# Outcome of Minimaly Invasive Plate Osteosynthesis (MIPO) Technique with Locking Compression Plate in Distal Tibial Fracture Management

**Atin Kumar Kundu[1,*], Satyendra Phuljhele[2], Mantu Jain[3], Kamal Kishore Sahare[4]**

[1]Assistant Professor, [2]Professor, Dept. of Orthopaedics, Pt. JLN Medical College, Raipur
[3]Consultant, TRI Hospital, Orissa
[4]Professor, Dept. of Anaesthesia, Pt. JLN Medical College, Raipur

***Corresponding Author:**
Email: atin.bestdoc@gmail.com

## ABSTRACT

**Background**: *Distal tibial fractures including tibial pilon present a challenge as to their best method of management due to subcutaneous location of larger portion of tibia, paucity of soft tissue coverage and precarious blood supply of distal leg. MIPO (Minimal invasive plating osteosynthesis) has evolved as a newer concept to treat distal tibial fractures with minimal articular comminution and minimal soft tissue damage. It works on Biological fixation principle which assists physiological process of bone healing wisely with minimal operative intervention.*

**Method**: *A prospective study for the management of distal tibial fractures by MIPO technique by using pre-contoured metaphyseal LCP (locking compression plate) was done, in 20 patients, between January 2012 and October 2013. Fractures were classified as per AO system and patients were followed and scored according to TEENY and WISS clinical scoring criteria.*

**Result**: *Among 20 patients operated, there were 15 males and 5 females with a mean age of 38.95yrs (range from20-67yrs). 17 patients sustained extra-articular fractures (type A), 02 partial-articular fractures (type-B) and 01 total-articular fracture (type-C). High energy trauma (road traffic accident) predominated causing 13 fractures. Average trauma surgery interval was 12 days (02-22days). Patients were followed minimum for 6 months (range 06-18 months). Superficial wound infections were seen in 02 cases, surgical wound breakdown with implant exposure in 01 case and prominent hardware in 01 case. 17 patients (85%) had excellent/good outcome and 03 cases with complications had fair (02 cases) to poor (01 case) outcome.*

**Conclusion**: *MIPO is an effective and safe technique for the management of distal tibial fractures without intra-articular comminution and minimum soft tissue damage. It preserves bone biology by maintaining balance between devascularisation and mechanical perfection. Further studies with longer follow-up and large sample size are warranted.*

**Key Words**: *Distal tibia, MIPO technique, Locking Compression Plates (LCP), Tibial pilon*

| Access this article online | |
|---|---|
| **Quick Response Code**: | **Website:** www.innovativepublication.com |
| | **DOI:** 10.5958/2395-1362.2015.00015.8 |

## INTRODUCTION

The fractures of distal tibia including tibial pilon pose great challenge to the surgeon due to subcutaneous location, scarcity of blood supply and paucity of soft tissue coverage. The involvement of the ankle joint and the vulnerability of the surrounding soft tissues further complicate these already complex injuries. Numerous classifications have been proposed for these fractures; however AO-OTA alphanumeric classification is the most comprehensive and commonly quoted classification. Ruedi and Allgower popularized open reduction and internal fixation for these fractures. However, their impressive results were not paralleled by other authors and subsequent reports showed significant number of major complications which are mainly attributed to damage of soft tissues. This led to change in the philosophy of treating such injuries. Currently, two methods are gaining popularity. One method is wire fixators, which is useful in highly comminuted fractures with significant soft tissue damage. Other is MIPO technique (Minimal invasive plating osteosynthesis) when there is minimal articular comminution and the soft tissue envelop is minimally damaged. It works on Biological Fixation Principle, in which blood supply to the fracture fragments is maximally preserved and percutaneously inserted plate is placed epiperiosteally and fixed at a distance proximal and distal to the fracture site through minimal exposure. Principles of Biological Fixation in MIPO are as follows-

1. Repositioning and realigning by manipulation at a distance to the fracture site, preserving soft tissues (indirect reduction technique).
2. Leaving comminuted fragments out of the mechanical construct, while preserving their blood supply.
3. Using low elastic modulus, biocompatible material.
4. Limited operative exposure.

## MATERIAL AND METHOD

This study was conducted in Department of Orthopaedic, Pt. JNM Medical College and associated Dr. B.R. Ambedkar Memorial Hospital, Raipur (CG) during the period January 2012- October 2013. Total 20 patients of distal tibial fracture were managed and evaluated during the study period. The objective was to evaluate functional and clinical outcome of MIPO technique in distal tibial fractures, in patients of age group 20 years and above. Fractures were classified as per AO Classification and Type A, Type B and Type $C_1$ were included in the study (Fig.1).

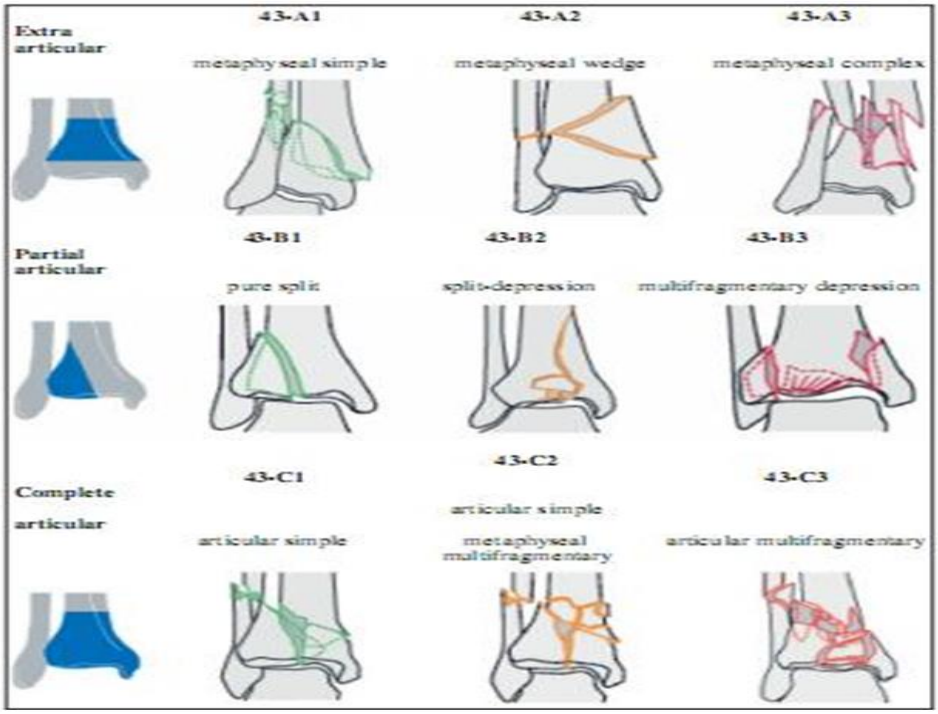



**Fig. 1: AO/OTA Classification of Distal Tibial fracture. Three types i.e. extra-articular, partial articular, and complete articular and nine groups based on the amount of comminution**

Patients with open fractures except grade I, severely crushed and contaminated, those associated with major head injuries and injuries presented AO-OTA types $C_2$, $C_3$ were excluded from the study. The associated injury, routine pre-anesthetic investigation, standard anteroposterior and lateral radiographs of the ankle joint which included the tibia were recorded (Fig. 2). The patients with closed fracture were treated by anti-edema drug for 5-7 days until the skin was wrinkled. Preoperative antibiotics (first- generation cephalosporin) were administered 30 minutes before the operation.

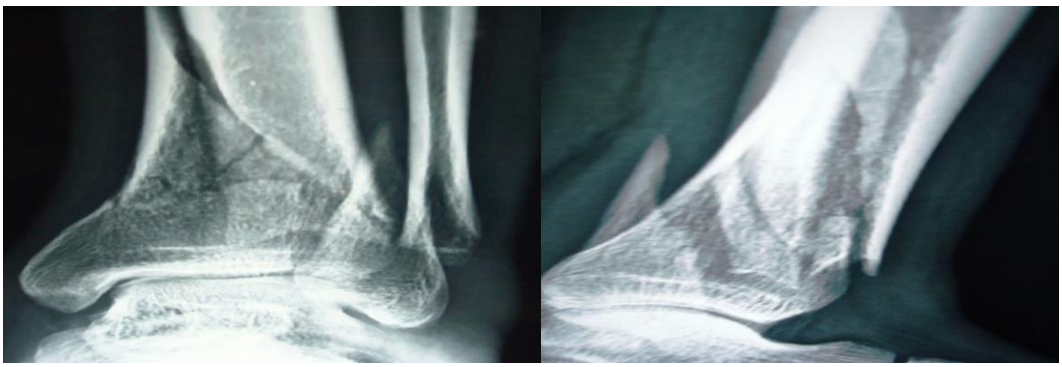


**Fig. 2: Anteroposterior and lateral view of distal tibial fracture**

## SURGICAL TECHNIQUE (Fig. 3)

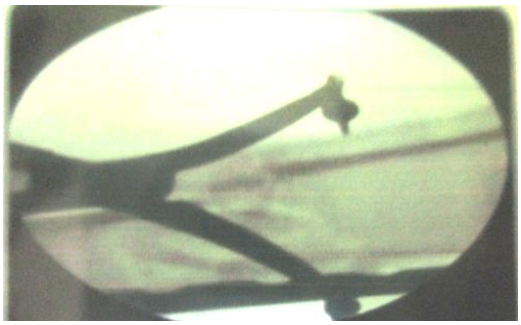
A vertical or curvilinear incision was made at the level of medial malleolus with utmost care not to injure saphenous vein and nerve. Subcutaneous plane was made with hemostat without striping periosteum and disturbance to fracture haemotoma. Fracture was reduced under C-arm, sometimes 3mm K-wire is used as joystick to aid in

fracture reduction and towel-clip or reduction clamp to hold reduction. Pre-contoured low metaphyseal plate LCP was tunneled into subcutaneous plane and its position was confirmed under fluoroscopy.

**(a)Incision at medial malleolus**

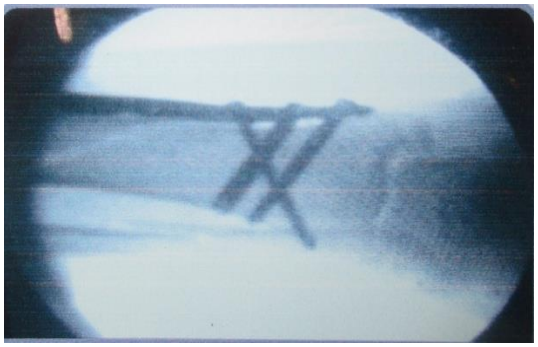
**(b) Sliding of the plate**

**(c) Indirect reduction technique**

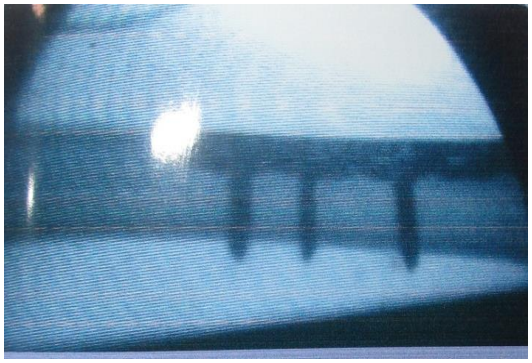


**(d) reduction checked under fluoroscopy**

**(e) Plate stabilized with K wire**



**(f) Distal cancellous screws**



**(g) Proximal cortical screws**

**(h) closure of the wound**

**Fig. 3: Showing steps of surgery in MIPO technique**

Biomechanically locking plates can be described as single beam construct, fixed angle device acting as internal fixator. Single beam construct means when there is no motion in between components of beam i.e. screw, plate and bone. Single beam construct is four times stronger than load shearing beam construct where motion occurs between individual components of the beam.

Fixed angle device implies that as locking plate convert shearing stress to compressive stress at screw-bone interface there is improve in fixation since the bone has much higher resistance to compressive stress than shearing stress. As screws are locked to the plate, the strength of fixation in locking plate equals the sum of all screw-bone interfaces rather than the single screw's axial stiffness or pull-out resistance as seen in unlocked plate.

Locking plates acts as internal fixator in which locking screws can be imagined as Schanz pin and locking plate as connecting tubular rod. This internal fixator is more rigid than external fixator as it is placed nearer to the bone. This optimizes strain at the fracture site, resulting into callus formation. As stability of this internal fixator does not depend upon frictional forces between plate and bone, periosteal perfusion does not get hampered. Theoretically, this result into rapid healing decreased bone necrosis and infection. Stress shielding is also avoided which decreases the chances of refracture after implant removal. Currently, used LCP has Combi holes (Fig 4) which allows placement of both locking and non-locking screws but lag screw is to be placed before locking screws.

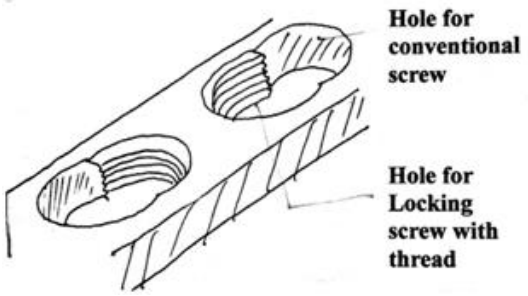



**Fig. 4: Locking plate showing combiholes**

**POST–OPERATIVE**

Depending upon the fracture configuration and stability of reduction achieved, the mobilization was modified. In most cases the protocol followed was; Static quadriceps- day1, gradual active knee and ankle mobilization –day3, crutch supported toe-touch ambulation-day7, partial weight bearing from 6$^{th}$ week and full weight bearing was allowed 12$^{th}$ week onwards. The patient was scheduled for follow-ups every 4 weeks until the fracture united. Wound condition and range of motion of ankle were evaluated and a radiograph of distal tibia was taken. Fracture healing was defined as radiological evidence of bridging mature callus in at least three cortices as seen in both anteroposterior and lateral radiographs (Fig.5).

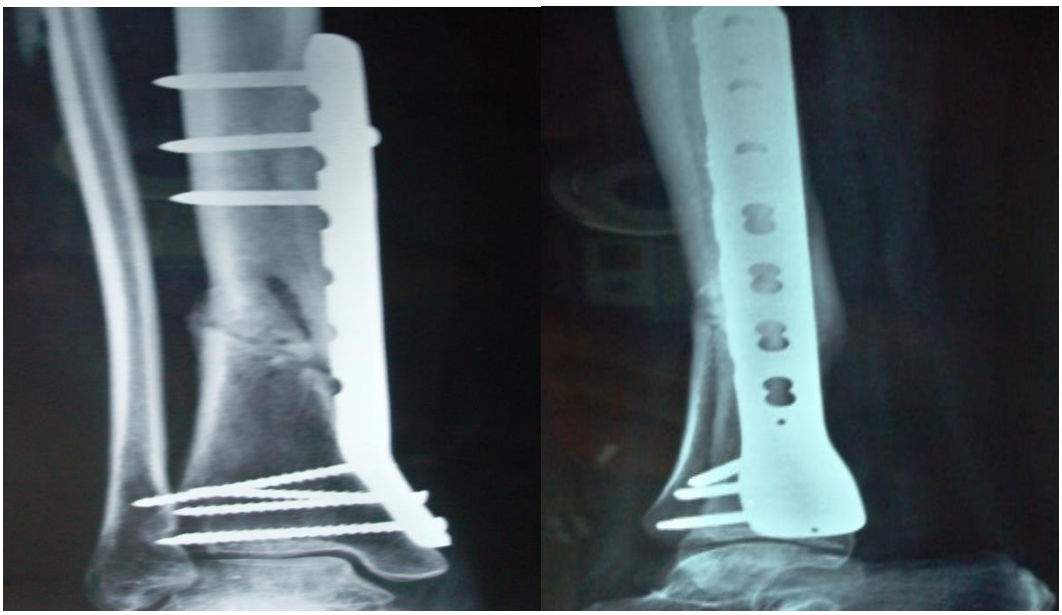


**Fig. 5**: **Three month follow-up Anteroposterior and lateral Xrays showing callus formation**

The functional outcome was evaluated with the clinical rating system for the ankle by Teeny and Wiss criteria at every 6 months follow-up (Table 1) and graded as Excellent (>92 points), good (87-92points), fair (65-86 points) and poor (<65 points).

**Table 1: Teeny and Wiss criteria (symptoms and functional evaluation of ankle)**

| Parameters | Points |
|---|---|
| 1. Pain | |
| a) No pain, including long walks, running or sports. | 50 |
| b) Slight or occasional pain, pain after long walk or sports, or mild pain at end of day. | 45 |
| c) Mild pain with walking or running, but no change in activities of daily living. | 40 |
| May have some pain going up or down stairs or walking on uneven ground. | |
| May require non-narcotic pain medicine several times a week. | |
| d) Mild-moderate pain, tolerable, but requires some concessions to pain. May required daily non-narcotic pain medicine? No night pain. | 30 |
| e) Moderate pain. Definite change in activities of daily living, pain at rest or at night, despite restriction of activities. Occasional weak narcotic needed. | 20 |
| f) Continuous pain, regardless of activities, most often not relieved with non- narcotic medication. Dependent on narcotic pain medicine for significant pain relief. Severe limitations of activities. | 10 |
| g) Disabled because of pain. Constant pain, no relief with medicines. | 0 |
| 2. Distance | |
| a) Unlimited | 8 |
| b) Limited, but greater than 6 blocks | 6 |
| c) 4-6 blocks | 4 |
| d) 1-3 blocks | 2 |
| e) Indoors only | 1 |
| f) Bed-chair, or unable to walk | 0 |
| 3. Supports or Orthosis | |
| a) None | 8 |
| b) Soft wrap needed for long walk | 7 |
| c) Cane or orthosis, only for long walks | 6 |
| d) Cane, single crutch or orthosis full time | 4 |
| e) Two canes or two crutches | 2 |
| f) Walker or unable to walk | 0 |
| 4. Running | |
| a) Unlimited, as such as desired | 5 |
| b) Limited, but able to run | 3 |
| c) Unable to run | 0 |
| 5. Toe raising | |
| a) Able to raise on toes x 10 repetitions | 5 |
| b) Able to raise on toes x 5 repetitions | 3 |
| c) Able to raise on toes x 1 repetitions | 1 |
| d) Unable to raise on toes | 0 |
| 6. Hills (up or down) | |
| a) Up and down normally | 3 |
| b) Climbs and /or descends with foot externally rotated | 2 |
| c) Climbs and/or descends on toes or by side stepping | 1 |
| d) Unable to climb and/or descend hills | 0 |
| 7. Stairs (up or down) | |
| a) Climbs and descends normally | 3 |
| b) Needs banister | 2 |
| c) Steps down and/or up with normal foot only | 1 |
| 8. Limp | |
| a) None | 8 |
| b) Only when fatigued | 6 |
| c) Slight, constant | 4 |
| d) Moderate, constant | 2 |
| e) Marked | 0 |
| 9. Swelling | |
| a) None | 3 |
| b) Only in the evening or after walking | 2 |
| c) Constant, mild (less than 1 cm difference around calf) | 1 |
| d) Marked | 0 |
| 10. Plantar range of motion | |
| a) Greater than 30° | 2 |

| | |
|---|---|
| b) Greater than 10° | 1 |
| c) Less than 10°, or presence of equines contracture | 0 |
| 11. Dorsal range of motion | |
| a) Greater than or equal to 15° | 5 |
| b) Greater than or equal to 10°, less than 15° | 4 |
| c) Greater than or equal to 0°, less than 10° | 3 |

## RESULTS

There were 20 patients of distal tibial fracture operated with MIPO technique among which 15 were males and 5 females with a mean age of 38.95years (range of 20-67 yrs). As per AO classification, 17 patients sustained extra-articular fractures (type A) and 03 intra-articular fractures (type B-02, type C-01). High energy trauma predominated in this study, causing 13 fractures. Average trauma surgery interval in this study was 12 days (02-22days). Complications like superficial wound infection was seen in 02 cases, surgical wound breakdown with implant exposed in 01 case which healed with antibiotic and daily dressing and prominent hardware was seen in 01 case which was asymptomatic. According to the Teeny and Wiss criteria 17 patients (85%) had excellent/good outcome and three cases with complications had fair outcome in 02 cases and poor in 01 case (Table 2).

**Table 2: Results in different types of Fracture**

| Results | Type A | Type B | Type C | Total |
|---|---|---|---|---|
| **Excellent** | 13 | 02 | 00 | 15 |
| **Good** | 01 | 00 | 01 | 02 |
| **Fair** | 02 | 00 | 00 | 02 |
| **Poor** | 01 | 00 | 00 | 00 |

## DISCUSSION

Distal tibia fracture with or without intra articular extension is one of the difficult fractures to manage. None of the treatment options available perfectly fulfill requirements of fracture characteristics of distal tibia. The goals of treatment of a distal tibia fracture are anatomical articular reduction, restoration of axial alignment, maintenance of joint stability, achievement of fracture union, pain free weight baring and motion, without any wound complications.

The treatment plan in distal tibia fracture depends on fracture pattern, soft tissue injury, patient co-morbidity, fixation resources, and surgical experience. Distal tibia has got circular cross sectional area with thinner cortex as compare to triangular diaphysis with thicker cortex. So intra-medullary nail which is designed for tight interference fit at diaphysis cannot provide same stability at distal fracture. Other potential complications of IMIL nailing are malunion (0-29%) and implant failure (5-39%). ORIF with conventional plate which needs striping of periosteum is also not an ideal treatment option because tibia is subcutaneous bone and periosteum provides 2/3rd of blood supply. Non-union, delayed union and infection are reported with the range of 8.3-35% and 8.3-25%respectively with ORIF plating.

The disadvantage of MIPO is more radiation exposure to the operating team compared with ORIF as it uses indirect reduction under fluoroscopy. However, the advantage of MIPO is soft tissue preservation under treatment with skillful surgeons and may lower the risk of radiation exposure and avoid unfavorable results. Similarly external fixators as a definitive method of treatment for distal tibia fracture are also reported with higher rate of infection, implant failure and malunion or non-union and hence recommended only for temporary method of stabilization in open fracture with severe soft tissue injury.

With the development of technique of MIPO with LCP which preserve extra osseous blood supply, respect osteogenic fracture haemotoma, biologically friendly and stable fixation method is available for distal tibia fracture. Indirect reduction method and sub-cutaneous tunneling of the plate and application of locking screws with small skin incisions in MIPO technique prevents iatrogenic injury to vascular supply of the bone.

The average age incidence in this study is 38.95 yrs (range 20 yrs-67 yrs) and sex distribution is of 15 males (75%) and 5 females (25%), showing similarity with other studies Hazarika S et al (2006), Vasu Pai et al (2006), Ghulam Shabbir et al (2011), Shreshta et al (2011). The high association of distal tibial fracture in males can be attributed to our Indian set up where female largely work indoor and do not travel much. High energy trauma, road traffic accidents predominate causing 50% of the fractures and has been similarly reported by studies in Neeraj mahajan(2008), Ghulam Shabbir et al (2011), Shreshta et al (2011).

Average trauma surgery interval in this study was 12 days (range 02-22 days) which is more than other studies of Ghulam Shabbir et al (2011), Shreshta et al (2011) where average range is 1-10 days. This is due to delay in reporting of patients to hospital and some institutional cause like lack of theater days and delay in pre-anesthetic fitness for surgery.

Radiologic union and full weight bearing was achieved in 13-16 weeks in 75% of cases while in 25% it was seen in 17-20 weeks showing similarity with other studies Hazarika S et al (2006), Vasu Pai et al (2006), Neeraj mahajan (2008), Ghulam Shabbir et al (2011) and Shreshta et al (2011). In Type A fracture, excellent/ good results as per Teeny & Wiss criteria were seen in 14 out of 17 cases, fair in 02 cases and 01 case has shown poor result. In Type B fracture excellent result in 02 cases and in type C fracture good result in 01 case. On overall assessment of results we are able to achieve 75% excellent results, 10% good results, 10% fair results and 5% with poor results.

Indirect reduction of fracture under fluoroscopy is difficult at time. Various reduction maneuvers such as calceneal pin traction, external fixators or mechanical distracters have been described to achieve reduction. In this study, Kirschner wire (3mm) has been used as a joystick or a towel clip after making small opening at fracture site whenever reduction could not be achieved by mechanical traction. Concominant fibula fracture also play the role in success of reduction especially when fracture is at same level of tibia. Some authors recommend fibula fixations before tibia fixation to achieve better tibial alignment and to prevent valgus malalignment but clear indication for fibula fixation are still lacking and controversial. In this study, 04 cases were treated with fibular plating along with tibial fixation due to syndesmosis involvement.

Complications like superficial wound infection in 02 cases and surgical wound breakdown with implant exposure in 01 case might be attributed to nosocomial infection which healed with antibiotics and daily dressing. Good preparation of soft tissue in preoperative program can reduce superficial wound infection. Prominent hardware was due to lean and thin patient but it did not require any treatment as it was of asymptomatic nature.

## CONCLUSION

Limited number of patients in the study, short duration of follow up and evaluation of extra-articular and intra-articular fracture in same study has limited the final result. Further studies with longer follow up and large sample size will give addition aid to results. But based on favorable outcome of 85% cases from the study we conclude that MIPO is an effective technique for the management of distal tibial fractures.

## BIBLIOGRAPHY


1. Anglen JO. Early outcome of hybrid external fixation for fracture of the distal tibia. J. Orthop Trauma 1999:13:92-7.
2. Bourne RB, Pilon Fractures of distal tibia. Clin Orthop 1989;240:42-46.
3. Bone L, Stegemann P, McNamara K, Seibel R. External fixation of severely comminuted and open tibial pilon fractures. Clin Orthop Relat Res, 1993;292:101-107.
4. Brumback RJ, Mc Garvey WC. Fractures of the tibial plafond. Evolving treatment concepts for the pilon fracture. Orthop Clin North Am. Apr 1995; 26(2); 273-85[Medline].
5. Borens O, kloen P, Richmond J, Roederer G, Levine DS, Helfet DL. Minimally invasive treatment of pilon fractures with a low profile plate: preliminary results in 17 cases. Arch Orthop Trauma Surg. Sep 2 2006:[Medline].
6. Bucholz W Robert: Rockwood and Green's fractures in adults, 6th edition 117-1204.
7. Campbell: Canale Beaty, A. Paige Whittle, Operative Orthopaedics; Vol-3, 11th edition; 3101-3110.
8. Cory Collinge, Mark Kuper, Kirk Larson and Robert Protzman. Minimally Invasive Plating of High- energy Metaphyseal Distal tibial fractures. J Orthop Trauma 2007;21:355-361.
9. E. J. Strauss, Daniel Alfonso, Frederick J. Kummer, Kenneth A. Egol and Nirmal C. Tejwani. The effect of concurrent fibular fracture on the fixation of distal tibia fractures: A laboratory comparison of intramedullary nails with locked plates. J Orthop Trauma 2007;21:172-177.
10. French B, Tornetta P. Hybrid external fixation of tibial pilon fractures. Foot Ankle Clin. 2000;5:853-871.
11. Francois J, Vandeputte G, Verheyden F, Nelen G. Percutaneous plate fixation of fractures of the distal tibia. Acta Orthop Belg.2004;70:148-154.
12. Gustilo R B and Anderson J T. Prevention of infection in the treatment of 1025 open fractures of long bones: retrospective and prospective analyses. J Bone Joint Surg. [Am] 1976; 58(4): 453-458.
13. Gupta RK, Rohilla RK, Sangwan K, Singh V, Walia S. Locking plate fixation in distal metaphyseal tibial fractures: series of 79 patients. Inter Orthop 2010, 34: 1285-1290.
14. Helfet DL, Shonnard PY, Levine D, Borrelli B Jr. Minimally invasive plate osteosynthesis of distal fractures of the tibia. Injury,1998;28 Suppl.1S.A42-S.A48.
15. Hazarika S, Chakravarthy J and Cooper J. Minimally invasive locking plate osteosynthesis for fractures of the distal tibia-results in 20 patients. Injury.2006;37,877-887.
16. Maffulli N, Toms AD, Mcmurtie A, Olivia F. Percutaneous plating of distal tibial fractures Int Orthop 2004 Jun;28 (3):159-62.
17. Janssen KW, Biert J, Van Kampen A Treatment of distal tibial fractures: plate versus nail: a retrospective outcome analysis of matched pairs of patients. Int Orthop 31(5): 709-714.
18. James Jih-Hsi Yeh, Ching-Hou Ma, Shang-Won Yu, Yuan-Kun Tu, Cheng-Yo Yen and Chin-Hsien Wu. Staged external and internal locked plating for open distal tibial fractures. A retrospective analysis of 16 patients. Journal Acta Orthop. 2010 June; 81(3): 382-386.
19. Konrat G, Moed BR, Watson JT, Kaneshiro S, Karges DE, Cramer KE. Intramedullary nailing of unstable diaphyseal fractures of tibia with distal intra-articular involvement. J Orthop trauma 1997;1:200-205.
20. Kenneth A Egol et al: Biomechanics of locked plates and screws, Journal of Orthopaedic Trauma: Vol 18, Sep 2004, 488-93.
21. Lau TW, Leung F, Chan CF, Chow SP. Wound complication of minimally invasive plate osteosynthesis in distal tibia fractures. Int Orthop.2008 Oct; 32:697-703.

22. Leung FK, Law TW. Application of minimally invasive locking compression plate in treatment of distal tibia fractures Zhongguo Xiu Fu Chong Jian Wai Ke Za Zhi. 2009 Nov;23(11):1323-5.
23. Mario Ronga, Umile Giuseppe Longo and Nicola Maffulli. Minimally invasive locked plating of distal tibia fractures is safe and effective. Clinical Orthopaedics and related Research. 2010 April; 468(4): 975-982.
24. Moll BN, Kerb B. Intra-articular fractures of the distal tibia. Acta Orthop Scand. 1982;53: 991-996.
25. Mcferran MA, Smith SW, Boulas HJ, Schwartz HS. Complications encountered in the treatment of pilon fractures. J Orthop Trauma. 1992;6:195-200.
26. Muller ME, Nazarian S, Koch P. The AO classification of fracture translated by J Schatzker. Toronto: Springer, 1988.
27. Macnab I. The role of periosteal blood supply in healing of fracture of tibia. Clinical Orth 1974;105:27.
28. Michelson J, Moskovitz P, Labropoulos P. The nomenclature for intra-articular vertical impact fractures of the tibial plafond: pilon versus pylon. Foot Ankle Int. Mar 2004;25(3):149-50[Medline].
29. Neeraj Mahajan. Minimally invasive technique in distal tibial fractures. JK Science, June 2008 Vol. 10No.2:78-80.
30. Pai V, Coulter G, Pai V. Minimally invasive plate fixation of the tibia. Int. Orthop, 2007;31 491-497.
31. Panchbhavi VK. Minimally Invasive Stabilization of Pilon Fractures. Techniques in foot and ankle Surgery,2005;4(4):240-248.
32. Pradyumna P Pai Raiturker, AA SA lunkhe. Minimally invasive plate osteosynthesis in the treatment of multi-fragmentary fractures of tibia. Bhj.org/journal/2001_4301_Jan
33. Pugh KJ, Wolinsky PR, Mc Andrew MP, Johnson KD. Tibial pilon fractures: a comparison of treatment methods. J Trauma. 1999: 47:937-941.
34. Rüedi TP, Allgöwer M (1979). "The operative treatment of intra-articular fractures of the lower end of the tibia". Clin Orthop Relat Res (138): 105–10.
35. Red fern DJ, Syed SU, Davies SJM. Fractures of the distal tibia: minimally invasive plate osteosynthesis. Injury 2004;35:615-20.
36. Shabbir G, Hussain S, Nasir ZA Shafi K and Khan JA. Minimally invasive plate osteosynthesis of close fractures of distal tibia. J Ayub Med Coll Abbottabad 2011;(2):121-124.
37. S M Perren. Evolution of the internal fixation of long bone fractures. The scientific basis of biological internal fixation: choosing a new balance between stability and biology. J Bone Joint Surg. Br. 2002 Nov;84(8):1093-110.
38. Sidhu AS, Brar BS, Mann HS, Bakshi AS, Tanwar YS, Sidhu DS: Minimally invasive plate osteosynthesis for proximal and distal tibial fractures. Pb journal of Orthopedics 2010;12:No.1:14-17.
39. Syed MA, Panchbhavi VK. Fixation of tibial pilon fractures with percutaneous cannulated screws.Injury.2004;35:284-289.
40. Sarminto A, Gersten LM, Sobol PA. Tibial shaft fractures treated with functional brace, experience with 780 fractures. J Bone and joint surgery 1989;71B:602-9.
41. Shreshta D, Acharya BM, Shreshta PM, Minimally invasive plate osteosynthesis with locking compression plate for distal diametaphyseal tibia fracture. Kathmandu Univ Med j 2011;34(2)62-8.
42. The Orthopedic Trauma Association Committee for Coding and Classification: Fracture and Dislocation compendium. J Orthop Trauma 1996, 10(suppl1):v-ix, 56-60.
43. Teeny SM, Wiss DA. Open reduction and internal fixation of tibial plafond fractures. Clin Orthop Relat Res. 1993;292:108-117.
44. Tarkin I S, Clare M P, MArcantonio A, Pape H C. An update on the management of high-energy pilon fractures. Injury. Feb 2008;39(2):142-54[Medline].
45. Vidyadhara S, Rao S K, Ilizarov treatment of complex tibial pilon fractures. International Orthopaedics (SICOT) 2006, 30:113-117.
46. Vallier HA, Cureton BA and Patterson BM. Randomized prospective comparison of plate versus intra-medullary nail fixation for distal tibial shaft fracture. J Orthop Trauma. 2011;0:1-6.
47. Watson J T, Moed BR, Karges DE, Cramer KE. Pilon fractures: treatment protocol based on severity of soft tissue injury. Clin Orthop Relat Res. 2000;375:78-79.
48. Zelle-Borris-A, Bhandari Mohit, Espiritu Michael, Koval Kenneth J, Zlowodzki Michael. Treatment of distal tibia fractures without articular involvement: a systematic review of 1125 cases. Journal of Orthopedic trauma 2006;20(1):76-9.
49. Zou J, Shi Z M, Zhang W, Zhang C Q. Open reduction and internal fixation better than percutaneous plate osteosynthesis in distal tibial fracture. J Invest Surg,2012; (25):326-9.
50. Nuttaphan Kiriwichian, MD, Comparison between Open Reduction and Internal Fixation and Minimally Invasive Plate Osteosynthesis for Treatment of Distal Tibia Fractures. The Thai Journal of Orthopaedic Surgery: 37 No. 2-4:35-41.