Minimally Invasive Plate Osteosynthesis for Comminuted Fractures of Long bones: A Prospective Study on Outcomes and Complications

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KEYWORDS

Minimally invasive plate osteosynthesis; distal tibia fracture; proximal tibia fracture; distal femur fracture; humerus fracture

ABSTRACT

The surge in comminuted bone fractures, attributed to modern lifestyles and increased trauma incidents, poses significant challenges in management. Traditional open reduction and plating methods, while effective, are associated with drawbacks like delayed union and higher infection rates. The evolution of MIPO (Minimally Invasive Plate Osteosynthesis) seeks to overcome these limitations. The potential effects of MIPO in the management of severely comminuted long bone fractures are investigated in this work.

The Saveetha Medical College's Department of Orthopaedics carried out a prospective study from March 2022 to March 2024. Patients aged 20 to 60 with fractures of the femur, tibia, and humerus resulting from road traffic accidents were included. The AO Fracture classification system was utilized, and MIPO techniques were employed for fixation. Clinical and radiological assessments were conducted at various follow-up intervals. Statistical analysis using IBM SPSS Version 22.0 assessed outcomes, with a P-value<0.05 countedas significant.

MIPO was performed on twenty-four male patients, ages averaging 34.4 years, for severely comminuted fractures. The distal 1/3 of the femur, the tibia, and the humerus shaft were among the fractures. Union was rapid in 15 cases, with delayed consolidation in two requiring secondary bone grafting. Functional outcomes assessed using the Neer–Grantham–Shelton Criteria, demonstrated excellent outcomes- 65%, good- 30%, and fair- 5% of events. Complications included infection (5%), wound gaping (5%), joint stiffness (25%), and limb length discrepancy (20%).

This study reinforces MIPO as a promising approach for severely comminuted fractures, showcasing excellent union rates and functional outcomes. Studies highlight its advantages in preserving soft tissue and periosteal circulation. The shift from anatomic reduction to optimal stability in such fractures aligns with current trends. Complications, though present, are manageable. The study contributes to the growing body of evidence supporting MIPO, emphasizing its potential advantages in minimizing surgical trauma and maintaining biological stability. Further research, including comparative studies and exploration of other fixation methods, is warranted for a comprehensive understanding of MIPO's role in fracture management.

1. Introduction

The contemporary lifestyle has led to a rise in comminuted bone fractures, attributed to increased vehicular traffic as well as industrial activities. These fractures are the effect of high-energy forces. pose significant morbidity risks and present challenges in their management. However, advancements in internal fixation methods and innovative implants have improved the treatment of such fractures. Previously, comminuted fractures were addressed through anatomical reduction as well as stabilization via plating, aiming for impressive postoperative X-rays.

The word "osteosynthesis" was coined by Lambotte et al. in 1907 to explain the stable fixation of bone, with Robbert Danis credited as the pioneer of modern osteosynthesis for developing a plate enabling rigid fracture fixation as well as primary bone healing. Subsequently, in 1969, the "ArbeitsgemeinschaftfürOsteosynthesefragen" (AO) refined these plates into dynamic compare Introduction:

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However, open plating showed drawbacks, including delayed or non-union and higher infection rates because the fracture zone is widely exposed for anatomical reduction. Mast et al.^[2^] in 1989 emphasized reduced surgical dissection and indirect reduction techniques to preserve blood supply as well as fracture integrity, aiming to minimize fragment devascularization and associated complications. Krettek et al.^[4^] in 1997 and Wenda et al.^[3^] in 1995 pushed for less intrusive techniques, stressing the relative stability of fractures and little intervention with the fracture zone, such as sliding a plate into the submuscular plane. This approach coined the term MIPO, which has gained admiration since 1995. The study's objective is to prospectively evaluate the outcomes of the management of severely comminuted fractures of long bones by a novel MIPO approach.

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2. Methodology

Prospective research was carried out to evaluate the treatment outcomes of comminuted fractures of long bones using the MIPO approach. This prospective study from patients admitted to Saveetha Medical College, Department of Orthopaedics, diagnosed with fractures of long bones including the femur, tibia, and humerus between March 2022 and March 2024

Patients received immediate hemodynamic stabilization and treatment for related injuries upon arrival to the trauma ward. Clinical and radiological assessments were performed. Tetanus prophylaxis and antibiotics were given. After obtaining the anaesthesia fitness the definitive treatment was planned. The extensiveness of the fracture was precisely described using the AO Fracture classification system, which is renowned for its recordability and reproducibility in classifying fractures.

External splints immobilized fractures of the tibia and humerus, while upper tibial pin traction counteracted powerful muscle forces for femur fractures. The age range of the patients, who were all male, was 20 to 60 years old, with an average age of roughly 34.4 years. Eight individuals suffered fractures on the left side and thirteen on the right. The proximal tibia, shaft of the tibia, distal 1/3 of the femur, shaft of the humerus, and shaft of the femur were among the locations with comminuted fractures.

Every patient had experienced a traffic accident, and there was a range of time between the injury and surgery—from three days to six weeks. Nine patients had sustained polytrauma, with associated injuries such as fractures of both ipsilateral bones of the ipsilateral patella, leg, ipsilateral femur, and contralateral femur. AO – ASIF classifications of fractures included various subtypes, and the implants used for stabilization comprised Broad DCP, Narrow DCP Dynamic condylar screw with barrel plate, and Condylar Blade Plate.

The surgical technique involved specific approaches based on the fracture location, using the double

incision technique described by Wenda, except for humerus fractures treated with a single incision. With the utilization of a femoral distractor or fracture table, reduction and alignment were accomplished and fixation involved the placement of plates and screws. Postoperatively, patients were mobilized based on the stability of the fixation, and patients gradually progressed to partial weight-bearing over weeks and full weight-bearing after 2 months. Next Clinical and radiological results were evaluated at one-month, three-month, and one-year intervals. IBM SPSS Version 22.0 was utilized to do the statistical analysis of the gathered data; a P-value<0.05 was deemed statistically significant

3. Result and Discussion

This study employed the MIPO technique to address comminuted fractures in 24 patients. All of the patients were male, and their ages ranged between 20-60, with an average of about 34.4 years. Eight individuals had complicated fractures on the left side and thirteen on the right. Comminuted fractures occurred in various sites, including the shaft of the Humerus (5 cases), distal 1/3 Femur (10 cases), and shaft of the Tibia (9 cases). These injuries were primarily caused by road traffic accidents. The amount of time that passed between the date of the injury and the date of the operation was known as the "lag time," and it might range from three days to six weeks. Related injuries included fractures of the ipsilateral both bones leg (4 cases), ipsilateral patella (2 cases), contralateral femur (2 cases), and ipsilateral femur (1 case). The AO – ASIF classification of fractures covered a variety of types, with the majority falling into categories 12.C.1, 32.C.1, 32.C.2, and 42.C.2. Implants used for stabilizing the fractures included, Broad DCP in 5 cases, Narrow DCP in 5 cases, and Condylar Blade Plate in 10 cases, PROXIMAL TIBIAL plate in 9 cases , totaling 24 cases. In fifteen cases, union happened quickly, and between six and eight weeks, radiological observations showed the formation of a callus. On the other hand, in two instances of segmental fractures (one femur, two tibia), callus formation took longer to form, appearing at 14 and 16 weeks, and the consolidation process moved more slowly, delaying the time at which the patient could bear weight. About 16–18 weeks after the segmental fractures, three instances (two femurs and one tibia) showed callus formation at the lower end but no callus at the upper end. These instances were therefore subjected to additional bone grafting at the site of the delayed union.

Functional outcomes were assessed utilizing the Neer–Grantham–Shelton Criteria for the 19 lower limb cases, categorizing them as excellent, good, fair, or failure. Specifically, the femur cases (14 in total) showed excellent results-7 events, good- 6 events, and fair- 1 event. For the tibia cases (5 in total), all achieved excellent outcomes. The humerus case demonstrated an excellent result. In the overall evaluation, 65% of cases were deemed excellent, 30% good, and 5% fair.

Complications encountered during the study included infection (5%), wound gaping (5%), joint stiffness (<90°) observed in 25% of cases, and limb length discrepancy (>2cm) present in 20% of cases. Infection emerged in one patient approximately 1½ years post-surgery, leading to the necessity of implant removal. Post-operatively, the limb underwent immobilization and gradual mobilization, resulting in the subsidence of the infection. Wound gaping was experienced by a patient with a segmental tibia fracture post-operatively, successfully addressed through secondary suturing. Joint stiffness presented a significant challenge, affecting 14 out of 19 patients with a range of movements exceeding 100°. Additionally, five patients exhibited a range between 20° and 90°. Contributing factors included late definitive treatment, delayed mobilization, and conservative management of specific fractures. Limb length discrepancy was noted in four cases, presenting a significant (>1 inch) difference, attributed to severe comminution and ipsilateral polytrauma, causing the wounded limb to get shorter.

Discussion

Over the years, advancements in surgical techniques have evolved with a deeper understanding of biomechanics, biology, and biomaterials. The initiation of MIPO by Krettek&Wenda in 1995 faced initial skepticism among surgeons, emerging as pioneers in its comprehensive study [1]. Early research primarily focused on anatomical as well as technical feasibility, concentrating on the tibia & distal

femur. The development of MIPO was significantly influenced by the advent of new plate technologies, including Philos, PC fix, LISS PT, LISS DF, and LCP, enabling internal fixation without the need for precise plate adaptation [1]. This facilitated indirect fracture fixation, akin to the approach used with intramedullary nails, extending the application of MIPO to anatomical areas previously challenging for nailing, such as in populations with comminuted fractures.

The goal of minimally invasive surgical treatment for skeletal injuries is to uphold the biology of the bone as well as soft tissues. Restoring bone structure and mechanical function is the justification for mechanical stability with fracture fixation [2]. MIPO, in comparison to ORIF (Open Reduction and Internal Fixation), minimizes surgical trauma to soft tissue, maintains periosteal circulation, as well as reduces complications such as delayed healing or non-healing [2]. The loss of both medullary as well as periosteal perfusion with traditional procedures has been convincingly demonstrated in “cadaveric injection experiments comparing conventional and MIPO techniques of the distal femur” [2]. The study emphasized that MIPO is not determined by incision length but rather by the soft tissue handling and reduction technique [2]. By preserving periosteal circulation and reducing surgical stress on soft tissue, MIPO outperforms ORIF. Applying a plate with an open approach disrupts the local vascularization, which might cause osteonecrosis under the implant.

The initial report by Winquist et al. on 520 femur fractures cured in this way demonstrated an impressive >99 percent union rate and <1 percent infection rate that was comparable to functional outcomes. In our study, we evaluated the 19 lower limb cases using the Neer-Grantham-Shelton Criteria and classified them as excellent, good, fair, or failure [3]. Specifically, the femur cases (14 in total) showed excellent outcomes- 7 events, good- 6 events, and fair- 1 event. As shown by Klemm et al. [4], subsequent reports on the femur showed encouraging outcomes, with 98 percent union rates & 2.4 percent infection rates. In other studies similar to ours with the five total tibia cases, Naik et al. observed that Tibial shaft fractures cured with intramedullary nailing showed a greater probability of union, but still showed promising non-union and infection rates reaching at most 10%. All of these studies had outstanding outcomes [5]. Even with intramedullary devices, these findings amply illustrated the advantages of least invasive exposures and fixation.

In managing severely comminuted fractures, the study aimed to achieve optimal outcomes through the application of MIPO. The success of fracture fixation using plate osteosynthesis is intricately tied to the surgical technique employed. Before the advent of MIPO, ORIF approaches often yielded discouraging results, marked by increased instances of delayed union and non-union because of soft tissue violation [6]. As a result, more recent methods have emerged that place more emphasis on the value of good biological stability than maximal stability. In severely comminuted fractures, the previously suggested AO-ASIF criteria for a certain number of cortices as well as screws in each fragment are no longer recommended [6]. The study highlighted that in diaphyseal comminuted fractures, the goal shifted from anatomic reduction to the restoration of length, alignment, and optimal stability to prevent delayed healing and fatigue failure.

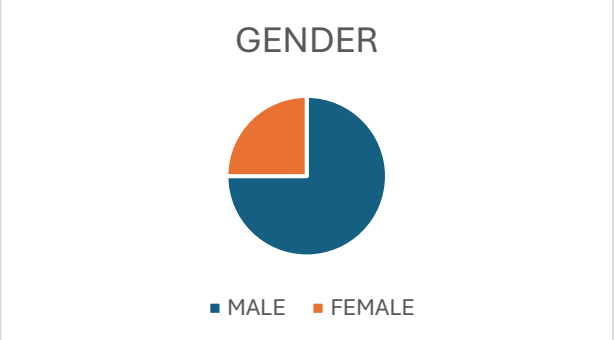

Fig 1 – gender distribution

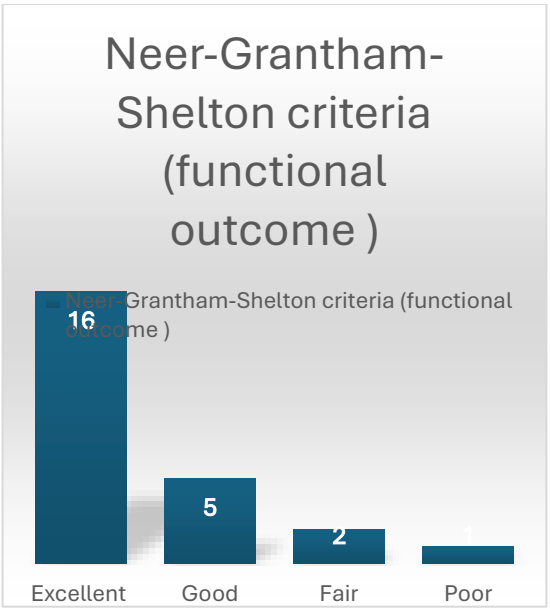

FIG 2 Functional outcomes using Neer- Grantham-Shelton criteria

A point of contention in comminuted fractures is the indication for primary bone grafting, which is contraindicated if it involves significant soft tissue dissection. The study did not employ primary bone grafting, reserving it for cases where healing progress was not satisfactory [6]. In distal and proximal fractures with small fragments, the conventional method of a large lever arm for the plate may not be applicable. To address this, improving fixation of smaller fragments could be achieved using a 95° condylar blade plate or condylar screws, reflecting a current trend favoring plates over intramedullary nails for distal & proximal shaft fractures [6]. This study would provide a more representative evaluation of outcomes for the average orthopedic surgeon using this treatment modality.

Table 1- AO – ASIF CLASSIFICATION OF THE FRACTURES

Humerus	12.C.1	5
Femur	33.A.2	5
	33.A.3	2
	33.C.1	2
	33.C.2	1
Tibia	42.C.1	5
	42.C.2	4

Table 2 – Implants used

IMPLATNTS USED TO STABILIZE THE FRACTURES Implants	**Cases**
Broad DCP / extraarticular plate	5
Condylar Blade Plate	10
Proximal tibia lcp	9
24	

Evidence for MIPO: lower extremity – Confirmation supporting MIPO is prominently demonstrated in lower extremity fractures, particularly those at the distal end of the femur [7]. The robust presence of literature indicates a significant application of MIPO techniques in managing such fractures. Biomechanical studies, as reported by Zlowodzki et al., underscore “the superior distal fixation

achieved with LISS (Locking Compression Plates) compared to angled blade plates & intramedullary fixation [7]. Despite theoretical advantages, a meta-analysis revealed a 19 percent incidence of loss of reduction and various difficulties in studies utilizing LISS, challenging the assumption of a decreased risk of distal loss of fixation".

In a retrospective investigation, Rodriguez et al. highlighted the unsatisfactory outcomes even with contemporary implants, with nonunion rates ranging from 0–21% [8]. Open fractures, infection, and the utilization of stainless-steel plates were risk aspects that together increased the chance of nonunion to 96% [8]. The application of MIPO techniques, initially devised for distal femur fractures, has naturally expanded to address biologically challenging situations in other areas of the lower extremity, such as distal & proximal tibia injuries. MIPO techniques in treating proximal tibia fractures have shown promise, as demonstrated by Cole et al. in 2003 [7]. Their study achieved stable fixation and union in 96% of cases with a 4% infection rate, presenting MIPO as a viable option for intra-articular proximal tibia fractures.

Comparative analyses of MIPO techniques with traditional open techniques, intramedullary nails, and limited open reduction with external fixation have been conducted [9]. Meta-analyses and studies comparing MIPO with various fixation methods indicate that MIPO offers similar outcomes concerning union time, infection rates, functional scores, return to work, and secondary operations [9]. However, studies like Li et al. and He et al. found no distinct advantage of MIPO and suggested considerations of longer operating time and increased radiation exposure [9]. The evaluation of MIPO techniques extends to pilon fractures, historically treated with extensive exposures for complex articular injuries.

However, low-profile MIPO plating has demonstrated promising results in treating type C3, C2, C1 &pilon injuries. Borens et al. reported favorable outcomes in a retrospective case series of 18 cases [10], suggesting "limited open reduction and percutaneous plate fixation as a viable alternative to direct" ORIF for distal tibial plafond injuries. In conclusion, the paragraph highlights the growing body of evidence supporting the efficacy of MIPO techniques in addressing fractures in lower extremities, particularly in the distal femur and tibia, with considerations for various fracture types and complexities.

Proof for MIPO: upper extremity – Over the years, MIPO has been explained primarily for fractures of the upper extremity, with a focus on the humerus and clavicle. Cadaveric studies, such as the one by Xue et al., have demonstrated that MIPO techniques in the humerus result in a reduced vascular insult compared to open reduction and plating techniques [11]. Despite these advantages, MIPO has not shown better time-to-union or functional outcomes as compared to alternative techniques.

Studies like Concha et al. reported a favorable union rate of 91.5% at an average of 12 weeks for humeral fractures, with all cases achieving union without the requirement for primary or secondary bone grafting comparable to our study with 65% of cases deemed excellent, 30% good, and 5% fair using constant murley score [12]. Esmailiejah et al. reported good outcomes with MIPO in terms of surgery time, iatrogenic radial nerve injury (3% versus 12%), infection rates (0% versus 6%), and a shorter duration for union, leading to an earlier return to previous activity levels [13]. When it comes to the results of the intraoperative procedure, MIPO has proven to be superior to intramedullary nailing in that it results in less blood loss and radiation exposure.

On the other hand, radiation exposure is still greater than in open plate osteosynthesis. When compared to open plate osteosynthesis and intramedullary fixation, MIPO produced fewer problems, including radial nerve palsy, and shorter operating times, according to meta-analyses conducted by Hohmann et al. and Zhang Q et al. [12, 13]. Interestingly, these studies could not distinguish between intramedullary nailing & open plate osteosynthesis. Liu et al. carried out a meta-analysis that comprised non-randomized trials that compared intramedullary nailing or open reduction and plate fixation with minimally invasive plating for humeral shaft fractures. The findings of these comparisons were compatible with one another

4. Conclusion and future scope

In conclusion, this prospective research evaluating MIPO for severely comminuted fractures of long bones demonstrates promising results. The MIPO technique, which minimizes soft tissue dissection and preserves periosteal circulation, was applied to patients aged 20 to 60 with complex fractures. The study includes a comprehensive analysis of fractures in the femur, tibia, and humerus caused by road traffic accidents. Union rates were high, with only two cases of delayed consolidation requiring secondary bone grafting. Functional outcomes assessed using the Neer–Grantham–Shelton Criteria, revealed excellent results- 65% of events, good- 30%, and fair- 5%. Complications included infection, wound gaping, joint stiffness, and limb length discrepancy. The study emphasizes the shift from anatomic reduction to optimal stability in severely comminuted fractures and highlights MIPO's potential benefits in minimizing surgical trauma and maintaining biological stability. The findings contribute to the growing body of evidence supporting MIPO, particularly in lower extremity fractures, while acknowledging the need for further research and comparison with other fixation methods, considering factors like operating time and radiation exposure.

Reference

[1] fractures. Presse Med. 1907;15:221-3.

[2] 2.Huldani, H., AbdalkareemJasim, S., Bokov, D.O., Abdelbasset, W.K., Nader Shalaby, M., Thangavelu, L., Margiana, R., Qasim, M.T. 2022, Application of extracellular vesicles derived from mesenchymal stem cells as potential therapeutic tools in autoimmune and rheumatic diseases, International Immunopharmacology, 106, 108634,

[3] 3.GowhariShabgah, A., Abdelbasset, W.K., Sulaiman Rahman, H., Bokov, D.O., Suksatan, W., Thangavelu, L., Ahmadi, M., Malekahmadi, M., Gheibihayat, S., GholizadehNavashenaq, J. 2022, A comprehensive review of IL-26 to pave a new way for a profound understanding of the pathobiology of cancer, inflammatory diseases and infections, Immunology, 165 (1), 44-60.

[4] Jasim, S.A., Yumashev, A.V., Abdelbasset, W.K., Margiana, R., Markov, A., Suksatan, W., Pineda, B., Thangavelu, L., Ahmadi. 2022, Shining the light on clinical application of mesenchymal stem cell therapy in autoimmune diseases, Stem Cell Research and Therapy, 13 (1) 101

[5] Krettek, C., & Wenda, K. (1995). Minimally invasive plate osteosynthesis of the distal humerus. Injury, 26(Suppl 1), A20-A30.

[6] Winquist, R. A., Hansen, S. T., & Clawson, D. K. (1984). Closed intramedullary nailing of femoral fractures: A report of five hundred and twenty cases. The Journal of Bone & Joint Surgery, 66(4), 529-539.

[7] Klemm, K. W., Borner, M., & Thelen, S. (1998). Results of operative treatment of fractures of the distal femur. Der Unfallchirurg, 101(9), 713-720.

[8] NEHA, BANSALA, and DR VENU MADHAV KATLA. "Design and characterization of Methotrextate Mucoadhesive Microspheres." International Journal of Pharmacy Research & Technology (IJPRT) 13.2 (2023): 35-45.

[9] Zlowodzki, M., Williamson, S., Zardiackas, L. D., Kregor, P. J., & Biomechanical, S. (2008). Biomechanical evaluation of the less invasive stabilization system, angled blade plate, and retrograde intramedullary nail for the internal fixation of distal femur fractures. Journal of Orthopaedic Trauma, 22(10), 635-641.

[10] Rodriguez, E. K., Boulton, C., Weaver, M. J., Herder, L., & Morgan, J. H. (2015). Predictive factors of distal femoral nonunion after distal femoral fracture. Journal of Orthopaedic Trauma, 29(5), e121-e126.

[11] Cole, P. A., Zlowodzki, M., Kregor, P. J., & Guy, P. (2004). Treatment of proximal tibia fractures using the less invasive stabilization system: Surgical experience and early clinical results in 77 fractures. Journal of Orthopaedic Trauma, 18(8), 528-535.

[12] Borens, O., Kloen, P., & Richmond, J. (2012). Minimally invasive and subvastus approaches for tibial plateau fractures. In Schatzker J, Cole P (Eds.), Fractures of the Tibial Pilon (pp. 247–255). Springer, Berlin, Heidelberg.

[13] Xue, D., Zheng, Q., Li, H., Qian, S., Zhang, B., Pan, Z., & Xie, X. (2011). Percutaneous minimally invasive plate osteosynthesis (MIPO) of middle and distal third humeral shaft fractures. Journal of Orthopaedic Trauma, 25(9), 530-537.

[14] Concha, J. M., Sánchez, A., & Zylberberg, A. (2013). Percutaneous fixation of extra-articular fractures of the distal third of the humeral shaft using anteromedial and anterolateral limited approaches. Journal of Shoulder and Elbow Surgery, 22(10), 1347-1353.

[15] Esmailiejah, A. A., Abbasian, M. R., Safdari, F., & Karimi, A. (2017). Minimally invasive plate osteosynthesis for humeral shaft fractures: Clinical outcomes. Archives of Bone and Joint Surgery, 5(4), 225-231.

[16] Hohmann, E., Glatt, V., &Tetsworth, K. (2015). Minimally invasive plating versus either open reduction and plate fixation or intramedullary nailing of humeral shaft fractures: a systematic review and meta-analysis of randomized controlled trials. Journal of Shoulder and Elbow Surgery, 24(7), 1118-1125.

[17] 17. Liu, G., Zhang, W., & Zhang, L. (2018). Minimally invasive plating osteosynthesis versus open reduction internal fixation in humeral shaft fractures: a meta-analysis. Journal of Orthopaedic Surgery and Research, 13(1), 176