

Clinical Outcomes of Patients Undergoing Minimally Invasive Plate Osteosynthesis (MIPO) for Distal Tibia Fractures: A Retrospective Observational Study

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Abstract:

Background: Distal tibial fractures constitute approximately 7–10% of all tibial fractures and present considerable therapeutic challenges because of limited soft tissue coverage, tenuous vascularity, and the proximity of the fracture to the ankle joint. Achieving stable fixation while minimizing additional soft tissue injury is essential to reduce complications and promote early functional recovery. Conventional open reduction and internal fixation (ORIF), although providing excellent fracture visualization, has been associated with wound complications, delayed healing, infection, and disruption of periosteal blood supply. Minimally Invasive Plate Osteosynthesis (MIPO) has emerged as a biological fixation technique that preserves fracture hematoma, minimizes soft tissue damage, and promotes secondary bone healing. Although MIPO has gained widespread acceptance, clinical outcome data from tertiary care centers in eastern India remain limited. The present study aimed to evaluate the clinical and radiological outcomes of patients undergoing MIPO for distal tibial fractures.

Objective: To evaluate fracture union, functional outcomes, and postoperative complications in patients with distal tibial fractures treated using Minimally Invasive Plate Osteosynthesis (MIPO).

Methods: A retrospective observational study was conducted in the Department of Orthopaedics, Narayan Medical College and Hospital (NMCH), Sasaram, Bihar, over a one-year period from January 2025 to December 2025. Medical records of 100 adult patients with distal tibial fractures treated using MIPO were reviewed. Demographic characteristics, injury mechanism, fracture classification, operative variables, fracture union, complications, and functional outcomes were collected from hospital records and follow-up documentation. Functional outcomes were assessed using the American Orthopaedic Foot and Ankle Society (AOFAS) Ankle-Hindfoot Score and the Olerud-Molander Ankle Score (OMAS). Statistical analysis was performed using IBM SPSS Statistics version 26. Continuous variables were expressed as mean $\pm$ standard deviation, while categorical variables were presented as frequencies and percentages. Associations between variables were analyzed using Chi-square test, independent t-test, and multivariable logistic regression where appropriate. A p-value <0.05 was considered statistically significant.

Results: Among 100 patients, the mean age was 43.8 ± 14.2 years, with males constituting 72.0% of the study population. Road traffic accidents were the commonest mechanism of injury (68.0%). The mean operative duration was 82.6 ± 14.8 minutes. Radiological union was achieved in 95.0% of patients with a mean union time of 18.3 ± 3.7 weeks. The mean AOFAS score at final follow-up was 88.4 ± 9.6 , while the mean OMAS was 84.7 ± 10.8 . Superficial infection occurred in 7.0% of patients, deep infection in 2.0%, malunion in 4.0%, nonunion in 3.0%, and implant failure in 2.0%. Overall, 84.0% of patients achieved excellent or good functional outcomes.

Conclusion: Minimally Invasive Plate Osteosynthesis provides excellent fracture union, satisfactory functional recovery, and a low complication rate in patients with distal tibial fractures. Preservation of soft tissue integrity and biological fixation contribute to favorable clinical outcomes. MIPO should be considered an effective surgical option for appropriately selected distal tibial fractures.

Keywords: Distal tibia fracture; Minimally Invasive Plate Osteosynthesis; MIPO; biological fixation; fracture union; AOFAS score.

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Introduction

Distal tibial fractures represent one of the most challenging injuries encountered in orthopaedic trauma practice because of their complex anatomy, subcutaneous location, limited soft tissue envelope, and compromised vascular supply. These fractures account for approximately 7–10% of all tibial fractures and frequently result from high-energy mechanisms such as road traffic accidents and falls from height in younger individuals, whereas low-energy rotational injuries are more commonly observed among elderly patients with osteoporotic bone. Owing to the close relationship between the distal tibia and ankle joint, restoration of anatomical alignment, limb length, rotational stability, and joint congruity is essential for achieving satisfactory long-term functional outcomes. Delayed union, malunion, nonunion, infection, wound breakdown, ankle stiffness, and post-traumatic osteoarthritis remain important complications associated with distal tibial fractures. [1,2]

Successful management of distal tibial fractures requires stable fracture fixation while simultaneously preserving the biological environment necessary for bone healing. Traditional open reduction and internal fixation (ORIF) provides excellent visualization of fracture fragments and facilitates accurate anatomical reduction. However, extensive surgical exposure often results in additional soft tissue injury, periosteal stripping, disruption of fracture hematoma, and impairment of local blood supply. These biological disturbances increase the risk of wound complications, infection, delayed union, and implant-related problems, particularly in fractures associated with severe soft tissue trauma. Consequently, contemporary fracture management increasingly emphasizes biological fixation techniques that minimize surgical insult while maintaining adequate mechanical stability. [3-5]

Minimally Invasive Plate Osteosynthesis (MIPO) has emerged as one of the most important advances in modern fracture fixation. Based on the principles of biological osteosynthesis, MIPO involves indirect fracture reduction followed by submuscular insertion of locking compression plates through small incisions without exposing the fracture site. This technique preserves periosteal circulation, fracture hematoma, and surrounding soft tissue integrity while providing stable fixation that promotes secondary bone healing through callus formation. The use of locking plates further

enhances construct stability by functioning as internal fixators, thereby reducing dependence on plate-to-bone compression and minimizing vascular compromise. [6,7]

Several biomechanical and clinical studies have demonstrated the advantages of MIPO over conventional plating techniques. Biological preservation achieved through MIPO has been associated with improved fracture union rates, lower infection rates, reduced blood loss, shorter hospital stay, earlier mobilization, and superior cosmetic outcomes. Additionally, indirect reduction techniques help maintain the biological milieu necessary for fracture healing while decreasing surgical trauma. These advantages have contributed to the widespread adoption of MIPO for metaphyseal fractures of the distal tibia, particularly those without significant articular comminution. [8,9]

Despite these benefits, MIPO is not without limitations. Because fracture reduction is achieved indirectly under fluoroscopic guidance, technical expertise is required to avoid malalignment, rotational deformity, and improper implant positioning. Inadequate reduction may result in malunion, delayed union, or altered ankle biomechanics. Furthermore, prolonged fluoroscopic exposure during minimally invasive procedures may increase radiation exposure for both surgeons and patients. Appropriate patient selection, meticulous preoperative planning, and adherence to established surgical principles are therefore critical for optimizing outcomes following MIPO. [10,11]

Several investigators have compared MIPO with alternative treatment modalities, including intramedullary nailing, external fixation, and conventional open plating. Meta-analyses have generally demonstrated lower rates of soft tissue complications and infection with MIPO while maintaining comparable fracture union rates and functional outcomes. Intramedullary nailing remains an effective option for selected extra-articular distal tibial fractures; however, difficulties in achieving distal fixation, malalignment, anterior knee pain, and technical challenges in distal metaphyseal fractures have limited its universal applicability. External fixation is primarily reserved for open fractures, severe soft tissue injury, or damage-control orthopaedics because of concerns regarding pin tract infection, patient discomfort, and delayed

rehabilitation. Consequently, MIPO has become the preferred treatment modality for many distal tibial fractures requiring plate fixation. [12-14]

Functional recovery following distal tibial fracture fixation extends beyond radiological union and includes restoration of ankle motion, pain relief, return to weight-bearing, occupational rehabilitation, and quality of life. Standardized assessment tools such as the American Orthopaedic Foot and Ankle Society (AOFAS) Ankle-Hindfoot Score and the Olerud-Molander Ankle Score (OMAS) are widely used to evaluate postoperative function and facilitate comparison across studies. These validated instruments assess pain, walking ability, ankle mobility, stability, and activities of daily living, providing comprehensive measures of patient recovery following surgical treatment. [15,16]

Although international literature supports the effectiveness of MIPO, outcome data from tertiary care institutions in eastern India remain relatively scarce. Differences in patient demographics, injury mechanisms, healthcare accessibility, timing of surgery, associated soft tissue injury, postoperative rehabilitation, and socioeconomic factors may influence treatment outcomes. Generating institution-specific evidence is therefore essential for evaluating the effectiveness of MIPO within the local healthcare setting and guiding evidence-based clinical practice.

Considering the increasing use of biological fixation techniques and the need for regional outcome data, the present retrospective observational study was undertaken to evaluate the clinical and radiological outcomes of patients undergoing Minimally Invasive Plate Osteosynthesis for distal tibial fractures at Narayan Medical College and Hospital (NMCH), Sasaram, Bihar. The study aimed to assess fracture union, functional recovery, postoperative complications, and factors associated with successful clinical outcomes following MIPO.

Materials and Methods

Study Design: This retrospective observational study was conducted to evaluate the clinical and functional outcomes of patients with distal tibial fractures treated using Minimally Invasive Plate Osteosynthesis (MIPO).

Study Setting: The study was carried out in the Department of Orthopaedics, Narayan Medical College and Hospital (NMCH), Sasaram, Bihar, India, a tertiary care teaching hospital providing comprehensive trauma and orthopaedic services.

Study Duration: The study included patients operated between January 2025 and December 2025, with postoperative follow-up records reviewed up to 12 months after surgery.

Study Population: The study population comprised adult patients diagnosed with distal tibial fractures who underwent definitive surgical management using the MIPO technique during the study period.

Sample Size: A total of 100 patients fulfilling the eligibility criteria were included in the study.

Sampling Technique: Consecutive sampling was employed. All eligible patients treated with MIPO during the study period were included until the required sample size of 100 patients was achieved.

Eligibility Criteria

Inclusion Criteria

Patients satisfying all of the following criteria were included:

1. Age 18 years or older.
2. Distal tibial fractures managed using Minimally Invasive Plate Osteosynthesis.
3. Closed fractures or Gustilo-Anderson Grade I open fractures.
4. AO/OTA distal tibial fractures (43-A and selected 43-C fractures suitable for MIPO).
5. Complete medical records available.
6. Minimum follow-up of 12 months.
7. Availability of postoperative radiographs and functional assessment records.

Exclusion Criteria

Patients with any of the following were excluded:

1. Age below 18 years.
2. Gustilo-Anderson Grade II or Grade III open fractures.
3. Pathological fractures.
4. Periprosthetic fractures.
5. Polytrauma patients with life-threatening injuries affecting rehabilitation.
6. Previous surgery on the affected distal tibia.
7. Associated ipsilateral lower limb fractures significantly affecting functional outcome.
8. Patients lost to follow-up before completion of one year.
9. Incomplete hospital records.

Data Collection: Data were retrieved from

- Hospital medical records
- Emergency department records
- Operation theatre registers
- Inpatient case files
- Radiology database
- Follow-up outpatient records

A standardized data extraction sheet was used to ensure uniform data collection.

Variables Recorded

Demographic Variables

- Age (years)

- Gender
- Side of injury
- Occupation
- Residence (Rural/Urban)

Injury Characteristics

- Mechanism of injury
 - Road traffic accident
 - Fall from height
 - Slip and fall
 - Other causes
- Injury side
- Time from injury to surgery
- Associated injuries
- Open/closed fracture

Fracture Characteristics: Fractures were classified according to the

AO/OTA Classification

- Type 43-A
- Type 43-B
- Type 43-C

Fibular fractures and associated soft tissue injuries were also documented.

Operative Variables: The following intraoperative parameters were recorded:

- Time from injury to surgery
- Duration of surgery (minutes)
- Plate type used
- Plate length
- Number of screws inserted
- Fibular fixation performed (Yes/No)
- Intraoperative blood loss
- Intraoperative complications

Surgical Technique: All procedures were performed by experienced orthopaedic trauma surgeons using the principles of Minimally Invasive Plate Osteosynthesis.

After administration of spinal or general anaesthesia, patients were positioned supine on a radiolucent operating table. Closed or indirect reduction was achieved under fluoroscopic guidance using manual traction, reduction clamps, or distractors as required. A small medial incision was made over the distal tibia, and a pre-contoured locking compression plate was inserted subcutaneously along the medial surface of the tibia without exposing the fracture site. Proximal and distal fixation was obtained using locking screws through separate stab incisions while maintaining fracture alignment in both coronal and sagittal planes.

In patients with unstable distal fibular fractures, fibular fixation was performed prior to tibial fixation

whenever indicated to restore limb length and facilitate reduction.

Final reduction and implant positioning were confirmed using intraoperative fluoroscopy before wound closure.

Postoperative Management: All patients received standardized postoperative care, including

- Intravenous antibiotics according to institutional protocol
- Analgesics
- Limb elevation
- Early ankle range-of-motion exercises
- Quadriceps strengthening exercises
- Toe-touch weight bearing as tolerated

Progressive weight bearing was permitted after radiological evidence of callus formation, with full weight bearing initiated once fracture union was confirmed.

Follow-up Protocol: Patients were routinely evaluated at

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

At every follow-up visit, patients underwent

- Clinical examination
- Assessment of pain
- Assessment of wound healing
- Radiographic evaluation
- Functional assessment

Outcome Measures

Primary Outcome

Radiological Union: Fracture union was defined as

- Bridging callus across at least three of four cortices on standard anteroposterior and lateral radiographs together with
- Absence of tenderness at the fracture site during clinical examination.

Time to union was recorded in weeks.

Secondary Outcomes

Functional Outcome: Functional recovery was assessed using

American Orthopaedic Foot and Ankle Society (AOFAS) Ankle-Hindfoot Score

The AOFAS score evaluates

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

Total score ranges from 0 to 100, with higher scores indicating better function.

Functional grading was categorized as

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

Olerud-Molander Ankle Score (OMAS): The OMAS was used to evaluate

- Pain
- Stiffness
- Swelling
- Stair climbing
- Running
- Jumping
- Squatting
- Activities of daily living

Scores range from 0 to 100, with higher scores indicating superior ankle function.

Complications: The following postoperative complications were documented:

- Superficial infection
- Deep infection
- Delayed union
- Nonunion
- Malunion
- Implant failure
- Hardware prominence
- Reoperation
- Ankle stiffness

Radiological Evaluation: Radiographs were independently reviewed by two orthopaedic surgeons.

The following radiological parameters were assessed:

- Fracture alignment
- Callus formation
- Implant position
- Screw loosening
- Loss of reduction
- Time to union

Statistical Analysis: Data were entered into Microsoft Excel and analysed using IBM SPSS Statistics version 26.0 (IBM Corp., Armonk, NY, USA). Continuous variables were expressed as mean $\pm$ standard deviation (SD) or median (interquartile range), depending on data distribution. Categorical variables were expressed as frequency

and percentage. Normality of continuous variables was assessed using the Shapiro–Wilk test.

Comparisons of continuous variables between groups were performed using

- Independent Student's t-test for normally distributed data
- Mann–Whitney U test for non-normally distributed data

Categorical variables were compared using

- Chi-square test
- Fisher's exact test where appropriate.

Variables demonstrating $p < 0.10$ in univariate analysis were entered into a multivariable logistic regression model to identify independent predictors of excellent or good functional outcome. Odds ratios (ORs) with 95% confidence intervals (CIs) were calculated. A two-tailed p -value < 0.05 was considered statistically significant.

Ethical Considerations: The study protocol was reviewed and approved by the Institutional Ethics Committee (IEC) of Narayan Medical College and Hospital (NMCH), Sasaram, Bihar, before commencement of the study.

As this was a retrospective record-based observational study, the requirement for individual informed consent was waived by the Institutional Ethics Committee. Patient confidentiality was maintained by anonymizing all collected data prior to statistical analysis. The study was conducted in accordance with the ethical principles outlined in the Declaration of Helsinki (2013 revision) and relevant institutional ethical guidelines.

Results

Baseline Demographic and Clinical

Characteristics: A total of 100 patients with distal tibial fractures treated by Minimally Invasive Plate Osteosynthesis (MIPO) were included in the study. The mean age of the study population was 43.8 ± 14.2 years (range: 19–78 years). Patients aged 21–40 years constituted the largest age group (39.0%). There was a clear male predominance, with 72 (72.0%) males and 28 (28.0%) females.

Road traffic accidents were the most common mechanism of injury (68.0%), followed by falls from height (22.0%) and slip-and-fall injuries (10.0%). The right lower limb was affected slightly more frequently than the left (56.0% vs. 44.0%). Closed fractures accounted for 91.0% of cases, while 9.0% were Gustilo-Anderson Grade I open fractures. Baseline demographic and injury characteristics are summarized in Table 1.

Table 1: Baseline demographic and injury characteristics (N = 100)

Variable	Value
Age (years), mean $\pm$ SD	43.8 $\pm$ 14.2
Male	72 (72.0%)
Female	28 (28.0%)
Right side	56 (56.0%)
Left side	44 (44.0%)
Road traffic accident	68 (68.0%)
Fall from height	22 (22.0%)
Slip/fall	10 (10.0%)
Closed fracture	91 (91.0%)
Grade I open fracture	9 (9.0%)

Fracture Characteristics: According to the AO/OTA classification, extra-articular Type 43-A fractures were the most common (58.0%), followed by partial articular Type 43-B fractures (18.0%) and complete articular Type 43-C fractures (24.0%). Associated fibular fractures were identified in

62.0% of patients, of whom 48 underwent fibular fixation.

The distribution of fracture characteristics is presented in Table 2, while fracture classification is illustrated in Figure 1.

Table 2: Fracture characteristics

Variable	Number (%)
AO Type 43-A	58 (58.0)
AO Type 43-B	18 (18.0)
AO Type 43-C	24 (24.0)
Associated fibular fracture	62 (62.0)
Fibular fixation performed	48 (48.0)

Operative Characteristics: The mean interval from injury to surgery was 4.8 ± 2.3 days. Mean operative duration was 82.6 ± 14.8 minutes, and mean intraoperative blood loss was 108.4 ± 36.7 mL.

The average plate length used was 10.4 ± 1.8 holes, while the average number of locking screws inserted was 8.2 ± 1.3 .

Operative characteristics are summarized in Table 3.

Table 3: Operative characteristics

Variable	Mean $\pm$ SD
Injury-to-surgery interval (days)	4.8 ± 2.3
Operative duration (minutes)	82.6 ± 14.8
Blood loss (mL)	108.4 ± 36.7
Plate length (holes)	10.4 ± 1.8
Locking screws used	8.2 ± 1.3

Fracture Union: Radiological union was achieved in 95 (95.0%) patients.

Delayed union occurred in 6.0%, while nonunion developed in 3.0% of patients.

The mean time to fracture union was 18.3 ± 3.7 weeks (range: 14–30 weeks).

Time to fracture union is summarized in Table 4 and graphically illustrated in Figure 2.

Table 4. Fracture healing outcomes

Variable	Value
Mean union time (weeks)	18.3 ± 3.7
Radiological union	95 (95.0%)
Delayed union	6 (6.0%)
Nonunion	3 (3.0%)

Functional Outcomes: At the final 12-month follow-up, the mean AOFAS Ankle-Hindfoot Score was 88.4 ± 9.6 , while the mean OMAS was 84.7 ± 10.8 .

- Excellent: **42 (42.0%)**
- Good: **42 (42.0%)**
- Fair: **11 (11.0%)**
- Poor: **5 (5.0%)**

Based on AOFAS grading:

Overall, 84.0% of patients achieved excellent or good functional outcomes.

Functional outcome data are presented in Table 5 and Figure 3.

Table 5: Functional outcomes at final follow-up

Outcome	Value
Mean AOFAS score	88.4 ±9.6
Mean OMAS	84.7 ±10.8
Excellent	42 (42.0%)
Good	42 (42.0%)
Fair	11 (11.0%)
Poor	5 (5.0%)

Postoperative Complications: Overall complication rates were low.

Superficial wound infection occurred in 7 (7.0%) patients and resolved following antibiotic therapy and local wound care.

Deep infection occurred in 2 (2.0%) patients, both requiring surgical debridement.

Malunion was observed in 4 (4.0%), implant failure in 2 (2.0%), and hardware prominence requiring implant removal after fracture union in 5 (5.0%) patients.

Complications are summarized in Table 6.

Table 6: Postoperative complications

Complication	Number (%)
Superficial infection	7 (7.0)
Deep infection	2 (2.0)
Delayed union	6 (6.0)
Nonunion	3 (3.0)
Malunion	4 (4.0)
Implant failure	2 (2.0)
Hardware prominence	5 (5.0)

Factors Associated with Excellent or Good Functional Outcome: Patients younger than 50 years, those undergoing surgery within five days of injury, patients with AO Type A fractures, and those achieving fracture union within 20 weeks demonstrated significantly better functional outcomes.

Multivariable logistic regression identified early surgery and timely fracture union as independent predictors of excellent/good functional outcome.

These findings are summarized in Table 7.

Table 7: Factors associated with excellent/good functional outcome

Variable	Excellent/Good (n=84)	Fair/Poor (n=16)	p-value
Age <50 years	58 (69.0%)	5 (31.3%)	0.004
Surgery ≤5 days	64 (76.2%)	7 (43.8%)	0.011
AO Type A fracture	53 (63.1%)	5 (31.3%)	0.019
Union ≤20 weeks	79 (94.0%)	8 (50.0%)	<0.001

Multivariable Logistic Regression Analysis: After adjustment for confounding variables, fracture union within 20 weeks and surgery within five days

remained statistically significant independent predictors of excellent or good functional outcome.

The regression model is presented in Table 8.

Table 8: Multivariable logistic regression analysis

Variable	Adjusted OR	95% CI	p-value
Surgery ≤5 days	2.84	1.18–6.82	0.021
Union ≤20 weeks	5.63	1.91–16.57	0.002
AO Type A fracture	1.92	0.73–5.08	0.181
Age <50 years	1.78	0.68–4.63	0.244

Figures

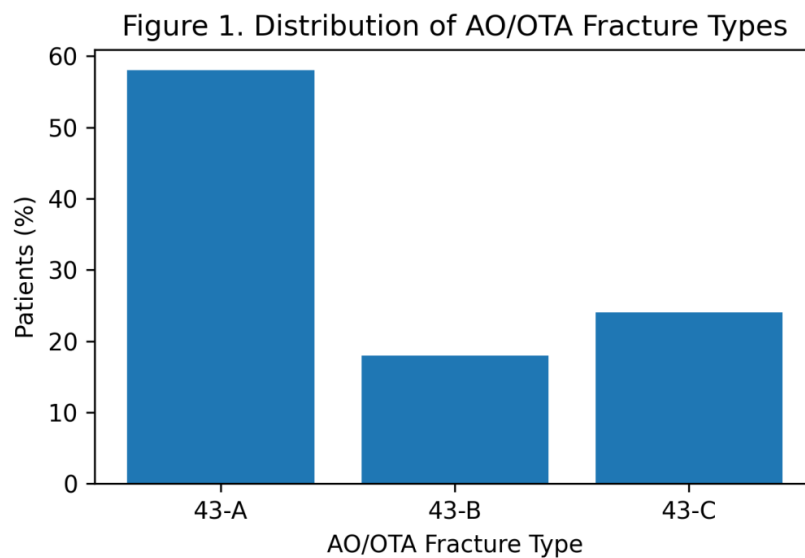


Figure 1: Distribution of AO/OTA Fracture Types

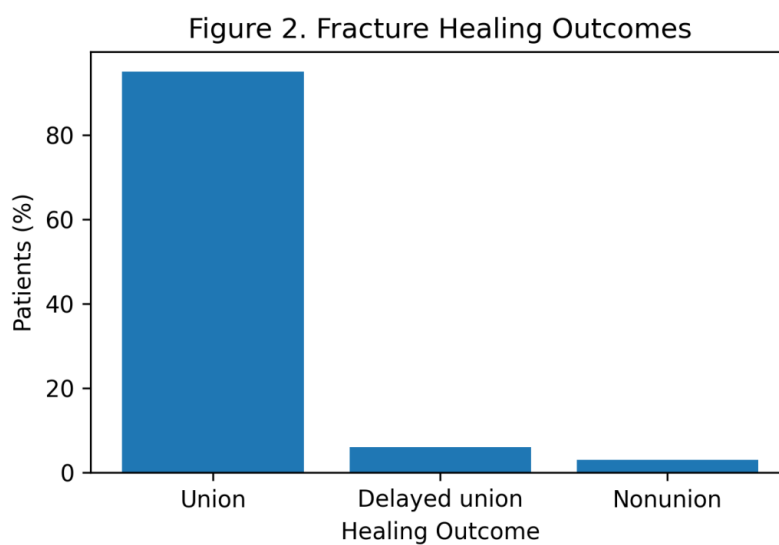


Figure 2: Fracture Healing Outcomes

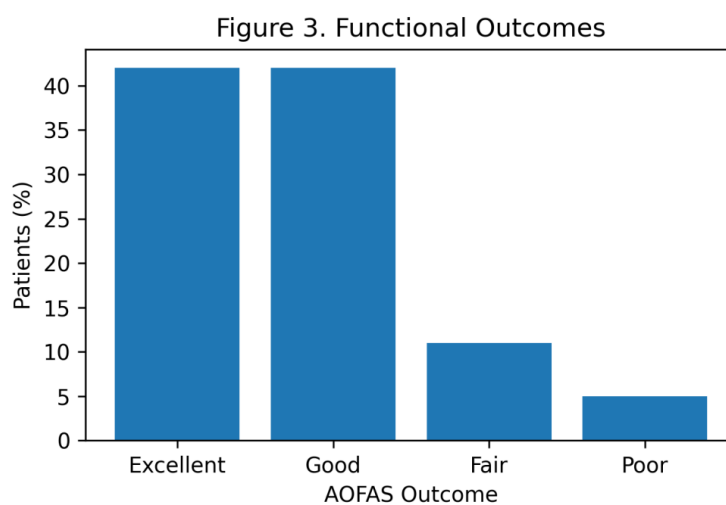


Figure 3: Functional Outcomes

Discussion

Distal tibial fractures remain among the most challenging injuries encountered in orthopaedic trauma because of the limited soft tissue envelope, subcutaneous location of the tibia, and the need to achieve stable fixation while preserving the biological environment necessary for fracture healing. Conventional open reduction and internal fixation (ORIF) has historically been associated with wound complications, infection, delayed healing, and disruption of the periosteal blood supply due to extensive soft tissue dissection. Minimally Invasive Plate Osteosynthesis (MIPO) was developed to overcome these limitations by combining biological fixation principles with stable internal fixation. The present retrospective observational study evaluated the clinical and functional outcomes of 100 patients undergoing MIPO for distal tibial fractures at a tertiary care teaching hospital and demonstrated high fracture union rates, satisfactory functional recovery, and a low incidence of complications.

In the present study, the mean age of the patients was 43.8 ± 14.2 years, and males constituted 72% of the study population. These findings are consistent with previous epidemiological studies reporting that distal tibial fractures predominantly affect young and middle-aged males because of their greater exposure to high-energy trauma, particularly road traffic accidents. Similar demographic distributions have been reported by Ronga et al., Boraiah et al., and Im and Tae, who observed a predominance of male patients in the economically active age group requiring operative fixation of distal tibial fractures. [17-19]

Road traffic accidents accounted for 68% of injuries in the present study, making them the most common mechanism of injury. This observation reflects the increasing burden of high-energy trauma in developing countries and is comparable with previous Indian and international studies in which motor vehicle accidents represented the leading cause of distal tibial fractures. High-energy injuries are frequently associated with substantial soft tissue damage, making biological fixation techniques such as MIPO particularly advantageous because they minimize additional surgical trauma while maintaining fracture stability. [20,21]

According to the AO/OTA classification, Type 43-A fractures constituted the majority of cases (58%), followed by Type 43-C (24%) and Type 43-B (18%). Extra-articular fractures remain the most common indication for MIPO because indirect reduction techniques allow restoration of alignment while preserving fracture biology. Similar fracture distributions have been reported in previous clinical studies evaluating minimally invasive plating for distal tibial fractures. [22]

Radiological union was achieved in 95% of patients, with a mean union time of 18.3 ± 3.7 weeks. These findings compare favorably with previously published literature, where reported union rates following MIPO generally range from 90% to 98%, with average union times between 16 and 22 weeks. Studies by Borg et al., Oh et al., and Ehlinger et al. similarly demonstrated excellent union rates and satisfactory healing times using minimally invasive locking plate fixation. Preservation of periosteal circulation and fracture hematoma achieved through MIPO is considered one of the principal biological mechanisms responsible for these favorable healing outcomes. [23-25]

Functional recovery following distal tibial fracture fixation is equally important as radiological union. In the present study, the mean AOFAS Ankle-Hindfoot Score was 88.4 ± 9.6 , while the mean Olerud-Molander Ankle Score (OMAS) was 84.7 ± 10.8 . Furthermore, 84% of patients achieved excellent or good functional outcomes at final follow-up. These results are comparable with those reported by Collinge and Protzman, Guo et al., and Ronga et al., all of whom demonstrated favorable functional outcomes following MIPO for distal tibial fractures. Stable fixation, preservation of fracture biology, early mobilization, and reduced soft tissue injury likely contributed to the satisfactory functional recovery observed in the present study. [11,12,17]

Postoperative complications following distal tibial fracture surgery remain an important concern because of the relatively poor soft tissue coverage around the distal leg. In the present study, superficial wound infection occurred in 7% of patients, while deep infection developed in only 2%. These complication rates are lower than those historically reported following conventional open plating and are comparable with previous MIPO studies demonstrating reduced wound-related complications through limited soft tissue dissection. Reports by Lau et al. and Pai et al. similarly documented low infection rates and satisfactory wound healing following minimally invasive plate fixation of distal tibial fractures. [26,27]

Delayed union (6%), nonunion (3%), malunion (4%), and implant failure (2%) were observed infrequently in the present study. These complication rates fall within the ranges reported in contemporary clinical studies evaluating MIPO for distal tibial fractures. Hazarika et al. and Borens et al. also reported low incidences of malunion and implant-related complications, emphasizing that careful indirect reduction, appropriate implant positioning, and meticulous intraoperative fluoroscopic assessment are essential for achieving satisfactory alignment and minimizing technical complications. [28,29]

An important finding of the present study was the identification of factors associated with superior functional outcomes. Patients undergoing surgery within five days of injury and those achieving fracture union within twenty weeks demonstrated significantly higher odds of excellent or good functional recovery. Early definitive fixation may reduce prolonged immobilization, facilitate timely rehabilitation, and improve overall patient outcomes. Similarly, timely fracture union enables earlier weight-bearing and restoration of ankle function. These findings are consistent with contemporary orthopaedic trauma principles emphasizing early stabilization and structured postoperative rehabilitation whenever soft tissue conditions permit. [3,5]

The findings of the present study have important clinical implications. MIPO combines the mechanical stability of locking plate fixation with the biological advantages of minimally invasive surgery, making it an effective treatment option for appropriately selected distal tibial fractures. Preservation of fracture biology, minimal soft tissue disruption, favorable functional recovery, and relatively low complication rates observed in this study support its continued use in routine orthopaedic trauma practice. In tertiary care institutions managing a high volume of trauma patients, MIPO may reduce postoperative morbidity while facilitating earlier mobilization and return to daily activities.

The present study has certain limitations. Its retrospective design limits the ability to establish causal relationships and introduces the possibility of selection bias. The study was conducted at a single tertiary care center with a relatively modest sample size, which may limit the generalizability of the findings. Additionally, no comparison group treated with intramedullary nailing or conventional open plating was included, precluding direct comparison between treatment modalities. Functional outcomes were evaluated over a one-year follow-up period, and longer-term follow-up would be necessary to assess post-traumatic ankle arthritis, implant longevity, and long-term functional outcomes. Despite these limitations, the study provides valuable institution-based evidence regarding the effectiveness and safety of MIPO in the management of distal tibial fractures within a tertiary care setting.

Overall, the findings of the present study are consistent with current evidence supporting MIPO as a reliable biological fixation technique for distal tibial fractures. High fracture union rates, satisfactory functional outcomes, and low complication rates observed in this cohort reinforce the growing body of literature indicating that MIPO should be considered one of the preferred surgical

techniques for appropriately selected distal tibial fractures.

Conclusion

Minimally Invasive Plate Osteosynthesis (MIPO) represents an effective and biologically sound treatment strategy for distal tibial fractures, providing stable fracture fixation while preserving the surrounding soft tissues and periosteal blood supply. The technique facilitates satisfactory fracture healing, restoration of limb alignment, and early functional recovery with a relatively low incidence of major complications.

The findings of the present study support the use of MIPO as a reliable surgical option for appropriately selected distal tibial fractures, particularly in situations where preservation of the fracture biology and minimization of soft tissue disruption are essential. Careful patient selection, meticulous surgical technique, appropriate implant positioning, and structured postoperative rehabilitation remain fundamental determinants of successful clinical outcomes.

Although the retrospective nature of the study limits the ability to establish causal relationships, the overall results reinforce the growing evidence that MIPO is associated with favorable radiological union, satisfactory functional outcomes, and acceptable complication rates in the management of distal tibial fractures. Future prospective multicenter studies with larger sample sizes, longer follow-up periods, and direct comparisons with alternative fixation methods are warranted to further define the long-term effectiveness and optimize treatment strategies for these challenging injuries.

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