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# Prospective evaluation of functional and radiological outcomes following minimally invasive plate osteosynthesis for distal tibial fractures

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**Abstract:**
Distal tibial fractures are challenging because limited soft-tissue coverage and vascularity require stable fixation with minimal tissue disruption. This prospective study evaluated 20 adults treated with minimally invasive plate osteosynthesis using locking compression plates, assessing functional, pain, radiological and complication outcomes. At 6 months, AOFAS scores increased from 59.80±6.74 to 91.15±3.42, while VAS scores decreased from 5.35±0.75 to 1.45±0.51 (both $p<0.001$); all fractures united and 75% achieved excellent functional outcomes. MIPO provided reliable union, progressive pain reduction and good functional recovery with a low complication rate. Thus, data support MIPO with locking compression plates as an effective option for appropriately selected distal tibial fractures.

**Keywords:** Distal tibial fracture, minimally invasive plate osteosynthesis (MIPO), locking compression plate, functional outcome, AOFAS score, biological fixation

**Background:**
The incidence of distal tibial fracture is around 3-10% of all tibial fracture and is one of the complex fracture types seen in orthopaedic trauma practice **[1]**. The complications of wound, delayed union, malunion, nonunion and functional failure make these fractures more susceptible to wound problems, because of the distal location, soft-tissue envelope, poor vascularity and nearness to the ankle joint **[2]**. Additionally, these injuries are often caused by high energy trauma in younger adults and low energy fracture mechanisms in elderly (Osteoporotic) patients, making fracture selection and treatment decisions complex as both fracture morphology and soft-tissue status should be taken into account **[3].** Primarily, surgical management has the goal of providing stable fixation while maintaining the biological environment to facilitate fracture healing. Direct visualization and anatomic reduction of fracture with open reduction and internal fixation (ORIF) carries with it an increased potential for wound complications, infection and delayed union, especially in fractures of the distal metaphysis, where soft-tissue coverage has been established to be least favorable **[4].** Such concerns have led to the evolution of these ideas to include the preservation of periosteal blood supply, fracture haematoma and surrounding soft tissues and biological fixation techniques have emerged. Minimally Invasive Plate osteosynthesis (MIPO) is one of the treatments preferred for distal tibial fractures whenever possible, using indirect fracture reduction by fixation of locked compression plates by a limited surgical exposure. MIPO helps in achieving angular stability without the disruption of fracture biology, leading to secondary bone healing by callus formation, while also allowing for early mobilisation with significantly low soft-tissue complications **[5].** Using locking compression plates results in higher stability of the construct, especially in materials like osteoporotic bones and comminuted fractures, without having to compress the plate to the bone which would tamper with the integrity of the periosteal circulation **[6].** The clinical results of MIPO are increasingly shown with distal tibial fractures. The effectiveness of functional recovery, fracture union rates, considerable postoperative pain reduction and low complication rates with locking compression plates following MIPO have been consistently shown in recent prospective studies **[7–11].** Comparative studies have also indicated that the preservation of soft tissues in MIPO is better and wound complications are lower than with standard ORIF while clinical results when adequately selected for extra-articular fractures are comparable to intramedullary nailing **[12-15].** Very recently, a systematic review and meta-analysis further demonstrated that MIPO is a very effective biological fixation method for distal tibial fractures that helps to avoid complications related to the injured wound without reducing the fracture union or functional recovery from the procedure compared with ORIF **[16].** In spite of these promising results, there are some debates concerning patient selection, fracture configuration, the restoration of alignment, implant selection and functional outcomes over time. Furthermore, available evidence from the Indian populations is still limited and most of the studies conducted so far are small in sample size, or have a retrospective design **[7-10].** Therefore, it is of interest to assess the functional and radiological results of the MIPO with locking compression plate in adult distal tibial fractures.

**Materials and Methods:**
**Study design and setting:**
This Prospective Observational study was conducted in the Department of Orthopaedics of Netaji Subhash Chandra Bose Medical College and hospital, Jabalpur, India within an 18 month period. The study aimed to assess the functional and radiological results of minimally invasive plate osteosynthesis (MIPO), with locking compression plates in distal tibial fracture. Prior to study initiation, study received ethical approval by the Institutional Ethics Committee and written informed consent was received from all participants.

**Patient selection:**
All consecutive adult patients (age > 18 years) with distal tibia fractures (closed or Gustilo & Anderson 1) who were eligible for MIPO were enrolled prospectively. Fractures were classified according to the AO/OTA classification. Patients were excluded if they were diagnosed with Gustilo–Anderson grade II or III open tibia fracture, pathological fractures, previous ipsilateral tibial surgery or had neurovascular injuries requiring vascular reconstruction, polytrauma which prevented definitive fixation, or was not followed up for an adequate time.

**Pre-operative evaluation:**
Demographic information, mechanism of injury, any associated chronic medical conditions and fracture characteristics were established. All patients had standard anteroposterior and lateral films of the leg and ankle. Definitive fixation was done following satisfactory soft tissue healing.

**Surgical technique:**
All procedures have been undertaken by well-trained orthopaedic surgeons at spinal or general anaesthetic using the supine position on a radiolucent table. Indirect reduction techniques with the assistance of fluoro-radiographic imaging were employed for fracture reduction. Proximal and distal incisions were made into the skin without cutting through the periosteum and without opening the fracture site to place a pre-contoured locking compression plate. Gross alignment, rotation and limb length were established fluoroscopically prior to definitive fixation. Selective fibular fixation was done as required for restoration of length and rotation stability. The operative time, blood loss in the operation and complications in and out of the operating room were documented.

**Post-operative rehabilitation and follow-up:**
Post-operative rehabilitation was standardized; this involved early ankle mobilization, non-weight-bearing (NWB) protected and then subsequent return to full weight bearing (FWB) based on clinical and radiographic signs of fracture healing, respectively. The subjects were assessed 6 weeks, 3 and 6 months after surgery.

**Outcome Measures:** Functional recovery (American Orthopaedic Foot & Ankle Society (AOFAS) Ankle-Hindfoot Score). Secondary outcomes were pain (measured on a Visual Analogue scale), time to radiological union, length of the procedure, bleeding and complications (such as infection, delayed union, non-union, malunion, implant failure, wound complications and ankle stiffness). Radiological union was considered to be when there was bridging callus in at least three cortices showed on orthogonal radiographs with no tenderness at fracture site and comfort with full weight bearing.

**Statistical analysis:**
A statistical analysis utilizing IBM SPSS v30 (IBM Corp., Armonk, NY, USA) was used to analyse the data. Results of continuous variables are displayed as mean ± standard deviation and those of categorical variables as frequencies and percentages. The scores of AOFAS and VAS were compared across time with repeated measures analysis of variance (ANOVA) with Bonferroni adjustments for multiple comparisons. The categorical variables were correlated by the Chi-square and the Fisher's exact test and the continuous variables were compared by the independent Student's t-test when appropriate. The values of $P < 0.05$ were taken as significant for all the statistical tests used and all the tests were two-tailed tests.

**Results:**
Twenty consecutive patients with distal tibia fractures were treated with minimally invasive plate osteosynthesis followed by necessary postoperative follow up. Patients enrolled were included in final analysis. The baseline demographic and fracture characteristics are summarized in **Table 1**. Of the 20 patients, 11 (55.0%) were younger than 60 years and 9 (45.0%) were aged ≥60 years. There were more males than females in the study population (80.0%). The most common mechanism of injury was falls (80.0%) followed by road traffic accidents (20.0%). According to the AO/OTA classification, type 43A1 fractures constituted the majority of cases (60.0%), followed by 43A2 (20.0%), 43C1 (10.0%) and 43A3 and 43C2 (5.0% each). AOFAS score was used to evaluate functional recovery, which is presented in **Table 2.** The mean AOFAS score improved significantly from 59.80 ± 6.74 at 6 weeks to 82.85 ± 4.76 at 3 months and 91.15 ± 3.42 at 6 months ($P<0.001$, repeated-measures ANOVA). Postoperative pain, evaluated with VAS decreased gradually along the follow-up period **(Table 3).** The mean VAS score declined from 5.35 ± 0.75 at 6 weeks to 3.35 ± 0.67 at 3 months and 1.45 ± 0.51 at 6 months. The difference in the amount of pain that was experienced over time was statistically significant ($P<0.001$). Radiological outcomes and complication: Radiological union and postop complications are summarized in **Table 4**. Fracture unions were obtained with respect to all of the patients. Radiological union occurred within 12–13 weeks in 5 patients (25.0%), between 14 and 16 weeks in 9 patients (45.0%) and after 16 weeks in 4 patients (20.0%). There was delayed union in 2 patients (10.0%). A superficial surgical-site infection developed in one patient (5.0%) and one patient (5.0%) had ankle stiffness. Deep infection, implant failure, or non-union did not occur on any cases Results of functional outcome based on the AOFAS grading system is seen at 6 months follow-up **(Table 5).** Five (25.0%) patients achieved a good outcome (AOFAS score 75-89) and then 15 (75.0%) achieved excellent outcome (AOFAS score 90-100). None of the patients got fair functional results and none got poor functional results. Distal Tibial Fracture Distribution over the AO/OTA classification, as seen in **Figure 1.** The most common fracture types were Type 43A1 (12 cases/60.0%) and 43A2 (4 cases/20.0%). Two patients (10.0%) had Type 43C1 fractures, while one patient (5.0%) each had Type 43A3 and Type 43C2 fractures. The AOFAS Ankle-Hindfoot Score improved over the 6-month study period **(Figure 2).** The mean AOFAS score increased from 59.80 ± 6.74 at 6 weeks to 82.85 ± 4.76 at 3 months and 91.15 ± 3.42 at 6 months. There was a statistically significant improvement during follow-up intervals (repeated-measures ANOVA; $P<0.001$). The postoperative pain intensity measured by the VAS is shown in **Figure 3**. The mean VAS score decreased from 5.35 ± 0.75 at 6 weeks to 3.35 ± 0.67 at 3 months and 1.45 ± 0.51 at 6 months. This pre-to-post change in pain scores was significant (Repeated Measures ANOVA, $P<0.001$). The distribution of patients by the time to radiological fracture union is shown in **Figure 4**. Union was achieved within 12–13 weeks in 5 patients (25.0%), between 14 and 16 weeks in 9 patients (45.0%) and after 16 weeks in 4 patients (20.0%). Delayed union was seen

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in 2 patients (10.0%) and there were no patients with non-union or implant failure throughout the study.

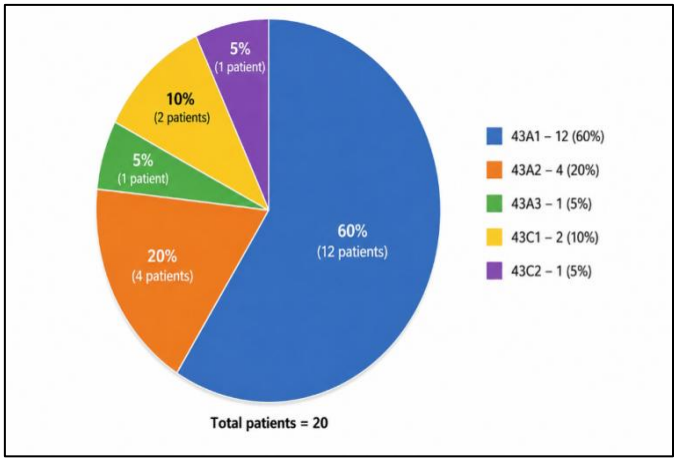



**Figure 1:** Distribution of patients according to AO/OTA fracture classification

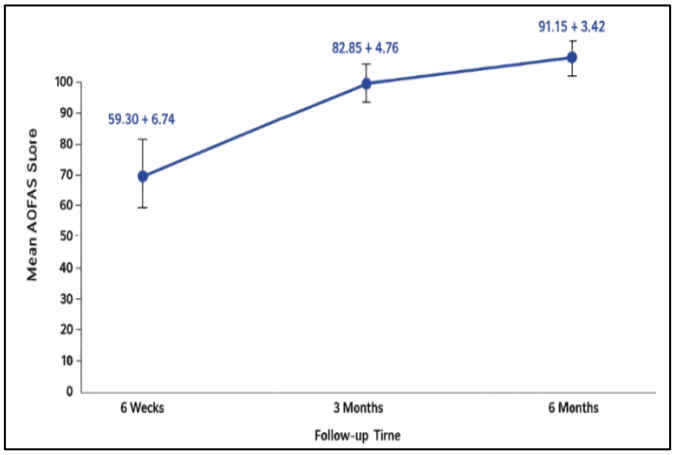



**Figure 2:** Progressive improvement in mean AOFAS score during postoperative follow-up

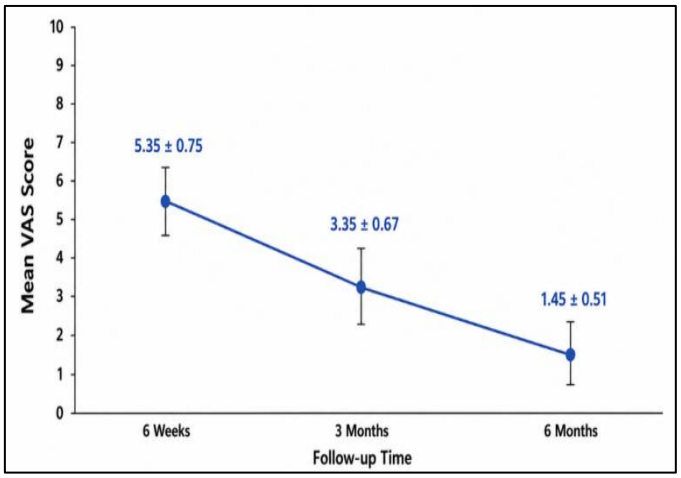



**Figure 3:** Progressive reduction in post-operative pain measured using the Visual Analogue Scale

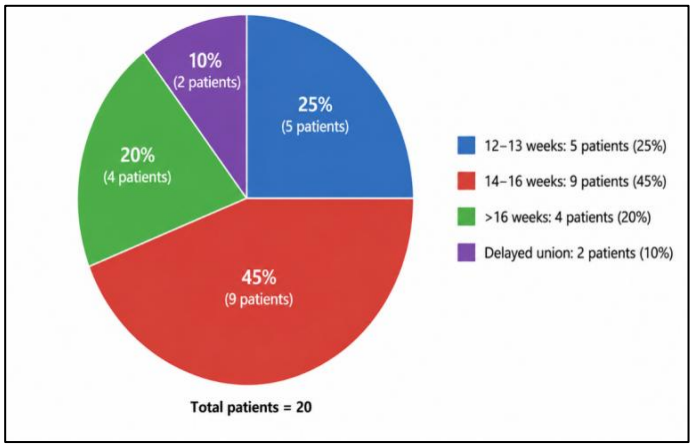



**Figure 4:** Distribution of patients according to radiological fracture union times

**Table 1:** Baseline demographic and fracture characteristics of the study population

| Variable | n (%) |
|---|---|
| **Age** | |
| **<60 years** | 11 (55.0) |
| **≥60 years** | 9 (45.0) |
| **Gender** | |
| **Male** | 16 (80.0) |
| **Female** | 4 (20.0) |
| **Mode of injury** | |
| **Fall on ground** | 16 (80.0) |
| **Road traffic accident** | 4 (20.0) |
| **AO Classification** | |
| **43A1** | 12 (60.0) |
| **43A2** | 4 (20.0) |
| **43A3** | 1 (5.0) |
| **43C1** | 2 (10.0) |
| **43C2** | 1 (5.0) |

**Table 2:** Functional recovery assessed by AOFAS score

| Follow-up | Mean ± SD |
|---|---|
| **6 weeks** | 59.80 ± 6.74 |
| **3 months** | 82.85 ± 4.76 |
| **6 months** | 91.15 ± 3.42 |
| **Repeated measures ANOVA** | P <0.001 |

**Table 3:** Pain assessment using Visual Analogue Scale (VAS)

| Follow-up | Mean ± SD |
|---|---|
| **6 weeks** | 5.35 ± 0.75 |
| **3 months** | 3.35 ± 0.67 |
| **6 months** | 1.45 ± 0.51 |
| **Repeated measures ANOVA** | P <0.001 |

**Table 4:** Radiological fracture union and complications

| Variable | n (%) |
|---|---|
| **Time to union** | |
| **12–13 weeks** | 5 (25.0) |
| **14–16 weeks** | 9 (45.0) |
| **>16 weeks** | 4 (20.0) |
| **Delayed union** | 2 (10.0) |
| **Complications** | |
| **Superficial infection** | 1 (5.0) |
| **Delayed union** | 2 (10.0) |
| **Ankle stiffness** | 1 (5.0) |
| **Implant failure** | 0 |
| **Deep infection** | 0 |

| | |
|---|---|
| **Nonunion** | 0 |

**Table 5:** Final functional outcome according to AOFAS grading

| Outcome | n (%) |
|---|---|
| **Excellent (90–100)** | 15 (75.0) |
| **Good (75–89)** | 5 (25.0) |
| **Fair** | 0 |
| **Poor** | 0 |

## Discussion:

Minimally invasive plate osteosynthesis (MIPO) is a biological fixation that has been proven to provide stable fixation while maintaining the periosteal blood supply and soft tissues in the surrounding areas of the fracture site, which makes it an ideal option for treating distal tibia fractures. In this prospective study the usage of locking compression plates resulted in highly successful clinical and radiological results after MIPO. There were patients showing functional recovery and pain scores improving significantly over the follow-up period and there was no fracture-union failure or low rate of complications. The results in this study do agree with other published studies that MIPO is a successful treatment option for suitable fractures of the distal tibia. The demographic profile of the present study showed the following: the age group less than 60 years had a 55% occurrence and male accounted for 80% of the study population. Khader *et al.* **[1]** and Kisku and Keshkar **[2]** also saw the majority of fracture distal tibia patients being males performing the MIPO surgery, while Sarukte *et al.* **[4]** noted the same in their study. This trend is probably due to the higher levels on male outdoor and occupational exposure to trauma, especially in developing countries. Similarly, Magadum *et al.* **[3]** and Dhakal *et al.* **[9]** concluded that the demographic of the distal tibial fracture injury was prevalently the economically active adult with a corresponding socio-economic impact. Falls was the commonest cause for the 80 % of the injuries, while 20 % were as a result of road traffic accidents. This distribution is a bit different from some of the distributions published where high-energy road traffic accidents were the mechanism of injury leading cause. Road traffic accidents were identified as the most common cause of distal tibial fractures by Khader *et al.* **[1]** and Kumar *et al.* **[5]** explained the differences in the patient demographics, referral patterns and epidemiology of the traffic accidents in different regions around the world. On the other hand, it could be that the wide majority of fractured bones had relatively uncomplicated fracture patterns that were found in our study, while also illustrating favourable fracture healing outcomes at follow-up, due to the higher rate of fall-related injuries we encountered. This study found that 60% of fracture sites were classified as 43A1 fractures, 20% as 43A2 fracture and few as complex intra-articular fractures, according to the AO/OTA classification. Kisku and Keshkar **[2]** reported, those who showed excellent results after MIPO in extra-articular distal tibial fractures, had a similar pattern of extra-articular fracture pattern in their patients. Similarly, Baskey *et al.* **[8],** Dhakal *et al.* **[9]** and Magadum *et al.* **[3]** found the same prevalence of extra-articular fracture patterns in their patients with a good outcome after MIPO respectively. The relative lack of complex articular fractures in the present study should be taken into account when evaluating the excellent functional outcomes because fracture complexity is an important factor influencing prognosis. Schiavi *et al.* investigated distal tibial fractures associated with posterior or medial malleolar injuries and found that, although the associated-injury group required a longer time to achieve full weight-bearing, fracture-union time and clinical outcomes at six months did not differ significantly between groups **[17].** The main focus of this study was functional recovery. The mean AOFAS score improved significantly from 59.80 ± 6.74 at six weeks to 82.85 ± 4.76 at three months and 91.15 ± 3.42 at six months (P<0.001). The results obtained are similar to those of Khader *et al.* **[1]** who proved improvement with increasingly good final ankle function following MIPO. The same was observed by Sarukte *et al.* **[4]** Baskey *et al.* **[8]** and Dhakal *et al.* **[9]** which reported positive changes in the postoperative functional scores with the serial follow-up, being thought as the consequence of maintenance of fracture biology and satisfactory fixation obtained using the minimally invasive techniques. Similar-appearing figures are also found in comparative studies. Kumar *et al.* **[5]** showed good functional results both medially and anterolaterally using compression plates and there was no difference in the results of the final functional outcomes based on the treatment position of the compression plate. Similarly, Kaya *et al.* **[7]** compared the functional outcomes of extra-articular distal tibial fractures treated with MIPO versus intramedullary nailing and found no difference in these outcomes despite the different types of fixation. In more recent results Liu *et al.* **[10]** also showed similar clinical results when comparing retrograde intramedullary nailing with locking plate fixation, similar to the latter the use of MIPO has proved to be a viable alternative for specific distal tibial fractures. The present study also revealed a significant decrease in pain by 6 weeks and 6 months after surgery with mean VAS scores dropping from 5.35 ± 0.75 to 1.45 ± 0.51, respectively (P<0.001). Mannan *et al.* **[18]** and Magadum *et al.* **[3]** found that pain decreased gradually with healing of the fracture and rehabilitation. There was also progressive pain reduction after the treatment after fracture healing and rehabilitation, observed by Sarukte *et al.* **[4].** Several studies have suggested that the lower postoperative pain associated with MIPO compared with conventional open plating is because the soft-tissue dissection is limited, the periosteal vascularity is preserved and surgical trauma is less. These biological benefits allow early mobilisation and reduce patients discomfort post-surgery. The radiological results in the present study were favourable, as well. Union of all fractures occurred, most of which united between 14–16 weeks and only two had delayed union. No cases of implant failure or non-union were noted. The results obtained are similar to Magadum *et al.* **[3]** who reported union rates of 98% after MIPO; Nabil *et al.* **[16]** who reported 98% rates of union after MIPO; and Kang *et al.* **[18]** who reported 96% union rates after MIPO. Similarly, Kadar *et al.* reported a mean fracture-union time of 15 weeks following medial minimally invasive percutaneous plate osteosynthesis, with functional outcomes classified as excellent in 54.5% of patients, good in 31.8% and fair in 13.6% **[19].** Likewise, another group, Dhakal *et al.* **[9]** has recorded the high fracture union rate

with minimal complications, which shows that the bony principles of the minimally invasive fixation are also valid. No complications were seen in the present study. A surface infection (5%), delayed union (10%) and ankle stiffness (5%) were noted, but deep infection, implant failure and non-union were not seen in any patients. Similar results were obtained by Khader *et al.* **[1]** and Kisku and Keshkar **[2]** and Mannan *et al.* **[20]** who also showed low incidences of wound complications after MIPO. Additionally, in distal tibial and pilon fractures, the recent systematic review by Sourougeon *et al.* **[11]** found that union rates and complication profiles with the use of protective measures for the soft tissue, when patient selection is appropriate, were satisfactory with the characteristics of minimally invasive plating. The above observations are further supported by high-level evidence. In a recent systematic review and meta-analysis Hassaan *et al.* **[14]** showed that MIPO led to a significant decrease in wound-related complications, similar to ORIF regarding other perioperative outcomes, such as unions and functional outcomes. These comparative studies done by Kaya *et al.* **[7]** and Liu *et al.,* Prabhat *et al.* and Mulla *et al.* **[10, 13 and 15]** have also been able to reach the same conclusions that both MIPO and intramedullary nailing have led to improvement with good results. Peng *et al.* reported satisfactory fracture healing and functional recovery following retrograde tibial intramedullary nailing in nine patients, with a mean healing time of 3.3 months and excellent or good AOFAS outcomes in all patients **[21].** Wang *et al.* found that intramedullary nailing was associated with shorter operative times and faster fracture healing than distal tibial plate fixation **[22].** Liu *et al.* also reported satisfactory outcomes following retrograde tibial intramedullary nailing in 13 high-risk patients with extra-articular distal tibial fractures. All patients achieved fracture union, with a mean healing time of 5.0 months and 76.9% achieved good or excellent AOFAS outcomes **[23].** And in fractures in which there is involvement of the soft tissue around the bone or there is any evidence of metaphyseal comminution, fractures involving the use of MIPO may be particularly advantageous. All of the results indicate that MIPO is an effective tool in the armamentarium of biological fixation for distal tibial fractures and should be continued to be used. The strength of the present study is a prospective design, standardized surgical technique, a uniform post-operative rehabilitation protocol and serial assessment using validated functional and pain outcome measures. These methodological characteristics minimise information bias and give a full assessment of early clinical and radiological results after MIPO. This study has several limitations. The findings may not be easily generalizable due to the relatively small sample size from a single tertiary-care centre. Direct comparison of treatment modalities was not attainable because there was no control group which underwent intramedullary nailing or an open reduction and internal fixation. In addition, the six month follow up period allowed for did not enable long-term functional outcome evaluation or the development of post traumatic arthritis or implant related complications. Further larger multicentre randomised controlled trials with more extended follow-up are needed to confirm these conclusions and clarify the best approach for the management of various distal tibial fracture patterns. The results of the present study are in accordance with the recent evidence available that shows good functional recovery and the recovery of the fracture at the short term with a low complication rate and pain reduction with this technique of minimally invasive plate osteosynthesis. With proper patient selection, surgical precision and rehabilitation protocol, MIPO is a safe and effective treatment for distal tibial fracture.

**Conclusion:**

Minimally invasive plate osteosynthesis using locking compression plates for distal tibial fractures produced favorable clinical and radiological outcomes over 6 months, with radiological union in all cases, good pain relief and excellent functional recovery based on the American Orthopaedic Foot and Ankle Society score. These findings support biological fixation with preservation of soft tissue integrity as an effective approach for appropriately selected distal tibial fractures. Larger multicenter studies with longer follow-up and comparisons with alternative fixation methods are needed to establish its broader applicability.

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