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Functional and radiological outcomes of distal tibia fractures treated by intramedullary nailing versus plate fixation: Comparative prospective observational study

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Abstract:
Extra-articular distal tibia fractures remain controversial in terms of optimal surgical fixation, with intramedullary nailing (IMN) and minimally invasive percutaneous plate osteosynthesis (MIPPO) offering distinct trade-offs in functional recovery and complication profiles. Therefore, it is of interest to compare the 30 Gustilo-Anderson Type I AO Type A distal tibia fractures treated with IMN or MIPPO, evaluating surgical time, blood loss, weight-bearing, union, complications and 6-month AOFAS outcomes. AOFAS scores were comparable between IMN (92.0 ± 4.97) and MIPPO (90.2 ± 4.41; $p = 0.303$), while IMN had shorter operative time (46.0 versus 78.33 min; $p < 0.001$) and faster union (4.80 vs 6.07 months; $p = 0.014$). MIPPO caused less blood loss (85.67 versus 245.33 ml; $p < 0.001$) and fewer knee symptoms, whereas plating showed more wound complications and IMN more anterior knee pain. Thus, data shows that both techniques yield similar functional outcomes, with implant choice best guided by fracture pattern, soft-tissue status and patient-specific factors.

Keywords: Distal tibia fracture; intramedullary nailing (IMN); plate fixation; minimally invasive percutaneous plate osteosynthesis (MIPPO); AOFAS score; functional outcome; fracture union

Background:
Although they only make up about 7% of all tibial fractures and less than 10% of all lower extremity fractures, distal tibia fractures are a clinically relevant subgroup of these injuries **[1].** Their occurrence has been on the rise due to the rise in urbanization and the number of vehicles on the road. The majority of these fractures occur in men between the ages of 30 and 60 and they can be caused by a variety of things, including low-energy rotational forces in the elderly and high-energy axial loading in younger patients, the latter of which is usually the result of things like falls from great heights or car accidents **[2-5]**. Both conservative and surgical treatment of the distal tibia is technically hard because to the anatomical peculiarities of its subcutaneous location, restricted soft tissue envelope and precarious blood supply **[6, 7]**. Complications can arise from even a small residual angular deformity near the ankle's weight-bearing surface after an extra-articular metaphyseal fracture (one that occurs within 7.5 cm of the tibial plafond)—this can lead to degenerative joint disease and long-term functional disability **[8-10]**. There is a significant risk of loss of reduction and extended immobilization-related morbidity when non-operative therapy is used, while it is suitable for patients who do not have displaced fractures or who are medically unfit. Therefore, it is best to have surgical intervention in order to correct alignment, maintain the length of the limbs and allow for early mobility **[11-13]**. Intramedullary interlocking nailing (IMN) and minimally invasive percutaneous plate osteosynthesis (MIPPO) with locking compression plates (LCP) are two methods that are often used to treat extra-articular distal tibia fractures internally **[14]**. While both methods aim to provide stable fixation while minimizing disturbance to soft tissues and fracture biology, they are not interchangeable in terms of risk-benefit analysis. The benefits of intramedullary nailing include less soft tissue stripping, early mobilization and load-sharing fixation **[15]**. But in very distal fractures, when distal purchase is minimal, it might be accompanied with anterior knee discomfort and misalignment. While plate fixation allows for accurate anatomical reduction and several distal locking choices, it also increases the risk of wound problems since the anteromedial tibia does not protect as much soft tissue **[16, 17]**. Therefore, it is of interest to compare the functional and radiological results of IMN and MIPPO plate fixation, as well as to characterize the complication profiles linked to each method, the current prospective observational research was carried out.

Materials and Methods:
Study design and setting:
A prospective observational comparative study was conducted at the Department of Orthopaedics, government medical college, Sheopur and district hospital Sheopur following institutional ethics committee approval. All participants provided written informed consent before enrolment.

Participants:
Participants ranged in age from 18 to 60 and had consecutive extra-articular distal tibia fractures of Gustilo-Anderson Grade I severity (AO Type A, 43-A1, 43-A2, 43-A3). Exclusion criteria included a history of compartment syndrome, polytrauma, multiple fractures, polyarticular extension (AO Types B or C), or a medical determination that the patient was not surgically suitable. Thirty individuals who were eligible were included in the study.

Surgical technique selection:
Intramedullary nailing was used to repair fractures that were 6.8 cm or beyond from the tibial plafond; this threshold was based on biomechanical factors and it was set at 1.2 cm as follows: 0.5 cm between the nail tip and the plafond, 1.5 cm between successive distal interlocking screws and 2.0 cm between the fracture line and the most proximal distal screw. When the

fracture was less than 6.8 cm from the ceiling, plate fixation was used to treat it. Prior to surgery, every single patient had their edema and skin condition optimized. Usually between two and six days after admission, surgery was carried out as soon as the wrinkle sign became positive, indicating that the edema had dissipated. Rush nail fixation was used to stabilize the associated fractures of the distal fibula.

Intramedullary nailing technique:
After positioning the patient on a radiolucent table with their knee bent at least 90 degrees, we found an appropriate entry location in the sagittal plane midway between the tibial articular surface and the tibial tuberosity. In the coronal plane, it was slightly medial to the lateral tibial spine. The titanium interlocking nail was placed after serial reaming to ensure it had the right diameter and length. Under fluoroscopic supervision, at least three distal interlocking screws were free-handedly put and the insertion jig was used to fix at least two proximal screws.

Plate fixation technique (MIPPO):
A minimally invasive percutaneous plate osteosynthesis technique was used to install a 3.5 mm medial distal tibia locking compression plate submuscularly using tiny longitudinal incisions. Under fluoroscopic supervision, closed reduction was successfully accomplished. Prior to engaging the subchondral bone, three locking screws with diverging tips were inserted at the distal end. Proximal cortical screws were then used. Always careful not to remove the periosteum or handle sensitive tissues with excessive care.

Post-operative protocol:
Within 48 hours following surgery, active exercises were started for the knees and ankles. The course of treatment included 14 days of intravenous antibiotics. On day 14 after surgery, the sutures were removed. After the radiographs showed a bridging callus, partial weight-bearing may begin and after the fracture had healed, full weight-bearing could begin. After the operation, all patients were reevaluated three and six months later.

Outcome measures:
The ankle score, as measured at the 6-month follow-up, was the main functional outcome according to the American Orthopedic Foot and Ankle Society (AOFAS). Excellent (95–100), Good (75–94), Fair (51–74) and Poor (0–50) are the possible outcomes of the three sections of this 100-point validated test that assess pain, function and alignment. Time to partial and complete weight-bearing after surgery, time to fracture union as seen on plain radiographs, problems that occurred after surgery and intraoperative blood loss were all considered secondary outcomes. When a bridge callus could be seen on three or more cortices in orthogonal views, it was considered a radiological union.

Statistical analysis:
We used SPSS version 26.0 to analyze the data. The means ± standard deviations of continuous variables are shown and independent samples t-tests are used for comparison. We used Fisher's Exact Test to compare the categorical variables. A significance level of $p < 0.05$ was used.

Results:
We included 30 patients, including 25 males and 5 females (M:F = 5:1), in our study. The age group including individuals between the ages of 31 and 40 accounted for 33.3% of the total, with a mean age of 43.17 ± 11.53 years (ranging from 19 to 60 years). Injuries sustained in car accidents accounted for 86.7% of all injuries, with 6.7% each from ankle twists and falls from the ground. There was an average of 30.17 ± 19.18 hours between the injury and hospital admission and an average of 3.8 ± 1.16 days between admission and operation **(Table 1)**. In comparison to the plating group, the nailing group had a much lower average operation time (46.0 ± 8.90 min) with a mean difference of −32.33 min ($p < 0.001$). On the other hand, the comparison between the nailing and plating groups revealed a considerably higher intraoperative blood loss (245.33 ± 53.17 ml vs. 85.67 ± 9.42 ml; mean difference +159.67 ml, $p < 0.001$) **(Table 2)**. Partial weight-bearing began at an average of 7.30 ± 2.07 weeks and complete weight-bearing at 11.23 ± 1.76 weeks for the whole group. In comparison to the plating group, which took an average of 6.07 ± 1.53 months to achieve fracture union, the nailing group finished the process much faster (mean 4.80 ± 1.08 months), with a mean difference of -1.27 months ($p = 0.014$). Within 5 months, 63.3% of patients were able to establish union **(Table 3)**. In the end, no problems arose after surgery for 66.7% of patients. Only four out of fifteen patients in the group who underwent nailing had anterior knee discomfort, making it the most common adverse event at 13.3%. Only in the plating group were wound dehiscence and deep infection detected, with two occurrences each. Antibiotic treatment cleared up a superficial infection in one patient in each group. There were no instances of implant fracture, non-union, or revision surgery being necessary. Overall, there was no statistically significant difference in the distribution of complications across groups, according to Fisher's Exact Test ($p = 0.148$). Across the total group, the average AOFAS score was 91.1 ± 4.71, with a range of 82-100 **(Table 4).** The mean AOFAS score in the nailing group was 92.0 ± 4.97, whereas in the plating group it was 90.2 ± 4.41; nevertheless, there was no statistically significant difference between the two groups (mean difference 1.8, $p = 0.303$). In all, no patient received a rating of Fair or Poor; 26.7% received an excellent rating and 73.3% received a Good rating. The group who underwent nailing had a greater range of motion in their ankles at the last follow-up. In the plating group, the average dorsiflexion was 10 degrees, whereas in the nailing group, it was 35 degrees and in the other group, it was 28 degrees. Secondary intervention was not necessary for any patient due to functional impairment **(Table 5).**

Table 1: Age distribution of study participants

Age Group	Frequency (n)	Percentage (%)
< 30 years	3	10.0
31–40 years	10	33.3
41–50 years	8	26.7

51–60 years	9	30.0
Mean ± SD	43.17 ± 11.53 years	–

Table 2: Comparison of surgery duration and blood loss between treatment groups

Variable	Nailing (n=15)	Plating (n=15)	Mean Difference	p-value
Surgery Duration (min)	46.0 ± 8.90	78.33 ± 10.97	−32.33	< 0.001*
Blood Loss (ml)	245.33 ± 53.17	85.67 ± 9.42	+159.67	< 0.001*

**Statistically significant at p < 0.05.*

Table 3: Fracture union time by treatment group

Group	N	Mean Union Time (months)	SD	Mean Difference	p-value
Nailing	15	4.80	1.08	−1.27	0.014*
Plating	15	6.07	1.53		

Table 4: Post-operative complications by treatment group

Complication	Nailing n (%)	Plating n (%)	Total n
Anterior Knee Pain	4 (26.7%)	0 (0.0%)	4
Superficial Infection	1 (6.7%)	1 (6.7%)	2
Wound Dehiscence	0 (0.0%)	2 (13.3%)	2
Deep Infection	0 (0.0%)	1 (6.7%)	1
Implant Prominence	0 (0.0%)	1 (6.7%)	1
None	10 (66.7%)	10 (66.7%)	20

Fisher's Exact Test, p = 0.148 (not statistically significant).

Table 5: Functional outcome (AOFAS score) by treatment group

Group	N	Mean AOFAS Score	SD	Mean Difference	p-value
Nailing	15	92.0	4.97	1.8	0.303 (NS)
Plating	15	90.2	4.41		

NS = not statistically significant.

Discussion:

This prospective comparative research shows that minimally invasive plate fixation and intramedullary nailing are both good surgical choices for extra-articular distal tibia fractures and that at six months follow-up, the functional results are similar. In addition to providing useful information for surgeons, the results add to the growing corpus of literature on the topic. The current study's male preponderance (83.3%) and mean age of 43.17 ± 11.53 years are in line with previously reported epidemiological statistics. Mukherjee *et al.* **[18]** found a similar demographic profile in a similar cohort, with a mean patient age of 42 years and a male-to-female ratio of 4:1. There was a heavy load of vehicle trauma in the study population, since 86.7% of injuries in this series were caused by road traffic accidents. The time it took to do the operation was much less in the group that had the nails placed (46.0 vs. 78.33 min; p < 0.001). The literature has repeatedly documented this benefit. Nailing operations took an average of 94 minutes in the study by Cheng *et al.* **[19]** and 87 minutes in the study by Bahari *et al.* **[20]**, which is longer than the current series. This might be due to variations in fracture complexity, surgeon expertise, or institutional protocols. Nail trimming shortens surgical procedures, which means less time under anesthesia and maybe less peri-operative complications. With a p-value less than 0.001, the nailing group had significantly higher intraoperative blood loss (245.33 vs. 85.67 ml). This result is in line with what Jain *et al.* **[21]** found; they found that a MIPO group lost 91.3 ± 25.7 ml of blood compared to 222.8 ± 70.6 ml during nailing. If a patient has a history of anemia or cardiorespiratory impairment, they may want to reconsider having the medullary canal reamed since it is the main cause of blood loss in the nailing group. The nailing group was able to achieve fracture union at a considerably earlier time (4.80 vs. 6.07 months; p = 0.014). Reason being, intramedullary fixation's load-sharing biomechanical properties encourage subsequent fracture healing via copious callus production while maintaining periosteal vascularity, which is a benefit. The results of Wang *et al.* **[16]** and Greenfield *et al.* **[22]**, who also found that IMN led to quicker union, are supported by these findings. Arora *et al.* reported excellent functional and radiological outcomes in 88% of patients with extra-articular distal tibia fractures treated with expert tibial nails, supporting the effectiveness of intramedullary fixation in achieving stability and favorable recovery **[23]**. Im and Tae **[7]** did not find a significant difference in union rates across the groups, which might be due to differences in patient selection or fracturing patterns. Only 26.7% of those in the nailing group reported discomfort in the front of the knee. Nail prominence at the entrance site may affect this known outcome of the suprapatellar or infrapatellar nail insertion trajectory. Consistent with the susceptibility of the skin on the outside of the tibia, the plating group was the only one to experience wound dehiscence (13.3%) and deep infection (6.7%). It is possible that variations in fracture severity and soft tissue treatment account for the lower infection incidence here compared to the comparable study by Megas *et al.* **[24]**, who found no infections in the nailing group and seven deep operative site infections in twenty-five patients treated with plating. The lack of a statistically significant difference in the distribution of complications (p = 0.148) in this series is indicative of proper surgical technique and care of soft tissues. Ensuring adequate distal fixation is a crucial technical aspect when nailing the tibia. The nail tip should be at least 6.2 mm from the tibial plafond, according to Nork *et al.* **[9]** and 10-15 mm, according to Köksal *et al.* **[25]**, a standard deviation of 12 mm was upheld in this investigation. The biomechanical stability was improved over two-screw constructions by using three distal interlocking screws in all nailing situations. According to the geometry of the nailing system in use, for a fracture to be suitable for three-screw distal fixation, it must be at least 6.8 cm proximal to the tibial plafond. This criterion is in agreement with the 5 cm described by Fan *et al.* **[13]**, which takes into consideration different nail systems. Nailers had a wider range of motion in their ankles (15° dorsiflexion vs. 10° plantar flexion vs. 28°). Although MIPPO is less invasive than nailing, it nevertheless involves more manipulation of soft tissues around the medial compartment, which might lead to periarticular fibrosis and limited mobility. These results are in agreement with those of Gupta *et al.* **[15]** (12.6° vs. 9.6°; 32.4° vs. 25.0°) and Bahari *et al.* **[20]** (14.6° vs. 7°) regarding dorsiflexion. According to Jain *et al.* **[21]** (IMN 92.6 ± 5.41 vs. MIPO 91.2 ± 6.81) and Patil *et al.* **[26]**, total AOFAS scores were similar across groups (92.0 vs. 90.2; p = 0.303), even though the ankle range of motion was better and the union with nailing was quicker. Mulla *et al.* similarly found favorable outcomes with both IMN and locking compression plating, although IMN was associated with shorter operative time, fewer complications, and better early functional outcomes, while long-term results were comparable **[27]**.

Kumarjuvekar *et al.* also reported earlier fracture union with intramedullary interlocking nailing, although functional outcomes were comparable between IMIL and MIPO, reinforcing the importance of fracture pattern in implant selection **[28]**. These results show that both methods are equally effective in restoring ankle function and patient-reported well-being in cases with simple extra-articular fractures at six months. Several limitations are included in this investigation. The results cannot be applied to larger populations with more complicated fractures due to the small sample size of 30 patients, which reduce statistical power. There is a chance of selection bias in the allocation of surgical methods based on fracture site since the observational design does not allow for randomization and blinding. To evaluate long-term functional recovery, implant removal rates, post-traumatic osteoarthritis and other late outcomes, a longer follow-up duration is required. Validation of these results should be pursued via future multicenter randomized controlled studies with bigger populations.

Conclusion:

Both intramedullary nailing and MIPPO plate fixation provide comparable 6-month AOFAS functional outcomes for extra-articular distal tibia fractures with equivalent overall safety profiles. IMN offers advantages in shorter operative time (46 versus 78 min) and faster union (4.8 versus 6.1 months) despite greater blood loss (245 versus 86 ml) and anterior knee pain risk. Surgical approach should be individualized based on fracture-plafond distance (≥6.8 cm for IMN), soft-tissue status, surgeon expertise and patient comorbidities to optimize clinical results.

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Conflicts of interest:

The authors declare no conflicts of interest.

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