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Functional and Radiological Outcomes in Humeral Diaphyseal Fractures: A Comparative Observational Study of Intramedullary Nailing Versus Dynamic Compression Plating

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ABSTRACT

Background: The optimal fixation method for diaphyseal fractures of the humerus remains debated. Both plate osteosynthesis and intramedullary interlocking nailing are widely practiced, but comparative evidence on functional outcome is limited. This study compared the functional and radiological outcomes of interlocking intramedullary nailing and plate osteosynthesis in the operative management of humeral shaft fractures.

Methods: This prospective observational study was conducted in the Department of Orthopedics, Andhra Medical College and King George Hospital, over 18 months (January 2022 to July 2023). Thirty humeral shaft fractures in 28 adult patients (age >18 years) with closed, simple, comminuted or segmental fractures, including polytrauma cases, were allocated alternately to plate osteosynthesis (15 patients, 15 fractures) or antegrade interlocking intramedullary nailing (13 patients, 15 fractures; 2 patients had bilateral injuries). Patients with compound fractures, pathological fractures, neglected nonunion, infected fractures or severe medical comorbidity were excluded. Radiological union, time to union, shoulder and elbow range of motion, complications, and the Disabilities of the Arm, Shoulder and Hand (DASH) score were recorded at a minimum follow-up of 18 months.

Results: Mean age was 41.5±16.4 years in the plating group and 47.6±12.2 years in the nailing group (p=0.27); the plating group had a male preponderance (80.0% vs 53.8%, p=0.23). All 30 fractures united; mean time to union was 18.1±1.8 weeks with plating and 18.0±1.4 weeks with nailing (p=0.91). Complications occurred in 4/15 (26.7%) plated fractures (2 superficial infections, 2 radial nerve palsies, both fully recovered) versus none in the nailing group (p=0.10). Residual shoulder pain was reported by 2/15 patients after plating and none after nailing (p=0.48). The mean DASH score was significantly better after nailing (3.94±2.40) than after plating (14.02±11.55; p=0.005).

Conclusion: Plate osteosynthesis and interlocking intramedullary nailing both reliably achieve union of humeral diaphyseal fractures with comparable time to union. Interlocking nailing was associated with significantly better DASH functional scores and a trend towards

fewer complications, and may be preferable when minimally invasive fixation, preservation of fracture biology and early rehabilitation are priorities, particularly in polytrauma and osteoporotic bone.

Keywords: Humeral shaft fracture; Intramedullary nailing; Plate osteosynthesis; DASH score; Functional outcome; Radiological union

INTRODUCTION

Humeral diaphyseal fractures account for approximately 3% of all fractures and 14% of humeral fractures [1]. The humeral shaft is surrounded by a substantial muscular envelope with a rich vascular supply, which contributes to its favorable healing potential. In contrast to the lower extremity, the humerus is not subjected to weight-bearing forces, and the shoulder and elbow can accommodate a limited degree of shortening and angular deformity. The distinctive anatomy of the humerus, its vascular muscular envelope, and the mobility afforded by the adjoining shoulder and elbow joints have traditionally favored non-operative management: closed reduction with functional bracing achieves union rates approaching 100% with a low complication rate in appropriately selected patients [2,3].

Operative fixation is nonetheless indicated when closed reduction fails to maintain acceptable alignment, in segmental or pathological fractures, in the presence of vascular or brachial plexus injury, in open fractures, and in polytrauma, where early mobilization and nursing care are facilitated by stable fixation [4]. Two operative techniques dominate current practice: open reduction and internal fixation with a dynamic compression plate, and closed or open reduction with an intramedullary interlocking nail, inserted antegrade or retrograde. Plate osteosynthesis, popularized by the AO/ASIF group, is regarded by many as the historical gold standard, achieving reliable union but requiring wider soft-tissue dissection and deliberate protection of the radial nerve [4]. Intramedullary interlocking nailing was subsequently developed on the strength of its success in the femur and tibia, and offers a biological, load-sharing alternative with a smaller incision, an undisturbed fracture hematoma and reduced soft-tissue stripping. Evolution from early flexible nail systems (Rush, Ender, Hackethal) and first-generation interlocking designs (Seidel) to modern solid interlocking nails has progressively addressed problems of rotational instability and implant failure [5,6].

Despite these theoretical advantages, comparative evidence between plating and interlocking nailing report morbidity from shoulder impingement, rotator-cuff injury and iatrogenic radial nerve palsy varying widely between series. Functional outcome, rather than radiological union alone, is increasingly recognized as the more clinically meaningful endpoint, and instruments such as the Disabilities of the Arm, Shoulder and Hand (DASH) questionnaire provide a validated, patient-reported measure of upper-limb function [7].

Aims and objectives:

Primary Objective

To compare intramedullary interlocking nailing and plate osteosynthesis in the operative management of humeral diaphyseal fractures with respect to functional outcome of the upper limb, assessed using the Disabilities of the Arm, Shoulder and Hand (DASH) score.

Secondary Objectives

1. To compare the rate and time to radiological and clinical union of the fracture between the two treatment groups.
2. To compare postoperative range of motion of the shoulder and elbow joints achieved with each technique.
3. To document and compare the incidence of intra-operative and postoperative complications associated with each

technique, including surgical-site infection, radial nerve palsy, residual shoulder pain and restriction of joint movement.

4. To correlate patient factors - age, sex, mode of injury and AO/OTA fracture pattern - with the functional and radiological outcome in each group.
5. To derive practical recommendations, on the basis of the above comparisons, to guide the choice of fixation technique for a given fracture pattern and patient profile.

MATERIALS & METHODS

This prospective observational study was conducted in the Department of Orthopedics, Andhra Medical College and King George Hospital, Visakhapatnam, over a period of 18 months (January 2022 to July 2023), following approval of the Institutional Ethics Committee. Written informed consent was obtained from all participants.

Sample and eligibility criteria:

Thirty humeral diaphyseal fractures were enrolled.

Inclusion criteria were:

- age >18 years; simple,
- comminuted or segmental closed fractures of the humeral shaft, including fractures associated with polytrauma; and
- willingness to provide informed consent.

Exclusion criteria were:

- age <18 years;
- compound (open) fractures;
- pathological fractures and nonunion;
- infected fractures; and severe medical comorbidity precluding surgery or anesthesia.

Patients were allocated to plate osteosynthesis or interlocking intramedullary nailing alternately. Twenty-eight patients (30 fractures) completed follow-up and were analyzed; two patients in the nailing group had bilateral humeral shaft fractures, so this group comprised 13 patients contributing 15 fractures, compared with 15 patients contributing 15 fractures in the plating group.

Surgical Technique

Plate osteosynthesis: Fractures in the upper and middle thirds were approached anterolaterally and those in the distal third posteriorly, with identification and protection of the radial nerve throughout. [8] A dynamic compression plate or limited-contact dynamic compression plate was applied in compression mode for transverse fractures and with an interfragmentary lag screw for oblique fractures (Fig 1).

Interlocking intramedullary nailing: Antegrade closed interlocking nailing was performed under image-intensifier control in all 15 nailed fractures. The entry portal was established medial to the tip of the greater tuberosity, and reamed or un-reamed nails were passed under fluoroscopic guidance with static proximal and distal interlocking to achieve axial and rotational stability [6] (Fig 2,3).

Postoperative Protocol

A broad arm sling or pouch was applied, and parenteral antibiotics were continued for 48–72 hours. Wounds were inspected on the second and fifth postoperative days, and sutures were removed on the twelfth to fourteenth day. Active-assisted pendular and shoulder range-of-motion exercises and elbow flexion exercises were commenced as pain allowed, with progressive strengthening thereafter.

Figure 1- Distal third humeral shaft fracture treated with open reduction and plating

Figure 2 – Proximal third shaft of humerus fracture treated with nailing

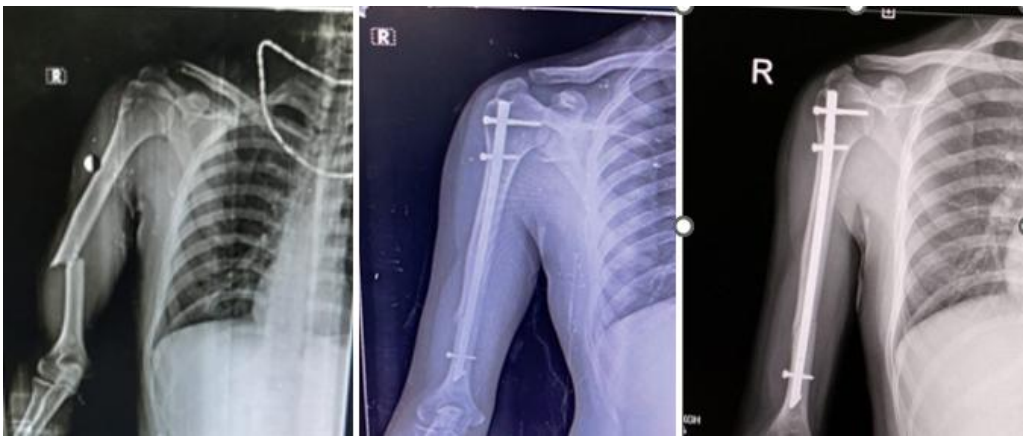

Figure 3 – Middle and distal third junction fracture of shaft of humerus treated with nailing.

Follow-up and Outcome Assessment

Patients were reviewed fortnightly until radiological union. At each visit, the fracture site was assessed clinically for tenderness, stability and pain, shoulder and elbow range of motion and wound status were recorded, and antero-posterior and lateral radiographs were obtained. Clinical union was defined as a painless, stable fracture site; radiological union was defined as bridging bone trabeculae or a crossing cortex on at least three of four cortices on orthogonal radiographs. Delayed union was defined as absence of union at 16 weeks, and nonunion as absence of union at 36 weeks.

Functional outcome was assessed using the DASH questionnaire at six months, or at full recovery if earlier. [7] The 30-item, AAOS-validated instrument yields a

disability/symptom score from 0 (no disability) to 100 (maximum disability), calculated as {(sum of n responses) − 1} × 25/n, and graded as excellent (0–20), good (21–40), fair (41–60) or poor (>60).

Statistical Analysis

Continuous variables (age, time to union, follow-up duration, DASH score) are expressed as mean ± standard deviation and were compared between groups using the independent-samples (Welch) t-test. Categorical variables (sex, mode of injury, complications, residual pain) are expressed as counts and percentages and were compared using Fisher's exact test. A two-tailed p-value <0.05 was considered statistically significant.

RESULT

Twenty-eight patients (30 fractures) completed the minimum 18-month follow-up (mean 20.8±1.9 months, range 18–24). Baseline demographic and injury characteristics are summarised in Table 1. Mean age was comparable between groups (plating 41.5±16.4 years, range 23–82, vs nailing 47.6±12.2 years, range 22–72; p=0.27). The plating group had a male preponderance (12/15, 80.0%) compared with a more even distribution in the nailing group (7/13 male, 53.8%; p=0.23). Road traffic accidents were the commonest mode of injury in both groups (plating 66.7%, nailing 61.5%; p=1.00), and all 30 fractures were closed injuries. Six of 28 patients had associated injuries requiring surgical management (head injury in four, and one each of distal radius, olecranon/distal femur/tibia-fibula, Monteggia/lateral condyle humerus, shaft of ulna, sacral ala with splenic laceration, and lateral end of clavicle fracture).

Table 1. Baseline demographic and injury characteristics. RTA = road traffic accident. *Two patients in the nailing group had bilateral fractures (n=15 fractures in 13 patients)

Characteristic	Plating (n=15)	Nailing (n=13)	p value
Age, years, mean ± SD (range)	41.5 ± 16.4 (23–82)	47.6 ± 12.2 (22–72)	0.27
Sex, male, n (%)	12 (80.0%)	7 (53.8%)	0.23
Sex, female, n (%)	3 (20.0%)	6 (46.2%)	—
Mode of injury – RTA, n (%)	10 (66.7%)	8 (61.5%)	1.00
Mode of injury – fall, n (%)	5 (33.3%)	5 (38.5%)	—
Side – right, n (%)	7 (46.7%)	6 (46.2%) *	—
Side – left, n (%)	8 (53.3%)	5 (38.5%) *	—
Type of injury – closed, n (%)	15 (100%)	13 (100%)	—
Follow-up, months, mean ± SD (range)	20.5 ± 1.7 (18–23)	21.2 ± 2.1 (18–24)	0.31

AO/OTA type A2 and B2 fracture patterns were the most frequent morphology overall [8,9] (Table 2).

Table 2. Distribution of humeral shaft fractures by AO/OTA classification. Percentages are of total fractures per group (n=15 each); the nailing group's 15 fractures occurred in 13 patients.

AO/OTA type	Plating, n (%)	Nailing, n (%)	Total, n (%)
A1	2 (13.3%)	2 (13.3%)	4 (13.3%)
A2	6 (40.0%)	2 (13.3%)	8 (26.7%)
A3	1 (6.7%)	5 (33.3%)	6 (20.0%)
B2	6 (40.0%)	5 (33.3%)	11 (36.7%)
C2	0 (0%)	1 (6.7%)	1 (3.3%)
Total fractures	15 (100%)	15 (100%)	30 (100%)

All 30 fractures (100%) achieved radiological union; there were no cases of delayed union or nonunion in either group. Mean time to union was 18.1±1.8 weeks (range 15–21) in the plating group and 18.0±1.4 weeks (range 16–20) in the nailing group, a difference that was not statistically significant (p=0.91).

Complications occurred in 4 of 15 fractures (26.7%) in the plating group: two superficial surgical-site infections that settled with antibiotic therapy, and two radial nerve palsies, both of which recovered fully with conservative management. No complications occurred in the nailing group. This difference did not reach statistical significance (p=0.10), likely reflecting the limited sample size.

Table 3. Complications by treatment group. p values by Fisher's exact test; p<0.05 considered significant.

Complication	Plating (n=15)	Nailing (n=13)	p value
Any complication, n (%)	4 (26.7%)	0 (0%)	0.10
Superficial infection, n (%)	2 (13.3%)	0 (0%)	—
Radial nerve palsy, n (%)	2 (13.3%)	0 (0%)	—
Residual shoulder pain, n (%)	2 (13.3%)	0 (0%)	0.48

Full elbow range of motion was recorded in all patients in both groups. Full shoulder range of motion was achieved in 26 of 28 patients; shoulder movement was mildly restricted in the two plated patients who also developed superficial infection. Residual shoulder pain on heavy manual activity was reported by 2 of 15 patients (13.3%) after plating and by none after nailing (0/13); this difference was not statistically significant (p=0.48).

The mean DASH score was 14.02±11.55 (range 2.0–37.8) in the plating group and 3.94±2.40 (range 1.4–8.8) in the nailing group. This difference was statistically significant (p=0.005), indicating better patient-reported upper-limb function after interlocking nailing. Applying the standard DASH grading, outcomes in the nailing group fell uniformly in the excellent range, whereas the plating group included a wider spread from excellent to fair (Table 4).

Table 4. Union and functional outcome by treatment group. ROM = range of motion; DASH = Disabilities of the arm, Shoulder and Hand score (lower is better).

Outcome	Plating (n=15)	Nailing (n=13)	p value
Union rate, n (%)	15 (100%)	15/15 fractures (100%)	—
Time to union, weeks, mean ± SD (range)	18.1 ± 1.8 (15–21)	18.0 ± 1.4 (16–20)	0.91
Full shoulder ROM, n (%)	13 (86.7%)	13 (100%)	—
Full elbow ROM, n (%)	15 (100%)	13 (100%)	—
DASH score, mean ± SD (range)	14.02 ± 11.55 (2.0–37.8)	3.94 ± 2.40 (1.4–8.8)	0.005

DISCUSSION

Humeral shaft fractures constitute 2–3% of all fractures in the body and around 14% of fractures involving the humerus, and treatment must be individualised to fracture pattern, associated injury and patient factors. [1]

This prospective study compared plate fixation with antegrade intramedullary interlocking nailing for acute closed humeral diaphyseal fractures in adults. The principal findings were a significantly lower mean DASH score at final follow-up in the nailing group, a shorter mean time to radiological union that approached but did not reach statistical significance, and fewer recorded complications. These findings suggest that both techniques provide reliable

fracture healing, while intramedullary nailing may offer advantages in selected patients; however, the small sample size and loss to follow-up warrant cautious interpretation.

The demographic profile of our cohort was broadly consistent with previous epidemiological and comparative series, in which humeral shaft fractures predominantly affect working-age adults and are frequently associated with high-energy trauma. Road-traffic accidents were the most common mechanism in our series, accounting for approximately 60% of injuries, and men constituted the majority of participants. The higher proportion of associated injuries in the nailing group likely reflects the inclusion of polytrauma patients and may also have influenced postoperative functional recovery. Such baseline differences are important when interpreting functional outcomes in a small cohort.

Radiological union was achieved in all 28 patients who completed follow-up, with no case of nonunion in either group. Although the mean time to union was shorter following intramedullary nailing than plating (16 versus 18 weeks), this difference did not reach conventional statistical significance ($P = 0.051$). The direction of effect is nevertheless consistent with contemporary evidence. A meta-analysis restricted to randomized controlled trials reported significantly faster union following intramedullary nailing, although no significant difference in non-union rates was identified between nailing and plating [10]. Similarly, studies have demonstrated comparable union rates between the two techniques, with intramedullary nailing associated with a modest reduction in time to union [10,11]. The biological rationale for this finding is that intramedullary fixation can be performed with limited disruption of the fracture hematoma and periosteal blood supply, although the clinical importance of a difference of approximately 2 weeks remains uncertain.

The absence of non-union in either treatment group should therefore be interpreted in the context of the small sample rather than as evidence that either technique eliminates the risk of non-union. Larger series have reported high union rates with both plate fixation and intramedullary nailing, with no consistent evidence that one method provides a clinically meaningful advantage in ultimate fracture healing [12]. The 100% union rate observed in our study may also reflect the exclusion of open, pathological, infected, and established non unions.

Postoperative radial nerve palsy occurred exclusively in the plating group, affecting 2 of 15 patients (13.3%). Both patients recovered completely during follow-up, consistent with a transient neurapraxic injury rather than permanent nerve dysfunction. The incidence observed in our series is higher than that reported in most contemporary comparative studies and should therefore be interpreted cautiously. A recent systematic review of more than 5000 humeral shaft fractures reported iatrogenic radial nerve injury rates of approximately 6% with plate fixation and 2.8% with intramedullary nailing, with variation according to surgical approach [13]. Meta-analyses of comparative studies have similarly demonstrated a greater risk of iatrogenic radial nerve palsy with plating in some datasets, although randomised-trial evidence has not consistently demonstrated a statistically significant difference [14,15]. The lower incidence associated with nailing is biologically plausible because the fixation construct can be inserted without direct exposure of the radial nerve; however, careful surgical technique remains essential with either method.

Superficial wound infection occurred in 2 patients (13.3%) in the plating group and in none of the patients treated with intramedullary nailing. Both infections resolved with antibiotic therapy without reoperation. Although the difference was not statistically significant, the direction of effect is consistent with pooled evidence

showing lower surgical-site infection rates following intramedullary nailing compared with open plating [14,15]. The reduced soft-tissue exposure associated with nailing provides a plausible explanation for this finding. Nevertheless, the small number of events in the present study precludes reliable estimation of comparative infection risk.

The significantly lower DASH score observed in the nailing group represents the most notable functional finding of this study. Patients treated with intramedullary nailing had a mean final DASH score of 4.67 compared with 13.8 following plating ($P = 0.003$). This difference was influenced in part by higher scores in two patients in the plating group who experienced shoulder pain and restricted function. Although the magnitude of the difference favored nailing, its clinical importance should be interpreted cautiously because the study was not powered specifically to detect a clinically important between-group difference in DASH score. Furthermore, previous comparative evidence has not consistently demonstrated functional superiority of one fixation method. The randomized trial by Chapman et al. [16] reported comparable clinical outcomes between locked intramedullary nailing and plate fixation, while the trial by McCormack et al. [17] found no significant differences in shoulder and elbow function or return to activity and reported greater shoulder-related morbidity with antegrade nailing. More recent meta-analyses of randomised trials likewise suggest broadly comparable functional outcomes overall, despite differences in operative time, infection, and time to union [14]. Thus, our finding of a lower DASH score with nailing should be regarded as hypothesis-generating rather than definitive evidence of functional superiority.

Shoulder morbidity remains an important consideration with antegrade humeral nailing because the proximal entry portal traverses the rotator-cuff region. In our series, one patient developed transient limitation of shoulder motion, which resolved with physiotherapy. Appropriate entry-point selection, avoidance of nail prominence, careful handling of the rotator cuff, and meticulous repair of the tendon split are therefore important technical considerations. Previous randomized evidence has reported a higher frequency of shoulder impingement with antegrade nailing, although contemporary implant design and refinements in surgical technique may have reduced this complication [14]. The absence of persistent shoulder dysfunction in our cohort should therefore not be interpreted as evidence that antegrade nailing is free of shoulder-related morbidity.

Intramedullary nailing may also be advantageous in selected polytrauma patients because it permits definitive stabilization through relatively limited exposure and may facilitate early mobilization. In our cohort, associated injuries were present in more than half of the patients allocated to nailing. However, the study was neither designed nor powered to assess the efficacy of either fixation method specifically in polytrauma, and this observation should not be interpreted as evidence that nailing is universally preferable in multiply injured patients.

Limitations

This study has several limitations. The sample size was modest, limiting the power to detect between-group differences in less frequent outcomes such as complications and residual pain, both of which showed a trend favoring nailing without reaching statistical significance. Retrograde nailing was not evaluated, and follow-up, although a minimum of 18 months in all patients, was not uniform in duration. As a single-center observational study without blinding of outcome assessment, residual confounding cannot be excluded, and larger multicenter randomized trials would be needed to confirm these findings.

CONCLUSION

In this small, single-center series, plate osteosynthesis and interlocking

intramedullary nailing both achieved reliable union of humeral diaphyseal fractures, with no significant difference in time to union. Interlocking nailing was associated with significantly better DASH functional scores; the numerically lower complication rate with nailing (0/13 vs 4/15) did not reach statistical significance and should be interpreted with caution. These findings suggest a possible functional advantage of interlocking nailing, particularly in polytrauma or osteoporotic bone, but given the limited sample size, single-center design and quasi-random allocation, they should be confirmed in larger, multicenter randomized trials before firm treatment recommendations can be made. Plate osteosynthesis remains a reliable option, particularly where anatomical open reduction is required.

Declaration

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