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Functional Outcomes and Radiological Union of Midshaft Humeral Fractures Treated With Medial Plating Through an Anterolateral Approach: A Prospective Observational Study

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Abstract

Background

Humeral shaft fractures are common long-bone injuries that can be managed either conservatively or surgically, depending on fracture characteristics and patient-related factors. Medial plating through an anterolateral approach is an alternative surgical technique for fixation of mid-third humeral shaft fractures. This study aimed to evaluate functional outcomes and fracture healing following medial plating through an anterolateral approach for acute mid-third humeral shaft fractures, including radiological union, postoperative complications, and the association between injury-to-surgery interval and radiological union time.

Methodology

A prospective observational study was conducted in the Department of Orthopedics between March 2025 and September 2025. Forty-eight patients with acute mid-third humeral shaft fractures underwent open reduction and internal fixation using medial plate osteosynthesis through an anterolateral approach. Patients were followed for a minimum period of six months and a maximum of one year. Functional outcome assessment using the Rodríguez-Merchán criteria was performed at the final study assessment (six months). Radiological union, time to union, postoperative complications, and the association between time to surgery and union time were evaluated.

Results

The mean age of the study population was 47.0 ± 17.7 years. Road traffic accidents accounted for 32 (66.7%) of injuries, and males comprised 28 (58.3%) of the study population. At the final follow-up, excellent and good functional outcomes were achieved in 18 (37.5%) and 22 (45.8%) patients, respectively, resulting in an overall satisfactory outcome rate of 40 (83.3%). All fractures achieved radiological union, with a mean radiological union time of 14.9 ± 4.9 weeks. Delayed union occurred in four patients (8.3%). Postoperative complications included superficial surgical site infection in three patients (6.3%), radial nerve palsy in two patients (4.2%), and implant failure in one patient (2.1%). A statistically significant positive correlation was observed between the interval from injury to surgery and radiological union time (Pearson's $r = 0.565$, $P < 0.001$).

Conclusions

Medial plating through an anterolateral approach was associated with satisfactory functional outcomes, a high fracture union rate, and a low complication rate in patients with acute mid-third humeral shaft fractures. A longer interval from injury to surgery was associated with a longer radiological union time.

Categories: Trauma, Orthopedics

Keywords: anterolateral approach, fracture union, functional outcome, humeral shaft fracture, medial plating, plate osteosynthesis, rodríguez-merchán criteria

Introduction

Humeral shaft fractures account for approximately 1%-3% of all fractures and represent a common injury encountered in orthopedic practice [1]. These fractures demonstrate a bimodal age distribution, occurring in younger individuals following high-energy trauma and in older patients as a result of low-energy falls and osteoporotic bone fragility [2]. Road traffic accidents, falls, and sports-related injuries remain the most frequently reported mechanisms of injury.

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Although non-operative treatment using functional bracing has historically been associated with high union rates and acceptable functional outcomes, surgical intervention is increasingly performed in selected patients [3]. Operative management is indicated in cases of fracture displacement, inability to maintain acceptable alignment, polytrauma, pathological fractures, open fractures, associated neurovascular injuries, floating elbow injuries, and failed conservative treatment [1].

The two principal surgical options for humeral shaft fractures are intramedullary nailing and plate osteosynthesis. Plate fixation offers several advantages, including direct fracture visualization, anatomical reduction, rigid fixation, and early mobilization of adjacent joints [4]. Various surgical approaches have been described for plate placement, including posterior, anterolateral, anterior, and medial approaches [2]. Among these, the anterolateral approach is widely used for fractures involving the proximal and middle thirds of the humeral shaft because it provides adequate exposure while facilitating fracture reduction and fixation [5].

Anteromedial plating through an anterolateral approach has gained increasing attention as an alternative method of fixation. The medial surface of the humerus provides a relatively flat surface for plate application and allows stable fixation with minimal implant prominence. Furthermore, this technique may reduce the need for extensive radial nerve dissection, thereby potentially lowering the risk of iatrogenic radial nerve injury while preserving soft tissue integrity [6]. Previous clinical studies have reported satisfactory fracture union and favorable functional outcomes following medial plating, suggesting that it is a viable alternative to conventional plating techniques. However, variations in patient selection, fracture characteristics, outcome measures, and reported complication profiles among published studies make direct comparison of results difficult and limit definitive conclusions regarding the technique.

Although encouraging clinical results have been reported, further prospective evidence describing functional outcomes, fracture union, postoperative complications, and factors associated with fracture healing following medial plating through an anterolateral approach remains valuable. The present prospective observational study was therefore undertaken to evaluate these outcomes in patients with acute mid-third humeral shaft fractures. The study evaluated functional outcomes using the Rodríguez-Merchán criteria together with fracture union, postoperative complications, and the association between injury-to-surgery interval and radiological union time.

Materials And Methods

Study design and setting

This prospective observational study was conducted in the Department of Orthopedics between March 1, 2025, and September 30, 2025. The study was approved by the Institutional Ethics Committee, and informed consent was obtained from all participants before enrollment.

The sample size was calculated prospectively before commencement of the study using the formula $n = Z^2 pq / d^2$, where n is the required sample size, Z is the standard normal deviate corresponding to a 95% confidence level (1.96), p is the expected proportion of satisfactory functional outcome based on the study [6] (68.51%), $q = 100 - p$ (31.49%), and d is the relative precision, taken as 20% of the expected proportion (13.7). The minimum calculated sample size was 44 patients. After accounting for an anticipated 10% attrition rate, the required sample size was 48 patients. During the study period, 48 consecutive eligible patients were enrolled. All enrolled patients completed the minimum six-month follow-up, and no patients were lost to follow-up or excluded from the final analysis.

Patient selection

A total of 48 consecutive patients with acute mid-third humeral shaft fractures who met the eligibility criteria were included in the study. Operative fixation was performed in patients with displaced or unstable mid-third humeral shaft fractures, fractures considered unsuitable for conservative treatment because acceptable alignment could not be maintained. Inclusion criteria were patients aged 18 years and above with acute middle-third humeral shaft fractures, no preoperative neurovascular deficits in the affected limb, and fractures treated surgically within four weeks of injury. Exclusion criteria included pathological humeral shaft fractures, associated neurovascular injuries, additional traumatic injuries of the affected upper limb that could influence functional assessment, and patients lost to follow-up before completion of the study period.

Surgical technique

All procedures were performed under general anesthesia with the patient in the supine position. An anterolateral skin incision was made along the lateral border of the biceps brachii. A sub-brachialis approach was utilized, in which the brachialis muscle was preserved and retracted laterally following blunt dissection between the biceps brachii and brachialis muscles, thereby avoiding routine exposure of the radial and musculocutaneous nerves. The anteromedial surface of the humerus was exposed, the fracture was anatomically reduced, and fixation was achieved using a 4.5-mm narrow dynamic compression plate applied

to the medial surface of the humerus. Wound closure was performed in layers without placement of a suction drain.

Postoperative management and follow-up

Postoperatively, once the patient became pain-free, passive and active shoulder range of motion and elbow exercises were started on the second post-operative day. Patients underwent clinical and radiological follow-up at two weeks, six weeks, eight weeks, and six months after surgery. The minimum follow-up duration was six months, while the maximum follow-up was one year. Functional outcome assessment using the Rodríguez-Merchán criteria was performed at the final study assessment (six months). Radiographs obtained beyond six months were part of routine clinical follow-up and were not included in the statistical analysis.

Outcome Measures

The primary outcome was assessed by the principal investigator during scheduled follow-up visits using the Rodríguez-Merchán criteria. Radiological union was determined by evaluation of serial anteroposterior and lateral radiographs together with clinical examination and was confirmed by the treating consultant. Based on elbow range of motion, shoulder range of motion, pain, and disability, outcomes were classified as excellent, good, fair, or poor. Secondary outcome measures included Radiological union time, delayed union, postoperative complications, including surgical site infection, radial nerve palsy, and implant failure, and the association between the interval from injury to surgery and radiological union time.

Radiological union was defined as the presence of bridging callus across the fracture site on orthogonal radiographs, along with the absence of pain or tenderness at the fracture site. Delayed union was defined as failure to achieve radiological union within 24 weeks following surgery.

Statistical analysis

Statistical analysis was performed using IBM SPSS Statistics for Windows, version 27.0 (IBM Corp., Armonk, NY). Data were entered into Microsoft Excel and analyzed using SPSS. Continuous variables were expressed as mean $\pm$ standard deviation (SD), median, and range, as appropriate, while categorical variables were summarized as frequencies and percentages.

The association between the interval from injury to surgery and radiological union time was evaluated using Pearson's correlation coefficient. Patients were additionally stratified according to the interval from injury to surgery (≤ 10 days, 11–20 days, and > 20 days), and mean radiological union times were compared using one-way analysis of variance (ANOVA). A two-tailed P -value of < 0.05 was considered statistically significant.

Results

Patient demographics and injury characteristics

A total of 48 patients with acute mid-third humeral shaft fractures were included in the study. The mean age of the study population was 47.0 ± 17.7 years (range, 18–75 years). The majority of patients were aged 61 years or above (17, 35.4%), followed by those aged 21–40 years (15, 31.3%) and 41–60 years (13, 27.1%). Males constituted 28 (58.3%) of the study population, while females accounted for 20 (41.7%).

Road traffic accidents were the most common mechanism of injury, accounting for 32 cases (66.7%), whereas falls were responsible for 16 cases (33.3%). The left side was involved in 25 patients (52.1%), and the right side in 23 patients (47.9%) (Table 1).

Variables	Number of patients	Percentage (%)
Age-wise distribution and incidence		
Under the age of 21 years	3	6.3
21-40 years	15	31.3
40-60 years	13	27.1
61 years or above	17	35.4
Mode of injury		
RTA	32	66.7
Fall	16	33.3
Sex distribution		
Male	28	58.3
Female	20	41.7
Side of injury		
Left	25	52.1
Right	23	47.9

TABLE 1: Demographics and injury characteristics.

RTA, road traffic accident

Fracture characteristics

Fracture patterns were classified according to the Arbeitsgemeinschaft für Osteosynthesefragen (AO)/Orthopedic Trauma Association (OTA) classification system. The study group consisted of AO/OTA type A and B fracture patterns, while no type C fractures were identified during the study period. Wedge spiral fractures were the most common pattern, observed in 12 patients (25.0%), followed by simple oblique fractures in 11 patients (22.9%). Simple transverse fractures were identified in nine patients (18.8%), while wedge bending and simple spiral fractures each accounted for eight cases (16.7%) (Table 2).

AO/OTA classification	Number (%)
A1 - Simple spiral	8 (16.7)
A2 - Simple oblique	11 (22.9)
A3 - Simple transverse	9 (18.8)
B1 - Wedge spiral	12 (25.0)
B2 - Wedge bending	8 (16.7)
Total	48 (100.0)

TABLE 2: Fracture characteristics (n = 48).

AO, Arbeitsgemeinschaft für Osteosynthesefragen; OTA, Orthopedic Trauma Association

All fractures were managed with open reduction and internal fixation using a 4.5-mm narrow dynamic compression plate applied to the medial surface of the humerus through an anterolateral approach.

Functional outcomes

Functional outcomes were assessed at final follow-up using the Rodríguez-Merchán criteria. Excellent outcomes were achieved in 18 patients (37.5%), while 22 patients (45.8%) demonstrated good outcomes. Fair outcomes were observed in six patients (12.5%), and poor outcomes in two patients (4.2%).

Overall, excellent or good functional outcomes were achieved in 40 patients (83.3%), indicating satisfactory restoration of upper limb function following medial plating (Table 3).

Outcome	Number of patients	Percentage (%)
Excellent	18	37.5
Good	22	45.8
Fair	6	12.5
Poor	2	4.2
Total	48	100.0

TABLE 3: Functional outcomes according to Rodríguez-Merchán criteria (n = 48).

Radiological union and complications

Radiological union was achieved in all 48 patients (100%). The mean radiological union time was 14.9 ± 4.9 weeks, with a median union time of 14 weeks (range, 8-28 weeks). Delayed union, defined as failure to achieve radiological union within 24 weeks, occurred in four patients (8.3%). Among these patients, additional bone grafting procedures were required to achieve union, after which fracture union was achieved. Three patients (6.3%) developed superficial surgical site infections, all of which resolved with oral antibiotics and regular wound care. Two patients (4.2%) developed postoperative radial nerve palsy, both of whom recovered completely with conservative management during follow-up. One patient (2.1%) experienced implant failure and subsequently underwent revision fixation, after which fracture union was achieved. Overall, postoperative complications were infrequent (Table 4).

Variable	Value
Mean union time (weeks), mean $\pm$ SD	14.9 $\pm$ 4.9
Median union time (weeks)	14
Range (weeks)	8–28
Delayed union (≥ 24 weeks), n (%)	4 (8.3)
Surgical site infection, n (%)	3 (6.3)
Radial nerve palsy, n (%)	2 (4.2)
Implant failure, n (%)	1 (2.1)

TABLE 4: Radiological union and postoperative complications (n = 48).

Representative radiographs demonstrating preoperative fracture morphology, postoperative fixation, and progressive fracture healing at six months and one year are shown in Figures 1-2.

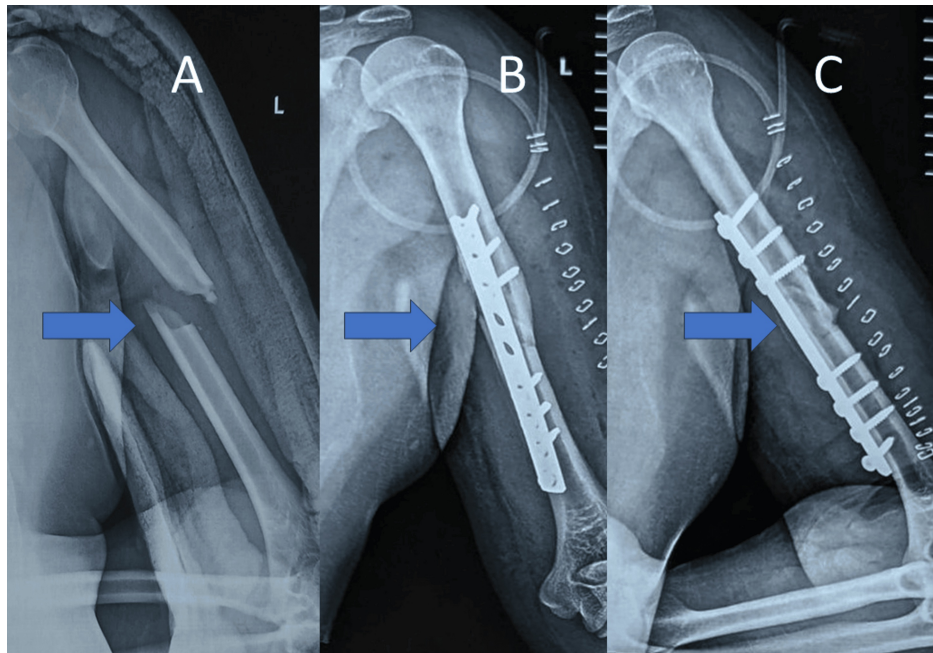


FIGURE 1: Preoperative and immediate postoperative radiographs of a middle-third humeral shaft fracture treated with medial plating through an anterolateral approach

(A) Preoperative anteroposterior radiograph demonstrating a displaced middle-third humeral shaft fracture (arrow).
(B) Immediate postoperative anteroposterior radiograph showing anatomical reduction and fixation with a medial 4.5-mm narrow dynamic compression plate (arrow).
(C) Immediate postoperative lateral radiograph demonstrating satisfactory alignment and implant position (arrow).

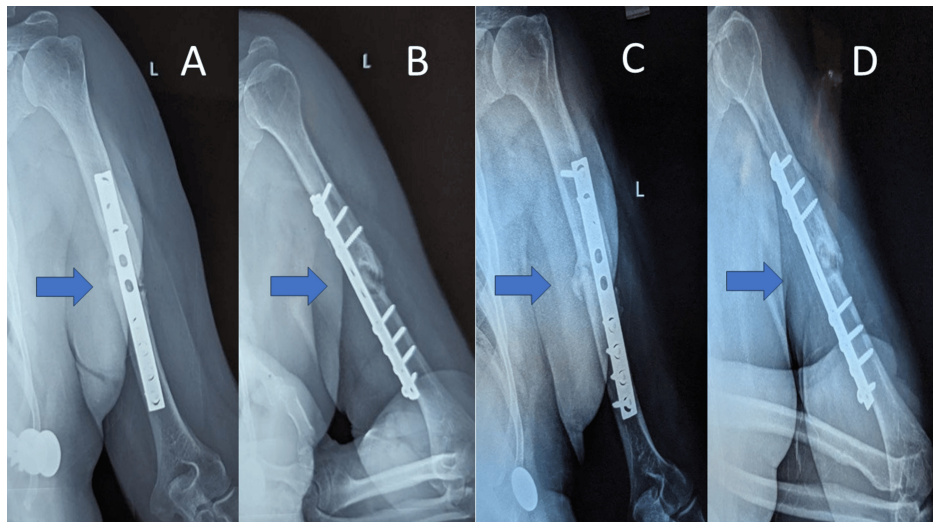


FIGURE 2: . Follow-up radiographs demonstrating fracture healing.

(A) Six-month anteroposterior radiograph demonstrating progressive callus formation (arrow).
(B) Six-month lateral radiograph showing maintenance of alignment and implant position (arrow).
(C) One-year anteroposterior radiograph demonstrating complete fracture union (arrow).
(D) One-year lateral radiograph confirming radiological union and stable fixation (arrow).

Association between time to surgery and radiological union time

A statistically significant positive correlation was observed between the interval from injury to surgery and radiological union time (Pearson's correlation coefficient, $r = 0.565$; $P < 0.001$).

When stratified according to the interval from injury to surgery, patients operated on within 10 days achieved radiological union in a mean of 13.1 ± 3.0 weeks, while those treated between 11 and 20 days achieved radiological union in a mean of 13.8 ± 3.7 weeks. Patients undergoing surgery more than 20 days after injury had a mean radiological union time of 20.9 ± 5.6 weeks (one-way ANOVA, $P < 0.001$) (Table 5).

Time to surgery	Number of patients	Mean union time (weeks)	Standard deviation
≤10 days	22	13.1	3.0
11-20 days	16	13.8	3.7
>20 days	10	20.9	5.6

TABLE 5: Association between time to surgery and radiological union time.

One-way analysis of variance (ANOVA): $P < 0.001$. Pearson's correlation coefficient (r) = 0.565, $P < 0.001$.

Discussion

The present study evaluated the functional outcome of medial plating through an anterolateral approach for acute middle-third humeral shaft fractures. The principal findings were that 40 (83.3%) patients achieved excellent or good functional outcomes, the mean radiological union time was 14.9 ± 4.9 weeks, complication rates were low, and delayed surgical fixation was associated with prolonged fracture healing. These findings support medial plating as a safe and effective treatment option for middle-third humeral shaft fractures.

The demographic profile of our study population was consistent with the established epidemiology of humeral shaft fractures. Humeral shaft fractures commonly demonstrate a bimodal age distribution, occurring in younger patients following high-energy trauma and in older individuals following low-energy falls [2]. In the present study, road traffic accidents accounted for 32 (66.7%) injuries, reflecting the predominance of high-energy trauma in the study population. Similar observations have been reported in previous studies evaluating the operative management of humeral shaft fractures [3].

Functional outcomes following medial plating were encouraging, with 40 (83.3%) patients achieving excellent or good results according to the Rodríguez-Merchán criteria. These findings are comparable to those reported in previous studies that demonstrated favorable functional recovery following anteromedial plating of humeral shaft fractures [6,7]. Stable fixation achieved with plate osteosynthesis permits early mobilization of the shoulder and elbow, which is an important determinant of successful functional recovery [8]. Furthermore, placement of the plate on the medial surface of the humerus avoids implant prominence and provides a biomechanically stable construct, thereby facilitating rehabilitation and return to daily activities [9].

The mean radiological union time in the present study was 14.9 ± 4.9 weeks, with delayed union observed in 4 (8.3%) patients. These findings are comparable to previously published reports evaluating plate osteosynthesis for humeral shaft fractures [7,9]. Adequate fracture reduction, stable fixation, and preservation of the surrounding soft tissue envelope are important factors contributing to successful fracture healing [10]. The medial surface of the humerus provides a relatively flat surface for plate application, allowing secure fixation while minimizing disruption of periosteal blood supply [6,9].

A notable finding of the present study was the significant positive correlation between the interval from injury to surgery and radiological union time ($r = 0.565$, $P < 0.001$). The present study demonstrated a statistically significant association between a longer interval from injury to surgery and prolonged radiological union time. Because adjustment for potential confounding variables was not performed, this finding should be interpreted as an association rather than evidence of an independent effect of surgical delay. Previous studies have suggested that delayed fracture fixation may be associated with increased soft-tissue scarring, fracture-end resorption, and greater technical difficulty in achieving anatomical reduction, which could adversely influence the biological environment for fracture healing [11,12]. However, further studies with adjustment for potential confounding variables are required to determine whether surgical timing independently influences fracture union following medial plating of humeral shaft fractures.

The overall complication rate in the present series was low. Surgical site infection occurred in three (6.3%) patients, radial nerve palsy in two (4.2%) patients, and implant failure in one (2.1%) patient. All superficial surgical site infections resolved with oral antibiotics and regular wound care, both cases of postoperative radial nerve palsy recovered completely with conservative management, and the single implant failure was successfully managed with revision fixation. Patients with delayed union subsequently achieved fracture union following additional bone grafting. The low incidence of radial nerve palsy is particularly noteworthy

because routine radial nerve exploration was not performed. One of the proposed advantages of medial plating through an anterolateral approach is reduced manipulation of the radial nerve when compared with posterior plating techniques [6]. Our findings are consistent with previous reports that have highlighted the safety of medial plating and its potential role in minimizing iatrogenic nerve injury while maintaining stable fixation [9,13].

The present study has several strengths. It was conducted prospectively, utilized a uniform surgical technique with standardized implant fixation, and incorporated regular clinical and radiological follow-up for a minimum of six months. In addition, both functional outcome and radiological union were evaluated, providing a comprehensive assessment of treatment outcomes. However, certain limitations should be acknowledged. The study was conducted at a single institution and involved a relatively small sample size, which may limit the generalizability of the findings. The absence of a comparative control group precludes direct comparison with alternative fixation techniques such as posterior plating, anterolateral plating, or intramedullary nailing. Furthermore, the association between the interval from injury to surgery and radiological union time was evaluated without adjustment for potential confounding variables; therefore, this finding should be interpreted as an association rather than an independent effect of surgical timing. In addition, individual component scores of the Rodríguez-Merchán criteria were not recorded separately, limiting component-wise analysis of functional outcomes. Larger multicenter comparative studies with adequate adjustment for potential confounders are required to further validate these findings and define the relative role of medial plating in the management of humeral shaft fractures.

Conclusions

In this prospective observational study, medial plating through an anterolateral approach was associated with satisfactory functional outcome and radiological union, complete fracture union, and an acceptable complication profile in patients with acute mid-third humeral shaft fractures. A longer interval from injury to surgery was associated with a longer radiological union time. These findings should be interpreted within the limitations of a single-center observational study without a comparative control group, and further comparative studies are warranted.

Additional Information

Author Contributions

All authors have reviewed the final version to be published and agreed to be accountable for all aspects of the work.

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Disclosures

Human subjects: Informed consent for treatment and open access publication was obtained or waived by all participants in this study. Human Ethics Committee, Government Medical College, Thiruvananthapuram, Kerala, India issued approval 05/05/2025/MCT. **Animal subjects:** All authors have confirmed that this study did not involve animal subjects or tissue. **Conflicts of interest:** In compliance with the ICMJE uniform disclosure form, all authors declare the following: **Payment/services info:** All authors have declared that no financial support was received from any organization for the submitted work. **Financial relationships:** All authors have declared that they have no financial relationships at present or within the previous three years with any organizations that might have an interest in the submitted work. **Other relationships:** All authors have declared that there are no other relationships or activities that could appear to have influenced the submitted work.

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