



Outcome and complications of distal tibia fractures treated with intramedullary nails versus minimally invasive plate osteosynthesis and the role of fibula fixation

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Abstract

Introduction Distal tibia fractures have been managed conservatively as well surgically. A large number of implants have been used for surgical management of these fractures. No treatment method or implant has been proven to be superior to others. In this prospective comparative study, the complications and outcome of distal tibia fractures managed with intramedullary nails and minimally invasive plate osteosynthesis has been compared. Further, the role of fibula fixation in these fractures has been evaluated.

Materials and method One hundred and fifty-four patients of distal tibia fractures with concomitant fibula fractures were randomized into 4 treatment groups based on predetermined inclusion criteria. Functional outcome in these groups was compared based on AOFAS score at 1 year. Intra-operative, post-operative parameters as well as radiological alignment, complications and the need for reoperation were also compared in these groups.

Result The functional outcome in all four treatment groups was similar. The duration of surgery and radiation exposure was higher with minimally invasive plate osteosynthesis. There was no improvement in outcome with plating of fibula. However, fixation of fibula improved the rotational alignment in distal tibia fractures.

Conclusion Although there is no difference in outcome of distal tibia fractures with either nailing or minimally invasive plating, nailing is recommended for closed displaced extraarticular fractures. Fixation of fibula should not be done routinely but should be reserved only for a few specific fracture patterns.

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Introduction

Fractures of shaft tibia are one of the most common fractures encountered by an orthopaedic surgeon. Of these, the fractures of distal tibia present a challenge to the surgeon. Owing to poor muscle cover, compromised vascularity and proximity to the ankle, distal tibia fractures are often complicated with non-union, malunion and infection [1].

Although distal tibia fractures may be managed conservatively, surgical management remains the mainstay of treatment for these fractures. Surgical management of distal tibia fractures is associated with a better outcome as well as a rapid return to full function [2]. Distal tibia fractures may be managed with closed reduction and internal fixation with intramedullary nailing or with open reduction and internal fixation with plating. Minimally invasive percutaneous plate osteosynthesis may also be done for these fractures.

Closed displaced extra-articular fractures of distal tibia have been managed with intramedullary nails (IMN) as well as with plates and screws with good functional outcome

[3–6]. However, the wide medullary cavity of distal tibia makes it challenging to obtain reduction using an intramedullary nail. Loss of reduction is often encountered during distal locking [7]. This problem can be easily overcome with open reduction and internal fixation of these fractures with locking plates. Open reduction and internal fixation allows a surgeon to achieve anatomical reduction of these fractures. Reduced rate of malunion has been reported with open reduction and fixation with plates in these fractures [8, 9]. However, wound dehiscence and infection are commonly seen with this treatment modality due to its proximity to the ankle [3, 6, 9].

Minimally invasive plate osteosynthesis (MIPO) has been used successfully to overcome the drawbacks of open reduction. This technique employs the use of indirect reduction technique, preserves the periosteum and does not disturb the fracture hematoma. The smaller incisions used in this technique helps to reduce the risk of infections and wound dehiscence. Studies have suggested that MIPO helps to reduce the risk of non-union and superficial infections [10].

There is no consensus regarding the fixation of fibula in the management of distal tibia fractures. Absence of a fibula fracture is associated with an increased risk of non-union and delayed union as well as varus malunion of tibia fractures [11, 12]. This is explained by transmission of weight through the fibula instead of tibia which prevents cyclical loading of tibia necessary for fracture healing. Studies have shown that concomitant fixation of fibula in distal tibia fractures leads to better alignment of fractures immediate post operatively as well as decreased malunion on follow-up [13]. However, there is some evidence to suggest that fixation of fibula in shaft tibia fractures may increase the risk of non-union and local wound infection [14]. Thus, fixation of fibula creates a dilemma in surgeon's mind.

Very few studies have compared the functional outcome and complications associated with closed reduction and internal fixation with intramedullary nails with fixation using pre-contoured locking plates using MIPO technique. Similarly, there is no consensus regarding the fixation of fibula in these fractures. The purpose of this study was to compare the functional outcome and complications of distal tibia fractures managed with intramedullary nails and pre-contoured locking plates using MIPO technique. The role of fibula fixation in distal tibia fractures was also assessed. The functional outcome and complications in these fractures with and without fibula fixation were compared.

Materials and method

All the patients with closed displaced extraarticular fractures of distal tibia meeting the study criteria that were operated at level 1 trauma centre between January 2015 and December 2018 were randomized into four treatment groups. Group 1 consisted of those patients treated with IMNs without fixation of fibula while patients in group 2 were treated with IMNs and plating of fibula. Group 3 consisted of patients treated with pre-contoured locking plates using MIPO technique without fixation of fibula. Similarly, group 4 consisted of those cases where fixation of tibia was done using similar plates using MIPO technique along with plating for fibula. Approval was taken from the institutional ethics committee prior to the study. Informed consent was taken from all the study participants prior to the surgery in regional language (Figs. 1, 2, 3 and 4).

The inclusion criteria consisted of the presence of a closed extraarticular distal tibia fracture (fracture line between 3 and 12 cm from the ankle joint) with a concomitant distal



Fig. 1 Pre- and post-operative X-rays of distal tibia fracture treated with intramedullary nail with conservative management of fibula



Fig. 2 Pre- and post-operative X-rays of distal tibia fracture treated with intramedullary nail with plating for fibula



Fig. 3 Pre- and post-operative X-rays of distal tibia fracture treated with MIPO with conservative management of fibula

fibula fracture at the same level (within 2 cm of the distal tibia fracture) in a skeletally mature patient. The exclusion criteria consisted of pathological fractures, compound fractures, associated neurological or vascular injury, the presence of multiple fractures or polytrauma, immunodeficiency states.

The exclusion of patients without a fibula fracture or with a fibula fracture greater than 2 cm away from tibial fracture was done with the purpose of assessing the role of fibula fixation in obtaining acceptable reduction or alignment of the distal tibia fracture. Compound fractures were excluded from the study.

The baseline characteristics of the patients were noted including age, sex, AO fracture classification [15] and morbidity status using ASA grading. The patients were allotted

to the plating or nailing group with the flip of a coin. These cases were further subdivided into subgroups: with or without fibula fixation using a second flip of a coin.

All the patients were operated by the consultant orthopaedic surgeons in the department of orthopaedics or by a resident with at least 3 years of experience in traumatology under the supervision of a consultant. The time from injury to fixation was noted. All procedures were performed under epidural plus spinal anesthesia under tourniquet to control the bleeding and to obtain a clear operative field. However, tourniquet was deflated if the duration of surgery exceeded 90 min. The duration of surgery was noted.

In all cases randomized to fibula fixation groups, open reduction of fibula with internal with plating was done prior to fixation of distal tibia. In the patients managed with IMN,



Fig. 4 Pre- and post-operative X-rays of distal tibia fracture treated with MIPO with plating for fibula

the entry point was made using median patellar tendon splitting approach. Proximal locking was done using the locking jig available with the instruments, while distal locking was done using free hand technique. Two perpendicular locking screws were used for locking the nail distally. Poller screws, angle stable or multi directional locking systems were not used for improving reduction. In patients randomized to MIPO groups either with or without fibula fixation, indirect reduction was achieved under fluoroscopic guidance. Stainless steel pre-contoured locking medial plates were used for fixation of distal tibia.

All patients were followed at 2-week intervals until fracture union and monthly, thereafter, with radiographic examinations for 1 year. Time to union of the fracture was noted. After 1 year the patients were followed up for late complications every 6 months. Weight-bearing was allowed at 6 weeks. At one-year follow-up, all patients underwent clinical and radiological assessment. Anteroposterior and lateral radiographs were used to measure the alignment in both coronal and sagittal planes. Difference between the foot-thigh angle on operated side and normal side was measured clinically using a goniometer to assess the rotation clinically. Malunion was defined as varus or valgus angulation more than 5° in the coronal plane and recurvatum or procurvatum greater than 10° in the sagittal plane and external or internal rotation greater than 10° compared to contralateral side. Functional outcome was measured at 1 year using the American Orthopaedic Foot and Ankle surgery (AOFAS) scoring system.

Data analysis was performed using SPSS version 16.0 (SPSS Inc, Chicago, IL, USA). Frequencies of categorical variables were calculated, while continuous variables were presented as means. Chi-square test and Fischer's exact test were used for comparison between categorical variables, while Student's *t*-test was used for continuous variables.

One-way ANOVA test was used to compare the means of variables in the four groups. Tukey's post hoc test was also used wherever necessary. Statistical significance was accepted if the *p*-value was < 0.05 .

Results

Of the 154 eligible patients of distal tibia fractures that were taken up for the study, 12 patients (7.8%) were lost to follow-up. The final data set used for this study consists of 142 patients of distal tibia fractures. These patients were divided into four groups based on the operative treatment they received: Group 1 (IMN without fixation of fibula)—35 cases, Group 2 (IMN with fibular plating)—38 cases, Group 3 (MIPO without fixation of fibula fibular plating)—32 cases and Group 4 (MIPO with fibular plating)—37 cases.

Nailing versus MIPO

The baseline characteristics, intra-operative and post-operative findings, complications and functional outcome of the patients that underwent nailing (group 1 + 2) and MIPO (group 3 + 4) for distal tibia fractures are compared in Table 1. As depicted in Table 1, the 2 groups were found to be statistically similar in terms of age, sex distribution, fracture pattern based on OTA classification, operating surgeon, distance from tibial plafond and follow-up duration. Thus, these groups were statistically comparable.

The patients managed with IMN for distal tibia fractures were operated 2 days earlier than the patients that underwent MIPO. (5.1 days vs 7.1 days, respectively) The mean operative time for IMN group was 81.7 min which was significantly lower than that for MIPO group at 95.3 min. Similarly, the radiation exposure based on fluoroscopy time

Table 1 Comparison of baseline parameters and various outcome parameters in patients of distal tibia fractures treated with IMN and MIPO

	IMN group (group 1 + 2) <i>n</i> = 73	MIPO group (group 3 + 4) <i>n</i> = 69	<i>p</i> -value
Age (yrs.)	43.7 ± 15.3	45 ± 14.4	0.595*
Sex (M:F)	44:29	43:26	0.803**
OTA class			
42 A2.1	55	51	0.754***
42 A2.2	13	15	
42 A2.3	5	3	
Operating surgeon			
Consultant	28	23	0.533**
Resident	45	46	
Distance from plafond (mm)	81.1 ± 19.2	79.0 ± 17.2	0.483*
Days before surgery	5.1 ± 2.0	7.1 ± 1.8	0.00*
Follow-up duration (months)	34.6 ± 15.4	34.96 ± 14.0	0.895*
Intra-operative findings			
Duration of surgery (min)	81.7 ± 17.3	95.3 ± 20.1	0.000*
Radiation time (s)	72.9 ± 21.2	91.3 ± 25.3	0.000*
Immediate post-op malalignment (degrees)			
Coronal	2.5 ± 1.7	2.7 ± 1.7	0.368*
Sagittal	3.7 ± 1.8	3.9 ± 2.5	0.784*
Rotation	5.2 ± 2.4	5.3 ± 2.8	0.826*
Complications & secondary procedures			
Malunion	6 (8.2)	8 (11.6)	0.500**
Non-union	2 (2.7)	4 (5.8)	0.432***
Infection	5 (6.8)	6 (8.7)	0.681**
Total	13 (17.8)	18 (26.1)	0.233**
Dynamization	9 (12.3)	0 (0)	0.003***
Implant removal	4 (5.5)	11 (15.9)	0.043**
Secondary procedures total	15 (20.5)	16 (23.2) †	0.703**
Functional outcome based on AOFAS score at 1 year follow-up [‡]	<i>n</i> = 71	<i>n</i> = 65	
Pain	32.6 ± 3.8	32.0 ± 2.9	0.278*
Function	41.9 ± 3.6	40.8 ± 3.8	0.084*
Alignment	7.5 ± 1.9	7.6 ± 1.8	0.654*
AOFAS score (total)	82.1 ± 5.9	80.5 ± 5.6	0.104*

*Comparison of means using Student's *t*-test

**Comparison of frequencies using Chi-square test

***Comparison of frequencies using Fischer's exact test

†Includes one patient with MIPO with fibula plating who needed wound debridement for infection

‡The 6 cases that developed non-union were not included in the comparison of outcomes

was also higher for patients operated using MIPO (91.3 s) as compared to those treated with nailing (72.9 s) in this study. The immediate postoperative malalignment based on

X-rays (coronal and sagittal) and clinical assessment (rotational malalignment) was statistically similar in the 2 groups as shown in Table 1.

As shown in Table 1, there was no significant difference in the number of cases that developed malunion, non-union as well as infections in the two groups. Five patients in IMN group and 6 patients in MIPO group developed infections. One of these patients needed debridement of surgical wound. All the others required additional antibiotic courses based on microbiological reports along with delayed suture removal. Nine patients in the nailing group needed dynamization while implant removal was done for 11 patients among the patients that were treated with plating using MIPO technique. This was significantly (*p* 0.043) higher than the number of patients that needed implant removal in IMN group.

The functional outcome in the patients treated with nailing and MIPO was compared at one year follow-up using the AOFAS score. There is no statistical difference in the AOFAS score at 1 year between the 2 groups. Similarly, there was no difference in the pain, function as well as the alignment sub-scores of the AOFAS scoring system in the two groups.

Conservatively managed fibula versus fibular plating

The baseline characteristics and other findings including complications and functional outcome of the patients of distal tibia fractures with conservatively managed concomitant fibula fracture at same level (group 1 + 3) and those patients that underwent plating for fibula (group 2 + 4) are compared in Table 2. As depicted in Table 2, both the groups were found to be statistically similar in most baseline characteristics. However, the mean age of patients that conservatively managed concomitant fibula fractures (47.8 years) was significantly higher (*p* 0.010) than those treated with fibular plating (41.4 years).

Fixation of fibula fracture with plating (92.5 min) was associated with increased average duration of surgery as compared to the cases where concomitant fibula fracture was managed conservatively (83.7 min). However, there was no significant difference in the radiation exposure associated with either conservative or operative management of fibula fracture based on fluoroscopy time.

On radiological assessment of immediate post-op X-rays, there was no significant difference in the coronal or sagittal alignment without or with fibular fixation. Rotational malalignment was found to be higher in cases where fibula was treated conservatively (6.9 degrees) as compared to the patients with fibular plating (3.7 degrees). This malalignment was statistically significant. (*p* 0.000).

Table 2 Comparison of baseline parameters and various outcome parameters in patients of distal tibia fractures with conservative management and plating of concomitant fibula fracture

Based on fixation of fibula	Conservatively managed fibula (group 1 + 3) <i>n</i> = 67	Fibular plating (group 2 + 4) <i>n</i> = 75	<i>p</i> -value
Age (year)	47.8 ± 15.2	41.4 ± 13.9	0.010*
Sex (M:F)	45:22	42:33	0.173**
OTA class			
42 A2.1	47	59	0.489***
42 A2.2	15	13	
42 A2.3	5	3	
Operating surgeon			
Consultant	23	28	0.709**
Resident	44	47	
Distance from plafond (mm)	77.6 ± 18.1	82.3 ± 18.4	0.131*
Days before surgery	6.0 ± 2.1	6.2 ± 2.2	0.783*
Follow-up duration (months)	35.2 ± 14.9	34.4 ± 14.5	0.758*
Intra-operative findings			
Duration of surgery (min)	83.7 ± 17.3	92.5 ± 21.2	0.008*
Fluoroscopy time (s)	80.9 ± 25.3	82.7 ± 24.8	0.673*
Immediate post-op malalignment (degrees)			
Coronal	2.9 ± 1.6	2.4 ± 1.7	0.056*
Sagittal	4.1 ± 2.2	3.5 ± 2.1	0.104*
Rotation	6.9 ± 2.6	3.7 ± 1.5	0.000*
Complications & secondary procedures			
Malunion	10 (14.9)	4 (5.3)	0.046**
Non-union	3 (4.5)	3 (4.0)	1.000***
Infection	4 (6.0)	7 (9.3)	0.454**
Total	17(25.4)	14(18.7)	0.334**
Dynamization	4 (6.0)	5 (6.7)	1.000***
Implant removal	6 (9.0)	9 (12.0)	0.556**
Secondary procedures total	13 (19.4)	18 (24.0) [‡]	0.508**
Functional outcome based on AOFAS score at 1 year follow-up [†]			
	<i>n</i> = 64	<i>n</i> = 72	
Pain	32.9 ± 3.5	31.8 ± 3.3	0.079*
Function	41.3 ± 4.1	41.4 ± 3.4	0.966*
Alignment	7.0 ± 2.0	8.1 ± 1.5	0.001*
AOFAS score (total)	81.3 ± 6.4	81.4 ± 5.3	0.976*

*Comparison of means using Student's *t*-test

**Comparison of frequencies using Chi-square test

***Comparison of frequencies using Fischer's exact test

[‡]Includes one patient with MIPO with fibula plating who needed wound debridement for infection[†]The cases that developed non-union were not included in the comparison of outcomes

Similarly, 10 patients of distal tibia fractures with conservatively managed fibula developed malunion as compared to only 4 cases from fibula fixation group. This difference was statistically significant (p 0.046). This can be explained by significantly higher rotational malalignment in patients who received conservative treatment of fibula as shown in Table 2. The development of non-union of tibia was not statistically lower with either conservative or operative

management of fibula (p 1.00). In the present study, fixation of fibula did not affect the need for dynamization, implant removal or the overall reoperation rate in patients of distal tibia fractures.

The mean total AOFAS was statistically similar (p 0.976) in both these groups at 81.3 for conservatively managed fibula group and 81.4 for those fracture where fibula was fixed with a plate. However, the mean alignment sub-score

was significantly higher (p 0.001) for patients with operative management of concomitant fibula fracture at 8.1 as compared to those patients where fibula was treated conservatively at 7.0.

Comparison of all the four modes of treatment

The patients of distal tibia fractures were divided into four groups based on the operative treatment they received: Group 1 (IMN without fixation of fibula)—35 cases, Group 2 (IMN with fibular plating)—38 cases, Group 3 (MIPO without fixation of fibula)—32 cases and Group 4 (MIPO with fibular plating)—37 cases.

Tables 3 and 4 depict the baseline characteristics, operative parameters, functional outcomes and complications of these four groups. One-way ANOVA test was used to compare the means of various parameters. Chi-square test and Fischer's exact test were also used to compare the frequencies of sex distribution, fracture pattern and complications. All the 4 treatment groups were comparable in terms of baseline data like mean age, sex distribution, fracture pattern based on OTA classification, operating surgeon, distance from tibial plafond and mean follow-up. Thus, these groups were statistically comparable.

There was significant difference ($p < 0.001$) in the mean duration before surgery in the four groups based on one-sided ANOVA test. The mean duration of days before surgery was about 2 days higher in plating groups i.e., groups 3 and 4 (7.1 and 7.0 days, respectively) as compared to nailing groups i.e., groups 1 and 2 (5.1 and 5.0 days, respectively).

The outcome parameters of these groups are compared in Table 4. One-way ANOVA was used to compare the mean values statistically. Similarly, the frequencies of complications and reoperations have been compared using Chi-square and 2-sided Fischer's exact test. Further internal comparisons were made between group 1 and group 2 as well as between group 3 and group 4 using Tukey's post hoc test.

As shown in Table 4, there was a significant difference in the duration of surgery as well as fluoroscopy time in the 4 treatment groups based on one-way ANOVA test. The mean longest duration of surgery at 100.5 min was needed for fixation of distal tibia fractures with plating using MIPO along with plating for concomitant fibular fracture (group 4). The highest amount of radiation exposure was associated with group 3 (MIPO without fibula fixation) at 93.8 s. There was a significant difference in the post-operative rotational malalignment of these groups (p 0.000). The maximum malrotation was observed with distal tibia fractures treated with MIPO without fibular fixation at 7.1 degrees. The malrotation was significantly lower in patients that underwent nailing or plating for distal tibia fractures along with plating for concomitant fibula fractures at 3.8 and 3.7 degrees, respectively. On post hoc analysis, significantly lower rotational malalignment was observed in patients of nailing with fibula fixation as compared to those patients of nailing without fibula fixation (p -0.000). Similarly, significantly better rotational alignment (p 0.000) was found in patients of group 4 (MIPO with fibular fixation) as compared to group 3 (MIPO with fibular plating). Thus, the

Table 3 Comparison of baseline parameters of patients with distal tibia fractures in four treatment groups

	IMN without fibula fixation (group 1) <i>n</i> = 35	IMN with fibula plating (group 2) <i>n</i> = 38	MIPO without fibula fixation (group 3) <i>n</i> = 32	MIPO with fibula plating (group 4) <i>n</i> = 37	<i>p</i> -value	<i>F</i> -value one-way ANOVA
Age (year)	47.1 ± 15.9	40.7 ± 14.2	48.6 ± 14.6	42 ± 13.7	0.073*	2.377
Sex (M:F)	26:9	18:20	19:13	24:13	0.119**	–
OTA class						
42 A2.1	25	30	22	29	0.897***	–
42 A2.2	7	6	8	7		
42 A2.3	3	2	2	1		
Operating surgeon						
Consultant	14	14	9	14	0.760**	–
Resident	21	24	23	23		
Distance from plafond (mm)	78.6 ± 19.4	83.5 ± 19.1	76.6 ± 16.6	81.1 ± 17.8	0.424*	0.938
Days before surgery	5.1 ± 1.9	5.2 ± 2.2	7.1 ± 1.8	7.0 ± 1.9	<0.001*	11.106
Follow-up duration (months)	33.7 ± 16.0	35.4 ± 15.0	36.7 ± 13.8	33.4 ± 14.1	0.773*	0.373

*Comparison of means using one-way ANOVA test

**Comparison of frequencies using Chi-square test

***Comparison using 2 sided Fischer's exact test

Table 4 Comparison of various outcome parameters in patients with distal tibia fractures in four treatment groups using one way ANOVA and post hoc analysis

	IMN without fibula fixation (group 1) <i>n</i> = 35	IMN with fibula plating (group 2) <i>n</i> = 38	<i>p</i> -value Tukey's post hoc test	MIPO without fibula fixation (group 3) <i>n</i> = 32	MIPO with fibula plating (group 4) <i>n</i> = 37	<i>p</i> -value post hoc analysis	<i>p</i> -value	<i>F</i> -value one-way ANOVA
Intra-operative findings								
Duration of surgery (min)	78.5 ± 16.5	84.8 ± 17.8	0.462	89.4 ± 16.6	100.5 ± 21.8	0.066	< 0.001*	9.225
Fluoroscopy time (s)	69.2 ± 20.2	76.4 ± 21.9	0.549	93.8 ± 24.2	89.2 ± 26.3	0.846	< 0.001*	8.217
Immediate post-op malalignment (degrees)								
Coronal	2.7 ± 1.7	2.3 ± 1.8	0.629	3.1 ± 1.7	2.5 ± 1.7	0.416	0.206*	1.545
Sagittal	4.1 ± 1.8	3.3 ± 1.9	0.403	4.0 ± 2.7	3.7 ± 2.4	0.885	0.387*	1.017
Rotation	6.6 ± 2.4	3.8 ± 1.5	0.000	7.1 ± 2.8	3.7 ± 1.6	0.000	< 0.001*	25.066
Complications & reoperations								
Malunion	4 (11.4)	2 (5.3)	–	6 (18.8)	2 (5.4)	–	0.221***	–
Non-union	1 (2.9)	1 (2.6)	–	2 (6.2)	2 (5.4)	–	0.809***	–
Infection	2 (5.7)	3 (7.9)	–	2 (6.2)	4 (10.8)	–	0.883***	–
Total	7 (20.0)	6 (15.8)	–	10 (31.2)	8 (21.6)	–	0.467**	–
Dynamization	4 (11.4)	5 (13.2)	–	0 (0)	0 (0)	–	0.519**	–
Implant removal	1 (2.9)	3 (7.9)	–	5 (15.6)	6 (16.2)	–	0.184***	–
Total	6 (17.1)	9 (23.7)	–	7 (21.9)	9 [‡] (24.3)	–	0.882**	–
Functional outcome based on AOFAS score at 1 year follow-up [‡]								
	<i>n</i> = 34	<i>n</i> = 37		<i>n</i> = 30	<i>n</i> = 35			
Pain	33.3 ± 4.0	32.0 ± 3.5	0.371	32.4 ± 2.7	31.7 ± 3.1	0.838	0.216*	1.506
Function	42.4 ± 3.8	41.5 ± 3.5	0.692	40.1 ± 4.1	41.3 ± 3.5	0.593	0.126*	1.943
Alignment	6.9 ± 2.1	8.1 ± 1.5	0.024	7.2 ± 2.0	8.1 ± 1.6	0.227	0.009*	4.050
AOFAS score (total)	82.7 ± 6.6	81.6 ± 5.2	0.861	79.8 ± 5.9	81.1 ± 5.5	0.801	0.255*	1.371

*Comparison of means using one-way ANOVA test

**Comparison of frequencies using Chi-square test

***Comparison using 2 sided Fischer's exact test

[‡]Includes one patient with MIPO with fibula plating who needed wound debridement for infection[‡]The cases that developed non-union were not included in the final comparison of outcomes

rotational alignment was found to be better with fibula plating in the patients fixed with IMN as well as plating using MIPO.

There was no significant difference in the number of patients that developed complications as well as in the functional outcome at 1-year follow-up based on AOFAS score in the four treatment methods. However, alignment sub-score was significantly better in patient treated with IMN with fibula plating at 8.1 as compared to those treated with IMN without fibula fixation at 6.9 which was statistically significant. (*p* 0.009).

Discussion

Management of distal tibia fractures poses a challenge to orthopaedic surgeons. Distal tibia fractures are prone to complications such as non-union, infection, malunion as well as poor ankle function [1]. Distal tibia fractures have been managed conservatively as well surgically. Conservative management of these fractures has been associated with good functional outcome. However,

surgical management promises a more predictable outcome with rapid return to full function [2]. A large number of implants have been used for surgical management of closed extra-articular distal tibia fractures. This includes intramedullary nails, dynamic compression plates, pre-contoured locking plates. Plating may further be done as an open procedure or as a closed procedure using indirect reduction methods by MIPO technique. Previous literature suggests that the functional outcome of these treatment modalities is similar. No treatment method or implant has been proven to be superior to others [3–6, 8, 9, 16–19]

Management of concomitant fibula fracture remains another bone of contention. While some studies suggest that fixation of fibula may improve the outcome by improving the alignment of distal tibia fractures [13], others argue that fixation of fibula may increase the risk of non-union and delayed union in these fractures [20, 21].

The present study compares the outcome, complications and various other parameters in patients of closed displaced extraarticular fractures treated with intramedullary nailing to the patients with similar fractures treated with minimally invasive plating using pre-contoured locking plates. Further, the study analyses the role of fibula fixation in these patients.

The comparison of distal tibia fractures treated with plates using MIPO technique showed significantly higher time interval between injury and surgery as compared to those treated with nails at 7.1 days and 5.1 days, respectively. However, Polat et al. reported no difference in the interval between injury and operation [5]. This can be attributed to the tendency of surgeons, in this study, to delay plating in distal tibia fractures in order to reduce swelling and, thereby, prevent catastrophic complications like compartment syndrome and wound dehiscence.

The duration of surgery and radiation time were significantly higher with MIPO group (95.3 min and 91.3 s, respectively) as compared to IMN group (81.7 min and 72.9 s) in this study. The reason for this might have been the complicated techniques of indirect reduction in MIPO which require more time as well as increased use of a C-arm. The findings of the study by Guo et al. [6] are similar to this study. Li et al. [18] also reported increased duration of surgery with MIPO in their study as compared to IMN.

Implant removal was done as a secondary procedure in 15.9% cases of MIPO group as compared to mere 5.5% in IMN group. The prominence of percutaneous plates cause implant impingement. This impingement necessitates implant removal.

The results of this study show no statistical difference in the functional outcome in the patients that received intramedullary nails as treatment of distal tibia fractures as compared to those patients that were treated with MIPO. The mean AOFAS score at one-year follow-up for these patients was 82.1 and 80.5, respectively, as shown in Table 1. Various

comparative studies have reported similar functional outcome in these fractures treated by IMN and MIPO as shown in Table 5 [3–6, 18, 19, 22]. However, Guo et al. [6] in their study comparing the AOFAS score in 44 cases of IMN and 41 cases of MIPO have reported significantly better outcome with intramedullary nailing.

The use of either a nail or a pre-contoured locking plate for treatment of distal tibia fractures is associated with similar functional outcome at 1 year. Therefore, both these implants are equally effective in treatment of distal tibia fractures. The implant of choice, therefore, should be decided using other outcome parameters in this scenario. The present study shows that the patients treated using MIPO require increased surgical time, increased radiation time and are associated with an increased interval between timing of injury and surgery. Use of MIPO is also associated with increased hardware prominence, thereby, increased rate of implant removal. Although not significant, more patients in MIPO group also developed non-union and infection as compared to IMN group in the present study. Biomechanical studies have revealed that IMN is more forgiving than locking plate devices for axial loading [23, 24]. Thus, nailing allows early weight bearing by the patient. Therefore, nailing should be the treatment of choice for closed extraarticular distal tibia fractures.

The comparison of various parameters of distal tibia fractures revealed significantly longer duration of surgery in patients with fibula plating group as compared to conservatively managed fibula group (92.5 min vs 83.7 min) as shown in Table 2. This can be explained by additional time needed to fix the fibula fracture and suturing of the incision over fibula fracture at the end of the procedure. Taylor et al. found no significant difference in the duration of surgery in their study comparing 15 cases each of distal tibia fractures with and without fibula fixation. The average duration of surgery was, however, 21 min higher on an average in patients with fibula plating [25].

The fixation of concomitant fibula fracture at the same level helps in maintaining length, alignment as well rotation of the fracture of tibia. This assists in achieving acceptable reduction, thereby, reducing the use of C-arm in the surgery. This may explain why there was no difference (80.9 s in conservative fibula group vs 82.7 s in fibular plating group) in the radiation time of both these groups in this study.

The fixation of fibula, in this study, was associated with significantly better rotational alignment and subsequently, a significantly better alignment rotation AOFAS sub-score in the patients of distal tibia fractures. The results of sagittal and coronal alignment were similar with or without fibula fixation. Previous studies have also shown similar outcomes [25–27]. Egol et al. [13] in their study of distal tibia fractures fixed with intramedullary nails, have shown a comparatively lower rate of loss of reduction of tibia at one year

Table 5 Comparison of Outcomes and complications of distal tibia fractures in previous studies of similar design

Previous studies	Cases	Functional outcome	Significance (<i>p</i> value)	Complications (IMN/MIPO)
Guo et al. [6]	IMN-44 MIPO-41	AOFAS score-86.1 AOFAS score-83.9	< 0.05	Implant removal-37/38 Infection-3/6
Li et al. [18]	IMN-46 MIPO-46	Mazur Ankle score-0.87 Mazur Ankle score-0.90	> 0.05	Malunion-4/3 Non-union-1/1 Superficial infection-1/7 Deep infection-2/0 Reoperation-25/22
Polat et al. [5]	IMN-10 MIPO-15	Foot function index-25.7 Foot function index-22.7	0.790	Malunion-3/2 Non-union-0/0 Infection-0/1 Implant removal-0/1
Barcak et al. [19]	IMN-27 MIPO-37	AOFAS score-88.4 AOFAS score-86.6	0.24	Malunion-1/1 Non-union-2/3 Infection-1/0 Implant removal-7/3
Wani et al. [3]	IMN-30 MIPO-30	Foot function index-23.7 Foot function index-25.4	> 0.05	Malunion-5/3 Non-union-0/0 Infection-0/3 Secondary procedures-4/3
Mioc et al. [22]	IMN-27 MIPO-26	OMAS-75.5 (6 months) OMAS-74.23	> 0.1	Varus malunion-3/0 Recurvatum malunion-0/4 Infection-1/3 Non-union-4/1
Present study	IMN-73 MIPO-69	AOFAS score-82.1 AOFAS score-80.5	0.104	Malunion-6/8 Non-union-2/4 Infection-5/6 Dynamization-9/0 Implant removal-4/11 Wound debridement-0/1

follow-up when fibula was fixed (4% vs 13% when fibula was not fixed).

The functional outcome and complication rates were not statistically different in cases with or without fixation of fibula in the present study. Similarly, there was no difference in the non-union rate with or without fibula fixation. Although, the improved rotational alignment with fibula fixation may improve the reduction and, therefore, increase the chance of union, the fixation of fibula prevents cyclical loading of tibia which is necessary for fracture union. This may explain similar non-union rates in the present study with or without fixation of fibula [11, 12]. Similar to the present study, no change in complication rate was reported by many authors in previous studies with fixation of concomitant fibula fracture [25–27]. Berlusconi reported no change in non-union rate with fixation of fibula [20]. On the other hand, Williams et al. in their study of tibial plafond fractures have reported higher incidence of infection (23%) and non-union (9%) with fixation of fibula [14].

Absence of a fibula fracture is associated with an increased risk of non-union and delayed union as well as varus malunion of tibia fractures [11, 12]. This is explained by transmission of weight through the fibula instead of tibia which prevents cyclical loading of tibia necessary for

fracture healing. Absolute stability obtained with fixation of fibula fracture may create the same problem. However, open reduction and internal fixation fibula not only increases the risk of infection [14] but also increases the risk of non-union, theoretically, by disturbing the fracture biology for distal tibia fracture. This is exactly opposite to the principle of biological fixation that a surgeon intends to apply while using MIPO technique for the fixation of distal tibia fractures. Although not significant, the rate of infection (4 cases vs 7 cases), implant removal (6 cases vs 9 cases) were comparatively higher in this study with fibula fixation.

Therefore, fixation of fibula is not warranted routinely in distal tibia fractures. The fixation of fibula should therefore be reserved only for spiral oblique and severely comminuted fractures of distal tibia where the fixation of fibula may aid in maintaining rotation and length of the tibia.

There were a few limitations to this study. Firstly, the patients in conservatively managed fibula group and fibula fixation group had statistically dissimilar mean age. This may have affected the outcome parameters in these groups. Similarly, patients in IMN group and MIPO group differed in the interval between timing of injury and surgery. These differences in baseline characteristics may have affected the outcome of our study. Secondly, the small number of patients

in various groups that developed complications or required secondary procedure made it impossible to establish a significant relation between these complications and various treatment modalities. Randomized prospective multi-centric studies with larger sample size are needed to further validate the results of this study. Lastly, coin flipping method was used for randomization of cases into the four groups. First coin flip to determine the fixation of tibia—nail or plate, and a second flip to determine to determine the management of fibula—conservative or plating. This crude method of randomization was used due to the lack of feasibility in using other methods at the set up.

However, there were also a few positives to this study. Very few comparative studies of this magnitude with similar sample size and follow-up are available. Secondly, only the patients with closed fractures have been included in the study, thereby, minimizing the differences in outcome parameters such as non-union and infection in this study. Similarly, very few studies have strictly followed the protocol of fixation of concomitant fibula first in the treatment of distal tibia fractures. Finally, there was no use of poller screws, variable-angle locking nails and other such techniques in this study. The standardization of treatment method has resulted in standardization of results obtained.

Conclusion

Similar functional outcome and complication rates are obtained with use of IMN and MIPO for the treatment of distal tibia fractures. However, the use of intramedullary nailing is recommended for treatment of these fractures due to reduced duration of surgery, lower radiation exposure, decreased interval between injury and surgery along with biomechanical advantage that allows early mobilization as compared to the use of plates using MIPO technique. Fixation of fibula has no impact on the functional outcome of distal tibia fractures. However, it improves the rotational alignment. The fixation of fibula may, therefore, be reserved only for the management of specific patterns of distal tibia fractures.

Compliance with ethical standards

Conflict of interest Ankur Kariya, Pramod Jain, Kisan Patond and Anuj Mundra declared that they have no conflict of interest.

References

- Joveniaux P, Ohl X, Harisboure A, Berrichi A, Labatut L, Simon P et al (2010) Distal tibia fractures: management and complications of 101 cases. *Int Orthop* 34(4):583–588
- Hooper GJ, Keddell RG, Penny ID (1991) Conservative management or closed nailing for tibial shaft fractures. A randomised prospective trial. *J Bone Jt Surg Br* 73(1):83–5
- Wani IH, Ul Gani N, Yaseen M, Bashir A, Bhat MS, Farooq M (2017) Operative management of distal tibial extra-articular fractures—intramedullary nail versus minimally invasive percutaneous plate osteosynthesis. *Ortop Traumatol Rehabil* 19(6):537–541
- Natarajan G, Vijayaraghavan P, Srinivasan D (2014) Comparison of clinical, radiological, and functional outcome of closed fracture of distal third tibia treated with nailing and plate osteosynthesis. *Afr J Trauma* 3(2):68
- Polat A, Kose O, Canbora K, Yanik S, Guler F (2015) Intramedullary nailing versus minimally invasive plate osteosynthesis for distal extra-articular tibial fractures: a prospective randomized clinical trial. *J Orthop Sci* 20(4):695–701
- Guo JJ, Tang N, Yang HL, Tang TS (2010) A prospective, randomised trial comparing closed intramedullary nailing with percutaneous plating in the treatment of distal metaphyseal fractures of the tibia. *J Bone Jt Surg Ser B* 92(7):984–988
- Bong MR, Kummer FJ, Koval KJ, Egol KA (2007) Intramedullary nailing of the lower extremity: biomechanics and biology. *JAAOS J Am Acad Orthop Surg* 15(2):97–106
- Vallier HA, Le TT, Bedi A (2008) Radiographic and clinical comparisons of distal tibia shaft fractures (4 to 11 cm proximal to the plafond): plating versus intramedullary nailing. *J Orthop Trauma* 22(5):307–311
- Janssen KW, Biert J, Van Kampen A (2007) Treatment of distal tibial fractures: plate versus nail: a retrospective outcome analysis of matched pairs of patients. *Int Orthop* 31(5):709–714
- Cheng W, Li Y, Manyi W (2011) Comparison study of two surgical options for distal tibia fracture—minimally invasive plate osteosynthesis versus open reduction and internal fixation. *Int Orthop* 35(5):737–42
- Teitz CC, Carter DR, Frankel VH (1980) Problems associated with tibial fractures with intact fibulae. *J Bone Jt Surg Am* 62(5):770–776
- Sørensen KH (1969) Treatment of delayed union and non-union of the tibia by fibular resection. *Acta Orthop* 40(1):92–104
- Egol KA, Weisz R, Hiebert R, Tejwani NC, Koval KJ, Sanders RW (2006) Does fibular plating improve alignment after intramedullary nailing of distal metaphyseal tibia fractures? *J Orthop Trauma* 20(2):94–103
- Williams TM, Marsh JL, Nepola JV, DeCoster TA, Hurwitz SR, Bonar SB (1998) External fixation of tibial plafond fractures: Is routine plating of the fibula necessary? *J Orthop Trauma* 12(1):16–20
- Meinberg EG, Agel J, Roberts CS, Karam MD, Kellam JF (2018) Fracture and dislocation classification compendium—2018. *J Orthop Trauma* 32:S1–10
- Mao Z, Wang G, Zhang L, Zhang S, Du H et al (2015) Intramedullary nailing versus plating for distal tibia fractures without articular involvement: a meta-analysis. *J Orthop Surg Res [Internet]*. <https://doi.org/10.1186/s13018-015-0217-5>
- Lindvall E, Sanders R, Dipasquale T, Herscovici D, Haidukewych G, Sagi C (2009) Intramedullary nailing versus percutaneous locked plating of extra-articular proximal tibial fractures: comparison of 56 cases. *J Orthop Trauma* 23(7):485–492
- Li Y, Jiang X, Guo Q, Zhu L, Ye T, Chen A (2014) Treatment of distal tibial shaft fractures by three different surgical methods: a randomized, prospective study. *Int Orthop* 38(6):1261–1267
- Barcak E, Collinge CA (2016) Metaphyseal distal tibia fractures: a cohort, single-surgeon study comparing outcomes of patients treated with minimally invasive plating versus intramedullary nailing. *J Orthop Trauma* 30(5):e169–e174
- Berlusconi M, Busnelli L, Chiodini F, Portinaro N (2014) To fix or not to fix? The role of fibular fixation in distal shaft fractures of

- the leg. *Injury* [Internet] 45(2):408–411. <https://doi.org/10.1016/j.injury.2013.09.017>
21. Varsalona R, Liu GT (2006) Distal tibial metaphyseal fractures: the role of fibular fixation. *Strateg Trauma Limb Reconstr* 1(1):42–50
 22. Mioc ML, Prejbeanu R, Deleanu B, Anglitoiu B, Haragus H, Niculescu M (2018) Extra-articular distal tibia fractures—controversies regarding treatment options. A single-centre prospective comparative study. *Int Orthop* 42(4):915–9
 23. Kuhn S, Greenfield J, Arand C, Jarmolaew A, Appelman P, Mehler D et al (2015) Treatment of distal intraarticular tibial fractures: a biomechanical evaluation of intramedullary nailing versus angle-stable plate osteosynthesis. *Injury* 46:S99–S103
 24. Hoegel FW, Hoffmann S, Weninger P, Bühren V, Augat P (2012) Biomechanical comparison of locked plate osteosynthesis, reamed and unreamed nailing in conventional interlocking technique, and unreamed angle stable nailing in distal tibia fractures. *J Trauma Acute Care Surg* 73(4):933–938
 25. Taylor BC, Hartley BR, Formaini N, Bramwell TJ (2015) Necessity for fibular fixation associated with distal tibia fractures. *Injury* [Internet] 46(12):2438–42. <https://doi.org/10.1016/j.injury.2015.09.035>
 26. Rouhani A, Elmi A, Akbari Aghdam H, Panahi F, Dokht GY (2012) The role of fibular fixation in the treatment of tibia diaphysis distal third fractures. *Orthop Traumatol Surg Res* 98(8):868–872
 27. Prasad M, Yadav S, Sud A, Arora NC, Kumar N, Singh S (2013) Assessment of the role of fibular fixation in distal-third tibia-fibula fractures and its significance in decreasing malrotation and malalignment. *Injury* 44(12):1885–1891

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