International Journal of Research in Orthopaedics
Magadum M et al. Int J Res Orthop. 2025 May;11(3):550-554
http://www.ijoro.org

Original Research Article

DOI: https://dx.doi.org/10.18203/issn.2455-4510.IntJResOrthop20251133

Clinical and radiological outcome of minimally invasive plate osteosynthesis in distal tibial fractures: a retrospective analysis

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Received: 03 March 2025
Accepted: 16 April 2025

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ABSTRACT

Background: Distal tibial fractures are a common injury that poses challenges in terms of treatment and outcomes. Minimally invasive plate osteosynthesis (MIPO) has emerged as a promising technique, reducing the need for large incisions while promoting faster recovery and fewer complications compared to traditional open reduction and internal fixation (ORIF). This study evaluates the clinical and radiological outcomes of MIPO in patients with distal tibial fractures.

Methods: A retrospective analysis of 40 patients who underwent MIPO for distal tibial fractures between November 2022 and November 2024 at a Tertiary healthcare center, was conducted. Fractures were classified according to the AO/OTA system. Outcomes such as fracture healing, functional recovery (measured using the AOFAS score), pain relief (assessed via the VAS), and complication rates were evaluated. Statistical analysis was performed using SPSS version 25, with $p<0.05$ considered significant.

Results: The mean age of the patients was 42.5±12.3 years. The majority of fractures were classified as type 43-A (70%). Fracture healing was achieved in 95% of cases by 24 weeks, with a mean time to union of 14.3±3.2 weeks. The AOFAS scores improved significantly from 72.5±13.1 at 6 weeks to 85.2±10.3 at 12 weeks ($p<0.05$). Pain reduction was also significant, with VAS scores decreasing from 6.25±2.14 at 6 weeks to 1.56±1.26 at 24 weeks ($p<0.05$). Complications were noted in 10% of cases, including superficial infection and delayed union.

Conclusions: MIPO offers favourable outcomes in the treatment of distal tibial fractures, with significant improvements in fracture healing, functional recovery, and pain reduction. The technique is associated with a low complication rate, making it a viable option for managing these fractures.

Keywords: Distal tibial fractures, MIPO, Fracture healing, AOFAS score, Visual analog scale, Complications

INTRODUCTION

Distal tibial fractures are a common injury, often resulting from high-energy trauma, such as motor vehicle accidents or falls from significant heights, though they can also occur due to low-energy trauma, particularly in older individuals with osteoporotic bones.[1] These fractures typically involve the metaphyseal region of the tibia and are associated with a high risk of complications, including malalignment, nonunion, infection, and delayed healing, due to the relatively poor blood supply to the distal tibia.[2] Treatment of these fractures has historically been challenging, with various surgical and conservative approaches used depending on the severity and type of fracture.

Traditionally, ORIF have been the gold standard for managing distal tibial fractures, involving large incisions and soft tissue dissection, which can result in complications such as infection, wound healing issues, and

damage to surrounding tissues.[3] However, as the understanding of fracture healing and surgical techniques has evolved, there has been an increasing interest in minimally invasive techniques that offer the potential for improved outcomes with fewer complications.[4]

MIPO is a novel surgical technique designed to reduce soft tissue dissection while achieving stable fracture fixation. MIPO utilizes a small incision, often through a percutaneous approach, to insert the plate and screws, allowing for better preservation of the blood supply to the fracture site.[5] This technique is particularly advantageous in managing distal tibial fractures, where the risk of soft tissue injury and complications is high. MIPO aims to minimize soft tissue damage, reduce the risk of infection, and promote early functional recovery by preserving the surrounding muscles, tendons, and skin.[6]

Numerous studies have demonstrated the efficacy of MIPO in treating distal tibial fractures, highlighting its benefits, such as lower rates of infection, reduced blood loss, and faster rehabilitation compared to traditional methods.[7,8] Additionally, the technique allows for more accurate alignment and fixation of the fracture, which can result in improved long-term functional outcomes and lower rates of malunion or nonunion.[9] However, despite its advantages, MIPO also comes with its own set of challenges, including the technical difficulty of the procedure and the need for specialized equipment and expertise. So, the current investigation was undertaken to assess the functional and radiological outcomes associated with distal tibia fractures managed through MIPO.

METHODS

This study is a retrospective analysis of 40 patients who underwent MIPO for distal tibial fractures at department of orthopedics, tertiary healthcare center between November 2022 and November 2024. The primary objective was to evaluate the clinical and radiological outcomes of MIPO in terms of fracture healing, complication rates, functional recovery, and patient satisfaction. The study was approved by the institutional review board, and patient consent was obtained for the use of medical records.

Inclusion criteria

Adults aged 18 years or older, isolated distal tibial fractures (fractures occurring within 6 cm of the ankle joint), closed or grade I open fractures, fractures treated with MIPO technique and fractures classified according to the AO/OTA classification system were included.

Exclusion criteria

Patients with fractures with associated ipsilateral fractures (e.g., fibula or tibial plateau fractures), Gustilo-Anderson grade II and III open fractures, patients with a history of infection at the fracture site, patients with contraindications to surgery (e.g., severe comorbidities, inability to tolerate anesthesia) were excluded.

Preoperative assessment

All patients underwent a thorough clinical evaluation, including history, physical examination, and radiographic imaging (X-rays and CT scans) to assess the type, location, and displacement of the fracture. A thorough review of comorbid conditions was also performed to assess surgical risk factors, including diabetes, smoking, and nutritional status.

Surgical technique

The MIPO technique was performed under general or regional anesthesia with the patient in a supine position. A small incision (approximately 2-3 cm) was made on the medial or lateral aspect of the tibia, depending on the fracture site. The fracture was reduced using percutaneous manipulation, and a pre-contoured locking plate was inserted through the incision using a minimally invasive approach, avoiding excessive soft tissue dissection. Fracture fixation was achieved with locking screws, ensuring stable fixation while minimizing disruption to the surrounding tissues. Intraoperative fluoroscopy was used to confirm proper fracture reduction and plate positioning.

Postoperative care

Postoperatively, patients were monitored for complications such as infection, compartment syndrome, and neurovascular injury. Post-operative X-ray was done to document proper reduction and fixation of fracture fragments. Ankle mobilization was started from 2nd or 3rd post-operative day according to the tolerance of patients or associated injuries. Weight-bearing status was gradually allowed based on radiological healing. Antibiotics were administered prophylactically for 24-48 hours post-surgery. Regular follow-up visits were scheduled at 2 weeks, 6 weeks, and 12 weeks post-surgery to assess clinical healing and detect complications.

Outcome measures

Radiological outcomes

Fracture healing was assessed through serial radiographs at 6, 12, and 24 weeks, evaluating callus formation, alignment, and the time to union.

Clinical outcomes

The American orthopedic foot and ankle society (AOFAS) ankle and hindfoot score was used to assess functional recovery, including pain, function, and alignment at follow-up. The visual analog scale (VAS) for pain was recorded at each visit.

Complication rates

The incidence of complications such as infection, malunion, nonunion, hardware failure, and deep vein thrombosis was monitored throughout the follow-up period.

Patient satisfaction: A satisfaction questionnaire was given to patients at the final follow-up to assess their overall satisfaction with the surgery, including return to daily activities and sports.

Statistical analysis

Data were analyzed using SPSS version 25. Continuous variables such as age, fracture healing time, and AOFAS scores were presented as means and standard deviations (SD). Categorical variables such as complication rates were presented as frequencies and percentages. Paired student t test. A $p<0.05$ was considered statistically significant.

RESULTS

A total of 40 patients were included in this retrospective study, all of whom underwent MIPO for distal tibial fractures. The mean age of the patients was 42.5±12.3 years, with the majority (55%) being male. The fractures included in the study were classified according to the AO/OTA system, with most of the fractures being of type 43-A (closed fractures, non-displaced or minimally displaced). The results were shown in Table 1.

Table 1: Demographics and clinical characteristic of the patients.

Variables	N (%)
Mean age (±SD) (in years)	42.5±12.3
Gender	
Male	22 (55)
Female	18 (45)
Fracture classification (AO/OTA)	
Type 43-A (Closed, non-displaced)	28 (70)
Type 43-B (Closed, displaced)	8 (20)
Type 43-C (Open or complex fractures)	4 (10)

Table 2: Post-operative radiological outcome, (n=40).

Time point (in weeks)	N (%)
6	5 (12.5)
12	30 (75)
24	38 (95)

Fracture healing was evaluated based on radiographs obtained at 6-, 12-, and 24-weeks post-surgery. The mean time to union was 14.3±3.2 weeks. Radiological union was observed in 38 out of 40 fractures (95%), with two cases (5%) demonstrating delayed union, which required further intervention. Majority of fractures achieved radiological union by 12 weeks (75%), and by 24 weeks, 95% of fractures had healed radiologically. The results were shown in Table 2.

The functional recovery was assessed using the AOFAS score at 6, 12, and 24 weeks. The mean AOFAS score at the last follow-up (12 weeks) was 85±10, indicating good to excellent functional outcomes. There was a significant improvement in the AOFAS scores from 6 weeks to 12 weeks ($p<0.05$), with patients demonstrating further functional improvement by 24 weeks. The results were shown in table 3.

Table 3: AOFAS scores at follow-up.

Follow-Up (Weeks)	AOFAS Score (mean± SD)	P value
6	72.54±13.12	-
12	85.19±10.28	0.001*
24	90.38±5.43	0.001*

The data is shown as mean±SD. *Indicates statistically significant $p<0.05$; unpaired student t test)

The VAS for pain was recorded at each follow-up. At 6 weeks, the average VAS score was 6.25±2.14, decreasing to 3.19±1.72 at 12 weeks, and further improving to 1.56±1.26 at 24 weeks. This indicates significant pain reduction over time. Pain levels showed a significant decline over the course of the follow-up period, with a notable reduction by 12 weeks and it was significant ($p<0.05$). The results were shown in Table 4.

Table 4: Visual analogue scores at follow-up.

Follow-up (Weeks)	VAS score (Mean±SD)	P value
6	6.25±2.14	-
12	3.19±1.72	0.001*
24	1.56±1.26	0.001*

The data is shown as mean±SD. *Indicates statistically significant $p<0.05$; unpaired student t test)

Complications were observed in 4 patients (10%), with the most common being superficial wound infection (2 cases, 5%) and delayed union (2 cases, 5%). No cases of malunion, nonunion, or hardware failure were reported. The results were shown in table 5.

Table 5: Complication rate among the patients.

Complication	N (%)
Superficial infection	2 (5)
Delayed union	2 (5)
No complications	36 (90)

DISCUSSION

The management of distal tibia fractures, whether or not accompanied by intra-articular extension, presents

significant clinical challenges. None of the available treatment modalities adequately meet the specific requirements associated with the fracture characteristics of the distal tibia. The distal tibia exhibits a circular cross-sectional area characterized by a thinner cortical layer, in contrast to the triangular diaphysis, which possesses a thicker cortex. The intramedullary nail, engineered for a tight interference fit at the diaphysis, is unable to offer equivalent stability at the distal fracture site.[10] Additional possible complications associated with nailing include malunion, which occurs in 0-29% of cases, and implant failure, observed in 5-39% of instances.[10] ORIF utilizing a conventional plate that necessitates the stripping of the periosteum is not considered an optimal treatment approach. This is primarily due to the tibia being a subcutaneous bone, where the periosteum contributes approximately two-thirds of the blood supply. The incidence of non-union and delayed union, as well as infection, has been documented to range from 8.3% to 35% and 8.3% to 25%, respectively, in cases involving ORIF with plating.[11] External fixators, employed as a definitive treatment modality for distal diametaphyseal tibia fractures, have been associated with an elevated incidence of infection, implant failure, and malunion or nonunion. Consequently, their use is advised primarily as a temporary stabilization method in cases of open fractures accompanied by significant soft tissue injury.[12] The advancement of the MIPO technique utilizing locking compression plates (LCP) has facilitated the preservation of extraosseous blood supply and the maintenance of osteogenic fracture hematoma. This approach offers a biologically compatible and stable fixation method for distal diametaphyseal tibia fractures. The indirect reduction method, along with subcutaneous tunneling of the plate and the application of locking screws through small skin incisions in the MIPO technique, effectively mitigates the risk of iatrogenic injury to the vascular supply of the bone.[13] In contrast to traditional plates, LCP represent a friction-independent, self-stabilizing construct that offers both angular and axial stability. This design significantly reduces the risk of secondary loss of reduction, facilitated by a threaded interface between the screw heads and the plate body.

The radiological outcomes in this study were favourable, with 95% of fractures achieving union by 24 weeks. The mean time to union was 14.3±3.2 weeks, which is consistent with other studies that have shown similar results with MIPO techniques for distal tibial fractures. The majority of fractures (75%) had achieved union by 12 weeks, highlighting the relatively rapid healing time for fractures managed with MIPO compared to more invasive methods. In a study done by Gupta et al the mean time for radiological union was 17 weeks in patients with proximal and distal tibial fractures who had underwent MIPO.[14]

The functional recovery, as measured by the AOFAS scores, demonstrated significant improvement over time. The AOFAS score increased from 72.54±13.12 at 6 weeks to 85.19±10.28 at 12 weeks, and further improved to 90.38±5.43 by 24 weeks, indicating a good to excellent functional outcome. These improvements were statistically significant ($p<0.05$). The findings suggest that MIPO not only facilitates fracture healing but also promotes faster functional recovery, which is a crucial aspect of patient satisfaction and quality of life. Likewise, in a study done by Ranjan et al there was a significant improvement in the AOFAS score when compared preoperative and 6 months post-operative in patients undergoing MIPO for distal tibial fractures (45±12 vs 85±14).[15]

Pain reduction, measured using the VAS, showed a significant decline over the follow-up period. The average VAS score decreased from 6.25±2.14 at 6 weeks to 1.56±1.26 at 24 weeks. This improvement was statistically significant ($p<0.05$). The reduction in pain is likely attributable to the minimal soft tissue dissection and less surgical trauma associated with MIPO, which reduces the postoperative inflammatory response. These results support the notion that MIPO leads to less postoperative pain and faster recovery compared to traditional open techniques. Likewise, in a study done by Sonmez et al after a follow up period of 20 months the mean VAS score was 2.58±0.83 in patients with distal tibial fractures undergoing MIPO.[16]

The complication rate in this study was relatively low, with 10% of patients experiencing complications. The most common complications were superficial wound infections (5%) and delayed union (5%). These rates are lower than those typically reported with ORIF techniques for distal tibial fractures, where complications such as infection, malunion, and nonunion are more common. Likewise, in a study done by Kundu et al only 2 patients had wound infection, and 1 case had implant exposed.[6]

The absence of severe complications, such as malunion or hardware failure, further supports the safety and efficacy of MIPO. Nonetheless, the occurrence of delayed union in two cases highlights the need for careful patient selection and appropriate postoperative management, as certain fracture patterns or comorbid conditions can influence the healing process.

Limitations

While the results of this study are promising, there are several limitations to consider. This was a retrospective analysis, which introduces potential biases related to patient selection, surgical technique, and postoperative care. Additionally, the sample size of 40 patients may limit the generalizability of the findings. Future prospective, randomized controlled trials with larger sample sizes are needed to further confirm the long-term efficacy and safety of MIPO for distal tibial fractures.

CONCLUSION

In conclusion, MIPO is an effective and safe technique for managing distal tibial fractures, providing excellent radiological and functional outcomes with a low rate of complications. The technique's ability to minimize soft tissue damage, reduce pain, and accelerate recovery makes it an attractive alternative to traditional open surgical approaches. As experience with the technique increases, and with further evidence from larger studies, MIPO may become the gold standard for the treatment of distal tibial fractures.

Funding: No funding sources
Conflict of interest: None declared
Ethical approval: The study was approved by the Institutional Ethics Committee

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Cite this article as: Magadum M, Chitragar DD, Zalariya S, Manjunath KL. Clinical and radiological outcome of minimally invasive plate osteosynthesis in distal tibial fractures: a retrospective analysis. Int J Res Orthop 2025;11:550-4.