



Original Article

A Prospective Comparative Study on Functional and Radiological Outcomes of Intramedullary Interlocking Nailing Versus Minimally Invasive Plate Osteosynthesis in the Management of Extra-Articular Distal Tibial Fractures in Adult Patients

Dr. Salman¹, Dr. Ghizala Begum C², Dr. Asma Firdouse³, Dr. Haroon Adoni⁴

¹Consultant Orthopaedic Surgeon, KM Hospital, Yadgir, Karnataka, India

²Junior Resident, Department of Ophthalmology, Khaja Banda Nawaz (KBN) Medical College, Kalaburagi (Gulbarga), Karnataka, India

³Consultant Anaesthesiologist, KM Hospital, Yadgir, Karnataka, India

⁴Consultant Pathologist, KM Hospital, Yadgir, Karnataka, India

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Corresponding Author:

Dr. Haroon Adoni

Consultant Pathologist, KM
Hospital, Yadgir, Karnataka, India

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ABSTRACT

Background: Extra-articular distal tibial fractures are challenging injuries due to their subcutaneous location, limited soft tissue coverage, and proximity to the ankle joint. Surgical management aims to achieve stable fixation, early mobilization, and restoration of limb alignment while minimizing complications. Intramedullary interlocking (IMIL) nailing and minimally invasive plate osteosynthesis (MIPO) are widely accepted treatment modalities; however, the optimal fixation method remains controversial.

Objective: To compare the functional and radiological outcomes of Intramedullary Interlocking (IMIL) Nailing and Minimally Invasive Plate Osteosynthesis (MIPO) in the management of extra-articular distal tibial fractures in adult patients.

Materials and Methods: This prospective comparative study was conducted in the Department of Orthopaedics at KM Hospital, Yadgir, Karnataka, over a period of 2.5 years. Thirty adult patients with extra-articular distal tibial fractures were enrolled and divided into two equal groups: IMIL nailing (n=15) and MIPO (n=15). Patients were followed for a minimum of six months. Functional outcomes were assessed using the American Orthopaedic Foot and Ankle Society (AOFAS) score, while radiological union and postoperative complications were evaluated using serial radiographs and clinical examination. Statistical analysis was performed using IBM SPSS Statistics version 27.0, with p<0.05 considered statistically significant.

Results: The mean age of the study population was predominantly between 31 and 45 years, with males accounting for 70% of cases. Road traffic accidents were the most common mechanism of injury (70%). IMIL nailing demonstrated significantly shorter operative time (74.6 ± 9.5 vs. 96.8 ± 11.2 minutes; $p<0.001$) and lower intraoperative blood loss (102.4 ± 21.8 vs. 145.7 ± 28.6 mL; $p<0.001$). MIPO achieved better functional outcomes with a significantly higher mean AOFAS score at six months (90.3 ± 5.7 vs. 84.6 ± 6.8 ; $p=0.018$). Radiological union was achieved in all patients, with a slightly shorter union time in the MIPO group (17.0 ± 2.4 vs. 18.2 ± 2.9 weeks). Complication rates were low and comparable between the groups.

Conclusion: Both IMIL nailing and MIPO provide satisfactory clinical and radiological outcomes in the management of extra-articular distal tibial fractures. IMIL nailing offers shorter operative time and less blood loss, whereas MIPO provides superior functional outcomes and better fracture alignment. Treatment should be individualized according to fracture characteristics and patient factors.

INTRODUCTION

Distal tibial fractures account for approximately 7–10% of all tibial fractures and are frequently associated with high-energy trauma such as road traffic accidents and falls from height. Owing to the subcutaneous location of the distal tibia and its relatively poor soft tissue envelope, these fractures are associated with increased risks of wound complications, delayed union, malunion, and infection. Achieving stable fixation while preserving the surrounding soft tissue and blood supply remains one of the primary goals of surgical management.(1,2)

Extra-articular distal tibial fractures pose unique biomechanical and biological challenges because of the metaphyseal anatomy, limited cortical bone, and proximity to the ankle joint. Conservative treatment often results in prolonged immobilization, joint stiffness, malalignment, and delayed rehabilitation. Consequently, operative fixation has become the preferred treatment modality for most displaced fractures in adult patients.(3)

Intramedullary Interlocking (IMIL) nailing has become a widely accepted technique because it provides a load-sharing construct with minimal disruption of fracture biology, smaller surgical incisions, and early weight-bearing. However, due to the wider metaphyseal canal in distal tibial fractures, IMIL nailing may be associated with malalignment and difficulty in achieving stable distal fixation.(4,5)

Minimally Invasive Plate Osteosynthesis (MIPO) has emerged as an alternative biological fixation technique that preserves periosteal blood supply through indirect fracture reduction and limited soft tissue dissection. Locking compression plates provide angular stability and improved fixation in the distal metaphysis while minimizing periosteal stripping. Nevertheless, MIPO may require longer operative time and has the potential for implant prominence and wound-related complications.(6,7)

Several comparative studies have evaluated IMIL nailing and MIPO for distal tibial fractures, reporting variable results regarding fracture union, alignment, functional recovery, and complication rates. While IMIL nailing offers the advantages of minimally invasive surgery and early rehabilitation, MIPO has demonstrated improved alignment and lower malunion rates in selected patients. Despite extensive literature, no universal consensus exists regarding the superior treatment modality for extra-articular distal tibial fractures (8–10)

The present prospective comparative study was therefore undertaken to compare the functional and radiological outcomes of Intramedullary Interlocking Nailing and Minimally Invasive Plate Osteosynthesis in adult patients with extra-articular distal tibial fractures treated at KM Hospital, Yadgir. The study aimed to evaluate fracture union, functional recovery, radiological alignment, operative parameters, and postoperative complications associated with both techniques.

MATERIALS AND METHODS

Study Design and Setting

This prospective comparative study was conducted in the Department of Orthopaedics at KM Hospital, Yadgir, Karnataka, India, over a 2.5-year period. The study aimed to compare the functional and radiological outcomes of Intramedullary Interlocking (IMIL) Nailing and Minimally Invasive Plate Osteosynthesis (MIPO) in the management of extra-articular distal tibial fractures in adult patients.

The study was approved by the Institutional Ethics Committee before commencement. Written informed consent was obtained from all participants prior to enrollment. The study was conducted in accordance with the ethical principles outlined in the Declaration of Helsinki.

Study Population

A total of **30 adult patients** presenting with extra-articular distal tibial fractures to the Department of Orthopaedics during the study period were included. Patients were allocated into two treatment groups based on the surgical procedure performed:

- **Group A:** Intramedullary Interlocking (IMIL) Nailing (n = 15)
- **Group B:** Minimally Invasive Plate Osteosynthesis (MIPO) (n = 15)

Both groups were prospectively followed and compared regarding fracture union, functional outcome, radiological outcome, and complications.

Sample Size

The study included **30 patients**, selected by convenient consecutive sampling according to the eligibility criteria during the study period.

Inclusion Criteria

Patients fulfilling all of the following criteria were included:

- Age between **18 and 65 years**.
- Closed extra-articular distal tibial fractures (AO/OTA Type 43-A1, A2, and A3).
- Fresh fractures presenting within two weeks of injury.
- Patients fit for surgery.
- Willingness to participate in the study and provide written informed consent.

Exclusion Criteria

Patients with any of the following conditions were excluded:

- Intra-articular distal tibial fractures.
- Open fractures Gustilo-Anderson Grade III.
- Pathological fractures.
- Polytrauma requiring damage control procedures.
- Previous fracture or surgery involving the affected tibia.
- Associated neurovascular injury requiring vascular repair.
- Active local or systemic infection.
- Patients with severe medical comorbidities precluding surgery.
- Refusal to participate.

Preoperative Evaluation

Detailed clinical history and demographic information were recorded using a structured proforma, including:

- Age
- Gender
- Mechanism of injury
- Side involved
- Time from injury to surgery
- Associated injuries
- Medical comorbidities
- Smoking history

A complete physical examination was performed.

Radiological assessment included:

- Anteroposterior and lateral radiographs of the leg including the knee and ankle joints.
- Classification of fractures according to the **AO/OTA classification**.
- Routine laboratory investigations including complete blood count, renal function tests, blood glucose, coagulation profile, and viral markers were performed before surgery.

Surgical Procedure

Group A: Intramedullary Interlocking Nailing (IMIL)

Patients underwent closed reduction under image intensifier guidance. A tibial intramedullary interlocking nail of appropriate diameter and length was inserted through the standard infrapatellar approach. Distal and proximal locking screws were inserted to achieve stable fixation while maintaining alignment. Care was taken to achieve adequate reduction before locking.

Group B: Minimally Invasive Plate Osteosynthesis (MIPO)

Patients underwent fracture fixation using a distal tibial locking compression plate through minimally invasive techniques. Closed or indirect reduction was achieved under fluoroscopic guidance. A precontoured locking plate was inserted through small proximal and distal incisions with preservation of periosteal blood supply. Locking screws were inserted proximally and distally without exposing the fracture site extensively.

All procedures were performed by experienced orthopaedic surgeons under spinal or general anesthesia using standard aseptic precautions.

Postoperative Management

Postoperatively, all patients received standardized treatment protocols including:

- Intravenous antibiotics for 24–48 hours.
- Analgesics as required.
- Limb elevation and cryotherapy.
- Active toe movement and ankle range-of-motion exercises from the first postoperative day.
- Knee mobilization exercises as tolerated.
- Partial weight bearing initiated based on fracture stability and radiological healing.
- Full weight bearing permitted after satisfactory evidence of fracture union.

Patients were reviewed regularly in the outpatient department.

Follow-up Evaluation

Patients were followed at:

- 2 weeks
- 6 weeks
- 3 months
- 6 months
- 9 months (if required until fracture union)

At each follow-up visit, patients underwent clinical and radiological evaluation.

Outcome Measures

Primary Outcome

- Functional outcome assessed using the **American Orthopaedic Foot and Ankle Society (AOFAS) Ankle-Hindfoot Score** at final follow-up.

Secondary Outcomes

- Time to radiological union.
- Time to full weight bearing.
- Malalignment.
- Delayed union.
- Non-union.
- Infection.
- Implant-related complications.
- Range of ankle motion.
- Duration of surgery.
- Intraoperative blood loss.
- Length of hospital stay.

Radiological Assessment

Standard anteroposterior and lateral radiographs were obtained during each follow-up.

Radiological union was defined as:

- Bridging callus across at least three of four cortices on orthogonal radiographs.
- Absence of tenderness or pain during full weight bearing.

Malunion was defined as:

- Angular deformity greater than 5° in any plane.
- Rotational deformity greater than 10°.
- Shortening greater than 1 cm.

Functional Assessment

Functional outcome was assessed using the American Orthopaedic Foot and Ankle Society (AOFAS) Ankle-Hindfoot Score, which evaluates:

- Pain (40 points)
- Function (50 points)
- Alignment (10 points)

The total score ranges from 0 to 100, with higher scores indicating better functional outcome.

Functional results were categorized as:

- **Excellent:** 90–100
- **Good:** 80–89
- **Fair:** 70–79
- **Poor:** <70

Statistical Analysis

Data were entered into **Microsoft Excel 2021** and analyzed using **IBM SPSS Statistics version 27.0**. Continuous variables were expressed as **mean $\pm$ standard deviation (SD)**, whereas categorical variables were expressed as frequencies and percentages.

Comparisons between the IMIL nailing and MIPO groups were performed using:

- Independent Student's *t*-test for normally distributed continuous variables.
- Mann–Whitney *U* test for non-normally distributed continuous variables.
- Chi-square test or Fisher's exact test for categorical variables.

A **p-value <0.05** was considered statistically significant. All statistical tests were two-tailed.

RESULTS AND OBSERVATIONS;

A total of 30 adult patients with extra-articular distal tibial fractures were included in the study. Fifteen patients underwent Intramedullary Interlocking (IMIL) Nailing (Group A) and fifteen underwent Minimally Invasive Plate Osteosynthesis (MIPO) (Group B). All patients completed the scheduled follow-up until fracture union and final functional assessment. Both groups were comparable with respect to baseline demographic and injury characteristics. MIPO demonstrated superior fracture alignment and functional outcomes, whereas IMIL nailing was associated with shorter operative duration. The incidence of complications was low in both groups.

Table 1. Age Distribution of Study Participants (n = 30)

Age Group (Years)	IMIL (n=15)	MIPO (n=15)	Total	Percentage (%)
18–30	3	2	5	16.7
31–45	5	6	11	36.7
46–60	5	5	10	33.3
>60	2	2	4	13.3
Total	15	15	30	100

Observation: Most patients (36.7%) belonged to the 31–45 years age group.

Table 2. Gender Distribution

Gender	IMIL (n=15)	MIPO (n=15)	Total	Percentage (%)
Male	11	10	21	70.0
Female	4	5	9	30.0
Total	15	15	30	100

Observation: Males constituted the majority (70%) of patients.

Table 3. Mechanism of Injury

Mode of Injury	IMIL	MIPO	Total	Percentage (%)
Road Traffic Accident	10	11	21	70.0
Fall from Height	3	2	5	16.7
Slip/Fall	2	2	4	13.3
Total	15	15	30	100

Observation: Road traffic accidents were the commonest cause of injury.

Table 4. AO/OTA Fracture Classification

Fracture Type	IMIL	MIPO	Total	Percentage (%)
43-A1	6	5	11	36.7
43-A2	5	6	11	36.7
43-A3	4	4	8	26.6
Total	15	15	30	100

Observation: AO Type A1 and A2 fractures were equally common.

Table 5. Comparison of Operative Parameters

Parameter	IMIL	MIPO	p-value
Operative Time (minutes)	74.6 ± 9.5	96.8 ± 11.2	<0.001
Blood Loss (mL)	102.4 ± 21.8	145.7 ± 28.6	<0.001
Hospital Stay (days)	5.8 ± 1.2	6.5 ± 1.4	0.118

Observation: IMIL nailing required significantly shorter operative time and less blood loss.

Table 6. Radiological Union

Parameter	IMIL	MIPO	p-value
Time to Union (Weeks)	18.2 ± 2.9	17.0 ± 2.4	0.184
Delayed Union	2 (13.3%)	1 (6.7%)	0.543
Non-union	0	0	—

Observation: Fracture union was achieved in all patients. MIPO showed a trend toward earlier union, although the difference was not statistically significant.

Table 7. Functional Outcome (AOFAS Score)

Follow-up	IMIL	MIPO	p-value
3 Months	71.8 ± 8.1	76.9 ± 7.4	0.082
6 Months	84.6 ± 6.8	90.3 ± 5.7	0.018

Observation: Functional recovery improved significantly in both groups, with MIPO demonstrating significantly better AOFAS scores at six months.

Table 8. Final Functional Outcome Category

Outcome	IMIL	MIPO	Total
Excellent	4	7	11 (36.7%)
Good	7	6	13 (43.3%)
Fair	3	2	5 (16.7%)
Poor	1	0	1 (3.3%)
Total	15	15	30 (100%)

Observation: Excellent-to-good outcomes were observed in **80.0%** of IMIL patients and **86.7%** of MIPO patients.

Table 9. Postoperative Complications

Complication	IMIL	MIPO	Total
Superficial Infection	1	2	3 (10.0%)
Delayed Union	2	1	3 (10.0%)
Malalignment	2	0	2 (6.7%)
Implant Irritation	0	1	1 (3.3%)
Non-union	0	0	0

Observation: Malalignment occurred only in the IMIL group, whereas superficial wound complications were slightly more frequent in the MIPO group.

Table 10. Overall Comparison Between IMIL Nailing and MIPO

Variable	IMIL	MIPO	p-value
Operative Time (minutes)	74.6 ± 9.5	96.8 ± 11.2	<0.001
Time to Union (weeks)	18.2 ± 2.9	17.0 ± 2.4	0.184
Final AOFAS Score	84.6 ± 6.8	90.3 ± 5.7	0.018
Excellent/Good Outcome	12 (80.0%)	13 (86.7%)	0.624
Overall Complication Rate	5 (33.3%)	4 (26.7%)	0.691

Observation: Both surgical techniques produced satisfactory clinical and radiological outcomes. IMIL nailing offered shorter operative time and less intraoperative blood loss, while MIPO achieved better fracture alignment and significantly superior functional outcomes at six months. Overall complication rates were low and comparable between the two groups.

DISCUSSION

The present prospective comparative study evaluated the clinical and radiological outcomes of Intramedullary Interlocking (IMIL) Nailing and Minimally Invasive Plate Osteosynthesis (MIPO) in the treatment of extra-articular distal tibial fractures. Both techniques achieved satisfactory fracture union and functional recovery, although each demonstrated distinct advantages.

The majority of patients in the present study were males (70%), with the highest incidence occurring in the 31–45-year age group. Road traffic accidents accounted for 70% of injuries. These findings are consistent with previous studies by Vallier et al.(8) and Guo et al.(9), who reported that distal tibial fractures predominantly affect young and middle-aged adults involved in high-energy trauma.

Operative time and intraoperative blood loss were significantly lower in the IMIL group compared with the MIPO group. The minimally invasive nature of intramedullary nailing, smaller incisions, and reduced soft tissue dissection likely contributed to these findings. Similar observations have been reported by Li et al.(10), who demonstrated shorter operative duration and less blood loss with IMIL nailing.

Radiological union was achieved in all patients. Although fracture union occurred slightly earlier in the MIPO group, the difference was not statistically significant. The preservation of periosteal blood supply and fracture hematoma through indirect reduction techniques may explain the favorable healing observed with MIPO. Redfern et al.(6) also reported excellent union rates following minimally invasive plating of distal tibial fractures.

Functional outcome assessed using the AOFAS score showed significant improvement in both groups, with the MIPO group demonstrating superior scores at six months. Better maintenance of fracture alignment and stable fixation in the metaphyseal region may have contributed to improved ankle function. Guo et al.(9) similarly reported better functional outcomes and lower malalignment rates with locking plate fixation.

Malalignment occurred only in the IMIL group, whereas superficial wound complications were slightly more common in the MIPO group. These findings reflect the inherent advantages and disadvantages of each technique. IMIL nailing may present challenges in controlling distal fragment alignment because of the wider metaphyseal canal, whereas plate fixation requires additional soft tissue handling despite minimally invasive techniques. Similar trends have been reported by Vallier et al.(8) and Im et al.(11).

No cases of non-union or implant failure were observed in either group, indicating that both techniques provide reliable fixation when appropriate surgical principles are followed. The low complication rates observed in the present study are comparable to those reported by recent systematic reviews comparing IMIL nailing and MIPO for distal tibial fractures.(12)

The strengths of the present study include its prospective design and uniform postoperative follow-up. However, certain limitations should be acknowledged. The sample size was relatively small, the study was conducted at a single institution, and the follow-up period was limited to six months. Larger multicenter randomized controlled trials with longer follow-up are required to establish definitive treatment recommendations.

Overall, the findings of the present study suggest that both IMIL nailing and MIPO are effective treatment options for extra-articular distal tibial fractures. IMIL nailing offers advantages of shorter operative time and reduced blood loss, whereas MIPO provides superior functional outcomes and better maintenance of fracture alignment. The choice of fixation should be individualized based on fracture configuration, soft tissue condition, surgeon expertise, and patient-related factors.

CONCLUSION

Both Intramedullary Interlocking (IMIL) Nailing and Minimally Invasive Plate Osteosynthesis (MIPO) are effective treatment options for extra-articular distal tibial fractures, providing satisfactory fracture union and functional recovery. IMIL nailing offers the advantages of shorter operative time and reduced blood loss, whereas MIPO achieves better functional outcomes and improved fracture alignment. The choice of surgical technique should be individualized based on fracture characteristics, soft tissue condition, and surgeon expertise.

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