



GEOMETRIC MORPHOMETRY OF GLENOID CAVITY IN DRY ADULT SCAPULA AND ITS SURGICAL IMPLICATIONS

Anatomy

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ABSTRACT

Background: An understanding of variations in normal anatomy of the glenoid cavity is a prerequisites for better understanding of the mechanics of shoulder joint and shoulder joint arthroplasty.

Aim: The aim of this osteological study was to do a complete morphometry of glenoid cavity in an adult North-Indian population and to establish its possible surgical implications.

Materials and Methods: A total of 206 adult dry undamaged scapulae (106 left side, 100 right side) were selected from the osteology museum of Department of Anatomy, Maulana Azad Medical College, New Delhi. The shapes of the glenoid were evaluated. All the linear measurements were taken by using digital vernier caliper. The glenoid version angle was calculated by using ImageJ software.

Statistical Analysis: The comparison of morphometric values of the two sides was carried out by using student's t-test in SPSS version 17. Statistical significance of p value ≤ 0.05 was taken.

Results: The present study showed the pear shaped glenoid cavity was the most common type. The average supero-inferior diameter on right and the left sides were 35.94 ± 2.30 mm and 35.68 ± 2.14 mm respectively. The mean antero-posterior diameter-1 of the right glenoid was 24.37 ± 2.34 mm and on left it was 24.20 ± 2.28 mm. The right mean antero-posterior diameter-2 was 16.62 ± 2.82 mm while on left it was 16.14 ± 2.84 mm. The right and left mean glenoid cavity index were found to be $66.94 \pm 6.46\%$ and $68.04 \pm 4.66\%$ respectively. The right glenoid cavity was found to be significantly more retroverted than left.

Conclusion The sound knowledge of various parameters of glenoid cavity is important for the anatomists, anthropologists, orthopaedicians and prosthetists.

KEYWORDS

Glenoid cavity index, glenoid version angle, shoulder joint, shoulder arthroplasty

INTRODUCTION

The scapula is a pair of flat triangular bone that lies on the posterolateral aspect of the chest wall over 2nd to the 7th rib. On its lateral angle there is a shallow, pyriform articular surface known as glenoid cavity which articulates with the head of the humerus [1].

The vertical diameter of the glenoid cavity is the longest and it is broader below than above. Depending on the presence or absence of a notch on the anterior glenoid rim, various shapes of the glenoid cavity have been described like pear-shaped, oval or inverted comma shaped. It has been found that if the notch is distinct, then the glenoid labrum is not fixed to the bony margin of the notch but bridges the notch itself. This could make the shoulder joint less resistant to dislocating forces [2,3]. The angle between glenoid cavity and the plane of scapula is known as glenoid version which is recorded as anteversion if the glenoid opens anteriorly and retroversion if it faces posteriorly. Anteversion is recorded with a positive sign whereas retroversion is recorded with a minus sign [4].

The shoulder joint is the most frequently dislocated joint in the body and dislocations with fractures of the glenoid are also quite common in trauma. Thus, an understanding of the normal glenoid cavity morphometry is of great significance to sports medical professionals and its anthropometry cannot be overlooked by anatomist and medico-legal forensic experts. The restoration of normal anatomy is the goal in orthopedic surgery [5].

The geometric measurements of glenoid will be useful in software remodeling and reconstruction of damaged or missing parts. The disproportionate sizes of the head of the humerus and the small, shallow glenoid cavity combined with a lax articular capsule give this joint a wide range of movements but make the joint inherently unstable which is one of the predisposing factors for rotator cuff pathology [6,7,8].

The purpose of the current study was to obtain the morphometrical data and various shapes of the glenoid cavity relevant to the north Indian

population and to compare the data obtained from the present study with earlier reports.

MATERIALS AND METHODS

The present study included 206 adult dry scapulae which were part of the osteology museum of Department of Anatomy, Maulana Azad Medical College, New Delhi. Out of these 106 belonged to left side and 100 to right side. Only bones with clear and intact features were used for the study while damaged scapulae were excluded. Morphological evaluation and morphometric measurements for glenoid cavity were done in each scapula. All linear measurements (in millimeters) were ascertained by using digital Vernier caliper (accuracy 0.01mm). The angular measurements were calculated by using ImageJ software. The following parameters were studied:

Morphological evaluation

-Shapes of the glenoid cavity: The tracing of the shape of the glenoid cavity was taken on a white paper with the help of a lead pencil. Three types of glenoid were found on the basis of tracings drawn: (a) Pear shape (b) Inverted comma shape and (c) Oval shape [Figure 1].

[Figure 1] Morphological shapes of glenoid cavity (a- Pear shaped, b- Oval shaped, c- Inverted comma shaped)



Morphometric evaluation

A) Linear parameters

-Supero inferior glenoid diameter (SI): The maximum distance between the inferior point of the glenoid border and the most prominent point of the supraglenoid [Figure 2].

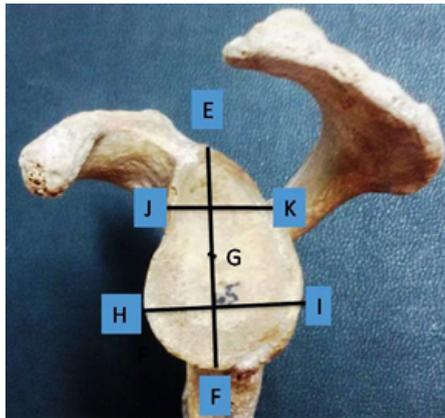
-Antero posterior-1 (AP-1) glenoid diameter: The maximum breadth of the articular margin of the glenoid cavity perpendicular to the glenoid cavity height [Figure 2].

-Antero posterior-2 (AP-2) glenoid diameter: The anterior-posterior diameter of the superior half of the glenoid cavity at its mid-point [Figure 2].

-Glenoid cavity index (GCI): is calculated with the help of following formula

$$GCI = \frac{\text{Antero-posterior-1 glenoid diameter}}{\text{Supero-inferior glenoid diameter}} \times 100$$

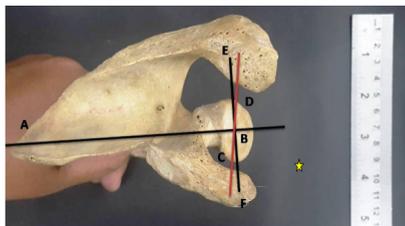
[Figure 2] Diameters of glenoid cavity (E-F: Supero inferior, H-I: Antero-posterior-1, J-K: Antero posterior-2)



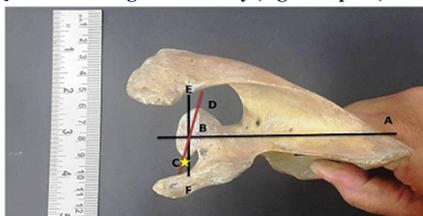
B) Angular parameter

- Glenoid version angle: The scapula to be stand on its inferior angle on the photographic board. The superior view of the scapula was captured by digital camera and transferred to the computer. As a procedure for analysis, lines were drawn using Microsoft power point^R 2007 software. The transverse axis of the scapula was determined by a line (AB) drawn from the medial end of the spine of scapula (A) to the midpoint of the glenoid fossa (B) on the image. The second line (CD) was drawn between the anterior most (C) and posterior most points (D) of the glenoid cavity and the third line (EF) was drawn perpendicular to the transverse axis which is the line of neutral version of the glenoid. This image was saved as a picture and opened with a software image J analyser for measuring the angle. The angle between CD and EF line was measured which denotes glenoid version angle. The version angle is recorded as anteversion if glenoid is opens anteriorly [Figure 3]. and retroversion if it opens posteriorly [Figure 4].

[Figure 3] Anteverted glenoid cavity (left scapula)



[Figure 4] Retroverted glenoid cavity (right scapula)



Statistical analysis

The mean and standard deviations of the linear and angular parameters were calculated. The morphometric values of the two sides were analysed using an unpaired t-test. Statistical significance was set $p \leq 0.05$.

Results

In the present study, pear shaped glenoid cavity presented with the highest incidence among the total scapulae examined while the oval shaped showed the lowest incidence [Table 1]. The average supero-inferior diameter on right and the left sides were 35.94 ± 2.30 mm and 35.68 ± 2.14 mm respectively. The mean antero-posterior diameter-1 of the right glenoid was 24.37 ± 2.34 mm and on left it was 24.20 ± 2.28 mm. The right mean antero-posterior diameter-2 was 16.62 ± 2.82 mm while on left it was 16.14 ± 2.84 mm. The right and left mean glenoid cavity index were found to be $66.94 \pm 6.46\%$ and $68.04 \pm 4.66\%$ respectively. In all the above measurements, bilateral differences were found to be statistically insignificant (P values > 0.05) [Table 2]. The values of glenoid version showed wide distribution ranging from -14.58° to $+4.36^\circ$. On left side 86 out of the 106 glenoids were retroverted with a mean angle of $-5.25^\circ \pm 2.89^\circ$ and 20 were anteverted with a mean angle of $+2.80^\circ \pm 0.93^\circ$. On right side 90 glenoids out of 100 were retroverted with a mean angle of $-6.25^\circ \pm 3.79^\circ$ and 10 were anteverted with mean angle of $+1.91^\circ \pm 0.91^\circ$ [Table 3]. The right glenoid showed significantly greater retroversion than left side ($p \leq 0.05$).

[Table 1]: Different shapes of glenoid cavity

Shape	Left (%)	Right (%)	Total (%)
Pear shaped	49.04%	51%	50%
Inverted comma	31.14%	30%	30.58%
Oval	19.82%	19%	19.42%

[Table 2]: Various morphometric parameters of glenoid cavity

Parameters	Range (mm)		Mean + SD (mm)		Total Mean + SD (mm)	P value
	Right	Left	Right	Left		
Superior-inferior (SI) glenoid diameter	32.17 to 43.23	31.44 to 42.60	35.94 + 2.30	35.68 + 2.14	35.81 + 2.22	0.39
Antero-posterior (AP) glenoid diameter 1	18.73 to 29.35	16.62 to 28.52	24.37 + 2.34	24.20 + 2.28	24.28 + 2.31	0.61
Antero-posterior (AP) glenoid diameter 2	12.14 to 22.64	11.02 to 20.88	16.62 + 2.82	16.14 + 2.84	16.37 + 2.84	0.23
Glenoid cavity index (GCI)	50.22 to 87.79 %	48.67 to 86.28 %	66.94 + 6.46 %	68.04 + 4.66 %	67.37 + 5.80 %	0.30

[Table 3]: Results of glenoid version angle

Parameter	Side	Numbers	Glenoid version Mean \pm SD ($^\circ$)	Range ($^\circ$)	P value
Retroversion angle	Left	86	$-5.25^\circ \pm 2.89^\circ$	-11.08 to -1.02	0.04
	Right	90	$-6.25^\circ \pm 3.79^\circ$	-14.58 to -1.08	
	Total	176	$-5.76^\circ \pm 3.41^\circ$	-14.58 to -1.02	
Anteversion angle	Left	20	$+2.80^\circ \pm 0.93^\circ$	+1.22 to +4.36	0.01
	Right	10	$+1.91^\circ \pm 0.91^\circ$	+1.04 to +2.92	
	Total	30	$+2.50^\circ \pm 1.01^\circ$	+1.04 to +4.36	

N = number of scapulae , SD =standard deviation , ($^\circ$) = unit in degree

DISCUSSION

The present study was performed on dry adult human scapulae and after taking the measurements of the glenoid cavity, our results were compared with the results of the other authors [Table 4]. Our findings indicate that the most frequently glenoid type is pear shaped while the least one is oval shaped. These results are in match with Rajput et al, Mamatha et al, and Sarwar et al [7,9,10].

Coskun et al reported oval shaped glenoid to be more common (72%)

[Table 4]:Comparison of various glenoid cavity parameters with other osteological studies

Observer	Year	Population studied	No. of specimens	Shape of glenoid cavity			Mean SI Diameter (mm)	Mean AP-1 Diameter (mm)	Mean AP-2 Diameter (mm)
				Pear shaped (%)	Oval shaped (%)	Inverted comma shaped (%)			
Preschner et al [3]	1997	Germans	Male-118	55	45	-	-	-	-
			Female-118						
Von Schroeder et al [13]	2001	Canadian	30	-	-	-	36.0 ± 4.0	29.0 ± 3.0	-
			30						
Frutos LR [15]	2002	North Americans	Male-65	-	-	-	36.08 ± 2.0	26.30 ± 1.5	-
			Female-38						
Coskun et al [11]	2006	Turkish	90	72	28	-	36.3 ± 3	24.6 ± 2.5	-
Karelese et al [14]	2007	Europeans	40	-	-	-	35.9 ± 3.6	27.2 ± 3.0	-
			40						
Mamatha et al [7]	2011	Indians	Right -98	46	20	34	33.67 ± 2.82	23.35 ± 2.04	16.27 ± 2.01
			Left-104	43	24	33	33.92 ± 2.87	23.05 ± 2.30	15.77 ± 1.96
Rajput HB et al [9]	2012	Indians	Right -43	49	16	35	34.76 ± 3.0	23.31 ± 3.0	15.10 ± 2.54
			Left-57	46	15	39	34.43 ± 3.21	22.92 ± 2.80	13.83 ± 2.45
Kavita et al [12]	2013	Indians	Right -67	58	30	11	35.2 ± 3.0	25.07 ± 2.7	16.8 ± 1.8
			Left-62				34.7 ± 2.8	24.9 ± 2.0	16.3 ± 2.0
Sarwar et al [10]	2015	Indians	Right -50	56	20	24	35.22 ± 3.26	23.95 ± 2.78	16.16 ± 2.38
			Left-50	64	16	20	34.53 ± 3.21	23.64 ± 2.37	15.34 ± 2.17
Wael Amin el din et al [18]	2015	Egyptians	Right-80	35	48.75	16.25	38.88 ± 2.63	21.33 ± 2.06	28.31 ± 2.38
			Left-80	27.5	52.50	20	39.01 ± 2.49	21.69 ± 2.06	27.99 ± 2.55
Present study	2017	Indians	Right-100	51	19	30	35.94 ± 2.30	24.37 ± 2.34	16.62 ± 2.82
			Left-106	49.04	19.82	31.14	35.68 ± 2.14	24.20 ± 2.28	16.14 ± 2.84

in Turkish population[11] while Gamal et al found inverted comma shaped glenoid in 30.88% of Ezyptians. They explained that in the area of the notch glenoid labrum is not fixed to bony margins of glenoid cavity but bridges the notch itself. Such an attachment of glenoid labrum makes the shoulder joint less resistant to dislocating forces, tear and avulsions. This means one third of Eryptian population were prone to the Bankart lesion[8]. We also propose that the oval shaped glenoid are the most stable type as the glenoid labrum is attached all along the borders of glenoid cavity.

In the present study the average superior-inferior (SI) diameter of the right glenoid was 35.94±2.30 mm and the average superior- inferior diameter of the left glenoid was 35.68 ± 2.14 mm. Though the right glenoid value was slightly more than the left, it was not statistically significant. Rajput et al and Kavita et al also measured the SI diameter of right and left side separately and our readings were nearest to the readings of Rajput et al [9,12]. Coskun et al, Von Schroeder et al, and Karelese et al reported higher values of SI diameter than of ours. [11,13,14]. Frutos LR, Taser F et al and Ozer et al measured the SI diameter of the male and female glenoid separately. The average SI diameter of male glenoid are significantly higher than that reported in our present study. The average SI diameter of the female glenoid measured by these authors was 31.17 ± 0.17 mm, 34.1±2.9 mm and 33.79 ± 3.08 mm respectively which are close the present study [15,16,17]. As the sex of scapulae was not known to us, we could not measure male and female scapula separately.

In the our study the average anterior- posterior 1 (AP 1) diameter of the right glenoid was 24.37± 2.34 mm and the average anterior- posterior diameter of the left glenoid was 24.20 ± 2.28 mm. The right glenoid cavity was noted to be broader than the left side. Von Schroeder et al, Coskun et al and Karelese et al noted higher values than those noted by us [11,13,14]. Frutos LR ,Ozer et al and Taser F et al recorded much higher AP 1 diameter for the male glenoids but female glenoid values were found to be very close to that of ours [15,16,17]. Our mean anterior-posterior diameter 2 of the glenoid was also close to the results of kavita et al, mamatha et al and sarwar et al [7,9,12]. Wael Amin NED et al [18] reported very higher and Rajput et al [9] found lower values than ours. The relationship between the glenoid cavity dimension and shape is very crucial in understanding physiologic and pathological luxation of the glenohumeral joint (GHJ). It could be deduced that the higher the difference between the mean glenoid height and mean glenoid width, the lower will be the glenoid index and the narrower the cavity; thus a suggestion of possible GHJ problems.

The combined mean of glenoid cavity index (GCI) in the present study came out to be 67.37 ± 5.80. Polguy et al and Dhindsa et al noted the combined glenoid cavity index to be 72.35±5.55 and 69.48±4.22

respectively [5,19] which were quite higher than our observations. As the glenoid index is in the proportionate relationship between the glenoid height and glenoid width, it becomes very significant in understanding the morphometric role of glenoid cavity in shoulder joint stability.

In the present study, values of glenoid version angle ranges from - 14.58 ° to +4.36° and the retroversion angle found to be more on the right side than on left. Similar to our results, Cyprien et al also reported increased retroversion towards the right side [20]. As the prevalence of right handedness is more and excessive wear and tear also depends on the handedness, retroversion angle is expected to be more on the right side than on left as in our study [21]. Biomechanical studies have linked glenoid version with subluxation of the humeral head. Churchill et al reported that the glenoids from white patients were significantly more retroverted than those from black [6]. The glenoid version angle is increased in pathological conditions like osteoarthritis, rheumatoid arthritis and dislocations. Hoenecke demonstrated that in majority of osteoarthritic patients the maximum wear and tear lies posteriorly in the 8'o clock and 9'o clock position due to increased glenoid retroversion [21]. Scalise reported more than twice an increase in the version angle in arthritic group compared to normal [22]. We suggest that the racial and sexual differences can interfere in the development of bone projections, providing morphological and morphometric alterations. The differences in the retroversion angle in different studies can be attributed to the different methodologies and population.

These days shoulder arthritis presents a unique challenge to the orthopedic surgeon. Due to the complex anatomy of the concerned region it is relevant to understand the dimensions of the screw and implants to be utilized. The specimens used in present study were non-arthritic which mean that the average glenoid diameter in an arthritic glenoid would be lesser due to bone loss. Moreover, the diameter would further decrease following reaming of the glenoid.

LIMITATIONS

The bones were not separated based on sex and age. The version angle of dry ones cannot be directly extrapolated for live glenoid and humeral torsion angle also contributes for the gleno-humeral instability which has not been taken for our study.

CONCLUSION

The knowledge about the different shapes and dimensions of glenoid cavity could be useful during evaluation and management of defects and lesions of glenoid. The present study may be helpful to biomechanical engineers and orthopedic surgeons during designing and fitting the implants for total shoulder arthroplasty.

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