5 months (range 6–13 months). The highest mean AOFAS score was recorded in the plate osteosynthesis group (86.2 ± 6.5), followed by intramedullary nailing (78.3 ± 9.2), hybrid external fixation (73.1 ± 10.3), and conservative management (69.2 ± 11.7); the difference between groups was statistically highly significant ($p < 0.001$). Good to excellent outcomes were achieved in 72.7% of the plating group, 54.5% of the nailing group, 45.5% of the hybrid fixator group, and 36.4% of the conservative group, with no poor outcome in the plating group. Complications occurred in nine patients, including non-union (2), malunion (1), ankle stiffness (3), and infection (3); no case of deep vein thrombosis, pulmonary embolism, or mortality was recorded.

Conclusion: Both intramedullary nailing and plate osteosynthesis offer satisfactory functional outcomes in distal tibial fractures, with plate osteosynthesis achieving the highest AOFAS scores in this series. Hybrid external fixation remains a valuable option in open and comminuted fractures with severe soft tissue injury, though it carries a higher complication rate, while conservative treatment retains a role in selected low-risk patients. An individualised approach based on fracture pattern, soft tissue status, and surgeon expertise is essential for optimising outcomes.

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Keywords: Distal tibial fracture, intramedullary nailing, hybrid external fixation, plate osteosynthesis, conservative treatment, AOFAS score, functional outcome

1. Introduction

Fractures of the distal tibia continue to be a demanding problem in orthopaedic practice, requiring careful diagnostic assessment and a complex treatment process. They impose a considerable burden on the individual patient as well as on the health care system [1]. In younger patients these injuries usually result from high-velocity trauma, whereas in the geriatric population comparable fracture patterns may follow relatively low-impact falls. Osteoporotic bone, reduced capacity for partial weight

bearing, and a cluster of comorbidities in elderly patients further increase the complexity of treatment [2, 3].

Several factors account for the difficulty of managing these injuries. The soft tissue envelope around the distal tibia is thin and frequently compromised, particularly in open injuries, so that open reduction and internal fixation carries a substantial risk of infection, wound breakdown, and delayed healing [4]. The distal tibial metaphysis is composed predominantly of porous cancellous bone, which provides limited screw purchase and predisposes to early implant loosening, especially in osteoporotic bone. Comminuted fracture patterns reduce the possibility of achieving rigid internal fixation, and weak fixation in trabecular bone restricts early weight bearing and joint movement, which in turn may lead to pressure sores, joint stiffness, and post-traumatic osteoarthritis. High-energy trauma may severely disrupt both the metaphyseal bone and the articular surface, making precise anatomical reduction and restoration of function particularly difficult.

A range of treatment approaches is therefore available, each with its own indications, benefits, and limitations depending on fracture type, soft tissue status, and patient condition [5]. Non-operative management with casting is considered for closed, uncomplicated fractures and for patients with significant medical comorbidities who are unfit for anaesthesia, but carries the risk of prolonged immobilisation and its associated complications [6]. Intramedullary nailing is suitable for simple fracture patterns with minimal comminution and intact soft tissues, offering stable fixation with early mobilisation [7, 8]. Hybrid external fixation, which combines the principles of Ilizarov ring fixation with AO external fixation, is used in fractures with significant soft tissue injury, open injuries, or severe swelling where internal fixation may not be advisable, providing stable fixation while minimising additional soft tissue damage [9]. Plating techniques — either minimally invasive plate osteosynthesis (MIPO) or open reduction and internal fixation (ORIF) — are indicated in fractures without major soft tissue compromise and enable anatomical reduction, though with a higher risk of soft tissue complications if patient selection is not careful [10, 11, 12].

Because each of these modalities has distinct advantages and drawbacks, and because the reported functional results vary between series [13], the present study was conducted to compare the functional and radiological results of distal tibial fracture treatment by conservative management, intramedullary nailing, hybrid external fixation, and plate osteosynthesis in a single institutional setting.

1.1. Aim and Objectives

The aim of the study was to evaluate the functional outcomes associated with various treatment modalities for distal tibial fractures. The specific objectives were: (1) to compare the functional results of distal tibial fractures managed using different management techniques; (2) to analyse the age distribution, fracture types, and mechanisms of injury among the study population; (3) to evaluate the radiographic progression and union time of fractures treated by the various techniques; and (4) to investigate the rates of complications related to each management technique.

2. Materials and Methods

2.1. Study Design, Setting and Duration

This prospective analytical study was carried out in the Department of Orthopaedics, Saraswathi Institute of Medical Sciences (SIMS), Hapur, Uttar Pradesh, over a period of two years from March 2024 to February 2026. Patients attending the outpatient, inpatient, and emergency departments were enrolled after informed written consent was obtained in the language they understood (English or Hindi).

2.2. Ethical Considerations

Ethical approval for the study was obtained from the Institutional Ethics Committee of Saraswathi Institute of Medical Sciences, Hapur (Reg. No. EC/NEW/INST/2022/UP/0125). All participants who met the inclusion criteria received a thorough explanation of the study objectives before enrolment, and written informed consent was obtained from each of them. Good Clinical Practice guidelines were followed throughout the study.

2.3. Sample Size

The sample size was calculated using the formula $n = z^2pq/d^2$, taking a prevalence of 7% ($p = 0.07$) from a previous study by Vipul Kumar *et al*. [13], $q = 0.93$, an absolute error of 7.5% ($d = 0.075$), and $z = 1.96$ at a 95% confidence interval, which gave $n = 44.46$ (approximately 50 patients). As the present study compared four groups, 12 subjects per group were considered adequate to maintain an equivalent distribution across all groups, giving an overall sample size of $12 \times 4 = 48$ patients.

2.4. Inclusion and Exclusion Criteria

Patients aged 15 to 64 years with AO distal tibia type A fractures, including open Gustilo–Anderson type 1, 2, 3A, and 3B fractures, who gave informed written consent were included. Patients with intra-articular fractures, crush injuries with neurovascular impairment, and Gustilo–Anderson type 3C injuries were excluded.

2.5. Grouping and Methodology

A well designed and organised proforma was used to collect data. The diagnosis was confirmed radiographically in patients assessed in the orthopaedic outpatient department or presenting to the trauma unit with obvious deformity and swelling across the distal leg and ankle region. Only AO type 43-A fractures were included, and fractures were categorised using the AO/OTA classification system [14]. Pre-operative radiological evaluation comprised anteroposterior and lateral views of the leg and ankle. Patients were allocated into four treatment groups of 12 patients each: Group I – conservative management, Group II – intramedullary nailing, Group III – hybrid external fixation, and Group IV – plate osteosynthesis. A comprehensive pre-anaesthetic evaluation was carried out in cases scheduled for surgical management, a C-arm was used for fluoroscopic guidance during the procedures, and every operation was carried out by an orthopaedic specialist surgeon or directly under supervision.

Interlocking nailing was performed under spinal anaesthesia with the patient supine and the knee flexed to about 90 degrees, using a midline patellar tendon-splitting approach with the entry site formed about 1 to 1.5 cm distal to the tibial articular surface; after sequential reaming, an interlocking nail of appropriate size was placed, and distal and proximal locking were performed through the jig under fluoroscopic guidance. In plate osteosynthesis, either ORIF through a longitudinal anteromedial incision or MIPO through small incisions with subcutaneous extraperiosteal plate insertion

was used, and a precontoured distal tibia locking compression plate was applied to the anteromedial surface with cortical screws proximally and locking screws distally. In hybrid external fixation, two crossed Kirschner wires were inserted horizontally in the distal tibial fragment at least 3 cm from the tibial plafond and attached to a tensioned full circular ring, while two sets of Schanz pins in the proximal segment were connected to external fixator clamps and linked to the distal ring with connecting rods, male posts, nuts, and fixation bolts. One gram of a third-generation cephalosporin was given intravenously before surgery and continued twice daily for three days postoperatively, and all wire and pin entry sites were dressed with povidone-iodine soaked gauze wicks to minimise pin tract infection.

Postoperatively, patients treated by interlocking nailing were mobilised at the knee and ankle from the first postoperative day, with above-knee slab immobilisation reserved for non-compliant patients or those with insufficient axial stability; weight bearing was deferred until radiographic callus was evident. Patients managed by bridge plating were initially immobilised in an above-knee slab, converted to a below-knee brace at about three weeks with commencement of range-of-motion exercises, and weight bearing was restricted until satisfactory callus formation. Patients treated by hybrid external fixation were permitted to begin weight bearing at approximately three weeks once radiological callus was observed, with early knee and ankle mobilisation from the first postoperative day where the fracture did not involve the articular surface.

2.6. Outcome Assessment

Patients were monitored in the orthopaedic outpatient department at regular intervals, with clinical and radiological evaluation at each follow-up visit. At the six-month follow-up, the American Orthopaedic Foot and Ankle Society (AOFAS) ankle–hindfoot score was used to assess the functional result, and the scores obtained for the various treatment approaches were compared. The AOFAS score comprises pain (maximum 40 points), function (maximum 50 points, covering activity limitation and support, maximum walking distance, walking surfaces, gait abnormality, sagittal motion, hindfoot motion, and ankle–hindfoot stability), and alignment (maximum 10 points), giving a maximum total of 100 points. Outcomes were categorised as excellent (90–100 points), good (80–89 points), fair (70–79 points), and poor (below 70 points).

2.7. Statistical Analysis

Data were entered into a Microsoft Excel sheet and analysed using SPSS software version 29.0. Continuous data were expressed as mean and standard deviation, and categorical data as proportions and percentages. The ANOVA test was applied for comparison between groups, and a p value of less than 0.05 was considered statistically significant.

3. Results

Forty-eight patients with distal tibia shaft fractures were treated and evaluated during the study period. There was a clear male preponderance, with 32 male patients (66.7%) and 16 female patients (33.3%). The age distribution was skewed towards younger adults, the 25–34 year group accounting for the largest proportion of patients (15 cases; 31.3%), while the remaining age groups were distributed fairly evenly (Table 1, Figure 1).

Table 1: Age and sex distribution of the study participants (n = 48)

Age group (years)	Male (n)	Female (n)	Total (n)	%
15–24	6	3	9	18.8
25–34	9	6	15	31.3
35–44	5	2	7	14.6
45–54	6	3	9	18.8
55–64	6	2	8	16.7
Total	32 (66.7%)	16 (33.3%)	48	100.0

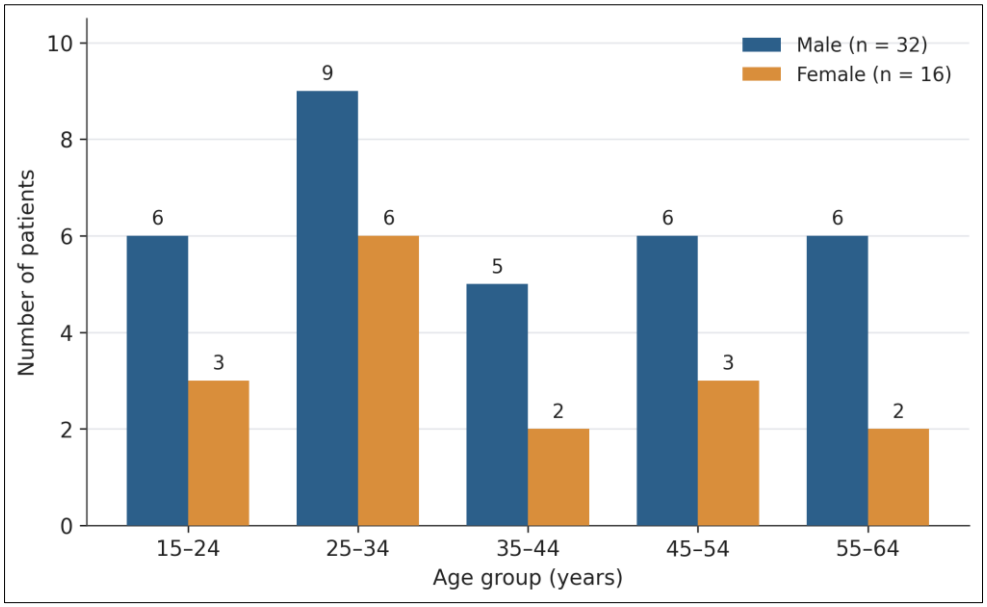


Fig 1: Age and sex distribution of the study participants (n = 48)

3.1. Mode and Side of Injury, Fracture Pattern and Follow-up

Road traffic accidents were the most frequent cause of injury, accounting for 28 cases (58.3%), followed by falls in 12 cases (25.0%); fall of a heavy object, wall collapse, and assault together contributed the remaining cases. Left-sided injuries predominated, involving 29 patients (60.0%) compared with 19 patients (40.0%) on the right. According to the AO classification, type A3 fractures were the most common, accounting for 22 cases (45.8%), followed by type A1 in 16 cases (33.3%) and type A2 in 10 cases (20.8%). Overall, 35.4% of the fractures were open and 64.6% were closed: non-Gustilo–Anderson (closed) injuries accounted for 31 cases (64.6%), while among open injuries GA type 1 was the most frequent (10 cases; 20.8%), followed by GA type 2 (4 cases; 8.3%) and GA type 3A/3B (3 cases; 6.3%), indicating relatively few severe open injuries in the study population. The mean duration of follow-up was 7.5 months, with a minimum of 6 months and a maximum of 13 months; 20 patients (41.7%) were followed for 6–7 months and 14 patients (29.2%) for 8–9 months. These findings are summarised in Table 2 and Figure 2.

Table 2: Injury characteristics, fracture pattern and duration of follow-up (n = 48)

Characteristic	Number of patients (n)	Percentage (%)
Mode of injury		
Road traffic accident	28	58.3
Fall	12	25.0
Fall of heavy object	4	8.3
Wall collapse	2	4.2
Assault	2	4.2
Side of injury		
Left	29	60.0
Right	19	40.0
AO classification (type 43-A)		
A1	16	33.3
A2	10	20.8
A3	22	45.8
Gustilo–Anderson (GA) type		
Non-GA (closed)	31	64.6
GA type 1	10	20.8
GA type 2	4	8.3
GA type 3A / 3B	3	6.3
Duration of follow-up (months)		
6–7	20	41.7
8–9	14	29.2
10–11	6	12.5
12–13	4	8.3

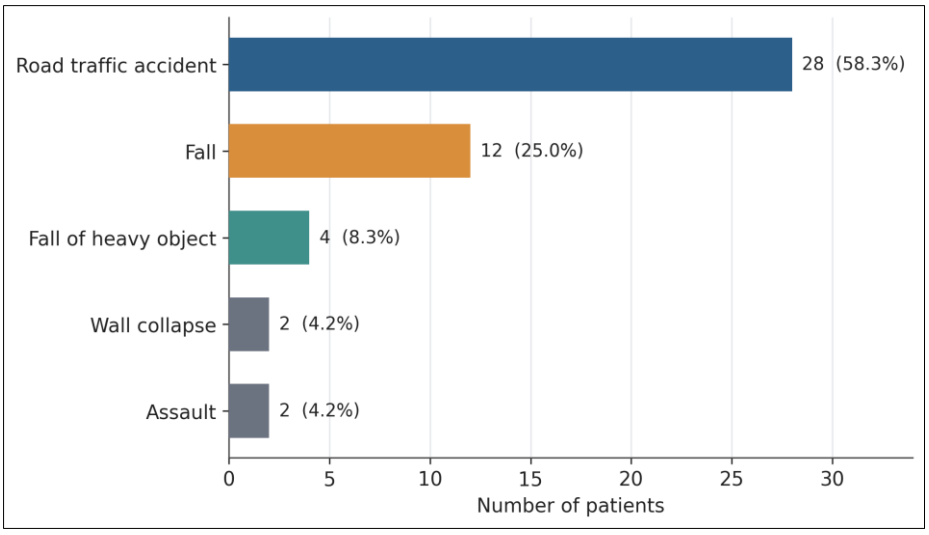


Fig 2: Distribution of mode of injury among the study participants (n = 48)

3.2. Treatment Groups

The 48 patients were distributed equally among the four treatment groups, with 12 patients in each: Group I (conservative management; 7 males, 5 females), Group II (intramedullary nailing; 8 males, 4 females), Group III (hybrid external fixator; 10 males, 2 females), and Group IV (plate osteosynthesis; 7 males, 5 females). One patient from each group was lost to follow-up during the study period, so functional outcome grades were computed for 11 patients per group.

3.3. Functional Outcome

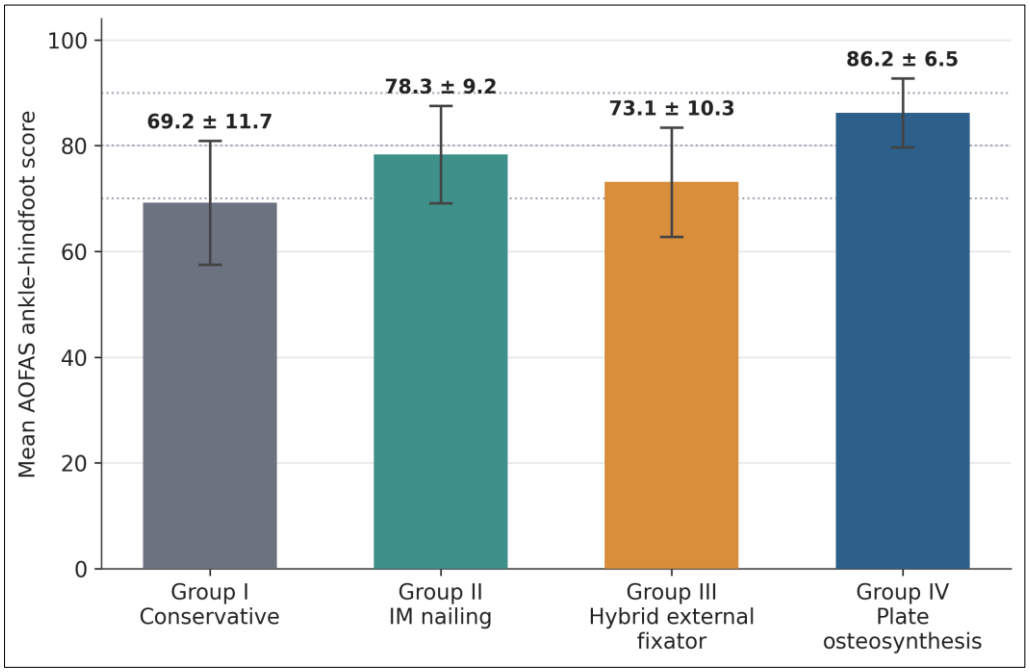
The highest mean AOFAS score was observed in the plate osteosynthesis group (86.2 ± 6.5), followed by

intramedullary nailing (78.3 ± 9.2), hybrid external fixation (73.1 ± 10.3), and conservative treatment (69.2 ± 11.7). The difference among the groups was statistically highly significant ($p < 0.001$). Good to excellent outcomes were seen in 72.7% of patients treated with plate osteosynthesis, compared with 54.5% with intramedullary nailing, 45.5% with hybrid external fixation, and 36.4% with conservative management. Poor outcomes were noted in a small proportion of patients in the conservative, intramedullary nailing, and hybrid fixator groups, whereas no poor outcome was observed in the plating group (Table 3, Figure 3).

Table 3: Mean AOFAS score and functional outcome by treatment modality (n = 48)

Parameter	Group I Conservative (n = 12)	Group II IM nailing (n = 12)	Group III Hybrid external fixator (n = 12)	Group IV Plate osteosynthesis (n = 12)	p value
Mean AOFAS score ± SD	69.2 ± 11.7	78.3 ± 9.2	73.1 ± 10.3	86.2 ± 6.5	< 0.001
Good / excellent outcome	4 (36.4%)	6 (54.5%)	5 (45.5%)	8 (72.7%)	—
Fair outcome	5 (45.5%)	4 (36.4%)	4 (36.4%)	3 (27.3%)	—
Poor outcome	2 (18.2%)	1 (9.1%)	2 (18.2%)	0 (0%)	—
Lost to follow-up	1	1	1	1	—

Outcome grade percentages are calculated for the 11 patients evaluated in each group, as one patient in every group was lost to follow-up. AOFAS: American Orthopaedic Foot and Ankle Society; p value derived from ANOVA.



Dotted reference lines mark the AOFAS outcome grade thresholds: excellent ≥ 90, good 80–89, and fair 70–79 points.

Fig 3: Mean AOFAS ankle–hindfoot score (± SD) by treatment modality (n = 48)

3.4. Complications and Deformities

A total of nine patients developed complications during the study. Infection occurred in three patients — one deep infection involving bone and two superficial infections, the latter managed with local wound care, pin site care, and appropriate oral antibiotics, while the deep infection required surgical debridement, culture-specific intravenous antibiotics, and fracture stabilisation. Non-union was recorded in two patients and was managed by revision fixation with autologous cancellous bone grafting, or by conversion to a more stable fixation technique such as plating or intramedullary nailing where stability was insufficient. Malunion occurred in one patient; mild malalignment without appreciable functional impairment was managed with physiotherapy and activity modification, while symptomatic malunion with substantial angular or rotational deformity would require corrective osteotomy and stable internal fixation. Ankle stiffness was observed in three patients and was managed primarily with aggressive physiotherapy including active and passive range-of-motion exercises, muscle strengthening, and gradual weight bearing. Varus deformity was noted in three patients, one each in Groups I, II, and III, and valgus deformity in three patients, two in Group I and one in Group III; no deformity was recorded in the plate osteosynthesis group. No case of deep vein thrombosis, pulmonary embolism, or mortality was observed during the study period (Table 4).

Table 4: Complications and deformities across the four treatment groups (n = 48)

Complication / deformity	Group I Conservative	Group II IM nailing	Group III Hybrid external fixator	Group IV Plate osteosynthesis
Complications				
Non-union	1	1	0	0
Mal-union	1	0	0	0
Ankle stiffness	1	1	1	0
Infection	0	0	2	1
Deformities				
Varus deformity	1	1	1	0
Valgus deformity	2	0	1	0

4. Discussion

Forty-eight distal tibial fractures were treated at our facility between March 2024 and February 2026. Each patient's treatment plan was customised on the basis of fracture type, soft tissue condition, time of presentation, associated injuries, and accessibility of treatment facilities, using interlocking intramedullary nailing, plate osteosynthesis, hybrid external fixation, or conservative management.

About 32% of the patients in the present study were in the 25–34 year age range, indicating a higher incidence in the economically productive age group, and there was a noticeable male predominance attributable to greater outdoor activity and higher exposure to road traffic trauma — a pattern consistent with the reported epidemiology of tibial fractures [2]. Open injuries accounted for 35.4% and closed injuries for 64.6% of the series, which is comparable with the study by Hazarika *et al*., in which 40% of fractures were open and 60% closed [15]. A relatively higher number of A3 subtype fractures was observed on AO classification, suggesting that many injuries were associated with high-energy mechanisms and reflecting the severity and high-velocity nature of the trauma involved.

In most cases the first line of treatment involved immobilisation with a plaster of Paris slab and closed reduction. As part of damage-control orthopaedics, some patients required temporary external fixation or calcaneal pin traction; because sufficient soft-tissue stabilisation was needed, definitive surgical intervention was delayed in about 35.5% of patients who presented with open fractures. Calcaneal pin traction proved to be a valuable interim method in our setup, particularly in fractures with marked displacement and fragment overlap, helping to maintain alignment while awaiting improvement in soft-tissue condition. Conservative treatment with plaster of Paris after closed manipulative reduction was reserved for individuals who were unwilling to undergo surgery, were medically unfit for it, or had serious comorbidities that made anaesthesia impossible; this approach was linked to an increased risk of ankle stiffness from prolonged immobilisation in an above-knee cast, as well as varus or valgus malalignment resulting from insufficient fracture control, in keeping with the known limitations of non-operative management [6].

Patients treated with intramedullary nailing had a mean AOFAS score of 78.3, those treated conservatively 69.2, and those treated with hybrid external fixation and plate osteosynthesis 73.1 and 86.2 respectively. These values are comparable with the study by Joveniaux *et al*., in which the mean AOFAS score was 67.6 for external fixation and 85.2 for limited internal fixation by plate osteosynthesis [13]. When planned according to fracture pattern, location, and soft-tissue status, surgical management produced superior functional outcomes compared with conservative treatment, an observation supported by comparative series and meta-analyses of operative fixation in distal tibial fractures [16,17,18]. Interlocking intramedullary nailing yielded better outcomes in fractures with minimal soft-tissue injury and limited comminution [7,8]. In cases with severe comminution but an intact articular surface and minimal soft-tissue compromise, plate osteosynthesis was preferred, particularly when the fracture was located proximal to the articular surface [10,11,12]. External fixation produced better results in fractures with severe soft-tissue injury and substantial comminution; although this method remained necessary in open fractures requiring flap coverage or skin grafting, wound management in these situations was difficult, a limitation also reported in series of circular and hybrid external fixation for distal tibial trauma [9,19].

Sutures were usually removed by the 12th to 14th postoperative day after examination of the wound site. Once radiographic callus formation became apparent, patients were permitted partial weight bearing with steady progression as tolerated; the average time to partial weight bearing was about 8 weeks (range 6–10 weeks), except in plating cases, where it was postponed to roughly 14 weeks (range 12–16 weeks). Clinical and radiological union occurred at an average of five months, with a range of three to eight months. Approximately 6% of patients (3 of 48) developed post-treatment infection, and the typical hospital stay lasted between four and six weeks; the risk of infection remains the principal concern in open distal tibial injuries and justifies meticulous soft-tissue handling and antibiotic protocols [4]. Approximately 80% of patients were able to fully restore their ankle and knee range of motion, and about 13% of cases had angular abnormalities (varus or valgus of 10–20 degrees), mostly after conservative treatment. The majority of patients achieved good to excellent overall functional evaluation scores, with only a small proportion recording fair or poor results.

The limitations of this study include the relatively small sample size, with only 12 patients per treatment group, and a comparatively short duration of follow-up, which restrict the ability to draw definitive conclusions or to establish a standardised treatment protocol. Allocation to treatment groups was based on clinical judgement rather than randomisation, and one patient in each group was lost to follow-up. Larger studies with longer follow-up periods are required to validate these findings.

5. Conclusion

Management of fractures involving the distal tibia is often difficult because of the unique anatomical structure and biomechanical properties of this region. In this prospective analytical study, intramedullary nailing and plate osteosynthesis showed better results than external fixation

and conservative treatment in terms of early pain remission, quicker radiographic union, enhanced weight-bearing progression, and fewer complications, with the best functional outcomes specifically linked to plate osteosynthesis (mean AOFAS 86.2 ± 6.5). For the majority of distal tibia shaft fractures, surgical fixation should therefore be the recommended course of action, even though conservative treatment can be useful in certain low-risk patients and external fixation remains a useful alternative in managing high-grade open fractures with significant soft tissue destruction. The choice of treatment should nevertheless continue to be tailored to the patient's unique circumstances, soft tissue condition, and fracture pattern. It is acknowledged that the limited sample size and relatively short duration of follow-up restrict the ability to draw definitive conclusions or establish a standardised treatment protocol, and larger studies with longer follow-up are required to validate these findings and standardise management strategies for distal tibial fractures.

Conflict of Interest
Nil.

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Nil.

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