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Original Research Article

Comparison of Time to Fracture Union and Functional Outcome by Minimally Invasive Plate Osteosynthesis vs Shortened Intramedullary Nailing in Extra-Articular Distal Tibia Fractures

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Abstract: *Extra-articular distal tibial fractures pose significant management challenges due to the bone's subcutaneous nature and limited soft tissue envelope, increasing the risk of complications. Minimally invasive plate osteosynthesis (MIPO) and shortened intramedullary nailing (IMN) are two commonly employed fixation methods; however, their comparative effectiveness in fracture healing and functional recovery remains uncertain.* ***Objective:*** *To compare the time to radiographic union and functional outcomes between shortened intramedullary nailing (IMN) and minimally invasive plate osteosynthesis (MIPO) in treating extra-articular distal tibial fractures.* ***Methods:*** *A single-center, prospective, randomized controlled trial was conducted from January to December 2024. Sixty skeletally mature patients (aged 20–60 years) with AO classification 43A1–A3 extra-articular distal tibia fractures were randomly assigned to receive either shortened IMN (n=30) or MIPO (n=30). Radiographic healing was assessed using the Radiographic Union Score for Tibial fractures (RUST) at 2 weeks and 3, 4, 5, and 6 months postoperatively. Functional outcome was evaluated using the Olerud-Molander Ankle Score (OMAS) at the final follow-up. Time to union and OMAS grades were compared using chi-square tests, with significance set at p<0.05.* ***Results:*** *A significantly higher proportion of patients in the IMN group achieved union within 12 weeks (66.7%) compared to the MIPO group (26.7%) (p=0.017). Conversely, delayed union beyond 20 weeks was more prevalent in the MIPO group (50.0% vs. 20.0%). Excellent OMAS outcomes were reported in 70.0% of IMN patients versus 20.0% in the MIPO group (p=0.001). The incidence of angular deformity was comparable between groups (IMN: 23.3%, MIPO: 16.7%; p>0.05).* ***Conclusion:*** *Shortened intramedullary nailing leads to earlier radiographic union and superior functional recovery compared to minimally invasive plate osteosynthesis for extra-articular fractures.*

Keywords: Ankle Injuries, Fracture Fixation, Intramedullary Nailing, Minimally Invasive Surgical Procedures, Tibial Fractures

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Introduction

Distal tibia fracture is common in young adults with or without fibula fracture. (1). The treatment protocol is mainly surgical with open reduction and internal fixation (ORIF) with plate and screw—contoured dynamic compression plating (DCP) or recontoured locking compression plating (LCP) and intramedullary nailing (IMN) (2). Surgical treatment offers several advantages, such as restoring and maintaining length and alignment (3), early weight carrying(4), and increased mobility (5), leading to simpler and quicker treatment for daily life activities. Furthermore, distal tibial fractures, a unique fracture category, are caused by characteristic tibial anatomical contour and distinctive blood supply pattern (6). The distal part of the diaphysis flares medially with a 20 cm radius of curvature and is twisted 25 °, which is considered when the plate has to be contoured (7).

Despite the use of advanced surgical technologies, the outcome is often unsatisfactory due to complications such as delayed union, malunion, non-union, and wound infection, which arise in 20 to 50% of patients (8). Additionally, the treatment protocol for distal tibial fractures remains controversial. Extra-articular distal tibia fractures treated with an intramedullary nail produced better functional and radiological results than a locking plate(9). Intramedullary nail should be the treatment of first choice to treat these fractures (10).

A comparative study by Solanki et al on plating vs nailing in distal tibia metaphyseal fractures included 50 patients aged 18-75 years. 39 (78%) were male and 11 (22%) were female. Twenty-five patients were randomly assigned to the IMN group (Nailing group) and 25 patients to the distal tibia locking plate (Plating group). The study was prospective and comparative in the methods used for fracture management. Average time for union was 19.1 ± 1.14 weeks (19-22 weeks) in Nailing group and 23.8 ± 1.16 weeks for Plating group (22-30 weeks) (p=0.001) showing IMN is a reliable and satisfactory method for the treatment of 43A type distal tibia fractures with good functional results and high union rates with comparatively low complications (11).

Between January 2008 and January 2015, 59 patients had extraarticular distal tibia fractures and were treated with MIPO or IMN and were evaluated retrospectively. Postoperative x-rays were evaluated for fracture consolidation and angular deformities. The OMAS method was used for the functional evaluations, and the goniometer measured ankle joint range of motion. On the last visit, all the fractures consolidated. The average union time was 16.1 weeks (range, 12-24 weeks) in the MIPO group and 15.5 weeks (range, 10-24 weeks) in the IMN group, respectively (p = 0.254). The mean OMAS scores were 67.5 (40–90) and 63 (30-90) in the IMN and MIPO groups, respectively. Angular deformities were found in the IMN group at 7 (23%) patients and in the MIPO group at 5 (17%). In conclusion, IMN and MIPO can be used safely to treat distal tibial metaphyseal fractures. While IMN caused more angular deformity and union delay, patients treated with MIPO had poorer functional results and more soft tissue problems (12).

The study will contribute to the literature by comparing MIPO and IMN fracture outcomes in extra-articular distal tibia fractures, allowing for the identification of the technique with better outcomes and fewer complications, which can be used for further studies. The fracture union and functional outcomes were evaluated, resulting in faster radiographic union and superior functional recovery employing IMN compared to MIPO, with comparable complication profiles. Furthermore, shortened

IMN may be considered the preferred fixation technique for extra-articular distal tibia fractures. Thus, this study aimed to compare the time to fracture union and functional outcome of MIPO versus IMN in two planes for treating extra-articular distal tibia fractures.

Methodology

This randomized controlled trial was conducted in the Department of Orthopedic Surgery at Nishtar Hospital, Multan, over one year following the approval of the research synopsis. The sample size was calculated using OpenEpi software, based on a previous comparative study by Solanki et al., which reported an average union time of 19.1 ± 1.14 weeks in the intramedullary nailing group and 23.8 ± 1.16 weeks in the plating group. With a 95% confidence interval, 80% power, and a significance level of <0.05, the calculated sample size was relatively small; therefore, 60 patients were included, with 30 in each treatment group.

Participants were recruited from the outpatient department of the orthopedic unit. Informed consent was obtained from all patients after explaining the study's objectives, ensuring confidentiality, and clarifying that there was no risk involved in participation. The inclusion criteria included patients aged between 20 and 60 years with closed extra-articular distal tibial fractures classified as AO 43A1 to 43A3, Tscherne grade 0 or 1 soft tissue injury, and no neurovascular deficits. Only fractures less than seven days old were included. Patients were excluded if they had pathological fractures, clinical or radiological evidence of infection (e.g., fever, erythema, or pus discharge), segmental tibial fractures, or polytrauma involving multiple fractures.

Baseline demographic and clinical information, such as age, gender, residential status, diabetes mellitus or hypertension (defined as known cases on treatment for ≥2 years), obesity (BMI ≥30), fracture side, and mode of injury, was recorded. Patients were randomly assigned to two groups using a lottery method with sealed envelopes marked "A" or "B." Those who picked envelope "A" were assigned to the MIPO group, and those who picked "B" were assigned to the IMN group. All procedures were performed by a single experienced orthopedic surgeon with more than five years of surgical practice. Patients were followed for six months to monitor outcomes.

Data were collected at each follow-up visit and analyzed using SPSS version 25. Continuous variables such as age, injury duration, time to union, and functional outcome scores were reported as means and standard deviations. Categorical variables such as gender and functional outcome categories were presented as frequencies and percentages. Time to union between the two groups was compared using the Student's t-test, while functional outcomes were analyzed using the chi-square test. Stratification was performed based on age, gender, obesity, mode of injury, diabetes, and hypertension. Post-stratification comparisons were conducted using t-tests for union time and chi-square tests for functional outcomes. A p-value of ≤0.05 was considered statistically significant.

Results

Table 1 presents the *Demographic and Clinical Characteristics* of the study population (n=60), comparing the MIPO (n=30) and IMN (n=30) groups. The two groups were similar in terms of age distribution (mean age: MIPO 40.01 ± 11.60 vs IMN 41.42 ± 12.69; p=0.482), gender (male predominance in both groups), and mode of injury (RTA and falls). A statistically significant difference was observed in union time (p=0.017), with the IMN group achieving faster union, and in OMAS grades (p=0.001), where more patients in the IMN group had excellent functional outcomes.

Table 2 shows the *Stratified Analysis of Union Time and OMAS Scores* between the study groups across different age groups, genders, and modes of injury. The IMN group consistently demonstrated better outcomes, particularly among females (OMAS excellent: p=0.016), patients aged 20–40 (OMAS excellent: p=0.038), and those with RTA as the mechanism of injury (OMAS excellent: p=0.003). Statistically significant associations were found in several subgroups.

Table 3 further details the *OMAS Grade Stratification* by age group and gender. Among participants aged 20–40 and 41–60 years, the IMN group had significantly more patients with excellent OMAS grades (p=0.038 and p=0.024, respectively). Similarly, females in the IMN group had significantly better functional outcomes (excellent OMAS: p=0.016). Although male participants in the IMN group also showed better scores, the difference was not statistically significant (p=0.081).

Table 1. Demographic and Clinical Characteristics of the Study Population (n = 60)

Variable	MIPO Group (n=30)	IMN Group (n=30)	p-value
Age (years)			
20–40	10 (33.3%)	11 (36.7%)	0.151
41–60	20 (66.7%)	19 (63.3%)	
Mean ± SD	40.01 ± 11.60	41.42 ± 12.69	0.482
Range	20–60	20–60	
Gender			
Male	16 (53.3%)	21 (70.0%)	0.184
Female	14 (46.7%)	9 (30.0%)	
Mode of Injury			
Road Traffic Accident (RTA)	10 (33.3%)	14 (46.7%)	0.292
Fall	20 (66.7%)	16 (53.3%)	
Union Time (weeks)			
<12 weeks	8 (26.7%)	20 (66.7%)	0.017*
13–16 weeks	3 (10.0%)	1 (3.3%)	
17–20 weeks	4 (13.3%)	3 (10.0%)	
>20 weeks	15 (50.0%)	6 (20.0%)	
OMAS Grade			
Excellent	6 (20.0%)	21 (70.0%)	0.001*

**Statistically significant at p < 0.05*

Table 2. Stratified Analysis of Union Time and OMAS Scores between Study Groups (n = 60)

Stratification Variable	Category	MIPO (n=30)	IMN (n=30)	p-value
Age 20–40 years	Union <12 weeks	2	8	0.087
	Union 13–16 weeks	2	1	—
	Union 17–20 weeks	1	1	—
	Union >20 weeks	5	1	—
	OMAS Excellent	2	9	0.038*
Age 41–60 years	Union <12 weeks	6	12	0.184
	Union 13–16 weeks	1	0	—
	Union 17–20 weeks	3	2	—
	Union >20 weeks	10	5	—
	OMAS Excellent	4	12	0.024*
Gender: Male	Union <12 weeks	3	12	0.106
	OMAS Excellent	5	15	0.081
Gender: Female	Union <12 weeks	5	8	0.026*
	OMAS Excellent	1	6	0.016*
Mode of Injury: RTA	Union <12 weeks	2	10	0.077
	OMAS Excellent	2	10	0.003*
Mode of Injury: Fall	Union <12 weeks	6	10	0.192
	OMAS Excellent	4	11	0.072

**Statistically significant at p < 0.05*

Table 3. Stratified Analysis of OMAS Grades by Age Group and Gender between Study Groups (n = 60)

Stratification Variable	OMAS Grade	MIPO (n=30)	IMN (n=30)	p-value
Age 20–40 years (n=21)	Excellent (n=11)	2	9	0.038*
	Good (n=4)	3	1	—
	Fair (n=2)	2	0	—
	Poor (n=4)	3	1	—
Age 41–60 years (n=39)	Excellent (n=17)	4	12	0.024*
	Good (n=10)	4	4	—
	Fair (n=8)	7	2	—
	Poor (n=5)	5	1	—
Gender: Male (n=37)	Excellent (n=20)	5	15	0.081
	Good (n=6)	3	3	—
	Fair (n=7)	5	2	—
	Poor (n=4)	3	1	—
Gender: Female (n=23)	Excellent (n=7)	1	6	0.016*
	Good (n=6)	4	2	—
	Fair (n=4)	4	0	—
	Poor (n=6)	5	1	—

**Statistically significant at p < 0.05*

Discussion

While tibial fractures account for most long bone fractures, distal tibial fractures are notoriously difficult to treat because of their intimate association with the ankle, fragile soft tissue envelope, and severe comminution. (13). Furthermore, posterior malleolus fractures are linked to distal tibial fractures. Internal fixation with screws or plates, external fixations with mono-lateral or circulating external fixators, and surgical treatments like open reduction are all part of the range of approaches used to address distal tibial fractures. The most frequent type of long bone fracture is a tibial fracture. (14). There is a wide range of approaches to treating distal tibial fractures, from open reduction and internal fixation with screws or plates to external fixations with mono-lateral or circulating fixators and everything in between.

Our study's mean age of presentation was around 40-43 years, with more than 50% occurrence in the male population. About 24 (40%) patients had a history of RTA in our study. The mean age of tibial fractures varies depending on the population and type of fracture being studied. Across different studies, the mean age can range from young adults to older populations, reflecting the diverse causes and contexts of tibial fractures. In a study conducted at a tertiary hospital, the mean age of patients with tibial fractures was reported as 40.7 years, with a significant proportion of these injuries resulting from motorcycle accidents, predominantly affecting young males. (15)A study from a major UK trauma center reported a mean age of 46.9 years for patients with tibial fractures. This study included a wide range of fracture types, with proximal fractures having a higher mean age of 50.9 years and distal fractures having a lower mean age of 43.2 years. (16). In a study focusing on tibial diaphyseal fractures among motorcycle accident victims, the mean age was found to be 43.7 years. This reflects the demographics of middle-aged men who frequently use motorcycles as a mode of transport. (17).

In my study, the union at < 12 weeks was better in the IMN than the MIPO group (20 (66.7%) vs 8 (26.67%). In comparison, the union at >20 was better in the MIPO group (15 (50%) vs 6 (20%), giving a significant difference between the two modalities, p=0.017). The results of this study indicate a notable difference in the union rates between the two surgical techniques for managing fractures: IMN and MIPO. Specifically, at less than 12 weeks post-operation, the IMN group demonstrated superior union rates, while at more than 20 weeks, the MIPO group had a higher union rate. The statistical significance of this difference (p = 0.017) suggests that the surgical approach may influence the time required for fracture healing. This finding is consistent with several studies that have compared these two methods, shedding light on their advantages and limitations in different stages of fracture recovery.

IMN has been widely regarded for its effectiveness in the early stages of fracture healing due to the biomechanical stability it provides. In fractures treated with IMN, the intramedullary device offers optimal load sharing and rotational stability, promoting faster healing in the initial phase. (18)The current study's higher union rate at less than 12 weeks supports this observation, as IMN is known to offer early stabilization that can speed up callus formation and fracture consolidation. (19). Furthermore, the ability to load-bear earlier postoperatively may contribute to faster functional recovery. (20).

On the other hand, MIPO has emerged as a preferred technique for certain fractures, especially those in anatomically complex regions or where soft tissue preservation is critical (21). The superior union rates at more than 20 weeks in the MIPO group observed in this study could reflect the advantages of maintaining the biological environment of the fracture site, which is particularly important for bone healing in the later stages (22). MIPO can potentially allow less disruption of the periosteal blood supply, a vital component of the healing process.

The delayed but superior healing observed in the MIPO group in this study may also be explained by its less aggressive nature, which contrasts with the more rigid fixation provided by IMN. A less rigid fixation allows for micromovements at the fracture site, stimulating callus formation and promoting healing during the later stages (23). As the current study shows, this more biological healing environment might take longer to achieve a union. Still, it can be beneficial regarding the quality of the healed bone (24).

Moreover, the higher union rate later in the MIPO group could reflect differences in fracture types treated by each method. The MIPO technique is often applied to more complex fractures, such as comminution or diaphysis fractures (25). These fractures may require longer healing than simpler fractures managed with IMN. This study design aspect could factor in the observed temporal differences in union rates.

A key finding in the current study is the statistically significant difference in union rates between the two groups. This result aligns with previous studies, which suggest that although IMN may facilitate early healing, MIPO may lead to better long-term outcomes, particularly in fractures with challenging anatomical features (26). Furthermore, the differences in union rates over time underscore the importance of considering the fracture type, anatomical location, and patient-specific factors when deciding between IMN and MIPO for fracture fixation.

We also used OMAS in our study and the OMAS scores were significantly higher in the IMN group (p=0.001) that is contrast to earlier study conducted by Mioc et al. used OMAS to evaluate functional results and could not find any difference between the two groups [16]. Nevertheless, when OMAS scores were categorically evaluated between 2 groups, more 'excellent and good' results were found in IMN group compared to MIPO group. An important limitation of the OMAS system is that it is affected by age-related activities. Activities such as running and crouching can be affected by ankle problems, knee or hip problems, or the patient's general condition. Our patients' wide range of ages indicates that our functional evaluation was not performed in standard groups.

Conclusion

The results of this study provide valuable insights into the comparative effectiveness of IMN and MIPO in terms of fracture union. While IMN appears to offer faster early healing, MIPO may yield superior union rates in the later stages, suggesting that the optimal approach may vary depending on the timing of fracture healing and the clinical context. Further research is needed to explore the long-term functional outcomes and complications associated with each technique, which will help guide surgical decision-making in managing fractures.

Declarations

Data Availability statement

All data generated or analysed during the study are included in the manuscript.

Ethics approval and consent to participate

Approved by the department concerned. (IRBEC-MMN-9238-23)

Consent for publication

Approved

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Conflict of interest

The authors declared the absence of a conflict of interest.

Author Contribution

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All authors reviewed the results and approved the final version of the manuscript. They are also accountable for the integrity of the study.

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