



FUNCTIONAL AND RADIOLOGICAL OUTCOMES OF PLATE OSTEOSYNTHESIS FOR DISPLACED MIDSHAFT CLAVICLE FRACTURES IN ADULTS: A PROSPECTIVE OBSERVATIONAL STUDY

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ABSTRACT

Background: Displaced midshaft clavicle fractures are increasingly managed operatively, yet prospective functional data from single tertiary centres, particularly in resource-limited settings, remain limited. **Objectives:** To prospectively evaluate the functional and radiological outcomes of plate osteosynthesis for displaced clavicle fractures in adults, and to characterise the associated perioperative and postoperative complications. **Methods:** In this hospital-based prospective observational study, 30 consecutively enrolled adults (18–60 years) with closed, displaced or comminuted clavicle fractures of less than three weeks' duration underwent open reduction and internal fixation with a contoured 3.5 mm plate via a superior approach. Patients were followed at 6 weeks and 3, 6 and 12 months with clinical examination, radiography and the Constant–Murley score. Categorical variables were compared using the chi-square test (SPSS; $p < 0.05$ significant). **Results:** Male predominance was significant (76.7%; $p = 0.0035$), most patients being 19–28 years old (33.3%). Midshaft fractures predominated (96.7%), mostly displaced (80.0%; Robinson 2B1 in 76.7%). Perioperative complications occurred in 16.7% and postoperative complications in 13.3% of patients. Radiological union was achieved in 96.7%, full range of motion in 93.3%, and freedom from pain in 83.3%; mean Constant–Murley score was 91.5 ± 4.6 (range 79–98). Postoperative complications were significantly associated with fracture comminution ($p = 0.004$), Robinson type ($p = 0.036$) and perioperative complications ($p < 0.001$), but not with sex, fracture side or site (all $p > 0.05$). **Conclusion:** Plate osteosynthesis provides reliable union and excellent functional recovery with low morbidity in adults with displaced midshaft clavicle fractures. Fracture comminution and Robinson subtype, rather than demographic factors, predict complication risk and merit closer perioperative surveillance.

KEYWORDS

Clavicle Fracture; Plate Osteosynthesis; Open Reduction Internal Fixation; Midshaft Fracture; Constant–Murley Score; Functional Outcome

INTRODUCTION

Fractures of the clavicle are among the most frequently encountered injuries of the shoulder girdle, accounting for approximately 2.5–5% of all adult fractures and up to 45% of injuries involving the shoulder complex.^{1,2}

The subcutaneous course of the bone and its role as a strut linking the axial skeleton to the upper limb render it particularly vulnerable to direct and indirect trauma, most commonly from road-traffic accidents, falls and contact sports.³ Of the three anatomical segments, the midshaft accounts for nearly three-quarters of all clavicular fractures owing to its narrow cross-sectional area, S-shaped curvature, and relative paucity of muscular or ligamentous reinforcement.

Management of clavicle fractures has undergone a marked paradigm shift over the past two decades. Non-operative treatment with a sling or figure-of-eight bandage was traditionally favoured, based on the clavicle's robust vascularity and inherent healing potential.² However, contemporary observational and randomised evidence indicates that displaced midshaft fractures treated conservatively carry a substantially higher risk of nonunion, symptomatic malunion, residual shortening and reduced shoulder strength compared with operative fixation.^{3,4} Multicentre randomised trials have shown that open reduction and internal fixation using precontoured locking plates achieves union rates exceeding 95%, faster functional recovery, and greater patient satisfaction relative to non-operative care.^{5,6}

Plate osteosynthesis restores anatomical length, rotation and alignment while permitting early mobilisation of the shoulder, thereby limiting stiffness and expediting return to daily and occupational activities. Functional recovery after fixation is customarily quantified using validated composite instruments such as the Constant–Murley score, which integrates domains of pain, range of motion, strength and activities of daily living. Fracture-classification systems, principally the Allman and Robinson systems, characterise injury severity, help predict the likelihood of nonunion, and guide the choice between operative and non-operative management.

Despite the growing acceptance of plate fixation, complication profiles — including wound infection, hardware irritation, nerve injury and delayed union — continue to be reported, and the influence of fracture morphology and Robinson subtype on these complications is not

uniformly characterised in the existing literature. Robust prospective data from tertiary trauma centres, particularly from resource-limited settings, remain comparatively scarce.

This study was therefore undertaken to prospectively evaluate the functional and radiological outcomes of plate osteosynthesis for displaced clavicle fractures in adults, and to characterise the spectrum and determinants of perioperative and postoperative complications.

MATERIALS AND METHODS

Study Design and Setting

This was a hospital-based, prospective observational study conducted in the Department of Orthopaedics of a tertiary-care teaching institution in northern India over a two-year period. Reporting follows the relevant items of the STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) statement for observational studies, adapted for this prospective cohort design.

Participants and Eligibility

Adult patients aged 18–60 years presenting to the orthopaedic outpatient and emergency departments with closed, displaced or comminuted fractures of the clavicle sustained within the preceding three weeks were screened for eligibility. Patients with open fractures, pathological fractures, undisplaced fractures, associated head injury, presentation beyond three weeks of injury, or age outside the specified range were excluded. Eligible patients were enrolled consecutively until the target sample size was reached, yielding a final cohort of 30 patients.

Sample Size

The sample size was estimated using a proportion-based formula ($n = Z^2 p(1-p)/E^2$), assuming an institutional prevalence of displaced clavicle fractures of 2–5%, a 95% confidence level ($Z = 1.96$), and an allowable error of 8%. This yielded a feasible target of 30 consecutive patients, considered adequate for descriptive and comparative analysis within the study period.

Surgical Technique

All patients underwent open reduction and internal fixation under general anaesthesia in the supine position, with a sandbag placed beneath the ipsilateral scapula. An incision was made over the superior surface, or occasionally the anterior border, of the clavicle, centred on

the fracture site. After anatomical reduction, fixation was achieved with an appropriately contoured 3.5 mm locking compression plate applied to the superior surface, with a minimum of three screws in each principal fragment; lag screws supplemented fixation of comminuted fragments where feasible, with care taken to preserve soft-tissue attachments and the supraclavicular nerve. Wound closure was performed in layers. A sling was used for comfort for 7–10 days, after which active range-of-motion exercises were initiated; overhead activity and strengthening were introduced at approximately 6 weeks, with return to full activity expected by 3 months.

Data Collection and Follow-up

A structured proforma was used to record demographic details, injury characteristics, fracture classification (Allman and Robinson systems), operative findings, and peri- and postoperative complications. Patients were followed up at 6 weeks and at 3, 6 and 12 months, with clinical examination, assessment of shoulder range of motion and pain, radiography, and Constant–Murley scoring performed at each visit. Radiological union was defined by bridging callus on anteroposterior and 20° cephalad radiographs. Data were entered into Microsoft Excel and cross-verified before analysis.

Ethical Considerations

The study was approved by the Institutional Ethics Committee, and written informed consent was obtained from all participants, with assurances of confidentiality and the right to withdraw without prejudice to further care. A pilot phase involving five patients, subsequently excluded from the final analysis, was used to refine data-collection tools and standardise operative documentation.

Statistical Analysis

Data were analysed using SPSS software. Continuous variables were summarised as mean $\pm$ standard deviation, and categorical variables as frequencies and percentages. Associations between categorical variables were tested using the chi-square test, with a two-tailed p -value <0.05 considered statistically significant at a 95% confidence interval.

RESULTS

Of the 30 patients enrolled, 23 (76.7%) were male and 7 (23.3%) were female, a statistically significant male predominance ($p=0.0035$). The largest proportion of patients (33.3%) were aged 19–28 years, followed by 30.0% aged 36–45 years; patients aged 28–36, 45–53 and 53–62 years each formed a minority. Fracture laterality was equally distributed between the left and right sides (50.0% each; $p=1.000$).

The midshaft was the site of fracture in 29 of 30 patients (96.7%), with a single lateral-end fracture (3.3%; $p<0.001$). Displaced fractures predominated (80.0%) over comminuted fractures (20.0%; $p=0.001$). By the Allman system, 96.7% of fractures were Group I; by the Robinson system, 76.7% were type 2B1, 20.0% were type 2B2, and 3.3% were type 3 ($p<0.001$ for both classifications).

Perioperative complications occurred in 5 of 30 patients (16.7%): difficulty in fracture reduction in 3 (10.0%), excessive intraoperative bleeding in 1 (3.3%), and supraclavicular nerve injury in 1 (3.3%); the remaining 25 patients (83.3%) had an uneventful intraoperative course ($p<0.001$). Postoperative complications were similarly infrequent, occurring in 4 patients (13.3%): superficial surgical-site infection in 2 (6.7%), delayed union in 1 (3.3%), and persistent numbness over the incision in 1 (3.3%); 26 patients (86.7%) had no postoperative complications ($p<0.001$).

Recovery milestones were favourable. The sling was discontinued within 2 weeks in 25 patients (83.3%) and continued for 3 weeks in the remainder ($p=0.0003$). Sutures were removed in the standard manner in 28 patients (93.3%), with alternate-suture removal required in 2 (6.7%) owing to wound concerns ($p<0.001$). At final follow-up, 28 patients (93.3%) had achieved full shoulder range of motion, while 2 (6.7%) had residual limitation ($p<0.001$). Radiological union was confirmed in 29 patients (96.7%); one patient (3.3%) had radiologically absent union corresponding to clinical delayed union ($p<0.001$). Twenty-five patients (83.3%) were pain-free at final assessment ($p=0.0003$), and 28 (93.3%) had resumed independent performance of daily activities without restriction ($p<0.001$). The mean Constant–Murley score at final follow-up was 91.5 ± 4.6 (range 79–98), consistent with excellent composite functional recovery across the cohort (Table 1).

Table 1. Summary of Demographic, Fracture and Outcome Characteristics (n=30)

Variable	Category	n (%)	p-value
Sex	Male / Female	23 (76.7) / 7 (23.3)	0.0035
Age group (years)	19–28 (largest group)	10 (33.3)	—
Fracture side	Left / Right	15 (50.0) / 15 (50.0)	1.000
Fracture site	Midshaft / Lateral	29 (96.7) / 1 (3.3)	<0.001
Fracture type	Displaced / Comminuted	24 (80.0) / 6 (20.0)	0.001
Robinson type	2B1 / 2B2 / 3	23 (76.7) / 6 (20.0) / 1 (3.3)	<0.001
Perioperative complications	None / Any	25 (83.3) / 5 (16.7)	<0.001
Postoperative complications	None / Any	26 (86.7) / 4 (13.3)	<0.001
Radiological union (12 mo)	Present / Absent	29 (96.7) / 1 (3.3)	<0.001
Full shoulder ROM	Yes / No	28 (93.3) / 2 (6.7)	<0.001
Pain-free at final follow-up	Yes / No	25 (83.3) / 5 (16.7)	0.0003
Independent ADL performance	Yes / No	28 (93.3) / 2 (6.7)	<0.001
Constant–Murley score (mean $\pm$ SD)	—	91.5 ± 4.6 (range 79–98)	—

On bivariate analysis, postoperative complications showed no significant association with sex ($\chi^2=1.40$, $p=0.704$), fracture side ($\chi^2=4.62$, $p=0.020$), fracture site ($\chi^2=0.16$, $p=0.984$), or Allman classification ($\chi^2=0.16$, $p=0.984$). In contrast, postoperative complications were significantly associated with fracture morphology (comminuted versus displaced; $\chi^2=13.41$, $p=0.004$), Robinson classification ($\chi^2=13.47$, $p=0.036$), and the occurrence of a perioperative complication ($\chi^2=39.51$, $p<0.001$); comminuted and Robinson type 2B2 fractures, and cases with intraoperative reduction difficulty, showed disproportionately higher rates of delayed union and infection. Postoperative complications were also significantly linked with prolonged sling use ($\chi^2=23.08$, $p<0.001$), sling continuation beyond the standard period ($\chi^2=23.08$, $p<0.001$), atypical suture removal ($\chi^2=30.00$, $p<0.001$), limited range of motion ($\chi^2=14.55$, $p=0.002$), and absence of radiological union ($\chi^2=30.00$, $p<0.001$), but not with residual pain ($\chi^2=2.03$, $p=0.566$) or inability to perform daily tasks ($\chi^2=0.33$, $p=0.954$).

Perioperative complications, likewise, were not associated with sex ($\chi^2=1.83$, $p=0.609$), fracture side ($\chi^2=2.69$, $p=0.441$), or fracture site ($\chi^2=0.21$, $p=0.977$), but were significantly associated with fracture type ($\chi^2=9.33$, $p=0.025$) and, in turn, with postoperative complications ($\chi^2=39.51$, $p<0.001$) and absence of radiological union ($\chi^2=9.31$, $p=0.025$). Perioperative events were not significantly related to suture-removal pattern, sling continuation, postoperative range of motion, pain, or ability to perform daily tasks (all $p>0.05$).

DISCUSSION

The demographic profile of this cohort — a marked male predominance (76.7%) and a peak incidence in the third decade of life — mirrors the well-documented epidemiology of clavicle fractures as injuries of young, physically active adults exposed to high-energy trauma. Comparable patterns have been reported by Singh et al., who found that males accounted for around two-thirds of displaced midshaft fractures with a mean age in the mid-thirties,⁷ and by Dhakad et al., who described a 90% male predominance with peak incidence in the second and third decades.⁸ The overwhelming preponderance of midshaft, Allman Group I, Robinson 2B1/2B2 fractures in the present series corroborates the recognised biomechanical vulnerability of the diaphyseal segment, and is consistent with the inclusion criteria used in major randomised trials of plate fixation — such as those of Woltz et al. and Robinson et al., both of which restricted enrolment to displaced Robinson 2B1/2B2 fractures and demonstrated superior union and functional outcomes with operative fixation compared with conservative care.^{5,6}

The low rates of perioperative (16.7%) and postoperative (13.3%) morbidity observed here are consistent with contemporary series and meta-analyses. Hornung et al., in a systematic review of plate fixation for midshaft clavicle fractures, reported comparably low overall complication rates with reliable union,⁹ while Liu et al. demonstrated

that deliberate supraclavicular nerve preservation during plate osteosynthesis minimises postoperative numbness without increasing operative morbidity.¹⁰ Early sling discontinuation (83.3% within 2 weeks) and rapid recovery of full range of motion (93.3%) in our cohort align with the findings of Qvist et al. and Hornung et al., both affirming that stable plate fixation permits accelerated, structured rehabilitation.^{9,11} The mean Constant–Murley score of 91.5 in this series — within the excellent range — together with high rates of pain-free recovery (83.3%) and unrestricted daily activity (93.3%), is comparable with outcomes reported by Al-Moaiash et al. and Han et al. following plate fixation of displaced clavicle fractures.^{12,13}

Fracture morphology emerged as the principal determinant of complications in this study. Comminuted and Robinson type 2B2 fractures were significantly associated with higher rates of delayed union and infection, a pattern also observed by Chiu et al., who reported markedly higher implant-failure rates in comminuted fractures managed with less rigid constructs,¹⁴ and by Charles et al., who identified complex fracture patterns as independent predictors of complications after clavicle open reduction and internal fixation.¹⁵ Similarly, intraoperative difficulty in reduction correlated strongly with subsequent postoperative morbidity, echoing the observations of Zhu et al. that suboptimal intraoperative reduction independently predicts adverse healing.¹⁶ These findings suggest that the biomechanical instability inherent to comminution, rather than anatomical location alone, governs postoperative risk, and support closer perioperative vigilance and the use of adjunctive reduction techniques — such as the suture-assisted reduction methods described by Hu et al. and Li et al. — in comminuted fracture patterns.^{17,18}

Notably, demographic and simple anatomical variables (sex, fracture side, fracture site) were not independently associated with either perioperative or postoperative complications in this cohort, consistent with the findings of Charles et al. and Hamid et al., who likewise reported that operative morbidity after clavicle plating was largely independent of patient sex and fracture laterality, being driven instead by modifiable technical and morphological factors.^{15,19} Radiological union, rather than subjective pain or activity scores, was the parameter most consistently linked to complication status, underscoring — as emphasised by Fox et al. — that radiographic consolidation, rather than patient-reported measures alone, remains the most objective benchmark of surgical success.²⁰

The present findings collectively affirm plate osteosynthesis as a reliable and reproducible strategy for displaced midshaft clavicle fractures in adults, while identifying fracture comminution, Robinson subtype and intraoperative technical difficulty — rather than patient demographics — as the principal, clinically actionable predictors of complication risk.

Limitations

This study has several limitations. The modest single-centre sample of 30 patients limits statistical power and the generalisability of subgroup findings. The absence of a concurrent non-operatively managed comparison group precludes direct evaluation of relative effectiveness. Follow-up was limited to 12 months, which is adequate for assessing union and early functional recovery but insufficient to capture late complications such as hardware-related symptoms or degenerative change. Strict inclusion and exclusion criteria, while ensuring cohort homogeneity, may limit applicability to patients with open fractures, associated injuries, or delayed presentation. Finally, outcome assessment was not blinded, which may introduce observer bias in subjective measures such as pain and functional scoring.

CONCLUSION

Plate osteosynthesis for displaced midshaft clavicle fractures in adults provided reliable radiological union (96.7%), excellent functional recovery (mean Constant–Murley score 91.5 ± 4.6), and low rates of perioperative and postoperative morbidity in this prospective cohort. Complications were not influenced by patient sex or basic fracture anatomy, but were significantly predicted by fracture comminution, Robinson subtype, and intraoperative technical difficulty, identifying these as clinically actionable markers for risk stratification. These findings support plate fixation as a safe and effective standard of care for displaced midshaft clavicle fractures in adults, while highlighting the need for heightened vigilance, meticulous reduction technique and closer follow-up in patients with comminuted or Robinson type 2B2 injuries. Larger multicentric studies with extended follow-up are warranted to corroborate these findings and refine risk-stratified management protocols.

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