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Study of results of extra articular distal tibial fracture treated with locking plate by minimally invasive percutaneous plate osteosynthesis

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Abstract
Introduction: Distal tibial fractures present a challenge due to subcutaneous location of tibia 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.
Methodology: This study was carried out at Department of Orthopaedics, Tertiary care Hospital. 45 patients with distal tibia fractures were identified of which 42 patients were enrolled in the study based on the inclusion and exclusion criteria. With 2 patients being lost to follow-up during the course of study before completing at least 6 months of follow-up, we had 40 patients remaining to study.
Results: 37(92.5%) fractures were united between 10-14 weeks. Average time of union was 12 weeks. Majority of patients 20 (50%) had 50-70 degree of plantar flexion at final follow-up while 8 patients (20%) had <30 degree of plantar flexion. 12 patients (30%) had 30-50 degree of plantar flexion. Majority of patients 30 (75%) had 10-30 degree of dorsi flexion at final follow-up while 6 patients (15%) had <10 degree of dorsi flexion. 4 patients (10%) had 30-40 degree of dorsi flexion at final follow up.Results were evaluated by AOFAS score consists of pain (40 points) and Function (50 points). 38 had good to excellent results. 2 had poor results.
Conclusion: Newer anatomically contoured locking compression plates is a simple, has a rapid and straight forward application and has a reduced surgical time in fractures of the distal tibia fractures.

Keywords: MIPPO, distal tibia fracture, tibia plate

Introduction
Treatment of distal tibial fractures has always been challenging because of less vascularity of the region, subcutaneous location, and proximity of ankle joint. Open reduction Internal Fixation often necessitates extensive dissection and tissue devitalization, creating an environment less favorable for fracture union and more prone to bone infection. As a result, other, less invasive methods were developed to treat diaphyseal fractures of the tibia.
They are increased in frequency because of higher incidences of Road Traffic Accidents, Accounts to 1% of all lower extremity fractures, 10% of tibial fractures and bilateral in 0-8% and compartment syndrome in 0-5%. The mechanism of injury is axial loading due to talus hitting hard the lower end of the tibia. The axial loading on the distal tibia determines the articular surface injury, metaphyseal communition, joint impaction and associated soft tissue injuries. Although the mechanism of injury may be complex, the predominant force is vertical compression. The location of the articular portion of the fracture is determined by the position of the foot at the moment of impact.
Surgical fixation of distal tibia fractures, require careful preoperative planning because of Fracture pattern, soft tissue injury, and bone quality and articular involvement critically influence the selection of fixation technique. Several techniques have emerged – conservative, plate fixation, hybrid external fixation, intramedullary nailing.
Conservative treatment by cast application led to malunion, shortening of affected leg, prolonged immobilization leading to ankle and knee stiffness affecting quality of life of the patient.

External fixation can be useful in open fractures with soft tissue injury which preclude nail or plate fixation, but may result in inaccurate reduction, a relatively high rate of malunion or nonunion, pin loosening and pin tract infection, With regards to Intramedullary interlocking nailing, a stable fixation with nail in distal tibia may be difficult to achieve two distal locking screws and also the hourglass shape of the intramedullary canal prevents a tight endosteal fit and compromises torsional and angular stability. Secondary displacement of the fracture on insertion of nail, breakage of nail and locking screws and malunion of the tibia are potential risks.

Introduction of the locking compression plate was a revolution in the evolution of management of fractures where prolonged bed rest is avoided and return to work is satisfactorily helpful. Fractures involving the distal third of tibia involve the metaphyseal flare which poses the difficulty of decreased implant contact leading to less stability and increased malalignment. This kind of malalignment causes gross mechanical alteration of the ankle thereby leading to increased pain and functional disability.

We aimed to see the results of the distal tibial fracture fixation with Anatomical Plate (LCP) using Minimally Invasive Plate Osteosynthesis (MIPO). These techniques are based upon the principles of limited soft tissue stripping, maintenance of the osteogenic fracture hematoma, and preservation of vascular supply to the individual fracture fragments while restoring axial and rotational alignment, and providing sufficient stability to allow progression of motion, uncomplicated fracture healing, and eventual return to function. Classic open reduction and internal plate fixation require extensive soft tissue dissection and periosteal stripping with high rates of infections, malunion, delayed union, non-union and also requires secondary procedures like bone grafting.

Several minimally invasive plate osteosynthesis techniques have been developed, with union rates ranging between 80% and 100%. These techniques aim to reduce surgical trauma and to maintain a more biological favorable environment for fracture healing. Nevertheless, complications such as angular deformities greater than 7°, hardware failure and non- unions have been reported.

A new advance in this field is represented by the “locked internal external fixators”. It consists of plate and screw systems where the screws are locked in the plate at a fixed angle. Screw locking minimizes the plate and bone contact because the plate does not need to be tightly pressed against the bone to stabilize the fracture.

The system works as flexible elastic fixation that stimulates callus formation. The anatomical shape prevents primary displacement of the fracture, and allows a better distribution of the angular and axial loading around the plate. Because of minimally invasive the periosteal blood supply of the bone and fracture hematoma not disturbed. Despite with advances in identification, understanding and treatment of soft tissue injury and with the liberal use of Computed Tomography scanning, advances in implant design which includes locking plate technology, still the management of these challenging fractures remains elusive.

Aims and Objectives

- To evaluate the functional and radiological results of fixation of distal tibia fractures by minimally invasive percutaneous plate osteosynthesis
- To compare results with standard studies and draw conclusion.

Materials and Methods

This study was carried out at Department of Orthopaedics, Tertiary care Hospital. 45 patients with distal tibia fractures were identified of which 42 patients were enrolled in the study based on the inclusion and exclusion criteria. With 2 patients being lost to follow-up during the course of study before completing at least 6 months of follow-up, we had 40 patients remaining to study.

This study was mainly an observational prospective study.

Inclusion Criteria

- Both male and female patients above 18 years of age with Extra articular Distal Tibial Fracture
- All closed and OG- I & II fractures
- Consent for the surgery and to participate in the study

Exclusion Criteria

- Patient less than 18 years
- Gustillo Anderson III open fractures
- Compartment syndrome
- Revision surgeries
- patients who are not giving Consent for the surgery and not willing to participate in the study

Management

(A) Primary Management

Patients satisfying the selection criteria were identified after emergency management as per ATLS protocol in the casualty. History taking, general examination and local examination were conducted in the trauma care center. Once stabilized, relevant X-rays were asked for. Fractures were classified according to Rudie & Allgower classification. All patients were monitored stringently for signs and symptoms of compartment syndrome. All wounds (if any) were covered by sterile dressing after cleansing and normal saline wash. Temporary immobilization was given by above knee posterior plaster splint. Calcaneal pin traction was given in all cases under local anesthesia and primary debridement and suturing was performed in open fractures. Tetanus prophylaxis in form of Tetanus Toxoid and Tetanus immunoglobulin were given. Parenteral antibiotics and analgesics were started in all open injuries.

(B) Pre-operative Management

Necessary investigations for surgical fitness were conducted. Closed fractures with edema were splinted and regular calf girth charting was done with oral proteolytic enzymes, intravenous antibiotics and limb elevation. Surgery was done after swelling subsided. The closed fractures were operated as soon as the fitness for anesthesia was obtained.

Open fractures were dressed daily after primary thorough debridement. Once the wounds healed surgery was planned.

(C) Selection of implant

In all our patients we used distal locking compression tibia plate. Plate placement and its length were evaluated according to the fracture geometry visible on antero-posterior and lateral X-rays of view of the affected limb. Size of implant was decided pre-operatively considering magnification on X-rays. The size was determined as requiring 6-8 cortices in the metaphysis and 8-10 in the diaphysis spanning the fracture.

(D) Anaesthesia

Spinal, epidural or general anesthesia was given to the patient as per the anesthetic’s opinion. But spinal anesthesia was

most preferred. Tourniquet was not used in any case.

(E) Surgery
Position: Surgery was performed on plain table. The ipsilateral greater trochanter was raised to 20-25° to keep the knee facing upwards and counter normal external rotation of the lower limb. The affected limb was scrubbed and prepared with diluted savlon. Painting and draping were done under aseptic and antiseptic conditions. Draping was done in such manner that the area from middle of thigh to lower third leg was exposed for proper recognition of anatomical landmarks. Intravenous antibiotic was administered prior to incision.

(I) Minimally invasive Plate Osteosynthesis
After painting and draping, again the reduction was checked in image intensifier and incision was put depending on the fracture and size of implant used. Incisions were anticipated and planned. It was attempted to keep length minimum at the proximal side though enough to negotiate the plate. However, this was not achieved at cost of the difficulty of surgeons at the same time care was taken not to do over retraction. Distally small incisions were kept directly over the holes of the plate either by clinical palpation or after confirmation under image intensifier.

Reduction and Fixation
At the distal incision the subcutaneous tissue was cut in the line of the incision & care was taken not to damage great saphenous vein. The periosteum was not stripped off. The plate was now slided across the fracture site under IITV image control (under submuscular plane). Thus, here a space was created by gentle blind dissection in the plane beneath the muscle and the periosteum. The drill guide threaded in to one of the combi holes in the proximal part of the plate was used as a handle for percutaneous insertion of plate.
Before and after the implant was slide, indirect reduction was achieved as far as possible mainly by longitudinal traction and manipulation under image intensifier. Under image intensifier now the implant was manipulated and exact position of the implant was achieved. Provisional k-wires were also used away from anticipated plate placement site to maintain reduction. Once the position of the plate was confirmed on image intensifier it was held with the bone in the same position by a k-wire.
After confirming the position of plate under IITV and finalizing the reduction the remaining proximal screws were passed. (3.5 mm simple cancellous or locking cancellous). At least 4 screws were passed proximally in metaphyseal bone for adequate stability. Locking cancellous screws were preferred for better stability in osteoporotic bone. Metaphyseal cancellous screws and cortical screws in diaphysis in lag mode were used outside the plate as required to maintain reduction replacing provisional k-wire.
Depending on the quality of bone, cortex or locking screws were used to fix the plate distally. Insertion of cortex screw first distally pulls the bone flush to the plate. However, this was avoided if it compromised the quality of reduction and the fixation was continued using locking screws.

(F) Post-operative Regime
The patient was immobilized with an above knee posterior slab and care was taken to prevent dependent edema of limb. Intravenous antibiotics were given for first 3 days followed by oral antibiotics in closed fractures. However, in open fractures intravenous antibiotics were given till trauma wound showed signs of healing. A post-operative X-ray was advised when the patient could be shifted comfortably, usually after 48 hours of surgery. Depending on the post-operative fracture stability and pain tolerance of the patient, quadriceps strengthening exercises, knee and ankle mobilization exercises and non-weight bearing-crutch walking were started. After suture removal between 10-15th day, the patient was discharged with either partial or non-weight bearing-crutch walking depending upon the stability of the fixation.

(G) Data collection, Follow-up & Evaluation
Data related to demographics, mechanism of injury, details of trauma, hospitalization detail, operation description, post-operative rehabilitation, complications, clinical and functional outcome were collected during the period of hospital stay and follow up visits in the OPD clinic. Follow up was conducted regularly at the interval of 4 weeks. The patients were followed up in the outpatient department. At the time of follow up a thorough clinical evaluation was done for progress of union, healing of trauma wound and joint stiffness. Once the fracture had shown early signs of union, partial weight bearing was started on the injured limb. On follow up the patients were evaluated clinically and radiologically according to the Performa decided (AOFAS score).

(H) Statistical Analysis
Descriptive statistical methods and expression of results in terms of mean, chi-square test and others using Microsoft excel software with significant p value <0.05 were used for computation of data.

Results
Age and Sex: There were 32 males and 8 female patients. Majority (52.5%) of our patients were males between 31-50 years of age. This can be attributed to outdoor activities being performed predominantly by young males and use of motor bikes.

Mode of injury: Road Traffic Accidents (30 patients) were the main reason for causing distal tibial fractures in all age groups with peak incidence in the fourth decade of life.

Side: Right side was involved in 55% of the patient (22 patients)

Life style: There was ~1:>2 distribution of patients in the moderate (household) {11 patients}and strenuous (laborer) {29 patients} age groups. People with sedentary life style do not seem to be affected by these fractures.

Rudie and Allgower classification: Of the 40 cases studied, 9 (22.5%) cases were Al, 14(35%) were A2, 17(42.5%) were A3.

Open/ close fracture: In our study, majority of fracture were closed type 33 patients (82.5%).

Injury Surgery Interval: 82.5% cases (33 patients) were operated within 1 week of injury. Average injury surgery interval was ~3 days. Delay in the surgery in other patients occurred due to various factors - associated head or chest injury, local site edema or blisters or other medical conditions

Hospital Stay: The average duration of hospital stay was 10 days. Majority of patients were discharged between 5th to 12th post-operative days.

Union Status: Union was defined as bridging of three of the four cortices and disappearance of the fracture line on the plain radiographs for patients who was able to bear full weight. Fracture in the process of union but not united at six months was considered as delayed union. All fractures that did not show any provisional signs of healing was labeled as non-union.

Table 1: Union status in Open and MIPPO technique

Union Status	Number of patients	Percentage (%)
United	37	92.5
Delayed Union	3	7.5
Non-union	0	0
Total	40	100

37(92.5%) fractures were united between 10-14 weeks. Average time of union was 12 weeks.

Time taken for Union

Table 2: Time taken for Union in Close & Open fracture

Time period in weeks	Fracture	Percentage (%)
8-10	16	40
10-12	10	25
12-14	8	20
>14	6	15
Total	40	100

Average time of Union was 12 weeks. Range of Union was 8-16 weeks.

Complication

Case no. 1 had superficial skin infection at surgical site which healed eventually by wound care. 2 patients had Ankle joint stiffness (case no. 4, 6). 1 patient had Varus deformity with implant failure (case no.18) at the fracture site.

Table 3: Ankle range of Motion – Plantar Flexion and Dorsi flexion

Range of Plantar Flexion	Patients	Range of Dorsi flexion	Patients
<30	8	<10	6
30-50	12	10-30	30
50-70	20	30-40	4

Progression of range of motion following surgery

Majority of patients 20 (50%) had 50-70 degree of plantar flexion at final follow-up while 8 patients (20%) had <30 degree of plantar flexion. 12 patients (30%) had 30-50 degree of plantar flexion.

Majority of patients 30 (75%) had 10-30 degree of dorsi flexion at final follow-up while 6 patients (15%) had <10 degree of dorsi flexion. 4 patients (10%) had 30-40 degree of dorsi flexion at final follow up.

Table 4: Outcome evaluation

Results	Clinical Results	Percentage
Excellent	12	30
Fair/Good	26	65
Poor	2	5
Total	40	100

Results

Results were evaluated by AOFAS score consists of pain (40 points) and Function (50 points). 38 had well to excellent results. 2 had poor results.

Discussion

Fractures of distal tibia are among the most difficult fractures to treat effectively. The status of the soft tissues, the degree of comminution and sustained at the time of injury affect the long-term clinical results. The goal of operative treatment is to obtain anatomic realignment of the joint surface while providing enough stability to allow early motion. This should be accomplished using techniques that minimize osseous and soft tissue devascularization in the hopes of decreasing the complications resulting from treatment.

The present study was under taken to determine the efficacy of the locking compression plates in treatment of the fractures of the distal tibial metaphysis.

We evaluated our results and compared them with those obtained by various other studies utilizing different modalities of treatment, our analysis is as follows:

Age distribution

Our study revealed the average age of patients with such injuries to be 35 years (18-60).

Table 5: It is comparable with a study on similar fractures conducted by below authors

Study	Min Age	Max Age	Average
Cory collingeetal [34]	17	62	43
Heather A Vallier *et al.* [35]	16	77	39.1
Present study	18	60	35

Table 6: Sex Distribution

Study	Male Percentage	Female Percentage
Cory collinge *et al.* [34]	67	33
Andrew Grose *et al.* [36]	75	23
Present study	77	26

In our study, the male preponderance for such kind of injuries were high 80% compared to the study by Cory collinge *et al.*, (which was 67%) possibly due to the fact of male dominance over the female in traveling, occupational injures etc., in

India. However, the study by Andrew Grose were comparable in the fact that they had 75% male patients.

Mechanism of Injury

Cory Collinge *et al.* observed 100% high energy fractures in his study. Andrew Grose *et al.* could attribute only 58% of such injuries to be of high energy.

However, our present study correlates with the study conducted by Cory Collinge *et al.* [34], but not with Andrew Grose *et al.* [36], and along with that Heather A. Vallier *et al.* [35], who contributed only 51% of high energy fractures.

Table 7: Comparision with other Study – Mode of Injury

Study	Mode of injury	
	High Energy (RTA, Fall from height)	Low Energy (Assault, Simple Fall, sporting injuries etc)
Cory collinge *et al.* [34]	100%	0%
Andrew Grose *et al.* [36]	58%	42%
Heather A Vallier *et al.* [35]	51%	49%
Present study	92.5%	7.5%

Clinical type

Our study had 17.5% open injuries. This was lesser to the studies conducted by Heather A Vallier *et al.* who has 30% open fractures, Hazarika *et al.* who has 40% open fractures.

Table 8: Comparision with other Study – Types of fracture Open & Close

Study	Open fracture Percentage	Closed Percentage
Heather A Vallier *et al.* [35]	30	70
Hazarika *et al.* [20]	40	60
Present study	17.5	82.5

Fracture Patterns

The present study could not be compared with the other studies because our primary aim was to study the distal metaphyseal fractures (without intra articular extension). We had also excluded the type B & C (AO/OTA) fractures.

However, study by Cory collinge *et al.* showed 16% CI, 32% C2 and 24% C3. Andrew Grose *et al.* also had fractures types 2% B1, 4% B2, 12% B3, 6% C1, 12% C2, 64% C3. Heather A Vallier *et al.* also had fractures 31% A, 21% B, 44% C. We had a higher percentage of type A fracture due to the selection process based on the aim of the study.

Table 9: Comparision with other Study – Types of fracture

Study	Al	A2	A3	Bl	B2	B3	CI	C2	C3
Cory collinge *et al.* [34]	9	9	10	-	-	-	16	32	24
Andrew Grose *et al.* [36]	5	5	7	2	4	6	6	12	64
Heather A Vallier *et al.* [35]	31			21	-	-	44	-	-
Present study	9	14	17	-	-	-	-	-	-

Duration of surgery

The average surgical time was 52 minutes. It is lesser comparable with the average of 97.9 minutes taken by J.J. Guo *et al.* [37] in their study.

Table 10: Comparision with other Study – Duration of Surgery

Study	Range (in minutes)	Average duration (in minutes)
J.J. Guo *et al.* [37]	94.76 - 100.75	97.9
Present study	31 – 80	52.0

The length of the operative time reflects a significant learning curve. The first few locking compression plates took 70-80 minutes in this study, whereas the most recent ones took 40-50 minutes.

Duration of fracture union

The average time for fracture union in various studies conducted using various methods was 16-28 weeks. Our study had an average fracture union of 12 weeks which were less comparable with studies conducted using the locking compression plates. Cory Collinge *et al.* had an average fracture union of 21 weeks and Abid Mushtaq *et al.* had an average of 22 weeks.

Table 11: Comparision with other Study – Average Union Time

Study	Method	Average fracture union
Cory collinge *et al.* [34]	MIPPO	21 weeks
Abidmushtaq *et al.* [38]	MIPPO	22 weeks
Im GI, *et al.* [19]	ORIF	20 weeks
Hazarika *et al.* [20]	MIPPO	19.3 weeks
Present study	MIPPO	12 weeks

Results and Complications

In a study that established open reduction with plate and screw fixation as the standard. Ruedi and Allgower12 achieved 74% acceptable results in 84 patients. These results did not deteriorate for 9 years. Mast *et al.* [39] reported 78% satisfactory results in 37 patients with a minimum follow up interval of 6 months. Less dramatic results were reported by a variety of authors when the plafond fractures studied included larger numbers of high energy injuries. Bourne and colleagues 14 studied 42 patients with tibial plafond fractures, 62% of whom were victims of high-energy trauma. Of the 16 Ruedi type III fractures treated by open reduction and internal fixation, only 44% had a satisfactory result. The majority of these fractures were complicated by nonunion (25%), infection (13%), and Arthrodesis (32%). Ovadia and Beals reviewed 34 fractures equivalent to Ruedi Type III treated with traditional open reduction and plate fixation.

Good to excellent results were achieved in only 47%. Complications were numerous and, although not sub classified according to fracture type, superficial infections or skinloss developed in 9 patients (11%), osteomyelitis developed in 5 patients (6%), 17 patients (12%) required either ankle Arthrodesis or Arthoplasty. Teeny and Wiss26 studied 60 tibial plafond fractures. 60% of those were secondary to high-energy trauma. They reported 50% poor results when open reduction and plate fixation was used. When the subset of 30 Ruedi Type III fractures was analyzed there were 12(40%) acceptable outcomes with 37% of these fractures complicated by a skin slough or deep infection. Mc

Ferran *et al.* [27] reported on 52 tibial plafond fractures treated with open reduction and internal fixation. Forty percent of these were Ruedi Type III injuries. Overall, 40% of the patients suffered some complication, with a deep infection or osteomyelitis occurring in 43% of fractures, and a wound breakdown requiring soft tissue coverage in 62% of fractures.

Table 12: Comparision with other Study – Method of Fixation with Acceptability of Union

Study	Methods	Acceptable (%)	Not Acceptable (%)
Ruedi and Allgower [12]	Open Reduction and internal fixation	74	26
Mast *et al.* [39]		78	22
Bourne *et al.* [14]		44	56
Teeny and Wiss [26]		50	50
Im GI *et al.* [19]	Open reduction & internal fixation with anatomic plates	88	12
Gao *et al.* [21]	MIPPO	87	13
Hazarika *et al.* [20]		87	13
Ozkaya U. *et al.* [22]		81	19
Present study	internal fixation with anatomic plates and MIPPO	87	13

NB: The excellent and good results have been tabulated as acceptable and the fair and poor results as not acceptable for easier comprehension.

Im GI *et al.*, In a study of 30 patients using anatomic plates and screws, open reduction and internal fixation was done with 88.2% excellent to good results according to oleurd and mollander function ankle score and with a better alignment of fracture fragments [19].

Hazarika *et al.*, a series of 20 patient of distal tibial fracture treated using locking compression plates through MIPPO technique. This approach aims to pressure bone biology and minimise surgical soft tissue trauma. This provided 87.5% of good to excellent results. Fractures were classified according to the AO system and performed as scored stage surgery after sterilization with external fixators primarily [20].

Gao *et al.*, studied 32 adult patients with very short metaphyseal fragments in fractures of distal treated with a polyaxial locking system. The polyaxial locking system shown results of 87.3 functions out come with American Orthopaedic Foot and Ankle Society score which offer more fixation versatility, may be a reasonable treatment option for distal tibia fracture with very short metaphyseal segments [21].

Ozkaya U, *et al.*, a retrospective review of 22 patients with distal third tibial fractures were treated with titanium locking compression plates using minimally invasive technique good biological fixation of distal tibial. A total of 81% of good to excellent outcome was assessed using American Orthopaedic Foot and Ankle Society [22].

Conclusion

According to the study, 40 patients with fractures of the distal tibial had undergone closed reduction through MIPPO techniques of application of the locking compression plates. This technique has resulted in the effective stabilization of these fractures. It does provide adequate stability and allows early motion. The open reduction not only helps in achieving reduction in difficult situations, but also in rapid union, because it facilitates preservation of the blood supply to the fragment and anatomical reduction of the fracture. Its greatest advantage is anatomical reduction is achieved and fracture hematoma is not disturbed much. It is most effective in extra articular fractures because intramedullary nails often do not provide enough stability and external fixators usually applied for primary stabilization and until soft tissue edema get subsided and delays the return to work with fixators.

Newer anatomically contoured locking compression plates is a simple, has a rapid and straight forward application and has a reduced surgical time in fractures of the distal tibia fractures.

Although, a larger sample of patients and longer follow up are required to fully evaluate this method of treatment, we strongly encourage its consideration in the treatment of distal tibia fractures.

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