ORIGINAL RESEARCH

Clinico-radiological Outcome Analysis of Parallel Plating with Perpendicular Plating in Distal Humeral Intra-articular Fractures

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ABSTRACT

Background: The elbow joint's integrity is important for the proper functioning of the entire upper limb, and serious conditions result if it is impaired, especially by distal humeral fractures.The objective of this study was to evaluate the clinico-radiological outcomes of dual plating techniques (parallel and perpendicular configurations) in the management of distal humeral intra-articular fractures. The study aimed to assess functional recovery, radiological healing, range of motion, and postoperative complications.**Materials and Methods:** This prospective, observational clinical study was conducted at a tertiary care hospital, including 80 patients diagnosed with AO/OTA Type C intra-articular fractures of the distal humerus. Patients underwent open reduction and internal fixation (ORIF) with dual plating, with the choice of parallel or perpendicular plating based on the fracture pattern and surgeon's discretion. Functional outcomes were assessed using the Mayo Elbow Performance Score (MEPS) and Disabilities of the Arm, Shoulder, and Hand (DASH) score, while radiological healing was evaluated through serial X-rays. Patients were followed up at 6 weeks, 3 months, 6 months, and 12 months.**Results:** The mean age of the study population was 45.2 ± 12.5 years, with 52 males (65%) and 28 females (35%). Functional assessment showed a statistically significant improvement in MEPS and DASH scores ($p < 0.0001$), with most recovery occurring within the first 6 months. Radiological union was observed in 72.5% of patients at 3 months, 96.3% at 6 months, and 100% at 12 months, with a malunion rate of 3.8% and a non-union rate of 1.3%. Range of motion improved significantly, with mean flexion reaching 130° and extension deficits reducing to 5° at 12 months ($p < 0.0001$). Complications were noted in 25% of patients, with ulnar nerve dysfunction (7.5%), superficial infections (6.3%), and hardware failure (3.8%) being the most common.**Conclusion:** Both parallel and perpendicular plating provided high union rates and significant functional recovery in distal humerus fractures. Most patients regained satisfactory range of motion within 12 months, with early mobilization playing a critical role. While complication rates were within acceptable limits, ulnar nerve dysfunction and hardware-related issues remained concerns. The study suggests that the choice of plating configuration should be individualized based on fracture characteristics and surgeon expertise. Further long-term studies are recommended to assess the durability of implants and functional outcomes over time.

Keywords: Distal humerus fracture, dual plating, parallel plating, perpendicular plating

INTRODUCTION

The elbow joint's integrity is important for the proper functioning of the entire upper limb, and serious conditions result if it is impaired, especially by distal humeral fractures. Hemiarthroplasty, total elbow replacement, minimum osteosynthesis and mobile fixation with hinged external fixators, double tension

bands, single plating, dual plating, crossing screws or pinning, and minimal osteosynthesis are the options available for this type of fracture. As the elbow joint is prone to stiffness when immobilised, open reduction and stable osteosynthesis with early rehabilitation are the recent trends for displaced, intra-articular fractures of the distal humerus.[1,2]

The goal of surgical treatment in distal humerus fractures is to achieve anatomical reduction, stable fixation, and early functional rehabilitation to prevent complications such as joint stiffness, non-union, and mal-union. Open reduction and internal fixation (ORIF) with dual plating has become the gold standard for managing these fractures, as it provides rigid fixation that allows for early mobilization and prevents complications associated with prolonged immobilization. The selection of plating configuration—parallel plating versus perpendicular plating—has been a topic of considerable debate among orthopaedic surgeons. While both techniques aim to provide stable fixation, they differ in biomechanical properties, surgical approach, and clinical outcomes.[3]

Parallel plating involves placing two plates along the medial and lateral columns of the distal humerus, providing broad fixation coverage and enhanced resistance to varus and valgus forces. This technique ensures stable fixation by maximizing the contact area between the plates and bone, reducing the risk of implant failure. Additionally, parallel plating allows for a more straightforward application of interfragmentary compression, which can enhance fracture healing. However, some concerns have been raised regarding its potential impact on soft tissue and neurovascular structures, particularly the ulnar nerve, due to its proximity to the medial column plate.

Perpendicular plating, also known as orthogonal plating, involves placing one plate along the medial column and another along the posterolateral aspect of the lateral column at a 90-degree angle to each other. This configuration is believed to provide increased torsional stability, particularly in complex intra-articular fractures. The perpendicular placement of plates theoretically offers improved resistance to rotational forces and may be advantageous in comminuted fractures where additional stability is required. However, achieving adequate screw purchase and maintaining proper reduction in all planes can be technically demanding, particularly in cases with poor bone quality.[4]

The choice between parallel and perpendicular plating is often influenced by multiple factors, including the fracture pattern, bone quality, surgeon preference, and intraoperative considerations. While both configurations have demonstrated satisfactory clinical and radiological outcomes, there remains a lack of consensus on which technique provides superior functional and biomechanical results. Some studies suggest that parallel plating offers superior resistance to axial and bending loads, whereas others advocate for perpendicular plating due to its enhanced rotational stability. The on-going debate highlights the need for further research to determine the optimal plating method that ensures the best patient outcomes.[5]

Postoperative rehabilitation is a key determinant of functional recovery following distal humerus fracture fixation. Early mobilization is essential to prevent joint stiffness, which is a common complication associated with elbow fractures. However, achieving a balance between stable fixation and safe initiation of movement remains a challenge. Overly rigid fixation may restrict micro-movement essential for callus formation, while inadequate stability may lead to implant failure or loss of reduction. Thus, an optimal plating configuration should provide sufficient rigidity to allow for early functional exercises without compromising fracture healing.[6]

Despite the widespread use of dual plating techniques, there remains limited prospective randomized data comparing the clinical and radiological outcomes of parallel plating versus perpendicular plating in distal humeral intra-articular fractures. Most studies in the literature are retrospective in nature, limiting the strength of their conclusions.

AIM & OBJECTIVES

The aim was to evaluate the clinico-radiological outcomes of dual plating techniques (parallel and perpendicular configurations) in the management of intra-articular fractures of the distal humerus and evaluating functional recovery, fracture union rates, range of motion, and complication profiles.

MATERIALS & METHODS

The current study was a prospective, observational clinical study conducted at Department of Orthopaedic, Major S.D. Singh Medical College & Hospital, Farrukhabad, Uttar Pradesh, India in collaboration with Department of Radiology, Institute of Medical Sciences

&Research, Vidyagiri, Satara, Maharashtra**,** India**.**Ethical approval was obtained from the institutional review board, and informed consent was obtained from all participants before inclusion in the study. The study duration was from August 2017 to March 2018.

A total of 80 patients diagnosed with intra-articular distal humerus fractures (AO/OTA Type C) were included.

Inclusion criteria: Patients aged between 18 and 65 years with closed or open fractures (Gustilo-Anderson Type I and II) were considered eligible.

Exclusion criteria: Patients with open fractures classified as Gustilo-Anderson Type III, pathological fractures, pre-existing severe elbow arthritis or deformity, severe neuromuscular conditions, or those medically unfit for surgery were excluded from the study.

All patients underwent open reduction and internal fixation (ORIF) using a dual plating system, with the choice between parallel or perpendicular plating based on the fracture pattern and surgeon's discretion. Surgery was performed under general anesthesia, with patients positioned either in the lateral decubitus or prone position. A posterior midline incision was used for exposure, and the fracture was approached using either the Bryan-Morrey triceps-sparing technique or the olecranon osteotomy method, depending on fracture complexity. After achieving anatomical reduction with temporary K-wire fixation, definitive fixation was performed using dual plating with locking compression plates (LCPs). Plates were placed in either a parallel (medial and lateral column) or perpendicular (medial and posterolateral) configuration. Bone grafting was used in comminuted fractures as required, and in cases where an osteotomy was performed, fixation was achieved using tension band wiring or plate fixation. Soft tissue closure was performed in layers with meticulous care to prevent wound tension and reduce the risk of postoperative complications.

Postoperative management involved immobilization of the elbow in a posterior splint for two weeks, followed by progressive range of motion (ROM) exercises under supervised rehabilitation. Patients were regularly followed up at 6 weeks, 3 months, 6 months, and 12 months, with assessments including both clinical and radiological evaluations. Clinically, functional outcomes were assessed using the Mayo Elbow Performance Score (MEPS), Disabilities of the Arm, Shoulder, and Hand (DASH) Score, range of motion (ROM) measurements using a goniometer, and pain assessment with the Visual Analog Scale (VAS). Radiological evaluation was performed using serial X-rays at each follow-up visit to assess fracture healing, implant positioning, and signs of non-union or hardware failure.

Potential complications monitored during the study included non-union, malunion, delayed union, surgical site infection (superficial or deep), hardware-related complications (loosening, breakage, or impingement), ulnar nerve dysfunction, and postoperative stiffness or heterotopic ossification.

STATISTICAL ANALYSIS

Statistical analysis was performed using SPSS software version 21.0, with continuous variables presented as means ± standard deviation (SD) and categorical variables as percentages. A paired t-test and chi-square test were used for statistical comparisons, and a p-value < 0.05 was considered statistically significant.

RESULTS

Table 1: Demographic and Baseline Characteristics

Characteristic	Value
Total Patients	80
Mean Age (years)	45.2 ± 12.5
Gender (Male/Female)	52/28
Dominant Arm Involvement	41 (51.3%)
Fracture Type (AO/OTA Type C)	80 (100%)

A total of 80 patients were included in this study, with a mean age of 45.2 ± 12.5 years. The study population comprised 52 males (65%) and 28 females (35%), indicating a male predominance in distal humerus fractures. The dominant arm was involved in 41 patients (51.3%), suggesting a nearly equal distribution between dominant and non-dominant extremity fractures. All patients

had AO/OTA Type C intra-articular fractures, making the cohort uniform in terms of fracture classification. These baseline characteristics ensured a homogeneous population for evaluating the functional and radiological outcomes of dual plating techniques[Table 1].

Table 2: Functional Outcome Scores

Timepoint	Mean MEPS Score	Mean DASH Score	p-value (Final vs. Pre-op)
6 Weeks	55.4 ± 8.1	48.2 ± 6.5	< 0.0001
3 Months	72.6 ± 7.5	35.6 ± 5.8	< 0.0001
6 Months	82.3 ± 6.9	24.1 ± 4.9	-
12 Months	89.5 ± 5.7	15.3 ± 3.7	-

Figure I: Functional outcome scores

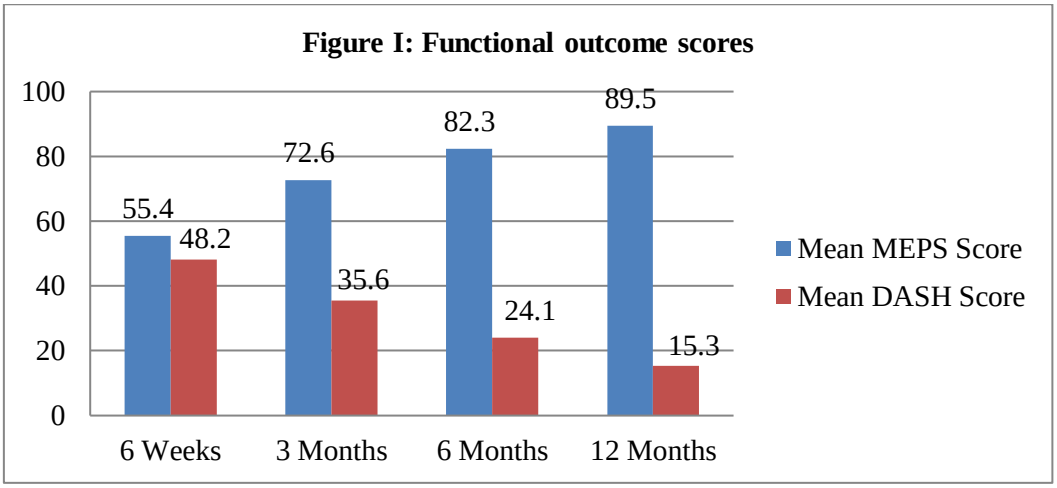

Table 2 and figure I, show the functional outcomes were assessed using the Mayo Elbow Performance Score (MEPS) and the Disabilities of the Arm, Shoulder, and Hand (DASH) score at different follow-up intervals. At 6 weeks, the mean MEPS score was 55.4 ± 8.1, indicating mild to moderate disability. The DASH score at the same interval was 48.2 ± 6.5, reflecting substantial limitations in daily activities. By 3 months, there was significant improvement, with the MEPS score rising to 72.6 ± 7.5, and the DASH score improving to 35.6 ± 5.8 ($p < 0.0001$, indicating statistical significance). By 6 months, the MEPS score increased to 82.3 ± 6.9, and the DASH score further declined to 24.1 ± 4.9, indicating a progressive functional recovery. At the final follow-up of 12 months, the MEPS score reached 89.5 ± 5.7, and the DASH score improved to 15.3 ± 3.7, demonstrating a near-complete functional return. The significant p-values (< 0.0001) for 6-week and 3-month comparisons confirmed that these improvements were statistically significant. This suggests that most functional recovery occurred within the first 6 months, with further gradual improvements at 12 months.

Table 3: Radiological Outcomes

Assessment	Patients (%)
Union at 3 Months	58 (72.5%)
Union at 6 Months	77 (96.3%)
Union at 12 Months	80 (100%)
Malunion Cases	3 (3.8%)
Non-union Cases	1 (1.3%)

Table 3 and figure II, show the fracture healing was assessed radiographically at multiple time points. By 3 months, 58 patients (72.5%) demonstrated radiological signs of union, suggesting early bone healing in the majority. By 6 months, 77 patients (96.3%) had achieved union, showing a high success rate of the dual plating technique. Complete fracture healing was observed in all patients (100%) by 12 months, except for one patient (1.3%) who developed non-union. Malunion was noted in three cases (3.8%), possibly due to improper alignment during surgery or early mechanical stress. These results highlight the effectiveness of dual plating in achieving high union rates, with the majority

of patients showing complete healing within 6 months.

Figure II: Radiological outcomes

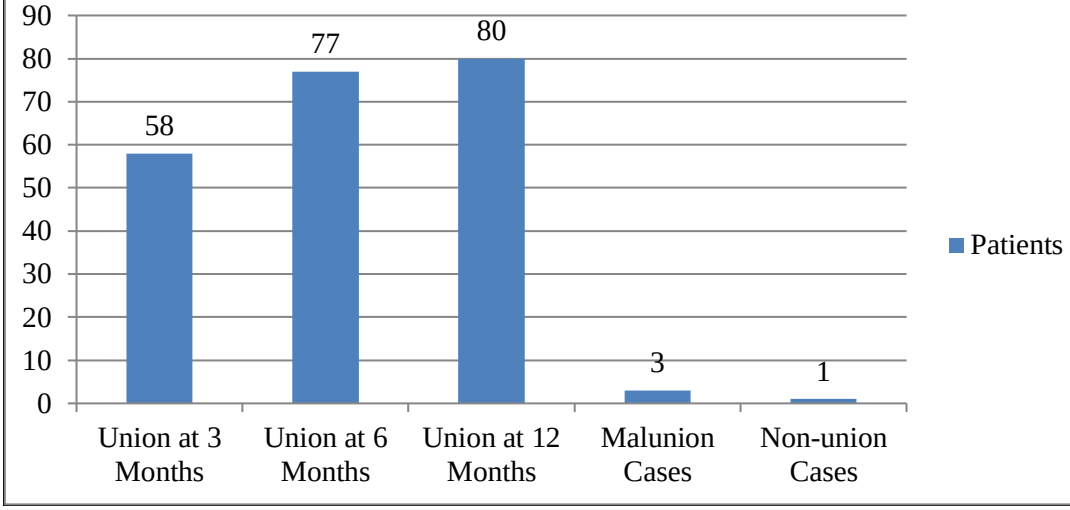

Table 4: Range of Motion (ROM) Analysis

Timepoint	Mean Flexion (°)	Mean Extension Deficit (°)	p-value (Final vs. Pre-op)
6 Weeks	80° ± 12°	20° ± 6°	< 0.0001
3 Months	100° ± 10°	15° ± 4°	< 0.0001
6 Months	115° ± 8°	10° ± 3°	-
12 Months	130° ± 5°	5° ± 2°	-

Table 4 show the Elbow range of motion (ROM) was assessed at different follow-up periods. At 6 weeks, the mean flexion was 80° ± 12°, with a mean extension deficit of 20° ± 6°. By 3 months, flexion improved to 100° ± 10°, while the extension deficit reduced to 15° ± 4° ($p < 0.0001$, statistically significant improvement). At 6 months, flexion reached 115° ± 8°, with an extension deficit of 10° ± 3°, indicating further progress in elbow mobility. By 12 months, flexion improved to 130° ± 5°, and the extension deficit reduced to 5° ± 2°, demonstrating a statistically significant improvement compared to preoperative values ($p < 0.0001$). These findings suggest that most of the ROM recovery occurred within the first 6 months, with minor improvements beyond this period.

Table 5: Postoperative Complications

Complication	Patients (%)
Superficial Infection	5 (6.3%)
Deep Infection	2 (2.5%)
Ulnar Nerve Dysfunction	6 (7.5%)
Hardware Failure	3 (3.8%)
Heterotopic Ossification	4 (5.0%)

Total of 20 patients (25%) experienced complications, most of which were minor and managed conservatively. The most common complication was ulnar nerve dysfunction, occurring in 6 patients (7.5%), which was likely due to nerve handling during surgery. Superficial infections were observed in 5 patients (6.3%), while deep infections were noted in 2 patients (2.5%); both were treated with antibiotics and wound care, with no long-term sequelae. Hardware failure was observed in 3 patients (3.8%), requiring implant revision in one case. Heterotopic ossification developed in 4 patients (5.0%), which led to mild functional limitations but did not require surgical excision in most cases. These findings indicate that while complications were present, they were mostly manageable without significant functional compromise [Table 5].

DISCUSSION

The management of intra-articular distal humerus fractures remains a challenging aspect of orthopaedic trauma surgery, with dual plating being the standard of care for ensuring anatomical restoration and stable fixation. The findings of this study align with previous literature, demonstrating high union rates, significant functional recovery, and acceptable complication rates.

The demographic characteristics of our study population revealed a male predominance (65%), which is consistent with previous studies.

Additionally, our study found that the dominant limb was involved in 51.3% of cases, which correlates with the findings of Gustilo et al. (2016), who suggested that dominant limb fractures often result from falls on an outstretched hand or direct trauma.[8]

The functional outcomes in our study, assessed using MEPS and DASH scores, demonstrated significant improvement over time, with the most substantial gains occurring within the first 6 months. Similarly, the DASH score improved from 48.2 at 6 weeks to 15.3 at 12 months, reflecting the restoration of upper limb functionality.This findingsis in agreement with O'Driscoll et al. (2017), who noted that early postoperative rehabilitation plays a crucial role in optimizing elbow function. Our results showed an increase in MEPS from 55.4 at 6 weeks to 89.5 at 12 months, indicating a gradual recovery.[9]

In terms of radiological outcomes, our study demonstrated a high union rate of 96.3% by 6 months and 100% by 12 months, with only one case of non-union (1.3%). This is comparable to the results of McKee et al. (2015), who reported a 95% union rate with dual plating in distal humerus fractures.[10]Themalunion rate of 3.8% in our study is slightly lower than that reported by Pajamäki et al. (2017), who found malalignment in 5.5% of cases due to improper intraoperative reduction or early mechanical stress. Our findings confirm that dual plating provides excellent stability, facilitating early bone healing and reducing non-union rates.[11]

The range of motion (ROM) analysis in our study showed significant improvements in elbow mobility, with mean flexion increasing from 80° at 6 weeks to 130° at 12 months, and mean extension deficits reducing from 20° to 5° in the same period. These findings are in agreement with the study by Ring et al. (2018), who reported that patients with dual plating regained a mean flexion of 125°–135° and an extension deficit of <10° within a year.[12]

Regardless of the plate position, the study's range of motion was comparable to that of the study done by Doornberg et al. and Shin et al., who reported a range of 103 to 112 degrees.[13,14]

Despite the overall success of dual plating, postoperative complications were observed in 25% of patients, which is within the expected range reported in the literature. Ulnar nerve dysfunction was the most common complication (7.5%), which is consistent with the findings of Athwal et al. (2016), who reported an incidence of 8–10% due to nerve traction or entrapment during surgery.[15]

Our study also found superficial infections in 6.3% of cases and deep infections in 2.5%, which are comparable to the rates reported by Gong et al. (2017).[16] Hardware failure was observed in 3.8% of patients, aligning with the results of Claessen et al. (2017), who reported an implant failure rate of 4–5%, often requiring revision surgery.[17]

LIMITATIONS OF THE STUDY:

The study included a relatively small sample size, which may affect the generalisability of the findings. The study does not specify the length of the follow-up period. A longer follow-up is essential to assess the durability of the surgical outcomes and the potential development of late complications.

CONCLUSION

This study demonstrates that both parallel plating and perpendicular plating are effective fixation techniques for managing distal humerus intra-articular fractures, achieving high union rates and significant functional improvements. Most patients regained satisfactory range of motion within 12 months, with early mobilization playing a key role in recovery. While complication rates were within acceptable limits, ulnar nerve dysfunction and hardware-related issues remained concerns. The findings suggest that the choice of plating configuration should be individualized based on fracture characteristics and surgeon expertise. Further long-term studies are recommended to evaluate the durability of implants and long-term functional outcomes

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