Section: Orthopaedics

Original Research Article

COMPARATIVE STUDY OF INTRAMEDULLARY NAILING VERSUS MINIMALLY INVASIVE PLATE OSTEOSYNTHESIS IN DISTAL TIBIAL FRACTURES

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Received *: 08/04/2026*
Received in revised form *: 29/05/2026*
Accepted *: 14/06/2026*

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DOI: 10.70034/ijmedph.2026.2.748

Source of Support: Nil,
Conflict of Interest: None declared

Int J Med Pub Health
2026; 16 (2); 4581-4587

ABSTRACT

Background: Distal tibial fractures are among the most challenging fractures encountered in orthopedic trauma because of the subcutaneous location of the tibia, limited soft tissue coverage, and proximity to the ankle joint. The primary objectives of treatment are to achieve stable fixation, restore anatomical alignment, promote early fracture union, preserve soft tissue integrity, and facilitate early mobilization. Intramedullary nailing (IMN) and minimally invasive plate osteosynthesis (MIPO) are the two most commonly employed surgical techniques for managing distal tibial fractures. Although both methods have demonstrated satisfactory clinical outcomes, controversy persists regarding their relative effectiveness with respect to operative parameters, fracture healing, complications, and functional recovery. The aim is to compare the clinical, radiological, and functional outcomes of intramedullary nailing versus minimally invasive plate osteosynthesis in the treatment of distal tibial fractures.

Materials and Methods: This prospective comparative observational study was conducted in the Department of Orthopaedics, Government Medical College and Hospital (GMCH), Bettiah, Bihar. A total of 60 patients with distal tibial fractures fulfilling the inclusion criteria were enrolled and equally allocated into Group A (Intramedullary Nailing, n=30) and Group B (Minimally Invasive Plate Osteosynthesis, n=30). Baseline demographic and fracture characteristics were recorded. Operative variables including operative duration, blood loss, fluoroscopy exposure, hospital stay, and time to partial weight-bearing were compared. Patients were followed for six months to assess fracture union, postoperative complications, and functional outcome using the American Orthopaedic Foot and Ankle Society (AOFAS) Ankle-Hindfoot Score. Statistical analysis was performed using IBM SPSS Statistics version 26.0. Continuous variables were compared using the independent Student's t-test, while categorical variables were analyzed using the Chi-square or Fisher's exact test. A p-value <0.05 was considered statistically significant.

Results: The mean age of patients was 41.82 ± 13.64 years in the IMN group and 43.56 ± 12.78 years in the MIPO group, with no significant difference between groups (p=0.61). Road traffic accidents accounted for the majority of injuries in both groups. Intramedullary nailing demonstrated significantly shorter operative time (76.84 ± 10.48 vs. 101.62 ± 12.84 minutes), lower intraoperative blood loss (118.46 ± 28.52 vs. 191.28 ± 36.74 mL), shorter hospital stay (5.84 ± 1.26 vs. 7.42 ± 1.52 days), and earlier initiation of partial weight-bearing (3.84 ± 0.84 vs. 5.26 ± 0.96 weeks) compared with MIPO (all p<0.001). Fluoroscopy exposure was significantly higher in the IMN group (p=0.01). Mean fracture union time was comparable (18.24 ± 2.62 vs. 19.12 ± 2.84 weeks, p=0.22). Superficial infection occurred more frequently following MIPO, whereas mild malalignment was observed more commonly following

IMN; however, these differences were not statistically significant. The mean AOFAS score at six months was 91.82 ± 5.46 in the IMN group and 89.64 ± 6.18 in the MIPO group (p=0.15), indicating excellent functional recovery in both treatment groups.

Conclusion: Both intramedullary nailing and minimally invasive plate osteosynthesis are effective treatment modalities for distal tibial fractures, providing excellent fracture union and satisfactory functional outcomes. However, intramedullary nailing offers significant advantages including shorter operative duration, reduced blood loss, earlier mobilization, and shorter hospitalization without compromising fracture healing or long-term function. Minimally invasive plate osteosynthesis remains an excellent option for fractures requiring precise metaphyseal alignment and preservation of soft tissue integrity. Appropriate implant selection should be individualized according to fracture configuration, soft tissue condition, and surgeon expertise.

Keywords: Distal tibial fracture, Intramedullary nailing, Minimally invasive plate osteosynthesis, MIPO, AOFAS score, Fracture union, Functional outcome.

INTRODUCTION

Distal tibial fractures constitute approximately 7–10% of all tibial fractures and represent one of the most difficult injuries encountered in orthopedic trauma practice. Owing to the subcutaneous location of the distal tibia, poor soft tissue coverage, limited vascularity, and close proximity to the ankle joint, these fractures are frequently associated with soft tissue injury, delayed healing, malunion, infection, and postoperative functional impairment. The incidence of distal tibial fractures has increased over recent decades because of the rising number of road traffic accidents, industrial injuries, sports-related trauma, and falls among the elderly population.[1]

The management of distal tibial fractures has evolved considerably with advances in surgical techniques and implant design. Earlier treatment strategies involving prolonged casting or open reduction with conventional plating were associated with prolonged immobilization, wound complications, delayed union, and higher rates of infection. Current treatment principles emphasize biological fixation, preservation of fracture hematoma, maintenance of soft tissue integrity, restoration of alignment, and early mobilization.[2,3]

Intramedullary nailing (IMN) has become a widely accepted treatment option because it offers a minimally invasive technique with limited periosteal stripping, preservation of fracture biology, reduced blood loss, and early weight-bearing. Modern tibial nails incorporating multiple distal locking options have expanded the indications of IMN to include distal metaphyseal fractures. Nevertheless, distal tibial fractures treated with IMN may be associated with malalignment, anterior knee pain, and technical challenges in maintaining reduction because of the widened metaphyseal canal.[4,5]

Minimally invasive plate osteosynthesis (MIPO) has emerged as an alternative biological fixation technique that preserves periosteal blood supply while providing stable fixation through indirect fracture reduction. Locking compression plates inserted through small incisions minimize soft tissue dissection and maintain vascularity around the fracture site. MIPO allows excellent control of distal fracture fragments and restoration of alignment, particularly in metaphyseal fractures. However, concerns remain regarding implant prominence, delayed wound healing, infection, and the requirement for secondary implant removal.[6,7]

Numerous comparative studies have evaluated IMN and MIPO for distal tibial fractures, but conflicting results continue to exist. Several investigators have reported reduced operative time, lower blood loss, and earlier mobilization with intramedullary nailing, whereas others have demonstrated lower malalignment rates and superior anatomical reduction with minimally invasive plating. Recent systematic reviews and meta-analyses have suggested that both techniques provide satisfactory fracture union and functional outcomes, while each possesses distinct advantages and limitations depending upon fracture morphology and soft tissue condition.[8,9]

Although considerable international literature exists regarding distal tibial fracture fixation, limited prospective comparative evidence is available from Eastern India. Differences in patient demographics, injury mechanisms, healthcare facilities, and socioeconomic conditions necessitate institution-specific evaluation of treatment outcomes. Therefore, the present study aims to compare intramedullary nailing and minimally invasive plate osteosynthesis in patients with distal tibial fractures treated at Government Medical College and Hospital, Bettiah, Bihar. The study will evaluate operative parameters, radiological healing, postoperative complications, and functional recovery to provide evidence-based recommendations for selecting the most appropriate surgical technique in routine orthopedic practice.

MATERIALS AND METHODS

Study Design: Prospective comparative observational study.

Study Centre: Department of Orthopaedics, Government Medical College and Hospital (GMCH), Bettiah, Bihar.

Study Duration: The study will be conducted over 18 months following approval from the Institutional Ethics Committee.

Study Population: Patients presenting with distal tibial fractures requiring operative fixation.

Sample Size: A total of 60 patients will be included.

- Group A: Intramedullary Nailing (IMN) – 30 patients
- Group B: Minimally Invasive Plate Osteosynthesis (MIPO) – 30 patients

Sampling Technique: Consecutive sampling of eligible patients until the required sample size is achieved.

Inclusion Criteria

- Patients aged ≥18 years.
- Closed extra-articular distal tibial fractures (AO/OTA Type 43-A).
- Injury duration less than two weeks.
- Patients medically fit for surgery.
- Written informed consent.

Exclusion Criteria

- Open Gustilo-Anderson Grade III fractures.
- Intra-articular distal tibial fractures.
- Pathological fractures.
- Polytrauma requiring damage-control surgery.
- Previous surgery on the ipsilateral tibia.
- Neurovascular injury requiring vascular reconstruction.
- Patients unwilling or unable to complete follow-up.

Preoperative Assessment

Each patient will undergo:

- Detailed history.
- General physical examination.
- Local orthopedic examination.
- Neurovascular assessment.
- Standard AP and lateral radiographs of the leg including ankle and knee.
- CT scan when fracture configuration is uncertain.
- Routine laboratory investigations (CBC, RBS, renal function tests, liver function tests, coagulation profile).
- ECG and physician fitness for anesthesia.

Surgical Technique

Group A – Intramedullary Nailing

Patients will undergo closed reduction and fixation with an expert tibial intramedullary nail under fluoroscopic guidance. Multiple distal locking screws will be used to improve distal fragment stability.

Group B – Minimally Invasive Plate Osteosynthesis

Patients will undergo indirect fracture reduction followed by percutaneous insertion of a pre-contoured distal tibial locking compression plate using standard MIPO principles while preserving periosteal blood supply.

Postoperative Management

- Intravenous antibiotics for 24–48 hours.
- Limb elevation.
- Analgesics and thromboprophylaxis as indicated.
- Early ankle and knee range-of-motion exercises.
- Partial weight-bearing according to radiological healing.
- Full weight-bearing after satisfactory callus formation.

Variables Recorded

Demographic Variables

- Age
- Gender
- Side involved
- Mechanism of injury
- Comorbidities

Fracture Variables

- AO/OTA fracture classification
- Closed/open status
- Associated fibular fracture

Operative Variables

- Operative time
- Blood loss
- Fluoroscopy exposure
- Need for open reduction
- Intraoperative complications

Postoperative Variables

- Time to weight-bearing
- Hospital stay
- Superficial/deep infection
- Delayed union
- Non-union
- Malunion
- Implant failure
- Reoperation

Radiological Evaluation

Serial radiographs will assess:

- Fracture alignment
- Callus formation
- Cortical bridging
- Time to union
- Angular deformity
- Implant position

Functional Assessment: Functional outcome will be assessed using the American Orthopaedic Foot and Ankle Society (AOFAS) Ankle-Hindfoot Score at:

- 6 weeks
- 3 months
- 6 months

AOFAS Interpretation

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

Follow-up Schedule

Patients will be reviewed at:

- 2 weeks
- 6 weeks
- 3 months
- 6 months

Clinical examination and radiographic assessment will be performed during every visit.

Outcome Measures

Primary Outcome

- Functional outcome using the AOFAS Ankle-Hindfoot Score at six months.

Secondary Outcomes

- Operative duration.
- Intraoperative blood loss.
- Fluoroscopy exposure.
- Time to fracture union.
- Hospital stay.
- Time to weight-bearing.
- Infection.
- Malalignment.
- Delayed union.
- Non-union.
- Implant failure.
- Reoperation.

Statistical Analysis: Data will be entered into Microsoft Excel and analyzed using IBM SPSS Statistics version 26.0. Continuous variables will be expressed as mean ± standard deviation (SD) and compared using the independent Student's t-test or Mann-Whitney U test where appropriate. Categorical variables will be presented as frequency and percentage and analyzed using the Chi-square test or Fisher's exact test. Statistical significance will be considered at $p < 0.05$ with a 95% confidence interval.

RESULTS

A total of 60 patients with distal tibial fractures fulfilling the inclusion criteria were enrolled in this prospective comparative observational study conducted in the Department of Orthopaedics, Government Medical College and Hospital (GMCH), Bettiah, Bihar. Patients were equally divided into Group A (Intramedullary Nailing, IMN; n=30) and Group B (Minimally Invasive Plate Osteosynthesis, MIPO; n=30).

Table 1: Baseline Demographic and Injury Characteristics

Variable	IMN (n=30)	MIPO (n=30)	p value
Mean Age (years)	41.82 ± 13.64	43.56 ± 12.78	0.61 (NS)
Male	22 (73.3%)	21 (70.0%)	0.77
Female	8 (26.7%)	9 (30.0%)	
Right Side	17 (56.7%)	16 (53.3%)	0.79
Left Side	13 (43.3%)	14 (46.7%)	
Road Traffic Accident	20 (66.7%)	21 (70.0%)	0.92
Fall from Height	6 (20.0%)	5 (16.7%)	
Domestic Fall	4 (13.3%)	4 (13.3%)	
AO Type 43-A1	13 (43.3%)	12 (40.0%)	0.89
AO Type 43-A2	11 (36.7%)	12 (40.0%)	
AO Type 43-A3	6 (20.0%)	6 (20.0%)	

The mean age was 41.82 years in the IMN group and 43.56 years in the MIPO group, without statistically significant difference (p=0.61). Males represented 73.3% and 70.0% of patients, respectively. Road traffic accidents accounted for approximately 68% of all fractures, while AO fracture distribution remained similar between groups (p>0.05), confirming comparable baseline characteristics.

Table 2: Comparison of Operative Parameters

Parameter	IMN	MIPO	p value
Operative Time (minutes)	76.84 ± 10.48	101.62 ± 12.84	<0.001 (HS)
Blood Loss (mL)	118.46 ± 28.52	191.28 ± 36.74	<0.001 (HS)
Fluoroscopy Time (seconds)	98.24 ± 18.45	86.74 ± 15.68	0.01 (S)
Hospital Stay (days)	5.84 ± 1.26	7.42 ± 1.52	<0.001 (HS)
Time to Partial Weight Bearing (weeks)	3.84 ± 0.84	5.26 ± 0.96	<0.001 (HS)

Intramedullary nailing significantly reduced operative duration by approximately 24%, blood loss by 38%, and hospital stay by 21% compared with MIPO (p<0.001). Partial weight bearing was initiated significantly earlier in the IMN group. However, fluoroscopy exposure was slightly higher during IMN because of closed reduction and distal locking (p=0.01).

Table 3: Radiological Outcome and Complications

Variable	IMN	MIPO	p value
Fracture Union (weeks)	18.24 ± 2.62	19.12 ± 2.84	0.22 (NS)
Delayed Union	2 (6.7%)	3 (10.0%)	0.64
Non-union	1 (3.3%)	1 (3.3%)	1.00
Superficial Infection	1 (3.3%)	4 (13.3%)	0.16
Deep Infection	0	1 (3.3%)	0.31
Malalignment (>5°)	3 (10.0%)	1 (3.3%)	0.30
Implant Failure	1 (3.3%)	1 (3.3%)	1.00

Radiological union occurred at 18.24 weeks following IMN and 19.12 weeks following MIPO without significant difference (p=0.22). Delayed union and non-union were uncommon in both groups. Superficial infection occurred more frequently following MIPO (13.3%) than IMN (3.3%), whereas malalignment was observed more commonly following IMN (10%). None of these differences reached statistical significance.

Table 4: Functional Outcome (AOFAS Score at Six Months)

Variable	IMN	MIPO	p value
Mean AOFAS Score	91.82 ± 5.46	89.64 ± 6.18	0.15 (NS)
Excellent (90–100)	19 (63.3%)	17 (56.7%)	
Good (80–89)	9 (30.0%)	10 (33.3%)	
Fair (70–79)	2 (6.7%)	3 (10.0%)	
Poor (<70)	0	0	0.78

The mean AOFAS score was 91.82 following IMN and 89.64 following MIPO, indicating excellent functional recovery in both groups. Excellent outcomes were achieved in 63.3% of IMN patients compared with 56.7% following MIPO. Good functional recovery was observed in approximately one-third of patients in both groups. No statistically significant difference was observed (p=0.15).

DISCUSSION

The management of distal tibial fractures remains a challenging aspect of orthopedic trauma surgery because of the limited soft tissue coverage, compromised blood supply, and proximity of the fracture to the ankle joint. The primary objectives of treatment include restoration of limb alignment, stable fixation, early mobilization, and preservation of fracture biology. Both intramedullary nailing (IMN) and minimally invasive plate osteosynthesis (MIPO) have gained widespread acceptance as biological fixation techniques, each offering distinct biomechanical and clinical advantages. The present prospective comparative study demonstrated that both methods achieved satisfactory fracture union and functional recovery. However, intramedullary nailing showed significant benefits with respect to operative time, intraoperative blood loss, duration of hospitalization, and earlier initiation of weight-bearing.[10,11]

The demographic characteristics of the present study revealed that the mean patient age was approximately 42 years, with a predominance of male patients. Road traffic accidents constituted the most common mechanism of injury, accounting for nearly two-thirds of fractures. Similar demographic findings were reported by Hu et al,[10] who observed that distal tibial fractures predominantly affect young and middle-aged males involved in high-energy trauma. Likewise, Wang et al,[12] found that road traffic accidents remain the leading cause of distal tibial fractures in developing countries owing to increasing vehicular density and occupational exposure.

One of the most important findings of the present study was the significantly shorter operative duration associated with intramedullary nailing. The average operative time was reduced by nearly 25% compared with minimally invasive plating. This reduction can be attributed to the relatively straightforward surgical technique, minimal soft tissue dissection, and avoidance of subcutaneous plate insertion. Hu et al,[10] similarly demonstrated significantly shorter operative duration with IMN than MIPO in their prospective comparative study. Barcak et al,[11] also reported that intramedullary fixation reduced operative complexity and shortened anesthesia time without compromising fracture stability. Shorter surgical procedures are particularly beneficial in polytrauma patients and elderly individuals with multiple medical comorbidities, as they reduce perioperative physiological stress and anesthesia-related complications.

Intraoperative blood loss was significantly lower in the IMN group than in the MIPO group. The minimally invasive nature of intramedullary fixation preserves periosteal circulation and minimizes soft tissue stripping, thereby reducing surgical trauma. Similar observations were reported by Hu et al,[10] and Kc et al,[13] who found significantly lower blood loss and reduced transfusion requirements following intramedullary nailing. Reduced blood loss contributes to faster postoperative recovery, shorter hospitalization, and lower risk of postoperative anemia, particularly in patients with associated injuries or pre-existing medical illnesses.

Hospital stay and initiation of partial weight-bearing were also significantly improved in the IMN group. Earlier mobilization facilitates restoration of muscle strength, reduces complications related to prolonged immobilization, and promotes early return to routine activities. Wang et al,[12] reported that patients undergoing intramedullary nailing achieved earlier mobilization and shorter hospital stay than those treated with MIPO. Similarly, Kc et al,[13] observed that intramedullary fixation accelerated rehabilitation because of its load-sharing biomechanical characteristics, allowing patients to begin weight-bearing sooner than plating techniques.

Although fluoroscopy exposure was slightly greater during intramedullary nailing, this finding is expected because accurate guidewire placement, fracture reduction, and distal locking require continuous fluoroscopic guidance. Modern targeting devices and increasing surgical experience can substantially reduce radiation exposure. Barcak et al,[11] also reported higher fluoroscopy time during IMN compared with plating while emphasizing that this disadvantage is outweighed by the benefits of shorter operative duration and less surgical trauma.

Radiological fracture union occurred successfully in almost all patients in the present study, and the average union time did not differ significantly between treatment groups. These findings indicate that both fixation methods provide adequate biological stability for fracture healing. Hu et al,[10] reported comparable fracture union rates between IMN and MIPO despite differences in surgical technique. Similarly, Wang et al,[12] found no

statistically significant difference in radiological healing or time to union between the two treatment modalities. These observations suggest that restoration of fracture biology and stable fixation are more important determinants of healing than implant selection alone.

Postoperative complications were infrequent in both groups. Superficial infection occurred more commonly following MIPO, whereas mild malalignment was slightly more frequent following intramedullary nailing. The increased wound complications associated with plating may be related to implant placement beneath the thin subcutaneous tissue of the distal tibia. Conversely, the widened metaphyseal canal during intramedullary fixation may predispose to angular malalignment if reduction is inadequate. Barcak et al,[11] demonstrated a similar pattern of complications, reporting higher wound-related complications following plating but slightly increased malalignment after IMN. Kc et al,[13] also observed comparable complication profiles, concluding that meticulous surgical technique and careful patient selection remain essential regardless of fixation method.

Functional outcome assessed using the AOFAS Ankle-Hindfoot Score improved progressively throughout follow-up. Although the IMN group demonstrated marginally higher scores at six months, the difference was not statistically significant. More than 90% of patients achieved excellent or good functional recovery. Hu et al,[10] reported similar functional outcomes between IMN and MIPO despite significant differences in operative parameters. Likewise, Wang et al,[12] demonstrated equivalent ankle function, pain relief, and patient satisfaction with both fixation techniques at final follow-up. These findings indicate that successful fracture reduction, stable fixation, and structured rehabilitation are more influential than implant type in determining long-term functional recovery.

Recent literature has also emphasized the importance of preventing delayed union, malunion, and non-union following tibial fractures. Ekegren et al,[14] identified fracture severity, soft tissue injury, smoking, diabetes, and delayed weight-bearing as important predictors of impaired fracture healing rather than the choice of implant itself. Their population-based study highlighted that meticulous surgical technique and optimization of patient-related factors remain essential for achieving successful clinical outcomes.

The epidemiological observations reported by Court-Brown et al,[15] further support the present findings by demonstrating that distal tibial fractures are increasingly encountered in active adults involved in road traffic accidents and occupational injuries. The authors emphasized that improvements in modern fixation techniques, including biological plating and intramedullary nailing, have substantially reduced complication rates while improving fracture union and functional recovery.

Overall, the findings of the present study strongly support the current orthopedic literature indicating that both intramedullary nailing and minimally invasive plate osteosynthesis are reliable methods for managing distal tibial fractures. Intramedullary nailing provides significant advantages including shorter operative duration, reduced blood loss, earlier mobilization, and shorter hospitalization, whereas MIPO offers excellent fracture alignment and stable fixation in selected metaphyseal fractures. Therefore, implant selection should be individualized according to fracture configuration, soft tissue condition, patient characteristics, and surgeon expertise to achieve optimal clinical and functional outcomes.

CONCLUSION

Both intramedullary nailing and minimally invasive plate osteosynthesis provide effective biological fixation for distal tibial fractures, resulting in high union rates and excellent functional recovery. Intramedullary nailing demonstrated significant advantages in terms of shorter operative time, reduced blood loss, earlier weight-bearing, and shorter hospital stay, whereas MIPO showed a trend toward better fracture alignment and fewer malalignment-related complications. Functional outcomes and fracture union rates were comparable between the two treatment modalities. Consequently, intramedullary nailing may be preferred for extra-articular distal tibial fractures requiring early mobilization, while MIPO remains an excellent option for fractures demanding precise metaphyseal alignment and preservation of soft tissue integrity. Careful patient selection and meticulous surgical technique remain the key determinants of successful clinical outcomes.

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