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Relationship between Hill-Sachs lesions and morphometry of glenoid, acromion and coracoid process

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ABSTRACT

OBJECTIVE: Hill-Sachs lesions are considered as an a priori risk factor for glenohumeral instability. Determination of glenoid and coracoacromial arch morphometric properties of patients with Hill-Sachs lesions may aid in the diagnosis, identification of optimal treatment strategies and prevention of recurrence.

METHODS: Computed tomography (CT) images of individuals between the ages of 20–40 were examined and the morphometric characteristics of the 39 patients with Hill-Sachs lesions and 71 control patients with healthy shoulder structures were compared. Glenoid inclination (GI), acromio-humeral distance (AHD), glenoid height (GH), glenoid superior width (GWs), glenoid inferior width (GWi), glenoid surface (GS), coraco-acromial distance (CAD), coraco-glenoid distance (CGD) and acromio-glenoid distance (AGD) were determined as morphometric features.

RESULTS: The average values of the measurements in Hill-Sachs and control groups, respectively, were; glenoid inclination (1.06±6.61°; 4.33±6.20°), acromio-humeral distance (6.66±1.26; 7.67±1.64 mm), glenoid height (33.90±2.34; 35.03±3.29 mm), glenoid superior width (19.89±5.89; 19.83±2.37 mm), glenoid inferior width (24.28±2.53; 26.04±3.06 mm), glenoid surface (647.93±91.26; 721.58±136.86 mm^2), coraco-acromial distance (40.24±3.99; 38.10±3.80 mm), coraco-glenoid distance (29.39±3.64; 29.96±4.44 mm) and acromio-glenoid distance (31.44±3.45; 31.64–33.56 mm). Glenoid inclination (p=0.011), acromio-humeral distance (p=0.001), glenoid height (p=0.039), glenoid inferior width (p=0.001), glenoid surface area (p=0.002) and coraco-acromial distance (p=0.008) were significantly different between the groups.

CONCLUSION: The glenoid and coracoacromial arch morphometry showed significant differences in patients with Hill-Sachs lesions. Recognizing these differences can reduce recurrence rates by reducing risk factors in the treatment of glenohumeral instability and providing the closest anatomical integrity to normal.

Keywords: Coracoacromial arch; glenoid; glenohumeral instability; Hill-Sachs lesions.

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Hill-Sachs lesions, first described in detail by H.A. Hill and M.D. Sachs in 1940, are postero-lateral defects of the humeral head usually occurring with anterior glenohumeral dislocations [1]. The prevalence has been reported in previous studies to vary between 31% and 94% for anterior shoulder dislocations, and this rate increases as the number of dislocations increases and may reach 100% [2–7]. This variability in the incidence

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is due to the difficulty of diagnosing a Hill-Sachs lesion with plain radiographs. Currently, three dimensional computed tomography (3D CT) it is seen as the gold standard for detecting these lesions [8].

The glenohumeral joint is the most commonly dislocated joint in the body and 90% of dislocations are anterior dislocations [9]. The etiology of anterior glenohumeral instability is multifactorial. However, anatomical features are important for instability. It is important to know the risk factors and features of the anatomical structure for the diagnosis and treatment of this common pathology [10]. Glenoid, acromion and coracoid process morphologies are important bone structures for glenohumeral joint stability. In patients with Hill-Sachs lesion, understanding the morphemetric properties of these structures may increase the chance of success in treatment by helping identify the risk factors for this lesion. In addition, it is necessary to know the anatomy and morphometry of the region very well to treat a region [11].

Although many treatment methods have been described for recurrent glenohumeral dislocations, post-treatment recurrence rates are still high [12]. Although Hill-Sachs lesions are a defect that develop as a result of recurrent anterior dislocations, they also appear as a risk factor in the success of the treatment. Previous studies mostly aimed to determine the relationship between the size and location of the Hill-Sachs lesion and glenohumeral instability. Very few studies have aimed to determine the risk factors and the effect of anatomical structure for Hill-Sachs lesions. The aim of the present study was to determine the relationship between glenoid, acromion and coracoid processes and Hill-Sachs lesions, which leads to recurrent pathology and decreases quality of life.

MATERIALS AND METHODS

Cohort's Selection

Our comparative study was planned retrospectively. Computed tomography (CT) images which included the shoulder area, obtained for any reason by the Department of Radiology of The Kocaeli University Hospital between 2010 and 2019 were used. Exclusion criteria included any image showing dislocation, fracture, degeneration, advanced osteoarthritis, and tumor or images that were not suitable for the measurement of any of the parameters for technical reasons. The age-range of subjects was also limited to 20–40 years of age to exclude possibility of bone development and/or osteoarthritis. The diagnoses of the patients were discussed by the radiologists of our institution. A senior radiologist was consulted in case of uncertainty.

Highlight key points

- Glenoid, acromion, and coracoid process morphometry differed significantly in patients with Hill-Sachs lesions.
- In patients with Hill-Sachs lesions, acromio-humeral distance, glenoid inclination, glenoid height, glenoid width, and glenoid surface area decreased significantly.
- In patients with Hill-Sachs lesions coraco-acromial distance increased significantly.

CT Scan Modalities

CT images were obtained with a Toshiba Aquilion 64 or a Toshiba Activion 16 Multislice CT (Toshiba Medical Systems, Otawara, Japan). Images were evaluated using the Kocaeli University hospital Picture Archiving and communication system (PACS) and Sectra Workstation IDS7 (Sectra AB, Linköping, Sweden) software was used for measurements.

Measurements

Measurements were made of the following features: glenoid inclination (GI); acromio-humeral distance (AHD); glenoid height (GH); glenoid superior width (GWs); glenoid inferior width (GWi); glenoid surface area (GS); coraco-acromial distance (CAD); coraco-glenoid distance (CGD); and acromio-glenoid distance (AGD). Patient group consisted of those images which included Hill-Sachs lesions while the control group consisted of images containing consensus healthy bone structure. All images were evaluated in two separate groups and measurements were compared using appropriate statistical tests. Each measurement was made by 2 investigators and averaged. Senior radiologist made the final decision in case of any disagreement. An example of a patient with Hill-Sachs lesion is shown in Figure 1.

Definitions of Measurement Parameters (Fig. 2)

Glenoid angle (°): Measured using the angle β, between the glenoid fossa and the cortical edge of the fossa supraspitanus in the coronal plane [13].

Acromio-humeral distance (mm): The section with the shortest distance between caput humeri and acromion in the coronal plan was determined and the distance between them was measured in this section [14].

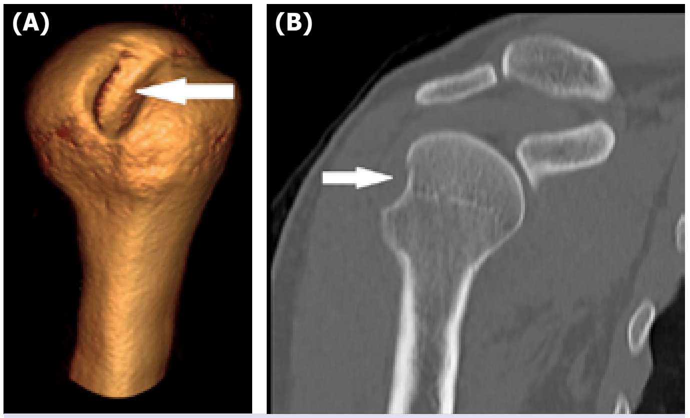

FIGURE 1. Patient with Hill-Sachs lesion on 3D CT (right) and CT (left). Hill-Sachs lesion view of a 27-year-old male patient. **(A)** Reconstructed 3D CT image; **(B)** CT image in the coronal plan.

Glenoid height (mm): The distance between the supraglenoid tubercle and the lowest point of the glenoid surface was measured in the 3D reconstructed image [15].

Glenoid superior width (mm): Calculated by measuring the anteroposterior width of glenoid in the upper half of the glenoid in the 3D reconstructed image.

Glenoid inferior width (mm): Calculated using the anteroposterior widest distance of the glenoid surface in the 3D reconstructed image [15].

Glenoid surface area (mm^2): The glenoid surface is regarded as an ellipse. In the 3D reconstructed image, an elliptical area was calculated using the distance between the supraglenoid tubercle and the infraglenoid and the widest anteroposterior distance [16].

Coraco-acromial distance (mm): The distance between the extreme point of the acromion and the extreme point of the coracoid process was measured in the 3D reconstructed image [17].

Acromio-glenoid distance (mm): The distance between the extreme point of acromion and supraglenoid tubercle was measured in the 3D reconstructed image.

Coraco-glenoid distance (mm): The distance between the extreme point of the coracoid process and the supraglenoid tubercle was measured in the 3D reconstructed image.

Statistical Analysis

Descriptive statistics were assessed. For continuous variables mean, standard deviation, confidence interval are shown. For categorical data, numbers and per-

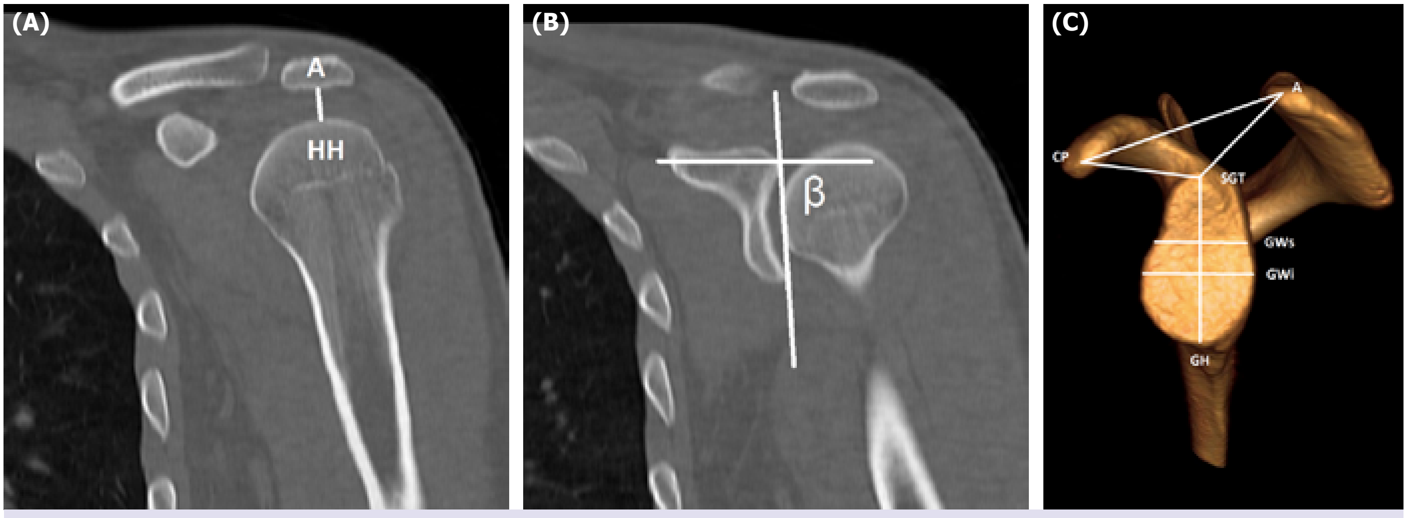

FIGURE 2. Images showing dimensions used to obtain measurements. **(A)** Acromio-humeral distance: The shortest distance between acromion and humeral head in the coronal plane. **(B)** Glenoid inclication: The angle β between the line drawn from the deepest point of the supraspinatus fossa and the line between the most superior and the most inferior of glenoid fossa in the coronal plane. The β angle was obtained using the following (90-x) = β where x = the measured angle. **(C)** Coraco-acromial distance: the line between acromion and coracoid process; acromio-glenoid distance: the line between acromion and supraglenoid tubercle; coraco-glenoid distance: the line between coracoid process and supraglenoid tubercle; glenoid hight: the line between supraglenoid tubercle and the lowest point of the glenoid; glenoid superior width: the widest anteroposterior distance of superior half of glenoid; glenoid inferior width: widest anteroposterior distance of the glenoid.

A: Acromion; HH: humeral head; CP: Coracoid process; SGT: Supraglenoid tubercle; GH: Glenoid height; GWs: glenoid superior width; GWi: Glenoid inferior width.

Table 1. Demographic characteristics of the patient and control groups

Groups	Hill-Sachs n=39	Controls n=71	p
Gender			0.387
Male	79.5	71.8	
Female	20.5	28.2	
Side			0.825
Right	64.1	61.9	
Left	35.9	38.1	
Age (years)			0.223*
Mean±SD	26.26±5.82	27.43±5.48	
Range	20-40	20-40	

SD: Standard deviation; Chi-square test was used; *: Mann-Whitney U test was used.

centages are presented. The compliance of continuous data to normal distribution was evaluated by Kolmogorov-Smirnov and Shapiro-Wilk tests. The t-test was used to compare two independent groups with parametric distribution and the Mann-Whitney U test was used to compare two independent groups with non-parametric features. Chi-square test was used for comparison of categorical data. For statistical significance, $p<0.05$ in 95% Confidence Interval were considered significant. Intraclass correlation coefficient (ICC) was used to determine the level of agreement between observers. A values between 0.50 and 0.75 was accepted as moderate agreement, values between 0.75 and 0.90 was considered as good agreement and values between 0.90 and 1.00 was considered excelent agreement level [18].

For statistical analyses, 21.0 version of the Statistical Package for the Social Sciences (SPSS), version 21.0, (IBM Inc., Chicago, IL, USA) was used.

Ethics Committee Approval

The study was approved by Kocaeli University Non-Interventional Ethics Committee with the decision number GOKAEK 2020/20.30 and project number 2020/347. The study was performed according to Helsinki Declaration.

RESULTS

Study images were obtained from 39 patients (31 males; 79.5%) which were compared with 71 controls (51 males; 71.8%). Demographic features of these two groups are compared in Table 1.

In the Hill-Sachs group nearly two-thirds of the affected shoulders were on the right (n=25, 64.1%) while 14 (35.9%) left shoulder views were obtained. In the control group there were 44 (61.9%) right and 27 (38.1%)

Table 2. The comparison of glenohumeral morphological parameters between Hill-Sachs and control groups

	Hill-Sachs n=39		Normal n=71		p
	Mean±SD	95% CI	Mean±SD	95% CI	
GI (°)	1.06±6.61	-1.08–3.20	4.33±6.20	2.84–5.72	0.011*
AHD (mm)	6.66±1.26	6.25–7.07	7.67±1.64	7.27–8.06	0.001*
AGD (mm)	31.44±3.45	30.32–32.56	32.63±3.88	31.64–33.56	0.114
CAD (mm)	40.24±3.99	38.95–41.53	38.10±3.80	37.28–39.07	0.008*
CGD (mm)	29.39±3.64	28.21–30.57	29.96±4.44	28.98–30.96	0.496
GH (mm)	33.90±2.34	33.14–34.66	35.03±3.29	34.26–35.81	0.039
GWs (mm)	19.89±5.89	17.98–21.80	19.83±2.37	19.27–20.40	0.042*
GWi (mm)	24.28±2.53	23.46–25.11	26.04±3.06	25.37–26.78	0.001*
GS (mm^2)	647.93±91.26	618.34–677.51	721.58±136.86	690.96–753.96	0.002*

GI: Glenoid inclication; AHD: Acromio-humeral distance; AGD: acromio-glenoid distance; CAD: Coraco-acromial distance; CGD: coraco-glenoid distance; GH: glenoid hight; GWs: glenoid superior width; GWi: Glenoid inferior width; GS: Glenoid surface; SD: Standard deviation; CI: Confidence interval; *: Mann Whitney U test was used.

left shoulder views. There was no significant difference between the groups according to the image laterality (p=0.825) and there was no significant difference between the groups according to age (p=0.223)

Intraclass correlation coefficent values between two observers were found as (0.93) for glenoid inclination, (0.89) for acromio-humeral distance, (0.78) for glenoid height, (0.80) for superior glenoid width, (0.90) for inferior glenoid width, (0.94) for coraco-acromial distance, (0.96) for coraco-glenoid distance and (0.96) for acromio-glenoid distance.

Measurements of a total of nine morphometric properties were made in both patient and control groups and compared statistically. These results and comparisons are shown in Table 2.

Glenoid inclication (β angle) was significantly smaller in the Hills-Sachs group compared to the control group (p=0.011). Acromio-humeral distance was significantly larger in the control group compared to the Hill-Sachs group (p=0.001). Acromio-glenoid distance tended to be smaller in the Hill-Sachs group than in the controls but this was not significant (p=0.114). Distance measurement between acromion and coracoid was significantly greater in the Hill-Sachs group (p=0.008). Coraco-glenoid distance tended to be larger in the control group but not significantly so (p=0.496). There was a significant difference between the groups for glenoid height (p=0.039), glenoid inferior width (p=0.001) and glenoid superior width (p=0.042) with the Hill-Sachs patients having lower values. The glenoid surface area was found to be significantly larger in the control group compared to the Hill-Sachs group (p=0.002).

DSCUSSION

Although there are different measurement methods and definitions of glenoid inclination, the most widely accepted definition is the angle between the vertical axis of the glenoid and the transverse axis of the scapula [19]. According to the method described by Mauerer et al. [13] it is calculated by subtracting the β angle from 90 degrees. Previous studies have reported this angle in healthy individuals to be 4.63°±4.86° [20], while Churcill et al. [21] reported a gender difference with the angle varying from 4.0°±3.4° in men to 4.5°±3.8° in women. The glenoid inclination has been evaluated as a risk factor for rotator cuff pathologies in several previous studies [19, 22, 23]. There are few studies investigating the relationship between glenohumeral instability and glenoid inclination. Hohmann et al. [24] determined the mean glenoid inclination to be 1.6°±5.9° in patients with glenohumeral instability and 4.0°±6.8° in control groups in their magnetic resonance imaging (MRI) study. Control group values and Hill-Sachs group values in our study are in agreement with these previous studies and in our cohort, as the value decreases, the glenoid tends towards the inferior. Our results suggest that an inferior change in glenoid inclination appears to be a risk factor for Hill-Sachs lesions.

The acromio-humeral distance has also often been associated with rotator cuff pathologies [25–27]. According to Goutallier et al. [28], distances below 6 mm are associated with rotator cuff tears, while values above 6 mm do not have diagnostic value for rotator cuff tears. In healthy shoulders without rotator cuff pathology, the acromio-humeral distance ranged between 6–14 mm [29]. Saygi et al. [30] using MRI reported that there was a significant difference in acromio-humeral distance between patients with glenohumeral instability and control groups. Although there are very few studies determining the relationship between acromio-humeral distance and glenohumeral instability, our study supports the study of Saygi et al. [30] In our study, the acromio-humeral distance was significantly smaller in the Hill-Sachs group. However in order to clarify the relationship of acromio-humeral distance measurement to Hill-Sachs, we think that further MRI studies are needed to exclude rotator cuff lesions since soft tissue pathologies cannot be ruled out in the CT studies.

Glenoid, as a combined morphology, has an important function in glenohumeral joint stability. Matsumura et al. [31] assumed that glenoid bone loss would be greater in recurrent glenohumeral dislocations. These authors therefore examined the contra-lateral shoulder and the dislocated shoulder, and confirmed that there was loss of glenoid bone in the shoulder with significant dislocation. Peltz et al. [32] reported that there was a significant difference in glenoid height and width between the contralateral glenohumeral joints of patients with glenohumeral instability. In contrast to previous studies, the width of the glenoid was measured in two places, superior and inferior, in the present sudy. In addition, we assumed that the glenoid was an ellipse, and calculated the surface area. Our results showed a significant difference in both glenoid height, superior glenoid with, inferior glenoid width and surface area in

Hill-Sachs patients. Thus, the present study demonstrates that glenoid bone loss is both supero-inferior and antero-lateral in patients with a Hill-Sachs lesion.

The effect of coraco-acromial arc morphometry on glenohumeral instability has been investigated by 3D reconstruction methods in recent years. Jacxsens et al. [17], compared the shoulders with instability and control groups and showed that the coracoid process was significantly shorter and the coraco-acromial distance increased in the group with instability. Lopez et al. [33] reported that the reduced coraco-acromial arch angle was associated with glenohumeral instability in a radiography study performed on 100 patients. There are few studies examining the glenohumeral relationship with coraco-acromial arch morphometry. In our study, it was found that the coraco-acromial distance significantly increased in patients with Hill-Sachs lesions, in agreement with the results of Jacxsens et al. [17] In addition, there was no significant relationship between coraco-glenoid and acromio-glenoid distances.

Conclusion

In conclusion, it was shown that glenoid, acromion, and coracoid process morphometry differed significantly in patients with Hill-Sachs lesions. In patients with Hill-Sachs lesions, acromio-humeral distance, glenoid inclination, glenoid height, glenoid width, and glenoid surface area decreased significantly, and coraco-acromial distance increased significantly. By identifying the differences in shoulder structure between individuals with Hill-Sachs lesion and healthy individuals the diagnosis, treatment and follow-up of these patients may be better understood by orthopedic specialists.

Ethics Committee Approval: The Kocaeli University Non-Interventional Ethics Committee granted approval for this study (date: 10.12.2020, number: 2020/347).

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Authorship Contributions: Concept – AO, TC; Design – AO, TC; Supervision – TC, NB; Materials – TC, NB; Data collection and/or processing – AO, BK; Analysis and/or interpretation NB, CE; Literature review – AO, BK, CE; Writing – AO, BK; Critical Review – BK, CE.

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