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Evaluation of area and volume changes in the costoclavicular region in patients treated nonoperatively after mid-shaft clavicle fracture

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ABSTRACT

OBJECTIVE: The aim of this study is to radiologically compare area and volume changes in the costoclavicular region with the unaffected side in patients treated nonoperatively after unilateral midshaft clavicle fracture and to evaluate functional outcomes.

METHODS: This study included 16 patients (14 males, 2 females) with midshaft clavicle fractures who were admitted between 2017–2018 and union was achieved with conservative methods. Magnetic resonance imaging (MRI) of the shoulder including the costoclavicular region was performed after union. Area and volume calculations of the fractured and unaffected costoclavicular region of the patients were performed on the standard MR sections under the guidance of a specialist radiologist. The Short Version of Disabilities of the Arm, Shoulder and Hand (QDASH) score was used for functional assessment. Range of motion was measured on the affected and unaffected sides at the last follow-up visit.

RESULTS: The mean age of the patients was 30.4±20.8 years (5–69) and the mean follow-up was 8.3±1.3 (6–10) months. The mean shortening was 14.3 mm±8.2 (3–29). The area measurements of the costoclavicular region were divided into 3 levels in axillary section: acromioclavicular joint, mid 1/3 of the clavicle, and sternoclavicular joint level. The median area measurements were 1115 (364–3675) mm^2, 1495 (365–4199) mm^2, and 1201 (197–3812) mm^2 on the unaffected side and 895.5 (351–3670) mm^2, 1098.5 (340–3191) mm^2, and 1037.5 (166–3237) mm^2 on the fractured side, respectively (p=0.905, p=0.491, p=0.888). In volume measurements, the median volumes of the unaffected side and the fractured side were 34.3 (10.7–69.7) mm^3 and 28.9 (8.1–60.9) mm^3, respectively (p=0.268). No significant difference was found in the statistical analysis of area and volume measurements. At the end of the follow-up period, the QDASH score and functional outcome of the patients were good.

CONCLUSION: Conservative treatment of midshaft clavicle fractures did not result in significant area and volume changes in the costoclavicular region. The inability to clinically demonstrate the theoretical expectation of decreased area and volume on the fractured site suggests that other biomechanical factors are involved in the healing process of the human body.

Keywords: Clavicle fracture; conservative treatent; costoclavicular region.

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Clavicle fractures are among the most common problems among skeletal system injuries. Clavicle fractures account for approximately 2.6% to 4% of all fractures. They constitute approximately 44% of fractures around the shoulder [1]. Although various conservative and surgical approaches have been described for the treatment of clavicle fractures, no standard treatment has been established. Regardless of the treatment chosen, the primary goal is to achieve a painless and functional shoulder joint [2]. The aim of clavicle fracture treatment is to minimise deformity and pain at the fracture line while restoring shoulder joint movements to normal levels. Middle third clavicle fractures with less than 20 mm of shortening and intact cortical alignment or displaced fractures with less than 100% displacement can be treated conservatively [3–5] A study found that more than 100% displacement of midshaft clavicle fractures was the strongest radiographic determinant of persistent symptoms and negative sequelae in patients [6]. Many authors who reported non-surgical treatment of clavicle fractures described very satisfactory union rates and functional results [7–9].

In addition to the radiological and functional results of clavicle fractures in both adolescents and adults, biomechanical studies have also been performed [10–14]. Although these studies theoretically suggest that the causative factor is a narrowing in the costoclavicular region, no data have proven this. No biomechanical study has been found in the literature that mentions the area and/or volume change in the costoclavicular region after clavicle fracture.

Considering all the data in the literature, in this study we investigated whether there is an area and/or volume change in the costoclavicular region due to the shortening that occurs after clavicle fracture. We evaluated functional outcomes by radiographic comparison of the fractured side with the unaffected side.

Highlight key points

- Approximately 44% of shoulder fractures are clavicle fractures.
- Although there is a theory that the costoclavicular region may be constricted after a midclavicular fracture, there is no data to support this.
- There is no statistically significant difference in the area and volume of the costoclavicular region in patients treated conservatively after displaced midclavicular fracture.
- The biomechanical factors influenced the radiological and functional results by tolerating the shortening.

MATERIALS AND METHODS

Data Collection

The study was performed following the ethical standards of the Declaration of Helsinki. Ethical approval for the study was obtained from the Institutional Ethics Committee for Clinical Research on 11/07/2018. (No: 2018/227). The study was designed as a prospective cohort study. 16 patients (14 males, 2 females; mean age: 37.4±17.8 years; range, 18 to 69 years) were included in the study. The mean follow-up was 8.3±1.3 months; range, 6 to 10 months. Patients between December 2017 and July 2018, diagnosed with midshaft clavicle fracture and applied eight bandages with closed reduction, and whose last outpatient clinic check was after July 2018 were included. Routine outpatient clinic check-ups of the patients were performed on the 3rd day, 10th day, 1st month, 3rd month, and 8th month. At the 8th month follow-up, the last outpatient visit, informed consent was obtained to perform MRI of the costoclavicular region of the fractured side and the healthy side, including axial, sagittal, and coronal sections. Open fractures, operated clavicle fractures, proximal and distal 1/3 end fractures, patients under 18 years of age were not included in the study.

Radiological and Functional Assessments

Fractures of the middle third of the clavicle were identified by bilateral anteroposterior (AP) shoulder radiographs using the Neer classification [15]. The resulting shortening was measured by comparison with the clavicle on the unaffected side. All patients participated in the final radiologic and functional evaluation. Images were obtained on a 3T MRI scanner (Philips, Einthoven). Sequences and parameters acquired during scanning: coronal T1 TSE TR:543, TE:28, slice thickness 3 mm, slice spacing 3 mm, coronal STIR TR4150 msec, TE 30 msec, slice thickness: 3 mm, slice spacing 3 mm, coronal T2 TSE TR 3828 msec, TE 120 msec, slice thickness: 3 mm, slice spacing 3 mm, axial T1 TSE TR 665 msec, TE 15 msec, slice thickness: 3 mm, slice spacing 3 mm, axial T2 TSE EPI TR 5242 msec, TE 100, slice thickness: 3 mm, slice spacing taken as 3 mm. The average scanning time was 25 minutes. Measurements were performed on the Vital Vitrea workstation by evaluating the axial T1 TSE and axial T2 TSE EPI sequences of the MRI images acquired during the scans. Measurements were performed by a radiologist experienced in area and volume measurements.

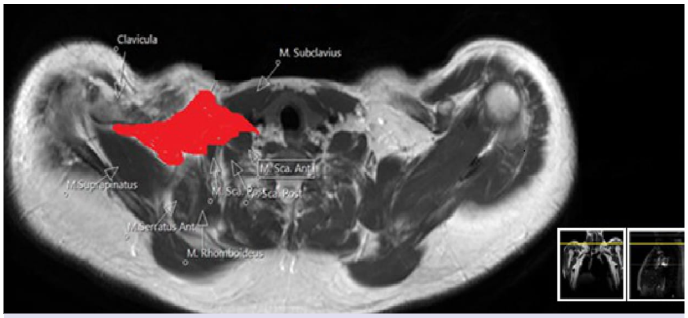

Figure 1. Comparative view of area 1 (colored in red). The proximal part starts at the level of the acromioclavicular joint and the yellow line indicates the corresponding cross-sectional position of area 1 in both the coronal and sagittal planes.

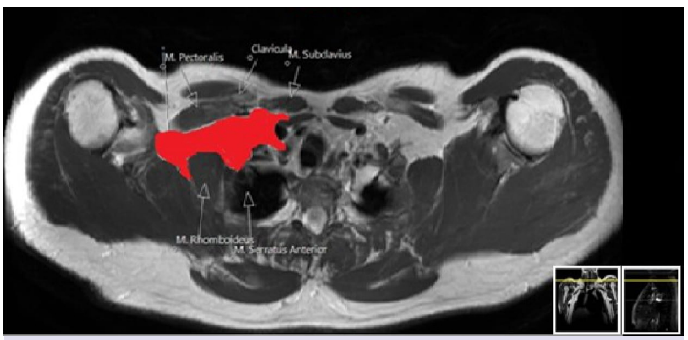

Figure 2. Comparative axial view of area 2 (colored in red). The proximal part starts at the the level of the middle 1/3 of the clavicle and the yellow line indicates the corresponding cross-sectional position of area 2 in both coronal and sagittal planes.

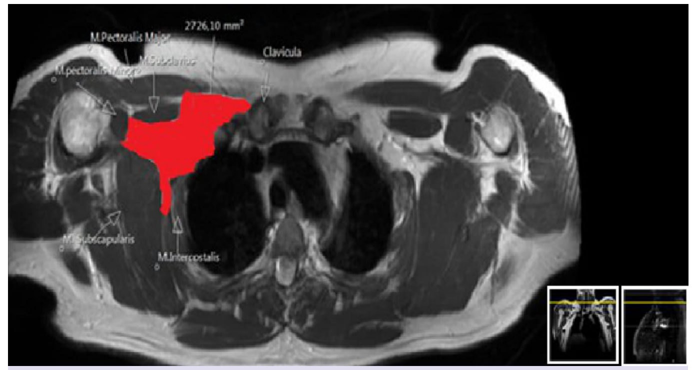

Figure 3. Axial view of area 3 (colored in red). The proximal part starts at the level of the sternoclavicular joint and the yellow line indicates the corresponding cross-sectional position of area 3 in both the coronal and sagittal planes.

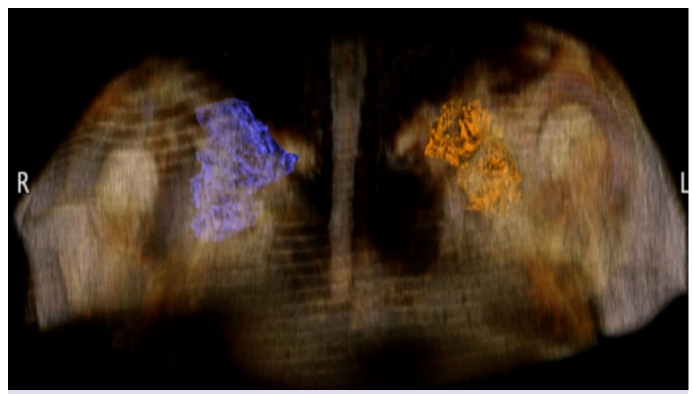

Figure 4. Three-dimensional image of the volume calculation (blue for the unaffected side, orange for the fractured side).

Area measurements were made bilaterally from cranial to caudal, with area 1 at the level of the acromioclavicular joint, area 2 at the mid-part of the clavicle, and area 3 at the most caudal level of the sternoclavicular joint. Measurements were made using axial T1 TSE images. Area 1 was measured by calculating the area bounded anteriorly by the acromioclavicular joint and clavicle, subclavius muscle; posteriorly by the scalenius posterior, rhomboideus, and serratus anterior muscles; laterally by the supraspinatus; and medially by the scalenius anterior muscle. (Fig. 1). Area 2 was measured based on the area bounded by the clavicle, pectoralis major and minor, subclavius muscles anteriorly; serratus posterior and rhomboideus muscles posteriorly; supraspinatus muscle laterally; serratus anterior muscle and trachea medially (Fig. 2). Area 3 was calculated by measuring the area bounded by the sternoclavicular joint, clavicle, and pectoralis major and minor muscles anteriorly, the supraspinatus muscles posteriorly and laterally, the intercostal muscles posteriorly, and the intercostal muscles, ribs, and lung apex medially (Fig. 3).

Volume measurements were taken bilaterally from cranial to caudal. This volume was bounded anteriorly by the clavicle, subclavius, pectoralis major and minor muscles; posteriorly by the scalenius posterior, rhomboideus, serratus anterior, supraspinatus muscles; laterally by the supraspinatus muscle; and medially by the scalenius anterior, serratus anterior muscles, ribs, and lung apex. Cranial measurements were taken with the acromioclavicular joint level of the clavicle as the upper limit and the sternoclavicular joint level as the lower limit (Fig. 4).

The Quick DASH score and joint range of motion were measured to assess functional outcomes. Quick DASH is a shortened version of the DASH Outcome Score and uses 11 items from the questionnaire to measure function and symptoms in patients with any upper extremity disorder [16]. At the end of the survey, patients receive a score between 0 and 100 (0 = no disability, 100 = maximum disability).

Statistical Analysis

Statistical analysis was performed using the IBM SPSS 20.0 (IBM Corp., Armonk, NY, USA). The normal distribution of the data was assessed using the Shapiro-Wilk test. Numerical variables with a normal distribution were presented as mean±standard deviation, while those with a non-normal distribution were presented as median (25^{th}–75^{th} percentiles). Categorical variables were expressed as frequencies (percentages). Differences between groups for numerical variables with a normal distribution were determined using the Student's t-test, and for those without a normal distribution, the Mann-Whitney U test was used. A significance level of $p<0.05$ was considered sufficient for testing two-tailed hypotheses.

RESULTS

Complete union was detected at the end of the 3^{rd} month in all patients who participated in the study. Of the patients, 9 had a shortening of 20 mm or more and 7 had a shortening of less than 20 mm. The mean shortening was 14.3±8.2 mm; range, 18 to 69 mm. At the end of treatment, the Quick DASH score was 15.6±6.4 points; range, 21 to 8 points. In one patient, physical examination at month 8 revealed limitations in flexion (30 degrees), extension (20 degrees), and abduction (40 degrees). These findings were considered suboptimal due to an additional rotator cuff rupture in this particular patient. No joint range of motion limitations were noted in the other patients at their last follow-up visits.

In the measurements of area 1, that is, measurements at the level of the acromioclavicular joint, the median value was 1115 (364–3675) mm^2 on the unaffected side and 895.5 (351–3670) mm^2 on the fractured side. The statistical comparison revealed no significant difference (p=0.905).

In the measurements of area 2, that is, at the middle 1/3 level of the clavicle, the median value was 1495 (365–4199) mm^2 on the unaffected side and 1098.5 (340–3191) mm^2 on the fractured site. The comparison revealed no statistically significant difference (p=0.491).

In the measurements made at the level of the sternoclavicular joint, the median value of area 3 was 1201 (197–3812) mm^2 on the unaffected side and 1037.5 (166–3237) mm^2 on the fractured side. There was no significant difference in the statistical comparison (p=0.888) (Table 1).

TABLE 1. Measurements of the area and volume of the costoclavicular region on the affected and unaffected sides

Paramaters	Affected side	Unaffected side	p
Area 1	895.5	1115	0.905
Area 2	1098.5	1495.5	0.491
Area 3	1201	1037.5	0.888
Volume	34.3	28.9	0.268

P<0.05: Statistically significant.

In volume measurements, the median value on the unaffected side was 34.3 (10.7–69.7) mm^3, while on the fractured side it was 28.9 (8.1–60.9) mm^3, which showed no statistically significant difference (p=0.268).

DISCUSSION

Previous studies have attributed brachial plexus paralysis rarely observed after clavicle fractures to causes such as malunion, hypertrophic callus, or pseudoaneurysm of the subclavian artery or vein [17]. Malunion has been identified as the main cause of the rare vascular and neurogenic thoracic outlet syndrome following these fractures [18–22]. While these studies are mostly case reports and lack biomechanical investigations. When previous biomechanical studies were analysed, changes in the scapulothoracic joint angle after clavicle fracture were measured, and the changes in that angle were observed to be more prominent in the conservative treatment group than in the surgery group [10]. It has been demonstrated how the load on the glenoid and anteversion changes in patients with shortness, affecting the kinetics of the glenohumeral joint and scapula [11–13]. It has been shown that malunion that develops after fracture affects radiological and functional results by causing glenoid malposition [14]. Our study is, to our knowledge, the first to measure area and volume in the costoclavicular region after clavicle shortening and present it along with functional outcomes.

The definition of the costoclavicular region has not been established in previous studies. By measuring the area and volume of this region, we have defined markers that will be informative for future studies. The costoclavicular space is a triangular space bounded anteriorly by the medial portion of the clavicle and the underlying subclavian muscle, its tendon, and the costocoracoid ligament. It is bounded posteromedially by the first rib and the insertion of the anterior and middle scalene muscles, and posterolaterally by the superior border of the scapula [23]. The area of a triangle is found by dividing the multiplication of the height and sides by 2. Considering the clavicle as one side of the triangle, each 1 cm of shortening at the edge will mathematically result in an average 15–20% reduction in area and volume.

Clavicular fractures are managed based on severity, fracture site, and associated neurovascular injury. The most common fracture site is the middle third of the clavicle (approximately 80%) [24], and this region is prone to displacement. The majority of these fractures are treated conservatively with figure-of-eight bandages or arm slings. In general, most of these fractures heal completely and the rate of nonunion is very low (less than 1%) [25]. An initial shortening of the clavicle by ≥20 mm is considered to be a risk factor for nonunion [26]. The findings of Wick et al. [27] support the notion that fractures with ≥20 mm shortening predispose to nonunion. A 2012 meta-analysis found a nonunion rate of 15% in conservatively treated midshaft clavicular fractures [28]. In our study, complete healing was achieved in all patients, including those with an initial shortening of ≥20 mm.

Hill et al. [29], in their evaluation of post-treatment shortening in clavicle fractures, reported that shortening of ≥20 mm was associated with poor symptomatic and functional outcomes only in healed fractures. Oroko et al. [30], in their study of 41 patients after fracture union, found that three patients with more than 15 mm of shortening had worse functional outcomes. However, they concluded that shoulder function was not affected by shortening. In our study, we found good functional outcomes in all patients, including those with initial shortening of ≥20 mm.

In a study by Mırzatolooeı, the average DASH score for clavicle fractures treated surgically and conservatively was reported to be 8.6 and 21.3, respectively [31]. In another study comparing plate osteosynthesis with an arm sling, the DASH score at 1-year follow-up of 132 patients with clavicular fractures treated surgically and conservatively was 5 versus 15 [32]. In a study by Ozler et al. [33], the DASH score for surgically treated patients was 12.8. In our study, the Quick DASH score yielded results consistent with the literature and did not exceed the scores reported in other studies.

Considering the limiting factors of our study, although we reached 52 patients within 1 year, the exclusion of those, who accounted for the majority of fractures, significantly reduced our sample size. Another aspect of our study that could be criticized is that measurements of the costoclavicular region of the clavicle, in terms of area and volume, were performed after the fractured clavicle had healed. If we could have assessed changes in area and volume immediately after the initial fracture in the early period and performed further examinations for changes in area and volume after union, or if we could have extended the follow-up period to observe ongoing remodeling after fracture healing, the reliability of the results would have been further increased.

Conclusion

In this study, which we conducted to contribute to the literature, despite the geometric reduction observed in the area and volume of the costoclavicular region in patients with displaced midclavicular fractures treated conservatively, no statistically significant difference was found in this study. This suggests that biomechanical factors in this region may tolerate shortening and influence radiologic and functional outcomes.

Ethics Committee Approval: The Kocaeli University Faculty of Medicine Clinical Research Ethics Committee granted approval for this study (date: 11.07.2018, number: 2018/227).

Informed Consent: Written informed consents were obtained from patients who participated in this study.

Conflict of Interest: No conflict of interest was declared by the authors.

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