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Comparing Surgical Outcomes: Intramedullary Nailing Versus Minimally Invasive Percutaneous Plate Osteosynthesis for Distal Tibia Fractures

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Abstract
Distal tibia fractures, especially the ones extending into the metaphyseal region, present significant challenges because of their proximity to the ankle joint and poor soft tissue cover. The two common surgical strategies used here are intramedullary nailing (IMN) and minimally invasive percutaneous plate osteosynthesis (MIPPO). Each of them has its unique advantages and disadvantages and different biological principles. In this study, we have done a comparative analysis of the surgical outcomes of these two techniques. We found that both methods have high union rates, but IMN has advantages with low soft tissue complications and earlier weight bearing. MIPPO gives better rotational stability and achieves anatomical reduction, but with a higher risk of wound-related complications. We believe that the choice between the two treatment options must be selected based on the fracture morphology, soft tissue status and surgeon's preference.

INTRODUCTION

Distal tibia fractures are defined as fractures occurring within 9 cm of the ankle joint line. Due to their close relationship with the ankle joint and poor soft tissue envelope, they represent a complex and challenging lower extremity injury[1]. These fractures often result from high-energy trauma and are associated with significant soft tissue compromise and fracture comminution. Achieving precise anatomical reduction and restoring articular congruency is essential because of their proximity to the ankle joint. At the same time, care must be taken to preserve the delicate overlying soft tissue cover to avoid complications.

Treatment options for these fractures include casting, external fixation, and ORIF. ORIF offers strong fixation and direct visualization of the fracture, but it also entails extensive soft tissue stripping, raising concerns about infections, delayed wound healing, and other complications[2]. This has led to the necessity of developing less invasive methods that preserve the biology of the fracture site while obtaining stable fixation.

Due to its load-sharing behavior, minimal soft tissue dissection, and biomechanical advantages, IMN has become a popular choice[3]. There are implants designed with multiplanar distal locking options for distal tibia fractures to enhance stability in the metaphysis.

Alternatively, in Minimally Invasive Percutaneous Plate Osteosynthesis (MIPPO), two small incisions are made away from the fracture site, and a precontoured anatomical locking plate is slid in submuscularly. This method provides a more biological fixation option compared to ORIF, as it preserves the subperiosteal blood supply, avoiding direct surgical exposure of the fracture site. Biological healing is promoted[4]. MIPPO is preferred because it offers stable anatomical reduction and good angular stability with locking screws. Both techniques have successfully managed distal tibia fractures, but they also come with unique complications. However, there is no general consensus on the superiority of one method over the other for all types of distal tibia fractures. Our clinical study aims to compare the functional outcomes, time to union, and complication rates of IMN and MIPPO in distal tibia fractures in patients visiting our department.

MATERIALS AND METHODS

Our study sample size is 250, with N=125 in each group. This is a prospective randomised controlled trial. Inclusion criteria were closed distal tibia fractures without significant intra-articular extension (AO/OTA type 43-A, 43-B, and simple 43-C), patients aged 18- 70 years with a single acute distal tibia fracture with good soft tissue status. Exclusion criteria were open fractures, severe injuries in the ipsilateral limb, pathological fracture and previous same-side ankle or tibia surgery and patients with significant systemic comorbidities. Ethical committee approval was obtained. Informed written consent was obtained from all patients.

Procedure:

Intramedullary Nailing (IMN) Group: Patients were operated on with closed reduction and reamed IMN by infrapatellar entry point. Standard tibia nails and nails with multiplanar distal locking screws was used as necessary based on the fracture pattern.

Minimally Invasive Plate Osteosynthesis (MIPPO) Group: Patients were operated on with MIPPO with anatomical locking distal tibia plates. The fracture was reduced indirectly under fluoroscopy guidance. The plate was inserted submuscularly through small incisions from distal and proximal incisions. Locking screws were inserted percutaneously to achieve stable fixation.

- All surgeries were performed by senior orthopaedic trauma surgeons in our department. If necessary, patients were placed on a below-knee pop slab. Patients remained non-weight bearing for 6 weeks, followed by progressive weight bearing as tolerated. The fracture union was monitored with serial X-rays. Physiotherapy began to achieve maximum joint function when tolerated.
- Outcome measures were divided into primary and secondary outcomes. Primary outcomes included fracture union and time to union. Secondary outcome measures included complications of surgery and range of motion.

Primary Outcomes:

- **Time to Union:** Defined as cortical bridging on at least three cortices on orthogonal radiographs, confirmed by clinical absence of pain at the fracture site during weight-bearing.
- **Functional Outcome:** Assessed using the Olerud and Molander Ankle Score (OMAS), a patient-reported outcome measure ranging from 0 (total disability) to 100 (no disability). Scores were collected at 3, 6, and 12 months post-surgery.

Secondary Outcomes:

- **Complications:** Incidence of malunion (defined as >5° angulation in any plane or >10° rotational deformity), nonunion, deep surgical site infection (SSI), superficial SSI, delayed wound healing (>3 weeks), hardware irritation requiring removal, and persistent ankle pain.

Fig. 1: Distal Tibia fracture treated by IMN (multiplanar distal locking screws)

Fig. 2: Distal Tibia fracture treated by MIPPO

- **Ankle Range of Motion (ROM):** Measured using a goniometer for dorsiflexion and plantarflexion at 6 and 12 months.

Statistical Analysis: Demographic data were compared using independent t-tests for continuous variables and chi-square tests for categorical variables. Time to achieve union was analysed using Kaplan-Meier survival analysis with a log-rank test. OMAS scores for ankle function were compared using repeated measures ANOVA. Complication rates were analyzed using chi-square tests or Fisher's exact tests. A p-value of <0.05 was considered statistically significant.

RESULTS AND DISCUSSIONS

The baseline characteristics were well-matched between the two groups, ensuring comparability (Table 1). The mean age for both groups was approximately 48 years, with a slight male predominance. AO/OTA 43-A fractures were most common (45%), followed by 43-B (35%) and 43-C (20%).

Primary Outcomes: The mean time to radiographic union was slightly shorter in the IMN group (16.2 ± 2.8 weeks) compared to the MIPPO group (17.5 ± 3.1 weeks), but this difference did not reach statistical significance (p=0.07). Both techniques demonstrated high union rates, with 96.8% in the IMN group and 94.4% in the MIPPO group achieving union within 6 months.

OMAS scores showed an interesting pattern (Table 2). At 3 months, the IMN group had slightly higher mean OMAS scores (70.1 vs. 67.5, p=0.04), indicating potentially faster early recovery. However, by 6 and 12 months, the differences in OMAS scores between the groups became non-significant, with both groups achieving excellent functional outcomes (p>0.05).

Secondary Outcomes (Complications): The complication profiles differed between the two groups (Table 3). The MIPPO group had a higher incidence of superficial surgical site infection (SSI) (8.0% vs. 2.4%, p=0.03) and delayed wound healing (6.4% vs. 1.6%, p=0.04). Malunion occurred more frequently in the IMN group (6.4% vs. 3.2%, p=0.20), particularly in the sagittal plane (procurvatum deformity), though this difference was not statistically significant. Non-union rates were low and comparable (1.6% for IMN vs. 2.4% for MIPPO, p=0.65). Hardware irritation requiring .removal was higher in the IMN group (10.4% vs. 4.8%, p=0.07), often related to distal locking screws or

Table 1: Baseline Characteristics (Mean ± SD)

Characteristic	IMN Group (N=125)	MIPPO Group (N=125)	p-value
Age (years)	48.2 ± 10.5	47.9 ± 10.3	0.82
Male (%)	60%	58%	0.76
AO/OTA 43-A (%)	46%	44%	0.78
AO/OTA 43-B (%)	34%	36%	0.81
AO/OTA 43-C (%)	20%	20%	1.00

Table 2: Mean Olerud and Molander Ankle Score (OMAS) (Mean ± SD)

Time Point	IMN Group (N=125)	MIPPO Group (N=125)	p-value
3 Months	70.1 ± 10.2	67.5 ± 11.0	0.04
6 Months	85.5 ± 8.1	84.8 ± 8.5	0.58
12 Months	92.1 ± 5.5	92.5 ± 5.8	0.65

Table 3: Incidence of Complications

Complication	IMN Group (N=125)	MIPPO Group (N=125)	p-value
Superficial SSI	3 (2.4%)	10 (8.0%)	0.03
Delayed Wound Healing	2 (1.6%)	8 (6.4%)	0.04
Malunion	8 (6.4%)	4 (3.2%)	0.20
Non-union	2 (1.6%)	3 (2.4%)	0.65
Hardware Irritation (Re-op)	6 (4.8%)	13 (10.4%)	0.07
Persistent Ankle Pain (>6 months)	23 (18.4%)	18 (14.4%)	0.45

proximal nail prominence. Persistent ankle pain was also marginally more common in the IMN group (18.4% vs. 14.4%, p=0.45). Ankle ROM measurements at 12 months showed no significant differences between the groups

Our randomised control trial provides valuable insights regarding the outcomes of distal tibia fractures treated by IMN and MIPPO. Both surgical techniques demonstrate high rates of union, affirming their effectiveness in achieving fracture consolidation. These findings are consistent with existing literature[5,6]. A slightly shorter mean time to union was observed in the IML group due to the load-sharing properties of the IMN technique, which encourage early callus formation under physiological axial loading[3]. However, subtle differences between the two methods were noted concerning complications. A statistically higher incidence of superficial SSI and delayed wound healing was observed in the MIPPO group. This finding, though contrary to the belief about the biological advantage of MIPPO, is similar to some studies stating that the extensive subcutaneous tunnelling required for plate insertion can create dead space and compromise soft tissue viability, particularly in the distal tibia where soft tissue coverage is naturally thin, despite small incisions[7].

In contrast, the IMN approach avoids exposure of the fracture site, thereby reducing these wound-related complications.Conversely, higher rates of malunion were observed in the IML group, although this was not statistically significant. The procurvatum deformity is a recognised issue in distal tibia fractures due to the wider metaphyseal canal, which complicates coronal and sagittal plane control without direct visualisation[8]. Ankle pain in the IML group, persisting for a longer duration, is often associated with anterior ankle impingement caused by proximal nail prominence or prominent distal locking screws[3].

For fractures with complex geometries, the use of anatomically contoured plates and fixed-angle locking screws through the MIPPO technique provides superior control over reduction and rotational stability[4]. A study by Akra GA *et al*. indicated that angular and rotational deformities were present in the MIPPO group. However, these deformities were not statistically significant and did not affect functional outcomes[9]. Beytemür O *et al*. reported that valgus malunion was more prevalent in the IMLN group and recurvatum in the MIPPO group[10]. They also noted that the valgus deformity in the IMN group could be reduced by fixing fibula fractures. Non-union rates were significantly lower in both groups; however, when compared, the IML group experienced 2 cases of non-union, while the MIPPO group had 3 cases. Vallier et al. mentioned that non-union was more common in the IMN group, which contradicts our findings. They observed that non-union rates were higher following concurrent fibula fixation[11] .They further noted that delayed union, non-union, and secondary procedures were more frequent in the IMN group. Hardware irritation was seen more in the MIPPO group, likely due to the thin soft tissue coverage at the distal tibia.

The functional outcomes, assessed using OMAS, showed better outcomes in the IMN group during the early post-operative period. However, both techniques demonstrated excellent functional outcomes at 6 and 12 months. This suggests that diligent rehabilitation and achieving union are important for good long-term functional recovery, regardless of the fixation method. Our study has some weaknesses. All surgeons were experts in the procedures performed, but due to multiple surgeons operating, techniques varied, which may have affected the results. The fibula fracture fixation rate differed between the groups.

CONCLUSION

We found that both surgical options are effective treatments for distal tibia fractures. Both groups achieved high union rates and excellent long-term outcomes. Comparative analysis of our data showed that the IMN group had a higher risk of malunion but

fewer soft tissue-related complications. MIPPO had the advantage of achieving anatomical reduction and strong fixation but a higher rate of soft tissue-related complications. We conclude that there is no optimal choice between the two options; rather, the choice should be made carefully based on the patient's clinical features, such as fracture characteristics, status of soft tissue coverage, comorbidities, and patient-specific needs. The surgeon's experience and expertise with the surgical technique should also be considered. A multicenter clinical trial with a larger sample size would provide more definitive evidence and help establish clearer guidelines for optimal fracture management.

Conflict of Interest: All authors declare that they have no conflict of interest.

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