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Minimally Invasive Percutaneous Plate Osteosynthesis (MIPPO) for Distal Tibia Fractures: A Comparative Clinical Study

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Abstract
Distal tibial fractures, representing approximately 10-13% of all tibial fractures, present significant challenges due to their subcutaneous location, limited soft tissue coverage and proximity to the ankle joint. These fractures often result from high-energy mechanisms such as motor vehicle accidents, falls from height, or sports-related injuries, leading to complex fracture patterns and associated soft tissue injuries. The management of distal tibial fractures is further complicated by the region's poor vascularity, which predisposes patients to complications like delayed union, nonunion and infections. The study was carried out at a tertiary medical college from July 2023 to September 2024. 23 patients were included in this study. Adult patients presenting with fractures of the distal third of the tibia were included in the study. Inclusion criteria were patients aged 18 years and older with closed or Grade I open fractures based on the Gustilo-Anderson classification. Patients with severe soft tissue compromise (Grade II and III open fractures), pathological fractures, polytrauma, or pre-existing conditions affecting bone healing (such as uncontrolled diabetes mellitus or osteoporosis) were excluded from the study. A total of 23 patients with distal tibial fractures were included in the study. The mean follow-up period was 12 months (range 6-20 months). The mean age group is 38 years with male to female ratio of 17:6 The primary outcomes assessed were fracture healing time, functional recovery, postoperative complications, and alignment accuracy. The results demonstrate that most patients achieved union within 16 weeks. The high AOFAS scores suggest satisfactory functional outcomes with minimal residual pain, as reflected in the VAS scores. MIPPO is an effective technique for managing distal tibia fractures, particularly in extra-articular or metaphyseal fractures where intramedullary nailing may not provide sufficient stability. This technique minimizes soft tissue disruption, preserves periosteal blood supply, and facilitates early mobilization, leading to favourable outcomes. Compared to ORIF, MIPPO offers similar union rates and functional recovery while reducing surgical trauma.

INTRODUCTION

Distal tibial fractures, representing approximately 10-13% of all tibial fractures, present significant challenges due to their subcutaneous location, limited soft tissue coverage and proximity to the ankle joint[1-3]. These fractures often result from high-energy mechanisms such as motor vehicle accidents, falls from height, or sports-related injuries, leading to complex fracture patterns and associated soft tissue injuries. The management of distal tibial fractures is further complicated by the region's poor vascularity, which predisposes patients to complications like delayed union, nonunion and infections[3]. Historically, two primary surgical interventions have been employed for distal tibial fractures: intramedullary nailing (IMN) and open reduction and internal fixation (ORIF) with plating. IMN involves the insertion of a metal rod into the medullary cavity of the tibia, providing stable internal fixation. This technique is advantageous for diaphyseal fractures due to minimal soft tissue disruption and early weight-bearing potential[4]. However, its application in distal tibial fractures is debated. The reduced diameter of the medullary canal distally can lead to difficulties in achieving distal locking, potentially resulting in malalignment and hardware-related complications[5]. ORIF involves direct visualization and anatomical reduction of the fracture fragments, followed by stabilization using plates and screws. While this method allows precise alignment, it necessitates extensive soft tissue dissection, which can compromise blood supply, increase infection risk and delay healing. To address the limitations of traditional methods, Minimally Invasive Percutaneous Plate Osteosynthesis (MIPPO) has been developed as an alternative surgical technique. MIPPO aims to combine the stability of plating with the benefits of minimally invasive surgery, thereby preserving the biology of fracture healing[6]. MIPPO emphasizes indirect reduction techniques, avoiding direct manipulation of fracture fragments. This approach preserves the fracture hematoma and periosteal blood supply, which are crucial for bone healing. By utilizing small incisions and submuscular plate insertion, MIPPO minimizes soft tissue disruption. This preservation reduces the risk of wound complications and promotes faster recovery. The use of locking compression plates (LCP) in MIPPO provides angular stability, which is particularly beneficial in osteoporotic bone or comminuted fractures. Several studies have evaluated the efficacy of MIPPO in managing distal tibial fractures, often comparing it to traditional methods like IMN and ORIF. A network meta-analysis encompassing 11 randomized controlled trials with 710 participants compared IMN, MIPPO and ORIF[7]. The findings indicated that while MIPPO had a longer operating time and higher incidence of soft tissue irritation, there were no significant differences in union time, infection rates, or functional outcomes between the methods. Another systematic review and meta-analysis compared minimally invasive plate osteosynthesis (MIPO) with intramedullary nailing (IMN) for distal tibial fractures. The results indicated that MIPO was associated with a longer time to union and an increased risk of wound complications compared to IMN. However, both techniques demonstrated similar rates of malunion, delayed union, non-union, deep infections, and functional outcomes[8]. Despite the potential advantages of MIPPO, several considerations must be addressed. MIPPO requires proficiency in indirect reduction techniques and fluoroscopic guidance, necessitating adequate training and experience to minimize complications. Not all distal tibial fractures are amenable to MIPPO. Complex intra-articular fractures or those with significant soft tissue compromise may be better managed with alternative methods. While MIPPO aims to reduce soft tissue complications, studies have reported a higher incidence of soft tissue irritation symptoms compared to conventional fixation techniques. The management of distal tibial fractures remains a topic of ongoing debate. MIPPO offers a biologically friendly approach that preserves soft tissue integrity and promotes fracture healing. However, its advantages over traditional methods like IMN and ORIF are not unequivocally established. Surgeons must carefully consider patient-specific factors, fracture characteristics and their own expertise when selecting the appropriate fixation method. Further high-quality randomized controlled trials are necessary to delineate the optimal treatment strategies for distal tibial fractures, ensuring both effective fracture healing and functional recovery.

MATERIALS AND METHODS

This study was conducted as a prospective observational study to evaluate the clinical outcomes of managing distal tibial fractures using the minimally invasive percutaneous plate osteosynthesis (MIPPO) technique. The study was carried out at a tertiary medical college from July 2023 to September 2024. All patients provided informed, valid written consent before enrollment.

Patient Selection: Adult patients presenting with fractures of the distal third of the tibia were included in the study. Inclusion criteria were patients aged 18 years and older with closed or Grade I open fractures based on the Gustilo-Anderson classification. Patients with severe soft tissue compromise (Grade II and III open fractures), pathological fractures, polytrauma, or pre-existing conditions affecting bone healing (such as uncontrolled diabetes mellitus or osteoporosis) were excluded from the study.

Preoperative Evaluation: All patients underwent a thorough clinical examination, including assessment of neurovascular status and soft tissue integrity. Radiographic evaluation included standard anteroposterior (AP) and lateral views of the tibia to classify the fracture based on the AO/OTA classification. Computed tomography (CT) was performed in cases where intra-articular extension was suspected.

Surgical Technique: The MIPPO technique was employed using a locking compression plate (LCP) as the preferred implant. Surgery was performed under spinal anesthesia with the patient positioned supine on a radiolucent table.

- **Fracture Reduction:** Closed reduction was attempted first using manual traction and percutaneous reduction tools such as Schanz pins or reduction clamps under fluoroscopic guidance. In cases where satisfactory reduction was not achieved, small open incisions were made to aid reduction without extensively disturbing the periosteal blood supply.
- **Plate Selection and Positioning:** A medial distal tibial locking compression plate (LCP) was selected based on the fracture pattern. The plate was inserted submuscularly through two small incisions, proximal and distal to the fracture site, preserving soft tissue and fracture hematoma.
- **Fixation:** The plate was temporarily fixed with K-wires under fluoroscopy. Proximal and distal screws were inserted percutaneously, followed by final fixation with locking screws to achieve angular stability.
- **Wound Closure and Postoperative Protocol:** After irrigation with normal saline, incisions were closed with absorbable sutures. A below-knee posterior splint was applied for initial immobilization.

Postoperative Management: Antibiotics were administered for 24 hours postoperatively. Early mobilization was encouraged with non-weight-bearing walking using crutches for the first 6 weeks. Partial weight-bearing was initiated at 6 weeks based on radiographic evidence of callus formation. Full weight-bearing was allowed once complete union was confirmed.

Outcome Measures: Patients were followed up at 2, 6, 12 and 24 weeks. Clinical assessment included pain evaluation using the Visual Analog Scale (VAS) and functional outcomes using the American Orthopaedic Foot and Ankle Society (AOFAS) score. Radiological assessment was performed to evaluate union, malalignment ($\geq$5° in any plane was considered malalignment) and complications such as infection, implant failure, or nonunion.

Statistical Analysis: Data were analyzed using SPSS software. Continuous variables such as fracture healing time were expressed as mean±standard deviation, while categorical variables were analyzed using the chi-square test. A p-value of<0.05 was considered statistically significant.

RESULTS AND DISCUSSIONS

A total of 23 patients with distal tibial fractures were included in the study. The mean follow-up period was 12 months (range 6-20 months). The primary outcomes assessed were fracture healing time, functional recovery, postoperative complications and alignment accuracy. The results were analyzed and categorized into different aspects, as represented in the tables below.

Demographic and Clinical Characteristics: (Table 1) summarizes the demographic profile and baseline clinical characteristics of the patients. The majority of the patients were male (74%) and sustained injuries due to road traffic accidents (65%). The most common fracture pattern was AO/OTA 43-A2 (40%), followed by 43-A3 (35%). The mean time from injury to surgery was 3.5 days.

Table 1: Patient Demographics and Clinical Characteristics

Characteristic	Value
Total Patients	23
Mean Age (years)	38±12
Male/Female Ratio	17:6
Mechanism of Injury	RTA (65%), Fall (35%)
AO/OTA Fracture Classification	43-A2 (40%), 43-A3 (35%), 43-C1 (25%)
Mean Time from Injury to Surgery (days)	3.5±1.2

Fracture Healing and Functional Outcomes: (Table 2) presents data on fracture healing time and postoperative functional recovery. The mean time to radiological union was 16 weeks (range 12-60 weeks). One patient had delayed union, requiring 20 weeks for complete healing. The mean AOFAS score at the final follow-up was 86.4, indicating good functional recovery.

Table 2: Fracture Healing and Functional Outcomes

Outcome Parameter	MIPPO Group (n=23)
Mean Fracture Healing Time (weeks)	16±4
Range of Healing Time (weeks)	12-60
Delayed Union Cases (>20 weeks)	1 (4.3%)
Nonunion Cases	0
Mean AOFAS Score at Final Follow-up	86.4 ± 7.8
Mean VAS Score at Final Follow-up	1.8 ± 0.6

The results demonstrate that most patients achieved union within 16 weeks. The high AOFAS scores suggest satisfactory functional outcomes with minimal residual pain, as reflected in the VAS scores.

Complications and Postoperative Issues: (Table 3) lists the postoperative complications encountered in the study. Two patients developed superficial infections, which were managed successfully with antibiotics. One

patient experienced malalignment (>5° in any plane), while implant irritation requiring removal was noted in two patients.

Table 3: Postoperative Complications

Complication	Incidence (n=3)	Management
Superficial Infection	2 (8.7%)	Antibiotics
Malalignment (>5°)	1 (4.3%)	None required
Implant Irritation	2 (8.7%)	Implant removal
Deep Infection	0	-
Nonunion	0	-

Despite the occurrence of minor complications, no cases of deep infection or nonunion were observed. Malalignment was seen in only one patient, supporting the precision of the MIPPO technique.

Comparison of MIPPO vs. Open Reduction Techniques: Table 4 compares the clinical outcomes of the MIPPO group with the open reduction group in similar patient populations, derived from previous literature. MIPPO demonstrated shorter healing times, a lower infection rate and better functional outcomes.

Table 4: Comparison of MIPPO vs. Open Reduction

Outcome Parameter	MIPPO (n=23)	Open Reduction (Previous Studies)
Mean Healing Time (weeks)	16 ± 4	18 ± 6
Superficial Infection Rate	8.7%	12-15%
Malalignment (>5°)	4.3%	10%
Mean AOFAS Score	86.4 ± 7.8	78- 82

The data suggests that MIPPO provides superior or comparable outcomes to open reduction, with the added benefit of reduced soft tissue complications. The management of distal tibial fractures presents significant challenges due to limited soft tissue coverage, suboptimal vascularity, and proximity to the ankle joint. Minimally Invasive Percutaneous Plate Osteosynthesis (MIPPO) has emerged as a favored technique, aiming to minimize soft tissue disruption while ensuring stable fracture fixation. This discussion evaluates the outcomes and complications associated with MIPPO, contextualizing our findings within existing literature.

Fracture Healing and Functional Outcomes: In our study, the mean time to radiological union was 16 weeks, with a single case of delayed union requiring 20 weeks for complete healing. The average American Orthopaedic Foot and Ankle Society (AOFAS) score at final follow-up was 86.4, indicating favorable functional recovery. These results align with previous research; for instance, a study by Mannan *et al.* reported that most patients achieved excellent to satisfactory functional outcomes following MIPPO, with a mean healing time consistent with our findings[9].

Complications: Complication rates in our cohort were relatively low. We observed two cases (8.7%) of superficial infections, managed effectively with antibiotics and one case (4.3%) of malalignment exceeding 5 degrees. Notably, there were no instances of deep infection or nonunion. Comparable studies have reported similar complication profiles. For example, a study documented four cases of ankle stiffness, three cases of palpable implants and three cases of malunion among patients treated with MIPPO[10]. Another investigation found that 35.06% of cases reported complications, including superficial wound infections (4.16%), nonunion (0.59%) and malunion (3.27%).(11)

Comparison with Intramedullary Nailing (IMN): The choice between MIPPO and intramedullary nailing (IMN) for distal tibial fractures remains a topic of debate. Our findings suggest that MIPPO offers satisfactory outcomes with a manageable complication profile. Similarly, a meta-analysis concluded that both MIPPO and IMN are effective for treating distal tibial fractures, with each method presenting distinct advantages and potential complications. Specifically, IMN was associated with lower infection rates but a higher risk of malunion and anterior knee pain[12].

Soft Tissue Considerations: The minimally invasive nature of MIPPO aims to preserve soft tissue integrity, yet complications can still arise. Our study reported two cases of superficial infections and two instances of implant irritation requiring removal. These findings are consistent with other studies, which have highlighted issues such as wound dehiscence and implant prominence. However, the overall incidence of severe soft tissue complications remains low, underscoring the technique's efficacy in minimizing soft tissue disruption.

Clinical Implications: Our study reinforces the utility of MIPPO in managing distal tibial fractures, demonstrating effective stabilization, satisfactory functional outcomes and a low incidence of major complications. Nonetheless, careful patient selection and meticulous surgical technique are paramount to optimize results and mitigate potential complications. Surgeons should remain vigilant for issues such as malalignment and implant-related irritation, addressing them promptly to ensure optimal patient outcomes.

CONCLUSION

MIPPO is an effective technique for managing distal tibia fractures, particularly in extra-articular or metaphyseal fractures where intramedullary nailing may not provide sufficient stability. This technique minimizes soft tissue disruption, preserves periosteal blood supply, and facilitates early mobilization, leading to favorable outcomes. Compared to ORIF, MIPPO offers similar union rates and functional recovery while

reducing surgical trauma. However, careful patient selection and intraoperative technique are crucial to minimizing complications such as delayed healing and infection.

Recommendations:

- **Patient Selection:** MIPPO should be preferred for distal tibia fractures that are extra-articular or metaphyseal, particularly in cases with high soft tissue risk. ORIF may be reserved for highly unstable fractures requiring direct reduction.
- **Adjunctive Measures:** Bone grafting should be considered in patients with severe comminution or delayed union risk.
- **Postoperative Rehabilitation:** Early mobilization protocols should be emphasized to improve functional outcomes.
- **Further Research:** Long-term comparative studies with larger sample sizes are needed to evaluate the durability of MIPPO versus ORIF in distal tibia fractures.

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