Osteosynthesis of unstable distal clavicular fractures with and without coracoclavicular ligament reconstruction

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Objective and design
The aim was to compare the clinical and radiological results of internal fixation of displaced distal clavicular fractures using 3.5 mm locking T-plate alone and the same plate augmented by coracoclavicular (CC) loop using coracoid-based anchor loaded by two high-strength suture threads. This is a prospective clinical study.
Patients and methods
A total of 41 patients (33 males and eight females) with a displaced distal clavicular fracture were divided randomly into two groups. The mean age of the patients was 30.2 years (range: 21–41 years). All patients underwent internal fixation using 3.5-mm locking T-plate: in group 1 (21 patients), the fracture was fixed with locked plate only (single attack), and in group 2 (20 patients), fracture was fixation with locked plate augmented with CC reconstruction using suture anchor fixed at base of coracoid (double attack). Constant functional score was used to assess the overall clinical outcome and patients' satisfaction. A standard anteroposterior radiograph was used to assess the union and measure the acromioclavicular overlap.
Results
The mean follow-up period was 20 months (range: 18–28 months). At the final follow-up, there was a highly significant improvement in Constant score ($P<0.001$) in both groups. However, patients treated by locked plate augmented by anchor reconstruction of CC ligaments (double attack approach) had better early clinical and range-of-motion outcomes.
Conclusion
Osteosynthesis with CC ligament reconstruction is an effective technique for fixation of displaced distal clavicular fractures. It does not only provide rigid fixation but also offers promising early clinical results especially regarding the range of motions.
Level of evidence
The level of evidence is that of a therapeutic case series level IV.

Keywords:
distal clavicle, double attack, locked plate, single attack

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Introduction

Most clavicular fractures (80–85%) occur in the midshaft of the bone. Distal-third fractures are the next most common type (20%) [1]. Neer [2] classified this fracture into two types based on the status of the coracoclavicular (CC) ligament: type I are minimally displaced fractures that occur lateral to the CC ligament and type II are displaced fractures in which the proximal fragment is detached from the CC ligament. The type II fracture is further subcategorized into two subtypes by Rockwood [3]: type IIA, in which the fracture occurs medial to the CC ligament, and type IIB, in which the fracture occurs more laterally with the CC ligament disrupted from the proximal fragment. These fractures were also classified by the Orthopaedic Trauma Association into extraarticular (15-C1) and intra-articular (15-C2) [4].

From the biomechanical point of view, distal clavicular fractures are usually unstable because of the two perpendicular forces that act on them making them prone to nonunion or delayed union. The proximal fragment is usually pulled by the sternomastoid superiorly and posteriorly. The weight of the arm usually pulls the distal fragment inferiorly. This leads to vertical and horizontal instabilities. The lateral fragment itself is often small and comminuted and has a poor bone quality. Therefore, it does not contribute sufficiently to vertical stability with osteosynthesis alone, and ligamentous repair is thus required [5].

Approximately 25% of distal clavicle fractures are unstable (Neer II), and operative stabilization is the mainstay for treatment for most clinicians. Stable fixation of the distal clavicle is essential for proper support of the suspensory mechanism of the upper limb [6]. Because there is no agreement on the standard of operative care for these injuries, the orthopedic surgeon continues to deal with a significant dilemma. No single surgical technique has been shown to be superior. Many fixation techniques were developed for the fixation of these types of fractures, and none of them proved to be the best. In fact, there is no definite classification of these types of management.

Some authors targeted only one force (single attack concept): either the vertical instability by 'CC reconstruction' [7] or the horizontal instability by 'osteosynthesis' [8]. Assuming that osteosynthesis alone is not sufficient for restoration of vertical and horizontal stability of this pattern of fractures, others aimed to neutralize both forces together (CC reconstruction with osteosynthesis) [5,9]. Therefore, a CC sling or suture is needed to augment osteosynthesis (double attack concept) for faster healing and early better range of motion (ROM) without implant failure. According to our knowledge, no clinical and radiological comparative studies have been conducted between these two techniques except cadaveric and biomechanical studies.

The aim of this study was to compare the clinical and radiological results of open reduction and internal fixation of Orthopaedic Trauma Association 15-C1 (Neer II) distal clavicular fractures using small 3.5-mm locking T-plate alone (group 1) and using the same plate augmented by CC loop using a coracoid-based anchor loaded by two high-strength suture threads (group 2). The null hypothesis was that there would be no significant clinical or radiological difference between the two groups.

Patients and methods

A case series study was conducted from August 2011 to January 2014. A total of 41 acute type II distal clavicular fractures (15-C1) in 41 patients were included in the study. Patients with other musculoskeletal injuries or fractures other than type II (15-C1) distal clavicle were excluded from the study. Patients were randomly divided into two groups using computer-generated randomization list. Group 1 included 21 patients whose fractures were fixed with locked plate only. On the other side, 20 patients in group 2 had fixation with locked plate augmented with suture anchor fixation. The study was approved by the local ethics committee, and a written informed consent was taken from every participant included in the study.

All the cases had surgical treatment within the first week of injury. There was no statistically significant difference between the two groups considering the mean age, sex distribution, the percentage of heavy workers, or the affection of the dominant hand (Table 1). The minimum follow-up was set at 18 months after surgery (range: 18–28 months). No patient was lost to follow-up.

All patients underwent thorough clinical examination followed by radiological evaluation with plain

Table 1 Analysis of demographic factors and clinical and radiological outcomes among patients with lateral clavicular fractures treated either with locked plate alone (group 1) versus locked plate augmented by anchor (group 2)

	Group 1 (*n*=21)	Group 2 (*n*=20)	*P* value
Demographic data			
Age (mean±SD)	30.2±6.8	28±6.5	0.31
Range (years)	21–41	22–39	
Male sex [*n* (%)]	16 (80)	17 (85)	0.68
Heavy workers [*n* (%)]	9 (45)	5 (25)	0.91
Dominant side [*n* (%)]	15 (75)	14 (70)	0.73
Clinical data			
Follow-up (range) (months)	20.5 (18–26)	24 (19–28)	
Clinical union (range) (weeks)	8 (6–9)	8 (6–10)	0.09
Constant score 2 (months)	69.5 (58–81)	81 (82–85)	<0.05
Constant score 6 (months)	82 (78–91)	89 (84–95)	<0.05
Constant score 18 (months)	91 (82–96)	94 (89–98)	0.39
Radiological data			
Radiological union (weeks)	10 (9–14)	10 (7–12)	0.86
AC overlap (mm)	4 (3–6)	0 (0–2)	<0.05

AC, acromioclavicular.

radiography and computed tomography. The Constant score was used to monitor the shoulder state before and after 2, 6, and 18 months from the operative intervention.

At the time of surgery, all patients were treated by open reduction and internal fixation using 3.5-mm T-shaped locked plates. Surgery was performed with the patient under general anesthesia. The patient was placed in semisitting (modified beach-chair) position. An oblique saber incision was made along Langer's lines medial to acromioclavicular joint (ACJ) to fully visualize the fracture site and, only in group 2, to allow dissection to coracoid base for anchor placement. Then the fracture site in both groups was identified by fully exposing the proximal and distal fragments (Fig. 1). After that the clavicle was realigned by elevating the downward displaced distal fragment. A 3.5-mm small T-shaped locked plate was applied to the superior surface of the clavicle and held in position with reduction clamps so that the transverse limb of the plate with three locking screws was applied to the distal fragment and similar three to four locked screws were applied to the proximal segment. The ACJ was identified by putting a needle in it. It was spared throughout the procedure.

In group 2, the plate fixation is augmented with coracoclavicular sutures of the coracoid-based 5-mm anchor. The anchor was inserted at the coracoid base after meticulous coracoid dissection. The sutures (orthocord #2) were tightened around the clavicle and over the plate (Fig. 2).

Patients were discharged with their arm immobilized in a sling. Pendulum exercises were stated during the first postoperative week and active-assisted motion at 2 weeks. Immediate motion of the elbow and shoulder was encouraged to improve function and to restore patient independence. After 4 weeks, full active and passive motions were initiated, and the patient was weaned off the sling. Patients were followed at 2-, 4-, 6-, and 18-month intervals (each visit of those was within 2 weeks of the predetermined appointment).

Patients were assessed clinically using Constant score and radiologically through anteroposterior radiograph with 15° cephalic tilt (Zanca view) along with axillary shoulder views to ensure that the reduction was maintained and that the implant had not loosened or changed position. Moreover, the distance between the highest point of the coracoid and the inferior border of the clavicle (CC distance) on both sides as well as the acromioclavicular overlap (AC overlap) was assessed. The CC distance is between 11 and 13 mm. Radiographs of the contralateral shoulder were obtained in all cases.

Univariate analysis was done using MedCalc version 15.6.1 for Windows (MedCalc Software, Ostend, Belgium). Mann–Witney test was used to rank and compare quantitative variables between the two groups. Fisher's exact test was used to compare dichotomous variables between groups. Repeated measure analysis of variance was used to compare the clinical score over time. *P* value of less than 0.05 was considered statistically significant.

Results

Patients treated by locked plate augmented by anchor reconstruction of CC ligaments (augmented repair group) had better early clinical outcomes as measured by Constant score. The difference between

Figure 1

Fracture site exposed.

Figure 2

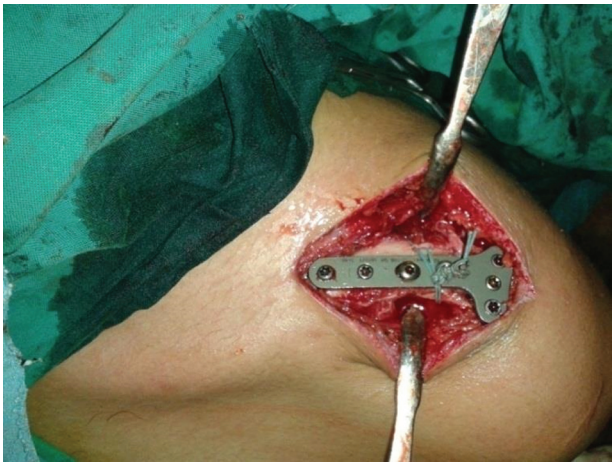


Plate fixation with suture augmentation.

the two groups at 2 months and at 6 months was statistically significant ($P<0.05$), as shown in Table 1.

At 2 months of follow-up, the mean Constant score in group 1 was 69.5 points whereas in group 2 was 81 points. The difference was statistically significant, with P value less than 0.01. At 6 months of follow-up, the difference was less (81 in group 1 and 89 in group 2). At the final follow-up, group 2 still had higher scores, but the difference was statistically insignificant. However, both groups improved significantly over time till the final follow-up. The time for improvement was similar between the two groups ($P=0.2$) (Fig. 3).

Clinical and radiological union occurred in all patients. The mean time for clinical union (disappearance of pain on trial moving the fracture) in both groups was 8 weeks. However, the radiological union occurred in both groups at 10 weeks.

Regarding the ROM (using the standard goniometer), group 2 had better early ROM concerning forward flexion and abduction. The mean Constant score at 2 months after surgery for forward flexion in group 1 was 7.1 whereas in group 2 was 9.5 ($P<0.05$). The mean Constant score at 2 months after surgery for abduction (lateral flexion) in group 1 was 6.4, whereas in group 2 was 8.9 points. The mean forward flexion at 2 months in group 1 was 100°, whereas in group 2 was 170°. The mean abduction at 2 months in group 1 was 90°, whereas in group 2 was 150°. This explains the better postoperative performance of group 2, with faster rehabilitation and earlier active exercises.

Anteroposterior radiographs taken at the final follow-up showed a significant difference between AC overlap, with P value of less than 0.05. The mean AC overlap distance was 4 mm in group 1, whereas in group 2, there was no overlap. Moreover, there was no posterior subluxation on axillary views.

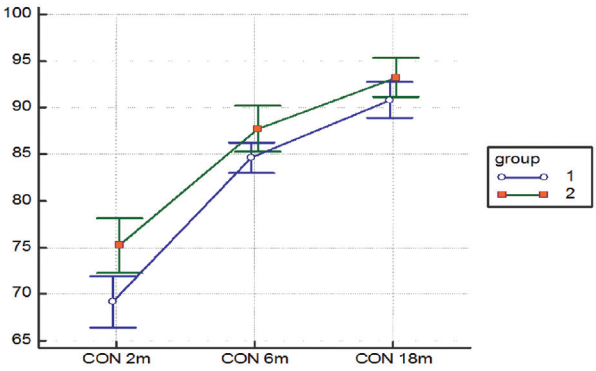
None of group 2 patients sustained any complications. Five patients of group 1 (nonaugmented group) experienced ACJ subluxation with on-going shoulder pain and prominent plate. They underwent removal of plate and stabilization of the ACJ by coracoid-based anchor suture. Intraoperative findings showed that the fracture had fully united, but there was a sublaxation of the ACJ. Six weeks later, the pain as well as the range of movement showed significant improvement.

An example of preoperative and postoperative radiographies of one of patients is shown in Fig. 4a and b.

Discussion

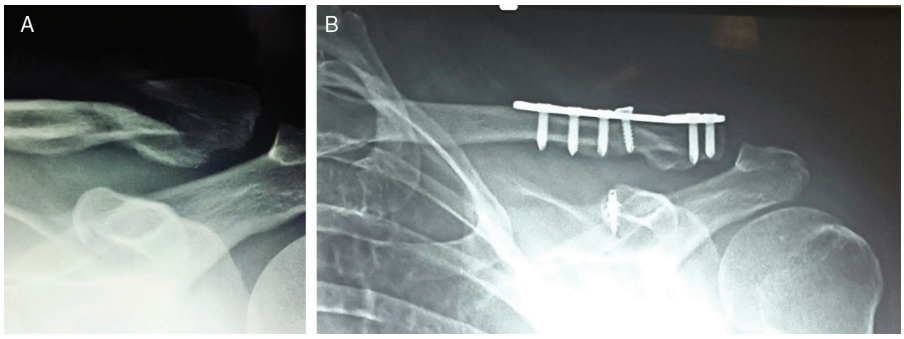
Fractures of the clavicle are common injuries with an incidence of 29 per 100 000 population per year [10]. Almost a quarter of clavicle fractures occur at the lateral end [11]. Although minimally displaced fractures of the lateral end of the clavicle can be managed nonoperatively with good clinical outcome, displaced fractures of the lateral end of the clavicle have a higher

Figure 3



Repeated measure analysis of variance showing significant improvement in the Constant score from early to late follow-up. Group 2 had better early score ($P=0.05$), but the difference at the last follow-up was statistically insignificant.

Figure 4



(a) Preoperative radiography. (b) Postoperative radiography.

rate of nonunion. Therefore, operative management is preferred for most displaced fractures [11].

The use of a superiorly placed locking plate and screws for the lateral end of the clavicle is a recent development [12]. This mode of fixation has been used in other fractures with successful results [13]. Moreover, locking plates with fixed-angle constructs have greater resistance to screw pull-out [14]. However, this concept is not fully applicable in distal clavicular fractures as these fractures undergo significant displacing forces acting at the lateral end of the clavicle. The forces causing clavicle displacement are the weight of the arm, scapula rotation, and the pull of the following muscles: pectoralis major, pectoralis minor, latissimus dorsi, and sternocleidomastoid muscles. So there are two opposing forces (vertical and horizontal) with high shear stresses at the fracture site [15].

In the case of an unstable fracture of the distal clavicle, a locked plate placed superiorly does not adequately neutralize all of the forces acting at the fracture site, which act predominantly to pull the lateral fragment inferiorly. The plate only neutralizes the horizontally applied force [15].

Recent studies reporting the results of lateral clavicle locking plates have almost universally described the use of a CC sling or CC screw to augment locking plate fixation [16]. This 'belt and braces' approach to the locking plate fixation technique reinforces the plate and neutralizes the vertically applied forces over the construct.

Sajid *et al.* [13] reported two cases with ACJ subluxation without failure of fixation. They found when the lateral fragment is very small and multifragmentary, accurate plate placement and adequate fixation with the locking screws on the lateral end can be technically difficult. Moreover, as the lateral fragment is exposed up to the ACJ, iatrogenic injury to the joint capsule with resultant instability of the joint may occur.

Brouwer *et al.* [17] reported failure of cases of nonaugmented locked plate for lateral clavicular fractures with axial pull-out of all of the locking screws from the lateral clavicular fragment. Bishop *et al.* [18] performed a biomechanical study to compare the biomechanical strength of fixation of distal clavicle locking plates with and without suture augmentation. They found that augmented plate construct was stronger with higher load to failure. Rieser *et al.* [6] biomechanically compared three treatment groups: the distal-third locking plate alone, the AC TightRope alone, and distal-third locking plate together with AC TightRope. They found that the combined construct of the locking distal clavicle plate and CC reconstruction resulted in increased stiffness, maximum resistance to compression, and decreased displacement compared with either construct alone.

Herrmann *et al.* [5] used a locking T-plate for osseous stabilization in combination with vertical stabilization by suture anchors in only eight patients. In all cases, bony union was achieved by 6 weeks. Excellent function was regained with a Constant score of 93.3 6.1 (range: 82–99) in all but one case. At 3-month final follow-up, one person complained of mild pain during strenuous activity. All patients had full ROM except one, who revealed mild restriction of internal rotation. For further assessment of the possible lack of vertical reduction, CC distance was measured in the stress radiographs. The distance was 11±2.7 mm on the operated side and 10±3.1 mm on the opposite side, showing a mean 1-mm side-to-side difference.

Our study compared between double- and single-attack techniques. Although at the final follow-up, both showed satisfactory results, the double attack provided better postoperative ROM, faster rehabilitation, early active ROM, anatomical restoration of the CC distance, neutralization of the vertical force on ACJ after fixation, decreased risk of plate cut-off, and reliable vertical as well as horizontal clinical and radiological stability.

A limitation of this study is the relative small sample size with the lack of blinding for better evaluation of the results.

Conclusion

Double attack approach using 3.5-mm T-shaped locked plate with CC ligament reconstruction using suture anchor is a method proven to be effective for fixation of displaced distal-third clavicular fractures. It provides strong stable fixation in addition to very promising early clinical results especially regarding ROMs on account of avoiding fixation of any nearby joints. Augmented fixation of unstable lateral clavicle fractures decreased secondary procedures; however, there was no statistical difference in the final Constant scores.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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