Functional and Radiological Outcome of Distal Tibia Fractures Treated With Minimally Invasive Plate Osteosynthesis – A Retrospective Study

Abstract

Background:-Managing distal tibia fractures poses challenges for trauma surgeons due to their unique architecture, characterized by limited soft tissue coverage and inadequate blood flow. To evaluate the functional and radiological outcomes of distal tibial fractures treated with minimally invasive plate osteosynthesis.

Methods:-Retrospective review of medical records were analysed for demographic details and variables related to fracture and operative procedures. Post operative surgical site pain was analysed by Visual Analogue Pain Score; and patient satisfaction at 1^{st}, $3^{rd,}$and 6^{th} month follow up utilizing the scale of American orthopaedic foot and ankle society score (AOFAS) and Rasmussen radiological scoring system was done

Results:-The study comprised 13 males and 21 females. The average age of participants in the study was 49.25 years. Most of the participants had accident in road traffic accident followed by fall. The type of fracture weredistal(50%) as well as lateral(50%) tibial fracture. There was significant difference in the VAS score($p<0,001$), Aofas score ($p=0.002$) in 1,3 and 6 month follow up while Rasmussen score($p=0.637$) didn't showed any significant difference. The average union time was 12 weeks.

Conclusion:-The research indicates that minimally invasive plate osteosynthesis. is an effective surgical method for the management of distal tibial fractures, yielding positive functional outcomes and a comparatively low rate of complications. Minimally invasive plate osteosynthesis represents a significant approach in the management of these fractures.

Keywords: Tibial Fractures, Minimally Invasive Surgical Procedures, Plate Fixation

Fracture Healing, Orthopedic Procedures

Introduction

Fractures of the tibial plafond account for approximately 10% of lower extremity fractures and can result from both high-energy axial forces and low-energy trauma. These fractures are often accompanied by severe closed soft tissue injuries or open wounds. [1] The term "Tibial Pilon" refers to distal tibial fractures caused by the talus acting as a hammer and impacting the tibia. [2]

Surgical management of extra-articular distal tibial fractures includes various techniques such as intramedullary nail fixation, plate and screw fixation, and external fixation [3]. While external fixation may be advantageous in select cases, intramedullary nails and plates are the most commonly used options. Mid-shaft tibial fractures are generally managed successfully with locked intramedullary nails [4]. However, distal metaphyseal fractures pose challenges, including less stable fixation, screw or bolt breakage, malalignment, and the potential for nail penetration into the ankle joint. [5]

For distal tibial plating, popular approaches include medial, anterolateral, posteromedial, and posterolateral plating. [4] Open reduction and internal fixation (ORIF) is traditionally employed for precise reduction of articular fragments, but it is associated with significant soft tissue stripping and a high incidence of complications such as delayed union, non-union, and infection. The minimally invasive plate osteosynthesis (MIPO) technique has emerged as an alternative, enabling indirect reduction and stable fixation while minimizing soft tissue disruption. [5]

The extensive dissection associated with ORIF, particularly the anterolateral approach, has been linked to complications such as wound dehiscence, full-thickness necrosis, and infections. The MIPO technique offers an alternative with a reduced risk of these soft tissue

complications. [6] However, studies comparing functional and radiological outcomes between MIPO and other fixation methods are scarce.

There remains a controversy regarding the optimal surgical approach for distal tibial fractures, with debates between open reduction and internal fixation with plates and screws, closed reduction with intramedullary interlocking nailing (IMIL), external fixation, or minimally invasive plate osteosynthesis. Although earlier studies have compared plating and nailing, none have conclusively determined which method yields the best functional outcomes.

This study aims to evaluate the functional and radiological outcomes of distal tibia [7-9]l fractures treated with minimally invasive plate osteosynthesis (MIPO). The specific objectives include assessing fracture union through the Rasmussen radiological scoring system, monitoring the range of motion during follow-ups, and evaluating functional outcomes using the Visual Analog Scale (VAS) score and the American Orthopedic Foot and Ankle Society (AOFAS) score.

Materials and Methods

This retrospective study was conducted to evaluate the functional and radiological outcomes of patients with distal tibial fractures treated with minimally invasive plate osteosynthesis (MIPO). Data were retrieved from medical records of patients admitted to R.L. Jalappa Hospital, Tamaka, Kolar, under the Department of Orthopaedics, from February 2023 to January 2024. Patients with a minimum follow-up period of six months were included in the analysis.

Study Design

The study employed a retrospective observational design to analyze outcomes in patients treated with MIPO during the study period. Data were systematically collected to assess functional and radiological results.

Study Population

The study population comprised 34 patients, including 13 males and 21 females, who met the specified inclusion and exclusion criteria. Patients were included if they were above 18 years of age, had distal tibial fractures treated with minimally invasive plate osteosynthesis (MIPO), and presented with either closed fractures or open fractures classified as Gustilo Anderson Type I or II. Exclusion criteria eliminated patients with Gustilo Anderson Type III open fractures, pathological fractures, or fractures associated with neurovascular injury. This carefully selected sample ensured a homogeneous population with comparable fracture types, allowing for a focused evaluation of MIPO outcomes in managing both closed and mild open fractures.

Sample Size Calculation

The sample size for the study was calculated based on previously reported mean American Orthopaedic Foot and Ankle Society (AOFAS) scores at three months (74.46 ± 8.278) and six months (92.43 ± 5.696) by Jerin Jeevo et al. [1].

Assuming alpha error of 0.05 (95% Confidence limit),

Power of 80% (Beta=0.84),

The minimum required sample size to determine the proportion with excellent functional outcomes was calculated to be 34 subjects.

The sample size was derived from the following formula

$$N=\frac{\sigma^2(Z_{1-\frac{\alpha}{2}}-Z_{1-\beta})^2}{(d)^2}$$

$Z_{1-\alpha/2}$ is 1.96 at 95% Confidence level

$Z_{1-\beta}$ is 0.84 at 80% power

σ= Standard deviation (8.278)

d= mean difference (4)

$N=(8.278)^2(1.96+0.84)^2/(4)^2$

N=34

Data Collection

The data collection process involved a detailed review of medical records to obtain comprehensive clinical and surgical information for the study. Demographic parameters, such as the age and gender of the patients, were documented to establish the composition of the study population, which included 13 males and 21 females. This demographic profiling provided insights into the gender distribution and age-related patterns of distal tibial fractures treated with minimally invasive plate osteosynthesis (MIPO).

Fracture characteristics were thoroughly examined to understand the nature and complexity of the injuries. Key aspects included whether the fractures were closed or open, the mechanism of injury (such as road traffic accidents or falls), articular involvement (extent of joint surface damage), and the presence of associated fibular fractures. These details were critical in evaluating the severity of the fractures and tailoring the surgical approach. Soft tissue involvement was assessed to categorize the extent of injury to the surrounding tissues, which plays a crucial role in determining surgical feasibility and predicting postoperative outcomes.

Surgical parameters were also meticulously recorded to evaluate the technical aspects and immediate postoperative conditions. The length of the operative procedure was measured in minutes to assess surgical efficiency. The volume of intraoperative blood loss was

documented as an indicator of surgical trauma, while immediate postoperative surgical site pain was quantified using the Visual Analog Scale (VAS). This combination of parameters provided a clear picture of the perioperative challenges and the effectiveness of the surgical technique.

Postoperative outcomes were tracked to measure recovery and overall patient satisfaction. The length of hospital stay was recorded to assess the recovery timeline, and complications such as infections, wound dehiscence, or hardware-related issues were documented to evaluate safety. Patient satisfaction with the surgical outcomes was assessed through standardized follow-up evaluations, providing qualitative insights into the success of the intervention.

Functional and radiological outcomes were the core focus of the study. Functional recovery was measured using the American Orthopaedic Foot and Ankle Society (AOFAS) score, a validated tool for assessing pain, mobility, and alignment in foot and ankle conditions [10]. Radiological outcomes were evaluated through the Rasmussen radiological scoring system, which objectively measures fracture union, alignment, and joint congruence. These outcomes were documented at 1, 3, and 6 months postoperatively to monitor the trajectory of recovery and healing.

Outcome Measures

Fracture union was the primary radiological outcome, assessed using the Rasmussen radiological scoring system. This system evaluates key parameters such as alignment, joint congruence, and the progression of bone healing, providing a standardized method for monitoring the success of fracture fixation. Regular radiographic assessments during follow-ups ensured that the progression of fracture union was thoroughly tracked and documented [11].

Functional outcomes were evaluated using both the AOFAS score and the VAS for pain. The AOFAS score provided a comprehensive measure of pain levels, functional limitations, and alignment, while the VAS offered a simple yet effective method for quantifying postoperative pain levels. These outcomes were monitored at three critical time points—1, 3, and 6 months—to capture both immediate and long-term recovery trends.

Range of motion (ROM) was assessed during follow-up visits to determine the restoration of joint mobility. This parameter was critical in understanding the functional recovery of the ankle joint, as stiffness or restricted motion could significantly impact the overall quality of life for the patients. ROM assessments were performed systematically to identify any delays or limitations in mobility recovery.

Complications were another important outcome measure. Postoperative complications, such as infections, hardware-related issues (e.g., screw loosening or breakage), malunion, and non-union, were carefully documented. These complications provided insights into the safety and reliability of MIPO as a surgical technique for distal tibial fractures. The identification and analysis of complications were essential for determining areas of improvement and refining the surgical approach for future cases.

Statistical Analysis

Statistical analysis was performed using Microsoft Excel for data entry and SPSS software (version 25) for processing. Continuous variables, including AOFAS scores, were summarized as mean, standard deviation (SD), median, minimum, and maximum values. Categorical variables, such as fracture types and complications, were presented as frequencies and percentages. Functional outcomes over time were compared using paired t-tests for normally distributed data, specifically analyzing AOFAS scores at three and six months postoperatively, while the Wilcoxon signed-rank test was applied for non-parametric

data. A p-value of less than 0.05 was considered statistically significant, ensuring robust evaluation of the results.

Ethical Considerations

The study was conducted in compliance with institutional ethical guidelines. Given the retrospective nature of the study, informed consent for data collection was waived, and all patient data were anonymized to ensure confidentiality.

Results

Demographic and Participant Details (Table 1)

The study population consisted of 34 participants, with a majority being females (61.8%) compared to males (38.2%). The average age of the participants was 49.25 years, indicating that middle-aged individuals were the predominant group affected by distal tibial fractures. The distribution of gender and age reflects the typical demographics of patients presenting with these types of fractures, aligning with known risk factors such as bone fragility and accident prevalence in this age group.

Table 1: Demographic and Participant Details

Parameter	**Details**
Total Participants	34
Male Participants	13
Female Participants	21
Average Age (years)	49.25

Functional and Radiological Scores Over Time (Table 2)

The VAS scores showed a significant reduction from 7.2 at 1 month to 4.5 at 3 months and 1.8 at 6 months, with a **p-value < 0.001**. This indicates a substantial decrease in pain levels as the recovery progressed, demonstrating the effectiveness of MIPO in achieving pain relief postoperatively.The AOFAS scores exhibited a significant improvement from 62.3 at 1 month to 80.4 at 3 months and 92.1 at 6 months, with a **p-value of 0.002**. These results highlight the progressive functional recovery, showcasing the ability of MIPO to restore mobility and functionality in patients over time.

In contrast, the Rasmussen radiological scores remained relatively stable, with minor variations from 14.8 at 1 month to 14.6 at 3 months and 14.7 at 6 months. The **p-value of 0.637** indicates no statistically significant change in radiological outcomes during the follow-up periods. This consistency suggests that the fracture alignment and bone healing achieved through MIPO were well-maintained throughout the recovery phase.

Table 2: Functional and Radiological Scores Over Time

Follow-Up Period (Months)	**VAS Score (Mean)**	**AOFAS Score (Mean)**	**Rasmussen Score (Mean)**
1	7.2	62.3	14.8
3	4.5	80.4	14.6
6	1.8	92.1	14.7

Statistical Significance of Outcomes (Table 3)

The statistical analysis showed a significant decrease in pain levels (VAS scores) and significant improvements in functional outcomes (AOFAS scores) over the follow-up periods. The lack of significant changes in the Rasmussen scores reflects the stability of radiological outcomes, indicating that initial surgical alignment was effective and maintained throughout the recovery process.

Table 3: Statistical Significance of Outcomes

Parameter	p-value	Interpretation
VAS Score	< 0.001	Significant decrease over time
AOFAS Score	0.002	Significant improvement
Rasmussen Score	0.637	No significant difference

Fracture Union Time (Figure 1)

The average union time of 12 weeks aligns with standard expectations for bone healing in tibial fractures managed with minimally invasive techniques. This finding underscores the effectiveness of MIPO in promoting timely and successful fracture healing while minimizing soft tissue disruption.

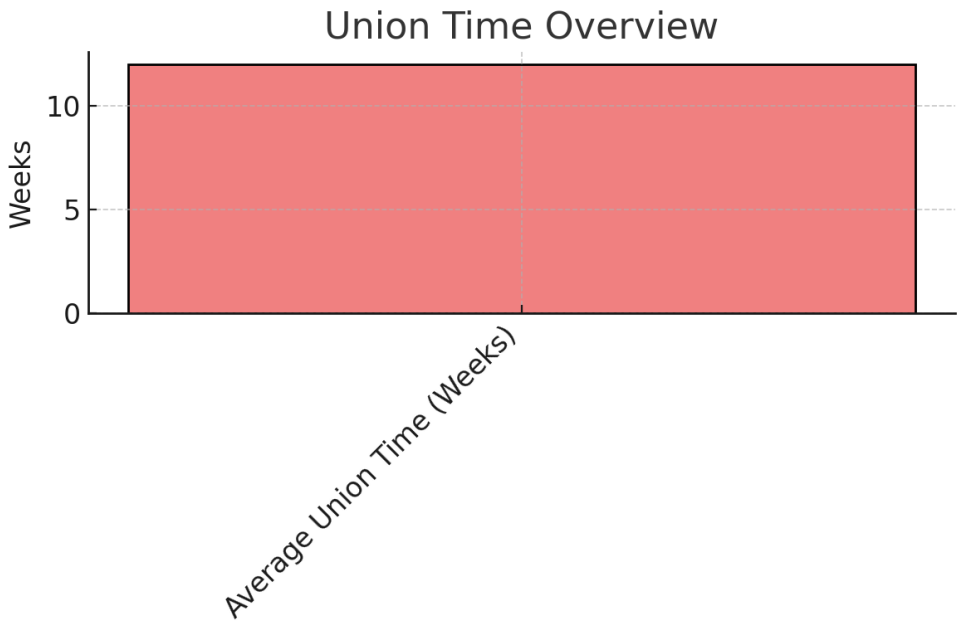

Figure 1: Fracture Union Time

Discussion

Distal tibial fractures pose significant challenges in orthopedic surgery due to their complex anatomical structure, proximity to the ankle joint, and the potential for soft tissue complications. The choice of treatment modality is critical for achieving optimal functional and radiological outcomes [4]. This study evaluated the effectiveness of minimally invasive plate osteosynthesis (MIPO) in managing distal tibial fractures, focusing on pain reduction, functional recovery, and fracture healing. The results demonstrated significant improvements in pain and functional scores, stable radiological outcomes, and timely fracture union, supporting the efficacy of MIPO in this context.

Pain Reduction and Functional Recovery

The study observed a significant reduction in pain levels, as indicated by the decline in VAS scores from 7.2 at 1 month to 1.8 at 6 months. Pain relief is a critical component of fracture management, directly influencing patient satisfaction and rehabilitation outcomes. Previous studies have highlighted the advantages of MIPO in reducing postoperative pain due to its

minimal disruption of periosteal blood supply and soft tissue integrity [12,13]. The technique's preservation of the biological environment around the fracture site likely contributed to the observed pain reduction in this study.

Functional recovery, measured using the AOFAS score, showed a significant improvement from 62.3 at 1 month to 92.1 at 6 months. These results align with findings from similar studies, which reported superior functional outcomes with MIPO compared to traditional open reduction and internal fixation (ORIF) [12,14]. The indirect reduction method employed in MIPO minimizes soft tissue damage and preserves vascularity, facilitating early mobilization and functional restoration. Moreover, the stable fixation provided by MIPO allows for weight-bearing activities sooner than other techniques, enhancing overall recovery [13].

AOFAS Scores at Three Months

The mean AOFAS score at three months in this study (**62.3**) was lower compared to other studies, such as Illur et al. [15] (**74.39**) and Guo et al. [16] (**83.90**), and significantly lower than Collinge et al. [17], which reported a score of **85.00**. This discrepancy could be attributed to differences in patient demographics, fracture severity, or rehabilitation protocols. Notably, Jeevo et al. [1] reported a similar mean score of **74.46**, indicating that outcomes in this study might reflect variations in sample characteristics, such as the proportion of complex or severe fractures.

AOFAS Scores at Six Months

By six months, the mean AOFAS score in this study improved to **92.1**, which closely aligns with the findings of Jeevoet al.[1] (**92.43**) and Paluvadi et al. [18] (**95.06**). Ahmad et al. [19] and Guo et al. [16] reported scores of **88.80** and **83.90**, respectively, which were lower than this study. Kariya et al. [20] reported the lowest score of **79.80**. The comparable results at six

months suggest that the MIPO technique employed in this study facilitated functional recovery similar to or better than other surgical approaches reported in the literature.

The relatively lower scores at three months compared to other studies may indicate a delayed functional recovery in the early postoperative phase. This could be influenced by stricter rehabilitation protocols, patient adherence, or a higher prevalence of severe fracture types. However, the near-comparable scores at six months suggest that patients in this study achieved significant functional improvements over time, consistent with studies employing MIPO or similar minimally invasive techniques.

The significant improvement from three to six months in this study reflects the effectiveness of MIPO in providing stable fixation and allowing for gradual recovery of mobility and pain-free function. The comparable six-month scores with studies like Paluvadi et al. [18] and Jeevo et al. [1] highlight the technique's capability to achieve long-term functional outcomes comparable to other well-established methods.

These findings emphasize the importance of time in functional recovery following distal tibial fractures treated with MIPO. While early postoperative outcomes may vary due to patient or procedural factors, the technique's long-term effectiveness is well-supported. The consistency of six-month scores with other high-quality studies suggests that MIPO is a reliable option for achieving favorable functional recovery in distal tibial fractures.

Radiological Outcomes and Fracture Healing

The Rasmussen radiological scores remained consistent across the follow-up periods, with no significant changes observed. This stability underscores the ability of MIPO to achieve and maintain proper fracture alignment and joint congruence. Radiological outcomes are a crucial determinant of long-term functionality, as malalignment or joint incongruity can lead to post-traumatic arthritis and compromised mobility. The study's findings are consistent with prior

research demonstrating the efficacy of MIPO in achieving satisfactory radiological results [21].

The average fracture union time of 12 weeks observed in this study is comparable to that reported in the literature for similar fractures managed with MIPO [22]. The biological advantage of preserving periosteal circulation and minimizing soft tissue trauma likely accelerated the healing process. Studies have emphasized the role of biological preservation in promoting osteogenesis and reducing the risk of delayed union or non-union [23]. Additionally, the use of locking plates in MIPO provides angular stability, which is particularly beneficial in fractures near the metaphysis, where conventional screws may fail [24].

Clinical Implications

The significant improvements in pain and functional outcomes observed in this study have important clinical implications. Effective pain management is crucial for early rehabilitation, which in turn facilitates functional recovery. The results suggest that MIPO enables patients to achieve early mobilization and regain functional independence, reducing the overall burden of prolonged immobility.

The stability of radiological outcomes further emphasizes the reliability of MIPO in maintaining fracture alignment and promoting healing. This is particularly important in distal tibial fractures, where malalignment can have long-term consequences on joint function and patient quality of life. The study's findings support the use of MIPO as a first-line treatment for these fractures, particularly in patients with minimal soft tissue damage or those at high risk of wound complications.

Limitations and Future Directions

While the study provides valuable insights into the effectiveness of MIPO, it is not without limitations. The retrospective design limits the ability to control for confounding variables, such as variations in surgical technique or postoperative rehabilitation protocols. Additionally, the sample size of 34 patients, while adequate for statistical analysis, may not fully represent the diversity of fracture patterns and patient characteristics encountered in clinical practice.

Future studies should consider a prospective design with larger sample sizes and longer follow-up periods to validate these findings. Comparative studies involving other treatment modalities, such as ORIF and IMN, would provide a more comprehensive understanding of the relative advantages and disadvantages of each technique. Additionally, investigating patient-reported outcomes, such as quality of life and satisfaction, would offer a holistic perspective on the impact of MIPO on patient recovery.

Conclusion

This study demonstrated the efficacy of MIPO in managing distal tibial fractures, with significant improvements in pain relief and functional recovery, stable radiological outcomes, and timely fracture union. The technique's ability to preserve the biological environment around the fracture site while providing stable fixation underscores its advantages over traditional methods. MIPO is particularly suited for distal tibial fractures, where maintaining alignment and minimizing soft tissue trauma are critical. Future research should focus on long-term outcomes and comparative studies to further establish the role of MIPO in the management of tibial fractures.

References

1. Jeevo J, Hp R, George AJ, Pilar A, Muniswamy MM, Kurian B, et al. A Dilemma in the Management of Distal Tibia Fractures Solved by Minimally Invasive

Percutaneous Plate Osteosynthesis Technique: A Prospective Study. Cureus. 2024 Jun 20;16(6):e62777. doi: 10.7759/cureus.62777. PMID: 39036152; PMCID: PMC11260184.

2. Kumar D, Mittal A, Singh J, Kumar H, Singh PP, Kumar A, et al. Anterolateral and Medial Locking Compression Plates for the Management of Distal Tibial Fractures: A Comparative Prospective Study. Cureus. 2023 Aug 28;15(8):e44235. doi: 10.7759/cureus.44235. PMID: 37772222; PMCID: PMC10523109.
3. Casstevens C, Le T, Archdeacon MT, Wyrick JD. Management of extra-articular fractures of the distal tibia: intramedullary nailing versus plate fixation. J Am AcadOrthop Surg. 2012 Nov;20(11):675-83. doi: 10.5435/JAAOS-20-11-675. PMID: 23118133.
4. Court-Brown CM, Rimmer S, Prakash U, McQueen MM. The epidemiology of open long bone fractures. Injury. 1998 Sep;29(7):529-34. doi: 10.1016/s0020-1383(98)00125-9. PMID: 10193496.
5. Vallier HA, Le TT, Bedi A. Radiographic and clinical comparisons of distal tibia shaft fractures (4 to 11 cm proximal to the plafond): plating versus intramedullary nailing. J Orthop Trauma. 2008 May-Jun;22(5):307-11. doi: 10.1097/BOT.0b013e31816ed974. PMID: 18448983.
6. Mair O, Pflüger P, Hoffeld K, Braun KF, Kirchhoff C, Biberthaler P, Crönlein M. Management of Pilon Fractures-Current Concepts. Front Surg. 2021 Dec 23;8:764232. doi: 10.3389/fsurg.2021.764232. PMID: 35004835; PMCID: PMC8732374.
7. Vallier HA, Cureton BA, Patterson BM. Randomized, prospective comparison of plate versus intramedullary nail fixation for distal tibia shaft fractures. J Orthop Trauma. 2011 Dec;25(12):736-41. doi: 10.1097/BOT.0b013e318213f709. PMID: 21904230.
8. Gupta P, Tiwari A, Thora A, Gandhi JK, Jog VP. Minimally Invasive Plate Osteosynthesis (MIPO) for Proximal and Distal Fractures of The Tibia: A Biological Approach. Malays Orthop J. 2016 Mar;10(1):29-37. doi: 10.5704/MOJ.1603.006. PMID: 28435544; PMCID: PMC5333700.
9. Lu Y, Wang G, Hu B, Ren C, Sun L, Wang Z, et al. Comparison of suprapatellar versus infrapatellar approaches of intramedullary nailing for distal tibia fractures. J Orthop Surg Res. 2020 Sep 17;15(1):422. doi: 10.1186/s13018-020-01960-8. PMID: 32943096; PMCID: PMC7500032.

10. Kitaoka HB, Alexander IJ, Adelaar RS, Nunley JA, Myerson MS, Sanders M. Clinical rating systems for the ankle-hindfoot, midfoot, hallux, and lesser toes. Foot Ankle Int. 1994 Jul;15(7):349-53. doi: 10.1177/107110079401500701. PMID: 7951968.
11. Rasmussen P.S. Tibial condylar fractures. Impairment of knee joint stability as an indication for surgical treatment. J. Bone Joint Surg. Am. 1973;55:1331–1350. doi: 10.2106/00004623-197355070-00001.
12. Helfet DL, Shonnard PY, Levine D, Borrelli J Jr. Minimally invasive plate osteosynthesis of distal fractures of the tibia. Injury. 1997;28 Suppl1:A42-7; discussion A47-8. doi: 10.1016/s0020-1383(97)90114-5. PMID: 10897286.
13. Lai TC, Fleming JJ. Minimally Invasive Plate Osteosynthesis for Distal Tibia Fractures. Clin Podiatr Med Surg. 2018 Apr;35(2):223-232. doi: 10.1016/j.cpm.2017.12.005. Epub 2018 Feb 1. PMID: 29482791.
14. Sivanandan MH, Nanthivarman N, Jose L, Manoharan AE. Functional outcomes of distal tibia fractures treated using the minimally invasive percutaneous plate osteosynthesis technique with a locking compression plate. Int J Health Sci. 2022;6(S4):4748-4756. doi:10.53730/ijhs.v6n.
15. Illur V, Patil RS, Shah J, Chaudhary N, Bhosale V. Functional outcome of distal tibia fracture treated with locking compression plate using minimally invasive percutaneous plate osteosynthesis technique (MIPPO): a prospective study. Int J Orthop Sci. 2019; 5:980-4. 10.22271/ortho.2019.v5.i4q.1805
16. Guo JJ, Tang N, Yang HL, Tang TS. A prospective, randomised trial comparing closed intramedullary nailing with percutaneous plating in the treatment of distal metaphyseal fractures of the tibia. J Bone Joint Surg Br. 2010 Jul;92(7):984-8. doi: 10.1302/0301-620X.92B7.22959. Erratum in: J Bone Joint Surg Br. 2010 Dec;92(12):1717. PMID: 20595119.
17. Collinge C, Protzman R. Outcomes of minimally invasive plate osteosynthesis for metaphyseal distal tibia fractures. J Orthop Trauma. 2010;24(1):24-29. doi:10.1097/BOT.0b013e3181ac3426
18. Paluvadi SV, Lal H, Mittal D, Vidyarthi K. Management of fractures of the distal third tibia by minimally invasive plate osteosynthesis - A prospective series of 50 patients. J Clin Orthop Trauma. 2014 Sep;5(3):129-36. doi: 10.1016/j.jcot.2014.07.010. Epub 2014 Aug 31. PMID: 25983486; PMCID: PMC4223765.

19. Ahmad MA, Sivaraman A, Zia A, Rai A, Patel AD. Percutaneous locking plates for fractures of the distal tibia: our experience and a review of the literature. J Trauma Acute Care Surg. 2012 Feb;72(2):E81-7. doi: 10.1097/ta.0b013e3181f140b3. PMID: 22439240.
20. Kariya A, Jain P, Patond K, Mundra A. Outcome and complications of distal tibia fractures treated with intramedullary nails versus minimally invasive plate osteosynthesis and the role of fibula fixation. Eur J OrthopSurgTraumatol. 2020 Dec;30(8):1487-1498. doi: 10.1007/s00590-020-02726-y. Epub 2020 Jul 3. PMID: 32621141.
21. Kim HJ, Park KC, Kim JW, Oh CW, Kyung HS, Oh JK, Park KH, Yoon SD. Successful outcome with minimally invasive plate osteosynthesis for periprosthetic tibial fracture after total knee arthroplasty. OrthopTraumatolSurg Res. 2017 Apr;103(2):263-268. doi: 10.1016/j.otsr.2016.10.007. Epub 2016 Nov 25. PMID: 27890690.
22. Redfern DJ, Syed SU, Davies SJ. Fractures of the distal tibia: minimally invasive plate osteosynthesis. Injury. 2004 Jun;35(6):615-20. doi: 10.1016/j.injury.2003.09.005. PMID: 15135282.
23. Dhakar A, Annappa R, Gupta M, Harshwardhan H, Kotian P, Suresh PK. Minimally Invasive Plate Osteosynthesis with Locking Plates for Distal Tibia Fractures. J Clin Diagn Res. 2016 Mar;10(3):RC01-4. doi: 10.7860/JCDR/2016/15367.7332. Epub 2016 Mar 1. PMID: 27134954; PMCID: PMC4843339.
24. Egol KA, Kubiak EN, Fulkerson E, Kummer FJ, Koval KJ. Biomechanics of locked plates and screws. J Orthop Trauma. 2004 Sep;18(8):488-93. doi: 10.1097/00005131-200409000-00003. PMID: 15475843.