

Comparative Study of Minimally Invasive Plate Osteosynthesis (MIPO) Versus Intramedullary Nailing for Distal Third Tibial Shaft Fractures: A Prospective Analysis of Soft Tissue Healing and Union Rates

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Abstract

Background: The distal third tibial shaft fracture is one of the most difficult orthopedic injuries, due to poor soft tissue cover, vascularity and close proximity with the ankle joint. The ultimate goal of surgical fixation is to meet these objectives: safe, predictable fracture union and to maintain the integrity of soft tissues, with a minimal rate of complications. The two most commonly used fixation techniques are minimally invasive plate osteosynthesis (MIPO) and intramedullary nailing (IMN). Both techniques have been shown to have satisfactory clinical results but there is some debate about their relative effectiveness in healing fractures, preserving soft tissue, malalignment and functional recovery. The objective is to compare the functional outcomes, complication rate, the time of fracture union and soft tissue healing for minimally invasive plate osteosynthesis versus intramedullary nailing in the treatment of distal third tibial shaft fractures. **Material and Methods:** This was a prospective comparative study of 112 adult patients with distal third tibial shaft fractures over 2 years at IMS and SUM hospital, Bhubaneswar. There were 56 patients treated with minimally invasive plate osteosynthesis and 56 patients treated with intramedullary nailing. This at least 12-months follow-up assessed demographic and injury profile and operative variables, soft tissue healing, radiological fusion, complications, and functional outcome. The functional assessment was done using the American Orthopaedic Foot and Ankle Society (AOFAS) score. A multivariate analysis was conducted to see if any other factors predicted delayed union. **Results:** In the MIPO group, 53 patients (94.6%) had radiological union while 51 patients (91.1%) had IMN union. Treatment using MIPO showed to improve significantly the soft tissue healing, the rate of wound complication, and the fracture alignment, while intramedullary nailing showed to be associated with a shorter duration of surgery and earlier partial weight bearing. There were no significant differences between the two groups at 1 year in functional outcomes. **Conclusion:** Forearm fractures of the distal third of tibia were treated with satisfactory clinical and radiological results with both methods. The clinical and radiological results of both MIPO and intramedullary nailing was satisfactory for distal third tibial shaft fractures. MIPO preserved the soft tissues better and aligned the fracture more, whereas IMN had a more rapid operative time and mobilization. Surgical technique should be tailored to the fracture and patient.

Keywords: Distal tibial fracture, Minimally invasive plate osteosynthesis, Intramedullary nailing, Fracture union, Soft tissue healing, Prospective study.

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INTRODUCTION

The tibial shaft distal third fracture is approximately 10-15% of all tibial fractures and is among the most challenging fractures in orthopedic trauma surgery. The distal tibia is exposed subcutaneously, has a thin envelope of muscle, a less robust vascular supply and often it is both fractured and soft tissue injured, all which contribute to delayed fracture healing, infection, malalignment, and nonunion. Conservative surgical management aims to restore anatomical alignment with minimal added soft tissue insult. Improvements in biological fixation techniques have enhanced outcomes and have focused more on maintaining fracture biology and periosteal blood supply.^[1-4]

Tibial shaft fractures are treated by intramedullary nailing (IMN) which is considered the standard of care because it offers the best stability for load sharing fixation, early mobilization and reduces surgical exposure. Fixation of

distal third fractures is technically difficult, however, due to the relatively wide metaphyseal canal, the short distal fragment and increased risk for deformities, typically valgus and procurvatum. Technical advances, such as those in multiplanar distal locking screws, suprapatellar nailing techniques, and improved implant design, have improved fixation stability, although there are still concerns about rotational instability, anterior knee pain, and

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malunion.^[5-9]

Minimally invasive plate osteosynthesis (MIPO) is a new biological technique for fixing distal tibial fractures. The technique involves indirect fracture reduction and submuscular insertion of locking compression plates through small incisions without compromising periosteal circulation, fracture hematoma, and adjacent soft tissues. Because of the small amount of surgical dissection the MIPO allows less extra vascular damage and allows angular stability and increased control of distal fracture fragments. There have been recent comparative studies which have reported better soft tissue healing with lower malalignment, but delayed weight bearing and implant positioning are areas of ongoing investigation.^[10-15]

Although there are several comparative studies that suggest that one technique is superior to the other for distal third tibial shaft fractures, there is no agreement. The fracture configuration, soft tissue injury, patient-specific factors and surgeon preference are still important factors influencing the choice of treatment. In addition, there has been a trend in the literature recently to understand the biological healing process, functional recovery, and complication risk beyond the radiological union. Therefore, the present prospective comparative study was undertaken to evaluate minimally invasive plate osteosynthesis and intramedullary nailing in the management of distal third tibial shaft fractures, with particular emphasis on soft tissue healing, fracture union, postoperative complications, and functional outcomes.^[16-20]

MATERIALS AND METHODS

This prospective comparative study was conducted in the Department of Orthopaedics at IMS and SUM Hospital Bhubaneswar, over 2 years of study period hospital after obtaining approval from the Institutional Ethics Committee. Written informed consent was obtained from all participants before enrollment.

Adult patients aged 18–65 years presenting with closed or

Gustilo-Anderson Grade I open distal third tibial shaft fractures requiring operative fixation were eligible for inclusion. Patients with pathological fractures, Gustilo-Anderson Grade II or III open fractures, polytrauma requiring damage-control procedures, neurovascular injuries, previous ipsilateral lower-limb fractures, metabolic bone disease, or incomplete follow-up were excluded. A total of 112 patients satisfied the eligibility criteria and were allocated into two equal groups according to the surgical procedure performed: MIPO (n=56) and intramedullary nailing (n=56).

Demographic data, mechanism of injury, fracture classification (AO/OTA), associated fibular fractures, soft tissue status, and a base-line neurovascular examination were performed before surgery. All surgeries were done by experienced trauma orthopedic surgeons in a series of standardized procedures as per our institutional protocol. Patients in the MIPO and IMN groups were fixed with locking compression plates using the submuscular minimally invasive technique, and reamed intramedullary nailing with multiple distal locking screws, respectively.

Patients were followed at 2 weeks, 6 weeks, 3 months, 6 months, and 12 months. Outcome measures included operative duration, intraoperative blood loss, time to partial weight bearing, soft tissue healing, radiological union, malunion, delayed union, infection, implant-related complications, and functional outcome assessed using the American Orthopaedic Foot and Ankle Society (AOFAS) score. Radiological union was defined as bridging callus across at least three cortices on orthogonal radiographs with painless full weight bearing.

Statistical analysis was performed using SPSS version 26. Continuous variables were expressed as mean $\pm$ standard deviation, while categorical variables were expressed as frequencies and percentages. Student's t-test and Chi-square test were used for comparison between study groups. Multivariate logistic regression analysis was performed to identify independent predictors of delayed union. A p-value less than 0.05 was considered statistically significant.

RESULTS

Table 1: Baseline Demographic and Injury Characteristics

Variable	MIPO (n=56)	IMN (n=56)	p-value
Age (years)	39.8 $\pm$ 11.4	41.3 $\pm$ 10.8	0.468
Male gender	42 (75.0%)	40 (71.4%)	0.672
Road traffic accidents	38 (67.9%)	40 (71.4%)	0.689
AO/OTA Type 42-A	30 (53.6%)	28 (50.0%)	0.703
Associated fibular fracture	40 (71.4%)	42 (75.0%)	0.672
Closed fractures	50 (89.3%)	48 (85.7%)	0.562

Both treatment groups demonstrated comparable baseline demographic characteristics and injury profiles. Road traffic accidents represented the most common mechanism of injury, while simple extra-articular distal tibial fractures

predominated in both groups. The absence of significant baseline differences ensured appropriate comparison of postoperative outcomes.

Table 2: Operative Characteristics

Variable	MIPO	IMN	p-value
Operative duration (minutes)	94.6 $\pm$ 14.8	76.2 $\pm$ 12.5	<0.001
Blood loss (mL)	118 $\pm$ 34	82 $\pm$ 28	<0.001
Hospital stay (days)	5.6 $\pm$ 1.7	4.8 $\pm$ 1.5	0.012

Partial weight bearing (weeks)	6.8 ± 1.2	4.9 ± 1.1	<0.001
Fluoroscopy time (seconds)	86 ± 18	92 ± 20	0.094

Intramedullary nailing required significantly shorter operative time, lower intraoperative blood loss, and earlier initiation of partial weight bearing compared with MIPO.

However, both procedures demonstrated similar fluoroscopy exposure, indicating comparable intraoperative imaging requirements.

Table 3: Radiological and Soft Tissue Outcomes

Variable	MIPO	IMN	p-value
Mean union time (weeks)	18.2 ± 3.1	19.5 ± 3.8	0.041
Soft tissue complications	3 (5.4%)	9 (16.1%)	0.048
Superficial infection	2 (3.6%)	6 (10.7%)	0.143
Malalignment (>5°)	2 (3.6%)	8 (14.3%)	0.043
Delayed union	3 (5.4%)	5 (8.9%)	0.462
Nonunion	1 (1.8%)	2 (3.6%)	0.558

Patients treated with MIPO demonstrated significantly earlier fracture union, lower soft tissue complication rates, and superior fracture alignment. Rates of delayed union,

superficial infection, and nonunion were comparable between both treatment groups.

Table 4: Functional Outcomes and Complications

Variable	MIPO	IMN	p-value
AOFAS score (12 months)	91.8 ± 5.2	89.6 ± 6.4	0.047
Excellent/Good outcome	52 (92.9%)	49 (87.5%)	0.332
Anterior knee pain	—	10 (17.9%)	<0.001
Implant irritation	6 (10.7%)	2 (3.6%)	0.143
Reoperation	2 (3.6%)	3 (5.4%)	0.646
Implant failure	1 (1.8%)	2 (3.6%)	0.558

Functional outcomes at one year were excellent in both groups. Patients undergoing MIPO achieved slightly higher AOFAS scores and experienced fewer alignment-related complications, whereas anterior knee pain occurred exclusively among patients treated with intramedullary nailing. Implant failure and reoperation rates remained low in both treatment groups.

DISCUSSION

This prospective study aimed to compare the efficacy of minimally invasive plate osteosynthesis (MIPO) and intramedullary nailing (IMN) techniques for treatment of distal third tibial shaft fracture, focusing on a soft tissue healing and fracture union. Both surgical procedures had high rates of fracture union and adequate functional recovery, but MIPO had better soft tissue preservation, lower rates of malalignment and slightly earlier radiological union. Intramedullary nailing, however, provided a shorter operation time, lower blood loss and early initiation of weight bearing. The results indicated that both procedures are effective treatment modalities but each has its own particular benefits based on the fracture characteristics and patient factors. Systematic reviews and multicenter investigations have also recently reported similar union rates for the MIPO and IMN procedures with differing complication profiles and differing functional recoveries.^[1-5]

The present study resulted in one of the most important conclusions, that is, the excellent soft tissue healing with MIPO. The most important biological advantage of this technique is the preservation of the periosteal blood supply and the fracture hematoma with indirect reduction and submuscular plate insertion. The limited dissection of the

vessels, limits wound tension and decreases soft tissue complications after surgery. In contrast, fractures need to be manipulated in certain instances in order to achieve good fracture reduction, which may require larger incisions in the skin in intramedullary nailing, especially for fractures of the metaphyseal region. Recent clinical studies have shown reduced incidence of wound complications and better fracture alignment after MIPO, especially in fractures involving the distal metaphysis which have inadequate soft tissue coverage.^[6-10]

The overall union rates were excellent for both treatment groups, but with the MIPO group, radiological union occurred slightly earlier. Biological fixation principles used in MIPO will maintain the local vascularity and allow callus formation by relative stability, which will result in secondary bone healing. However, intramedullary nailing also had high union rates due to its load sharing biomechanical properties and early functional mobilization. The increased malalignment rate seen after IMN in the present study is similar to previous studies reporting that it may be technically a problem to maintain reduction of the shorter fracture fragments distally. This complication has been minimized but not eliminated in recent times with the advent of improved techniques in suprapatellar nailing, multiplanar distal locking screws, blocking screws, and modern nail designs.^[11-15] The intramedullary nailing procedure showed several important perioperative benefits: it shortened the time of surgery, the blood loss was lower and it allowed for the initiation of partial weight bearing earlier. This, in turn, could help the patient to be more progressive and mobilized earlier, thereby limiting muscle atrophy and decreasing the hospital stay in patients with isolated fractures, especially the younger ones. Anterior knee pain, however, was the only complication that was peculiar to the IMN group, and resulted from the irritation of the patellar tendon and

surrounding soft tissues during the insertion of the nail. However, implant prominence was more commonly seen after MIPO due to the distal tibia being placed subcutaneously, and sometimes needed the removal of the implant after bony union. A recent series of meta-analyses have also confirmed that the IMN is linked to earlier mobilization and the MIPO to improved fracture alignment and reduced soft tissue complications.^[16-21]

The present study has a few strengths, such as the prospective design, standardized surgical procedures, thorough evaluation of radiological and functional outcomes and the minimum follow-up period of 1 year. But some restrictions must be noted. The study was undertaken at one site using a small number of institutions, so results may not be generalizable. Despite similar baseline factors, treatment was allocated to fracture complexity and surgeon preference. Longer follow-up would yield a better understanding of the long-term outcomes for patients with respect to both post-traumatic ankle arthritis and implant survival, as well as quality of life and cost-effectiveness. However, the results indicate that treatment decisions should be made on a case-by-case basis, taking into account the fracture type, soft tissue condition, functional needs and surgeon's experience. When performed with good surgical technique and selection, both MIPO and intramedullary nailing are good options for treatment of the distal third tibial shaft fracture.^[22-25]

CONCLUSION

The treatment of distal third tibial shaft fractures with either minimally invasive plate osteosynthesis or intramedullary nailing yielded satisfactory clinical, radiological and functional outcomes. While MIPO showed the advantage of soft tissue healing, fracture alignment maintenance and slightly earlier fracture union, intramedullary nailing showed the advantage of better postsurgical mobility, less blood loss, and shorter operative time. Union rates and functional outcome long-term results were similar between the 2 procedures. Therefore, surgical treatment should be tailored to the fracture configuration, soft tissue status, patient factors and surgeon experience for best clinical outcomes.

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Conflicts of interest

There are no conflicts of interest.

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