

# Treatment of Extra-Articular Distal Tibial Fractures: Minimally Invasive Percutaneous Plate Osteosynthesis Versus Intramedullary Nailing

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## Abstract

**Background:** Extra-articular distal tibia fractures have always been a challenge for orthopedic surgeons, and currently there is no consensus on whether to manage such fractures through the use of a plate or with an interlocking nail.

**Objectives:** In this study, we compared the outcome of installing a medial distal tibial locking plate through minimally invasive percutaneous plate osteosynthesis (MIPPO) with closed intramedullary interlocking nailing in the treatment of extra-articular distal tibial fractures.

**Methods:** This prospective study was conducted on 60 patients with extra-articular distal tibial fractures. Thirty patients were treated with a distal tibial locking plate by MIPPO, and another thirty patients with closed intramedullary nailing. Patients were followed-up on every four weeks from time to full weight bearing and radiological union, alignment of the fracture, and the discovery of any complications. The final symptomatic and functional results were evaluated using the Teeny and Wiss clinical assessment criteria at nine months.

**Results:** Though mean time to full weight bearing was early in the plating group, and mean time to radiological union was early in the interlocking group, these values were not significant ( $P = 0.244$  and  $0.246$ , respectively). Both techniques had their own set of complications. Primary valgus malalignment was more common among the nailing group ( $P = 0.001$ ), but the majority of cases were in the acceptable range, so the occurrence of valgus mal-union was not clinically significant. The final Teeny and Wiss clinical and symptomatic scores at nine months were not statistically significant between the plating and nailing groups ( $P = 0.451$ ).

**Conclusions:** Both treatment via medial distal tibial locking plate by MIPPO and closed intramedullary interlocking tibia nailing are viable options for management of extra-articular distal tibia fractures, with each method having its own merits and demerits. The final choice between the two depends on the surgeon's experience and his or her familiarity with the respective technique.

**Keywords:** Distal Tibia, Locking Plate, MIPPO, Interlocking Nail, Extra-Articular Fractures, Implant breakage, Mal-Union, Wound Dehiscence

## 1. Background

The management of extra-articular distal tibia fractures has always been of particular interest to orthopedic surgeons. Not only are these fractures relatively common, but they are often difficult to treat because of the propensity for severe soft tissue injury or compounding as the bone is subcutaneous in location with limited vascularity, which increases the chances of infection, wound dehiscence and non-union, and small distal fragmentation. These are difficult to control while achieving closed reduction (1, 2). Presently, there is no clear consensus on the optimal method of managing these fractures. Various surgical modalities used for these fractures include closed in-

tramedullary nailing, plating by open or closed methods, and various types of external fixators (3, 4). Despite all of the advances that have been made in the available treatment options, fractures of the distal tibia still pose a challenge to orthopedic surgeons (5). The purpose of this study was to compare the two primary modalities of treatment for these fractures: namely, medial distal tibial locking compression plate by MIPPO and closed intra-medullary interlocking tibia nailing.

## 2. Objectives

The aim was to compare the results of the two surgical modalities of treatment for extra-articular fractures of

the distal one-fourth of the tibia with respect to the following parameters: (1) time to full weight bearing; (2) time to radiological union; (3) alignment (medio-lateral, antero-posterior, and rotational); (4) complications, if any; and (5) final symptomatic and functional scores.

### 3. Methods

This prospective study was conducted from October 2011 to October 2013 on patients attending the emergency department of our hospital. Sixty adult patients with extra-articular fractures of the distal one-fourth of the tibia were included in the study. The patients with odd serial numbers were allocated to group I, whereas those with even numbers were assigned to group II, with each group having 30 patients. The patients in group I were treated by closed reduction and internal fixation with a medial distal tibial locking plate through MIPPO. The patients in group II were treated by closed reduction and internal fixation with an intra-medullary interlocking tibia nail. Informed consent was obtained from each patient included in the study, and the study protocol conformed to the ethical guidelines of the 1975 declaration of Helsinki as reflected by prior approval of the institution's human research committee.

Only the following fractures were included in the study: (1) extra-articular fractures within two Muller squares from the distal articular surface; (2) simple and Gustilo type I open fractures; and (3) those in patients aged 18 years or more. The following exclusion criteria were adopted: (1) fractures with intra-articular extension (pre-operatively, intra-operatively, or post-operatively); (2) segmental fractures; (3) pathological fractures; (4) poly-trauma patients; (5) additional fractures of ipsilateral extremity; (6) Gustilo type II and III open fractures; (6) infected fractures; (7) time of injury more than three weeks prior; (8) associated neurovascular injury or compartment syndrome; (9) failure of intra-operative closed reduction; (10) severe soft tissue injury with fracture blisters; (11) medical co-morbidities such as diabetes, liver disease, or chronic renal disease; (12) chronic alcoholism; and (13) smoking or tobacco chewing.

After the selection and registration process, patients were prepared for elective surgery to be conducted in the main operation theater. The fractures were classified according to the AO/OTA classification system (6).

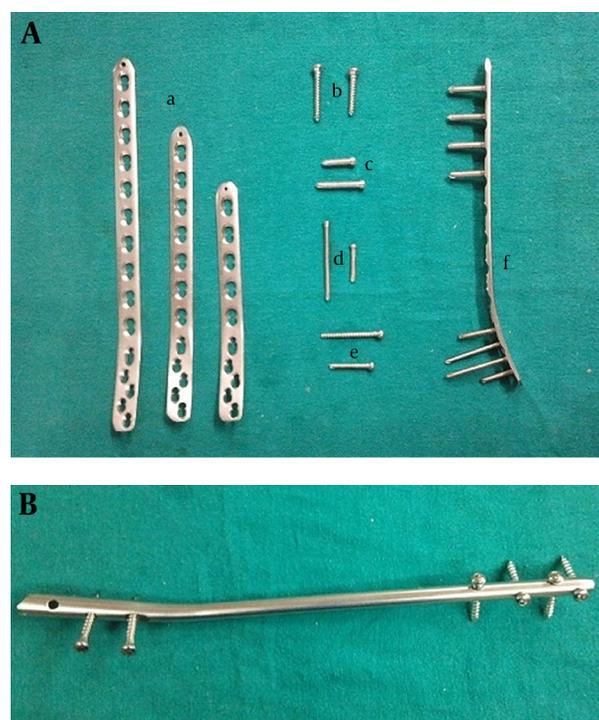
#### 3.1. Implant and Surgical Technique

Group I: The locking compression plate used was a 3.5 mm thick stainless steel plate with a limited contact profile, anatomically contoured for the medial surface of the distal tibia. The plate had combination holes where both

conventional cortical or locking screws could be used (Figure 1A).

Intra-operative closed reduction was done by combination of traction, manipulation, and reduction clamps. If there was a fibula fracture within seven cm of syndesmosis, it was anatomically reduced and fixed by a one-third semi-tubular plate or a 3.5 mm dynamic compression plate (DCP). A three to four cm curved incision was made over the medial malleolus, and an appropriately-sized medial distal tibial locking plate was inserted through the tunnel in the subcutaneous plane without disturbing the periosteum and the fracture hematoma (Figure 2A). After confirming reduction under a C-arm, the plate was fixed to the bone with an appropriate size and number of screws following the principles of locking compression plates.

Group II: The cannulated interlocking tibial nail used in our study had multiple distal locking options, with the distal most within the coronal plane and 5 mm from the tip of the nail. Other locking holes were at 15 mm, 25 mm, and 35 mm from the tip of the nail in the sagittal, coronal, and sagittal plane, respectively (Figure 1B).



**Figure 1.** 1A, medial distal tibial locking plate system; A, distal tibial locking plates; B, 4.5 mm cortical screws; C, 4.9 mm locking screws; D, 3.5 mm locking screws; E, 3.5 mm cortical screws; F, plate locking screw construct; 1B, interlocking tibial nail with multiple and bi-planar distal locking options

The preliminary reduction of the fracture and fixation of the fibula was conducted in a similar fashion as for

Group I. At least two locking bolts were used distally in the two planes. Fracture diastasis was reduced by the back strike technique of the nail, after which proximal locking was done (Figure 2B). Some surgeons use blocking screws to achieve reduction of the distal or proximal fractures of long bones during intramedullary nailing. We did not use this technique for reduction in any case.

### 3.2. Post-Operative Protocol

Weight bearing was started at four weeks or later depending on the fracture's anatomy, the fixation, and radiological assessment of the fracture's stage of healing, and then progressed as tolerated and according to radiological and clinical assessment. The patients were followed-up at intervals of four weeks with final follow-up at nine months (Figures 3 and 4).

### 3.3. Evaluation of the Results

The fracture was said to be radiologically united when there was bridging of at least three of four cortices on two orthogonal radiographic views. Healing time less than six months was considered normal, and between six and nine months was considered as a delayed union. Fractures not healed within nine months were considered a non-union according to the 1988 FDA guidelines (7). To label a case as mal-union, Trafton's recommendation was followed. According to Trafton, medio-lateral angulation less than 50, antero-posterior angulation less than 100, and rotation less than 100 is acceptable (8). Alignment in the frontal and sagittal planes was checked by plain radiographs, and rotational alignment was assessed by the fluoroscopic method.

Final evaluation of the clinical results was conducted at nine months using the Teeny and Wiss clinical assessment criteria, which are based on a 100-point rating system. As per the Teeny and Wiss criteria, the final clinical and symptom scores were graded as excellent ( $> 92$ ), good (87-92), fair (65-86), and poor ( $< 65$ ) (9). The data were analyzed using statistical software MS (Microsoft) Excel and SPSS (statistical package for social science) version 17 for Windows. Data was presented as percentages or mean  $\pm$  SD (standard deviation) as deemed appropriate for qualitative and quantitative variables, respectively. The chi-square test, Fisher's test, and Student's t-test were applied to evaluate the statistical significance between the two groups. A P value of  $< 0.05$  was considered as statistically significant. All P-values reported are two-tailed.

## 4. Results

Both the groups were similar with respect to mean age, sex, side involved, mode of trauma, clinical type of frac-

ture, radiological type of fracture, and the interval from injury to surgical intervention time (P value  $> 0.05$ ; Table 1).

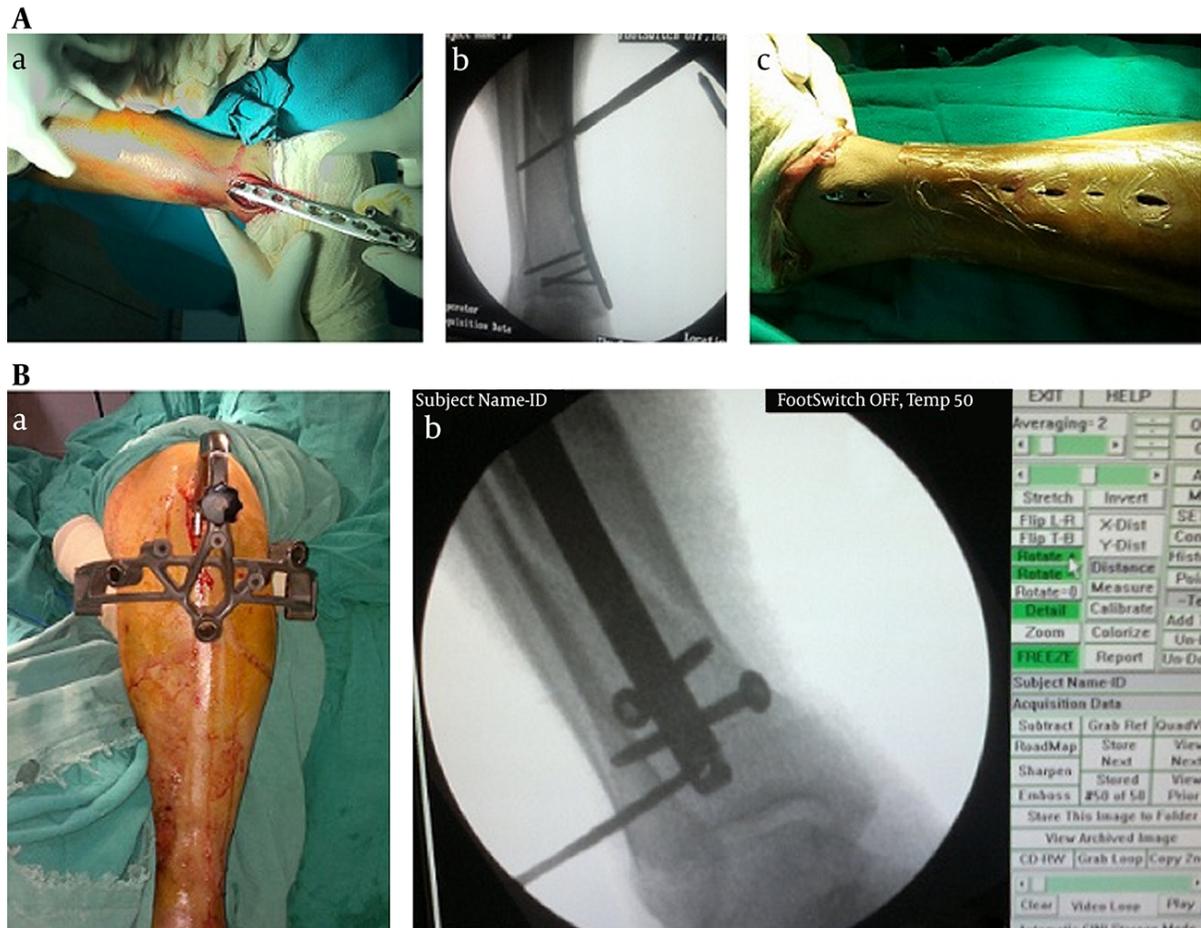
**Table 1.** Pre-Operative Patient Demographics and Fracture Characteristics

	Group I	Group II	P Value
Age, y	41.9 $\pm$ 13.5	40.4 $\pm$ 12.3	0.65
Sex (M/F)	21/9	23/7	0.55
Side (L/R)	13/17	10/20	0.42
<b>Mode of trauma</b>			
RTA	15	19	0.67
Twisting injury	9	5	0.39
Fall from height	4	5	1.0
Fall of heavy weight	1	1	1.0
Sports injury	1	0	1.0
Clinical type of (close/open type I)	23/7	20/10	0.39
<b>AO/OTA type of</b>			
42.A	16	17	1.0
42.B	5	6	1.0
42.C	1	0	1.0
43.A	8	7	1.0
Injury-to-surgery interval	5.6 $\pm$ 2.4	5.5 $\pm$ 3.9	0.91

Abbreviations: F, Female; M, Male; L, Left; R, Right; RTA, Road traffic accident.

There were no statistically significant differences between the two techniques with respect to time to partial weight bearing, time to full weight bearing, and time to achieve radiological union (Table 2). Mean medio-lateral, antero-posterior, and rotational alignment at final follow-up was not statistically significant, except for the mean valgus angulation of  $0.5^\circ$  in the MIPPO group and  $2.8^\circ$  in the nailing group ( $P = 0.001$ ; Table 2). All valgus angulations were in the Trafton's acceptable range, except for one valgus mal-union of  $150^\circ$ . The final functional and symptomatic scores of the two groups were also not statistically significant (Table 2). Twenty-one (70%) patients in the MIPPO group, whereas as 19 (63.3%) patients in the nailing group, had excellent and good results. Eight (26.67%) and nine (30%) patients had fair results in the two groups, respectively. One patient with MIPPO and two with nailing had poor results ( $P = 0.58$ ).

Complications were observed in both the groups, but none were statistically significant (Table 3). Overall mal-union was the most common complication. Valgus mal-union was the most common type of mal-union observed. Four (13.33%) patients with MIPPO had hardware symptoms, and one among them required removal of the implant after one year. One patient (3.33%) with an in-



**Figure 2.** 1A, medial distal tibial locking plate by MIPPO; A, plate insertion into subcutaneous tunnel; B, percutaneous insertion of lag screw through plate under image intensifier; C, proximal screws inserted percutaneously through stab incisions; 2B, interlocking tibia nailing; A, nail mounted on a jig inserted; B, Free hand distal locking in two planes under image intensifier

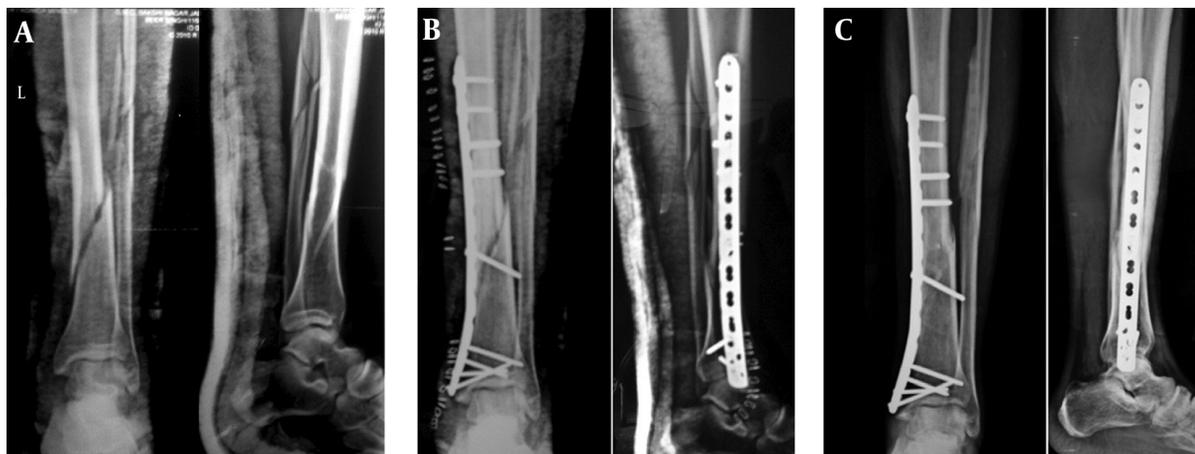
tramedullary nail had a palpable distal interlocking screw, which was removed after the fracture united at six months. In MIPPO, one patient had late and another one had early wound dehiscence with deep infection (Figure 5A). Both cases were managed by serial debridement and rotational fascio-cutaneous flap for coverage of the plate.

Delayed union was seen in both groups (Table 3). One patient in each group had bone grafting, and three patients with intramedullary nailing required dynamization for delayed union. One patient with MIPPO had non-union and subsequent fatigue failure of the implant at 38 weeks (Figure 5A). It was managed by re-plating and bone grafting. There were two cases of nail breakage, one at 12 weeks and another at 18 weeks (Figure 5B). In both these cases, the nail broke at the proximally most distal locking hole. In both patients, we removed the nail and achieved union by

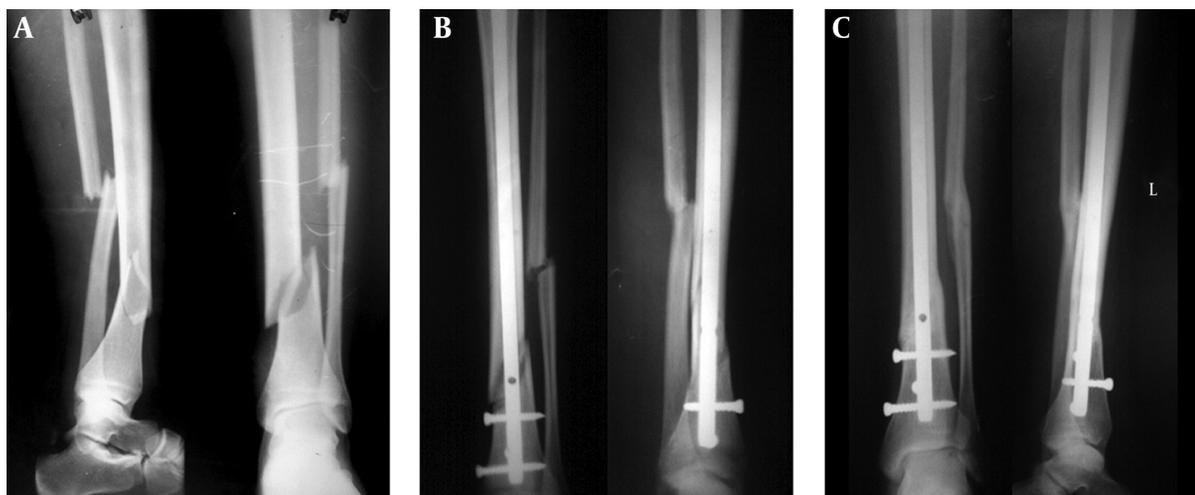
plating and bone grafting.

## 5. Discussion

Both modalities of treatment have been used for distal tibial fractures, each having its own merits and demerits (10). Because of the technical difficulties associated with intra-medullary nailing, many surgeons prefer plate osteosynthesis. Treatment with conventional interlocking tibial nails has been associated with less rigid fixation and a high incidence of mal-alignment because of the inability to engage more than one locking screw in the distal fragment (3, 11). This disadvantage was eliminated by the concept of shortened intra-medullary nailing, first introduced by Dogra et al. (12). Still, this nail has had its shortcomings for management of distal tibial fractures (3, 13). Due

**Figure 3.** Group I; Case No. 18

A, pre-operative radiograph; B, post-operative radiograph; C, final follow-up at nine months.

**Figure 4.** Group II; Case No. 16

A, Pre-operative radiograph; B, post-operative radiograph; C, final follow-up at nine months.

to these technical limitations, the available implants were continuously modified until the expert tibial nail (ETN) emerged in 2005, which has multiple and multi-planar distal locking options, thus eliminating the chance of postoperative loss of alignment (13).

Traditionally, open reduction and internal fixation of these fractures has been associated with high rates of infection, wound breakdown, delayed union, and non-union (14, 15). In their comparative study on distal metaphyseal fractures of the tibia, Im et al. concluded that although open reduction and plate and screw fixation can restore

alignment better than intra-medullary nailing, it is still plagued with a high rate of infection (16). Development of MIPPO techniques for distal tibia in the recent years has therefore attracted great interest (17).

In their comparative retrospective analysis of patients treated with plating and nailing, Janssen et al. reported an average time to full weight bearing (FWB) comparable to that of our study (18). However, in their comparative analysis of plating versus shortened intramedullary nailing, Yang et al. revealed a statistically significant difference in time to radiological union. This discrepancy from our



**Figure 5.** 5A, complications in group I; A, early wound dehiscence at distal end of the plate; B, late wound dehiscence at proximal end of the plate; C, non-union with screw breakage at 38 weeks. 5B, complications in group II; A, nail breakage at 12 weeks; B, nail bending at 18 weeks

study could be explained by the fact that plating was done by open reduction and not the MIPPO technique. They had mean postoperative valgus angulation of  $0.5^\circ$  in the plating group and  $3.7^\circ$  in the nailing group, which was as statistically significant as in our study. The mal-union rates were comparable to those of our study, though they had used open plating (11).

In our study, all of the mal-unions were primary in nature. There was no case of secondary mal-union due to loss of reduction in the post-operative-union interval. Mal-alignment of distal fractures can be corrected during intra-medullary nailing and stability maintained in the post-operative period by use of blocking (poller) screws, a method developed by Krettek et al. (19). Sengodan et al. using blocking screws with intramedullary nailing in distal tibial metaphyseal fractures, concluded that blocking

screws act as a tool to prevent loss of early reduction, thus extending the indication of intramedullary nailing in distal fractures (20). We, however, did not use blocking screws in any case.

In MIPPO for distal tibial fractures, Muller et al. reported delayed union in 10% of cases (21). In their study, Vallier et al. had delayed union and non-union in 12% of patients managed by intramedullary nailing (22). In their study on MIPPO in distal tibial meta-diaphyseal fractures, Muller et al. revealed non-union in 5% of cases, and Fan et al. reported no case with non-union in their study on interlocking nails in distal metaphyseal fractures, which is comparable to the results of our study (5, 21).

Despite the preservation of soft tissue coverage, MIPPO for distal tibia still carries the risk of soft tissue complications. In a similar type of comparative retrospective study,

**Table 2.** Post-Operative Clinical Results

	Group I	Group II	P Value
PWB, w	6.1 ± 1.6	6.0 ± 1.4	0.87
FWB, w	15.0 ± 3.8	16.2 ± 4.2	0.24
Radiological union, w	20.5 ± 4.8	18.8 ± 6.0	0.25
<b>Radiological alignment, mean, °</b>			
Valgus	0.5 ± 1.6	2.8 ± 3.2	0.001
Varus	0.6 ± 1.4	0.7 ± 1.5	0.74
Recurvatum	0.9 ± 2.3	1.3 ± 2.6	0.62
Procurvatum	1.1 ± 2.3	1.3 ± 2.7	0.91
External rotation	0.3 ± 1.3	0.4 ± 1.9	0.98
Internal rotation	0.2 ± 1.0	0.3 ± 1.5	0.73
Final functional score	88.6 ± 6.6	86.9 ± 10	0.45

Abbreviations: FWB, Full weight bearing; PWB, Partial weight bearing.

**Table 3.** Complications<sup>a</sup>

Complication	Group I	Group II	Fisher's Test
Mal-union	2 (6.67)	6 (20)	0.25
Delayed union	4 (13.33)	3 (10)	1.0
Ankle stiffness	4 (13.33)	1 (3.33)	0.35
Hardware symptoms	4 (13.33)	1 (3.33)	0.35
Superficial infection	2 (6.67)	2 (6.67)	1.0
Implant breakage	1 (3.33)	2 (6.67)	1.0
Anterior knee pain	-	3 (10)	0.24
Wound dehiscence	2 (6.67)	-	0.49
Non-union	1 (3.33)	-	1.0
Scar tenderness	1 (3.33)	-	1.0
Deep infection	1 (3.33)	-	1.0
Osteomyelitis	-	-	1.0
Screw breakage	-	-	1.0
Screw backout	-	-	1.0

<sup>a</sup>Values are expressed as No. (%).

Seyhan et al. reported higher rates of infection and implant irritation in the percutaneous plating group (23). In addition, Bahari et al. reported hardware symptoms in 11.9% of patients in distal tibial fractures managed by MIPPO using a medial distal tibial locking compression plate (LCP) (10).

Bhat et al. observed that 55.56% of broken nails were associated with fractures involving the distal one-third of the long bones in their study on mechanical failure of interlocking nails. In tibial nails with multiple distal locking

options for distal tibial fractures, one of the locking holes usually has a high chance of corresponding to the fracture site. Part of the nail having a locking hole or being mechanically weak and vulnerable to fracture could explain the fracture of the nail at the locking hole in the two cases in our study. In addition, there was little nail cortical contact in the distal fragment, which significantly increases the concentration of stress at the locking hole (24). Furthermore, the fibula in both cases was fixed with a low profile one-third tubular plate.

Dogra et al. conducted a series of distal tibial fractures managed by shortened intramedullary nailing, showing that dynamization was required for 13.33% of patients (12). However, no patient required bone grafting. In contrast, Nork et al. required dynamization in 19% patients. The higher requirement for dynamization in the series by Nork et al. could be explained by the inclusion of all types of open fractures, and thus higher incidence of open fractures (39%) in their series (4).

Li et al. reported a mean Olerud-Molander Ankle Score between the MIPPO group and the nailing group for distal tibial fractures that was statistically comparable and reproduced in our study (25). In a prospective randomized trial comparing the two modalities, Guo et al. concluded that both can be used for distal tibial metaphyseal (OTA Type 43A) fractures safely. However, nailing has the advantage of shorter operative time, less radiation exposure, and easy removal (26).

MIPPO, however, has the advantage of preservation of periosteal vascular integrity and osteogenic fracture hematoma, thus enhancing healing. In addition, the bone takes the contour of the anatomically pre-contoured locking plate, which reduces the chance of mal-alignment in the coronal plane, and, along with screws, forms a rigid and fixed angle construct which allows for early weight bearing while simultaneously preventing post-operative loss of reduction. The plate being directly under the subcutaneous tissue still carries the risk of wound breakdown. To prevent this complication, the technique demands careful handling and minimal stripping of the soft tissue while the tunnel for the plate is being created in the subcutaneous plane. The higher incidence of hardware symptoms can also be explained by the plate being in the subcutaneous plane.

Intra-medullary nailing has the added advantage of the avoidance of dissection of the scanty soft tissue surrounding the distal tibia, thus eliminating the chance of wound breakdown and deep infection. Intra-medullary tibial nailing with multiple, multi-planar distal locking options maintains a stable reduction, thus decreasing the chance of secondary loss of reduction or secondary mal-alignment. Unlike nailing of a tibial diaphyseal fracture,

nail insertion in a distal meta-diaphyseal fracture does not result in fracture reduction because of the wide medullary canal of the distal fragment in the latter. Primary mal-alignment is a concern, but is usually within acceptable range with good and comparable early functional results, and does not require any surgical correction. Nail breakage is common in distal fractures, but this may be prevented by rigid internal fixation of the fibular fracture by a dynamic compression plate if the fibular fracture corresponds to the same level as that of the tibia. Low profile one-third tubular plates are not strong enough to prevent fracture of the nail.

The main drawback of our study is that it has a relatively short-term follow-up, and more research is required to assess the long term effects of acceptable mal-alignment in distal tibial fractures managed by either of the aforementioned modalities. Additionally, we did not use blocking screws with intramedullary nailing, which may further improve alignment at the fracture site in the nailing group.

### 5.1. Conclusions

Based on our study, we conclude that both minimally invasive percutaneous plate osteosynthesis (MIPPO) with a medial distal tibial locking plate and closed reduction with intramedullary nailing are viable options for management of extra-articular fractures of the distal tibia, with each having its own merits and demerits.

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### Footnote

**Authors' Contribution:** Study concept and design: Nadeem Ali and Mehreen Maqsood; analysis and interpretation of data: Abedullah Bhat; drafting of the manuscript: Firdous Ahmad Bangroo; critical revision of the manuscript: Khalid Muzzafar and Suhail Ahmad Bhat; statistical analysis: Manjeet Singh Dhanda.

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