A study on the morphometric analysis of glenoid cavity of scapula using a polymerizing acrylic mould

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SUMMARY

The shoulder joint is the most commonly dislocated joint in the body. Several conditions can cause shoulder disability, like avascular necrosis, rotator cuff tear, or fractures. Therefore, patients are advised to consider shoulder joint replacement surgery as a long-term remedy. Glenoid component loosening is a long-term complication seen in arthroplasty. Biomechanics of the reconstructed glenohumeral joint need a better understanding, so that the reason behind glenoid component loosening can be identified. The goal of this study is to record and analyze the various parameters using a mould. In this study, 106 scapulae with intact glenoid were included in the study. Acrylic moulds were measured with a vernier caliper.

The values were found to be symmetrical with respect to the right and left sides. New parameters which were studied include the thickness of the mould. The mean values at T1, T2, T3 were 2.95±0.75 mm, 2.67±0.74 mm, 2.26±0.55 mm respectively. The statistical significance was observed with the parameters. P-value was 0.002, 0.001 and 0.001 between Surface area - AP1, SI - AP and AP1 - T1 respectively. The dimensions which were from a mould give an added information about the depth of glenoid component, used for total shoulder arthroplasty.

Key words: Glenoid cavity – Acrylic mould – Surface area – Diameters – Arthroplasty

INTRODUCTION

The shoulder joint has more mobility at the cost of stability (Blache et al., 2017). The glenoid cavity is the main component in the formation of the shoulder joint. Its shallowness allows for movements in all axes (Sandstrom et al., 2015). The glenoid labrum increases its depth to a certain degree (Almajed et al., 2021). Several conditions can cause shoulder disability like avascular necrosis, rotator cuff tear, or fractures, and patients are advised to consider shoulder joint replacement surgery as a long-term remedy (Orfaly et al., 2007). The morphology of the glenoid cavity is highly variable. The shape of the cavity, if we consider previous studies,can be classified into oval, pear-shaped, and inverted-comma-

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shaped (Mamatha et al., 2011). Alignment of the humerus and the glenoid articular surfaces is one of the predisposing factors for glenohumeral joint instability, which is one of the predisposing factors for rotator cuff pathology (Brewer et al., 1986). Diversified shapes of the glenoid cavity have been described with respect to the notched anterior glenoid rim (Prescher and Klumpen, 1997). The presence of a notch defines the shape of the glenoid cavity. The depth of the notch increases from oval to inverted-comma shape. 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 (Prescher and Klumpen, 1997). Variations in the dimensions of various parameters of the glenoid cavity have been studied before. The surface area and depth of the cavity in dry scapula are the new metrics evaluated to obtain further knowledge that could be of use for the surgeons in total shoulder arthroplasty (TSA).

In 1972, Neer used a single glenoid component size, which was completely made of polyethylene, during the first TSA cases (Neer, 1974). The present study designs a new method in acquiring morphometric data with the help of a glenoid mould. The mould gives much more insight on the dimensions of the prosthesis, which involves giving more depth by inclusion of parameters and helps improve efficacy in shoulder arthroplasty.

MATERIALS AND METHODS

The study was carried out in 106 dry scapulae of unknown age and sex. Side was determined, 52 belonging to the right and 54 belonging to the left glenoid. Only fully developed dry glenoid cavities without porosities were selected for the morphometric analysis. Moulding material (Dental products of India, Mumbai, India), an acrylic repair material used in dentistry, was taken along with cold mould seal. Sliding calipers were used for measurements.

The surface of the glenoid cavity was cleaned and dried. The mould material was added on the glenoid cavity and allowed to solidify. The solid moulds were removed from the glenoid cavity for analysis using vernier caliper. Parameters used for the analysis were:

Shape of the glenoid cavity: the shape of the cavity was taken with pencil tracing in white paper. Three different shapes based on the tracings were obtained. They were classified as a) oval shape, b) pear shape, and c) inverted-comma shape (Fig. 1).

Superoi diameter (SI): this was measured between the points A and B, extending from the highest point in the superior margin to the lowest point in the inferior margin of the glenoid cavity (Fig. 2).

Antero-posterior diameter (AP1): this was measured between the points C and D, extending from the anterior glenoid margin to the posterior glenoid margin. The line segment CD represents the maximum breadth of the glenoid cavity.

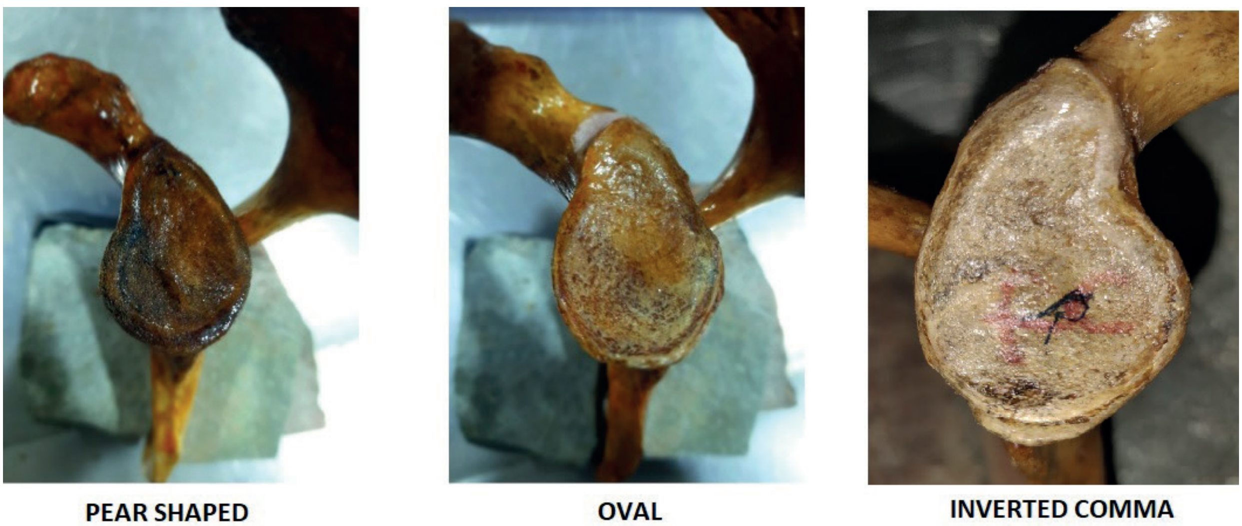

Fig. 1.- Shape of glenoid cavity. Shapes classified as a) Pear shape b) oval shape c) Inverted comma shape.

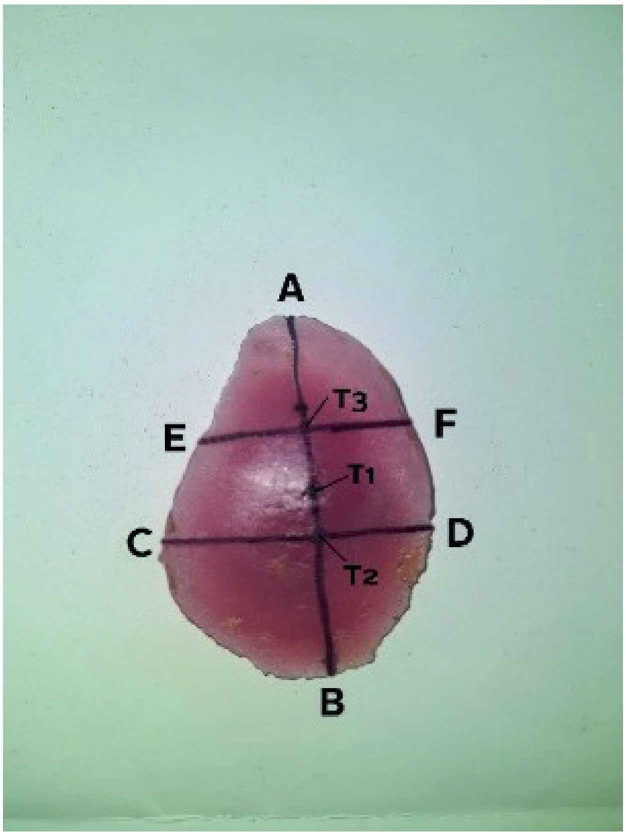

Fig. 2.- Diameters of glenoid mould. AB – Supero-Inferior diameter (SI). CD - Antero Posterior diameter (AP1). EF - Antero Posterior diameter (AP2). T1 – Thickness at midpoint between the points A and B. T2 - Thickness at midpoint between the points C and D. T3- Thickness at midpoint between the points E and F.

Antero-posterior diameter (AP2): this was measured between the points E and F, a horizontal line drawn at the midpoint between the points A and T1.

Surface area: outline tracing of the cavity was taken in graph sheet and measured in cm^2.

Thickness (T1): the thickness of the mould was measured at the midpoint taken between the points A and B, which corresponds to the mid-equator of the glenoid.

Thickness (T2): the thickness of the mould was measured at the midpoint taken between the line segment CD intersecting the line segment AB.

Thickness (T3): the thickness of the mould was measured at the midpoint taken between the line segment EF intersecting the line segment AB.

All measurements were made using a vernier caliper and the unit of measurement was millimeter. IBM SPSS software was used in order to find any statistical significance. The parameters were analyzed using unpaired sample t-test.

RESULTS

In the study which included 106 dry scapula the various metrics were tabulated with respect to side.

Supero-inferior (SI) and AP1 diameter presented symmetry in values of right and left glenoid. The right glenoid diameter in AP 2 was slightly higher than the left (Table 1).

Table 1. Comparison of diameters between the sides.

Sl. No	Ob-serva-tion	SI diameter (mm)		AP1 diameter (mm)		AP2 diameter (mm)	
		Right	Left	Right	Left	Right	Left
1	Range	27.3 to 36	27.1 to 36.3	17.3 to 28.4	18.5 to 28	12.3 to 20.5	11.9 to 18.9
2	Mean ±SD	31.65 ±2.32	31.78 ±2.56	22.91 ±2.86	22.99 ±2.48	16.10 ±2.11	15.69 ±1.62

Thickness at T1 and T2 presented the right-side marginally higher than the left-side values. In T3, the left side was slightly thicker than the right (Table 2).

Table 2. Comparison of thickness between the sides.

Sl. No	Ob-serva-tion	T1 (mm)		T2 (mm)		T3 (mm)	
		Right	Left	Right	Left	Right	Left
1	Range	1.5 to 4.3	1.4 to 5.1	1.4 to 4.3	1.8 to 4.6	1.1 to 3.5	1.2 to 3.3
2	Mean ±SD	2.90 ±0.79	2.99 ±0.76	2.64 ±0.76	2.70 ±0.73	2.33 ±0.62	2.23 ±0.47

The mean of the surface area of the right glenoid was 6.56±1.13 cm^2, and the left glenoid was 6.76±1.23 cm^2, which showed left dominance (Table 3).

Table 3. Comparison of surface area between the sides.

Sl.No	Observation	Right (cm^2)	Left (cm^2)
1	Range	3.5 to 8.5	4.5 to 9.5
2	Mean±SD	6.56±1.13	6.76±1.23

Out of 18 inverted-comma-shaped glenoids, 8 belonged to the right and 10 to the left side. In 58 pear-shaped glenoids, 30 were right and 28 were left. Oval shape was found in 14 right and 15 left glenoids (Table 4).

Table 4. Comparison of shapes between the sides.

Number of bones	Shape of glenoid	Incidence of shape	Right	Left
18	Inverted comma	16.98%	7.55%	9.43%
58	Pear	54.72%	28.30%	26.42%
30	Oval	28.30%	13.21%	15.09%

The shape and thickness were evaluated for statistical significance using IBM-SPSS software. P ≤ 0.05 was considered statistically significant. Confidence interval for the difference in means was 95%.

In Pearson correlation, statistical correlation was not found between sides and diameters. The correlation between other values reported significance at various levels: p-value was 0.002 between surface area and AP1, 0.001 between SI and AP1, 0.001 between AP1 and T1, and 0.002 between AP1 and T2 levels (Table 5).

Table 5. Statistical correlations between parameters (Table showing p-value and 95% confidence interval between the parameters). *significant at p<0.05

	Side	Surf Area (cm²)	SI	AP1	AP2	T1	T2	T3
Side		0.538	0.841	0.435	0.909	0.679	0.737	0.507
Surf Area (cm²)	0.538		0	0.002	0	0.166	0.187	0.381
SI	0.841	0		0.001*	0	0.133	0.148	0.267
AP1	0.435	0.002*	0.001*		0	0.001*	0.002*	0
AP2	0.909	0	0	0		0.115	0.16	0.127
T1	0.679	0.166	0.133	0.001*	0.115		0	0
T2	0.737	0.187	0.148	0.002*	0.16	0		0
T3	0.507	0.381	0.267	0	0.127	0	0	

Irrespective of shape, significance was found at T1 and T2 with p-values 0.04 and 0.008 respectively (Table 6).

Table 6. Statistical correlations between shape and thickness (95% confidence interval and p-value). *significant at p<0.05

Thickness	T1	T2	T3
Shape	0.04*	0.008*	0.207

DISCUSSION

The study which was carried out with a mould closely resembled a glenoid component used in shoulder arthroplasty. The measurements made in this study differs from other studies in that the glenoid cavity measurements were taken from a mould, whereas various authors did it in dry scapulae, or by radiographic measurements in living subjects. The study included new parameters which were not studied by other authors. The metrics of the present study were compared with those of other studies for differences and similarities.

The present study showed inverted-comma shape in 16.98%, pear shape in 54.72%, and oval shape in 28.30% of all glenoid cavities. In the present study, inverted-comma shape was found in 7,55% of right-sided scapulae and 9,43% of left-sided scapulae presented with inverted-comma shape. None of the studies were close to the results compared to present study. The closest results were registered by El-Din and Ali (2015), which recorded the values at 16.25% on the right and 20% on the left side. Another study similarly close to the present values was done by Neeta Chhabra et al. (2015), which showed 22% on the right and 13% on the left side. Pear shape was predominantly the shape seen in most glenoid cavities. El-Din and Ali (2015), whose study came close to the present study, has reported with 35% on the right and 27.5% on the left side as against 28.30% on the right and 26.42% on the left in our present study. With respect to oval shape, the study by Rajput et al. (2012) reported 16% on the right and 15% on the left; and Neeta Chhabra et al. (2015), with 30.90% on the right and 32.40% on the left side. Our study presented with 13.21% on the right and 15.09% on the left side. The findings in this study were comparatively low. The studies by Prescher et al. (1997) have shown that, when the glenoid notch is distinct, the glenoid labrum is loosely attached at the notch and can be a factor for anterior dislocation. Checroun et al. (2002) demonstrated a mismatch between glenoid and glenoid components regarding their shape. Our results compared the shape and thickness to help understand that shape alone was not the standout factor in glenoid component designing. (Table 7).

Table 7. Comparison of studies (shape of glenoid cavity).

Authors	Total no. of specimens	Pear shaped (%)	Inverted comma shaped (%)	Oval shaped (%)
Mamatha et al.	Right - 98	46	34	20
	Left - 104	43	33	24
Rajput et al.	Right - 43	49	35	16
	Left - 57	46	39	15
El-Din and Ali	Right - 80	35	16.25	48.75
	Left - 80	27.5	20	52.5
Neeta Chhabra et al.	Right - 55	47.28	21.82	30.9
	Left - 71	54.92	12.68	32.4
Present study	Right - 52	28.30%	7.55%	13.21%
	Left - 54	26.42%	9.43%	15.09%

In the present study, the supero-inferior diameter of 31.65±2.32 mm on the right and 31.78±2.56 mm on the left were recorded. The studies which were closest in values were recorded by Mamatha et al. (2011), and Rajput et al. (2012). The mean values in those studies were at 34.76 mm, 33.67 mm on the right side and 34.43 mm, 33.92 mm on the left side respectively. The values in Neeta Chhabra et al. (2015) were 38.46 mm, 39.03 mm on the right and the left sides respectively were much higher compared to the present study. Churchill et al. (2001), Frutos et al. (2002), and Ozer et al. (2006) recorded the diameters based on sex in contrast to the present study, which was based on side. Their mean values stood at 37.5 mm, 36.08 mm, 38.71 mm on the male scapula, and 32.6 mm, 31.7 mm, 33.79 mm on the female scapula respectively (Table 8).

The mean antero-posterior 1 diameter in the present study was 22.91±2.86 mm, 22.99±2.48 mm on the right and the left side respectively. There seems to be no significance in size difference between the right and the left side, as was reported in the present study. Except for Mamatha et al. (2011), other studies reported the right glenoid to be broader in diameter than the left side. The study by Mamatha et al. (2011) was quite close to the present , with values of 23.35 mm on the right and 23.02 mm on the left. The average of both sides was 22.95±2.64 mm, which was quite similar to female glenoids, as reported by Ozer et al. (2006) and Frutos et al. (2002), in which the values were found to be 22.31 mm and 22.72 mm respectively. In the present study, the left-side diameter was quite close to what was found by a study by Rajput et al. (2012), in which the value was 22.92 mm (Table 9).

Table 8. Comparison of studies (supero-inferior diameter).

Authors	Total no. of specimens	Mean SI diameter (mm)
Churchill et al.	Male: 200	37.5
	Female: 144	32.6
Frutos	Male: 65	36.08
	Female: 38	31.7
Ozer et al.	Male: 94	38.71
	Female: 92	33.79
Mamatha et al.	Right: 98	33.67
	Left: 104	33.92
Rajput et al.	Right: 43	34.76
	Left: 57	34.43
Neeta Chhabra et al.	Right - 55	38.46
	Left - 71	39.03
Present study	Right - 52	31.65
	Left - 54	31.78

Table 9. Comparison of studies (antero-posterior 1 diameter).

Authors	Total no. of specimens	Mean AP1 diameter (mm)
Churchill et al.	Male: 200	27.86
	Female: 144	23.6
Frutos	Male: 65	26.3
	Female: 38	22.31
Ozer et al.	Male: 94	27.33
	Female: 92	22.72
Mamatha et al.	Right: 98	23.35
	Left: 104	23.05
Rajput et al.	Right: 43	23.3
	Left: 57	22.92
Neeta Chhabra et al.	Right – 55	25.04
	Left – 71	24.85
Present study	Right – 52	22.91
	Left – 54	22.99

The mean antero-posterior 2 diameter recorded in this study was 16.10±2.11 mm on the right, and 15.69±1.62 mm on the left glenoid. The diameters reported by Mamatha et al. (2011), 16.27 mm and 15.77 mm on the right and left side respectively, were in accordance with the present study. Iannotti et al. (1992) reported a higher diameter of 23.77 mm against the mean diameter of 15.89 mm in our study. The studies carried out by Iannotti et al. (1992) and Churchill et al. (2001) showed that the values recorded were higher than the values in our study, carriedout in Indian scapulae, which is suggestive of difference in diameters among races. In the study by Rajput et al. (2012), with 15.10 mm right and 13.83 mm left glenoid, the right glenoid was broader than the left and the values were comparatively lower than in our study. Kavita et al. (2013) and Neeta Chhabra et al. (2015), with diameters of 16.8 mm (right), 15.77 mm(left) and 18.6 mm (right), 18.70 mm (left), suggested similarities in diameters of glenoid cavity irrespective of sides. Higher number of pear-shaped glenoid is attributed to much lower AP-2 diameter. The data from studies carried out by Mamatha et al. (2011), Rajput et al. (2012), and Neeta Chhabra et al. (2015) coincide with our study (Table 10).

Table 10. Comparison of studies (antero-posterior 2 diameter).

Authors	Total no. of specimens	Mean AP2 diameter (mm)
Iannotti et al.	140	23.77
Mamatha et al.	Right: 98	16.27
	Left: 104	15.77
Rajput et al.	Right: 43	15.1
	Left: 57	13.83
Kavita et al.	Right: 67	16.8
	Left: 62	16.3
Neeta Chhabra et al.	Right - 55	18.7
	Left - 71	18.6
Present Study	Right: 52	16.1
	Left: 54	15.69

The mean thickness at the midpoint between A and B on the right side was 2.90±0.79 mm, and on the left side 2.99±0. 76 mm. The mean thickness at the midpoint between C and D on right side was 2.64±0.76 mm and on left side 2.70±0.73 mm. The mean thickness at the midpoint between C and D on the right side was 2.33±0.62 mm and on the left side 2.23±0.42 mm. As far as we know, this is the first study of its kind to use a cast mould and measure the thickness of it. Previous studies on glenoid component concentrated in the longevity of the implant rather than its shape, size or thickness (Gonzalez et al., 2011).

The thickness of glenoid component plays a major role in giving the shoulder prosthesis its durability (Mamatha et al., 2011). The present study, which was done uniquely in a mould, reports parameters on the thickness of mould at three different points, which could be an aid in designing the glenoid component efficiently and in improving efficacy.

The mean surface area for the right glenoid was 6.56±1.13 cm^2, and for the left glenoid 6.76±1.23 cm^2. Homem et al. (2018) reported perimeter of right glenoid at 6.72 cm^2 and left glenoid at 9.63 cm^2.

Although statistical significance was found between the diameters and surface area in t-tests, it does not relate much in pathological changes altering the glenoid cavity and its rim to a certain degree. The available glenoid component in the market and dimensions of the glenoid cavity have to be taken into consideration in accordance with the demographic conditions (Mamatha et al., 2011). The goal of this study is to give an insight and advantage in designing the glenoid component by devising a replica through a mould.

To summarize, the presence of a glenoid notch was observed in 70% of glenoid cavities, with no difference in values between the sides. Marked symmetry was found in our study when compared to other studies, which had a difference in data between the right and left sides. 3D-imaging and patient specific instrumentation will have to be based on a profound knowledge of glenoid morphology (Zumstein et al., 2014). The most common long-term complication of TSA is glenoid loosening, which accounts for approximately 24% of all TSA complications (Gonzalez et al., 2011). We have devised a dataset with glenoid mould height, width, thickness and surface area.

This study provided new parameters to give an insight on the depth of the glenoid cavity by using a cold mould. The mould, although structurally different from actual glenoid component, provides knowledge for possible restructuring in designing of the glenoid component. A glenoid mould can serve a perfect module to study the component designing, which in turn can help the orthopedicians decide on the size of the component.

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