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Prospective Analysis of Functional Outcome of Clavicle Fractures Treated by Plate Osteosynthesis

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ABSTRACT

Background: Clavicle fractures are common injuries of the shoulder girdle, with displaced fractures potentially resulting in malunion, nonunion, and impaired shoulder function when managed conservatively. Plate osteosynthesis provides stable fixation and facilitates early postoperative mobilization. However, assessment of functional recovery over serial follow-up is important for evaluating treatment outcomes. This study evaluated the functional outcome and fracture healing following plate osteosynthesis for displaced clavicle fractures.
Materials and Methods: This prospective observational study was conducted over one year in the Department of Orthopaedics, Balrampur Hospital, Lucknow. Thirty adults with completely displaced clavicle fractures were enrolled and treated with open reduction and internal fixation using precontoured plates. Demographic and clinical characteristics, fracture displacement, operative duration, intraoperative blood loss, fracture union, and postoperative complications were recorded. Functional outcome was assessed using the Constant Shoulder Score at 6 weeks, 12 weeks, 18 weeks, and 6 months postoperatively. Changes in Constant Shoulder Scores over time were evaluated using repeated-measures analysis of variance, followed by Bonferroni-adjusted pairwise comparisons.
Results: The mean age of the participants was 41.57 ± 13.58 years, and 22 (73.33%) were male. Midshaft fractures were the most common fracture pattern (66.67%). The mean fracture displacement was 15.23 ± 5.19 mm, operative duration was 88.77 ± 15.02 minutes, and intraoperative blood loss was 179.00 ± 82.51 mL. Fracture union was achieved in all patients at a mean duration of 12.00 ± 2.24 weeks. The mean Constant Shoulder Score improved progressively from 69.97 ± 7.36 at 6 weeks to 78.83 ± 5.66 at 12 weeks, 84.30 ± 4.43 at 18 weeks, and 88.97 ± 5.80 at 6 months. Repeated-measures ANOVA demonstrated a significant effect of follow-up time ($F(3,87) = 74.79$, $p < 0.001$, partial $\eta^2 = 0.721$), with all Bonferroni-adjusted pairwise comparisons showing significant improvement. At 6 months, 50.00% of patients had excellent and 43.33% had good functional outcomes. Twenty-four patients (80.00%) experienced no complications.
Conclusion: Plate osteosynthesis was associated with progressive improvement in shoulder function, complete fracture union, and a favourable complication profile over six months in

this prospective cohort of patients with displaced clavicle fractures. Comparative studies with longer follow-up are warranted.
Keywords: *Clavicle fracture, Constant Shoulder Score, fracture union, functional outcome, midshaft clavicle, plate osteosynthesis*

INTRODUCTION

The clavicle, or collarbone, forms a structural bridge between the sternum and scapula, making up the shoulder girdle. Due to its superficial location, it is prone to fractures, accounting for 5-10% of all fractures and up to 44% of shoulder girdle injuries. Clavicle fractures commonly result from both low-energy and high-energy trauma. Approximately 70-80% occur in the midshaft, followed by the lateral third (12-15%) and medial third (5-8%).[1] These fractures are most frequent in males during the second and third decades of life, while females show a bimodal distribution with peaks in the young and elderly.[2] According to Allman's classification, clavicle fractures are divided into three types, with middle-third fractures being the most prevalent, comprising 80-85% of cases. [3,4]

Traditionally, nonoperative management was preferred for most clavicle fractures. However, this approach has been associated with higher rates of nonunion, malunion, and functional limitations, especially in displaced fractures.[5] Plate osteosynthesis has emerged as a widely used surgical method for specific indications, including displaced midshaft fractures, open fractures, neurovascular compromise, and nonunion or malunion. It allows anatomical reduction and stable fixation, enabling early mobilization and better outcomes. [6,7] Recent advancements, such as precontoured locking plates and minimally invasive techniques, have further improved outcomes by enhancing stability and minimizing soft tissue disruption.[8]

Despite its advantages, most existing research focuses on short-term radiological outcomes, with limited data on long-term functional recovery, shoulder strength, and quality of life. A better understanding of these outcomes is essential to optimize treatment and guide clinical decision-making. Therefore, the aim of this prospective study was to evaluate the functional outcomes, using the Constant Shoulder Score, in patients with clavicle fractures treated with plate osteosynthesis.

MATERIALS AND METHODS

This prospective study was conducted in the Department of Orthopaedics, Balrampur Hospital, Lucknow, over a period of one year, with a sample size of 30 patients. All enrolled patients had completely displaced clavicle fractures, classified according to Allman's classification. Inclusion criteria consisted of patients aged 18 years and above, with fresh displaced clavicle fractures, who were willing to undergo open reduction and internal fixation (ORIF). Patients with pathological fractures, those below 18 years of age, and individuals with undisplaced clavicle fractures were excluded from the study. Following ethical clearance and informed consent, eligible patients were evaluated clinically and radiologically. Baseline data, including demographic details, mode of injury, and associated injuries, were recorded, along with the duration of surgery, intraoperative blood loss, and time to union. Displacement of fractures was assessed using anteroposterior radiographs of the shoulder.

All procedures were performed under general anaesthesia. Patients were positioned supine on a radiolucent table with a sandbag placed between the scapulae. A longitudinal oblique incision was made over the superior surface of the clavicle, centred at the fracture site. The fracture fragments were exposed, reduced, and fixed using a precontoured plate and screws, ensuring a minimum of three screws in both proximal and distal fragments. Large, comminuted fragments were secured with lag screws, with care taken to preserve soft tissue attachments. The deltotrapezial fascia was closed with interrupted absorbable sutures, followed by skin closure.

Postoperatively, the affected limb was immobilized in an arm sling, and patients were advised to perform gentle pendulum exercises. Active shoulder mobilization was initiated at six weeks, at which point the sling was discontinued. Clinical and radiological follow-ups were conducted at 6, 12, and 18 weeks, as well as at six months postoperatively. Functional outcomes were assessed using the Constant Shoulder Score at each follow-up visit, while fracture union was confirmed radiographically by the presence of bridging callus at the fracture site.

Statistical Analysis

Statistical analysis was performed using IBM SPSS Statistics version 26.0 (IBM Corp., Armonk, NY, USA). Continuous variables were assessed for distributional characteristics and are presented as mean ± standard deviation (SD), while categorical variables are presented as frequencies and percentages. The Constant Shoulder Score, which was assessed repeatedly in the same patients at 6 weeks, 12 weeks, 18 weeks, and 6 months postoperatively, was analyzed using one-way repeated-measures analysis of variance (ANOVA) to evaluate changes in functional outcome over time. When the overall repeated-measures ANOVA demonstrated a statistically significant time effect, pairwise comparisons between follow-up time points were performed using Bonferroni adjustment for multiple comparisons. The magnitude of the overall time effect was quantified using partial eta squared (partial η^2), with values interpreted as small, moderate, and large effects according to conventional criteria. All statistical tests were two-sided, and a p-value <0.05 was considered statistically significant.

RESULT

The age distribution showed that 9 of the 30 patients (30.00%) were in the 38-47 years group, followed by 6 (20.00%) each in the 18-27- and 48-57-years groups; 5 patients (16.67%) were in the 58-67 years group and 4 (13.33%) in the 28-37 years group [Figure 1]. The mean age was 41.57 years (SD 13.58). Males comprised 22 of 30 patients (73.33%) and females 8 (26.67%) [Figure 2]. In terms of socioeconomic status, 16 patients (53.33%) belonged to the middle-income group, 11 (36.67%) to the low-income group, and 3 (10.00%) to the high-income group [Figure 3]. Falls and road traffic accidents were the leading causes of injury, each accounting for 13 patients (43.33%), while sports injuries were responsible for 4 (13.33%) [Figure 4]. According to Allman's classification, 20 fractures (66.67%) were midshaft (Group I), 8 (26.67%) were lateral (Group II), and 2 (6.67%) were medial (Group III) [Figure 5].

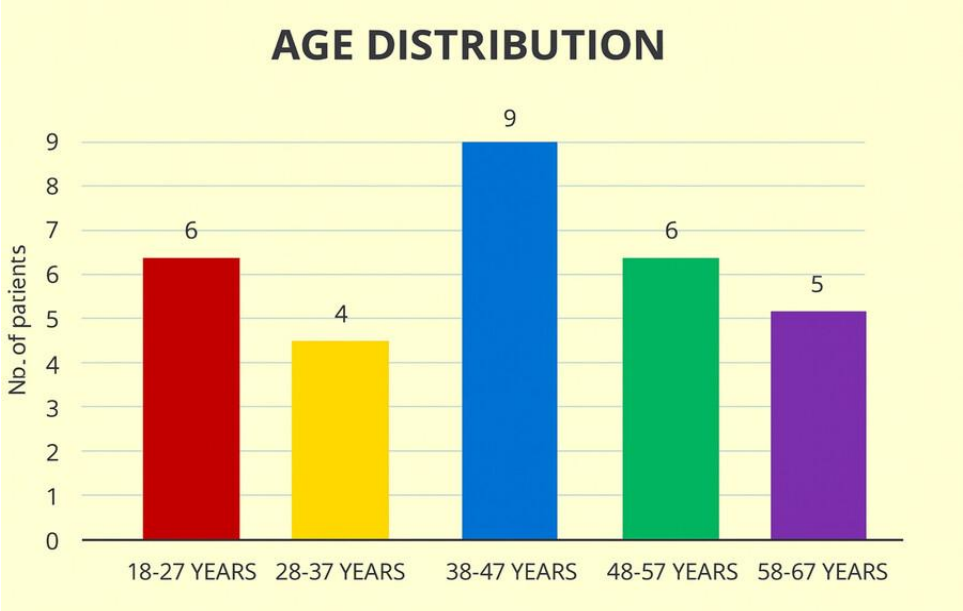

Figure 1: Age distribution of the enrolled patients.

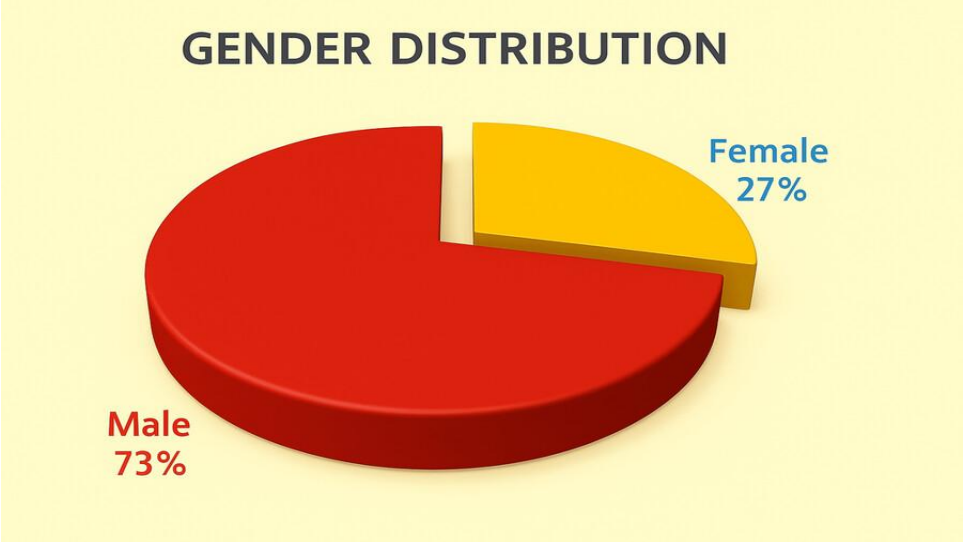

Figure 2: Gender distribution of the enrolled patients.

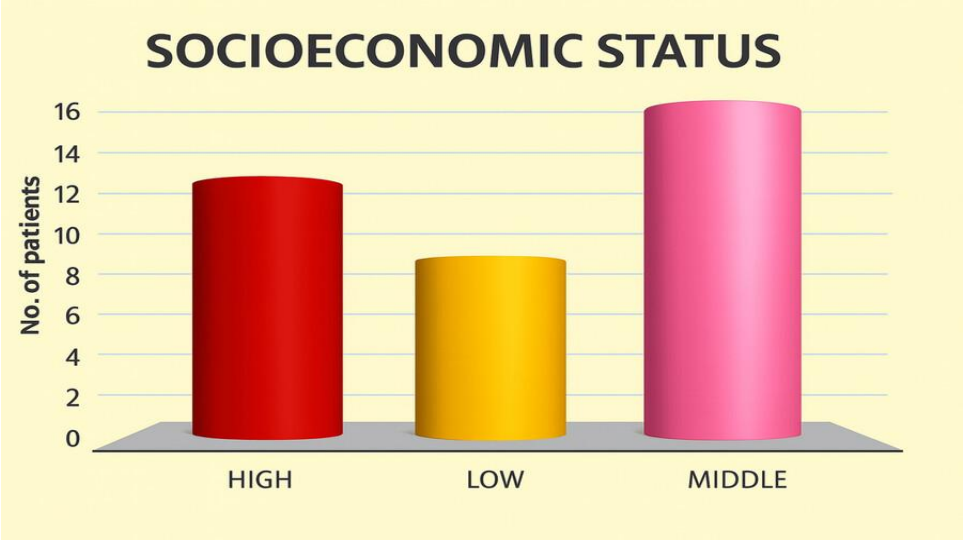

Figure 3: Socioeconomic status of the enrolled patients.

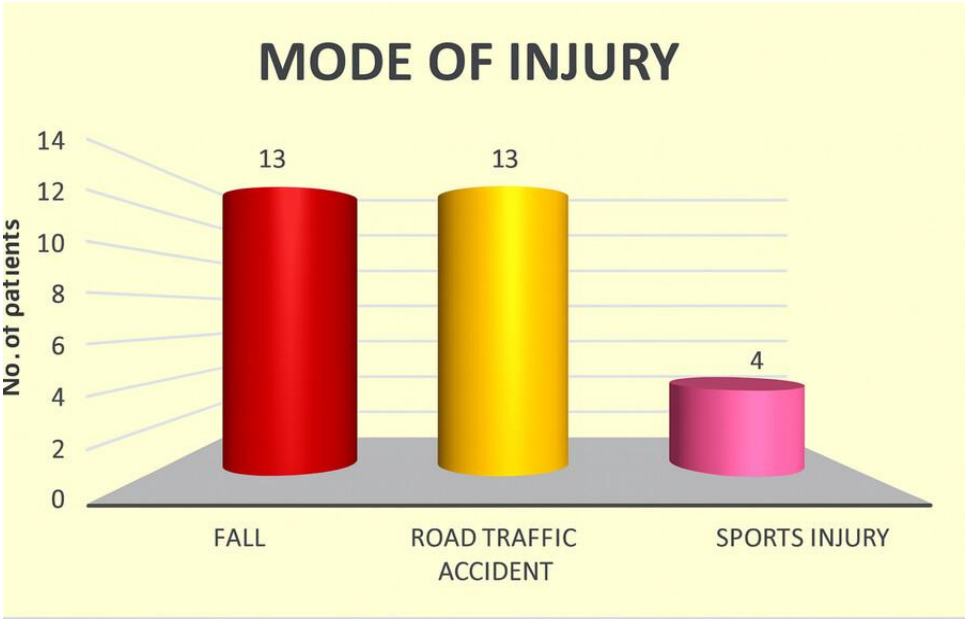

Figure 4: Mode of injury of the enrolled patients.

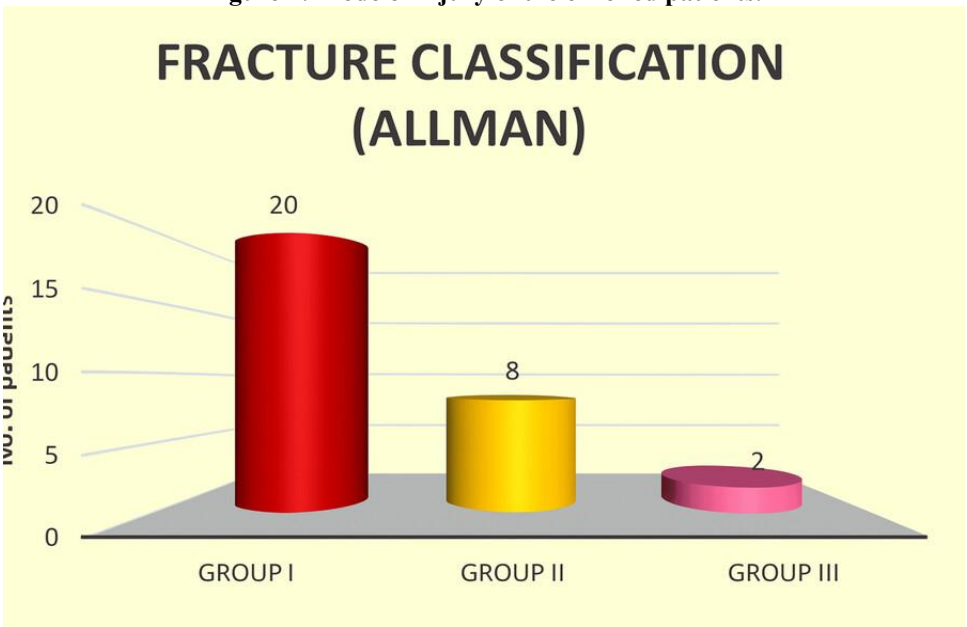

Figure 5: Fracture classification (Allman) of the enrolled patients.

The mean fracture displacement was 15.23 mm (SD 5.19). The mean duration of surgery was 88.77 minutes (SD 15.02), and the mean intraoperative blood loss was 179.00 ml (SD 82.51). Fracture union occurred at a mean of 12.00 weeks (SD 2.24); delayed union was observed in two patients, of whom one required supplementary bone grafting, and union was ultimately achieved in all 30 patients (table 1).

Table 1: Surgical parameters and healing metrics of the enrolled patients.

Parameters	Mean	SD
Displacement (mm)	15.23	5.19
Surgery duration (min)	88.77	15.02
Blood loss (ml)	179.00	82.51
Time to union (weeks)	12.00	2.24

There was a statistically significant effect of follow-up time on Constant Shoulder Score, $F(3,87) = 74.79$, $p<0.001$, partial $\eta^2=0.721$, indicating a large effect of time. The mean score increased progressively from 69.97 ± 7.36 at 6 weeks to 88.97 ± 5.80 at 6 months (table 2).

Table 2: Constant Shoulder Score over follow-up periods analysed using repeated-measures ANOVA

Variable	Group	Time interval	mean ± SD	F value	p value	Partial η^2
Constant Shoulder Score	Single group (n=30)	6 weeks	69.97 ± 7.36	—	—	—
Constant Shoulder Score	Single group (n=30)	12 weeks	78.83 ± 5.66	—	—	—
Constant Shoulder Score	Single group (n=30)	18 weeks	84.30 ± 4.43	—	—	—
Constant Shoulder Score	Single group (n=30)	6 months	88.97 ± 5.80	—	—	—
Time effect	Single group	Overall repeated-measures ANOVA	—	74.79 (df=3,87)	<0.001	0.721

Since the overall repeated-measures ANOVA was significant, pairwise comparisons were performed with Bonferroni adjustment for six comparisons. Repeated-measures analysis of variance demonstrated a significant effect of follow-up time on the Constant Score, $F(3,87) = 74.79$, $p<0.001$, partial $\eta^2=0.721$. The mean Constant Shoulder Score increased significantly from 69.97±7.36 at 6 weeks to 78.83±5.66 at 12 weeks, 84.30±4.43 at 18 weeks, and 88.97±5.80 at 6 months. Bonferroni-adjusted pairwise comparisons demonstrated statistically significant differences between all follow-up intervals (all adjusted $p<0.01$), confirming progressive improvement in Constant Scores throughout follow-up (table 3). The overall effect size was large (partial $\eta^2=0.721$).

Table 3: Bonferroni-adjusted post-hoc pairwise comparisons.

Comparison	Mean difference*	Bonferroni-adjusted p value	Effect size (Cohen's d)	Significant?
6 weeks vs 12 weeks	−8.87	<0.001	−1.04	Yes
6 weeks vs 18 weeks	−14.33	<0.001	−1.92	Yes
6 weeks vs 6 months	−19.00	<0.001	−2.45	Yes
12 weeks vs 18 weeks	−5.47	<0.001	−0.81	Yes
12 weeks vs 6 months	−10.13	<0.001	−1.47	Yes
18 weeks vs 6 months	−4.67	0.002	−0.74	Yes

*Mean difference calculated as earlier follow-up − later follow-up.

All six pairwise comparisons were statistically significant after Bonferroni adjustment. The largest improvement occurred between 6 weeks and 6 months (mean difference = 19.00 points).

At 6 weeks, 16 of 30 patients (53.33%) had poor outcomes, 11 (36.67%) fair, and 3 (10.00%) good. By 6 months, 15 patients (50.00%) achieved excellent outcomes, 13 (43.33%) good, and 2 (6.67%) fair (table 4).

Table 4: Distribution of Constant Shoulder Score categories over time.

Constant Score	Poor (n)	Poor (%)	Fair (n)	Fair (%)	Good (n)	Good (%)	Excellent (n)	Excellent (%)
6 weeks	16	53.33	11	36.67	3	10.00	0	0.00
12 weeks	3	10.00	14	46.67	12	40.00	1	3.33
18 weeks	0	0.00	5	16.67	21	70.00	4	13.33
6 months	0	0.00	2	6.67	13	43.33	15	50.00

Most patients (24 of 30, 80.00%) experienced no complications; the remaining six patients had one complication each. Delayed union was observed in 2 patients (6.67%), hardware failure in 1 (3.33%), and infection in 3 (10.00%), and these categories were mutually exclusive (table 5).

Table 5: Complications observed among the enrolled patients.

Complication	Number (n=30)	%
Delayed union	2	6.67
Hardware failure	1	3.33
Infection	3	10.00
None	24	80.00

DISCUSSION

Clavicle fractures often require surgical fixation when displaced, and plate osteosynthesis provides stable fixation, with favourable outcomes reported in displaced fractures. This one-year single-arm prospective study evaluated 30 patients treated with plate osteosynthesis. Functional outcomes were assessed using the Constant Shoulder Score, along with analysis of fracture type, associated injuries, surgery duration, blood loss, implant details, and time to union.

In our study of 30 patients, the mean age was 41.57 years, with the highest proportion (30.00%) in the 38-47 years group. This contrasts with previous studies that report younger age groups. Fridberg et al. reported a median age of 36 years (range 14-75) in 105 patients treated with locking plate osteosynthesis.[9] Patel et al. found a mean age of 34 years (range 19-58) among 20 patients.[10] Karthi et al. noted most patients were below 30 years.[11] The gender distribution in our study showed 73.33% males and 26.67% females, consistent with literature reporting male predominance. Patel et al. observed 90% male and 10% female.[10] Karthi et al. reported 95% male and 5% female.[11] The higher incidence in males is linked to greater involvement in high-risk activities. Our slightly higher female proportion may reflect regional or demographic difference. In our study, 53.33% of patients belonged to the middle socioeconomic group, 36.67% to the low group, and 10.00% to the high group. This pattern aligns with Patel et al., who observed a predominance of middle-income patients.[10] Karthi et al. also reported higher incidence among middle and lower socioeconomic groups.[11] The lower representation of high-income individuals may be due to better safety standards and reduced exposure to physical risk.

Regarding the mode of injury, falls and road traffic accidents (RTAs) each accounted for 43.33%, while sports injuries contributed 13.33%. This suggests high-impact trauma as the primary cause. Karthi et al. found RTAs in 60% of cases, followed by falls (30%) and sports injuries (10%).[11] Dalal et al. reported RTAs at 48%, falls at 40%, and sports injuries at 12%.[12] Hathiwale et al. observed RTAs in 50%, falls in 35%, and sports injuries in 15%.[13] These findings are consistent with ours, highlighting the need for improved road safety and fall-prevention strategies. In our study, 66.67% of fractures were Group I (midshaft), 26.67% Group II (lateral), and 6.67% Group III (medial), consistent with the known predominance of midshaft fractures due to biomechanical vulnerability. Patel et al. reported 70% Group I, 25% Group II, and 5% Group III.[10] Karthi et al. found 72% midshaft, 22% lateral, and 6% medial fractures.[11] Dalal et al. reported 68% midshaft, 24% lateral, and 8% medial.[12] Hathiwale et al. observed 65% midshaft, 28% lateral, and 7% medial fractures.[13] These findings align with our results, reaffirming midshaft fractures as the most common pattern.

The surgical and healing parameters in this study align with existing literature on clavicle fracture management using plate osteosynthesis. The mean displacement of 15.23 mm (SD 5.19) supports surgical intervention, consistent with Patel et al. and Dalal et al. [10,12] Displacement values ranging from 14.6 mm to 16.2 mm in these studies further support operative management for >15 mm displacement. The average surgery duration of 88.77 minutes (SD 15.02) and blood loss of 179.00 ml (SD 82.51) are comparable to those reported by Karthi et al. and Hathiwale et al., [11,13] indicating procedural consistency. The mean union time of 12.00 weeks (SD 2.24) reflects a predictable healing course. These findings indicate that, in this cohort, plate osteosynthesis was associated with

standardized operative metrics and consistent healing.

The progressive improvement in Constant Shoulder Scores in this study mirrors findings from previous research on plate osteosynthesis for clavicle fractures. A mean score of 69.97 (SD 7.36) at 6 weeks aligns with Patel et al. and Dalal et al., indicating early recovery.[10,12] By 12 weeks, the score rose to 78.83 (SD 5.66), similar to Karthi et al.,[11] and continued improving to 84.30 (SD 4.43) at 18 weeks and 88.97 (SD 5.80) at 6 months, consistent with Hathiwale et al.,[13] and Ramalingam et al.[14] Mishra et al. also reported superior functional outcomes with surgical treatment over conservative methods.[15] These findings are consistent with early and progressive functional recovery after plate osteosynthesis. The distribution of Constant Shoulder Score categories in this study shows a statistically significant improvement ($p<0.0001$) in functional outcomes following surgical fixation of displaced clavicle fractures. At 6 weeks, 53.33% of patients were in the poor category, but this dropped to 10.00% by 12 weeks, with most shifting to fair (46.67%) and good (40.00%) outcomes. By 18 weeks, 70.00% were in the good and 13.33% in the excellent category, with no patients remaining in the poor category. At 6 months, 50.00% achieved excellent and 43.33% good outcomes, confirming progressive recovery. These findings align with Patel et al., who reported similar recovery patterns, with most patients reaching good to excellent scores by 12 weeks.[10] Karthi et al. and others also noted improved scores over 3 to 6 months after plate osteosynthesis. [11,12] Ramalingam et al. and others further support this trend. [14,15] Overall, the observed recovery pattern is in keeping with the functional restoration reported after plate osteosynthesis in displaced clavicle fractures.

The complication profile in this study was favourable, with 24 of 30 patients (80.00%) experiencing no complications. Reported issues included delayed union in 2 patients (6.67%), hardware failure in 1 (3.33%), and infection in 3 (10.00%). These rates are comparable to previous studies. Patel et al. reported a 12% complication rate, including infection and nonunion.[10] Karthi et al. observed complications in 15% of cases, mainly infections,[11] while Dalal et al. reported an 18% rate in surgical patients, mainly hardware-related.[12] Hathiwale et al. noted a 16% complication rate, with infections and delayed union being most common.[13] Our complication rate was comparable to, or lower than, these series. Given the single-arm design without a control group, these observations should be interpreted as associations rather than evidence of comparative effectiveness, and further comparative studies are needed to guide individualized care.

CONCLUSION

In this single-arm observational cohort, plate osteosynthesis for displaced clavicle fractures was associated with early mobilization, a high rate of union, and significant functional improvement over the six-month follow-up. The low complication rate and the consistent improvement in Constant Shoulder Scores suggest that it is a safe and useful option in appropriately selected patients, although the absence of a control group precludes any conclusion regarding comparative effectiveness. This study has certain limitations, including a short follow-up period of six months, a limited sample size, the absence of a control group, and potential variability in rehabilitation adherence and selection bias. Future research should incorporate longer follow-up durations, standardized rehabilitation protocols, and comparative analyses with conservative management. Evaluating patient-reported outcomes and cost-effectiveness would further enhance the understanding of surgical intervention in clavicle fracture management.

Declaration

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Conflict of Interest: The authors declare no conflict of interest.

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