Section: Miscellaneous

Original Research Article

CORRECTIVE OSTEOSYNTHESIS FOR DISTAL TIBIAL MALUNION FOLLOWING EXTERNAL FIXATION OR TRADITIONAL TREATMENT: A RETROSPECTIVE COMPARATIVE STUDY OF INTRAMEDULLARY NAILING VERSUS LOCKING PLATE OSTEOSYNTHESIS

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ABSTRACT

Background: Distal tibial malunion can cause pain, deformity, altered gait, limb-length discrepancy, and impaired ankle function. Corrective osteotomy with stable fixation aims to restore alignment and function. This study compared clinical, radiological, and functional outcomes of intramedullary nailing (IMN) versus locking plate fixation for established distal tibial malunion.

Materials and Methods: retrospective comparative observational study was conducted at CMCRI, Chitradurga, involving 30 adults aged 20–50 years with symptomatic distal tibial malunion treated between January 2025 and July 2026. Patients underwent corrective osteotomy and fixation with IMN (n=15) or locking plate (n=15). Outcomes included final AOFAS Ankle-Hindfoot Score, union time, alignment, limb-length discrepancy, ankle range of motion, time to full weight bearing, return to work, and complications. Statistical analysis used Mann–Whitney U and Fisher's exact tests, with $p<0.05$ considered significant.

Results: Baseline characteristics were comparable. IMN resulted in lower blood loss (148±38 vs 236±52 mL; $p<0.001$) and shorter hospital stay (4.8±1.2 vs 6.3±1.5 days; p=0.006). Union rates were 100% and 93.3% (p=0.31), with comparable union times and alignment. IMN demonstrated higher final AOFAS scores (91.6±4.8 vs 86.9±6.2; p=0.03), earlier full weight bearing (10.8±1.6 vs 13.2±2.1 weeks; p=0.002), earlier return to work (15.4±2.8 vs 18.1±3.4 weeks; p=0.02), and greater ankle dorsiflexion and total range of motion (p=0.04 and p=0.02). Complications were lower with IMN (26.7% vs 53.3%; p=0.13).

Conclusion: IMN provided better functional recovery, earlier rehabilitation, lower blood loss, and shorter hospitalization, with comparable union and alignment. Implant selection should be individualized.

Keywords: Distal tibial malunion; Corrective osteotomy; Intramedullary nailing; Locking plate; Ankle function; Fracture union.

INTRODUCTION

Distal tibial fractures account for approximately 10% of all tibial fractures and 1–2% of all adult fractures, representing a challenging subset of lower-limb injuries because of their unique anatomical and biomechanical characteristics. They commonly result from high-energy mechanisms such as road traffic accidents, falls from height, and sports-related trauma. Owing to the subcutaneous location of the distal tibia, limited soft tissue envelope, relatively poor vascularity, and close proximity to the ankle joint, these fractures remain among the most challenging injuries to manage in orthopaedic trauma. Even when appropriate treatment is instituted, achieving stable fixation while preserving the biological environment for fracture healing is difficult. Failure to restore mechanical alignment or disruption of the surrounding soft tissues may adversely affect fracture union and long-term function.[1-3]

Malunion of the distal tibia is a recognized complication following fracture management and may develop because of inadequate initial reduction, unstable fixation, implant failure, prolonged external fixation, delayed definitive treatment, or treatment by traditional bone setters. In many developing countries, patients frequently seek traditional treatment before presenting to tertiary care centers, often after significant deformity has already developed. Similarly, patients initially managed with external fixation as part of damage-control orthopaedics may subsequently develop residual deformity if definitive reconstruction is delayed or alignment is inadequately maintained. Distal tibial malunion may present with angular, rotational, translational, or shortening deformities, either alone or in combination, resulting in altered lower-limb biomechanics.[4-6]

The clinical consequences of distal tibial malunion are substantial. Persistent pain, visible deformity, abnormal gait, limb-length discrepancy, reduced ankle range of motion, difficulty with weight bearing, and impaired functional capacity are common complaints. Malalignment also alters load transmission across the ankle joint, predisposing patients to accelerated cartilage degeneration and post-traumatic ankle arthritis. These functional limitations are particularly disabling in young and middle-aged adults, emphasizing the importance of timely recognition and appropriate corrective intervention.[7,8]

The primary objective of surgical management in distal tibial malunion is restoration of normal mechanical alignment, correction of rotational and angular deformity, achievement of stable fixation, and promotion of biological fracture healing while minimizing additional soft tissue injury. Corrective osteotomy, performed either at or near the site of the malunion, remains the standard reconstructive procedure. Successful correction requires meticulous preoperative deformity analysis using long-leg radiographs, precise surgical planning, stable fixation, and a structured rehabilitation program to restore the mechanical axis and optimize postoperative function.[5,9,10]

Among the available fixation methods, intramedullary nailing has gained increasing popularity because it combines minimally invasive fixation with preservation of fracture biology while providing stable load-sharing fixation. Additional advantages include minimal soft tissue disruption, preservation of periosteal blood supply, smaller surgical incisions, and the potential for earlier mobilization and weight bearing. However, distal metaphyseal fixation remains technically demanding because of the widened medullary canal, increasing the risk of malalignment, rotational instability, and difficulty in maintaining reduction. The use of adjunctive techniques such as poller (blocking) screws and multiple distal interlocking screws has improved fixation stability and expanded the indications for intramedullary nailing in distal tibial reconstruction.[11-14]

Locking compression plate fixation remains an established technique because it allows precise correction of angular, rotational, and translational deformities while providing stable fixed-angle fixation, particularly in short distal fragments. The advent of minimally invasive plate osteosynthesis (MIPO) has reduced soft tissue stripping and preserved fracture biology compared with conventional open plating. Nevertheless, plate fixation may still be associated with wound complications, hardware prominence, delayed wound healing, infection, and implant irritation, particularly in the distal tibia where soft tissue coverage is limited. Therefore, the choice between intramedullary nailing and plate osteosynthesis remains individualized and depends on fracture morphology, deformity characteristics, bone quality, soft tissue condition, and surgeon experience.[15-17]

Most published comparative studies and meta-analyses have focused on the management of acute extra-articular distal tibial fractures, comparing intramedullary nailing with plate osteosynthesis regarding fracture union, malalignment, infection, and functional outcomes. Although these studies provide valuable guidance for primary fracture treatment, their findings cannot be directly extrapolated to patients presenting with established distal tibial malunion. Corrective osteosynthesis for malunion involves different surgical objectives, altered bone biology, scarred soft tissues, deformity correction, and frequently more complex reconstruction than primary fracture fixation. However, comparative evidence evaluating intramedullary nailing and locking plate fixation specifically for distal tibial malunion following failed external fixation or traditional treatment is scarce, and the optimal fixation strategy remains uncertain.[18-21]

Therefore, the present study was undertaken to compare the clinical, radiological, and functional outcomes of corrective osteosynthesis using intramedullary nailing and locking plate fixation in adult patients with distal tibial malunion following external fixation removal or traditional treatment. We hypothesized that both fixation methods would achieve satisfactory deformity correction and fracture union, while intramedullary nailing may facilitate faster rehabilitation while maintaining radiological outcomes comparable to locking plate fixation.

MATERIALS AND METHODS

Study Design

This retrospective comparative observational study was conducted in the Department of Orthopaedics, CMCRI, Chitradurga. Hospital medical records, operative notes, and radiographic images of 30 consecutive adult patients treated for distal tibial malunion between January 2025 and July 2026 were retrospectively reviewed. The study compared the clinical, radiological, and functional outcomes of corrective osteosynthesis using intramedullary nailing (IMN) and locking plate osteosynthesis in patients with distal tibial malunion following previous external fixation or traditional bone-setter treatment.

Definition of Malunion

Distal tibial malunion was defined as a healed fracture with symptomatic deformity requiring corrective surgery, including one or more of the following: coronal or sagittal angulation greater than 5°, rotational deformity greater than 10°, limb shortening greater than 1 cm, or functional impairment associated with pain, deformity, or gait disturbance, as assessed clinically and/or radiographically

Patient Selection

Hospital records, operative notes, and radiographic archives were reviewed to identify all consecutive eligible patients who underwent corrective surgery for distal tibial malunion during the study period. Patients were screened according to the predefined inclusion and exclusion criteria. **A total of 30 patients met the eligibility criteria and were included in the final analysis.**

Inclusion Criteria

- Age between 20 and 50 years.
- Distal tibial malunion following previous treatment with external fixation or traditional bone-setter management.
- Definitive corrective osteosynthesis using either intramedullary nailing or locking plate fixation.
- Minimum clinical and radiological follow-up of 12 months.
- Complete clinical records and serial radiographs available for review.

Exclusion Criteria

- Active infection or chronic osteomyelitis at the fracture site.
- Pathological fractures.
- Skeletally immature patients.
- Associated neurovascular injury affecting functional assessment.
- Incomplete medical records or loss to follow-up before 12 months.

Study Groups

The 30 eligible patients were divided into two groups according to the definitive fixation method used.

Group A (Intramedullary Nail Group):

Fifteen patients underwent corrective osteotomy followed by fixation using a tibial intramedullary nail.

Group B (Plate Osteosynthesis Group):

Fifteen patients underwent corrective osteotomy followed by fixation using a locking compression plate.

The choice of fixation method was based on the treating surgeon's preference, fracture morphology, deformity characteristics, bone quality, and soft-tissue condition

Preoperative Assessment

All patients underwent detailed clinical and radiographic evaluation before surgery. Standard anteroposterior and lateral radiographs of the leg, including the knee and ankle joints, were obtained. Coronal, sagittal, rotational, and length deformities were assessed preoperatively. Routine hematological investigations and anesthetic fitness evaluation were completed before surgery.

Surgical Technique

All procedures were performed under spinal or general anesthesia with the patient in the supine position on a radiolucent operating table under fluoroscopic guidance.

Group A: Intramedullary Nailing

Following exposure of the malunion site, corrective osteotomy was performed to restore the mechanical axis and limb alignment. Fibrous tissue and sclerotic bone were excised where necessary to obtain healthy bleeding bone ends. A guidewire was inserted through the standard proximal tibial entry point, and sequential canal reaming was performed. After deformity correction, an appropriately sized tibial intramedullary nail was inserted. Poller (blocking) screws were used whenever required to facilitate reduction and improve metaphyseal stability. Fixation was completed using multiple distal and proximal interlocking screws under fluoroscopic guidance. Autologous cancellous bone grafting was performed when indicated based on the size of the defect and bone quality.

Group B: Plate Osteosynthesis

Following corrective osteotomy and restoration of alignment, definitive fixation was achieved using a precontoured locking compression plate. Depending on fracture morphology and soft tissue condition, either minimally invasive plate osteosynthesis (MIPO) or open reduction and internal fixation was performed. The plate was positioned on the anteromedial or medial aspect of the distal tibia, and fixation was obtained using an appropriate combination of locking and cortical screws to achieve stable fixation. Autologous iliac crest cancellous bone graft was used when indicated..

Fibular fixation was undertaken selectively in patients with associated fibular malunion or ankle instability when restoration of fibular length was necessary to achieve satisfactory tibial alignment.

Postoperative Protocol

All patients received intravenous prophylactic antibiotics for 24 hours following surgery according to institutional protocol. Limb elevation, pain management, and thromboembolism prophylaxis were provided as indicated. Active ankle and knee range-of-motion exercises were initiated on the first postoperative day under the supervision of a physiotherapist.

Toe-touch or partial weight bearing was permitted according to fixation stability and radiographic appearance, generally beginning at 6–8 weeks. Progressive weight bearing was allowed after radiological evidence of healing, with full weight bearing initiated once satisfactory fracture union was demonstrated.

Patients were reviewed at 2 weeks, 6 weeks, 3 months, 6 months, and 12 months postoperatively, and annually thereafter when available. Standard anteroposterior and lateral radiographs were obtained at each follow-up visit.

Outcome Measures

Primary Outcome

Functional outcome at final follow-up was assessed using the **American Orthopaedic Foot and Ankle Society (AOFAS) Ankle-Hindfoot Score**.

Secondary Outcomes

The following secondary outcomes were evaluated:

- Time to radiological union.
- Coronal plane alignment.
- Sagittal plane alignment.
- Limb-length discrepancy.
- Ankle range of motion.
- Time to full weight bearing.
- Superficial and deep surgical site infection.
- Implant-related complications.
- Delayed union.
- Nonunion.
- Requirement for secondary surgical procedures or implant removal.

Radiological union was defined as bridging callus across at least three of four cortices on standard anteroposterior and lateral radiographs together with painless full weight bearing. Coronal or sagittal malalignment greater than 5° and limb shortening greater than 1 cm were considered clinically significant.

Statistical Analysis

Statistical analysis was performed using **IBM SPSS Statistics version 26.0** (IBM Corp., Armonk, NY, USA). Continuous variables were expressed as **mean ± standard deviation (SD)** or **median (interquartile range)** depending on data distribution. Categorical variables were expressed as **frequency and percentage**.

Comparisons between the intramedullary nailing (IMN) group and the locking plate group were performed using the **Mann–Whitney U test** for continuous variables because of the relatively small sample size and non-normal distribution of continuous variables. Categorical variables were compared using the **Fisher's exact test**. A two-tailed p value of **<0.05** was considered statistically significant.

RESULTS

Table 1: Baseline Demographic and Injury Characteristics

Variable	IMN Group (n = 15)	Plate Group (n = 15)	p-value
Number of patients	15	15	—
Age (years), mean ± SD	36.8 ± 8.2	38.1 ± 7.9	0.65
Sex (Male/Female)	11 / 4	10 / 5	0.69
Side involved (Right/Left)	9 / 6	8 / 7	0.71
Mechanism of injury			0.83
• Road traffic accident	10 (66.7%)	11 (73.3%)	
• Fall from height	3 (20.0%)	2 (13.3%)	
• Others	2 (13.3%)	2 (13.3%)	
Previous treatment			0.72
• External fixation	**12 (80.0%)**	**11 (73.3%)**	
• Traditional bone-setter	**3 (20.0%)**	**4 (26.7%)**	
Open fracture (Gustilo grade)			0.74
• Gustilo I	2 (13.3%)	2 (13.3%)	
• Gustilo II	1 (6.7%)	2 (13.3%)	
• Gustilo IIIA	1 (6.7%)	1 (6.7%)	
Closed fracture	**11 (73.3%)**	**10 (66.7%)**	0.69
Time from injury to corrective surgery (months), mean ± SD	8.4 ± 2.1	8.8 ± 2.5	0.61

The baseline demographic and injury characteristics were comparable between the two groups, with no statistically significant differences in age, sex distribution, mechanism of injury, previous treatment, or time from injury to corrective surgery.

Table 2: Operative Characteristics			
Variable	**IMN Group (n = 15)**	**Plate Group (n = 15)**	**p-value**
Operative time (minutes), mean ± SD	**108.6 ± 15.8**	**119.4 ± 18.2**	0.09
Estimated blood loss (mL), mean ± SD	**148 ± 38**	**236 ± 52**	<0.001
Fibular fixation, n (%)	**8 (53.3%)**	**9 (60.0%)**	0.71
Bone graft used, n (%)	**5 (33.3%)**	**6 (40.0%)**	0.71
Corrective osteotomy performed, n (%)	**15 (100%)**	**15 (100%)**	—
Hospital stay (days), mean ± SD	**4.8 ± 1.2**	**6.3 ± 1.5**	0.006

Operative time, fibular fixation rate, and bone graft utilization were comparable between the two groups. However, the IMN group demonstrated significantly lower intraoperative blood loss and shorter hospital stay.

Table 3: Radiological Outcomes			
Variable	**IMN Group (n = 15)**	**Plate Group (n = 15)**	**p-value**
Time to radiological union (weeks), mean ± SD	**17.2 ± 2.8**	**18.6 ± 3.1**	0.18
Union achieved, n (%)	**15 (100%)**	**14 (93.3%)**	0.31
Coronal alignment (degrees), mean ± SD	**2.1 ± 1.2**	**1.8 ± 1.0**	0.44
Sagittal alignment (degrees), mean ± SD	**2.3 ± 1.3**	**2.0 ± 1.1**	0.48
Residual deformity (>5°), n (%)	**1 (6.7%)**	**2 (13.3%)**	1.00
Limb length discrepancy (cm), mean ± SD	**0.4 ± 0.3**	**0.5 ± 0.4**	0.52

Radiological outcomes were comparable between the two groups. Although the IMN group demonstrated a shorter mean time to radiological union and a higher union rate, these differences were not statistically significant. Coronal alignment, sagittal alignment, residual deformity, and limb-length discrepancy were also similar between groups.

Table 4: Functional Outcomes			
Variable	**IMN Group (n = 15)**	**Plate Group (n = 15)**	**p-value**
AOFAS score at final follow-up	**91.6 ± 4.8**	**86.9 ± 6.2**	**0.03**
Time to full weight bearing (weeks)	**10.8 ± 1.6**	**13.2 ± 2.1**	**0.002**
Return to work (weeks)	**15.4 ± 2.8**	**18.1 ± 3.4**	**0.02**
Ankle dorsiflexion (°)	**18.2 ± 3.1**	**15.7 ± 3.6**	**0.04**
Ankle plantarflexion (°)	**39.8 ± 4.2**	**36.9 ± 4.8**	**0.08**
Total ankle ROM (°)	**58.0 ± 5.6**	**52.6 ± 6.3**	**0.02**

Patients treated with IMN demonstrated superior functional recovery, particularly with respect to AOFAS score, time to full weight bearing, return to work, ankle dorsiflexion, and total ankle range of motion.

Table 5: Complications			
Complication	**IMN Group n (%)**	**Plate Group n (%)**	**p-value**
Superficial infection	1 (6.7%)	2 (13.3%)	0.54
Deep infection	0 (0%)	1 (6.7%)	0.31
Delayed union	1 (6.7%)	2 (13.3%)	0.54
Nonunion	0 (0%)	1 (6.7%)	0.31
Implant failure	0 (0%)	1 (6.7%)	0.31
Hardware irritation	1 (6.7%)	3 (20.0%)	0.28
Implant removal/Reoperation	1 (6.7%)	2 (13.3%)	0.54
Total complications*	**4 (26.7%)**	**8 (53.3%)**	**0.13**

The incidence of postoperative complications was numerically lower in the IMN group; however, differences in individual complications and overall complication rates did not reach statistical significance.

Figure 1: Preoperative and postoperative radiographs of distal tibial malunion treated with corrective osteotomy and intramedullary nailing

Figure 2: Preoperative and postoperative radiographs of distal tibial malunion treated with treated with corrective osteotomy and intramedullary nailing

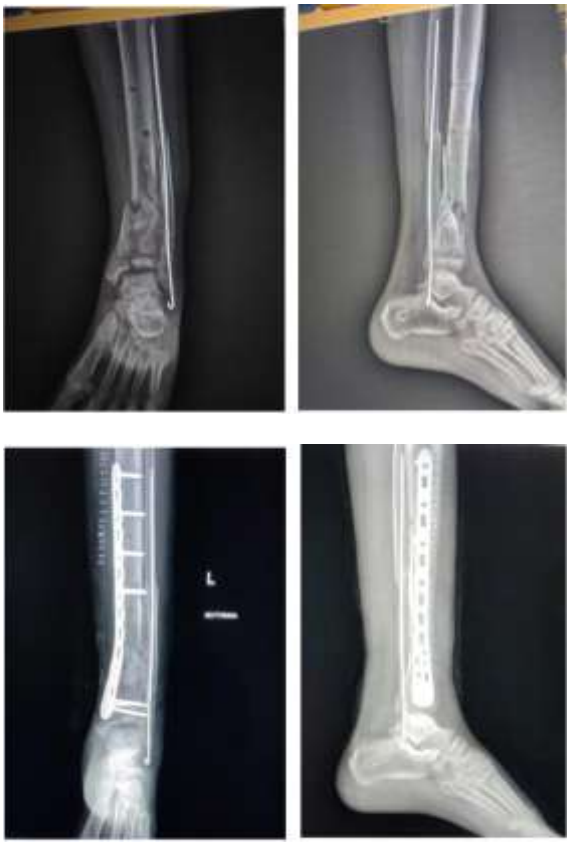

Figure 3: Preoperative and postoperative radiographs of distal tibial malunion treated treated with corrective osteotomy and locking plate osteosynthesis

Figure 4: Preoperative and postoperative radiographs of distal tibial malunion treated treated with corrective osteotomy and locking plate osteosynthesis

DISCUSSION

Distal tibial malunion remains one of the most challenging reconstructive problems in orthopaedic trauma because restoration of limb alignment must be achieved while preserving fracture biology and minimizing additional soft-tissue injury. Corrective osteotomy with stable internal fixation aims to restore the mechanical axis, promote fracture union, improve ankle function, and reduce the risk of post-traumatic osteoarthritis. The optimal method of fixation following corrective osteotomy, however, remains controversial. In the present study, both intramedullary nailing (IMN) and locking plate fixation achieved high union rates, satisfactory deformity correction, and favorable functional outcomes. Patients treated with IMN demonstrated significantly higher AOFAS scores, earlier full weight bearing, earlier return to work, greater ankle dorsiflexion and total ankle range of motion, shorter hospital stay, and significantly lower intraoperative blood loss. Although radiological union occurred slightly earlier in the IMN group and fewer postoperative complications were observed, these differences were not statistically significant.

Radiological union was achieved in all patients treated with IMN and in 93.3% of patients treated with locking plates. The mean time to radiological union was shorter in the IMN group (17.2 ± 2.8 weeks) than in the plate group (18.6 ± 3.1 weeks); however, this difference did not reach statistical significance ($p = 0.18$). Likewise, the difference in overall union rates between the two groups was not statistically significant. These findings are consistent with previous comparative studies demonstrating that both fixation methods provide reliable fracture healing. Vallier et al. reported comparable union rates between intramedullary nailing and plate fixation for distal tibial fractures, while meta-analyses by Yu et al., Guo et al., Wang et al., and Xue et al. similarly concluded that both techniques achieve satisfactory fracture union without consistent differences in union rates or time to union.[12-14,20,21] The trend toward earlier healing observed with IMN in the present study may be related to preservation of periosteal blood supply and the load-sharing characteristics of intramedullary fixation; however, the relatively small sample size may have limited the statistical power to detect a significant difference.

Restoration of lower-limb alignment is the principal objective of corrective osteotomy. Historically, distal tibial intramedullary nailing was associated with concerns regarding malalignment because of the widened metaphyseal canal and limited distal fixation.[11] However, advances in implant design, including multiple multiplanar distal locking options and the use of poller (blocking) screws, have substantially improved metaphyseal stability. In the present study, postoperative coronal and sagittal alignment were comparable between the two groups, and differences in residual deformity were not statistically significant. These findings support previous reports indicating that modern intramedullary nailing can achieve alignment comparable to locking plate fixation when meticulous deformity correction and intraoperative fluoroscopic guidance are employed.[12,19]

Functional recovery is a key determinant of treatment success in patients with distal tibial malunion. Patients treated with IMN achieved significantly higher AOFAS scores, earlier progression to full weight bearing, earlier return to work, greater ankle dorsiflexion, and greater total ankle range of motion than those treated with locking plates. Earlier mobilization following intramedullary fixation may reduce joint stiffness, preserve muscle strength, and facilitate rehabilitation. Similar observations have been reported in randomized trials and meta-analyses by Costa et al., Wang et al., and Xue et al., which demonstrated that intramedullary fixation is associated with improved early functional recovery and shorter rehabilitation periods, although long-term functional outcomes are often comparable between fixation methods.[18,20,21] Although plantarflexion was greater in the IMN group, the difference did not reach statistical significance, suggesting that overall functional improvement was primarily driven by enhanced dorsiflexion and earlier rehabilitation.

Another important finding of the present study was the significantly lower intraoperative blood loss (148 ± 38 mL vs 236 ± 52 mL; $p < 0.001$) and shorter hospital stay (4.8 ± 1.2 vs 6.3 ± 1.5 days; $p = 0.006$) in the IMN group. These findings are likely attributable to the minimally invasive nature of intramedullary fixation, which requires less soft-tissue dissection than plate osteosynthesis. Previous comparative studies have likewise demonstrated reduced surgical trauma, decreased blood loss, and shorter hospitalization following intramedullary nailing compared with plate fixation.[12,16,18]

Although fewer postoperative complications occurred in the IMN group, including superficial infection, delayed union, hardware irritation, implant failure, nonunion, and reoperation, none of these differences reached statistical significance. Similarly, the overall complication rate was lower in the IMN group (26.7% vs 53.3%), but this difference was not statistically significant ($p = 0.13$). Although wound-related complications were numerically more frequent in the plate group, this difference was not statistically significant in the present study. Nevertheless, previous literature has reported a greater propensity for wound complications following plate fixation because of the limited soft-tissue envelope over the distal tibia.[15,16] Hardware prominence is also more frequently encountered following plate fixation because of the subcutaneous location of the distal tibia, occasionally necessitating implant removal after fracture union. Nevertheless, both fixation methods demonstrated acceptable safety profiles in the present series.

Despite the favorable functional outcomes observed with intramedullary nailing, locking plate fixation continues to have an important role in selected patients. Plate osteosynthesis provides excellent visualization of the deformity and facilitates precise correction of complex angular, rotational, and translational malalignment, particularly in very distal metaphyseal deformities or when the distal fragment is too short for secure intramedullary fixation. Therefore, implant selection should be individualized according to fracture morphology, deformity characteristics, bone quality, soft-tissue condition, and surgeon experience rather than based solely on one fixation technique.

The present study has several limitations. First, its retrospective design introduces the possibility of selection bias, and implant choice was based on surgeon preference rather than randomization. Second, the relatively small sample size may have reduced the statistical power to detect significant differences in radiological and complication-related outcomes. Third, this was a single-center study, limiting the generalizability of the findings. Finally, follow-up primarily assessed fracture union and short-term functional recovery, whereas longer-term outcomes such as post-traumatic ankle arthritis, implant-related symptoms, and patient-reported quality-of-life measures were not evaluated.

Despite these limitations, the present study contributes to the limited literature addressing corrective osteosynthesis for distal tibial malunion following failed external fixation or traditional bone-setter treatment. Unlike most published studies that focus on acute distal tibial fractures, this study specifically evaluated patients undergoing corrective osteotomy for established malunion using standardized clinical, radiological, and functional outcome measures. The findings suggest that both intramedullary nailing and locking plate fixation are effective treatment options. Intramedullary nailing demonstrated significant advantages in functional recovery, earlier rehabilitation, lower intraoperative blood loss, and shorter hospital stay, while radiological union, alignment restoration, union rates, and complication rates were comparable between the two fixation methods.

CONCLUSION

Although the intramedullary nailing (IMN) group demonstrated a shorter mean time to radiological union than the locking plate group, this difference was not statistically significant. Corrective osteotomy with stable internal fixation is an effective treatment for distal tibial malunion, providing reliable deformity correction, high union rates, and satisfactory functional recovery. In the present study, both intramedullary nailing and locking plate fixation achieved favorable radiological and clinical outcomes, with comparable restoration of coronal and sagittal alignment and a high rate of fracture union. However, intramedullary nailing was associated with earlier progression to full weight bearing, faster return to work, higher final AOFAS scores, greater ankle range of motion, and a lower incidence of wound-related complications, although this difference was not statistically significant. Plate fixation, on the other hand, remained an effective option, particularly in cases requiring precise correction of complex deformities or fixation of very distal fracture segments where enhanced rotational control and distal fixation may be advantageous.

The findings suggest that implant selection should be individualized according to the characteristics of the malunion, fracture morphology, bone quality, soft-tissue condition, and surgeon expertise rather than adopting a single fixation method for all patients. While the present study suggests several potential functional advantages of intramedullary nailing in appropriately selected patients, its retrospective design, relatively small sample size, and single-center setting warrant cautious interpretation. Larger prospective, multicenter studies with longer follow-up are needed to validate these findings and establish evidence-based recommendations for the optimal management of distal tibial malunion.

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