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Correlation between glenoid bone structure and recurrent anterior dislocation of the shoulder joint

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Background: *The aim of the study was to investigate the anatomical characteristics and symmetry of the bilateral glenoid structures of Chinese people and to explore the relationship between the glenoid bone structure and recurrent anterior dislocation.*

Materials and methods: *The control group included 131 individuals with no history of shoulder dislocation. The dislocation group consisted of 131 patients with a history of unilateral shoulder dislocation. All subjects underwent computed tomography scans. Glenoid shape (pear-shaped, inverted comma-shaped, oval-shaped), width, height, depth, version angle, area, maximum fitting circle area and volume were measured.*

Results: *There was no significant difference in normal bilateral glenoid of Chinese people ($p > 0.05$). There were statistically significant differences in depth, height to width ratio, maximum fitting circle area and shape between the dislocation and control groups ($p < 0.05$). Regression analyses showed that the glenoid depth (odds ratio [OR] 0.48; $p < 0.01$), the glenoid height to width ratio (OR 28.61; $p < 0.01$), the glenoid maximum fitting circle area (OR 1.01; $p < 0.01$) and the glenoid shape ($p < 0.05$; pear-shaped OR 0.432; inverted comma-shaped OR 0.954) were associated with anterior shoulder instability. Pear-shaped and inverted comma-shaped glenoid had lower risk of recurrent anterior shoulder dislocation compared to oval glenoid. Receiver operating characteristic curve analysis showed that individuals with anterior shoulder instability had smaller glenoid depth and larger height to width ratio and the glenoid maximum fitting circle area compared with the control group.*

Conclusions: *The normal bilateral glenoids of Chinese people are basically symmetrical. The glenoid shape, depth, height to width ratio and maximum fitting circle area are risk factors for recurrent anterior shoulder dislocation. Evaluation of the glenoid bone structure enables more accurate prediction of the risk of recurrent shoulder dislocation.* (Folia Morphol 2023; 82, 3: 712–720)

Key words: shoulder glenoid, recurrent anterior shoulder dislocation, bony structures, glenoid shape

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INTRODUCTION

The glenohumeral joint is the most unstable joint and has the largest range of motion in the human body [9, 26]. Glenohumeral joint dislocation accounts for more than 40% of joint dislocations in the whole body [8], resulting in shoulder pain or dysfunction. It often occurs in young patients, with an average age of 20 years old, and more often in male patients than in female patients, the vast majority of which experience anterior dislocations (85–95%) [3, 6, 20, 25]. Unfortunately, this injury is associated with a very high rate of recurrence (85%) in younger athletes after the initial injury [8]. The first dislocation causes structural damage to the shoulder joint, and the external force required for the second dislocation is smaller than that required for the first dislocation. When dislocation occurs repeatedly, the structural damage is further aggravated, thereby making the next dislocation more likely to occur, forming a vicious cycle.

Previous studies have shown that the risk factors of anterior shoulder instability include soft tissues such as rotator cuff, ligaments, labrum, joint capsule, and bone anatomic features such as the glenoid morphology [19]. The bony structure of the glenoid plays an important role in maintaining the stability of the glenohumeral joint. The glenoid bone structure includes the glenoid width, height, depth, version angle, glenoid area and shape [5, 14]. However, the effect of the glenoid shape on anterior shoulder instability has been rarely studied.

Approximate glenoid symmetry is a feature of the human body [12], and this is the basis for using the contralateral normal side as the reference for analysing the correlation between the bony structure of the glenoid and recurrent shoulder dislocation. To date, the recognition of side-to-side glenoid symmetry has been based on basic measurements of maximum glenoid width, length, circumference, and area [22]. This presumed side-to-side symmetry nevertheless requires a more robust and detailed analysis before management decisions based on this assumption can reliably be undertaken.

The purpose of this study were to evaluate the anatomical characteristics and symmetry of the glenoid bone structures (width, height, depth, version angle, area, maximum fitting circle area, volume, shape) in the bilateral glenoids of Chinese patients and to explore the relationship between the glenoid bone structure and recurrent anterior dislocation.

MATERIALS AND METHODS

Internal review board approval was obtained for this retrospective study. The study was designed as a matched retrospective case-control study.

Compliance with ethical standards

The requirement for informed patient consent was waived for the retrospective study. The study protocol was approved by the institutional review board (number: IRB00006761-M2020544).

Subjects

Patients who were referred to the institution during the period between June 2018 and February 2021 were retrospectively reviewed. The dislocation group consisted of 131 patients with a history of unilateral shoulder dislocation with at least 2 or more anterior dislocations, including 108 males and 23 females, aged 28.16 ± 10.75 years. Patients were excluded if there was evidence of injuries to the previous shoulder dislocation with other direction, glenoid damage, tumour or previous surgery of the glenoid. The control group consisted of 131 individuals with no history of shoulder dislocation, shoulder joint developmental deformity or other disease that may lead to abnormal morphology of the shoulder glenoid. Individuals in the control group were matched by age, sex and height to the dislocation group, in order to increase confidence in the validity of the statistical results.

Imaging protocol

Images were acquired on a Germany Siemens 64-slice spiral computed tomography (CT) system with a 1-mm slice thickness and a 1-mm increment, a pitch of 1. All scans were performed according to a pre-established protocol. All images were acquired with the patient supine, the body centred on the scanning bed, the upper limbs in a neutral position during the examination. All subjects underwent CT examination, including complete imaging of the bilateral glenoids. Multiplanar reconstruction were accomplished and measurement were made on oblique coronal, sagittal and axial images, respectively. Three-dimensional volume rendered reconstructions with humerus-subtracted were accomplished on the CT images of the bilateral glenoid, and the glenoid cavities were rotated to create standardized en face views.

Measurements of the following variables were performed on corrected images:

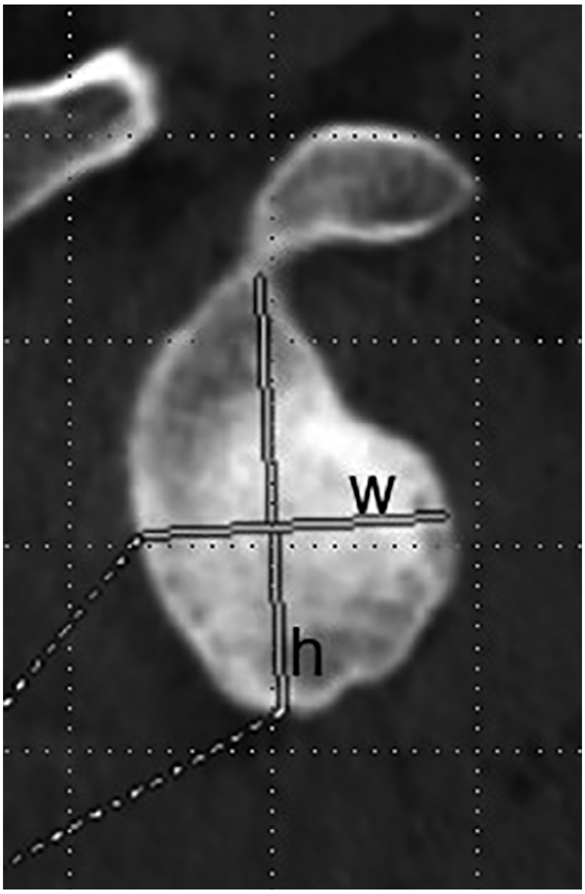

Figure 1. Measurement of glenoid height (shown as h) and glenoid width (shown as w).

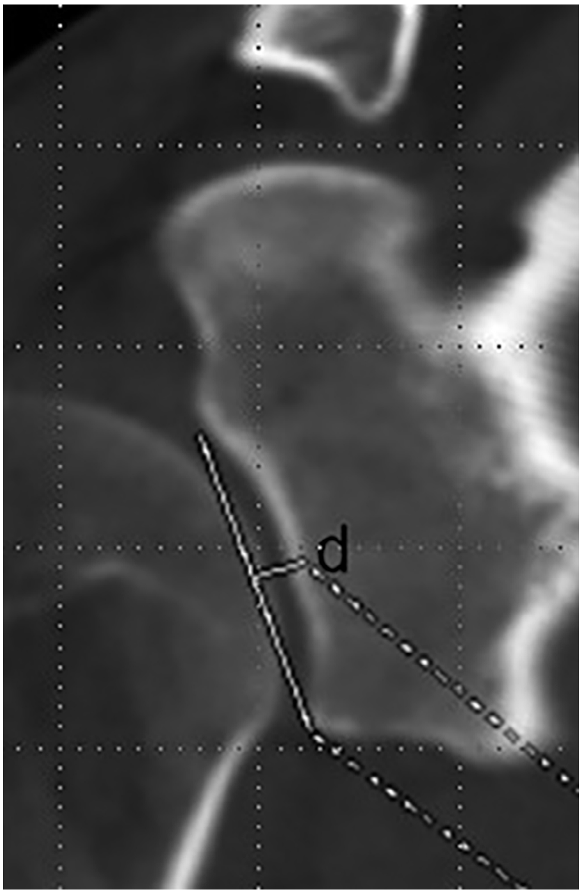

Figure 2. Measurement of glenoid depth (shown as d).

— glenoid width: length of the line connecting the anterior and posterior edges of the glenoid on oblique sagittal images (Fig. 1);
— glenoid height: length of the line connecting the supraglenoid tubercle to the infraglenoid tubercle on oblique sagittal images. Two lines (glenoid width and height) perpendicular to each other (Fig. 1);
— glenoid depth: on oblique coronal images a parallel line connecting the superior and inferior glenoid edges of the scapula through the deepest point of the articular surface was made. The distance between the two lines is the depth of the glenoid depression (Fig. 2);
— Glenoid area: draw a free hand region of interest delineated along the glenoid rim on oblique sagittal images, and measure area automatically (Fig. 3);
— maximum fitting circle area: first, a vertical line along the long axis of the glenoid through the supraglenoid tubercle was drawn. Then a best-fit circle with its centre on this line was placed along the inferior edge of the glenoid, and measure circle area automatically (Fig. 4);
— glenoid volume: automatically identify glenoid contours in oblique sagittal images, adjust contours as needed, and measure volumes (Fig. 5);
— version angle: defined as 90 minus the angle between the scapular plane and the glenoid circle on corrected oblique axial images, with a negative value representing retroversion (Fig. 6);
— glenoid shape: there are three types of glenoid shape, inverted comma shape — the glenoid cavity has a distinct notch; pear shape — the glenoid cavity has an indistinct notch; oval shape — the glenoid cavity has no notch. The shape assessed directly on the volume rendered images (Fig. 7).

Each glenoid was measured 3 times. To establish inter- and intraobserver reliability, 10 random CTs were selected. Two investigators used the methods described and correlation coefficients were calculated. The correlation coefficients for intraobserver

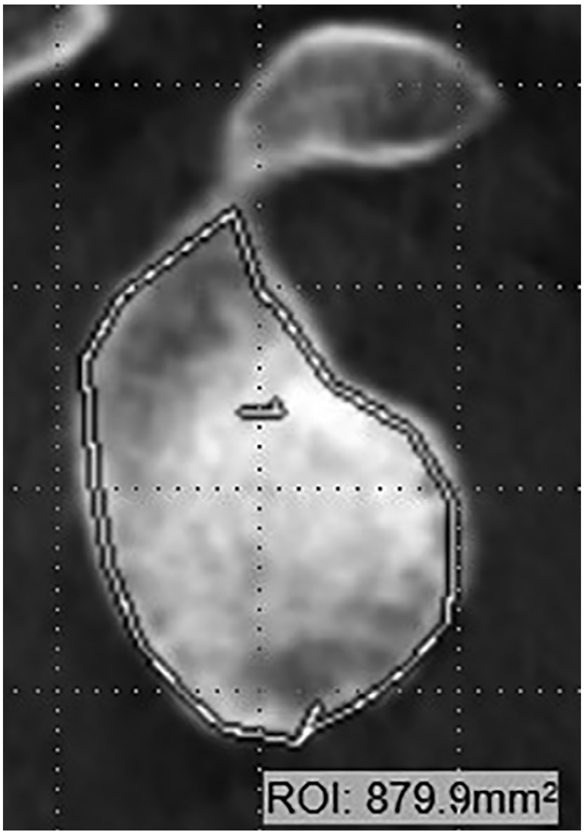

Figure 3. Measurement of glenoid area; ROI — region of interest.

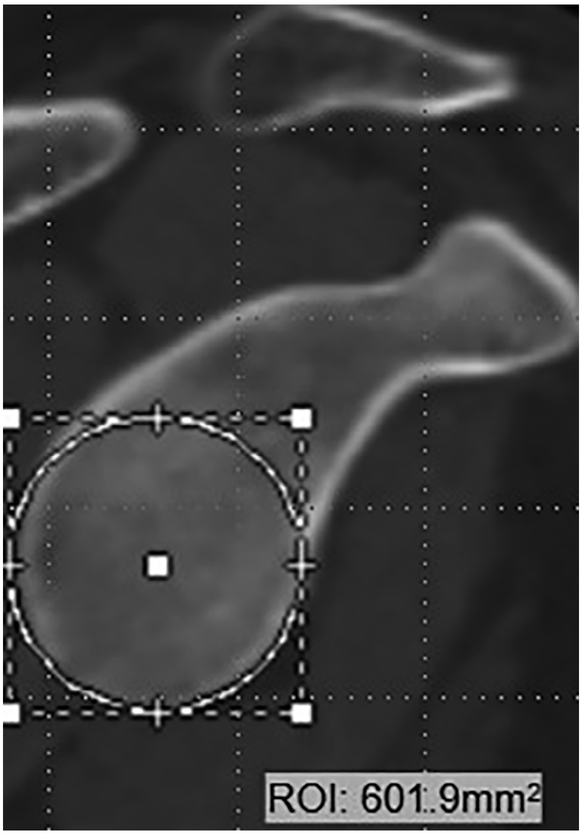

Figure 4. Measurement of glenoid maximum fitting circle area; ROI — region of interest.

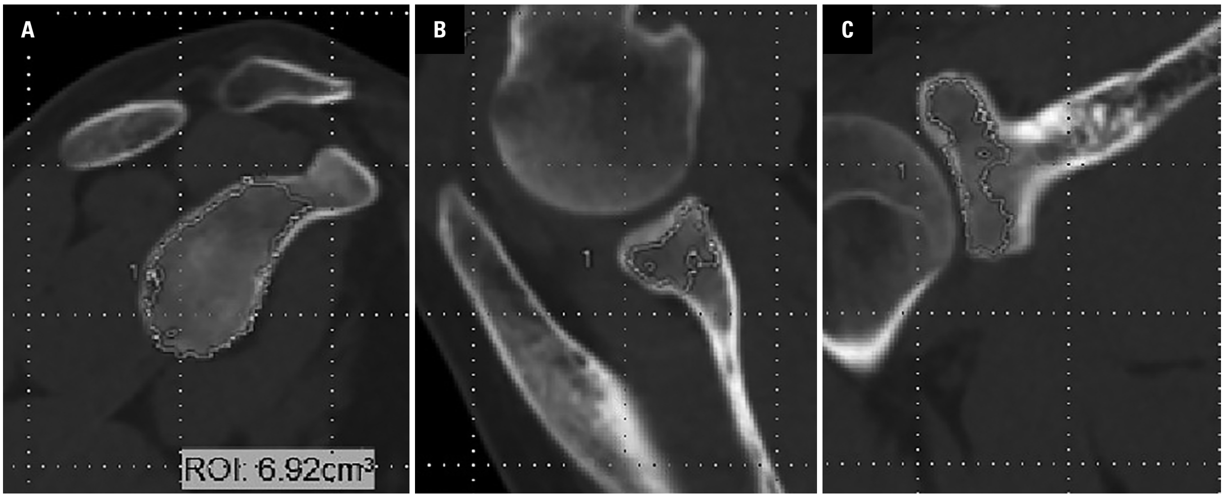

Figure 5. A–C. Measurement of glenoid volume; ROI — region of interest.

had higher scores than interobserver. Given the comparative nature of the project and the higher scores for intraobserver reliability, selection of CTs and all measurements were subsequently performed by the independent research associate only.

Statistical analysis

For continuous variables, we used paired t tests to examine the differences between participants who experienced anterior instability events and those who did not. For categorical variables, we examined the association between the variables and shoulder anterior instability using the χ^2 test. The parameters were further examined using binary logistic regression analysis. Due to the considerable number of patients, cutoff points were determined after using receiver operating characteristic (ROC) curve analysis as a complementary method. All measurements were presented as mean ± standard deviation unless otherwise stated.

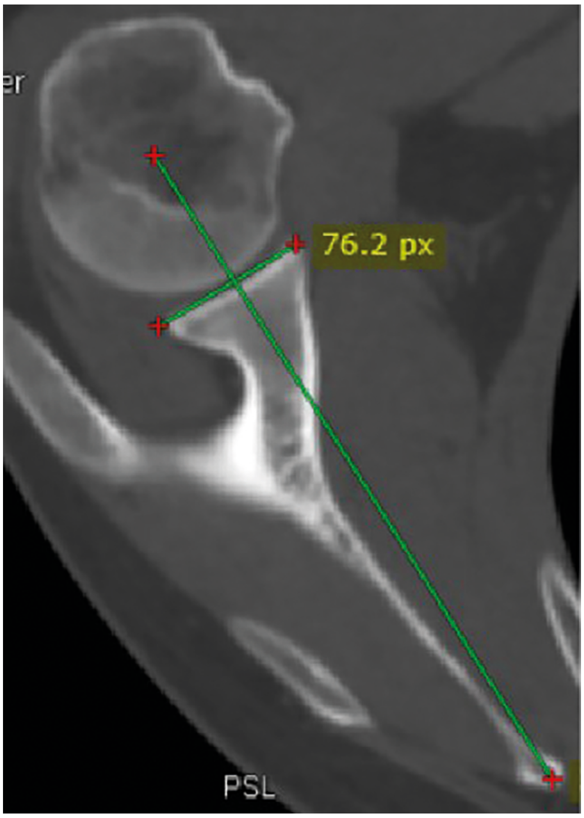

Figure 6. Measurement of glenoid version.

RESULTS

There were no significant differences in the height, width, height to width ratio, depth, area, maximum fitting circle area, volume, or version angle of the normal bilateral glenoids of Chinese patients ($p > 0.05$) (Table 1). There were no significant differences in demographic characteristics between the dislocation group and the control group. No significant differences were found between the control and dislocation group with respect to the glenoid width, height, version angle, area and volume. In contrast, there were statistically significant differences in depth, height to width ratio, maximum fitting circle area and shape between the dislocation and control groups ($p < 0.05$) (Table 2).

Because the values of depth, height to width ratio, maximum fitting circle area and shape had

Table 1. Skeletal anatomical parameters of bilateral glenoid in normal population

Parameters	Left	Right	P
Glenoid width [mm]	26.1 ± 2.14	26.53 ± 2.32	0.08
Glenoid height [mm]	41.43 ± 2.89	42.24 ± 3.2	0.06
Height to width ratio	1.59 ± 0.13	1.60 ± 0.12	0.81
Glenoid depth [mm]	4.26 ± 0.74	4.47 ± 0.88	0.11
Area [mm^2]	761.85 ± 85.27	774.55 ± 86.41	0.13
Maximum fitting circle area [mm^2]	526.39 ± 79.75	540.78 ± 81.31	0.06
Volume [cm^3]	5.94 ± 1.43	6.18 ± 1.6	0.16
Version angle [o]	–3.52 ± 3.59	–3.58 ± 3.81	0.61

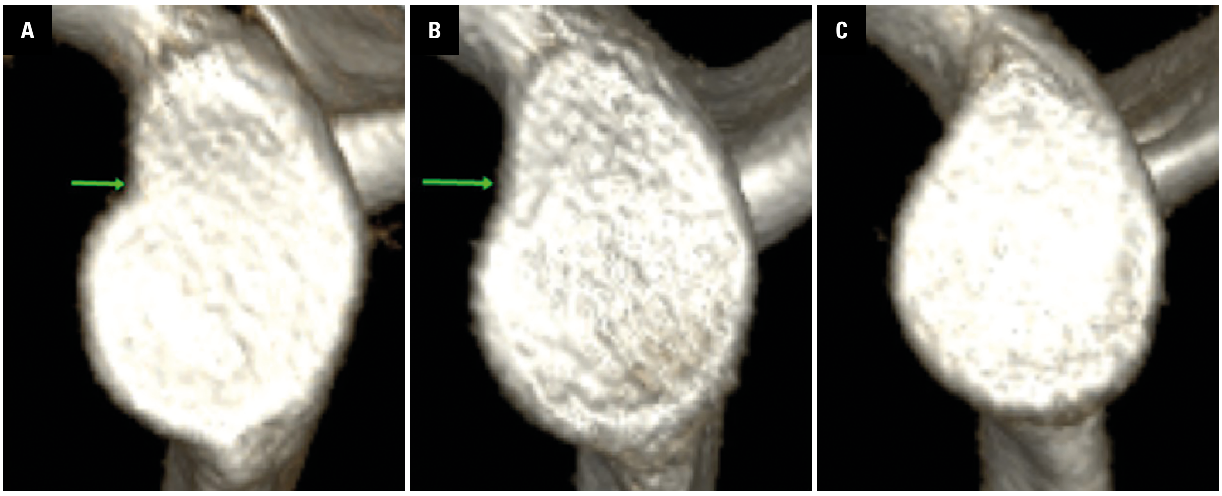

Figure 7. Inverted comma shape (**A**), pear shape or tear drop shape (**B**) and ovoid, oval or round shape (**C**).

Table 2. Comparison of glenoid bone anatomy between the dislocation group and the control group

	The dislocation group (n = 131)	The control group (n = 131)	χ^2/t	P
Gender, male [%]	108	108	–	1
Age	28.16 ± 10.75	28.4 ± 10.55	0.16	> 0.05
Height [cm]	171.62 ± 4.3	171.21 ± 3.6	–0.92	> 0.05
Glenoid width [mm]	25.48 ± 2.56	25.86 ± 2.41	0.99	> 0.05
Glenoid height [mm]	41.44 ± 3.2	41.06 ± 3.32	–0.81	> 0.05
Height to width ratio	1.63 ± 0.16	1.59±0.13	–2.07	0.04
Glenoid depth [mm]	3.99 ± 0.77	4.32 ± 0.72	3.09	< 0.01
Version angle [°]	–2.6 ± 3.27	–3.54 ± 3.75	1.83	> 0.05
Area [mm^2]	748.91 ± 103.89	748.38 ± 104.69	–0.03	> 0.05
Maximum fitting circle area [mm^2]	552.76 ± 93.65	497.26 ± 90.49	–4.27	< 0.01
Volume [cm^3]	6.31 ± 1.32	6.16 ± 1.74	–0.73	> 0.05
Shape:				
Inverted common shape	9	11	17.29	< 0.01
Pear shape	66	95		
Oval shape	56	25		

Table 3. Logistic regression analysis of risk factors for recurrent shoulder dislocation

Parameters	Odds ratio	95% confidence interval		P
		Minimum	Maximum	
Depth	0.48	0.305	0.757	< 0.01
Height to width ratio	28.61	3.018	271.266	< 0.01
Maximum fitting circle area	1.011	1.007	1.016	< 0.01
Shape:				
Oval shape	1			0.01
Pear shape	0.432	0.228	0.816	
Inverted common shape	0.954	0.231	3.937	

a $p < 0.05$, they were further examined using conditional logistic regression analysis, as reported in Table 3. Regression analyses showed that the glenoid depth (odds ratio [OR] 0.48; $p < 0.01$), the glenoid height to width ratio (OR 28.61; $p < 0.01$), the glenoid maximum fitting circle area (OR 1.01; $p < 0.01$) and the glenoid shape ($p < 0.05$; pear-shaped OR 0.432; inverted comma-shaped OR 0.954) were associated with anterior shoulder instability. Pear-shaped and inverted comma-shaped glenoids had lower risk of recurrent anterior shoulder dislocation compared to oval glenoids (Table 3).

Subsequently, ROC curve analysis was performed on parameters such as the glenoid depth, the glenoid height to width ratio and the glenoid maximum fitting circle area (Fig. 8). A comparison of cutoff points showed that individuals with anterior shoulder instability had smaller glenoid depth and larger height to width ratio and the glenoid maximum fitting circle area than those in the control group, identified by ROC curve analyses. The cutoff point for the glenoid depth was 4.25 mm, for the height to width ratio was 1.62, for the glenoid maximum fitting circle area was 515.55 mm^2 using ROC curves in these analyses.

DISCUSSION

In this study, data on the shoulder structure of patients with anterior shoulder dislocation were assessed by CT. CT has the advantages of extremely high spatial resolution and density resolution, and multiplanar reconstruction and quantitative analysis of the bone structure of the glenoid. We used

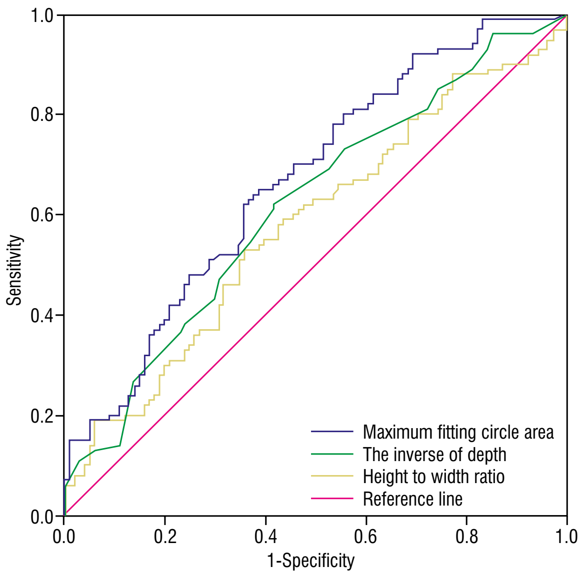

Figure 8. Receiver operating characteristic curves showed that individuals with anterior shoulder instability had smaller glenoid depth and larger height to width ratio and the glenoid maximum fitting circle area compared with the control group.

post-processing technologies such as three-dimensional volume-rendered reconstructions, which made it more intuitive and convenient for us to evaluate the shape of the glenoid [13, 23]. It is readily and rapidly available in most hospitals compared with magnetic resonance imaging [7]. The study shows that the normal bilateral glenoids of Chinese Han population is symmetrical in terms of height, width, height to width ratio, depth, area, maximum fitting circle area, volume and version angle, which implies that we can use the contralateral normal side as the reference for analysing the bony anatomy of the glenoid in patients with recurrent anterior shoulder dislocation.

For the first time, we have performed an analysis of the shape of the glenoid in Chinese patients. The glenoid fossa of the scapula is a shallow oval depression on the lateral corner of the scapula. There may be a notch at the anterior and superior edges of the glenoid. This notch is consequently a common finding, rather than a rare anatomical variant, but is often overlooked in studies [17, 18]. The notch is situated somewhat above the middle of the anterior margin of the cavity and can be very prominent, very shallow or absent. Preschers [17, 18] classified the shape of glenoid according to the presence or absence of glenoid notch. One hundred twenty-nine (55%) scapulae showed a more or less recognisable glenoid notch at the anterior margin of the glenoid cavity and were pear-shaped; 107 (45%) scapulae showed no notch and were of oval form [17, 18]. Sangeeta Gupta et al. [10] classified 60 scapula glenoid anatomical specimens into inverted comma-shaped, pear-shaped or teardrop-shaped, and oval-shaped, and the left and right sides were not always identical. The inverted comma-shaped was 38%, the pear-shaped was 42% and the oval-shaped was 20%, and the relationship with shoulder instability needs further study [10]. In this study, inverted comma-shaped, pear-shaped, and oval-shaped glenoid of the bilateral glenoids accounted for 8%, 72%, and 20% in the control group, including 118 (90%) symmetrically shaped scapular pairs and 13 (10%) asymmetrically shaped scapular pairs. The difference between the sides was not significant. In the dislocation group inverted comma-shaped, pear-shaped, and oval-shaped glenoid of the unaffected glenoids accounted for 7%, 50%, and 43%, respectively. The study showed that the control group had fewer oval-shaped glenoids compared with Preschers [17, 18], but the proportion of oval-shaped in the dislocation group was significantly increased.

This study showed that the shape of the glenoid was an important factor in cases of anterior instability of the shoulder. Pear-shaped and inverted comma-shaped glenoid had lower risk of recurrent anterior shoulder dislocation compared to oval glenoid. The results suggested that the pear-shaped and inverted comma-shaped glenoids were protective factors for recurrent anterior shoulder dislocation, the oval-shaped glenoid was a risk factor and may be prone to recurrent anterior shoulder dislocation. This may be inconsistent with the hypothesis of Preschers [18] that the labrum does not attach to the bone at the notch and liable to be sheared of (Bankart lesions). There is no doubt that evaluating the risk factors of recurrent shoulder dislocation by simple shape analysis is still a preliminary study, we also need to analyse the relationship between glenoid shape and soft tissues such as the glenoid labrum, ligaments, and whether there are racial differences. There was no priority of side for the glenoid notch, so that an influence of handedness on the shaping of the glenoid cavity is unlikely. This study used CT to analyse the shape of the glenoid in Chinese people. Unfortunately, visualising soft tissues in a CT scan is not possible without the use of contrast agents, so the relationship between the glenoid notch and the glenoid labrum could not be determined. If the notch was present, the glenoid labrum was not attached in this area to the anterior margin of the glenoid cavity.

A small recess of the articular cavity was regularly found at the glenoid notch. It was mentioned in the paper by Preschers [17, 18]. The middle glenohumeral ligament, a broad, thick structure with a variety of presentations, also originates at the superior part of the articular lip; whether it is related to the notch requires further study. In addition, the notch is mentioned by Frazer (1958) [4], who stated that the position of the notch indicates the line of the junction between the 'coracoid' and the 'scapular' parts of the glenoid cavity. However, the glenoid notch is located a few millimetres below the junction between these two developmental parts of the glenoid cavity.

The distance between the supraglenoid tubercle and the infraglenoid tubercle of the glenoid determines the height of the glenoid. The distance between the anterior and posterior edges of the glenoid determines the width of the glenoid. Saygi et al. [21] found that the height of the dislocation group was significantly different from that of the control group. This study showed that the differences of height and width between the dislocation and control group were not significant. Owens et al. [15] analysed the glenoid height of 714 young athletes and found that a tall and narrow glenoid was more unstable and associated with a higher risk of dislocation than a short and wide glenoid. Hong et al. [11] found that an increased ratio of glenoid height to width was a risk factor for anterior glenohumeral joint instability. The same conclusion was reached in this study. While neither height nor width was a significant risk factor in its own right, the glenoid height to width ratio was a significant finding. There were significant differences in the ratio of glenoid height to width between the dislocation group and the control group, suggesting that height to width ratio was a risk factor for recurrent anterior shoulder dislocation.

Previous studies did not consider glenoid depth to be risk factor of anterior shoulder instability [16]. In contrast, the glenoid depth played an important role in anterior shoulder instability. In our study, the depth of the dislocation group was significantly lower than that of the control group. We revealed that the glenoid depth was a risk factor for anterior shoulder instability. The cutoff point for glenoid depth was 4.25 mm.

The glenoid osseous Bankart injury is an avulsion fracture of the anterior inferior glenoid when the shoulder dislocation occurs, resulting in the reduction of the glenoid area. It is an important cause of shoulder instability and recurrent anterior dislocation. Previous studies showed that glenoid bone defects were generally measured by the maximum fitting circle method [8, 24]. This study we measured the maximum fitting circle area on one side of the control group and the unaffected side of the dislocation group. This study also found that there was a significant difference in the maximum fitting circle area between the dislocation group and the control group, and the dislocation group had a larger glenoid area. We revealed that the maximum fitting circle area was a risk factor for anterior shoulder instability. The cutoff point for maximum fitting circle area was 515.55 mm^2.

The version angle is the angle between the scapular plane and the glenoid plane in the cross-sectional view, with a positive value representing anterior tilt of the glenoid and a negative value representing posterior tilt, reflecting the anteversion or retroversion of the glenoid in the axial position. Churchill et al. [2] measured version angles using anatomical specimens and concluded that there were differences among different ethnic groups. Aygun et al. [1] concluded that the angles of glenoid version on the dislocated side were significantly more anteverted in the study group than in the dominant and nondominant shoulders of the control group. However, in our study, we did not identify a significant relationship between glenoid version and anterior shoulder instability in the Chinese Han population. The results of the glenoid version angle in this study were similar to previous study [11].

Limitations of the study

This study has several limitations. One possible limitation is the select and homogeneous nature of our study. The included population is ideal for a clinical study, but the sample may not be representative of the normal healthy population and could lead to the selective bias in this study. For version measurement, the results of intraclass correlation coefficient for intra- and interobserver reliability showed that intraobserver intraclass correlation coefficient was significantly more reliable; therefore, only one independent examiner did this work, but this may lead to bias.

CONCLUSIONS

The normal bilateral glenoids of Chinese people are basically symmetrical. The glenoid shape, depth, height to width ratio and maximum fitting circle area are risk factors for recurrent shoulder dislocation. Evaluation of the glenoid bone structure enables more accurate prediction of the risk of recurrent shoulder dislocation.

Conflict of interest: None declared

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