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ORIGINAL ARTICLE

Intramedullary Nailing verus Minimally Invasive Plate Osteosynthesis (MIPO) in Management of Distal Tibial Fractures

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ABSTRACT

Background: Distal tibial fractures remain surgical challenge because of its limited soft-tissue coverage and poor vascularity. Intramedullary nailing (IMN) as well as minimally invasive plate osteosynthesis (MIPO) are widely used, yet the optimal fixation method is still debated. This work compared the outcomes of intramedullary nailing and distal tibial locked plating using the MIPO technique in adult patients with extra-articular distal tibial fractures.

Methods: We performed this prospective randomized study on 36 adult patients having closed extra-articular distal tibial fractures randomized into two groups: Group A treated with IMN (n=18) while Group B managed by MIPO using a locked plate (n=18). Outcomes assessed included operative time, union rate, malalignment, infection, secondary procedures, as well as functional recovery utilizing the Olerud–Molander Ankle Score (OMAS).

Results: The mean operative time was slightly shorter with IMN (116 min) compared to MIPO (127 min), but without statistical significance (P=0.182). Union time was significantly shorter in the IMN group (13.1 vs. 16.8 weeks; P=0.016). No infections occurred after IMN, whereas two deep infections were observed with MIPO, both progressing to nonunion. Malalignment was more frequent after IMN (2 cases), while rotational deformity and delayed union were observed in MIPO (1 case each). Functional outcomes at 6 months were comparable between groups, with non statistically significant difference in OMAS scores (P=0.307).

Conclusion: Both IMN and MIPO are effective fixation methods for distal tibial fractures. IMN allows faster union and fewer infections but carries a higher risk of malalignment, whereas MIPO provides better alignment but with slower healing and more infection-related complications. Careful surgical planning and soft-tissue management remain crucial for successful outcomes.

Keywords: Intramedullary Nailing; Minimally Invasive Plate Osteosynthesis; Distal Tibial Fractures.

INTRODUCTION

Fractures occur when mechanical forces exceed the structural strength of bone, leading to biological consequences that disrupt healing. Understanding both the biomechanical and biological aspects of repairing fractures is essential when selecting the most appropriate treatment for a specific injury [1].

The tibia is considered the most prevalent fractured long bone in the human body. These injuries frequently necessitates hospitalization and surgical fixation, often resulting in long recovery periods that limit return to work and daily activities. The tibial shaft represents the most frequent fracture site, and nearly 80% of these cases are accompanied by an associated fibular fracture. Epidemiological studies have estimated the annual incidence to be approximately 17 per 100,000 individuals, though more recent reports suggest a gradual decline [2,3].

Fractures of the distal third of the tibia account for nearly 38% of all tibial injuries and affect patients across different age groups. Treating these fractures in skeletally mature individuals remains challenging because of their subcutaneous location, relatively poor vascular supply, and proximity to the ankle joint. Historically, open reduction and internal fixation (ORIF) was the standard approach. However, higher complication rates that are correlated with ORIF encouraged the adoption of alternative fixation strategies like minimally invasive percutaneous plate osteosynthesis (MIPO) as well as the intramedullary nailing (IMN) [4–6]. Some surgeons have also advocated the use of external fixation with limited open reduction (EF + LORIF), reporting lower rates of soft tissue problems and favorable functional outcomes [7].

With advances in locking plate technology and the concept of biological fixation, MIPO has gained widespread use for distal tibial fractures. This technique is considered reliable, with reduced periosteal stripping and preservation of fracture biology, often leading to satisfactory union rates. Conversely, intramedullary nailing provides a minimally invasive, biomechanically stable, and load-sharing construct that also aligns with biological fixation principles. Both MIPO and IMN have been shown to achieve good results, but each has distinct advantages and limitations [8,9]. Non-operative treatment, although historically practiced, is associated with high rates of joint stiffness (up to 40%) and malunion or shortening in over 30% of patients [10].

Despite numerous studies comparing MIPO and IMN, there remains no universal agreement on the optimal fixation method for distal tibial fractures. Variability in patient demographics, fracture morphology, soft tissue conditions, and surgeon expertise all contribute to heterogeneity in reported outcomes. More recently, several high-quality studies have expanded the evidence base. A 2024–2025 meta-analysis of 23 studies (n≈1,742) confirmed that IMN shortens union time and lowers infection risk, whereas MIPO provides better coronal alignment and slightly less anterior knee pain [11,12]. These updated findings reinforce the need for continued comparative evaluation of the two techniques. Therefore, this research compared the outcomes of intramedullary nailing and distal tibial locked plating using the MIPO technique in adult patients with extra-articular distal tibial fractures.

METHODS

We carried out this prospective randomized clinical study at Zagazig University Hospitals between January 2024 and October 2025. A total of 36 skeletally mature patients having extra-articular distal tibial fractures were enrolled. The participants were randomly allocated into two groups: Group A, managed with IMN, and Group B, managed with MIPO using a locked distal tibial plate. Each group included 18 patients.

Prior to initiation, the study protocol received approval from the Institutional Review Board (ZU-IRB# 626/10-9-2024), and written informed consent was obtained from all participants. The trial adhered to the principles of the Declaration of Helsinki.

Eligible patients were adults over 18 years of age with extra-articular meta-diaphyseal fractures of the distal third of the tibia. Only patients who were medically fit for surgery had good soft-tissue conditions, and presented with recent fractures (within 14 days of trauma) were included. Isolated grade I open fractures based on the Gustilo classification were also accepted.

Patients were excluded if they had Gustilo grade II or III open fractures, intra-articular extension, pathological fractures, associated vascular injury, compartment syndrome, deep venous thrombosis, or systemic medical contraindications to surgery.

Preoperative evaluation

On admission, detailed history and demographic data were collected, including patient age, sex, occupation, smoking status, comorbidities, and mechanism of injury. Clinical examination focused on general trauma assessment according to Advanced Trauma Life

Support (ATLS) protocols, followed by careful inspection of the injured limb for vascular integrity, neurological function, and soft-tissue condition.

Radiographic evaluation included anteroposterior and lateral radiographs of the tibia covering the knee and ankle. Computed tomography (CT) was performed selectively to rule out articular involvement. Routine laboratory investigations were obtained for all patients, while additional tests were ordered according to associated comorbidities.

Before surgery, patients were given systemic analgesics, and all fractures were temporarily stabilized in above-knee slabs. Diabetic patients underwent strict glucose control, and other comorbidities were optimized as needed. A single preoperative dose of intravenous ceftriaxone was administered 30 minutes before incision.

Operative procedures

Group A (Intramedullary Nailing):

Patients were placed supine on a radiolucent table, with the knee gently flexed to relax the extensor mechanism and allow easier entry point access. Nail insertion was carried out under continuous fluoroscopic control to ensure accurate placement. After identifying the entry point in line with the intramedullary canal, a ball-tipped guide wire was gently negotiated through the fracture to maintain alignment. Sequential reaming was performed until adequate canal preparation was achieved. The appropriate nail was inserted with attention to restoring length, alignment, and rotation. Distal and proximal interlocking screws were applied, and wounds were closed in layers. Both standard and expert tibial nails were used in this series.

Group B (MIPO with locked plate):

In the supine position on a radiolucent table, and after applying a tourniquet, an anteromedial mini incision was made. A subcutaneous extraperiosteal tunnel was then fashioned to advance the precontoured plate into position. Fracture reduction was achieved percutaneously using manual traction, clamps, or external fixation assistance when necessary. After distal fixation, the plate was secured proximally under fluoroscopic control. Wounds were closed carefully, ensuring proper soft-tissue coverage. Fixation of the fibula, when fractured within 7 cm of the lateral malleolus, was performed at the surgeon's discretion to assist with tibial alignment. In all cases requiring fixation, a standard lateral approach was used and the fibula was stabilized with a 3.5-mm one-third tubular plate applied in neutralization mode with cortical screws. No K-wires, reconstruction plates, or intramedullary screws were used.

When fibular fixation was performed, a standard lateral approach was used. Fixation was achieved with a 3.5-mm small-fragment plate (one-third tubular or locking compression plate) and cortical screws applied in neutralization mode according to fracture configuration. The choice to fix the fibula and the specific plate type were left to the individual surgeon's judgment; no separate study protocol mandated a standardized construct.

Postoperative protocol

Neurovascular status was carefully monitored in all cases, and immediate postoperative radiographs were obtained. Antibiotic prophylaxis was maintained with intravenous therapy for 48 hours, then shifted to oral agents for one week. Thromboprophylaxis with low-molecular-weight heparin was prescribed until mobilization. Early knee and ankle range-of-motion exercises and quadriceps strengthening were encouraged, while weight-bearing was initially restricted.

Patients were reviewed at 2 weeks for suture removal and wound assessment, at 6 weeks for radiographic follow-up and initiation of partial weight-bearing, and at 12 weeks for confirmation of fracture union before progression to full weight-bearing. Final follow-up at 6 months included radiological evaluation and functional assessment.

Outcome measures

Radiographic union was considered achieved once bridging callus was visible across three or more cortices, with clinical confirmation by the absence of tenderness at the fracture site. Malalignment was defined as >5° deviation in the sagittal or coronal plane or >15° rotational difference relative to the contralateral limb. Functional recovery was evaluated through the Olerud–Molander Ankle Score (OMAS) [13], assessing nine domains of ankle function. Final scores were categorized as excellent (91–100), good (61–90), fair (31–60), or poor (≤30).

Statistical analysis

All data, including patient demographics, diagnosis, surgical details, level of spinal fusion, and blood transfusion requirements, were systematically recorded. Statistical analysis was conducted using SPSS version 27. Data were presented as mean ± standard deviation for continuous variables and as frequencies with percentages for categorical variables. Group comparisons used the Independent Samples t-test, Chi-square, or Fisher's exact test, with significance defined as $p < 0.05$.

RESULTS

Both groups were comparable as regards age (early–mid 30s), sex distribution (72% males), comorbidities, trauma side, and associated fibular fractures (≈90%). Road traffic accidents and ground-level falls were the main injury mechanisms. Simpler AO patterns (43A1.1) predominated in the nailing group, while plating was associated with a higher share of complex subtypes (43A2–A3) (Table 1). Operative time was little bit longer in the plating group (127 ± 18.9 min) compared with the nailing group (116 ± 16.5 min), though the difference was not statistically significant (p = 0.182). In contrast, fibular fixation differed significantly between groups (p = 0.022), being performed in 66.7% of plating cases versus only 11.1% of nailing cases, where most fibular fractures were managed without fixation (Table 2). Malunion rates were comparable between groups (p = 0.261), with coronal deformity observed in 22.2% of nailing cases, while rotational deformity and nonunion occurred only in the plating group (11.1% each). Time to union, however, was significantly shorter with nailing (13.1 ± 1.5 weeks) compared to plating (16.8 ± 4.1 weeks, p = 0.016) (Table 3). Infection rates did not differ significantly between groups (p = 0.305). While no infections occurred in the nailing group, two cases (11.1%) of deep infection were reported with plating. The requirement for secondary procedures was observed only in the plating group (11.1% revision), whereas no such interventions were needed in the nailing group; however, the difference did not reach statistical significance (p = 0.305) (Table 4).

Functional outcome assessed by the Olerud and Molander score showed no statistically significant difference between groups (p = 0.307). The nailing group achieved a higher proportion of excellent results (77.8% vs. 44.4%), while the plating group demonstrated more good outcomes (44.4% vs. 22.2%) and included two cases (11.1%) with poor results (Table 5).

A 38-year-old female, nonsmoker, with a simple AO 43A1 distal tibial fracture following a fall to ground. Managed by closed reduction and fixation with Expert ILN, operative time only 60 minutes. Smooth recovery with uneventful follow-up, progressive weight-bearing, complete radiographic union at 6 months, and an excellent Olerud–Molander score at 6 months. (Figure 1).

A 40-year-old male smoker, manual worker, sustaining AO 43A2 fracture from RTA with associated fibular fracture. Treated with distal tibial locked plate using MIPPO technique and concurrent fibular fixation. The operating time was 100 minutes. Postoperative recovery was uneventful; at 20 weeks X-rays confirmed full callus formation with excellent OMAS. (Figure 2)..

To explore the potential confounding effect of fibular management, we compared outcomes between patients who underwent fibular fixation (n = 14) and those who did not (n = 22) irrespective of tibial fixation method. Mean union time was 15.7 ± 4.0 weeks with fibular fixation versus 14.5 ± 3.2 weeks without fixation (p = 0.38). Rates of malalignment (14.3% vs. 18.2%, p = 0.77) and nonunion (7.1% vs. 4.5%, p = 0.64) were also not significantly different. Within each tibial fixation group, no statistically significant association was found between fibular fixation and these primary outcomes.

Table 1: Demographic Data, Trauma Characteristics, and AO Classification of the Studied Cases (n=36)

Variable	Category	Nail Group (n = 18)	Plate Group (n = 18)	Test Value	P-value	Sig.
Age (years)	Mean ± SD	33.10 ± 10.90	36.30 ± 13.43	-0.585•	0.566	NS
	Range	20 – 57	20 – 55			
Sex	Male	13 (72.0%)	13 (72.0%)	0.000*	1.000	NS
	Female	5 (28.0%)	5 (28.0%)			
Occupation	Light Activity	2 (10.0%)	0 (0.0%)	3.818*	0.148	NS
	Moderate	4 (22.2%)	11 (61.0%)			
	Heavy	12 (68.0%)	7 (39.0%)			
HTN	No	16 (89.0%)	16 (89.0%)	0.000*	1.000	NS
	Yes	2 (11.0%)	2 (11.0%)			
DM	No	18 (100.0%)	16 (89.0%)	1.053*	0.305	NS
	Yes	0 (0.0%)	2 (11.0%)			
Mode of Trauma	Direct	4 (22.2%)	6 (33.3%)	1.167*	0.558	NS
	RTA	8 (44.4%)	6 (33.3%)			
	FFH	0 (0.0%)	0 (0.0%)			
	FTG	5 (33.3%)	6 (33.3%)			
Fracture Side	Right	8 (44.4%)	8 (44.4%)	0.000*	1.000	NS
	Left	10 (55.6%)	10 (55.6%)			
Fibular Fracture	Intact	2 (11.1%)	2 (11.1%)	0.000*	1.000	NS
	Fractured	16 (88.9%)	16 (88.9%)			
AO Classification	43A1.1	9 (50.0%)	2 (11.0%)	5.867*	0.319	NS
	43A1.2	4 (22.0%)	6 (33.0%)			
	43A1.3	2 (11.0%)	2 (11.0%)			
	43A2.1	0 (0.0%)	2 (11.0%)			
	43A2.3	3 (17.0%)	4 (22.0%)			
	43A3.3	0 (0.0%)	4 (22.0%)			

HTN: Hypertension, DM: Diabetes Mellitus, RTA: Road Traffic Accident, FFH: Fall From Height, FTG: Fall to Ground, AO: (AO classification of fractures).Statistical tests:* Chi-square test,• Independent t-test. P-value > 0.05: NS = Non-significant; P-value < 0.05: Significant; P-value < 0.01: Highly significant.

Table 2: Comparison Between Nail Group and Plate Group Regarding Operative Time and Fibular Fixation (n=36)

Variable	Category	Nail Group (n = 18)	Plate Group (n = 18)	Test Value	P-value	Sig.
Operative Time (minutes)	Mean ± SD	116.00 ± 16.47	127.00 ± 18.89	-1.388•	0.182	NS
	Range	100 – 150	100 – 150			
Fibular Fixation	Intact	2 (11.1%)	2 (11.1%)	7.611*	0.022	S
	Fixed	2 (11.1%)	12 (66.7%)			
	Not fixed	14 (77.8%)	4 (22.2%)			

SD: Standard Deviation. Statistical tests: * Chi-square test, • Independent t-test. P-value > 0.05: NS = Non-significant; P-value < 0.05: S = Significant; P-value < 0.01: Highly significant.

Table 3: Comparison Between Nail Group and Plate Group Regarding Malunion and Time for Union (n=36)

Variable	Category	Nail Group (n = 18)	Plate Group (n = 18)	Test Value	P-value	Sig.
Malunion	**No**	**14 (77.8%)**	**14 (77.8%)**	**4.000***	**0.261**	**NS**
	Sagittal plane deformity	**0 (0.0%)**	**0 (0.0%)**			
	Coronal plane deformity	**4 (22.2%)**	**0 (0.0%)**			
	Rotation	**0 (0.0%)**	**2 (11.1%)**			
	Nonunion	**0 (0.0%)**	**2 (11.1%)**			
Time for Union (weeks)	**Mean ± SD**	**13.10 ± 1.52**	**16.78 ± 4.06**	**-2.673•**	**0.016**	**S**
	Range	12 – 16	12 – 24			

SD: Standard Deviation. Statistical tests: * Chi-square test, • Independent t-test. P-value > 0.05: NS = Non-significant; P-value < 0.05: S = Significant; P-value < 0.01: Highly significant.

Table 4: Comparison Between Nail Group and Plate Group Regarding Infection and Need for Secondary Procedure (n=36)

Variable	Category	Nail Group (n = 18)	Plate Group (n = 18)	Test Value	P-value	Sig.
Infection	**None**	**18 (100.0%)**	**16 (88.9%)**	**1.053***	**0.305**	**NS**
	Superficial infection	**0 (0.0%)**	**0 (0.0%)**			
	Deep infection	**0 (0.0%)**	**2 (11.1%)**			
Need for Secondary Procedure	**No**	**18 (100.0%)**	**16 (88.9%)**	**1.053***	**0.305**	**NS**
	Dynamization	**0 (0.0%)**	**0 (0.0%)**			
	Debridement	**0 (0.0%)**	**0 (0.0%)**			
	Revision	**0 (0.0%)**	**2 (11.1%)**			

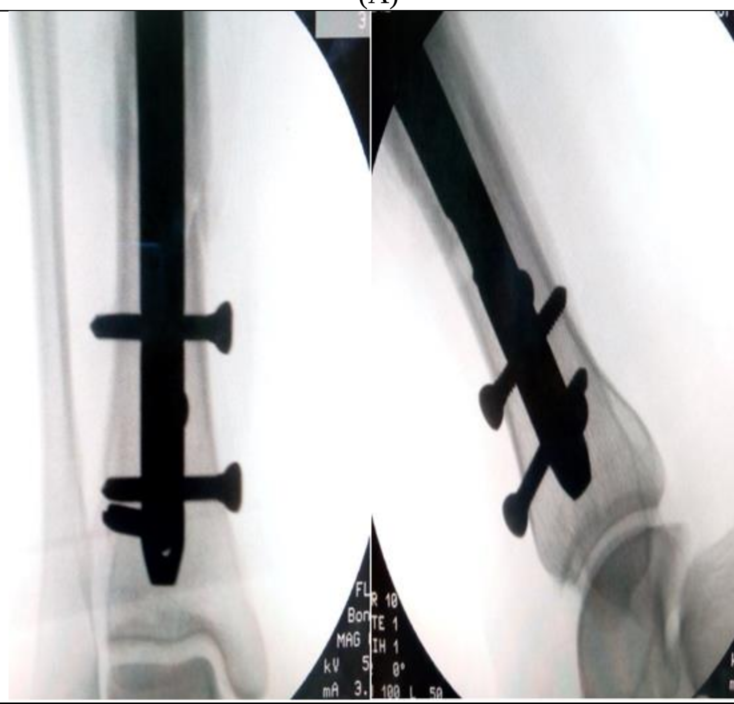
SD: Standard Deviation.Statistical tests: * Chi-square test, • Independent t-test. P-value > 0.05: NS = Non-significant; P-value < 0.05: S = Significant; P-value < 0.01: Highly significant.

Table 5: Comparison between nail group and plate group regarding Olerud and Molander score

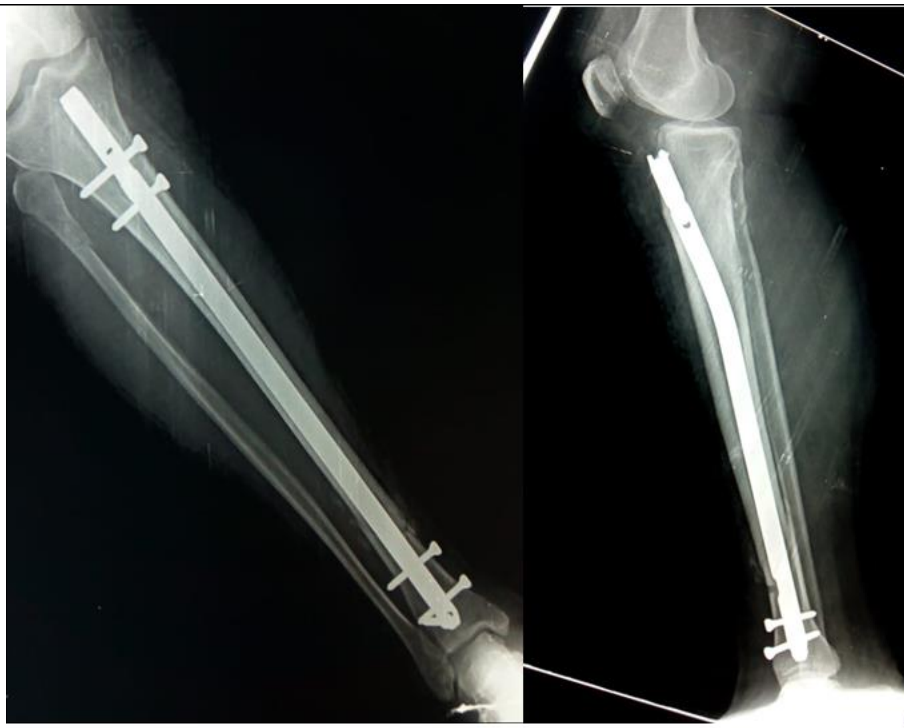
Score	Nail group	Plate group	Test value	P-value	Sig.
	No. = 18	**No. = 18**			
Excellent	**14 (77.8%)**	**8 (44.4%)**	**2.359***	**0.307**	**NS**
Good	**4 (22.2%)**	**8 (44.4%)**			
Fair	**0 (0.0%)**	**0 (0.0%)**			
Poor	**0 (0.0%)**	**2 (11.1%)**			

P-value > 0.05: Non significant; P-value < 0.05: Significant; P-value < 0.01: Highly significant *: Chi-square test

(A)



(B)

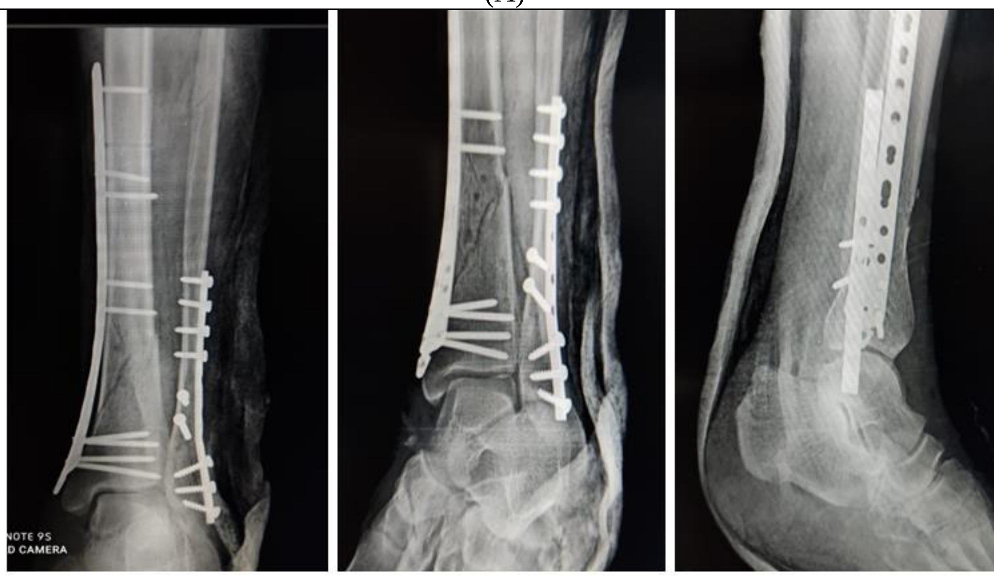


(C)

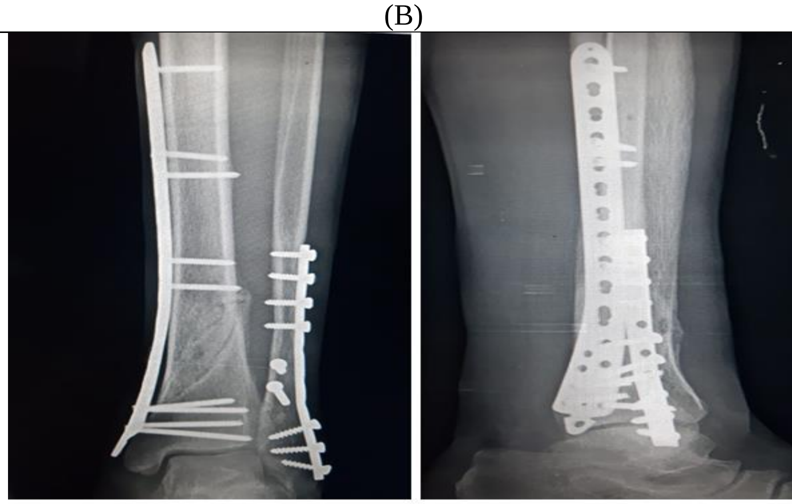
(D)

Figure 1: Case 1 from group Intramedullary Nailing – ILN (A):Preoperative x-ray, (B): Intraoperative images, (C): Post-operative x-ray, (D): Follow up X ray at 6 months

(A)



(B)



(C)

Figure 2: Case 2 from group Minimally Invasive Plate Osteosynthesis – MIPO (A):Preoperative x-ray, (C): Post-operative x-ray, (C): Follow up X ray at 20 weeks showed full union of the fracture by callus.

DISCUSSION

Tibial fractures are among the most frequently encountered long bone injuries, yet their management remains complex. Distal tibial fractures, in particular, pose a greater challenge due to the subcutaneous location of the bone, its limited vascular supply, and the relatively thin, soft tissue envelope. Although both IMN and MIPO with locked plates are widely accepted options, comparative evidence remains limited and sometimes conflicting [14].

Five randomized controlled trials have compared these two techniques in distal tibial fractures. Shrestha et al. [15] investigated the use of locking plates, while Guo et al. [16] conducted a trial using standard medial plates. Im and Tae [17] similarly compared closed reduction and IMN with open plating, and Guo et al. [18] evaluated percutaneous plating versus IMN in metaphyseal fractures. Mauffrey et al. [19] carried out a pilot randomized study comparing locking plate fixation with IMN in extra-articular fractures. The heterogeneity of these studies is notable, with different plating techniques (anterolateral versus medial) and inconsistent reporting of whether MIPO or open methods were used, which limits direct comparison of outcomes.

Fibular management is another variable that influences results. Some authors have observed that IMN performed in the presence of an intact or separately fixed fibula may increase the risk of delayed union or nonunion [20]. In three of the randomized trials, fixation of the fibula was performed at the discretion of the surgeon, and up to one-third of patients had their fibula stabilized [15-17]. While some evidence suggests that fixing the fibula helps restore tibial length and alignment, thereby reducing the risk of malalignment, robust data supporting this practice are limited [18,19]. In our study, fibular fixation was reserved for fractures within 7 cm of the lateral malleolus or when tibial reduction required additional stability, a strategy in line with selective fixation practices in earlier trials.

In our study, fibular fixation was performed far more often in the MIPO group (66.7% vs. 11.1%, $p = 0.022$). This difference likely reflects the intraoperative perception of greater fracture instability or complexity when plating was chosen. Because fibular stabilization can enhance tibial alignment and mechanical stability, this imbalance introduces a potential confounder, acting as a surrogate marker of fracture severity and potentially influencing union and alignment outcomes independent of the primary fixation method.

Beyond randomized studies, three additional comparative series have provided retrospective evidence. Janssen et al. [21] compared plating and IMN in a case-matched cohort of 12 patients per group, while Vallier et al. [22] and Kruppa et al. [23] assessed larger retrospective samples. When these studies are viewed collectively, several patterns emerge. Rates of deep infection and wound-healing complications appear similar between the two fixation methods, even in cases involving high-energy trauma or open injuries with significant soft tissue compromise [24].

Some studies have reported that patients treated with intramedullary nailing may regain function more quickly than those treated with locked plating, although this finding has occasionally been influenced by higher nonunion rates in the plating groups [25]. A historically recognized drawback of tibial nailing is the occurrence of anterior knee pain. However, more recent reports suggest that with careful surgical technique particularly avoiding nail prominence and minimizing trauma to the patellar tendon—the incidence of persistent knee pain is not higher than with plating [26,27].

The present study compared surgical and functional outcomes between IMN and MIPO with locked plating for extra-articular distal tibial fractures, and our results were interpreted in light of existing literature.

Guo et al. [16], in a randomized trial of 85 patients, compared closed intramedullary nailing with percutaneous plating and reported similar union rates and functional results, though plating was associated with longer

operative and fluoroscopy times. Likewise, Li et al. [18] conducted a larger prospective randomized study on 137 patients treated with MIPO, IMN, or external fixation. Their findings showed no significant difference in union rates between MIPO and IMN; however, nailing permitted earlier mobilization and shorter hospitalization, while plating was associated with fewer alignment problems.
Our results also align with the most recent meta-analyses. Zhou et al. [11] and Li et al. [12] reported that IMN offers faster union and fewer infections, while MIPO shows lower rates of malalignment and knee pain.
Mauffrey et al [19] carried out a smaller pilot trial, randomizing 12 patients to each technique. Although the sample size was limited, both treatment modalities achieved acceptable results, with no clear superiority demonstrated in terms of malunion, infection, or need for reoperation.
When compared to these published studies, the results of the present work align with the consensus that both IMN and MIPO provide satisfactory fixation in distal tibial fractures. Our study supports the view that the choice between these two techniques should be guided by fracture configuration, soft-tissue condition, and surgeon experience rather than expecting one method to be universally superior.
Vallier et al. [14] conducted a randomized prospective trial on 104 skeletally mature patients with extra-articular distal tibial fractures, treated with either a reamed intramedullary nail or a medial plate. They found no significant difference in malunion, nonunion, infection, or the need for secondary surgery, despite the inclusion of nearly 40% open fractures and frequent concomitant fibular fixation. In line with these findings, Yavuz et al. [28] compared intramedullary nailing and plating in 55 patients with distal tibial fractures extending toward the ankle. With more than two years of follow-up, both methods achieved satisfactory radiological healing and functional recovery, although implant-related irritation occurred more frequently in the plating group.
In the current study of 36 patients, baseline demographic characteristics, fracture classification, and operative variables did not differ significantly between groups. Mean operative time was slightly shorter for IMN (116 minutes) compared with MIPO (127 minutes), but this difference was not statistically significant. Our results differ from those of Guo et al. [16] and Li et al. [18], both of whom reported significantly shorter operative times in IMN groups. This discrepancy likely reflects multiple influencing factors such as associated fibular fractures, complexity of reduction, surgical assistance, and operator experience.
With respect to infection, none of the patients in our IMN group developed infectious complications, whereas two patients in the MIPO group experienced deep infections that proved resistant and ultimately progressed to nonunion requiring revision. This outcome contrasts with Li et al. [18], who found higher superficial infection rates after plating, and with Mauffrey et al. [19], who observed more infections following IMN. Several other reports, however, have described no significant difference in infection risk between the two techniques [14,28]. Taken together, these findings highlight that soft-tissue handling, early detection, and prompt intervention are critical factors influencing postoperative infection rather than fixation method alone.
In the present study, time to union was significantly shorter in the IMN group, averaging 13.1 weeks compared with 16.8 weeks in the MIPO group ($P = 0.016$). This was the principal statistically significant outcome of our series. The difference may be explained by the biomechanical properties of the two constructs: intramedullary nails act as load-sharing devices, permitting controlled micromotion at the fracture site and encouraging callus formation, whereas plates are load bearing and restrict early functional loading. This earlier capacity for partial weight-bearing in the IMN group may have accelerated union. In contrast, several other studies have reported no significant difference in time to

union between these two fixation strategies [16,18,19].

Complications in our study were relatively few. In the MIPO group, one patient developed a 25° external rotational deformity and another showed delayed union. In the IMN group, two patients had malalignment in the coronal plane. These findings align with Vallier et al. [14], who observed higher rates of malalignment in the IMN group, and with Mauffrey et al. [19], who noted more frequent nonunion in the plating group. Thus, while each technique carries its own pattern of complications, overall rates remain comparable.

Secondary procedures were also analyzed. In our study, the need for reoperation was low, but when required, the pattern reflected the fixation method. Plate fixation was complicated by deep infection and hardware irritation, leading to debridement and plate removal, whereas IMN cases required dynamization. This observation parallels Mauffrey et al. [19], who reported more frequent secondary procedures in patients treated with plates, although other series did not find significant differences between groups [14,28].

Functional recovery in this study was evaluated using OMAS. At six months, outcomes in the MIPO group included 12 excellent, four good, and two poor results, the latter corresponding to patients who developed infection and nonunion. In comparison, the IMN group showed 14 excellent and four good outcomes. Although intramedullary nailing appeared to yield slightly higher scores, the difference did not reach statistical significance ($p = 0.307$). These findings are consistent with previous comparative studies, where functional evaluation using different scoring systems such as the AOFAS and Mazur scales similarly failed to show significant differences between nailing and plating techniques [29].

The main strength of this study is its prospective randomized design with comparable groups, minimizing bias. All cases were managed in a single institution by experienced surgeons, ensuring uniform surgical technique and follow-up. The relatively small sample size and short follow-up limit the ability to detect rare complications or long-term outcomes. Functional assessment relied only on the OMAS, and the single-center design may restrict generalizability.

Importantly, the modest sample size (18 patients per group) limits the statistical power to detect smaller but clinically meaningful differences between IMN and MIPO. The study was designed as a pilot randomized trial to generate preliminary comparative data; thus, its findings should be interpreted as hypothesis-generating and confirmed by larger, adequately powered multicenter studies. Another limitation is the heterogeneity of fracture configurations within the AO 43A subtypes, which may affect healing characteristics and complication rates. Although randomization yielded comparable distributions between groups, this variability could still confound subtle differences in outcomes.

CONCLUSION

Both IMN and MIPO are effective for extra-articular distal tibial fractures. IMN showed faster union and fewer infections but more malalignment, while MIPO achieved better alignment with slower healing and higher infection risk. Careful soft-tissue handling and tailored preoperative planning remain essential for optimal outcomes.

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Availability of Data: Relevant datasets generated or utilized during the course of this research are not publicly available but may be provided by the corresponding author upon formal inquiry and reasonable justification.

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