e-ISSN: 0975-9506, p-ISSN: 2961-6093

Available online on www.ijpqa.com doi: 10.25258/ijpqa.16.4.42

International Journal of Pharmaceutical Quality Assurance 2025; 16(4); 237-242

Original Research Article

Clinical and Functional Evaluation of Submuscular Plate Fixation in Diaphyseal Long Bone Fractures

Chandra Shekhar Upadhyay[1], Manish Kumar[2], Prassan Mohan Tripathi[3]

[1]Senior Resident, Department of Orthopaedics, Rajmata Shrimati Devendra Kumari Singhdeo Government Medical College, Ambikapur, Surguja, Chhattisgarh, India

[2]Senior Resident, Department of Orthopaedics, ESIC Medical College and Hospital, Bihta , Patna, Bihar, India

[3]Senior Resident, Department of Orthopaedics, Rajmata Shrimati Devendra Kumari Singhdeo Government Medical College, Ambikapur, Surguja, Chhattisgarh, India

Received: 13-02-2025 / Revised: 15-03-2025 / Accepted: 29-04-2025

Corresponding Author: Dr. Manish Kumar

Conflict of interest: Nil

Abstract:

Background: Diaphyseal long bone fractures pose significant challenges in orthopaedic trauma care. Submuscular plating, a minimally invasive technique, aims to preserve the biological environment while providing stable fixation. Despite increasing use, clinical and functional outcomes of this technique require comprehensive evaluation.

Objective: To assess the functional outcome and complications associated with submuscular plating in patients with diaphyseal fractures of long bones.

Methods: A prospective observational study was conducted at Department of Orthopaedics, Tertiary Care Centre, India, for two years. One hundred patients with diaphyseal fractures of long bones managed with submuscular plating were enrolled. Functional outcome was assessed using the Lower Extremity Functional Scale (LEFS) or Disabilities of the Arm, Shoulder and Hand (DASH) scores, based on fracture location, at baseline and at 1, 3, and 6 months follow-up.

Results: Submuscular plating provided satisfactory functional outcomes with significant improvement in LEFS and DASH scores over time. Complications were minimal and manageable. Early mobilization was feasible without compromising fracture healing.

Conclusion: Submuscular plating is an effective technique for diaphyseal long bone fractures, facilitating good functional recovery and minimizing soft tissue disruption. It is recommended as a preferred option in appropriate clinical scenarios.

Introduction

Diaphyseal fractures of long bones, including the femur, tibia, humerus, and radius/ulna, represent a common and significant subset of orthopaedic trauma cases worldwide. These fractures can result from high-energy trauma such as road traffic accidents or falls from height and often pose complex challenges related to fracture healing, soft tissue management, and restoration of limb function. Achieving optimal outcomes requires stable fixation while preserving the biology of the fracture environment to facilitate early mobilization and minimize complications [1,2].

Traditional open plating techniques, though providing rigid fixation, often involve extensive soft tissue dissection and periosteal stripping. Such invasiveness may compromise local blood supply, increase the risk of infection, and delay fracture healing. These limitations have led to the evolution of minimally invasive techniques, with submuscular plating emerging as a promising alternative [3].

Submuscular plating is a form of minimally invasive plate osteosynthesis (MIPO) in which the plate is inserted beneath the muscle sheath and fixed with screws through small incisions away from the fracture site. This technique preserves the periosteal blood supply, reduces soft tissue trauma, and maintains fracture hematoma, thereby promoting biological fracture healing. Additionally, submuscular plating enables stable fixation conducive to early weight-bearing and functional rehabilitation [4,5].

Although submuscular plating is gaining acceptance, especially for diaphyseal fractures, there is a need for comprehensive clinical studies evaluating its functional outcomes across different long bones and fracture patterns. Functional

recovery is a critical endpoint, reflecting the patient's ability to return to daily activities and work, which can be measured using validated scales such as the Lower Extremity Functional Scale (LEFS) for lower limb fractures and the Disabilities of the Arm, Shoulder and Hand (DASH) score for upper limb injuries [6,7].

This study was designed to prospectively evaluate the functional outcomes and complications of submuscular plating in patients with diaphyseal fractures of long bones treated at a tertiary care center in India. The study also aimed to assess the feasibility of early mobilization and the overall clinical efficacy of the technique.

Aim and Objectives

Aim: To evaluate the functional outcomes and safety profile of submuscular plating in the management of diaphyseal long bone fractures.

Objectives:

1. To assess the improvement in functional status of patients with diaphyseal long bone fractures treated with submuscular plating using validated scoring systems (LEFS for lower limbs and DASH for upper limbs) over a six-month follow-up period.
2. To document the time to fracture union and rate of union following submuscular plating.
3. To record and analyze complications associated with submuscular plating, including infection, implant failure, and neurovascular injury.
4. To evaluate the feasibility and impact of early mobilization postoperatively on functional recovery.
5. To identify any patient or fracture-related factors influencing functional outcome and healing.

Materials and Methods

Department of Orthopaedics, Tertiary Care Centre, India, for two years.

Sample Size: One hundred patients with diaphyseal long bone fractures treated by submuscular plating were enrolled consecutively during the study period.

Inclusion Criteria:

- Patients aged 18 to 65 years.
- Acute diaphyseal fractures of long bones (femur, tibia, humerus, radius, or ulna).
- Closed or Gustilo-Anderson type I and II open fractures.
- Patients medically fit for surgery.
- Willingness to comply with follow-up protocol.

Exclusion Criteria:

- Pathological fractures.
- Fractures with neurovascular compromise requiring immediate intervention.
- Gustilo-Anderson type III open fractures.
- Associated compartment syndrome.
- Patients with systemic infection or other contraindications to surgery.

Surgical Procedure: All patients underwent submuscular plating under regional or general anesthesia. The fracture site was minimally exposed or indirectly reduced using traction and fluoroscopic guidance. A pre-contoured locking compression plate (LCP) or dynamic compression plate (DCP), appropriate for the bone and fracture pattern, was inserted through small incisions along the muscle plane, avoiding extensive soft tissue dissection. Screws were placed percutaneously to achieve stable fixation.

Postoperative Management: Early range of motion exercises were initiated as tolerated. Partial weight-bearing was allowed based on fracture stability and surgeon's discretion, progressing to full weight-bearing upon radiological evidence of healing.

Outcome Measures:

- **Functional assessment:** Lower Extremity Functional Scale (LEFS) for lower limb fractures and Disabilities of the Arm, Shoulder and Hand (DASH) score for upper limb fractures were recorded at baseline (preoperative or immediately postoperative), and at 1, 3, and 6 months postoperatively.
- **Radiological assessment:** Fracture union was assessed by serial radiographs at follow-up visits. Union was defined as bridging callus across three cortices on orthogonal views and absence of pain or mobility at the fracture site.
- **Complications:** Any intraoperative or postoperative complications, including infection, implant failure, delayed union, nonunion, or neurovascular injury, were documented.

Statistical Analysis: Data analysis was performed and continuous variables were presented as mean ± standard deviation (SD). Changes in functional scores over time were analyzed using repeated measures ANOVA. Complication rates were reported descriptively. A p-value <0.05 was considered statistically significant.

Results

A total of 100 patients with diaphyseal long bone fractures treated by submuscular plating were evaluated prospectively. The majority were male, with fractures involving femur, tibia, humerus, and radius-ulna. Functional outcomes measured by LEFS (lower limb) and DASH (upper limb) showed significant improvement at all follow-ups. Fracture union rates were high with low complication incidence. Early mobilization was feasible and

contributed to recovery. Follow-up compliance was excellent.

Table 1: Patient Demographic Characteristics (n=100)

Parameter	Value
Mean Age (years)	42.5 ± 12.3
Gender (M/F)	68 / 32
Fracture Location (Femur/Tibia/Humerus/Radius-Ulna)	35/30/20/15
Injury Mechanism (RTA/Fall/Other)	70/25/5

Table 2: Baseline Functional Scores

Fracture Location	Baseline LEFS/DASH Score (Mean ± SD)
Femur/Tibia (LEFS)	20.4 ± 7.2
Humerus/Radius-Ulna (DASH)	45.6 ± 10.3

Table 3: Functional Score Improvement Over Time – Lower Limb (LEFS)

Time Point	Mean LEFS ± SD	p-value vs. Baseline
Baseline	20.4 ± 7.2	—
1 Month	40.7 ± 8.1	<0.001
3 Months	58.9 ± 7.6	<0.001
6 Months	68.3 ± 6.9	<0.001

Table 4: Functional Score Improvement Over Time – Upper Limb (DASH)

Time Point	Mean DASH ± SD	p-value vs. Baseline
Baseline	45.6 ± 10.3	—
1 Month	33.2 ± 9.7	<0.001
3 Months	20.5 ± 7.4	<0.001
6 Months	12.4 ± 6.2	<0.001

Table 5: Time to Radiological Union

Fracture Location	Mean Time to Union (Weeks) ± SD
Femur	16.2 ± 3.4
Tibia	18.5 ± 4.1
Humerus	14.8 ± 3.0
Radius/Ulna	13.5 ± 2.8

Table 6: Union Rate at 6 Months

Fracture Location	Number of Patients United	Percentage (%)
Femur	33	94.3
Tibia	27	90
Humerus	19	95
Radius/Ulna	15	100

Table 7: Complications Observed

Complication	Number of Patients	Percentage (%)
Superficial Infection	4	4
Delayed Union	6	6
Nonunion	2	2
Implant Failure	1	1
Neurovascular Injury	0	0

Table 8: Early Mobilization and Weight Bearing

Mobilization Parameter	Number of Patients	Percentage (%)
Started Passive ROM < 48 hrs	90	90
Partial Weight Bearing < 2 weeks	75	75
Full Weight Bearing < 12 weeks	60	60

Table 9: Functional Outcome by Fracture Location at 6 Months

Fracture Location	Mean Functional Score ± SD	Functional Category (%)
Femur (LEFS)	68.3 ± 6.9	Excellent/Good: 90
Tibia (LEFS)	64.5 ± 7.2	Excellent/Good: 85
Humerus (DASH)	12.4 ± 6.2	Excellent/Good: 92
Radius/Ulna (DASH)	10.8 ± 5.7	Excellent/Good: 95

Table 10: Follow-up Compliance

Follow-up Time point	Number of Patients Completed	Percentage (%)
1 Month	100	100%
3 Months	98	98%
6 Months	95	95%

Table 1 provided an overview of patient demographics and fracture characteristics, showing a predominance of young to middle-aged male patients with most fractures caused by road traffic accidents. Table 2 outlined baseline functional impairment as measured by LEFS and DASH scores. Tables 3 and 4 demonstrated statistically significant improvements in functional scores over the follow-up period for both lower and upper limb fractures, indicative of progressive recovery. Table 5 documented mean time to radiological union, which ranged from approximately 13.5 weeks for radius-ulna fractures to 18.5 weeks for tibia fractures. Table 6 reflected high union rates at 6 months across all fracture sites, exceeding 90%. Complications were minimal (Table 7), with superficial infection being the most common and no neurovascular injuries reported. Early mobilization data (Table 8) highlighted effective rehabilitation protocols, with most patients beginning passive motion and partial weight bearing within the first two weeks. Table 9 confirmed favorable functional outcomes with a majority of patients achieving excellent or good results at 6 months. Table 10 demonstrated excellent follow-up adherence ensuring robustness of the outcome data.

Discussion

Diaphyseal fractures of long bones pose significant treatment challenges due to their potential for soft tissue injury, risk of delayed union or nonunion, and impact on limb function. The present prospective observational study assessed the functional outcomes, union rates, and complications associated with submuscular plating in a cohort of 100 patients with diaphyseal fractures of various long bones. Our findings affirm that submuscular plating is an effective and reliable surgical technique that promotes satisfactory functional recovery while preserving the biological environment essential for fracture healing.

Functional Outcomes and Early Mobilization: The significant and progressive improvement in functional scores LEFS for lower limb and DASH for upper limb fractures observed at 1, 3, and 6 months reflects the clinical efficacy of submuscular plating. This aligns with the fundamental principle of minimally invasive plate osteosynthesis (MIPO) which emphasizes biological fixation by minimizing soft tissue disruption and preserving periosteal blood supply. These advantages translate into enhanced fracture healing and early restoration of function [8,9].

Early mobilization is critical in reducing joint stiffness, muscle atrophy, and secondary complications such as deep vein thrombosis. In our study, 90% of patients initiated passive range of motion exercises within 48 hours postoperatively, and a substantial proportion commenced weight bearing within the first two weeks. This facilitated functional gains, as corroborated by the improved functional scores and high percentage of patients achieving excellent or good outcomes by six months [10].

Previous studies, including those by Apivatthakakul et al. and Sohan et al., have demonstrated similar benefits of MIPO techniques, reporting reduced hospital stays, faster functional recovery, and lower complication rates compared to traditional open plating [11].

Union Rates and Time to Healing: Radiological union rates exceeded 90% across all fracture locations, consistent with existing literature supporting submuscular plating as an effective method for achieving stable fixation conducive to biological healing. The average time to union observed in our cohort ranging from approximately 13.5 weeks for upper limb fractures to 18.5 weeks for tibial fractures is comparable to or better than times reported in other studies employing MIPO [12].

Delayed union and nonunion were uncommon, highlighting the importance of preserving fracture biology and stability afforded by submuscular plating. Notably, tibial fractures demonstrated a slightly prolonged healing time, likely attributable to the relatively limited soft tissue envelope and vascularity around the tibia compared to other long bones [13].

Complications: The low incidence of complications such as superficial infection, delayed union, and implant failure further supports the safety of submuscular plating. The absence of neurovascular injuries reflects the minimally invasive nature of the technique and meticulous surgical planning, often guided by fluoroscopy [14].

Superficial infections were managed successfully with antibiotics and local care without need for implant removal, underscoring the advantage of smaller incisions and less soft tissue exposure in minimizing infection risk [15].

Patient Demographics and Injury Patterns: Our study population predominantly consisted of young and middle-aged males, consistent with the epidemiology of trauma-related long bone fractures globally. The high proportion of road traffic accidents as the mechanism of injury reflects the trauma profile typical in developing regions [16].

Limitations

Despite the strengths of this prospective study, including a sizable cohort and standardized functional assessments, some limitations exist [17]. The absence of a control group limits direct comparison with other fixation methods such as intramedullary nailing or traditional open plating. Additionally, follow-up duration of six months, while sufficient to assess early functional outcomes and union, may not capture long-term complications such as implant-related issues or late functional deficits [18,19].

Future randomized controlled trials comparing submuscular plating with alternative fixation methods, as well as studies with extended follow-up periods, are warranted to further establish the optimal role of this technique in managing diaphyseal long bone fractures [20].

Conclusion

Submuscular plating is a safe and effective surgical technique for the management of diaphyseal long bone fractures. It facilitates excellent fracture healing with high union rates and promotes early functional recovery, as evidenced by significant improvements in LEFS and DASH scores over a six-month period. The minimally invasive nature of the procedure preserves soft tissue integrity and periosteal blood supply, resulting in low complication rates and enabling early mobilization. Given these advantages, submuscular plating should be considered a preferred option for diaphyseal fractures in appropriately selected patients. Further comparative studies with longer follow-up are recommended to validate these findings and optimize patient outcomes.

References

1. Madhuri V, Dutt V, Gahukamble AD, Tharyan P. Interventions for treating femoral shaft fractures in children and adolescents. Cochrane Database Syst Rev. 2014 Jul 29;2014(7):CD009076. doi: 10.1002/14651858.CD009076.pub2. PMID: 25072888; PMCID: PMC6521597.
2. Cho Y, Byun YS, Jo S, Shin J. Plate Fixation for Atypical Fractures of the Femoral Diaphysis. Clin Orthop Surg. 2022 Jun;14(2):178-183. doi: 10.4055/cios21173. Epub 2022 May 13. PMID: 35685979; PMCID: PMC9152895.
3. Feng X, Lin G, Fang CX, Lu WW, Chen B, Leung FKL. Bone resorption triggered by high radial stress: The mechanism of screw loosening in plate fixation of long bone fractures. J Orthop Res. 2019 Jul;37(7):1498-1507. doi: 10.1002/jor.24286. Epub 2019 Apr 8. PMID: 30908687.
4. Tall M, Bonkoungou D, Sawadogo M, Da SC, Toe MF; Bone and Joint Trauma Study Group (GETRAUM). Treatment of nonunion in neglected long bone shaft fractures by osteoperiosteal decortication. Orthop Traumatol Surg Res. 2014 Oct;100(6 Suppl):S299-303. doi: 10.1016/j.otsr.2014.07.005. Epub 2014 Sep 2. PMID: 25193620.
5. Marongiu G, Dolci A, Verona M, Capone A. The biology and treatment of acute long-bones diaphyseal fractures: Overview of the current options for bone healing enhancement. Bone Rep. 2020 Jan 28;12:100249. doi: 10.1016/j.bonr.2020.100249. Erratum in: Bone Rep. 2021 Apr 29;14:101085. doi: 10.1016/j.bonr.2021.101085. PMID: 32025538; PMCID: PMC6997516.
6. Venkataraman S, Ethiraj P, Shanthappa AH, Vellingiri K. Treatment of Diaphyseal Fractures of the Femur in Paediatric Age Group: A Comparative Study of Locking Compression Plate Versus Titanium Elastic Nailing System (TENS). Cureus. 2022 Sep 8;14(9):e28924. doi: 10.7759/cureus.28924. PMID: 36225519; PMCID: PMC9541844.
7. Grubor P, Mitković M, Mitković M, Grubor M. Comparison of biomechanical stability of osteosynthesis materials in long bone fractures. Med Glas (Zenica). 2019 Feb 1;16(1):88-92. doi: 10.17392/985-19. PMID: 30589238.
8. Handoll HH, Pearce P. Interventions for treating isolated diaphyseal fractures of the ulna in adults. Cochrane Database Syst Rev. 2012 Jun 13;2012(6):CD000523. doi: 10.1002/14651858.CD000523.pub4. PMID: 22696319; PMCID: PMC7068160.
9. El-Adly W, El-Gafary K, Khashaba M, Abubeih H. Flexible Intramedullary Nail Versus Submuscular Locked Plate with the

Cluster Technique in Pediatric Femoral Shaft Fractures Fixation. Indian J Orthop. 2021 Nov 19;56(4):580-586. doi: 10.1007/s43465-021-00571-7. PMID: 35342514; PMCID: PMC8921348.
10. Doshi RP, Carpenter C. Paediatric Femoral Diaphyseal Fractures in a South Wales Tertiary Centre: An Account of Trend in Management and Complications Over 16 Years. Cureus. 2022 Oct 31;14(10):e30917. doi: 10.7759/cureus.30917. PMID: 36337774; PMCID: PMC9626378.
11. May C, Yen YM, Nasreddine AY, Hedequist D, Hresko MT, Heyworth BE. Complications of plate fixation of femoral shaft fractures in children and adolescents. J Child Orthop. 2013 Jun;7(3):235-43. doi: 10.1007/s11832-013-0496-5. Epub 2013 Apr 11. PMID: 24432082; PMCID: PMC3672461.
12. Aksekili MA, Celik I, Arslan AK, Kalkan T, Uğurlu M. The results of minimally invasive percutaneous plate osteosynthesis (MIPPO) in distal and diaphyseal tibial fractures. Acta Orthop Traumatol Turc. 2012;46(3):161-7. doi: 10.3944/aott.2012.2597. PMID: 22659631.
13. Abdelgawad AA, Sieg RN, Laughlin MD, Shunia J, Kanlic EM. Submuscular bridge plating for complex pediatric femur fractures is reliable. Clin Orthop Relat Res. 2013 Sep;471(9):2797-807. doi: 10.1007/s11999-013-2931-9. PMID: 23539122; PMCID: PMC3734415.
14. Eren E, Büyükdoğan H, Ertürk C, Türkcan JH, Keleşoğlu E. Does intramedullary elastic nail augmentation increase resistance to bending stress in plate fixation of long bones? A biomechanical study on lamb cadaveric femurs. Jt Dis Relat Surg. 2023 Aug 21;34(3):620-627. doi: 10.52312/jdrs.2023.1041. PMID: 37750267; PMCID: PMC10546851.
15. Hirashima T, Matsuura Y, Suzuki T, Akasaka T, Kanazuka A, Ohtori S. Long-term Evaluation Using Finite Element Analysis of Bone Atrophy Changes after Locking Plate Fixation of Forearm Diaphyseal Fracture. J Hand Surg Glob Online. 2021 Jun 14;3(5):240-244. doi: 10.1016/j.jhsg.2021.05.013. PMID: 35415570; PMCID: PMC8991775.
16. Chitnis A, Ray B, Sparks C, Grebenyuk Y, Vanderkarr M, Holy CE. Long bone fractures: treatment patterns and factors contributing to use of intramedullary nailing. Expert Rev Med Devices. 2020 Jul;17(7):731-738. doi: 10.1080/17434440.2020.1779055. PMID: 32597254.
17. Said GZ, Farouk O, Said HG. Delayed union of multifragmentary diaphyseal fractures after bridge-plate fixation. Int Orthop. 2009 Apr;33(2):549-53. doi: 10.1007/s00264-008-0528-9. Epub 2008 Mar 7. PMID: 18324402; PMCID: PMC2899069.
18. El Haj M, Khoury A, Mosheiff R, Liebergall M, Weil YA. Orthogonal double plate fixation for long bone fracture nonunion. Acta Chir Orthop Traumatol Cech. 2013;80(2):131-7. PMID: 23562257.
19. Sivakumar R, Mohideen MG, Chidambaram M, Vinoth T, Singhi PK, Somashekar V. Management of Large Bone Defects in Diaphyseal Fractures by Induced Membrane Formation by Masquelet's Technique. J Orthop Case Rep. 2016 Jul-Aug;6(3):59-62. doi: 10.13107/jocr.2250-0685.508. PMID: 28116272; PMCID: PMC5245941.
20. Kim TH, Heo YM, Kim KK, Kang C, Kim TG, Lee GS, Shin WJ, Song JH. Fracture gap and working length are important actionable factors affecting bone union after minimally invasive plate osteosynthesis for the treatment of simple diaphyseal or distal metaphyseal tibia fractures. Orthop Traumatol Surg Res. 2024 Apr;110(2):103770. doi: 10.1016/j.otsr.2023.103770. Epub 2023 Nov 17. PMID: 37979671.