



Does Scapulothoracic Triangle Imbalance Following Clavicle Fracture Influence Functional Outcome after One Year Follow-Up? Retrospective Series of 40 Cases Comparing Orthopedic and Osteosynthesis Treatment

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Abstract

Introduction: Mediolateral shortening of the clavicle is a risk of orthopedic treatment of a diaphyseal clavicle fracture. This shortening may cause scapular dyskinesia and a negative functional impact. Many studies recommend surgical treatment if the shortening is greater than 1.5 cm. We wanted to retrospectively evaluate the impact of this shortening between a group of patients treated orthopedically vs. a group of patients treated by plate osteosynthesis.

Materials and Methods: This is a retrospective, comparative case-control study. The evaluation was performed by an independent evaluator. The measurement of the length of each clavicle was performed clinically with ultrasound and on radiological images. A ratio was calculated between the length of the pathological side and the healthy side. The functional impact was evaluated with Quick DASH Score. Scapular dyskinesia was assessed on a global antepulsion movement.

We found 119 cases with a 6-year follow-up. We were able to clinically review 20 patients treated orthopedically (by eight Americans) and 20 patients who had been osteosynthesized by locked plate (Stryker*), with a mean follow-up of 37.5 months.

Results: The quick dash score was significantly higher in the orthopedic group compared with the osteosynthesis group (11.363 [0-50] vs. 2.045 [0-11.36] or $p=0.0092$). The Pearson correlation test between the percentage of shortening and the Quick-DASH was -0.3956 [IC 95% -0.6295 ; -0.0959] with $p=0.012$. The clavicle length ratio was statistically different in the operated and non-operated groups ($+2.9\%$ vs. -8.2% with $p<0.0001$). The number of patients with shoulder dyskinesia was significantly higher in the orthopedic group (10 vs. 3, $p=0.018$). The relationships between clinical and radiological measurements showed a strong correlation.

Discussion: Numerous studies report the importance of managing diaphyseal clavicle fractures surgically if the shortening is greater than 1.5 cm. Our study shows that a shortening of 8.2% leads to long-term functional impairment.

Conclusion: Therefore, it seems legitimate to propose a surgical approach of osteosynthesis by locked plate in patients with a clinical shortening of more than 8%. Restoration of the length of the scapulothoracic triangle ensures restoration of shoulder kinetics.

Keywords: Clavicle fracture; Scapular dyskinesia; Ultrasound; Shortening

Introduction

Diaphyseal fractures of the clavicle constitute 2.6% of fractures [1]. The common indications for surgical treatment are [2-4]:

- Omo-cleido-thoracic syndrome
- Complicated fracture (open fracture, vascular or neurological trouble)
- Shortening of more than 15 mm (or 10%)
- Comminution
- Craniocaudal displacement of more than 100% of the clavicle.

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Some authors report poorer functional scores, loss of strength, and an increased incidence of scapulothoracic dyskinesia in case of orthopedic treatment of these fractures [5]. More and more studies advised operating patients with clavicle fractures [5-9].

Shortening of the clavicle causes an imbalance of the scapuloacromioclavicular triangle, which increased scapular dyskinesia incidence by decreasing external rotation, antero-posterior tilt, and increasing protraction of the scapulothoracic joint [10]. At the emergency, the X-rays are not standardized and a measurement of the actual shortening is exceptionally possible [6].

The objective of our study was to evaluate the functional impact of surgical vs. orthopedic treatment for the diaphyseal clavicle fracture with a minimal follow-up of one year. We measured shortening using ultrasound assistance the Quick DASH score to define the extremities of the clavicle. We hypothesized that the functional score was negatively impacted by clavicle shortening even in the long term.

Materials and Methods

Population

Our study was performed retrospectively, monocentric among patients who consulted in an emergency department of a University Hospital Center for a clavicle fracture between January 2014 and December 2019 to have a minimum follow-up of one-year post-fracture.

Among 1,079 emergency department files labeled "clavicle fracture" (ICD-10 diagnosis S420), 119 matched with the inclusion criteria. We were able to recontact 20 operated patients among the 67 patients who were surgically treated and subsequently matched with 20 orthopedically treated patients on age, follow-up time, and fracture type according to the AO classification.

Surgical treatment was always the same: Superior locking plate by an anterior approach. The post-operative treatment consists of three weeks of immobilization with a sling and after active mobilization.

Conservative treatment was an immobilization with an eight-figure sling for 5 weeks and after active mobilization.

The inclusion criteria of the study were: patients more than 18 years old, who had a fracture of the diaphysis of the clavicle classified according to the AO as type 15.2A1 to 15.2C1 operated or not operated. The patients came to the follow-up consultation with their last face radiography of the 2 clavicles to analyze the consolidation and to compare our US-clinical measure with the radiological measure.

Exclusion criteria were: Juveniles' patients, polytrauma patients with associated rib and/or scapula fractures, homo or contralateral clavicle fracture, fractures of the ¼ external clavicle or the 1/3 internal clavicle, clavicle pseudarthrosis, pathology of the scapulohumeral joint (osteoarthritis, prosthesis, capsulitis, rotator cuff pathology), neurological damage and spinal statics disorder.

The primary endpoint was functional impact assessed by the correlation between the Quick DASH score and scapuloacromioclavicular triangle imbalance.

Secondary endpoints were:

- The incidence of scapulothoracic dyskinesia

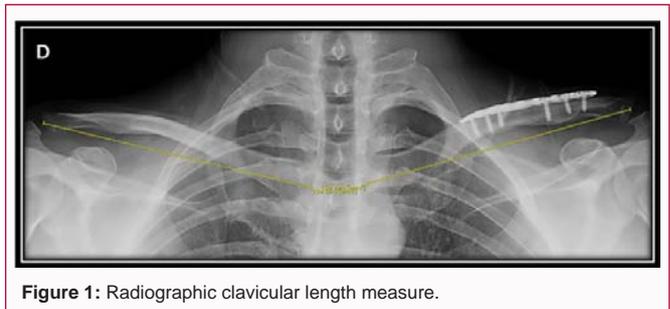


Figure 1: Radiographic clavicular length measure.

- The correlation between the ultrasound measure and the radiological measure.

Each patient was informed of the modalities and purpose of the study. Patients were given a non-opposition statement to the study. An IRB was obtained.

Clavicular length measurement

The radiological clavicle length measurement was performed by a single observer by locating the center of the acromioclavicular joint and the center of the sternoclavicular joint bilaterally. Then, the clavicle length was measured parabolically [2,6,11] (Figure 1).

The ultrasound-guided measure was performed by locating and marking the sternoclavicular joint and the acromioclavicular joint and then measuring the length between each point.

To be free about the radiographic scale, a shortening ratio was calculated: clavicle fractured/normal clavicle [3].

Functional impact

The functional impact was evaluated with the Quick DASH score [12].

Scapulo-thoracic dyskinesia

In this study, scapulothoracic dyskinesia was defined according to a dynamic criterion: the patients were observed during two antepulsion-elevation movements of the 2 upper limbs simultaneously, with the examiner behind him. We used Kibler's classification for the scoring [13,14] (Figures 2a-2c):

- Type I: prominence of the inferomedial border of the scapula
- Type II: prominence of the medial border
- Type III: prominence of the superior-medial border and superior translation of the scapula
- Type IV: symmetrical scapular position

The statistics were performed with SAS enterprise Guide SAS Institute Inc. Cary, NC, USA Version 7.1. Quantitative variables were examined by the Shapiro-Wilks normality test, presented by their means, standard deviations, minimum and maximum values. Unmatched quantitative variables were compared using a Student t-test. Categorical variables were presented with their number and percentage. Categorical variables were compared using a Chi-2 test and were presented by their numbers and percentages. We performed a Pearson ρ -test of correlation between clavicular shortening and Quick DASH score. A difference was considered statistically significant when the significance level of the test was less than 0.05.



Figure 2a: Scapulothoracic dyskinesia type III and clavicular shortening. A): Right scapular dyskinesia type III with contraction of the rhomboid muscles.



Figure 2b: Right dyskinesia type III during the lowering phase.



Figure 2c: Clavicular shortening.

Results

Population

Our population consisted of 40 patients: 20 operated with a locking plate (Stryker®) and 20 orthopedically treated patients. The mean follow-up was 37.5 months (range 12 to 69 months). There were 7 women for 13 men in the operated group and 4 women for 16 men in the non-operated group (p=0.3). Fourteen patients had fractured their non-dominant limb in the surgical group versus 10 in the orthopedic group (p=0.2). Fourteen patients played sports

regularly in both the surgical and non-operative groups (p=1). The mean Body Mass Index (BMI) of the operated patients was 22.8 and 25.1 in the non-operated group (p=0.007). In the surgical group, 5 patients had a monofocal fracture (i.e., AO 15.2 A1 to 15.2 A3) vs. 8 in the orthopedic group (p=0.311). Our populations were comparable on all criteria studied except the Body Mass Index (Table 1).

Primary outcome

The mean DASH Quick score was 2.045 [0-11.36] in the orthopedic group and 11.363 [0-50] in the surgical group (p<0.0001) Table 2. The clavicle length ratio was statistically different between operated and non-operated patients; lengthened by 2.9% in the surgical group and shortened by 8.9% in the non-operated group (p<0.0001) Table 2. A correlation test showed a significant decrease of the Quick DASH score when the clavicle was shortened ($\rho = -0.3956$ [IC 95% -0.6295; -0.0959]; p=0.012) Figure 3.

Secondary outcome

The ratios of ultrasound and radiological measures were strongly correlated with 0.96 (p<0.0001) Figure 4.

Scapular dyskinesia was significantly more frequent in the orthopedic group than in the surgical group (10 vs. 3, p=0.018),

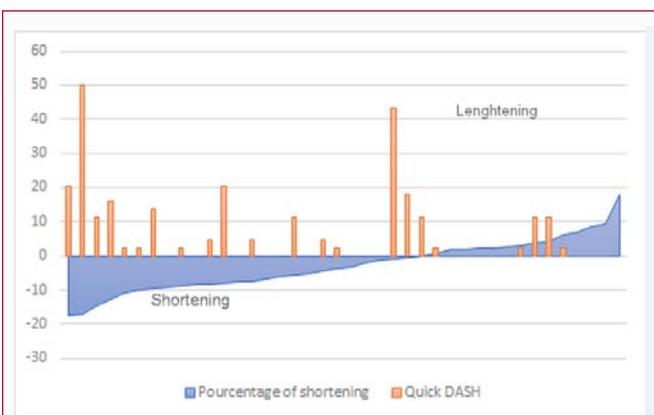


Figure 3: Correlation between present shortening and Quick DASH score.

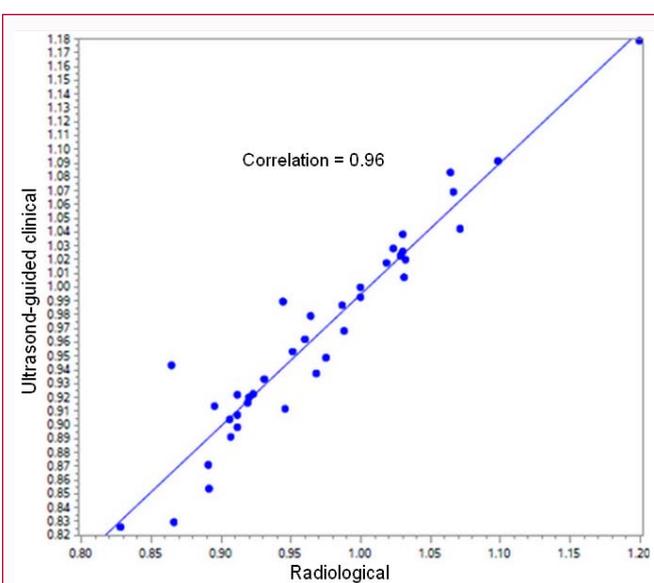


Figure 4: Correlation of fractured clavicle/healthy clavicle length ratios according to radiological and clinical echo-guided measurements.

Table 1: Demographic data of operated and non-operated patients.

	Surgical treatment (n=20)	Orthopedic treatment (n=20)	p-value
Sex			
Woman	7 (35%)	4 (20%)	0.3
Man	13 (65%)	16 (80%)	
Age (in years)	34.5 (18–63)	39.5 (22–64)	0.3
Follow-up time (in months)	37.8 (12–69)	37.1 (16–69)	0.42
Body Mass Index (kg/m ²)	22.8 (17–26)	25.1 (18–39)	0.007*
Limb fractured			
Right	5 (25%)	11 (55%)	0.005
Left	15 (75%)	9 (45%)	
Dominant-limb fractured	6 (30%)	10 (50%)	0.2
Sport	14 (70%)	14 (70%)	1
AO Classification			
Monofocal 15.2A1 to 15.2A3	5 (25%)	8 (40%)	0.311
Plurifocal 15.2B1 to 15.2C1	15 (75%)	12 (60%)	

The quantitative variables are in mean, standard-deviation, qualitative variables are in absolute number and percentage.

The quantitative variables are compared with t-test of student and qualitative variables with Chi-2 test (p-value <0.05).

Table 2: Assessment of functional impact and shortening as a function of the treatment performed in patients with isolated diaphyseal fracture of the clavicle.

	Surgical treatment	Orthopedic treatment	p-value
Shortening percentage (%)	2.9	-8.20%	p<0.0001*
Quick DASH score	2.045	11.363	P<0.0001*

t Student test (*: p-value <0.05)

Table 3: Comparison of patients with and without scapulothoracic dyskinesia.

	Scapulo-thoracic dyskinesia (n = 13) (32.5%)	No dyskinesia (n = 27) (67.5%)	p-value
Sex			
Woman	3 (15.4%)	9 (33.33%)	0.234
Man	11 (84.6%)	18 (66.67%)	
Age (in years)	42.15 (21–64)	34.37 (18–63)	0.116
Body Mass Index (kg/m ²)	23.75 (17–29)	24.01 (18–39)	0.851
Follow-up duration (in months)	38.31 (26–63)	37.04 (12–69)	0.808
Dominant-limb fractured	4 (30.77%)	12 (44.44%)	0.307
Sport	8 (61.5%)	20 (74%)	0.418
Treatment			
Surgical	3 (23.1%)	17 (63%)	0.018*
Orthopedic	10 (76.9%)	10 (37%)	
Type of fracture			
Monofocal	3 (23.1%)	10 (37%)	0.377
Plurifocale	10 (76.9%)	17 (63%)	
Shortening percentage (%)	-7.6 (-17.4; +2)	-0.2 (-17; +17)	0.0015*
Quick DASH	12.24 (0; 43.18)	4.04 (0; 18.18)	0.042*

The quantitative variables are in mean, standard-deviation, qualitative variables are in absolute number and percentage.

The quantitative variables are compared with t-test of student and qualitative variables with Chi-2 test (*: p-value <0.05).

with 5 stage I (38.5%), 6 stage II (46.1%) and 2 stage III (15.4%) scapular dyskinesias. Patients with scapulo-thoracic dyskinesia had a statistically significantly greater shortening than those without dyskinesia (7.6% vs. 0.2%, p=0.0015) Table 3. The 3 dyskinetic operated patients had fractured the non-dominant limb.

The mean Quick DASH score was statistically worse in the dyskinetic group than in the non-dyskinetic group (12.24 vs. 4.04, p=0.042). We didn't find any statistically significant difference that

could have an impact on the presence of dyskinesia concerning the fractured limb, physical activity, type of fracture, BMI or sex (p>0.05) Table 3.

Discussion

According to our study, orthopedically treated clavicle fractures have a significantly worse functional score even with a follow-up of more than 1 year. The Quick DASH score is negatively correlated with the shortening percentage. Surgery with a locked plate restores

the length of the scapula-clavicular triangle and ensures better recovery of scapulothoracic kinetics. Our clinical ultrasound-guided and radiological measurement reports are correlated.

Stefanos Lazarides et al. [6] report that the radiographs performed in the emergency are often non-standardized and don't allow a reliable measurement of clavicular shortening (no good frontal radiograph, shoulder radiograph often prescribed, only one side radiographed...). We decided to compare an ultrasound-assisted measure with the radiographic measure to avoid duplication of the X-rays performed in the emergency room. No study of ultrasound-guided clavicular length measurement has been found in the literature.

Our study investigated the correlation between a single ultrasound measure and a single radiological measure of clavicular shortening. The radiography was not done at the same center but we tried to decrease the realization bias by checking the quality of the radiograph as defined in the study by Stefanos Lazarides et al. [6]. Our radiographs were all of good quality with the spinous processes centered at equi-distances to the pedicles [6] (Figure 1).

Jung-Han Kim et al. [15], has showed that anteroposterior shortening results in a statistically significant difference in anterior tilt, internal rotation, and upward rotation of the scapula that increases with the degree of shortening. The increasing of the internal rotation of the scapula is explained by the rhomboid muscles that hold it to the rib cage medially and by the acromioclavicular joint that draws it laterally. The increase of the anterior tilt is explained by the contracture of the angular muscle of the scapula which pulls it forward. Matasumura et al. [16] studied the effect of clavicle shortening on scapular kinetics in 12 bodies and concluded that a clavicle shortening of more than 10% was correlated with a decrease in posterior tilt and external rotation of the scapula during anterior arm elevation. Our study correlates with this and shows that a shortening of 7.6% on average leads to more dyskinesia.

Of their 71 patients who had an orthopedically treated clavicle fracture, De Giorgi et al. [3], found that a shortening of more than 9.7% (SD \pm 1.6%) (15.2 mm SD \pm 3.3 mm) was correlated with a worse Constant score ($p < 0.0001$), which is quite comparable to the relationship present in our study. As demonstrated in numerous studies [3,4,6,17], the functional scores are worse when the shortening is greater than 15 mm. Magetsari et al. [12], report that the Quick DASH score is a very sensitive questionnaire, allowing a reliable assessment of the clinical evolution of patients with a fracture of the middle third of the clavicle.

Our results are consistent with the literature. A multicenter, prospective, randomized clinical trial [9] shows that the DASH Score and the Constant score are significantly worse in the case of orthopedic treatment ($p < 0.01$ for each time period studied for the Constant score, and $p < 0.01$ at 6 and 52 weeks post-fracture for the DASH score). In the clinical study of Ahrens et al. [18], the DASH score and the Constant score are better at 6 weeks and 3 months in operated patients. In the Rasmussen et al. [4], prospective study, involving 136 non operated patients, the difference in Constant score between the fractured and normalized sides was 7.3 points (CI [5.6-9.1]; $p < 0.001$) and the mean shortening was 11.6 mm (CI [10.2-13 mm]; $p < 0.001$).

However, in a prospective study [19] that evaluated early functional recovery following operated and non-operated clavicle fractures in 65 patients, the Quick DASH score and the Constant

score were significantly worse in orthopedic treatment as in our study, but their results aimed to become comparable and non-significant at 3 months and 6 months. Ilija Ban et al. [20], found similar results with DASH Score and Constant Score at 6 weeks ($p < 0.001$) and at 12 months ($p = 0.277$). Our study shows with a much longer follow-up that this functional impact related to shortening persists contrary to what previous studies report. We observed a higher incidence of scapulo-thoracic dyskinesias in the orthopedic group than in the surgical group. Our incidence of dyskinesia is similar to the Edward Shields et al. study [5] who found scapulothoracic dyskinesia present in 37% of cases, 66% were present in women and 78% on the side of the dominant limb. Our results differ concerning the incidence according to sex and dominant limb, with statistically insignificant results on these criteria.

In their study, Omid et al. [11], compared radiographic and CT measurement and thus demonstrated that radiography overestimates the length by 8.22 mm and is therefore not sufficiently reliable to measure shortening. As our ratio of ultrasound to radiographic measurement is similar, it might be interesting to evaluate the inter- and intra-observer variability of the clinical ultrasound-guided measurement of clavicle length to perhaps implement this measure in emergency departments to decrease radiation's patient and avoid to repeat radiography.

The weaknesses of our study are the retrospective character, and the measurement of the clavicular length which was carried out by a single observer and did not make it possible to evaluate the inter and intra-observer variability of this measurement. This measurement does not evaluate the anteroposterior shortening which would have more consequence on the scapular kinetics than the mediolateral shortening according to the study of Jung-Han et al. [15]. The AO classification of fractures does not predict displacement or shortening, the only comminution.

One of the strengths of our study is the confirmation of our hypothesis with a high rate of significance with a patient follow-up that is more than 3 years. The matching of the two groups and the correlation of the relationships between the ultrasound and radiological measurements are other strong points.

Conclusion

Orthopedically treated clavicle fractures have a poorer functional score correlated to the percentage of shortening even after hindsight of more than 1 year. Management with a locked plate allows restoration of this length and better functional results.

Furthermore, an evaluation of the echo-guided clinical length measure of the clavicle should be performed to measure this shortening in the emergency room and to make the most reliable surgical indication possible.

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