



E-ISSN: 2395-1958
P-ISSN: 2706-6630
IJOS 2021; 7(1): 43-48
© 2021 IJOS
www.orthopaper.com
Received: 17-11-2020
Accepted: 29-12-2020

Dr. A Sivakumar
Assistant Professor, Department
of Orthopaedics, Trichy SRM
Medical College and Hospital,
Trichy, Tamil Nadu, India

Dr. S Cyril Jonnes
Assistant Professor, Department
of Orthopaedics, Trichy SRM
Medical College and Hospital,
Trichy, Tamil Nadu, India

Dr. G Samynathan
Associate Professor, Department
of Orthopaedics, Trichy SRM
Medical College and Hospital,
Trichy, Tamil Nadu, India

Corresponding Author:
Dr. S Cyril Jonnes
Assistant Professor, Department
of Orthopaedics, Trichy SRM
Medical College and Hospital,
Trichy, Tamil Nadu, India

Functional outcome of distal tibia fracture fixed with locking compression plates using MIPPO technique: A prospective study

Dr. A Sivakumar, Dr. S Cyril Jonnes and Dr. G Samynathan

DOI: <https://doi.org/10.22271/ortho.2021.v7.i1a.2459>

Abstract

Background: The objective of this study is to evaluate the technique of surgical management distal tibial fractures treated by internal fixation with locking compression plates and screws through MIPPO.

Materials and Methods: In a prospective study conducted in the Postgraduate Department of Orthopaedics, Trichy SRM Medical College and Hospital, Trichy, Tamilnadu over a period of 2018 to 2020. 21 cases with distal tibial fractures and aged 18 to 65 years were included in this study. All fractures were classified under AO/ OTA '43' classification. This included both intra articular (tibial plafond) fractures and extra articular where interlocking intramedullary nailing was not feasible or would produce rotational instability.

Results: A total of 21 patients were taken up for study. The age of patients in the study ranged from 18 to 65 Years with an average of 44.42 years at the time of surgery. With about 11 and 10 patients with the right and left sides involved respectively, both sides appear to be equally involved. Majority of the patients sustained injury due to RTA. Among the 21 patients, 15 had extra-articular fractures and 6 intra-articular fractures. 85% of the fractures united within 16 weeks with an average of 15.7 weeks. We experienced delayed unions in three patients possibly due to excess traction intra-operatively and due to comminution. Based on Tenny and Weiss scoring criteria for the ankle nineteen patients (90%) had good and excellent results at 22 weeks with fracture union.

Conclusion: The use of locking compression plate for intra and extra articular fractures of the distal tibia through minimally invasive technique along with fibular fixation is safe and effective.

Keywords: Tibial fractures, extra articular, fibular fixation

Introduction

The distal part of the tibia is more superficial in nature. The soft tissue coverage of the bone in this area is comparatively less and so is the blood supply. Injuries to this region produce more morbidity due to the variable involvement of the articular surface, soft tissue damage and the compromised blood supply. Intra-articular fractures of the distal tibia are also called 'pilon fractures' or 'tibial plafond fractures'. With the recent increase in high velocity injuries, treatment of these have become demanding. Fracture pattern, soft tissue injury, and bone quality critically influence the selection of fixation technique. Various methods of treatment like external fixation, intramedullary nailing, and locking plates have been considered. Among these, intramedullary nailing is not feasible in this region due to the distal nature of the injury because of which the distal screws cannot be placed and to the possibility of rotational misalignment during the course of fracture healing. External fixators can lead to inaccurate reduction, malunion, non-union and pin tract infection. Intramedullary nailing is considered standard for surgically managing tibial fractures, but the distal tibia poses concerns regarding the stability of fixation, the risks of secondary displacement of the fracture on insertion of the nail, breakage of nails and locking screws, and final alignment of the tibia. Classic open reduction and internal plate fixation require extensive soft tissue dissection and periosteal stripping even in expert hands, with high rates of complications, including infection, delayed union, and nonunion. Minimally invasive techniques offer fixation in the biological manner with preservation of the bone's vascular soft tissue envelope and containment of the fracture haematoma.

Objective

Primary objective of this study is to evaluate the technique of surgical management distal tibial fractures treated by internal fixation with locking compression plates and screws through MIPPO.

Secondary objective is to analyse the functional outcome in terms of time taken to unite, range of ankle motion at the end of union, rate of wound infection, percentage of skin necrosis, amount of angulation at union and to comment on the efficacy of treatment of distal tibia fractures with Locking compression plates through MIPPO.

Materials and Methods

We prospectively followed up twenty one patients who presented to the casualty in tertiary care hospital. 21 cases with distal tibial fractures and aged 18 to 65 years were included in this study. Terminally ill patients with multiple medical comorbidities and poorly ambulatory patients were excluded. All fractures were classified under AO/ OTA '43' classification. This included both intra articular (tibial plafond) fractures and extra articular where interlocking intramedullary nailing was not feasible or would produce rotational instability. The study was conducted after receiving approval from the Institutional Human Ethics Committee. Patients were followed up at regular intervals.

Goals of treatment

Treatment goals include anatomic reduction of the fracture, maintaining soft tissue envelope, stable fixation and early mobilization to prevent stiffness of the ankle joint. The purpose of this study was to evaluate the functional outcome and the time taken for fracture union of the distal tibial fractures with the use locking plates through the minimally invasive percutaneous plate osteosynthesis (MIPPO) methods.

Initial surgical management

All patients with compound fractures were administered with intravenous antibiotics and tetanus prophylaxis. The wounds were thoroughly irrigated and washed with normal saline followed by the application of sterile dressings within 3 hours from the time of presentation of the patient in the emergency department. The decision of applying an external fixator was made by the attending surgeon based on the co-morbid conditions, soft tissue status and general condition of the patient but none in this study group were fixed so. All patients were put on calcaneal pin traction using Steinman pin except the one who had fracture of the calcaneum. Strict limb elevation using Bohler Braun splint was advised for all cases. Surgery was delayed until the skin conditions and ankle swelling was favourable, which was assessed by the presence of the 'wrinkle sign'. In the wrinkle sign, the ankle was dorsiflexed while the anterior aspect of the ankle was observed. The absence of a skin crease or wrinkle suggests severe swelling. Temporary skeletal stabilization was achieved until surgery was performed for which we used calcaneal pin tractions.

Anteroposterior, lateral and long leg alignment X-rays were necessary for careful pre-operative planning. If necessary CT scan was obtained to determine the optimal size and position of the articular fragments. It was also necessary to determine the optimal plate location. In the distal tibia, plate was normally applied to the medial aspect. Anatomic locking plates should not be bent because bending alters the biomechanical properties of the plate possibly leading to fatigue failure.

Surgical technique

With the patient positioned supine on a radiolucent table, antibiotic prophylaxis was administered and standard intraoperative fluoroscopy was used throughout the procedure. Care was taken to ensure that the fracture can be clearly visualised on anteroposterior and lateral views. The injured limb and the non-injured limb were prepared and draped above the knee, thus allowing intra operative alignment to be checked against the normal limb. Elevating the injured limb on radiolucent trays enable a clear lateral view and avoids interference from the other leg. The joint lines of the knee and ankle were defined and marked on the skin. Using manual traction, or a single Steinman pin inserted into the calcaneus, the fracture was reduced. If necessary pointed reduction clamp can be used to obtain reduction. Depending on the quality of the tibial fracture reduction reached, a fibula fracture, if present, was plated using a one third tubular plate to provide lateral stability and restoration of the correct length and to prevent over distraction at the fracture site. The main fracture fragments of the distal tibia were aligned and reduced percutaneously or through separate stab incisions and were then fixed with individual lag screws. With the fracture adequately reduced, an adequate transverse incision was made distal to the medial malleolus and a subcutaneous tunnel was created. An LCP passed along the tunnel, bridging the fracture site. The plate selected was long enough to bridge the metaphyseal zone and to allow at least two bicortical screws to secure, through the ad hoc holes proximal and distal to the fracture. Establishment of the correct rotation achieved was checked by comparison with the other limb. Additional screws were then inserted percutaneously as necessary, with a minimal of 2 bicortical screws at either end. The number of screws that can be placed in a short distal fragment was a limitation of the conventional low contact plate. This problem has been circumvented by using the Locking distal tibial plate with 9 distal holes instead of 4 holes of the conventional low-contact plate. The latter feature allows modulation of the rigidity of fixation more precisely. Axial stiffness and torsional rigidity were mainly influenced by the working length. By omitting 1 screw hole on either side of the fracture the construct became almost twice as flexible in compression and torsion.

Our concept was to use lengthy plates with minimal cortical purchases. The Morse cone mismatch which was present between the plate and the screw prevented screw toggle. The number of screws also significantly affected stability. More than 3 screws per fragment did little to increase axial stiffness, however, and 4 screws did not increase torsional rigidity. The other factor affecting the stability of the construct is the distance between the plate and the bone, which was kept small, and long plates were used to provide sufficient axial stiffness. The optimal plate distance was maintained to be 2mm or less from the surface of the bone. The stab incisions were closed in a standard fashion with a suction drain and the wound was dressed. The limb was immobilized in a below knee plaster of paris (POP) cast.



Fig 1: Picture showing the plate being slid beneath the skin to cross the fracture site.



Fig 2: Picture showing the second incision made in the region of the distal end of the plate enabling positioning of the plate.



Fig 3: Picture showing the plate being placed in position.



Fig 4: Picture showing the placement of screws and the drill guide in position.



Fig 5: Picture showing the minimal invasive surgical wounds after closure and placement of drains.

Post-operative care

Patients were allowed ankle and toe mobilization immediately after the pain subsided. Drains were removed on the 3rd post-operative day. Strict limb elevation was maintained until five days from surgery. Non-weight bearing crutch walking was allowed from then on. The limbs were maintained in below knee slabs where the patient had an associated injuries in the lower limbs. Patients above 50 years were administered with Low Molecular Weight Heparin for three days post operatively. Sutures were removed around the 14th day after inspection of the wound. Patient was then discharged from hospital. Outpatient physiotherapy was instituted.

Follow up

Partial weight bearing was started from 1 month post-operatively. Patients were followed up for a minimum period of 10 weeks. Patients were assessed once in 3 weeks both clinically and radiologically. Radiologically, sign of callus formation is noted and clinically, the improvement in the range of motion and the reduction in pain were noted. All

patients were assessed according to Tenny and Weiss scoring system. In patients who requested for the implant to be removed, it was done after consolidation of the callus was noted in the radiographs, usually not before 18 months from surgery.

Results

The age of patients in the study ranged from 18 to 65 Years with an average of 44.42 years at the time of surgery. Among 21 patients twelve were males and nine were female patients showing a male preponderance. With about 11 and 10 patients with the right and left sides involved respectively both sides appear to be equally involved.

Mode of injury

Majority of the patients sustained injury due to RTA. The various modes of injury and the number of patients are shown in the table.

Table 1: Mode of injury

Mode	No. of patients	%
RTA	12	57.14
Self fall	8	38.09
Crush	1	4.8

Relationship between the mode of the injury and the fracture pattern.

Among the 21 patients, 15 had extra-articular fractures and 6 intra-articular fractures. Two were compound fractures and 7 patients had associated injuries. This shows that RTA was the major cause for intra-articular fractures. The following table shows the nature of the injuries and the number of patients.

Table 2: Relationship between the mode of the injury and the fracture pattern

Fracture pattern	Total No. of patients	No. of patients due to RTA	No. of patients due to Fall	No. of patients due to Crush injury
Extra-articular fractures	15	8	7	
Intra-articular fractures	6	5	-	1
Compound fractures	2	1		1
With associated injuries	7	4	2	1

Time from injury to surgery

Patients without any soft tissue complications were operated early and surgery was delayed for those with severe soft tissue damage. Surgery was performed only after the soft tissue status was stable. The table a represent the total number of patients and time duration before surgery.

Table 3: Time from injury to surgery

Days	No. of patients	%
<4	5	23.8
4-8	11	52.4
>8	5	23.8

Time to union

85% of the fractures united within 16 weeks with an average of 15.7 weeks. Two delayed unions were observed in patients

with compound and intra-articular fracture. The other one was also observed, and to be due to over jealous traction in the limb prior to fixation resulting in distraction at the fracture site. This can be corrected by maintaining apposition at the fracture sites during surgery. But all fractures united at nine months.

Table 4: Time to union

Weeks	No. of patients	%
10	2	9.52
11	1	4.76
12	4	19
14	4	19
16	7	33.33
22	2	9.52
38	1	4.76

Amount of angulation at union

90% of patients did not or had <5 degrees of angulation at union. One patient had 10 degrees of varus and one had 10 degrees of recurvatum but with no clinical deformity.

Relationship of angular deformities to fibular fixation

Fibular fractures were present in 20 patients out of the 21 in our study group. We fixed the fibulas in 6 patients for whom there was severe displacement and fracture at the level of the syndesmosis. Though we did not have any clinical angulations in the immediate and late post-operative period, we had 2 patients with radiological angulations. One patient had 10 degrees of varus, and the other had 10 degrees of recurvatum. Both the patients belonged the group in which the fibula was not fixed. The functional outcome of both the patients were excellent. None of patients in whom the fibula was fixed experienced radiological or clinical angulations.

Table 5: Relationship of angular deformities to fibular fixation

Description	No. of patients	%
Patients with fibula fractures	20	95.23
Fibula fractures fixed	6	28.6
Clinical angulations	0	0
Radiological angulations	2	9.5
Angular deformities with fixed fibulas	0	0
Angular deformities with fibula not fixed	2	14

Movements of the ankle at union

Eighteen (86%) patients had satisfactory ankle movements leading to normal walking or a minimal limp. The minimal limp was due to some amount of ankle stiffness in the elderly and diabetics. This improved with physiotherapy. Three (14%) patients had ankle stiffness which produced limping at 22 weeks. This reduced to two at 32 weeks, one due to prolonged immobilisation and one due to intra-articular nature of the fracture. The amount of plantar flexion, dorsiflexion and the number of patients are discussed below.

The table shows the amount of plantar flexion possible and the number of patients.

Table 6: Plantar flexion

Degrees	No. of patients	%
>30 degrees	13	61
11 to 30 degrees	7	33.33
0 to 10 degrees	1	4.8

The following table shows the amount of dorsiflexion present and the number of patients.

Table 7: Dorsiflexion

Degrees	No. of patients	%
>15 degrees	11	52.4
11 to 15 degrees	8	38.1
0 to 10 degrees	2	9.5

Time to full weight bearing

Eighteen (86%) patients with normal bone union were allowed full weight bearing at or before 18 weeks. The other 3 patients (14%) were allowed full weight bearing at or before 39 weeks.

Final outcome

Nineteen patients (90%) had good and excellent results with fracture union at 23 weeks. Fair results were observed in two patients. One was due to the crushing injury producing associated injuries in the foot, and another due to old age and prolonged immobilisation. The grading was based on Tenny and Weiss scoring criteria for the ankle. The table and chart show the final outcome and the number of patients based on Tenny and Weiss criteria.

Complications

Though many studies have shown delayed unions among patients with rheumatoid arthritis and those on steroids we experienced delayed unions in three patients possibly due to excess traction intra-operatively and due to comminution. We had two cases with implant impinging the skin for which we performed implant removal at 18 months. Two patients had ankle stiffness, one due to prolonged immobilization and one intra-articular fracture. We did not experience any infection or wound breakdown in our study.

Discussion

Collinge and Sanders have described indirect fracture reduction and percutaneous plating techniques for the lower extremity, as an evolutionary step in biological plating. Minimally invasive locking plate osteosynthesis, as used with our 21 patients, may permit a further advancement in this field of traumasurgery. Redfern *et al.* and Borg *et al.* reported good results for MIPPO using closed, indirect reduction and contoured dynamic compression plates for distal tibial fractures. Our study included similar numbers of patients; however we have focused upon fracture healing, need of fibular fixation and complications encountered with regards to our minimally invasive fixation technique.

The management of distal tibia fractures can be challenging because of the scarcity of soft tissue, their subcutaneous nature, and poor vascularity. The surgical treatment of a distal tibial fracture must achieve the necessary amount of mechanical stability without impairing the natural biology (callus formation).The distal tibia is covered only by a very thin layer of soft tissue, so that the treatment of distal tibial fractures is demanding, and complications occur frequently. The fractures are often displaced, so that surgical treatment is inevitable.

Primary definitive osteosynthesis is quite dangerous because of the difficult soft-tissue situation. The timing of surgery should be optimized to allow the soft tissues to stabilize and to minimize the severe postoperative wound problems often associated with the surgical management of these complex fractures. Locking plates have the biomechanical properties of internal and external fixators, with superior holding power because of fixed angular stability through the head of locking screws, independent of friction fit. Minimally invasive plating

techniques reduce iatrogenic soft tissue injury and damage to bone vascularity, in addition to preserving the osteogenic fracture hematoma. Primary stabilisation with external fixation is much safer where soft tissue is extensively damaged. Concomitant fibular fractures should be stabilized with a plate as early as possible, thereby increasing the stability of the tibial reduction, facilitating achieving the correct alignment of the tibia, and preventing a loss of the limb length, as we can show in our patients. We had 20 fibula fractures out of the 21 patients, out of which 6 were fixed. Though we did not have any clinical deformities and the functional outcome was excellent, there was 10 degrees of varus in one and 10 degrees of recurvatum in one. Both the patients belonged to the group where the fibula was not fixed. The choice of fibular fixation in our study group was based on the level of fracture and the amount of displacement. Syndesmotic fractures were fixed. If the primary treatment can be done correctly with a good axis alignment and sufficient stability, time is gained for the treatment of additional soft-tissue trauma.

There are also alternatives to treatment with MIPPO. An external fixator can be used for the definitive treatment, possibly in combination with a cancellous bone graft in cases of trouble in fracture healing. If the fracture does not heal completely, mobilisation in a cast can be necessary after removal of the external fixation for a certain time. But, there are disadvantages like pin tract infection. In adolescents external fixation is a successful treatment option for tibial fractures. In the elderly, fracture healing takes a longer time, especially if there is associated significant soft-tissue damage. The stability of the external fixator is nonetheless not sufficient for early full weight-bearing, and the compression on the fracture is very limited, so that many cases with long treatment periods and only partial bony healing are seen.

Bridging plate osteosynthesis permits micromotion between the individual fragments, where by the healing process is stimulated, by the formation of callus. The implant selected must be of adequate length to achieve bridging of the fracture site. It is important that a certain length remains free of screws (unoccupied plate holes) so that the osteosynthesis is more tolerant towards fatigue failure due to the lack of point-contact tension peaks. We preferred to use lengthier plates with minimal cortical purchases. We also had a criterion of having minimal of 4 cortical purchases on either sides of the fracture. In the osteosynthesis we performed, at least three holes at the fracture site were always left unoccupied by screws; plate failure did not occur in any of our cases.

The slide-insertion technique has not been applied previously to the distal tibia where only the medial aspect is suitable for subcutaneous slide-insertion of a plate. Since there is no muscle cover, it has been regarded as a dangerous procedure that would create too much tension in the sensitive cutaneous mantle. Nevertheless, despite bridging plate osteosynthesis and careful attention to the soft tissues, ankle stiffness and/or delayed unions were observed in 3 of 21 patients which united at 30 weeks. An analysis of these cases revealed a common aetiological factor which was A3, B3 and C3 in AO/OTA '43', and old age with associated injuries. We did not experience any infection or skin breakdown during our study. Fracture reduction may be more difficult than with open wounds. As a consequence of this, the surgeon depends on intraoperative fluoroscopy to confirm that an adequate reduction has been achieved before positioning the locking plate. In periarticular fractures, additional incisions may be needed to visualize and assess the joint surface to ensure that

the articular surfaces are anatomically aligned. The cost of the locking plates, the technically demanding procedure, and the increased exposure to radiation required to perform the procedure have to be considered when comparing the efficacy of this device with that of normal plates.

Conclusion

Minimally invasive locking plate osteosynthesis aims to reduce surgical tissue trauma and help preserve the periosteal vascular integrity and osteogenic fracture haematoma. We have strived to use this as a biomechanically sound method of biological plating for treating closed and open, peri-articular fractures of the distal tibia, an area associated with significant complication rates and which continues to provide a management challenge to the trauma surgeon. Based on our study, good and excellent results were obtained in 90% of the cases. Two fair results were attributed to the crushing nature of the injury in one patient and old age with delayed union in another. Subjects in whom the fibula was fixed did not have any angulation at union. Ankle stiffness was attributed to old age, diabetes, associated injuries and intra-articular fractures which will improve with early mobilization and physiotherapy.

We thus conclude that the use of locking compression plate for intra and extra articular fractures of the distal tibia through minimally invasive technique along with fibular fixation is safe and effective.

References

1. Egol KA, Kubiak EN, Fulkerson E, Kummer FJ, Koval KJ. Biomechanics of locked plates and screws. *J Orthop Trauma*. 2004;18(8):488-93.
2. Wagner M. General principles for the clinical use of the LCP. *Injury* 2003;34(2):B31-42.
3. Paul M, Morin Rudolf Reindl, Edward J. Harvey, Lorne Beckman, and Thomas Steffen. Fibular fixation as an adjuvant to tibial intramedullary nailing in the treatment of combined distal third tibia and fibula fractures: a biomechanical investigation. *Can J Surg* 2008;51(1):45-50.
4. Strauss EJ, Alfonso D, Kummer FJ, Egol KA, Tejwani NC. 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(3):172-7.
5. Varsalona R, Liu GT. Distal tibial metaphyseal fractures: the role of fibular fixation. *Strategies Trauma Limb Reconstr* 2006;1(1):42-50.
6. Helfet DL, Shonnard PY, Levine D, Borrelli J Jr. Minimally invasive plate osteosynthesis of distal fractures of the tibia. *Injury* 1997;28:A42-8.
7. Asheesh Bedi MD, Toan Le T, Madhav A MD. Karunakar MD. Surgical Treatment of Nonarticular Distal Tibia Fractures. *J Am Acad Orthop Surg* 2006;14(7):406-416.
8. Hazarika S, Chakravarthy J, Cooper J. Minimally invasive locking plate osteosynthesis for fractures of the distal tibia--results in 20 patients. *Injury* 2006;37(9):877-87. Epub 2006 Aug 8.
9. Sheerin DV, Turen CH, Nascone JW. Reconstruction of distal tibia fractures using a posterolateral approach and a blade plate. *J Orthop Trauma* 2006;20(4):247-52.
10. Webb J, McMurtry I, Port A, Liow R. Fractures of the distal tibia: functional outcome following minimally invasive locking plate osteosynthesis. *J Bone Joint Surg*

- Br 2007;94-B:IV-90.
11. Manninen MJ, Lindahl J, Kankare J, Hirvensalo E. Lateral approach for fixation of the fractures of the distal tibia. Outcome of 20 patients. *Arch Orthop Trauma Surg* 2007;127:349-53.
 12. Kasper Janssen W, Jan Biert, Albert van Kampen. Treatment of distal tibial fractures: plate versus nail. A retrospective outcome analysis of matched pairs of patients. *Int Orthop* 2007;31(5):709-714.
 13. Hong Gao MD, Chang-Qing Zhang MD, PhD Cong-Feng Luo MD, PhD Zu-Bin Zhou, MD Bing-Fang Zeng MD. Fractures of the Distal Tibia Treated with Polyaxial Locking Plating. *Clin Orthop Relat Res* 2009;467(3):831-837.
 14. Lau TW, Leung F, Chan CF, Chow SP. Wound complication of minimally invasive plate osteosynthesis in distal tibia fractures. *Int Orthop* 2008;32(5):697-703.
 15. Sreevathsa Boraiah MD, Michael Gardner J, MD David L, Helfet MD, Dean Lorich G MD. High Association of Posterior Malleolus Fractures with Spiral Distal Tibial Fractures. *Clin Orthop Relat Res* 2008;466(7):1692-1698.
 16. Hong Gao MD, Chang-Qing Zhang MD, PhD Cong-Feng Luo, MD PhD Zu-Bin, Zhou MD, and Bing-Fang Zeng, MD. Fractures of the Distal Tibia Treated with Polyaxial Locking Plating. *Clin Orthop Relat Res* 2009;467(3):831-837.
 17. Abid Mushtaq, Rizwan Shahid, Muhammad Asif, Mohammad Maqsood. Distal Tibial Fracture Fixation with Locking Compression Plate (LCP) Using the Minimally Invasive Percutaneous Osteosynthesis (MIPO) Technique. *European Journal of Trauma and Emergency Surgery* 2009;35(2):159-164.
 18. Mathieu Assal, Richard Stern. Surgical Management of Distal Tibial Fractures in Adults. *European Instructional Lectures. European Federation of National Associations of Orthopaedics and Traumatology* 2009;9:97-112.
 19. Maximilian Faschingbauer, Benjamin Kienast, Arndt P Schulz, Rudolf Vukelic, Jan Meiners. Treatment of Distal Lower Leg Fractures: Results with Fixed-Angle Plate Osteosynthesis. *Eur J Trauma Emerg Surg* 2009;35(6):513-519.
 20. Mario Ronga MD, Chezhiyan Shanmugam MD, Umile Giuseppe Longo MD, Francesco Oliva MD, PhD, Nicola Maffulli MD. Minimally Invasive Osteosynthesis of Distal Tibial Fractures Using Locking Plates. *Orthopedic Clinics of North America. October* 2009;40(4):499-504.
 21. Yih-Shiunn Lee MD, Shih-Hao Chen MD, Jen-Ching Lin MD, Yun-O Chen MD, Chien-Rae Huang MD. Surgical Treatment of Distal Tibia Fractures: A Comparison of Medial and Lateral Plating. *Orthopedics* 2009;32(3):163.
 22. Feng Chen Kao, Yuan Kun Tu, Kuo Yao Hsu, Chin Hsien Wu, Cheng-Yo Yen, Ming Chih Chou. Treatment of distal tibial fractures by minimally invasive percutaneous plate osteosynthesis of three different plates: Results and cost-effectiveness analysis. *Formosan Journal of Musculoskeletal Disorders* 2010;1(1):35-40.
 23. Pierre Joveniaux, Xavier Ohl, Alain Harisboure, Aboubekr Berrichi, Ludovic Labatut, Patrick Simon. Distal tibia fractures: management and complications of 101 cases. *Int Orthop* 2010;34(4):583-588.
 24. Rakesh Gupta K, Rajesh Kumar Rohilla, Kapil Sangwan, Vijendra Singh, and Saurav Walia. Locking plate fixation in distal metaphyseal tibial fractures: series of 79 patients. *Int Orthop* 2010;34(8):1285-1290.
 25. Michael Clare P, Roy W. Sanders. Percutaneous ORIF of Periarticular Distal Tibia Fractures. *Minimally Invasive Surgery in Orthopedics* 2010;515-522.
 26. Jiayuan Hong MD, Rongming Zeng MD, Dasheng Lin MD, Linxin Guo MD, Liangqi Kang MD, Zhenqi Ding MD. Posteromedial Anatomical Plate for the Treatment of Distal Tibial Fractures with Anterior Soft Tissue Injury. *Orthopedics* 2011;34(6):161-166.
 27. Shrestha D, Acharya BM, Shrestha PM. Minimally invasive plate osteosynthesis with locking compression plate for distal diaphyseal tibia fracture. *Kathmandu Univ Med J* 2011;9(34):62-8.
 28. Wang Cheng, Ying Li, Wang Manyi. Comparison study of two surgical options for distal tibia fracture-minimally invasive plate osteosynthesis vs. open reduction and internal fixation. *Int Orthop* 2011;35(5):737-742.
 29. Mudassar Ahmad, Alagappan Sivaraman, Amarjit Rai, Amratlal Patel. Percutaneous locking plates for fractures of the distal tibia: our experience and a review of the literature. *J bone joint surg br* 2012;94-b:519.
 30. Bonner TJ, Green SM, McMurty IA. A biomechanical comparison of different screw configurations in distal tibial locking plates. *J bone joint surg br* 2012;94-b:20.
 31. Hosangadi N, Shetty K, Nicholl J, Singh B. Tibial locking plates for fractures of distal tibia using mipo technique – Results & complications. *J bone joint surg. br* 2012;94-b:18.