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ORIGINAL ARTICLE

Comparative Study between Superior and Anteroinferior Plate Fixation of the Clavicle

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Background The optimal plate position for the clavicle is still controversial. The current study sought to compare the results of superior versus anteroinferior plating for fixation displaced midshaft clavicle fractures.

Patients and Methods This study was a prospective comparative study. A 3.5mm plate (reconstruction or small dynamic compression) and screws construct was used either on the superior or anteroinferior surface. Functional results were evaluated at the final follow-up using the items of the disabilities of the arm, shoulder, and hand (DASH) score. Functional results, union rates, and complications were compared.

Results Each group consisted of 30 patients. The epidemiological and baseline characteristics in both groups were comparable including age, sex, injured side, smoking status, and AO/OTA fracture classification. The operative time was 96.3±15.1 in the superior plate group and 93.5±16.1min in the anteroinferior plate group, *P*= 0.490. The mean follow-up was 18.1±2.6 in the superior plate group and 16.9±3.9 months in the anteroinferior plate group, *P*= 0.166. Mean disabilities of the arm, shoulder, and hand score was 2.5±7.9 and 3.8±8.4 in the superior and anteroinferior plate groups, respectively, *P*= 0.539. The mean constant murley score was 8143±8.42 and 81.13±9.63 in superior and anteroinferior plate groups, respectively, *P*= 0.898. The bony union rate was 93.3% and 100% in the superior and anteroinferior plate groups, respectively, *P*= 0.150. Complications occurred at rates of 13.3 and 3.3% in superior and anteroinferior groups, respectively, *P*= 0.161. Total secondary intervention rates were 40 and 16.7% in superior and anteroinferior plate groups, respectively, *P*= 0.045.

Conclusions Superior and anteroinferior plate placement in fixation of displaced midshaft clavicle fractures have comparable functional results and union rates. Superior plating has a higher secondary intervention rate.

Keywords Anteroinferior surface, Clavicle fracture, Disabilities of the arm, shoulder, and hand, Open reduction and internal fixation, Outcomes, Plate fixation, Superior surface.
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INTRODUCTION

Clavicle fractures represent ~4% of fractures, with about 80% of clavicle fractures occurring in middle third (midshaft) [1,2].

Young male patients are most likely to sustain these fractures, which are frequently associated with direct trauma to the shoulder region in motor vehicle accidents [3,4].

These fractures have traditionally been managed conservatively [5,6]. However, previous literature has reported that nonoperative management of displaced midshaft clavicular fractures can be associated with high nonunion rates (up to 15%) [7,8].

Additionally, nonoperative treatment may lead to malunion and can affect upper-limb function with residual deficiencies in shoulder strength and endurance [9,10].

Some large multicenter clinical trials reported that operative treatment had better functional results and lower rates of nonunion and malunion [5,11,12].

Operative treatment, however, is more costly and may result in implant-related complications, in addition to the need for subsequent surgery for hardware removal in some cases [12,13].

Surgical management of clavicle fractures should be performed with caution as several vital structures are in close proximity to the clavicle, including subclavian vessels, brachial plexus, and lungs [14,15].

The optimal plate position in the superior or the anteroinferior surface remains controversial [16–18].

Excellent functional results have been achieved with superior plating with low nonunion rates [5,19].

However, superior plates may be associated with plate prominence with less soft tissue coverage, localized pain, and discomfort, which may necessitate hardware removal [20]. Also, the screws trajectories are directed toward the neurovascular structures [3].

Anteroinferior plate placement has a more favorable soft tissue covering, and the drilling trajectory for anteroinferior plating could have the advantage of being away from neurovascular structures [21,22].

The current study sought to compare the outcomes and complications of open reduction and internal fixation of displaced middle-third clavicle fractures using plates at the superior or anteroinferior position.

PATIENTS AND METHODS

This prospective comparative study included patients with acute displaced midshaft clavicle fractures treated by open reduction and internal fixation using a 3.5mm plate (reconstruction or small dynamic compression) and screws construct either on the superior or anteroinferior surface. Patients were operated on from August 2019 to January 2021. Institutional Review Board (IRB) approval and written consent were acquired for this study.

Inclusion criteria were adults of 18–60 years who presented within 4 weeks of trauma with acute displaced closed middle third clavicle fractures, with shortening more than 20mm, more than 1cm displacement, or impending skin disruption.

Patients with nondisplaced fractures, proximal or distal third fractures, open fractures, pathological fractures, previous fractures or surgery on the same side, associated fractures on the same limb, initial presentation with nonunion, or vascular or neurological injuries were excluded from the studies.

Full history was obtained, and full general and local clinical examination was performed, with emphasis on the skin condition overlying the fracture, the vascular and neurological status, and the presence of other associated injuries. Anteroposterior and cephalic tilt radiography of the affected clavicle were obtained to assess the fracture type.

Surgical steps

Surgeries were done under general anesthesia in the beach-chair position with under shoulder pad.

An 8–10cm skin incision was done over superior or anterior clavicle surface. Dissection was done down to the fascia, and the skin flaps were raised. Muscles were subperiosteally dissected off the bone.

Reduction of the two main fragments was performed using two bone reduction clamps. Any butterfly fragment was fixed using a 3.5mm cortical screw.

Following reduction, the appropriately sized plate was selected with the two middle holes positioned over the fracture, leaving three or four holes on both sides of the fracture. The plate was precontoured to fit the clavicle surface. The plate was then provisionally stabilized with bone clamps. The neurovascular structures were protected while drilling with a curved retractor placed at the posterior or inferior surface of the clavicle.

Using an appropriately sized drill pit, offset drill guide, and measure for depth, the screws were inserted into the plate holes. The direction of screws was from superior to inferior in the superior plate group and anteroinferior to posterosuperior in the anteroinferior plate group.

The first two screws were placed on both sides close to the fracture site. Then, the bone clamps were removed, and three or four screws were inserted on each side.

Once all screws were inserted and the stability of the construct insured, the field was copiously irrigated with normal saline and the wound was closed.

Postoperative and follow-up care

The limb was placed in a broad-arm sling for 2 weeks. Patients started active pendulum range of motion exercises in the first postoperative week. Passive motion exercises were started for the first 4 weeks. Active-assisted exercises were conducted from 4 to 6 weeks, and active strengthening was begun at 6 weeks postoperatively.

Radiological follow-up was continuous for at least six months with follow-up radiography every 2 weeks at the first 2 months and one radiography for each month later until full fracture union was noticed, defined as an invisible fracture site or the presence of a bridging callus across the fracture, (Figure 1, 2).

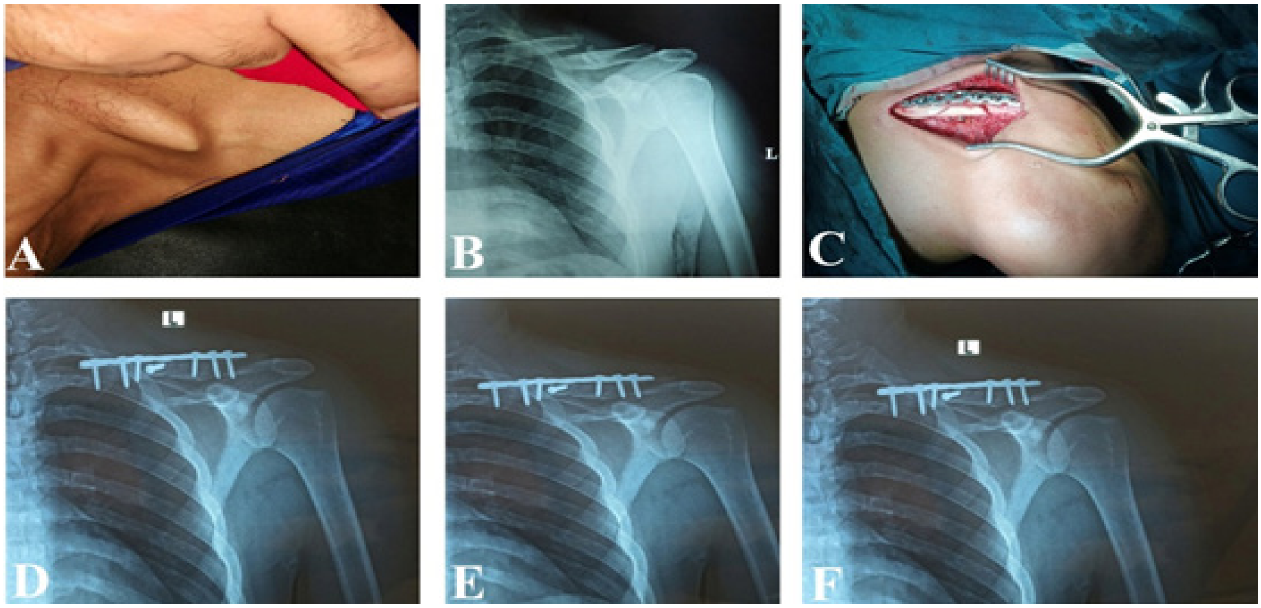

Figure 1: A 32-year-old male manual worker with a displaced midshaft clavicle fracture, with skin tenting. Open reduction and internal fixation was done using lag screw and 3.5 reconstruction plate placed on the superior surface. Full union was achieved without complications; (A): Preoperative clinical photograph; (B): Preoperative radiography; (C): Intraoperative photograph after fixation; (D): Postoperative radiography; (E): 6 weeks follow-up radiography; (F): 6 months follow-up radiography.

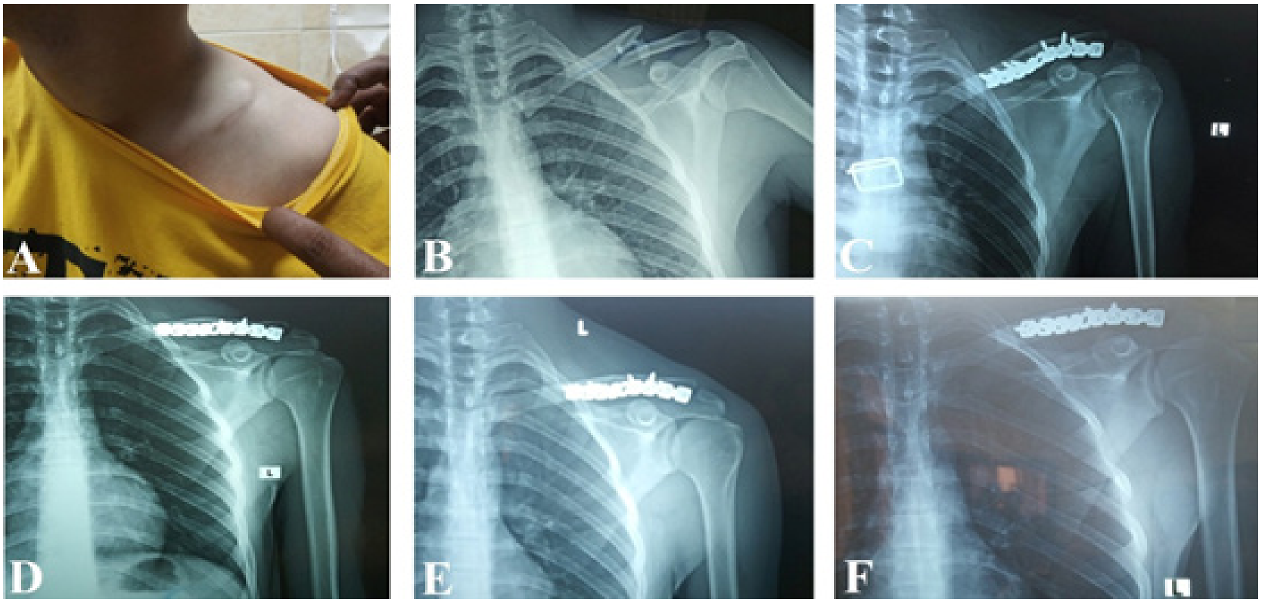

Figure 2: A 20-year-old delivery man with a displaced midshaft clavicle fracture. Open reduction and internal fixation was done using 3.5 reconstruction plate placed on the anteroinferior surface. Full union was achieved without complications; (A): Preoperative clinical photograph; (B): Preoperative radiography; (C): Postoperative radiography; (D): 2 weeks follow-up radiography; (E): 6 weeks follow-up radiography; (F): 6 months follow-up radiography.

Functional results were evaluated at final follow-up period based on the items of the disabilities of the arm, shoulder and hand (DASH) score [23].

Medical records reviewed for

Preoperative information includes medical history (age, sex, occupation, and comorbidities), clinical examination (local, general, inspection, and palpation), special tests (Patella Apprehension, Brush, and Clarke's tests), and radiological evaluation (MRI and plain radiograph).

Statistical analysis

Data were analyzed with IBM SPSS v. 21 (Armonk, New York: IBM Corp.).

Continuous data were reported as mean±SD and were compared using Student's *t* test or Mann–Whitney test. Categorical data were described as number (percentage) and were compared utilizing χ^2 or Fisher's exact test. A *P* value of less than 0.05 was significant.

RESULTS

A total of 60 patients were enrolled, 30 in each group. The mean age was 31.1±9 (range, 18–44) years and 31.9±10.7 (range, 18–49) in the superior and anteroinferior plate groups, respectively, *P*= 0.726.

There were 18(60%) males in superior plate group and 22(73.3%) in anteroinferior plate group, *P*= 0.273. The right side was injured in 17(56.7%) patients in the superior plate group and 21(70%) in the anteroinferior plate group, *P*= 0.284.

Smoking rate was 50% in the superior plate group and 60% in anteroinferior plate group, *P*= 0.436. Regarding AO/OTA classification, the most frequent type in both groups was type 15.2 A1, (*n*= 10, 33.3%) and (*n*= 13, 43.3%) in superior and anteroinferior plate groups, respectively, *P*= 0.347. The average time to surgery was 4.8±3.8 (range, 1–11) and 4.7±4.3 (range, 1–13) days in superior and anteroinferior plate groups, respectively, *P*= 0.704 (Table 1).

The operative time was comparable in both groups, 96.3±15.1 (range, 70–120) and 93.5±16.1 (range, 60–120) minutes in superior and anteroinferior plate groups, respectively, *P*= 0.490.

The mean follow-up time was 18.1±2.6 (range, 14–24) in the superior plate group and 16.9±3.9 (range, 13–27) months in the anteroinferior plate group, *P*= 0.166.

At final follow-up, the mean DASH score was comparable between both groups; 2.5±7.9 (range, 0–25) and 3.8±8.4 (range, 0–25) in superior and anteroinferior plate groups, respectively, *P*= 0.539. and the mean constand murley score was comparable between both groups; 81.43±8.42 (range, 54–go) and 81.13±9.63 (range 53,–95) in Superior and anteroinferior plate groups, respectively, *P*= 0.898.

Table 1: Distribution of patient characteristics data in the studied group:

Characteristics	Superior plate (*n*=30)	Anteroinferior plate (*n*=30)	*P* value
Age, years (mean±SD)	31.1±9	31.9±10.7	0.726
Sex (*n*, %)			0.273
Males	18(60)	22(73.3)	
Females	12(40)	8(26.7)	
Injured side (*n*, %)			0.284
Right	17(56.7)	21(70)	
Left	13(43.3)	9(30)	
Smoking (*n*, %)			0.436
Yes	15(50)	18(60)	
No	15(50)	12(40)	
AO/OTA classification (*n*, %)			0.347
A1	10(33.3)	13(43.3)	
A2	7(23.3)	10(33.3)	
A3	4(13.3)	3(10.0)	
B1	6(20)	4(13.3)	
B2	3(10)	0	
Time to surgery, days (mean±SD)	4.8±3.8	4.7±4.3	0.704

DASH: The disabilities of the arm, shoulder and hand.

Bony union was achieved in 28(93.3%) patients in superior plate group and 30(100%) patients in the anteroinferior plate group, *P*= 0.150. The average time of bone union was 12.7–0.7 (range, 12–14) weeks and 12.8–1.2 (range, 12–15) weeks in superior and anteroinferior plating, respectively, *P*= 0.695.

The overall complication rates were 13.3% (four patients) and 3.3% (one patient) in superior and anteroinferior groups, respectively, *P*= 0.161.

One patient in superior plate group had a screw penetrating the acromioclavicular joint which was noticed in the postoperative radiography and had revision surgery after 2 days of the first operation.

One (3.3%) patient in the anteroinferior plate group had a superficial infection, which was managed by dressing and broad-spectrum antibiotic coverage, and the infection was completely healed.

Nonunion occurred in two patients in the superior plate group. Both patients were treated successfully with fracture site refreshment and autologous iliac crest bone grafting, 4 months postoperatively.

Implant failure and refracture occurred in one patient in the superior plate group. The patient had a fall 6 months following the index surgery, and radiography images showed a broken plate and clavicle refracture. The patient was successfully treated with plate removal and the application of a locking plate and iliac crest bone grafting.

At the final follow-up, the implant removal rates were (*n*= 8, 26.7%) and (*n*= 5, 16.7%) in superior and anteroinferior groups, respectively, *P*= 0.347. Reasons for implant removals were plate prominence and skin irritation or patients own requests without symptoms.

The overall secondary reoperation surgery rates were 40% (*n*= 12) cases in superior plate group and 16.7% (*n*= 5) cases in the anteroinferior plate group, *P*= 0.045.

DISCUSSION

Controversy exists regarding the ideal positioning of plates in treating displaced midshaft clavicle fractures, with the traditional method being the superior placement [3]. Recently, anteroinferior plate positioning has gained popularity due to the safe screw trajectory and reduced hardware irritation [24]. This study compared the superior and anteroinferior plating for displaced midshaft clavicle fractures and showed comparable functional outcomes and union rates. The overall reoperation rate was significantly higher with superior plating.

In our study, the mean DASH score was comparable in both superior and anteroinferior plate groups at the final follow-up. Arojuraye *et al.,* [24] reported similar functional results in both plate positions on assessment with QuickDASH score at an average of 2.2 years follow-up. Similarly, Nolte *et al.,* [15] reported comparable QuickDASH scores in both plate positions, with a median follow-up of 4.9 years.

In the current study, comparable high union rates were achieved in superior (93.3%) and anteroinferior plating (100%). The two patients in the superior plate group with nonunion were young manual workers who did not adhere to postoperative protocol and restarted strenuous activities early. Nolte *et al.,* [15] reported high union rates of 96.4 and 96.1% with superior and anteroinferior plates, respectively. Additionally, Arojuraye *et al.,* [24] reported high union rates of 97.6 and 100% with superior and anteroinferior plates, respectively. Comparable high bone union rates were reported in other previous studies [25,26].

According to Wilkerson and colleagues, the superiorly plated specimens failed after fewer cycles and with lower force than the anteriorly plated specimens. The median number of cycles to failure was 2082 for anterior-plated specimens and 50 for superiorly plated (*P*= 0.028). The median load to failure was 587.5 N in the anterior group and 375 N in the superior group (*P*= 0.035). The median stiffness was 46.13 N/mm for anterior and 40.45 N/mm for superior (*P*= 0.375) plates [27].

But for Toogood and colleagues, more construct stiffness was achieved in axial compression and torsion (except for the oblique fracture pattern in clockwise torsion) with a superior plate, whereas more construct stiffness was achieved in cantilever bending with an anterior plate. Oblique fractures were significantly stiffer than bending wedge and complex comminuted fractures. Given the unknown relative importance of loading conditions, absolute recommendations for either superior or anterior plates cannot be made [28].

No major complications were reported in our study. Drilling for superior plate screws should be done with caution as the screw trajectories are directed towards the neurovascular structures. Formaini *et al.,* [25] reported a subclavian vein injury during drilling for screws that necessitated vascular repair.

In our study, anteroinferior plateing had a 3.3% infection rate, whereas no infection occurred with superior plating. Similarly, Formaini *et al.,* [25] reported 2.3 and 0% infection rates in the anteroinferior and superior plate groups, respectively.

In this study, the overall rate of secondary surgeries was higher in the superior plate group (40 vs. 16.7%). Nolte *et al.,* [15] reported a higher reoperation rate with superior plating (25 vs. 9.8%), without statistical significance. Serrano *et al.,* [26] reported significantly fewer secondary interventions with anteroinferior plating and recommended its routine use over superior plating.

In our study, the implant removal rate was slightly higher in the superior plate group (26.7 vs. 16.7%). Superior plating has been reported to have higher implant removal rates due to symptomatic or cosmetic issues [25,26]. Compared with superior plates, anteroinferior plates have the potential advantage of less prominence with more soft tissue coverage, with less need for hardware removal [22,25,26]. However, Nolte *et al.,* [15] reported that placing the plate in the superior or anteroinferior surfaces resulted in similar implant removal rates (60.7 vs. 66.7%) at mid-term follow-up. Similarly, Hulsmans *et al.,* [29] reported similar implant removal rates due to plate irritation (36 vs. 37%). Arojuraye *et al.,* [24] reported implant removal rates of 66.7 and 59.3% in superior and anteroinferior plate groups, respectively.

Biomechanical studies are controversial regarding the optimal plate position. Superior placement allows fixation on the tension side of the clavicle [3]. Some biomechanical studies reported that the superior plate is a more stable and stiff construct with higher torsion and bending loads to failure than the anteroinferior plate [28,30]. Celestre *et al.,* [31] reported that superior plates were found to have favorable load to failure and bending failure stiffness. However, Partal *et al.,* [21] reported that placing the plate on the anteroinferior surface provides significantly higher bending rigidity than placing the plate superiorly.

From a clinical perspective, the choice of plate position should be based on patient-specific characteristics. For example, anteroinferior plating would be beneficial in patients with limited soft tissue coverage. Superior plating would be more advantageous for manual workers with high physical demands, given its superior biomechanical stability.

LIMITATIONS

Our study has several limitations. The relatively small sample size limits the statistical power and generalizability of the findings. Additionally, the short follow-up period restricts our ability to assess long-term outcomes, such as late complications or hardware failures. The absence of detailed biomechanical testing is another limitation that could have strengthened the mechanistic understanding of the observed outcomes. Future studies addressing these issues with a larger cohort, longer follow-up, and biomechanical analyses will enhance the robustness and applicability of our findings.

CONCLUSION

Superior and anteroinferior plating of the clavicle for treating displaced midshaft fractures is safe and effective treatment options, with comparable functional results and union rates. However, the overall secondary intervention rate is higher with superior plating.

ACKNOWLEDGMENTS

Approval of Ethical Review Committee has been obtained.

CONFLICTS OF INTEREST

There are no conflicts of interest.

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