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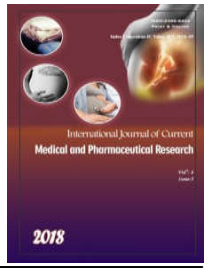

EXTRA-ARTICULAR PROXIMAL TIBIA FRACTURE: MINIMALLY INVASIVE PLATE OSTEOSYNTHESIS OR INTRAMEDULLARY NAILING - A COMPARATIVE STUDY

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ABSTRACT

Introduction: To compare the results of plating by Minimally Invasive Plate Osteosynthesis (MIPPO) technique and Interlocking intramedullary nailing (IMN) in various aspects in extra-articular fracture of the proximal tibia.

Methods: This prospective study included 68 patients with extra-articular proximal tibia fractures. They included Grade 1 and Grade 2 compound fractures and closed 41A2 and 41A3types fractures.34 were treated with IMN and 34 by MIPPO technique. They were followed up for one year and results were analyzed according to Knee Society Score, Lower Extremity Functional Scale (LEFS) and "Johner & Wruhs Criteria".

Results: The union rate after index procedure was 88.23% in MIPPO and 90% in IMN group. The mean time for the union in MIPPO group was 15.6 weeks and that for IMN group was 15.4 weeks. Postoperative mal-alignment in MIPPO was; Varus (2.94%), Apex Anterior (5.88%) and Apex Posterior (2.94%) and in IMN group: Varus(3.33%), Valgus(3.33%) and Apex Anterior (1%).In MIPPO there was 11.76% superficial infection as compared to 2.67% in IMN group. Implant irritation was 5.88% in MIPPO and Knee pain (6.67%) was common in IMN group. Malunion was 11.76% in MIPPO and 16.67% in IMN group. KSS in MIPPO was 81.70 and in IMN group was 84.30. The average LEFS was 65.16 for MIPPO and 67.05 for IMN group. The one year follow up Johner and Wruhs score was excellent to good in 82.36% in MIPPO and 90% in IMN group.

Conclusion: Both the treatment methods showed promising and adequate fracture stability in extra-articular proximal fracture provided care is taken to prevent infection, delayed union, nonunion and malunion.

INTRODUCTION

Extra-articular proximal tibia fractures constitute about 5-11% of all tibial fractures[1].They often result from high-energy trauma and are associated with significant comminution, soft tissue damage, compartment syndrome and vascular injuries. Closed management often leads to malunion, non-union, rotational deformity and stiffness of joints. Hence surgical management is necessary for better patient outcome.

The treatment protocols for these fractures includes dynamic compression plate (DCP), locking compression plate (LCP), interlocking intramedullary nailing (IMN) and external fixation (Ex-Fix). In compression testing of the four fixation methods, the highest degree of axial stiffness was found in the IMN group and lowest in the Ex-Fix group. In three-point bending test, DCP demonstrated the highest bending stiffness and Ex-Fix lowest. IMN often leads to mal-alignment deformities. LCP is stronger than DCP to fix the proximal tibial fractures with the additional benefit of being minimally invasive[1]. Earlier techniques emphasized precise anatomical reduction and absolute rigid fixation to achieve mechanical stability**.** However extensive surgical exposure and soft tissue stripping often resulted in devitalisation of fracture fragment and soft tissue complications. Minimally invasive plate osteosynthesis (MIPPO) in extra-articular proximal tibia fractures showed a promising result with minimal complications[2,3]. Improvements in surgical technique and implant design of IML have resulted in more acceptable outcomes with lesser commonly encountered apex anterior and/or valgus deformities. Using a variety of the reduction techniques such as an ideal starting point and insertion angle, polar screws, unicortical plates, a universal distractor, alternative positioning of patient and approaches minimizes

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these complications. An IMN can decrease the risk of infection because it uses a small incision that is not placed directly over the injured soft tissue, and it provides better axial load sharing than a plate. Final union rates for patients treated with either intramedullary nail or plate fixation are reported at 96% and 97%, respectively[3,4]**.** Neither IMN nor MIPPO showed a distinct advantage in the treatment of proximal extra-articular tibial fractures. Both provides a rigid fixation that prevents secondary fracture collapse. Apex anterior malreduction was the most common form of malreduction in either group. Various additional reduction techniques were used with IMN, whereas plate frequently needed removal. [5,6]

Theoretically, both plate and intramedullary nail have their own advantages and disadvantages. Therefore the optimal surgical option for fixation of extra-articular proximal tibia fractures is still controversial. This study was a prospective randomized trial comparing plate fixation by MIPPO technique and IMN for proximal extra-articular tibial fractures.

MATERIAL AND METHODS

The present study was from September 2014 to August 2016. A total number of 68 cases were randomly selected either for IMN (34) or MIPPO (34) technique. Patients were informed about their inclusions in the study and their written consents were duly obtained. Ethical clearance was obtained from the institutional ethics committee. Patients were treated alternatively either by IML or MIPPO irrespective of type of fracture or grading of compound fracture. Cases were classified according to AO classification. Patients were divided into two groups with inclusion criteria; age between 20-60 years, Grade I and Grade II compound fractures, 41A2 and 41A3 fractures, segmental fractures with at least one fracture line in the above-mentioned zone and with exclusion criteria; established compartment syndrome, intra-articular fractures, Grade III compound fractures, pathological fractures and fractures with distal neurovascular deficit. The affected limb was immobilized in above knee posterior splint till routine investigations were done. All the patients had a detailed pre-anaesthetic evaluation and informed written consent was obtained. The operative part was prepared overnight and a broad spectrum antibiotic was given half an hour before surgery to all patients.

Operative procedure

Patients were positioned supine on a radiolucent table.

Mippo technique: **Figure 1**

The reduction was achieved by manual traction after checking under image intensifier in both Anteroposterior (AP) and lateral view. A curvilinear incision of approximately 4-5 cms was given over the anterolateral surface of the proximal tibia. The incision was extended right up to the bone. Then a submuscular tunnel was created with a periosteal elevator and was extended across the fracture. The plate was inserted through the incision, held in position temporarily with K-wires. Proximal fragment fixation was done with a combination of locking and cancellous screws. Then the remaining screws were given in the distal fragment through small stab incisions.

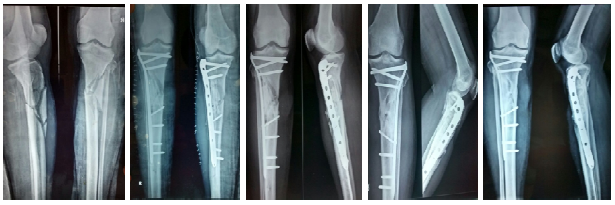

Figure 1 MIPPO X-ray: A, Pre-operative; B, immediate post -operative; C, 3 months post- operative; D, 6 months post -operative; E, one year post -operative.

Intramedullary interlocking nailing: **Figure 2**

Patellar tendon splitting approach was used in all of our cases. Under image intensifier in both AP and lateral views, the starting point was placed more laterally, in line with the lateral intercondylar eminence and the long axis of the tibia, and more proximally without damaging the articular structures. This places the Herzog's bend in the proximal fragment thus achieving a longer segment of the nail in proximal fragment. The medial side of the tibia deflects the nail laterally within the proximal segment and place the Herzog bend completely within the proximal segment. After manual reduction, a guide wire was made to pass and its alignment was checked in AP and lateral radiographs. Femoral distractor was used in some cases. Temporary low profile dynamic compression plate/recon plate on the anteromedial surface with unicorical screws were used in some of our cases to maintain reduction. Reaming was done with cannulated reamer. Blocking screws were used in some of our cases to align the proximal and distal fragment during reaming and nail insertion.(**Figure 3)** The nail was inserted over the guide wire. Care was taken to prevent rotational alignment and distraction at the fracture site. Both proximal & distal interlocking was done.

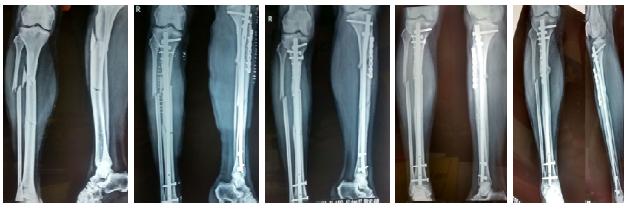

Figure 2 Intra Medullary Nailing X-ray: A, Pre-operative; B, immediate post -operative; C, 3 months post- operative; D, 6 months post - operative; E, one year post -operative.

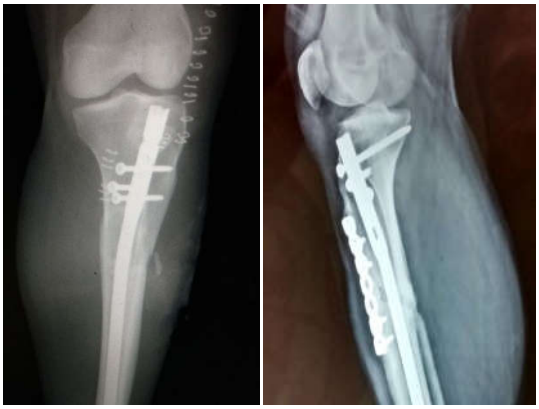

Figure 3 Additional procedures used A, Temporary plate; B, Polar screw.

Table 1

Sl.no					Number of cases n= 64 (%)
1	Age (year)		21-30		10(15.63)
			31-40		23 (35.93)
			41-50		20 (31.25)
			51-60		11 (17.19)
2	Sex		Male		55 (85.93)
			Female		9 (14.07)
3	Side involved		Right		36 (56.25)
			Left		28 (43.75)
4	Mode of injury		RTA		52 (81.25)
			Fall from height		8 (12.50)
			Assault		3(04.68)
			Sport injury		1 (1.57)
5	Type of fracture (AO classification)			41A2 n=26(40.61)	41A3 n= 38(59.39)
			MIPPO	11 (32.35)	22(67.65)
			IMN	16 (50)	15 (50)
6	Soft tissue injury (Gustilo-Anderson classification)		Closed n=41 (64.06%)	GI compound n=18(28.13%)	GII compound n=5(7.81%)
		MIPPO	24(37.50)	7(10.94)	1(1.56)
		IMN	17(26.56)	11(17.19)	4 (6.25)
7	Injury – Surgery interval			1-3 days	3 (8.82)
		MIPPO		4-7 days	25 (73.53)
				>7 days	6 (17.64)
				1-3 days	19 (30)
		IMN		4-7 days	9 (60)
				>7 days	3 (10)
8	Additional Procedures used	MIPPO		FD	4 (11.76)
		IMN		FD	7 (23.33)
				PS	5 (16.67)
				TP	2 (6.67)
9	Union rate	MIPPO		After index procedure	29(90.63)
				After additional procedure	32 (100)
		IMN		After index procedure	27(84.38%)
				After additional procedure	32 (100)

FD: Femoral distractor, PS: Polar screw, TP: Temporary plate

Postoperative Rehabilitation and Follow Up

Postoperatively, patients in both groups were given intravenous third-generation cephalosporin antibiotics for 5 days. Ankle pumps and isometric quadriceps strengthening exercises were started on the first postoperative day. Early mobilization of knee and range of motion [ROM] exercises were started as soon as the pain subsided and patients were allowed non-wait bearing walking (NWB) with help of walker/crutches from 2-4 days postoperatively. Stitches were removed on 10^{th}-12^{th} day and the patients were discharged with instruction to continue knee ROM exercises and NWB walking. First follow-up was done after 4 weeks interval thereafter till radiological union. Data was collected by verbal communication, clinical examination, and radiographic findings. Partial weight bearing (PWB) was allowed after 4-6 weeks and full weight bearing (FWB) was allowed when x-ray showed signs of union (Radiological union was defined as bridging callus in 3 out of 4 cortices) & clinically when there was absence of tenderness and movement at the fracture site. Acceptable alignment was defined as less than 5° anterior/posterior angulation, less than 5° varus/valgus deformity or less than 10° rotation difference, distraction/shortening at fracture site less than 1.5 cm. The measurement technique was according to Freedman and Johnson[6]**.** By the end of 12 weeks if there were no signs of callus formation in intramedullary nailing then dynamization was done and the patient was advised FWB and was followed up every 4 weeks till union. By end of 24 weeks if no adequate consolidation was seen at fracture site it was defined as nonunion and autologous cancellous bone grafting were done.

Stastical Analysis

MIPPO and IML data: Statistics were subjected to two –tailed 't -test', for each of variants, radiological union, KSS, LEFS and Oparation time, independently. The Z –value generated were used for comparison using the statistical Package for Medical Science version 17.0 (SPSS Inc., IL, USA).

RESULTS

In our study out of 68 cases, the average age of the patients was 38.6 years (20-60 yrs). Two cases from IMN group and one case from DHS group lost to follow-up. One case from DHS group died due to cardiac reason. So we analyzed total 64 cases. There were 55(85.93%) males and 9(14.07%) females. The right side was involved in 36(56.25) cases and left side in 28(43.75) cases. 52 (81.25%) cases were due to road traffic accident, 8 (12.50%) were due to fall from height, 3(04.68%) cases were due to assult and1 (1.57%) case was due to sports injury. We had 41(64.06%) cases of closed, 18 cases of grade-I compound (28.13%) and 5 cases of grade-II compound (7.81%) fractures (Gustilo-Anderson classification). We used the AO (OTA) classification to classify & treat our fractures.(Table 1) Out of 41 closed fractures 24 cases were

treated by MIPPO and 17 cases by IML.7 cases of G-I fracture was treated by MIPPO and 11 cases with IMN. Similarly 1 case of G-II was treated by MIPPO and 4 cases by IMN. Average injury to surgery interval was 2 to 7 days.(Table 1)

Union Rate

After index procedure union was achieved in29 (90.63%) cases in MIPPO group and 27(84.38%) cases in IMN group and after the additional procedure the union was 100% in both groups.(Table 1)

Radiological Union Time

Out of 64 cases, most of the fractures united radiologically between 12-15 weeks. In MIPPO group 20(62.50)% and in IMN group 18(70%) of the fractures united radiologically between 12-15 weeks. 6(18.74%) of MIPPO group and 11(34.38%) of IMN group achieved radiological union by 16-20 weeks. The mean time for the union in MIPPO group was 15.8 weeks and that for IMN was 15.2 weeks. (Table 2) Two tailed *p*- value was 0.1676 which was statistically significant.

Table 2 Radiological union time

Sl. no	Wks	MIPPO(n=32)	%	IMN(n=32)	%
1	12-15	20	62.50	18	56.25
2	16-20	6	18.74	11	34.38
3	21-24	3	9.38	2	6.25
4	>24	3	9.38	1	3.12

Post Operative Alignment

In our study postoperative alignment in both groups were recorded as shown in Table 3.

Table 3 Post-operative alignment

Sl. no	Alignment	MIPPO (n=32)		IMN(n=32)	
		No of cases	%age	No of cases	%age
1	Acceptable reduction	28	87.52	26	81.26
2	Varus	1	3.12	1	3.12
3	Valgus	0	0	2	6.25
4	Apex anterior	2	6.24	3	9.38
5	Apex posterior	1	3.12	0	0
6	Rotational malalignment	0	0	0	0
7	Total malreduction	4	12.50	6	18.75

Complications

We had 4(12.50%)cases of superficial infection, 1(3.12%)case of deep infection, 2(6.25%)cases of non-union, 2(6.25%)cases of implant irritation and 1(3.12%)case of peroneal nerve neuropraxia post-operatively in MIPPO group which recovered with time. In IMN group, we had 2(6.25%) cases of superficial infections, no deep infection, 1(3.12%) case of non-union, 1(3.12%) case of delayed union and 2(6.25%) patients had anterior knee pain. We did not had any post-operative fixation failures. (Table 4)

Table 4 Complications

Sl no	Type of complication		MIPPO (n=32)		IMN (n=32)	
			No	%age	No	%age
1	Infection	Superficial	4	12.50%	2	6.25%
		Deep	1	3.12%	0	0
2	Implant failure		0	0	0	0
3	Post op compartment syndrome		0	0	0	0
4	Common peroneal nerve palsy		1	3.12%	0	0
5	Implant irritation		2	6.25%	0	0
6	Anterior knee pain		0	0	2	6.25%
7	Non-union/Delayed union		2	6.25%	2	6.25%
8	Malreduction		4	12.50%	6	18.75%

Table 5 Lower Extremity Functional Scale (LEFS)

LEFS score	MIPPO(n-32)		IMN(n-32)	
	No	%age	No	%age
71-80	23	71.86%	25	78.13%
61-70	5	15.64%	5	15.63%
51-60	2	6.25%	1	3.12%
<50	2	6.25%	1	3.12%

Table 6 Final outcome according to "Johner & Wruhs' Criteria".

Outcome	MIPPO(n-32)		IMN(n-32)	
	No.	%age	No.	%age
Excellent	21	65.63	22	66.67
Good	9	23.53	8	23.33
Fair	1	11.76	1	6.67
Poor	1	5.88	1	3.33

Functional Outcome

In our study knee function score was excellent in 47.8%, good in 29.5%, fair in 15.9% and poor in 6.8%. Two tailed *p*- value was 0.8196 which was statistically significant. Mean score in MIPPO group was 81.71 and that in IMN group were 84.30. The average LEFS score at final follow-up was 65.16 for MIPPO group and 67.05 for IMN group (Table 5). Two tailed *p*- value was 0.6774 which was statistically significant. The final results at the end of 1-year follow-up were evaluated using the "Johner & Wruhs' Criteria" (Table 6).

DISCUSSION

Comparative studies between IMN and MIPPO for extra-articular proximal tibial fractures are very limited. In our study, the average age of patients was between 38.6 years as compared to Sean Nork *et al*[9]: 42 years, Peter A. Cole series[10]: 45 years, Eric Lindvall *et al*[5]:39.6 years, which showed a higher incidence in physically active patients. Out of 64 patients, there were 55 males and 9 females, (Male: Female - 6.1:1). This finding was similar to Sean Nork *et al*[9] (M: F=3:1) and in Eric Lindvall[5] (M: F=3.6:1), showing male predominance as they are exposed to outdoor activities. Most common cause of fractures in our series was high-velocity trauma due to road traffic accident (81.25%) which was in concordance with Eric Lindvall *et al*[5] (82%) and Sean Nork *et al*[9] (89%). Out of 64 cases, 26(40.61%) fractures were 41A2 and 38(59.39%) were 41A3 type as compared to Eric Lindvall *et al*[5] (16%: 41A2 and 84%: 41A3) and Nork *et al*[9] (14%: 41A2, 19%: 41A3, 67%: 42**).** We had 23(35.94%) compound fractures in comparison to Eric Lindvall[5]: 42.8% and Nork *et al*[9]: 35.5%, of which 15(65.22%) made up of IMN group and 8(34.78%) of MIPPO group as compared to Eric Lindvall *et al*.[5] 65% of IMN group and 35% of MIPPO group. Out of 64 patients, MIPPO was performed in 32 cases and IMN was done in 32 cases; Lindvall *et al*[5] series 34 were treated with MIPPO and 22 by IMN indicating a bias towards IMN in open fractures by the treating surgeon, as plating is known to have a higher incidence of infection in compound fractures. Fourteen cases (43.75%) in IMN group required one additional procedure and 4(12.50%) in MIPPO group as compared to Lindvall *et al*[5], 59% in IMN group and 11.7% in MIPPO group. Ricci *et al*[11] used blocking screws in 11 of their IMN cases. We had 4(12.50%) malreduction in MIPPO group and 6(18.75%) in IMN group. In both groups, apex anterior angulation was the most common deformity which was more in IMN group [MIPPO: IMN=2:3(6.24%:9.38%)]. Varus malreduction was almost equal incidence in both groups; (MIPPO: IMN=1:1(3.12%:3.12%)]. Valgus malreduction was

found in 1case (3.12%) in IMN group. Apex posterior malreduction was found in 1case (3.12%) in MIPPO group.In IMN group we had 6(18.75%)[3(9.38%) apex anterior; 1(3.12%) varus; 2(6.24%) valgus] malreduction > 5 degree. Lang *et al*[19] reported 84% (50% apex anterior; 14% valgus), Freedman and Johnson *et al*[6] reported 58% (42% apex anterior; 16% valgus), Buehler *et al*[12] and Ricci *et al*[18] reported 9%, Lindvall *et al*[5] reported 40% and Bhandari *et al*[15] reported of 20 %(range 1.5% - 26%) of significant mal-reduction of >5 degrees in their studies on IMN. In MIPPO series we had malreduction of >5 degrees in 4(12.50%) cases [2(6.24) apex anterior, 1(3.12%) apex posterior, 1(3.12%) varus]. Lindvall *et al*[5] reported 20.58% (5 apex anterior, 1 varus and 2 apex posterior), Peter A. Cole *et al*[10] reported 10.38% and Stannard *et al*[22] series reported 11.4% malreduction. Nork *et al*[9], Ricci *et al*[18], Buehler *et al*[12] have documented similar malreduction rates in both IMN and MIPPO group which was in concordance with our study.

Loss of initial reduction with IMN is reported as 0% in multiple studies. The data for MIPPO, however, is less clear as multiple studies have grouped both intra-articular and extra-articular fractures together. Cole *et al*[10] reported 2.6% loss of initial reduction. Boldin *et al*[13] reported 4% loss of reduction. We did not have any case of post-operative fixation failures, neither in MIPPO nor in IMN group.

Infection

In MIPPO group we had 4(12.50%) cases of superficial infection and 1(3.12%) had a deep infection requiring plate removal. Stannard *et al*[22] reported 6.67% cases of superficial infection and no deep infection and Cole *et al*[10] reported 1.29% cases of superficial infections and 2.59% of deep infection. In Phinit Phisitkul *et al*[14] had 22% deep infections and five of them had hardware removal; 1 eventually required an above-knee amputation. Lindvall *et al*[5] had 24% infection.

In IMN group we had 2(6.25%) superficial infections and no cases of deep wound infection. Ricci *et al*[18] reported 10% infection rate, Nork *et al*[9] reported 6% of deep wound infection and Lindvall *et al*[5] reported 27% of superficial infection and 9% of deep wound infection. Bhandari *et al*[15] reported that there was weak evidence to suggest a decrease in infections with IMN. However, his analysis did not include MIPPO technique.

Weight Bearing Time

No literature accurately identify an accepted time frame until full weight bearing (FWB) with either method. In various studies of these fractures treated with IMN, FWB has ranged from 0-16 weeks depending on the fracture location, fracture configuration, grade of the compound fracture and surgeon's preference. Similarly, in these fractures treated with MIPPO, FWB has ranged from 6–13weeks for the same reasons.[10] Studies often stated ‘‘weight bearing allowed as soon as the pain subsided or tolerated” which does not accurately define when FWB actually started and therefore cannot be relied upon to determine which technique allows earlier FWB.

Union/ Non-union

We had 2 cases (6.25%) non-union in MIPPO group as compared to Cole *et al*[10] reported 3%, Schutz *et al*[17] had 5% non-union, Ricci *et al*[18] had nil non-union and Eric Lindvall *et al*[5] reported 6% non-union. In IMN group we had 2(6.25%) cases of non-union as compared to Lang *et al*[19] 6.25% of non-union, Bleuler *et al*[12] had 7.14% of non-union in their IMN series. Bhandari *et al*[15] found the average incidence of non-union of 1.3% for plates and 3.5% for nailing groups.

Radiological Union Time

The mean union time in MIPPO group was 15.6weeks and that for IMN was 15.4 weeks. In Stannard *et al*[22] series the average time to radiological union was 15.6 weeks and OH-Jong *et al*[20] series it was 16.5 weeks.

Other Complications

2(6.25%) patients in IMN group had anterior knee pain. Implant irritation was observed in 2(6.25%) patients and 1(2.94%) patient had peroneal nerve neuropraxia in MIPPO group. Hardware irritation in different study series – Ricci *et al*[18] 5%, Cole *et al*.[10]-5%, Stannard *et al*.[22] – 18%, Boldin *et al*[13] -8%, Phinit Phisitkul *et al*[14] – 12%. Peroneal nerve neuropraxia as shown in various studies – Cole *et al*[10]-1%, Phinit Phisitkul *et al*[14]-3%.

Krettek *et al*[16] reported 1 case of post-operative compartment syndrome. Eric Lindvall *et al*.[5] reported one case of intraoperative fracture propagation during nailing. We didn't have any compartment syndrome or fracture propagation in our series.

Functional Assessment

The “KNEE SOCIETY SCORING SYSTEM” by John N. Insall *et al*.[7] was excellent in 47.8%, good in 29.5%, fair in 15.9% and poor in 6.8% of cases. Mean score in MIPPO group was 81.71 and in IMN group was 84.30. The average LEFS score by Binkley JM *et al*[8] at final follow-up was 65.16 for MIPPO group and 67.05 for IMN group. The “Johner & Wruhs’ Criteria”[21] in MIPPO group were 23(71.86%) excellent, 5(15.64%) good, 2 (6.25%) fair and 2(6.25%) poor results as compared to 25(78.13%) excellent, 5(15.63%) good, 1 fair (3.12%) and 1(3.12%) poor in IMN group. Weiner LS *et al*[23] reported 34% excellent, 48% good, 12% fair and 6% poor results and James J. Hutson [24] reported 85% excellent or good results.

CONCLUSION

Extra-articular fractures of proximal tibia are not so common. Most of these fractures are the result of high-energy trauma, often associated with soft tissue and vascular complications. Careful assessment of these fractures is necessary to reduce the post-operative complications. The optimal management of these fractures continues to be a topic of controversy till date. Both IMN and MIPPO provide adequate fracture stability. The decision on post-operative weight bearing should be done on an individual basis taking into account both clinical and radiological parameters. Intramedullary nailing is a safe and effective technique for the treatment of these fractures, especially in compound ones. Alignment can be maintained despite the short segment of the proximal tibia. MIPPO is relatively easy technique and does not need the use of additional expensive instrumentation. It improves the fracture union rate with reduced rates of infection than conventional plating. Closed fractures progress to predictable healing regardless of the surgical procedure employed. Utmost care should be taken to prevent infection, delayed union, non-union and malunion and if occurs should be treated accordingly. If principles of treatment are correctly followed, most of the

cases will have a good final outcome with either modality of treatment for extra-articular proximal tibia fractures.

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