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Clinical and radiological outcomes of distal one-third tibial fractures treated with minimally invasive plate osteosynthesis using anatomical locking plates: A prospective observational study.

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Abstract

Background

Fractures of the distal one-third of the tibia are associated with significant treatment challenges due to limited soft-tissue coverage, compromised vascularity, and proximity to the ankle joint. Conventional open reduction techniques are linked to higher rates of wound complications and delayed union. Minimally invasive percutaneous plate osteosynthesis aims to preserve fracture biology while providing stable fixation.

Objective: To evaluate the clinical and radiological outcomes of distal one-third tibial fractures treated using minimally invasive osteosynthesis with anatomical locking plates.

Methods

A prospective observational study was conducted on 30 adult patients with distal one-third tibial fractures treated between January 2021 and January 2024 at Vels Medical College and Hospital, Tiruvallur, Tamil Nadu. Fractures were classified according to the AO/OTA classification. Functional outcomes were assessed using the American Orthopaedic Foot and Ankle Society ankle–hindfoot score. Radiological union, time to union, alignment, and complications were documented over a minimum follow-up of 12 months.

Results

The mean age of patients was 56 ± 15 years. Road traffic accidents accounted for 60% of injuries. The mean time to radiological union was 17.4 ± 5 weeks. Excellent functional outcomes were observed in 83.3% of patients, while 16.7% achieved good outcomes. Complications included superficial infection (10%), deep infection (3.3%), malreduction (6.7%), and delayed union (10%). No cases of nonunion were recorded.

Conclusion

Minimally invasive plate osteosynthesis using anatomical locking plates results in reliable fracture union, excellent functional outcomes, and acceptable complication rates in distal one-third tibial fractures.

Recommendation

Minimally invasive plate osteosynthesis using anatomical locking plates is recommended for adult distal one-third tibial fractures where preservation of soft tissue and fracture biology is critical, particularly in fractures unsuitable for intramedullary nailing.

Keywords: *Distal tibia fracture; Minimally Invasive Percutaneous Plate Osteosynthesis; Anatomical locking plate; American Orthopaedic Foot and Ankle Society score; Minimally invasive osteosynthesis*
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Introduction

Fractures involving the distal one-third of the tibia are among the most challenging injuries encountered in orthopaedic trauma due to the subcutaneous location of the bone, limited soft-tissue envelope, and compromised vascularity [1]. These fractures constitute approximately 7–10% of all lower limb fractures and are associated with a high incidence of complications such as wound breakdown, infection, delayed union, and malunion [1,2]. Non-operative management is technically demanding and has been reported to result in joint stiffness in up to 40% of cases, along with shortening and rotational malunion in nearly 30% of patients [2,3].

Traditional open reduction and internal fixation requires extensive soft-tissue dissection and periosteal stripping, which disrupts fracture biology and increases the risk of infection, delayed union, and nonunion [4]. Although intramedullary nailing offers the advantage of limited surgical exposure, achieving and maintaining alignment in distal metaphyseal fractures remains problematic, with reported malunion rates reaching 58% in some series [16]. To overcome these limitations, minimally invasive osteosynthesis techniques were developed with the goal of preserving periosteal blood supply and fracture hematoma while maintaining stable fixation [9,10]. Minimally invasive percutaneous plate osteosynthesis allows insertion of anatomically contoured locking plates through small incisions, thereby reducing iatrogenic soft-tissue damage and improving biological conditions for fracture healing [10,11].

Several clinical studies have demonstrated favorable outcomes with minimally invasive plate osteosynthesis in distal tibial fractures, reporting reduced infection rates, reliable fracture union, and satisfactory functional outcomes [5,6,12]. Supe et al. reported excellent union rates with minimal complications using the American Orthopaedic Foot and Ankle Society scoring system in a prospective series of distal tibial fractures treated with minimally invasive techniques [5]. Similar findings have been reported by Devkota et al. and Wani et al., supporting the role of biological fixation in distal tibial injuries [6,12]. The necessity of routine fibular fixation remains debated, with some studies suggesting fixation only when syndesmotic instability is present [7,8].

Objective

To evaluate the clinical and radiological outcomes of distal one-third tibial fractures managed using minimally invasive plate osteosynthesis with anatomical locking plates.

Materials and methods

Study design

This study was designed as a hospital-based prospective observational study evaluating clinical and radiological outcomes of distal one-third tibial fractures managed using minimally invasive osteosynthesis.

Study setting

The study was conducted at Vels Medical College and Hospital (VISTAS), Tiruvallur, Tamil Nadu, a tertiary care teaching hospital equipped with advanced trauma services, dedicated orthopaedic operating theatres, image intensification facilities, and comprehensive postoperative rehabilitation support. The institution caters to both urban and semi-urban populations and serves as a referral center for complex orthopaedic trauma.

Study period

Patient recruitment and follow-up were carried out between January 2021 and January 2024.

Study population and participant selection

Adult patients presenting to the emergency department and orthopaedic outpatient services with distal one-third tibial fractures were screened consecutively for eligibility. Patients who fulfilled the inclusion criteria and provided written informed consent were enrolled in the study.

Inclusion criteria

- Age ≥18 years
- Distal one-third tibial fractures classified as AO/OTA types 43-A, 43-B, and 43-C
- Closed fractures and open fractures treated within 48 hours of injury
- Injury duration less than two weeks
- Patients willing to comply with follow-up protocol

Exclusion criteria

- Pathological fractures
- Infected distal tibial fractures
- Ipsilateral lower limb fractures
- Previous surgical intervention performed elsewhere

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Study size

A total of 30 adult patients were included. The sample size was determined based on feasibility, patient availability during the defined study period, and consistency with previously published single-center prospective studies evaluating minimally invasive plate osteosynthesis in distal tibial fractures. The study was intended as an outcome assessment rather than a comparative or powered inferential analysis.

Bias control

Selection bias was minimized through consecutive enrollment of eligible patients. Performance bias was reduced by following a standardized surgical protocol for all cases. Observer bias was addressed by using objective radiological criteria for fracture union and the validated American Orthopaedic Foot and Ankle Society (AOFAS) ankle–hindfoot scoring system for functional assessment. All evaluations were performed using uniform assessment methods.

Surgical technique

Minimally invasive osteosynthesis technique

Minimally invasive osteosynthesis was employed to minimize soft-tissue disruption and periosteal stripping associated with conventional open plating, thereby preserving fracture biology and reducing complication rates. Anatomically precontoured locking plates were used to maintain axial and angular alignment while providing stable fixation.

All patients received prophylactic intravenous antibiotics 30 minutes before skin incision. Procedures were performed under spinal anaesthesia with the patient positioned supine on a radiolucent operating table. The fundamental principle of the technique was preservation of the soft-tissue envelope and metaphyseal blood supply. Plate insertion was performed from distal to proximal through a subperiosteal tunnel, most commonly using a medial approach. This technique adheres to AO principles of biological fixation, emphasizing preservation of vascularity and minimization of soft-tissue trauma [9]. Minimally invasive percutaneous plate osteosynthesis, popularized in the early 2000s, enables submuscular insertion of precontoured locking plates through small incisions, thereby preserving periosteal circulation and fracture hematoma [10]. The locking compression plate system provides a fixed-angle construct by securing screws to the plate, enhancing stability [11].

A 3–5 cm longitudinal incision was made over the medial aspect of the distal tibia, terminating near the medial malleolus. The great saphenous vein and saphenous nerve were identified and protected. Proximal fixation was achieved through separate stab incisions, maintaining a minimum skin bridge of 7 cm to reduce wound complications. In selected oblique or spiral fracture patterns, additional percutaneous incisions were used for reduction clamps or lag screw insertion.

Fracture reduction was achieved using indirect techniques with manual traction and manipulation under fluoroscopic guidance. The anatomically contoured plate was advanced along the anteromedial surface of the tibia and positioned appropriately relative to the ankle joint. Temporary fixation was obtained using Kirschner wires. A proximal locking screw was inserted first and utilized as a hinge to optimize plate alignment. Final fixation was completed using a combination of locking and cortical screws. Implant position and fracture reduction were confirmed intraoperatively using fluoroscopy. Wounds were closed in layers, and sterile compressive dressings were applied.

Postoperative protocol

Early ankle and knee mobilization was initiated postoperatively. Partial weight bearing was permitted after radiological evidence of fracture union, with progression to full weight bearing upon confirmed union.

Outcome measures

The primary outcome measure was functional recovery assessed using the American Orthopaedic Foot and Ankle Society (AOFAS) ankle–hindfoot score, a validated scoring system integrating pain, function, and alignment [12].

Secondary outcome measures included:

Radiological outcomes: time to union, alignment, and implant stability

Functional outcomes: AOFAS ankle–hindfoot score

Complications: infection, delayed union, malunion, implant failure

Statistical analysis

Statistical analysis was performed using SPSS version 19.0. Continuous variables were expressed as mean ± standard deviation, while categorical variables were expressed as frequencies and percentages. A p-value <0.05 was considered statistically significant.

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Ethical considerations

The study was approved by the Institutional Ethics Committee of Vels Medical College and Hospital, Tiruvallur, Tamil Nadu. Written informed consent was obtained from all participants before enrollment. The study was conducted in accordance with institutional ethical standards and the principles of the Declaration of Helsinki.

Results

Participant flow

During the study period, 42 patients with distal one-third tibial fractures presented to the emergency department and orthopaedic outpatient services and were potentially eligible for inclusion. Of these, 38 patients were examined for eligibility following initial clinical and radiological assessment.

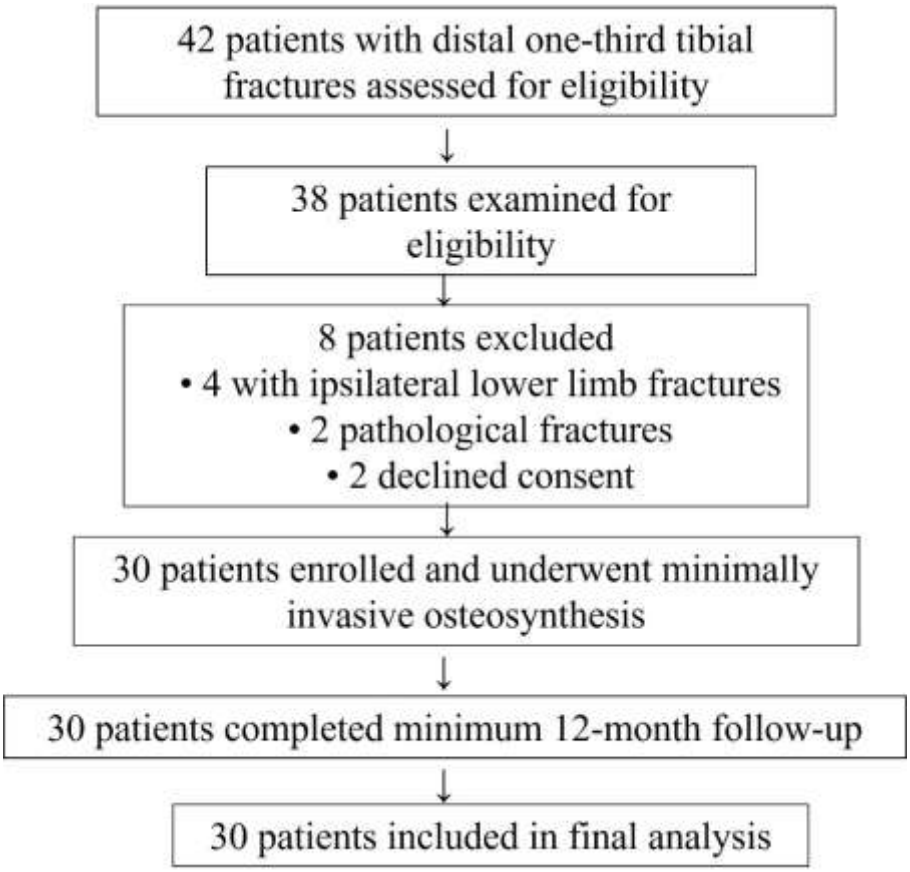

Figure 1. Flow diagram of participant recruitment and follow-up

Eight patients were excluded at this stage: four patients did not meet the inclusion criteria due to associated ipsilateral lower limb fractures, two patients had pathological fractures, and two patients declined to provide informed consent.

A total of 30 patients were confirmed eligible and enrolled in the study. All enrolled patients underwent surgical management using minimally invasive osteosynthesis and were followed for a minimum duration of 12 months. No patients were lost to follow-up, and all 30 patients were included in the final analysis (Figure 1).

Demographic characteristics

The study included 30 adult patients with a mean age of 56 ± 15 years (range: 28–80 years). Patients older than 60 years constituted the largest age group. Male patients accounted for 56% of the study population. Right-sided

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tibial fractures were more frequently observed. Demographic and baseline clinical characteristics are summarized in Table 1.

Table 1. Key clinical and outcome variables of the study population (n = 30)

Variable	Result
Number of patients	30
Mean age (years)	56 ± 15
Gender distribution	Predominantly male (56%)
Mean time to radiological union (weeks)	17.4 ± 5
Mean postoperative AOFAS score	92 ± 3.1

Mechanism of injury

Road traffic accidents were the most common mechanism of injury, accounting for 60% of cases. Low-energy falls accounted for 36.7%, while twisting injuries were observed in 3.3% of patients. Open fractures constituted 20% of the study population (Table 1).

Fracture characteristics

Most fractures were classified as extra-articular distal tibial fractures (AO/OTA 43-A). Partial articular fractures (43-B) were identified in six patients, while complete articular fractures (43-C) were present in three patients. Associated fibular fractures were observed in 23 patients, with fibular fixation performed selectively to aid in alignment and stability. Detailed fracture characteristics are presented in Table 2.

Table 2. Comparison of clinical and functional outcomes with published studies

Study	Technique	No. of Patients	Mean Age (years)	Mean Operating Time (minutes)	Time to Union (weeks)	Postoperative Infection (%)	Malalignment (%)	Mean AOFAS Score	Implant Removal (%)
Present study	MIO	30	56 ± 15	102 ± 25	17.4 ± 5	6.7	6.7	92 ± 3.1	3.3
Paluvadi et al. [21]	MIO	50	36	108	24.4	12	2	95.6	8
Piątkowski et al. [19]	ORIF	45	48	97.9	19	11	11.1	75	10
Guo et al. [20]	MIO	54	44.4	93.5	17.6	14.6	2.63	83.9	8

Operative details

The mean interval between admission and surgery was 3.2 days (range: 0–10 days). The mean operative time was 101.5 minutes, with longer operative durations noted in intra-articular fractures due to the requirement for meticulous indirect reduction and increased fluoroscopic guidance. Operative parameters are summarized in Table 2. Representative intraoperative steps are illustrated in Figure 2.

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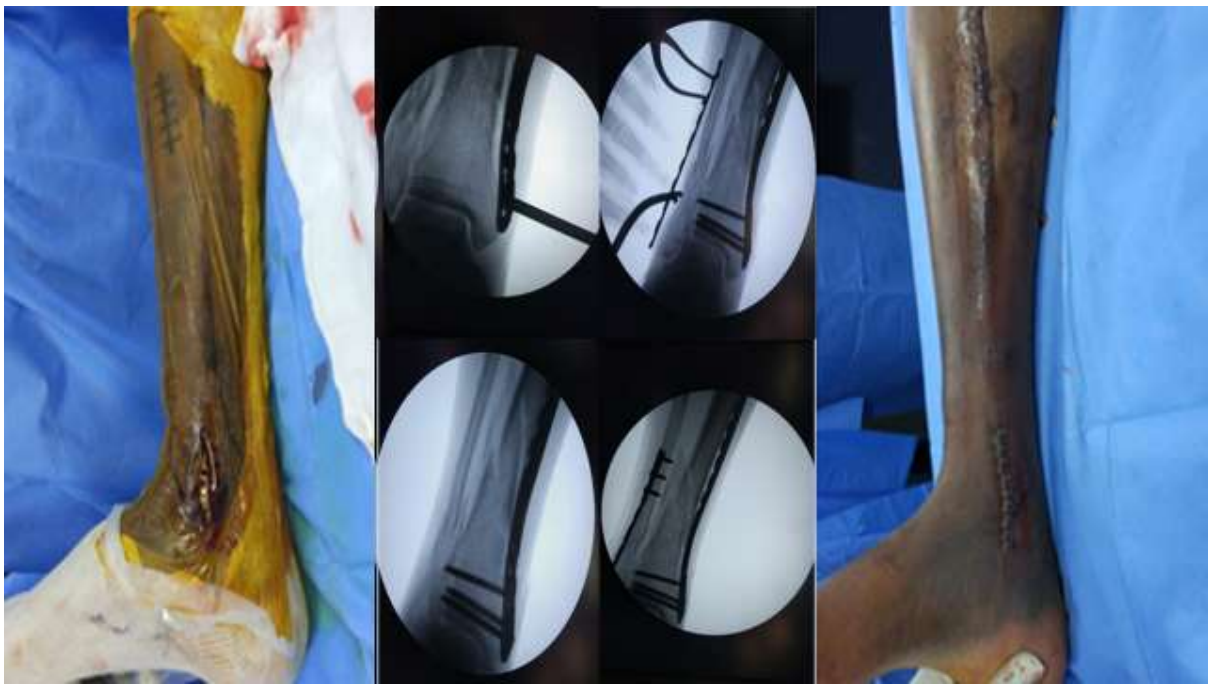

Figure 2: Surgical steps in fixation

Radiological outcomes

Radiological union was achieved in all patients. The mean time to union was 17.4 ± 5 weeks. Acceptable alignment was maintained in the majority of cases throughout the follow-up period. Follow-up radiographs demonstrating fracture union are shown in Figure 3.

Figure 3: Follow-up radiographs.

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Functional outcomes

Functional outcomes assessed using the American Orthopaedic Foot and Ankle Society ankle–hindfoot score demonstrated excellent results in 83.3% of patients and good results in 16.7% of patients. No fair or poor outcomes were recorded at final follow-up. Functional outcome scores are summarized in Table 1.

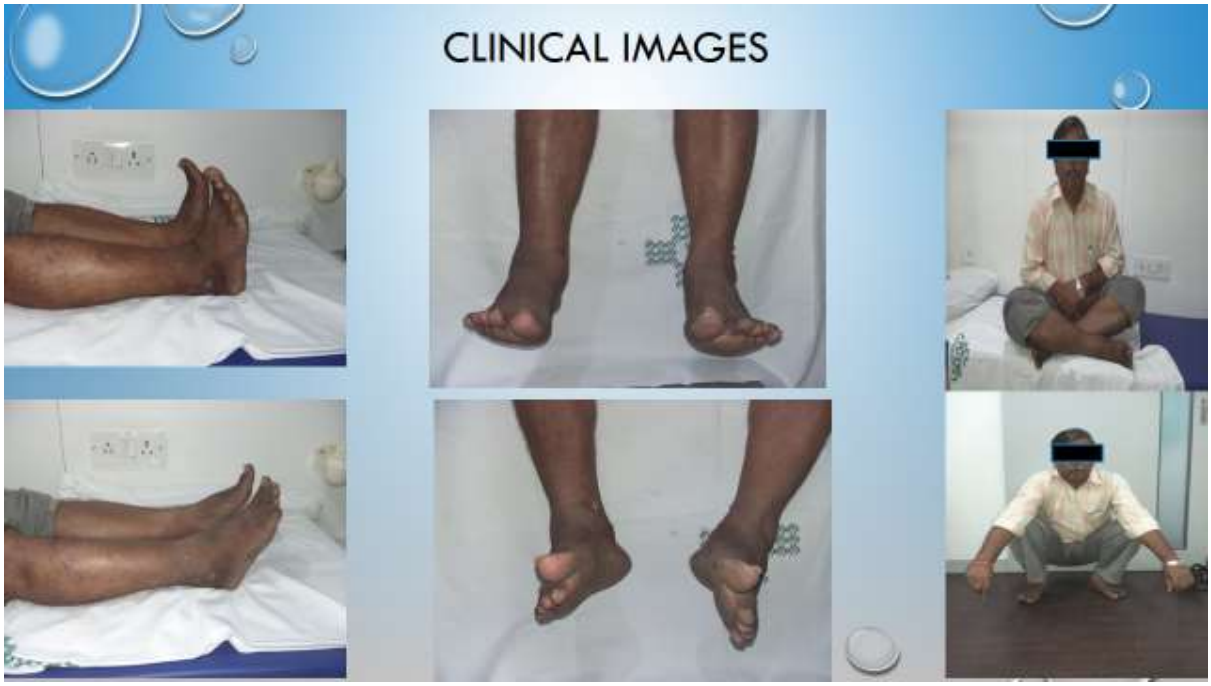

Figure 4 - Postoperative clinical images

Complications

Postoperative complications were observed in eight patients (23%). Superficial infection occurred in three patients (10%) and resolved with antibiotic therapy. One patient (3.3%) developed a deep infection requiring implant removal. Malreduction was identified in two patients (6.7%), and delayed union was observed in three patients (10%). No cases of nonunion or implant failure were recorded. The frequency and distribution of complications are detailed in Table 3.

Table 3. Frequency distribution of postoperative complications

Complication	Number of Patients	Percentage (%)
No complications	25	83.3
Superficial infection	3	10
Deep infection	1	3.3
Malreduction	2	6.7
Delayed union	3	10
Nonunion	0	0
Implant removal	1	3.3

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Discussion

The present study demonstrated consistent fracture union and favorable functional outcomes following minimally invasive plate osteosynthesis using anatomical locking plates for distal one-third tibial fractures. Radiological union was achieved in all patients, with a mean union time of 17.4 weeks. This finding supports the biological advantage of minimally invasive techniques, where preservation of periosteal blood supply and fracture hematoma facilitates timely fracture healing.

The high proportion of excellent functional outcomes, as reflected by American Orthopaedic Foot and Ankle Society ankle–hindfoot scores, indicates effective restoration of ankle function and alignment. The absence of fair or poor functional results suggests that stable fixation combined with limited soft-tissue disruption contributes to improved postoperative mobility and reduced joint stiffness. These findings align with previously published studies reporting reliable outcomes with minimally invasive plate osteosynthesis in distal tibial fractures.

Complication rates in this study were acceptable and comparable with existing literature. Superficial infections were successfully managed with antibiotic therapy, while the single case of deep infection occurred in a patient with an open fracture and associated comorbidities, highlighting the influence of injury severity and host factors on postoperative outcomes. Malreduction and delayed union were infrequent and were primarily attributed to the technical challenges inherent to indirect reduction methods, particularly in comminuted fracture patterns.

Associated fibular fractures were common, and selective fibular fixation contributed to improved alignment and stability in cases with syndesmotic involvement. This supports the practice of individualized fibular fixation rather than routine stabilization in all distal tibial fractures.

Generalizability

The findings of this study are generalizable to adult patients with distal one-third tibial fractures treated in tertiary care centers equipped with fluoroscopic facilities and surgeons experienced in minimally invasive fracture fixation techniques. The results are particularly applicable to closed fractures and selected open fractures managed within an early treatment window. Caution should be exercised when extrapolating these findings to polytrauma patients, pathological fractures, or healthcare settings with limited surgical infrastructure.

Limitations

This study has several limitations. The relatively small sample size and single-center design may limit the strength of the conclusions. The absence of a comparative control group precludes direct comparison with other fixation methods, such as intramedullary nailing or open reduction and internal fixation. Additionally, the follow-up duration was limited to a minimum of 12 months, which may not capture long-term functional outcomes or late complications.

Recommendations

Minimally invasive plate osteosynthesis using anatomical locking plates should be considered a preferred treatment option for distal one-third tibial fractures, particularly in cases where soft-tissue preservation is critical. Larger, multicenter comparative studies with longer follow-up periods are recommended to further validate these findings and establish standardized treatment protocols.

Conclusion

Minimally invasive plate osteosynthesis using anatomically contoured locking plates provides reliable fracture union, excellent functional outcomes, and an acceptable complication profile in distal one-third tibial fractures. Preservation of fracture biology and minimization of soft-tissue injury contribute significantly to improved healing and functional recovery. This technique represents an effective alternative to conventional open fixation methods when applied with appropriate patient selection and meticulous surgical technique.

List of abbreviations

AOFAS– American Orthopaedic Foot and Ankle Society
AO/OTA – Arbeitsgemeinschaft für Osteosynthesefragen / Orthopaedic Trauma Association
MIO – Minimally Invasive Osteosynthesis
MIPPO – Minimally Invasive Percutaneous Plate Osteosynthesis
ORIF – Open Reduction and Internal Fixation
SPSS – Statistical Package for the Social Sciences

Source of funding

The study did not receive any external funding from public, commercial, or not-for-profit sectors.

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Conflict of interest

The authors declare that there is no conflict of interest regarding the publication of this study.

Author contributions

Conceptualization and study design: **Sriram. S, Ganesh Ram. S**
Data acquisition: **Sriram. S, Kannan R.M.**
Surgical management: **K. Vijaya Bhaskar Reddy, Kannan R.M.**
Data analysis and interpretation: **Ganesh Ram. S, Ramasamy R**.
Manuscript drafting: **Sriram. S, Ganesh Ram S**
Critical revision of the manuscript: **All authors**
Final approval of the manuscript: **All authors**

Data availability

The datasets generated and analyzed during the current study are available from the corresponding author upon reasonable request.

Author biographies

Dr. Sriram. S is an Assistant Professor in the Department of Orthopaedics at Vels Medical College and Hospital, Tiruvallur, Tamil Nadu. His clinical and academic interests include orthopaedic trauma, minimally invasive fracture fixation, and functional outcome assessment.

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Dr. Kannan R.M. is an Associate Professor in the Department of Orthopaedics at Vels Medical College and Hospital with extensive experience in orthopaedic trauma surgery and reconstructive procedures.

Dr. K. Vijaya Bhaskar Reddy is a Professor of Orthopaedics at Vels Medical College and Hospital with vast experience in managing complex fractures and advanced trauma care.

Dr. Ramasamy R. is an Associate Professor in the Department of Forensic Medicine at Vels Medical College and Hospital. His expertise includes medicolegal documentation, injury analysis, and trauma-related forensic evaluation.

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