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Chapter 9

Post traumatic midshaft clavicular shortening does not result in relevant functional outcome changes

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Abstract

Background and purpose

Shoulder function may be changed after healing of a non-operatively treated clavicular fracture, especially in case of clavicular shortening or mal-union. We explored scapular orientations and functional outcome in healed clavicular fractures with and without clavicular shortening.

Patients and Methods

32 participants with a healed non-operatively treated midshaft clavicular fracture were investigated. Motions of the thorax, arm and shoulder were recorded by standardized electromagnetic 3D motion tracking. DASH and Constant-Murley scores were used to evaluate functional outcome. Orientations of the scapula and humerus in rest and during standardized tasks, strength and function of the affected shoulders were compared with the uninjured contralateral shoulders.

Results

Mean clavicular shortening was 25 mm (SD 16). Scapula protraction had increased with mean 4.4 degrees in rest position in the affected shoulders. During abduction, slightly more protraction, lateral rotation and less backward tilt was found for the affected shoulders. For anteflexion the scapular orientations of the affected shoulders also showed slightly increased protraction, lateral rotation, and decreased backward tilt. Scapulohumeral kinematics, maximum humerus angles and strength were not associated with the extent of clavicular shortening. All participants scored excellent on the Constant-Murley score and DASH score.

Interpretation

Scapulohumeral kinematics in shoulders with a healed clavicular fracture differ from those in an uninjured shoulder, but these changes are small, do not result in clinically relevant outcome changes and do not relate to the amount of clavicular shortening. These findings do not support routinely operative reduction and fixation of shortened midshaft clavicular fractures based on the argument of functional outcome.

Introduction

Displaced midshaft clavicular fractures are often treated non-operatively with good results, despite the frequently present initial clavicular shortening.[1-4] Studies on clinical outcome after clavicular shortening have reported conflicting results: some show shortening to be associated with poor functional outcome,[1,5,6] whereas others suggest no such relation.[7-10] Mal-union of the clavicle leads to an altered position of the scapula relative to the thorax,[11,12] which may cause shoulder problems, such as acromioclavicular osteoarthritis, decreased arm-shoulder functionality, and symptomatic winging of the scapula.[11,13,14] Primary operative treatment may therefore be preferred in patients with substantial clavicular shortening[15] or to prevent non-union.[16] Operative treatment of clavicular midshaft fractures has become more common.[17] However, the influence of shortening on clavicular and scapulohumeral movement and on functional outcome has not been sufficiently studied to substantiate the need for primary operative reduction and fixation of displaced clavicular fractures, in order to prevent poor functional outcome.

Our primary goal was to assess scapular orientation and arm-shoulder kinematics of patients with healed non-operatively treated midshaft clavicular fracture, and compare this to their uninjured contralateral shoulder. The secondary goal was to assess the relation between clavicular shortening and scapular orientation and between clavicular shortening and functional outcome.

Patients and methods

Inclusion criteria and participants

No sample size calculation was performed. 30 participants were considered sufficient for this exploratory study. Eligible candidates who sustained a unilateral, non-operatively managed, midshaft clavicular fracture healed within 4 months, were selected from the medical databases of 2006-2010 of the Leiden University Medical Centre and the Rijnland Hospital in the Netherlands. Further inclusion criteria were age between 18 and 60 years and no associated injuries at the time of trauma. Exclusion criteria were pathological fractures, neurovascular injury and other conditions influencing arm and shoulder function of either the affected or contralateral arm, current or previous acromioclavicular (AC) injury, such as AC luxation or symptomatic AC-osteoarthritis not caused by the clavicular fracture and a fracture in the proximal or distal third of the clavicle. Since an electromagnetic field was used in this study, candidates with a cardiovascular pacemaker were also excluded. All 74 eligible candidates received written information on this study and were subsequently contacted by phone, of whom 32 were willing to participate.

Motion recording

To collect 3D motion data of the arm and scapula with respect to the thorax, the “Flock of Birds” 3D Electromagnetic Motion Tracking Device (FoB, Ascension Technology Corp, Burlington, VT, USA) and specialized computer software for skeletal motion (FOBVis, Clinical Graphics, Delft, The Netherlands) were used. The FoB motion sensors were taped to the skin covering the posterolateral surface of the acromion, the sternum, on both arms on the posterior aspect just proximal from the humeral epicondyles, and on the wrist (Figure 1). Another

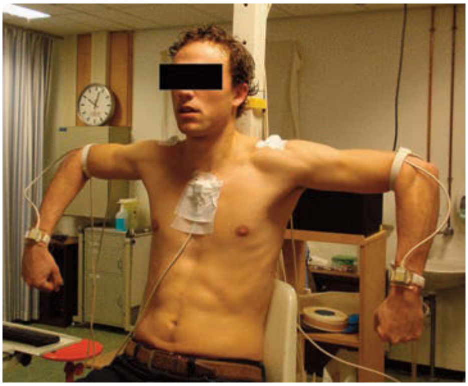


Figure 1 Positioning of the sensors during maximum internal rotation.

sensor was used to localize standardized pre-defined bony landmarks in 3D relative to the other sensors. Sensors were positioned in a standardized way by the primary researcher. The glenohumeral joint center was determined using a regression method. The recorded landmarks were used to create 3D local bone coordinate systems, based on the participants' individual anatomy.[18] For this purpose, the International Society of Biomechanics (ISB) definitions of joint coordinate systems were used.[19] Samples were taken at a sample rate of ± 30 Hz.

Participants were asked to perform a number of standardized tasks with both arms while seated with their trunk in erect position and the hip and knees flexed about 90 degrees. First, scapular orientation was measured in rest, expressed in degrees of protraction, lateral rotation and backward tilt (Figure 2). By convention, protraction means anterior rotation of the lateral border of the scapula, lateral

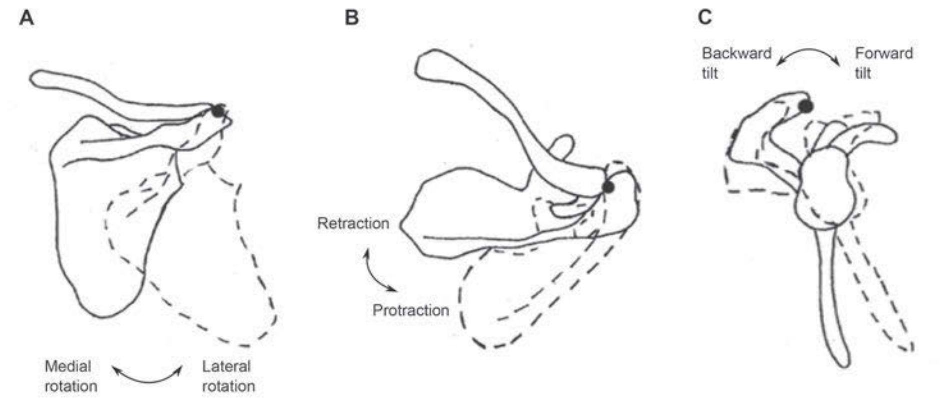


Figure 2 Scapular orientation.
Figures reprinted with permission from Borich MR, Bright JM, Lorello DJ, Cieminski CJ, Buisman T, Ludewig PM. Scapular angular positioning at end range internal rotation in cases of glenohumeral internal rotation deficit. J Orthop Sports PhysTher. 2006;36:926-934. http://dx.doi.org/10.2519/jospt.2006.2241. Copyright ©Journal of Orthopaedic& Sports Physical Therapy®.
We adapted the terminology used in the original figure in (A) from downward rotation/ upward rotation to medial rotation/ lateral rotation, in (B) from external rotation/ internal rotation to retraction / protraction, and in (C) from posterior tilting/anterior tilting to backward tilt/forward tilt.

rotation means lateral rotation of the inferior angle; backward tilt means that the scapula rotates in such a way that the cranial border of the scapula moves dorsally.[19] Second, maximum angles of humerus exertions relative to the thorax were measured for abduction (AB), anteflexion (AF), retroflexion (RF), and humerus internal and external rotation with the arm at 90 degrees of abduction with 0 degrees of horizontal abduction (Figure 1). Third, scapular orientations (protraction, lateral rotation and backward tilt) during AB and AF were measured. All measurements were acquired for both arms simultaneously, whereas the contralateral non-affected shoulder acted as control shoulder.

Clinical outcome

Arm strength of both arms was tested with a handheld dynamometer (MicroFET2, Hoggan Health Industries Inc, West Jordan, UT, USA). To measure maximum force (Newton), the Make Test was used, in which the examiner is holding the dynamometer stationary while the participant exerts a maximum force against the dynamometer and examiner.[20] The dynamometer was placed at the medial side of the elbow joint to measure strength during adduction, 1-2 cm above the elbow joint at the lateral side for AB, anterior of the elbow (distal of the upper arm) for AF, posterior of the elbow for RF, and on the ventral and dorsal side of the wrist for subsequent external and internal rotation, while the participant was seated with the elbow flexed in 90 degrees.

Objective functional outcome was measured using the Constant-Murley score, which ranges from 0 (worst function) to 100 (best function). The scores for the affected shoulders were adjusted for gender and age in decades to obtain relative Constant scores, which were compared with published reference values of the general population. Subjective functional outcome was measured using the Disabilities of the Arm, Shoulder and Hand (DASH) score. A lower DASH score indicates less disability and dysfunction. The scores were compared to reference values.[21]

Radiography

Clavicular shortening was expressed as a proportion of the total clavicular length before fracture, in order to obtain a relative measure that accounts for inter-individual variation in clavicular length. The length before fracture was calculated by adding the length of the affected clavicle to the amount of measured fracture overlap, as we did not have information of the length of the clavicle prior to fracture. The contralateral clavicle was not used as a reference, because of possible pre-existent clavicular asymmetry.[22,23] To calculate this relative shortening, the initial anteroposterior (AP) trauma radiograph was used as well as an AP panorama radiograph comprising both clavicles that was acquired during the study visit (i.e. after consolidation) of all participants. It was ensured that the participants were standing straight and that the spinous processes of the thoracic vertebrae were projected in the midline, to eliminate thoracic rotation and clavicular protraction on the panorama radiograph. On both radiographs, the length of the affected clavicle was digitally measured as the straight line between the mid-medial border of the sternoclavicular (SC-) joint and the most lateral edge of the acromioclavicular (AC-) joint. Overlap of fracture fragments was measured on the trauma radiograph as the axial distance between the cortical fragments ends. As a measure for relative shortening, the Clavicle Shortening Index after fracture consolidation (CSI_{cons}) was calculated:

$$CSI_{cons} = 1 - \frac{Lpanorama}{(Ltrauma + fracture\ overlap)} \tag{Eq. 1}$$

In which L_{trauma} is the length of the affected clavicle after trauma, *Fracture overlap* is the overlap between the fracture fragments measured on the trauma radiograph, and $L_{panorama}$ is the length of the consolidated affected clavicle. This equation is an adjustment of the equation proposed by Smekal et al.[24]

Statistics

Scapular orientation in rest and maximum humerus angles of the affected shoulders were compared to those of the patients' control shoulder using paired t-tests. The association of clavicular shortening (CSI_{cons}) on scapular orientation and maximum humerus angles was assessed using linear regression analysis. If a statistically significant association between CSI_{cons} and scapular orientation and maximum humerus angles was found, an interaction term with arm dominance was tested.

Scapular orientations during AB and AF were plotted for the complete range of motion. In the analysis of scapular orientations during AB and AF, measurements above 90 degrees of humerus elevation were not included, because above 90 degrees the accuracy of FoB acromion sensor recording is known to be reduced due to skin and soft tissue motion artifacts.[25] The association between humerus elevation and scapular orientations was analyzed using linear mixed models with a random effect per subject to account for repeated measures. To study whether the association between humerus elevation angle and scapular orientations was non-linear, a squared term for humerus elevation angle was tested and included in the model if statistically significant. To analyze whether scapular orientations during AB and AF differed between the affected and contralateral shoulder, side (control vs. affected) was also included as independent variable in the mixed models. To test whether the difference in scapular orientation between the affected and contralateral shoulders was constant during AB and AF, an interaction term between side and humerus elevation angle was tested in each model and included if statistically significant. To illustrate the effect of humerus elevation angle on scapular orientations during AB and AF, the model's predicted values for scapular orientations are plotted for affected and control shoulders. Also, predicted values for scapular orientations at 15, 30, 60 and 90 degrees of humerus elevation for affected and contralateral shoulders are tabulated for illustrative purposes. To assess the associations of clavicular shortening on scapular orientation of the affected shoulder during AB and AF, similar linear mixed models were fitted for only the affected shoulders, with CSI_{cons} as independent variable.

Arm strength was compared between affected and contralateral arms using paired t-tests. Linear regression analyses were performed to estimate the influence of CSI_{cons} on AB and AF strength.

All statistical analyses were performed with SPSS version 20.0 (Statistical Package for Social Sciences Inc, Chicago, IL). P-values <0.05 were considered statistically significant.

Ethics and registration

Approval for this exploratory study was obtained from the Medical Ethics Review Committee of the Leiden University Medical Center, the Netherlands. Each participant provided written informed consent. The study was registered in the Dutch Trial Registry (NTR3167) as an observational study and was conducted between December 2011 and April 2012. The study is reported according to the STROBE Statement for observational studies.[26]

RESULTS

32 subjects with a history of a midshaft clavicular fracture, (27 males, median age 31 (21-62) years) participated in the study (Table 1). 30 participants were right-handed and in 15, the consolidated clavicular fracture was on the dominant side. Mean clavicular shortening after consolidation was 25 mm (SD 16) and mean CSI_{cons} was 0.13 (SD 0.08). For 1 patient the CSI_{cons} could not be calculated, because the trauma radiograph had not been calibrated.

Scapular orientation in rest position

In rest position there was more scapula protraction in affected shoulders (mean difference 4.4 degrees; p=0.05; Table 2). No statistically significant effect of CSI_{cons} on the rest position of the scapula was found (regression coefficients for protraction: 0.11, lateral rotation: 0.07, and backward tilt: -0.1; all p>0.10).

Maximum humerus angles

Maximum humerus angles during AB, AF, RF, internal and external rotation were similar between affected and control shoulders (Table 2). No statistically significant effect of CSI_{cons} on the differences in maximum humerus angles was found (regression coefficients for AB: 0.01, AF: 0.07, RF: -0.07, internal rotation: -0.05, and external rotation: -0.1; all p>0.10).

Scapular orientations during abduction and anteflexion

The raw values for measurements of scapular orientations during AB and AF were plotted against humerus elevation angle in Figures 3A and 3B.

During AB, overall scapula protraction decreased by 1.8 degrees per 10 degrees increase in humerus angle. Over the studied range of humerus elevation (0-90 degrees), the difference in scapula protraction between the affected and contralateral shoulders was constant (4.4 degrees) (Figure 4; Table 3). Scapula lateral rotation increased exponentially during AB for both affected and control shoulders. Scapula lateral rotation of the affected shoulder was 2.4 degrees higher than that of the contralateral shoulder over the complete range of humerus elevation angles. Scapula backward tilt increased linearly during AB and was -1.9

Table 1 Demographic characteristics of the 32 participants.

Parameter		Total n=32	Male n=27	Female n=5
Age in years, median (range)		31 (21-62)	36 (21-62)	27 (25-31)
Side of fracture, n				
	Left	16	14	2
	Right	16	13	3
Dominant side affected, n				
	Yes	15	12	3
	No	17	15	2
Shortening after consolidation, mm ± SD		24.8 ± 16.2	26.3 ± 15.5	15.8 ± 18.7
Clavicle Shortening Index, mean ± SD		0.13 ± 0.08	0.14 ± 0.07	0.09 ± 0.11
Trauma mechanism, n				
	Bicycle	15	12	3
	Traffic (motorized vehicles)	6	5	1
	Sports injury	7	6	1
	Other	4	4	0
Occupation, n				
	Manual worker	12	10	2
	Office work	19	16	3
	Unemployed	1	1	0
Current complaint, n				
	None	13	11	2
	Crepitation	4	4	0
	Irritation/weary feeling	13	10	3
	Pain	2	2	0

Table 2 Differences between affected and contralateral (control) arms for scapular orientation in rest position and for maximum humerus angles.

Task	Affected		Control		Affected vs. Control		
	Mean	SD	Mean	SD	Mean diff	95%-CI	p-value
Scapular orientation in rest position (degrees)							
Protraction	27.9	9.6	23.5	6.9	4.4	0.0 – 8.9	0.05
Lateral rotation	3.4	5.0	1.8	6.3	1.6	-0.9 – 4.1	0.21
Backward tilt	-12.2	6.4	-10.7	5.3	-1.6	-3.5 – 0.4	0.11
Maximum humerus angle (degrees)							
Abduction	151.3	11.9	150.3	11.0	1.0	-1.8 – 3.8	0.48
Anteflexion	146.9	10.7	144.9	9.5	2.1	-0.5 – 4.6	0.11
Retroflexion	61.2	9.8	60.3	8.9	1.0	-1.3 – 3.3	0.40
Internal rotation	53.7	16.5	52.8	16.8	0.9	-3.7 – 5.5	0.70
External rotation	70.3	11.7	72.4	10.6	-2.1	-6.3 – 2.0	0.31

degrees lower for the affected shoulders with a systematic increase of 2.2 degrees. The difference between the affected and contralateral shoulders increased with 0.4 degrees per 10 degrees increasing humerus elevation angle (Figure 4; Table 3). No statistically significant effects were found for CSI_{cons} on the affected scapular movements per 10 degrees of humerus elevation for protraction (0.4 degrees), lateral rotation (-2.4 degrees), and backward tilt (-0.6 degrees).

During AF, scapula protraction increased hyperbolic (Table 3; Figure 4). Up to an angle of 90 degrees humerus elevation, protraction of the affected shoulders was constantly 3.8 degrees higher compared to the contralateral side. Scapula lateral rotation increased linearly during AF and was higher for the affected shoulders. The difference in scapula lateral rotation between the affected and contralateral shoulders increased with 0.3 degrees per 10 degrees increasing humerus elevation angle during AF. Scapula backward tilt increased linearly during AF. In the same way as during AB, backward tilt during AF was lower for the

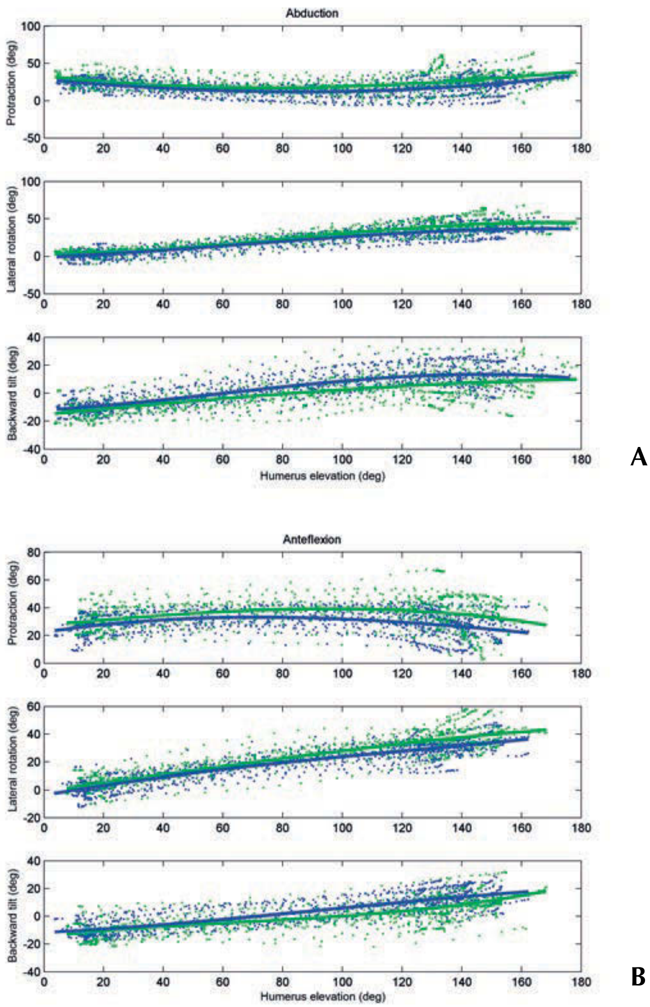
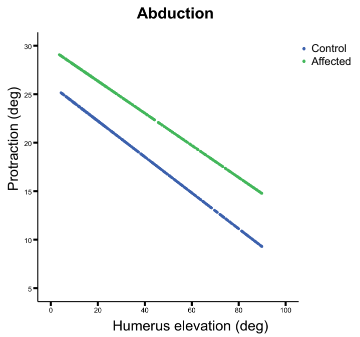


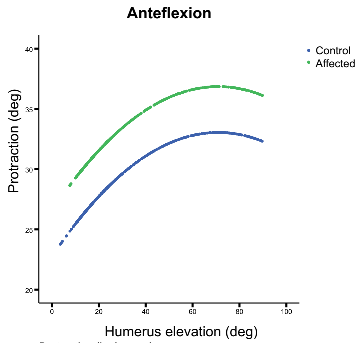
Figure 3 Scapular orientation during active arm abduction (A) and anteflexion (B) in affected shoulders (green lines) and contralateral shoulders (blue lines).*

*Values above 90 degrees were not included in analysis because of possible inaccuracy. Overall, affected shoulders have more scapula protraction, more lateral rotation and less backward tilt compared to the contralateral control shoulders.



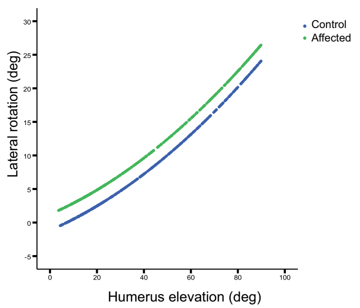
Protraction (in degrees)

Humerus elevation	15	30	60	90
Control	23.2	20.4	14.8	9.2
Affected	27.2	24.7	19.7	14.8



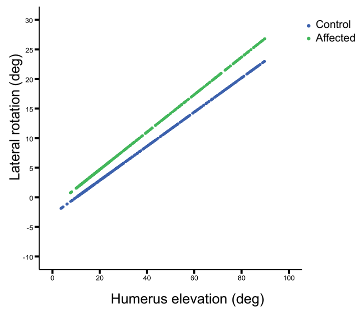
Protraction (in degrees)

Humerus elevation	15	30	60	90
Control	26.6	29.6	32.8	32.3
Affected	30.4	33.4	36.6	36.1



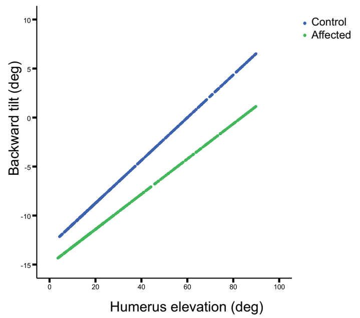
Lateral rotation (in degrees)

Humerus elevation	15	30	60	90
Control	1.5	4.7	13.1	24.1
Affected	4.8	8.1	16.5	27.5



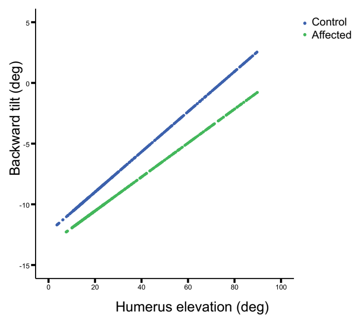
Lateral rotation (in degrees)

Humerus elevation	15	30	60	90
Control	1.4	5.7	14.4	23.1
Affected	3.1	7.8	17.4	26.9



Backward tilt (in degrees)

Humerus elevation	15	30	60	90
Control	-9.8	-6.6	-0.0	6.5
Affected	-12.3	-9.6	-4.2	1.2



Backward tilt (in degrees)

Humerus elevation	15	30	60	90
Control	-9.8	-7.3	-2.4	2.6
Affected	-11.25	-9.1	-5.0	-0.8

Figure 4 Estimated outcomes of the mixed model analyses on scapular orientations during abduction and anteflexion in affected and control shoulders.

Table 3 Outcomes of linear mixed model analyses on scapular orientations during abduction and anteflexion.

	Abduction			Anteflexion		
	Mean estimate	p-value	95%-CI	Mean estimate	p-value	95%-CI
Protraction						
Affected side	4.4	<0.0001	3.6 - 5.2	3.8	<0.0001	3.1 - 4.5
Humerus angle (per 10°)	-1.8	<0.0001	-1.9 - -1.6	2.9	<0.0001	2.1 – 3.7
Humerus angle squared (per 10°)	N/A	-	-	-0.02	<0.0001	-0.02 - -0.01
Affected side x humerus angle (per 10°)	N/A	-	-	N/A	-	-
Lateral rotation						
Affected side	2.4	<0.0001	2.0 - 2.8	1.3	<0.0001	0.6 - 1.9
Humerus angle (per 10°)	1.5	<0.0001	1.1 - 2.0	2.9	<0.0001	2.8 - 3.0
Humerus angle squared (per 10°)	0.01	<0.0001	0.01 – 0.02	N/A	-	-
Affected side x humerus angle (per 10°)	N/A	-	-	0.3	0.001	0.1 - 0.4
Backward Tilt						
Affected side	-1.9	<0.0001	-2.6 - -1.2	-1.0	0.001	-1.7 - -0.4
Humerus angle (per 10°)	2.2	<0.0001	2.1 - 2.3	1.7	<0.0001	1.5 - 1.8
Humerus angle squared (per 10°)	N/A	-	-	N/A	-	-
Affected side x humerus angle (per 10°)	-0.4	<0.0001	-0.5 - -0.2	-0.3	0.001	-0.4 - -0.1

affected shoulders and the difference increased with 0.3 degrees per 10 degrees increasing humerus elevation angle (Table 3; Figure 4). No statistically significant effect of CSI_{cons} on the affected scapular movements per 10 degrees of humerus elevation was found for protraction (-1.7 degrees), lateral rotation (-2.6 degrees), and backward tilt (-0.4 degrees).

Clinical outcome

19/32 included participants reported irritation, weary feeling and pain of the affected shoulder, mostly during prolonged activity of the shoulder (Table 1). None of the participants was under treatment for these complaints.

No statistically significant systematic differences in arm strength between control and affected shoulders were found for adduction (mean difference 7.2N; 95%-CI: -3.5-18), AB (mean difference -0.10N; 95%-CI: -8.8-8.6), AF (mean difference 9.6N; CI: -3.1-22), RF (mean difference 1.6N; CI: -6.7-9.8), external rotation (mean difference 2.0N; CI: -3.2-7.3) and internal rotation (mean difference 5.1N; -0.8-11.1). There was no association of CSI_{cons} with arm strength for all shoulder movements (adduction beta -1.29, p=0.07; AB beta -0.47, p=0.4; AF beta 0.59, p=0.5; RF beta -0.08, p=0.9; external rotation beta 0.08; p=0.8; internal rotation beta 0.37, p=0.3).

The mean Constant-Murley score was 96 points (SD 5.3). All participants scored in the normal range for controls of the same sex and age.[27] The DASH outcome measure had an overall score of 5.2 (SD 6.3), which is low compared to the normative values of 10 (SD 14.7).[21] Since all participants scored in range of normal values for the subjective and objective scores additional analysis was not found to be relevant.

Discussion

In this study we observed more scapular protraction in rest for affected arms, elevated scapula protraction and lateral rotation, and reduced backward tilt during motion. Clavicular shortening was not related to scapula rotation or to maximum humerus angles and strength. Clinical outcomes for the affected arms were similar to those of the control arms and not affected by clavicular shortening.

To our knowledge, this is the first study to assess changes in scapular orientations during active motion after consolidation of clavicular fractures and in relation to clavicular shortening. A few studies have been conducted to examine the kinematics of the scapula after clavicular fracture compared to the contralateral shoulder by means of computed tomography (CT),[11,14] cadaveric dissection[13,28,29] and computational models of shortened clavicles.[30] These studies all involved static or passive anatomic measurements and smaller numbers of patients. In our study, participants actively moved their arms symmetrically as instructed, which provided a more fluent motion of the humerus combined with scapular orientations instead of static measurements.

For scapular orientation in rest, only an increased protraction of the scapula on the affected shoulder could be demonstrated, which was not related to clavicular shortening. This increased protraction was also reported in other studies.[11,13,14] The more profound protraction may explain some of the subjective shoulder complaints reported by some of the participants, although this could not be objectified by a subjective or objective reduction of arm strength, range of motion or in the outcomes of the DASH and Constant-Murley score. It is questionable whether the difference we found between affected and control shoulders is clinically relevant. With an 95%-CI of 0.0–8.9 between affected and control arms, this 4.4 degrees difference seems to lay in the range of normal intra-individual variation.[31] Also, the maximum humerus angles were not influenced by the extent of clavicular shortening. These results are in concordance with several other studies testing range of motion after midshaft fractures of the clavicle.[13,15,32]

In healthy subjects, 3D scapulohumeral movement during arm elevation leads to increased protraction,[18,31] decreased lateral rotation, and increased backward tilting of the scapula.[33] In concordance with the findings of 2 other studies[13,29] we found more protraction, more lateral rotation and less backward tilt of the scapula in affected shoulders. We found no association between clavicular shortening and scapulohumeral movements, which is in contrast with the findings of Matsumura et al. (2010). Who found that during elevation of the humerus backward tilt decreased and protraction increased significantly, in case of 10% or more of clavicular shortening. However, his data was acquired in cadavers with manually created fractures, in which active motion is difficult to reproduce and pain is irrelevant. Pain could lead to coordinative dysfunction of the scapula and in severe cases to scapula dyskinesia, which would negatively influence scapular orientations. This cannot be evaluated in cadaveric studies. In our study population pain was not a limitation for subjective or objective functional outcome of the shoulder, although over half of the participants complained of some irritation, pain or weary feeling in the shoulder during prolonged activities when asked. As another explanation for the structural changes, one could speculate that changed axial rotation of the clavicle after mal-union and not clavicular shortening could have caused the altered 3D scapular orientations.

Changed muscular balance and altered kinematics of the closed chain mechanism of the shoulder may lead to a decrease in arm strength, especially in anteflexion, adduction and internal rotation.[11,32] In previous studies an association between shortening and clinical outcome was demonstrated if clavicular shortening was more than 15 mm.[1,5,6,11,34] In contrast to these studies, we found no evidence that the affected arms had less strength than the contralateral arms, or that the amount of shortening or altered scapular orientations influenced strength. Also, both Constant-Murley and DASH scores were excellent for the affected arms. These results are supported by the findings of other studies.[7-10] The lack of endurance and rapid fatigability was however not tested in our participants.

Concerning the limitations of our study, selection bias may have occurred because not all invited patients were willing to participate. The most frequent reason for non-participation was that candidates were not willing to invest time to participate in research. 4 of the 74 invited candidates had moved and were lost to follow-up, 1 developed non-union and 1 candidate was operated in another hospital. Since the FoB required static length of the clavicles to calculate the different angles, only former patients with a healed clavicular fracture could participate in our study. However, we do think that the participant group is a good representation of the total field of midshaft clavicular fracture patients at our hospitals, as all patients presenting with a midshaft clavicular fracture at the Emergency Department received primarily non-operative treatment in that period.

For all comparisons in our study, the unaffected shoulder of the participants served as a control, because we assumed that the scapular orientations of the control shoulder had remained unchanged after the contralateral clavicular fracture. One could speculate that the position of control shoulder may have altered also, due to the changed position of the affected side. This is known to happen in unilateral diseases such as stroke patients with hemiplegia.[35]

A limitation to our data analysis was that we could not obtain data of the scapula rotations achieved above 90 degrees of anteflexion and abduction. This was due to potential errors in position of the acromion sensor caused by skin and soft tissue motion. Therefore our conclusion can only be sustained for arm movements up to 90 degrees. More research is needed to assess this aspect of scapular orientation and possible functional limitations during overhead elevation (above 90 degrees).

In conclusion, midshaft clavicular fractures tend to affect the scapulohumeral rhythm for arm movements below 90 degrees compared to the unaffected sides, but these changes are small, do not seem to influence functional outcome of the shoulder and do not seem to be related to the amount of clavicular shortening. Therefore, it seems less important than previously assumed to reacquire the initial clavicle length for good functional outcome. On account of the clinically irrelevant changed scapulohumeral rhythm below 90 degrees after clavicular shortening and no significant differences in functional outcome compared to the unaffected shoulders, we cannot support the current tendency towards more routinely operative reduction and fixation of all shortened midshaft clavicular fractures based on these arguments. This conclusion does not include patients with an increased risk of non-union or those with a wish for early mobilization of the shoulder.

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