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Functional and radiological outcomes of medial minimally invasive percutaneous plate osteosynthesis in distal tibial pilon fractures: a prospective study

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ABSTRACT

Background: Distal tibial fractures represent 5-10% of all tibia fractures, with challenges arising from soft tissue damage and complications like nonunion and infection. Minimally invasive percutaneous plate osteosynthesis (MIPPO) is a biological plating technique for treatment these fractures, aiming to reduce complications by preserving periosteal blood supply and minimizing tissue disruption. This study evaluates the radiological and clinical outcomes of distal tibial fractures treated using biological plating with the radiographic union scale for tibia (RUST) and the American Orthopaedic Foot and Ankle Society (AOFAS) score system.
Methods: This prospective study conducted for 18 months involving 22 patients with distal tibial fractures, treated with MIPPO using distal tibial locking compression plates followed up. The inclusion criteria were patients aged above 18 years with fractures of AO classification types 43C, 43B, and 43A. Patients were followed up at 1, 2, 3 and 6 months postoperatively, with radiological assessments based on RUST score for fracture union and functional outcomes using the AOFAS score. Statistical package for the social sciences (SPSS) used for data analysis.
Results: The study included patients age averaging 48.4 years and consisted of 72.7% males. The primary cause of injury was road traffic accidents (54.5%). Fracture union was achieved in an average of 15 weeks using RUST score. AOFAS outcomes showed 54.5% of patients with excellent, 31.8% with good, and 13.6% with fair results. Complications such as infection and malalignment were observed in 27.3% of patients.
Conclusions: Biological plating using MIPPO technique offers reliable clinical and radiological outcomes for distal tibial fractures, with high union rates and favorable AOFAS scores. Despite few complications, Biological plating remains an effective method for the treatment of distal tibial fractures, particularly in cases requiring soft tissue preservation. Further research into long-term complications and functional outcomes is recommended.

Keywords: Medial MIPPO, Biological plating, Distal tibia, Pilon fractures

INTRODUCTION

Distal tibia fractures make up about 5-10% of all tibial fractures, with individuals aged 35-45 years, particularly males, being most affected.[1] These fractures often result from both high- and low-energy trauma, and they can involve the articular surface, complicating treatment. Known as pilon or plafond fractures, they present challenges due to the potential for infection, nonunion, and soft tissue irritation when treated with standard open reduction internal fixation (ORIF) using plates.

In 2007, Giannoudis et al introduced the "diamond concept," which highlights the importance of four key

factors for fracture healing: osteogenic cells, osteoconductive scaffolds, growth factors, and mechanical stabilization.[2] Disruption of any of these can hinder proper healing. This concept led to the development of biological plating techniques aimed at reducing soft tissue disruption, preserving blood supply, and promoting healing. Biological plating focuses on achieving stable fixation while minimizing disruption to the fracture site's biological environment. Techniques like minimally invasive percutaneous plate osteosynthesis (MIPPO) use smaller incisions and locking plates, which help preserve the bone's surrounding vascularity and tissues. This approach allows for some micromotion at the fracture site, which promotes biological healing, and reduces the risk of complications like infection, nonunion, and malunion. MIPPO also helps avoid the need for bone grafting while supporting early mobilization and improving functional outcomes. In recent years, minimally invasive plate osteosynthesis (MIPO) techniques have become increasingly popular, particularly with the advent of angular stable screw-plate systems such as the less invasive stabilization system (LISS) and locking compression plate (LCP).[3] These systems are commonly used for treating long bone fractures with minimal invasiveness. The principle of treatment of articular fracture are open anatomical reduction of articular fracture, rigid fixation and early mobilization. Relative stability is achieved for metaphyseal communition maintaining the length, alignment and rotation. A medial or lateral MIPPO plating can be done based on the fracture configuration.

MIPPO is especially useful for medial tibial fractures, including those in the distal medial aspect. It's often recommended for both stable and unstable closed fractures, particularly for patients with comorbidities like obesity or diabetes, or for elderly individuals with fragile bone quality. MIPPO preserves biology by not stripping the periosteum and soft tissues with the use of angular stable implants.

However, more research is needed to assess long-term outcomes of MIPPO, including the durability of fixation, risk of post-traumatic arthritis, and functional recovery over extended periods. Long-term studies could also provide deeper insight into potential complications, such as implant failure, nonunion, and malunion.

METHODS

This prospective study was conducted at the Department of Orthopedics, in a tertiary care center in South India over a period of 18 months. During this period, a total of 52 patients had presented with distal tibial fracture out of which 22 underwent medial MIPPO based on fracture configuration. Sample size calculation was done based on the previous study done by Baris et al with 95% confidence interval and 80% power, the total sample size is 22 including 10% non-response error.[4] These patients met the inclusion criteria and underwent biological plate fixation using the distal tibial locking compression plate. They were then followed up post-operatively for 6 months. Inclusion criteria included patients with distal tibial fractures classified as AO 43A, 43B, or 43C, and those aged over 18 years. Exclusion criteria included Gustilo-Anderson type 3 open fractures, Tscherne classification grade 3 closed fractures, anterolateral distal tibial fractures, and pathological fractures.

Surgical technique

A 3- to 4-cm incision was made just distal to the medial malleolus, extending proximally along the subcutaneous surface of the tibia (Figure 1). The size and positioning of the proximal incision were determined based on the implants used and confirmed under image intensifier control.

Figure 1: Site of skin incision.

There was no true internervous plane in this approach, as dissection was performed on the subcutaneous surface of the tibia. The skin flaps were mobilized carefully, preserving the long saphenous vein and its associated saphenous nerve branches. The skin incision was deepened to expose the periosteum, which was preserved for its vital role in the bone's blood supply. An epiperiosteal plane was developed between the distal and proximal incisions using a blunt dissector (Figure 2).

Figure 2: Development of epiperiosteal plane using Cobb elevator.

Closed reduction of the fracture was achieved under fluoroscopic guidance using multiple K-wires, the distal

tibial locking compression plate (DT LCP) about thrice of fracture size inserted through the epiperiosteal plane (Figures 3 and 4). After proper reduction and plate positioning, distal and proximal screws were inserted under fluoroscopy (Figure 5). The wound was thoroughly irrigated, closed in layers, and sutured with either Ethilon or staplers, followed by a sterile dressing.

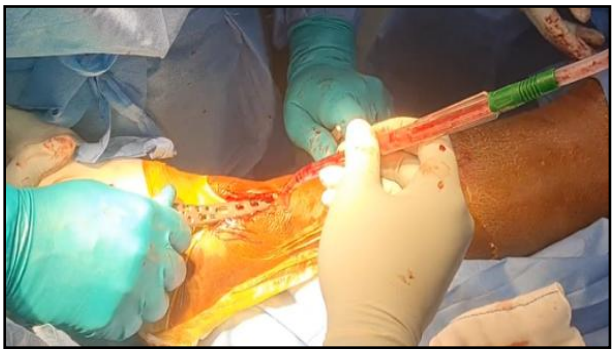

Figure 3: DTLCP slided through the minimal incision into the epiperiosteal plane and proximal plate exposed with stab incision after palpation of plate subcutaneously.

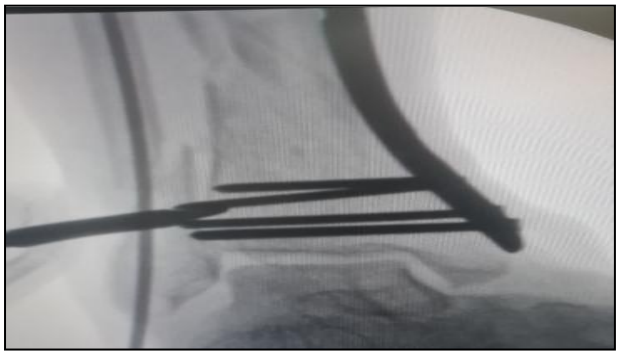

Figure 4: Under fluroscopic guidance after satisfactory reduction and plate position, distal locking screws are done.

Figure 5: Immediate post-operative wound.

Postoperative protocol

Postoperative standard rehabilitation protocol was followed. A below knee slab was given if swelling present and then removed and ankle mobilized. The patient was started on non-weight bearing walking with walker support

Follow-up

The patients were followed up at 1, 2, 3, and 6 months postoperatively. During these follow-ups, patients are assessed using radiographs, clinical features, and the American orthopedic foot and ankle score (AOFAS). Radiological union is evaluated using the RUST score (Figure 6).

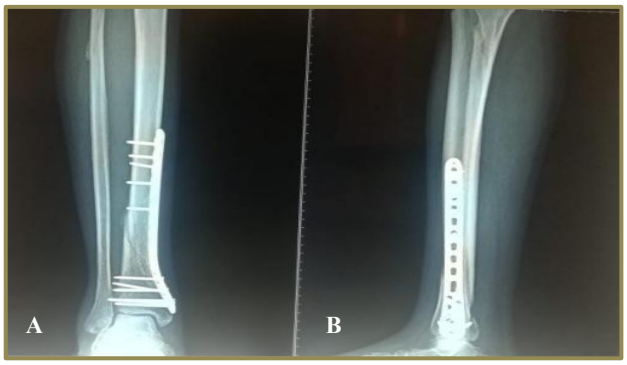

Figure 6 (A and B): Radiological outcome after 3 months.

Figure 7 (A-D): Functional Outcome after 3 months.

Statistical analysis

Data was entered into a master chart using Microsoft Excel and analyzed using statistical package for the social sciences (SPSS) version 26. Both qualitative and quantitative variables were included in the analysis. aired samples T-test was applied to compare preoperative and postoperative mean scores. A p value of less than 0.05 was considered statistically significant.

Figure 8 (A and B): Complication: infection and plate exposure.

RESULTS

In the study, the gender distribution showed a male-dominated population, with 72.7% of participants being male and 27.3% female. The average age of participants was 48.4 years, with the majority (31.8%) being over 61 years old, followed by 22.7% in the 41-50 age group. A total of 54.5% of participants were employed in independent occupations, while 45.5% had dependent occupations. Comorbidities were present in 40.9% of participants, with 27.3% suffering from type 2 diabetes mellitus, 18.2% from systemic hypertension, and 9.1% from coronary artery disease (Table 1).

Table 1: Demographic and clinical details of the study sample.

Variables	Category	Percentage (%)
Gender	Male	72.7
	Female	27.3
Age group (years)	>61	31.8
	41–50	22.7
	18-40 y	45.5
Mean age (years)	48.4	—
Occupation	Independent	54.5
	Dependent	45.5
Comorbidities (overall)	Present	40.9
	Absent	59.1
Specific comorbidity	Type 2 diabetes mellitus	27.3
	Systemic hypertension	18.2
	Coronary artery disease	9.1

Injury location was predominantly the right lower limb (68.2%), and road traffic accidents (RTAs) were the leading cause of injury (54.5%), followed by falls from height and self-falls (22.7% each). Fractures were split equally between extra-articular and intra-articular types, and the majority (50%) were classified as AO type 43A. Most fractures were closed (72.7%). Pre-operative stays had a mean of 6.23 days, and post-operative stays averaged 4.77 days, leading to a total hospital stay mean of 11.09 days. POP splints were used for fracture stabilization in 81.8% of cases.

The average AOFAS score was 88.55, with 54.5% of participants achieving an "excellent" outcome, 31.8% a "good" outcome, and 13.6% a "fair" outcome and none had “poor” outcome (Table 2).

Table 2: AOFAS outcome respondents.

AOFAS outcomes	Frequency	Percentage
Excellent	12	54.5
Fair	3	13.6
Good	7	31.8
Poor	0	0
Total	22	100.0

The union time for fractures using RUST score varied, with 45.5% of respondents achieving union in 14 weeks, followed by 31.8% in 16 weeks. A smaller percentage achieved union in 12 weeks (9.1%) and 18 weeks (13.6%), indicating that most patients experienced union with average of 15 weeks.

Wound healing was favorable in 95.5% of cases with delayed superficial infections (13.6%) and surgical site infections (9%). One case of skin necrosis required debridement and implant removal, while no cases of non-union or malunion were reported (Table 3).

Table 3: Infection respondents.

Infections	Frequency	Percentage
No	17	77.3
Yes	5	22.7
Total	22	100.0

A significant association was found between AOFAS outcomes and wound healing (p=0.036), suggesting that patients with healthy wounds had better functional outcomes (Table 4).

Table 4: Association between AOFAS outcome and wound healing.

AOFAS outcomes	Wound healing, N (%)		
	Healthy	Necrosis	P value
Excellent	12 (100.0)	0 (0.0)	0.036*
Fair	2 (66.7)	1 (33.3)	
Good	7 (100.0)	0 (0.0)	

*P value statistically significant

However, no significant associations were observed between AOFAS outcomes and factors such as age, comorbidities, or infection. Overall, most participants demonstrated favorable fracture healing with few

complications, pointing to the positive outcomes of the treatments administered.

DISCUSSION

Distal tibia fractures are challenging to treat due to the minimal soft tissue, subcutaneous bone, and tenuous skin vascularity around the ankle. MIPO has proven effective in treating these fractures, showing high union rates (85-95%) and better functional recovery compared to open reduction and internal fixation (ORIF), mainly due to reduced soft tissue disruption. MIPO also results in fewer wound complications and a quicker return to activity, although complications such as malalignment and hardware-related issues can still arise. Proper patient selection and surgical expertise are essential for success. The technique's benefits are further enhanced by its ability to minimize soft tissue elevation at the fracture site, reducing infection rates, refractures, and the need for autologous bone grafting. Additionally, the use of MIPO preserves the periosteal blood flow, offering biological advantages over ORIF and potentially lowering post-operative pain.

The mean age of participants in our study was 48.4 years, with no significant correlation between age and outcome. Similar age ranges were reported by Hazarika et al, Collinge et al, and Shabbir et al.[5-7] The gender ratio in our study was 16:6, reflecting the higher incidence of fractures in males, which is consistent with findings by other researchers like Nabil et al and Hazarika et al.[5,8] This gender disparity is likely related to occupations involving high-energy trauma, such as RTAs.

In our study, we used locking compression plates, which allowed for the placement of locking head screws in the metaphysis and epiphysis, improving mechanical stability. The plates were anatomically shaped to the bone, providing optimal stability and strength for the construct. In our study, 50% of the fractures were extra-articular, and 50% were intra-articular. The most common AO subtypes were type A3 (6 cases) and type C3 (7 cases), followed by type A1, A2, B1, B3, C1, and C2 in smaller numbers. These findings align with those of Kundu et al and Leung et al, although the specific distribution of fracture types varied between studies.[9,10]

In our study, of the 16 closed fractures, 56.25% were grade 1, and 43.75% were grade 2 according to the Tscherne classification. The open fractures were classified according to the Gustillo-Anderson system, with equal representation of type 1 and type 2 injuries. Our study was unique in that it emphasized the extent of soft tissue injury in management and outcomes. Tscherne classification is helpful in determining the suitability of MIPO by grading soft tissue injuries. A study by Li et al found no significant difference in fracture healing or functional outcomes between grade 1 and 2 injuries when treated with MIPO.[11] The mean hospital stay in our study was 11.09 days, with the average trauma-to-surgery interval being 6.22 days. These results are consistent with studies by Kisku et al and Shabbir et al who reported similar intervals, although other studies showed slightly longer intervals.[7,12]

The mean union time in our study was 13 weeks, aligning with studies by Shabbir et al and Patel et al who reported slightly longer union times (17.8 weeks).[7,13] Other studies, including those by Dhakar et al and Nath et al reported even longer union times, with MIPO showing comparable results to other techniques.[14,15] The mean AOFAS score in our study was 88, indicating favorable outcomes despite mild to moderate stiffness due to limited hind foot mobility and sagittal movement. These results are consistent with studies by Padmanabhan et al, Ronga et al, and Nork et al who reported similar scores and functional outcomes.[16-18]

Six participants experienced complications, including delayed superficial infections (13.6%) and surgical site infections (9%). One case of skin necrosis required debridement and implant removal, while no cases of non-union or malunion were reported. Our findings are consistent with other studies, such as those by Thampy et al and Dhakar et al who reported infection rates of 5-15% for MIPO techniques in distal tibia fractures.[14,19] Studies like Paluvadi et al and Ahmed et al showed lower infection rates with MIPO compared to ORIF.[20,21]

Despite the functional and radiological outcomes noted in the study, the limitations of the study are the small sample size and single center nature of the study hence it cannot be generalized to the population in question. Moreover, the short follow-up time (6 months) can miss the long term complications such as arthritis, delayed implant failure.

CONCLUSION

MIPPO using a distal tibial locking compression plate is a reliable and biologically respectful method of fixation for distal tibial pilon fractures. In this prospective series of 22 patients, the technique achieved radiological union at a mean of 15 weeks (RUST score) and yielded favourable functional outcomes, with 86.3% of patients attaining an excellent or good result on the AOFAS scale and a mean AOFAS score of 88.55. No cases of non-union or malunion were observed.

The technique preserves the fragile soft-tissue envelope and periosteal vascularity around the distal tibia, permits early ankle mobilisation and protected weight bearing, and is associated with acceptably low rates of wound complications. The statistically significant association between healthy wound healing and superior AOFAS outcome ($p=0.036$) underscores the importance of meticulous soft-tissue handling as a key determinant of functional success. Careful preoperative planning, respect for the soft-tissue envelope, and the use of angular-stable locking implants remain the cornerstones of a successful outcome.

Larger, multicentre, randomised comparative studies with extended follow-up are required to confirm the long-term durability of fixation, to delineate the role of medial MIPPO in relation to intramedullary nailing and lateral plating, and to evaluate post-traumatic arthritis, implant survival, and patient-reported quality-of-life outcomes beyond the early postoperative period.

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