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The Glenoid and Humeral Head in Shoulder Osteoarthritis: A Comprehensive Review

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ABSTRACT: The key management of glenohumeral osteoarthritis is shoulder arthroplasty which aims to reduce pain and restore full shoulder function: it has increased in recent years. A detailed understanding of the anatomy of the glenoid and humeral head, as well as morphological changes of the glenoid in osteoarthritis, are important factors to consider when deciding on replacement components. This review begins with a brief introduction of the

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glenohumeral joint itself, and then considers the detailed anatomy of the glenoid fossa and humeral head, both of which are reported to have variable morphology. Several studies have been undertaken to assess various parameters, especially of the glenoid fossa including its shape, height, width, and articular surface area, version and inclination, in an attempt to define a standard classification that can be applied to surgical intervention. Nevertheless, no definitive consensus concerning the classification of these morphologies has been forthcoming, hence the need for this review. Following a consideration of these morphologies, the current state of knowledge regarding glenoid deformity in osteoarthritis, as well as its surgical management, is considered.

Key words: anatomy; glenoid; humeral; shoulder; osteoarthritis.

INTRODUCTION

The shoulder (glenohumeral) joint is considered a multiaxial synovial joint of the ball and socket variety (Drake et al., 2005), formed by the articulation between the hemispherical head of the humerus laterally and the shallow glenoid fossa, situated at the superolateral angle of the scapula, medially (Ellis, 2006) (Figure 1). The humeral head is directed medially, superiorly and slightly posteriorly (Soames and Palastanga, 2019). It is approximately two-fifths of a sphere (Moore et al., 2010), with only one-third in contact with the glenoid fossa at any time during movement at the joint. According to Sinnatamby (2006), the ratio between the humeral head and glenoid cavity is 4 to 1. As in all synovial joints, both articular surfaces are covered by hyaline cartilage (Moore et al., 2010). The glenoid fossa is deepened (Drake et al., 2005) and extended (Smith et al., 1983) by the fibrocartilaginous glenoid labrum (Drake et al., 2005). The glenoid labrum is triangular in cross-section: its peripheral aspect is attached to the margin of the glenoid fossa while its inner surface articulates with the humeral head (Smith et al., 1983). The presence of the epiphyseal line, extending between the coracoid process anteriorly and the spine of scapula posteriorly, at the superior part of the glenoid fossa, permits the joint surfaces to change shape during growth (Soames and Palastanga, 2019). Being a multiaxial joint the glenohumeral joint provides a greater extent of movement compared to the hip joint (Drake et al., 2005). Because of this wide range of motion the joint is relatively unstable (Moore et al., 2010): mobility has been achieved at the expense of stability and security (Soames and Palastanga, 2019). Several studies have been undertaken to assess various parameters, especially of the glenoid fossa, including its shape, height, width, articular surface area, version and inclination, in an attempt to define a standard classification that can be applied to surgical intervention. Nevertheless, no definitive consensus concerning the classification of these morphologies has been forthcoming. Therefore, the aim of this review is to report (1) the detailed anatomy of the glenoid fossa and the humeral head, and (2) the glenoid deformity in osteoarthritis, as well as considering its surgical management.

Glenoid fossa

The glenoid fossa is variable in shape: it has been defined as a pear-shaped cavity (Rogers, 1992; Snell, 1995; Hassanein, 2015; Sinha et al., 2018; Vardhan et al., 2019; Singh et al., 2019; Soames and Palastanga, 2019) which faces anterolaterally and slightly superiorly (Hall-Craggs, 1990; Sinnatamby, 2006; Moore et al., 2011; Soames and Palastanga, 2019; Singh et al., 2019); an oval, shallow slightly concave cavity, also known as the head of the scapula (Moore et al., 2011; Hassanein, 2015; Singh et al., 2019; Vardhan et al., 2019); and a comma-shaped, shallow glenoid cavity (Drake et al., 2005; Hassanein, 2015; Singh et al., 2019; Vardhan et al., 2019) (Figure 1). The superior region of the glenoid cavity is well-defined, where as the inferior region of the glenoid cavity is irregular, shallow and concave vertically and horizontally (Soames and Palastanga, 2019). The margins of the glenoid cavity are more ambiguous due to the attachment of the glenoid labrum (Sinnatamby, 2006). Superiorly, the glenoid cavity is bounded by the supraglenoid tubercle (Hall-Craggs, 1990; Rogers, 1992; Drake et al., 2005) giving attachment to the tendon of the long head of biceps brachii (Drake et al., 2005; Sinnatamby, 2006; Abrahams et al., 2011), and inferiorly by a large triangular infraglenoid tubercle, to which the long head of triceps is attached (Hall-Craggs, 1990; Drake et al., 2005; Abrahams et al., 2011). In comparison, the convexity of the humeral head is greater than the concavity of the glenoid fossa (Soames and Palastanga, 2019).

Shape

The descriptions of glenoid fossa as being ‘pear-shaped’ or ‘comma-shaped’ shape, are due to the presence or absence of a glenoid notch on its anterior margin. Prescher and Klumpen (1997) observed a glenoid notch in 55% of 236 scapulae giving them a pear-shaped appearance, and absent in the remaining 45%, making them oval: no significant sex difference was reported. Sixty five percent of notches were symmetrical bilaterally, with no significant difference between sex; however, there was a significant difference between sex in asymmetrical notches. Chercoun et al. (2002), using 6 glenoid templates observed that the most common shape of the glenod cavity was pear-shaped (71%) then elliptical (29%). Merrill et al. (2009), in a study of 363 human scapulae, suggested that differences in shape were due to a significant difference in glenoid height and width between males and females, with males having a rounded glenoid fossa and females an oval fossa. Earlier, Iannotti et al. (1992) had noted that the transverse diameter of the lower glenoid was greater than that of the upper glenoid, consequently concluding that it was pear-shaped. Rajendra et al. (2016) reported that the glenoid fossa was commonly pear-shaped, which was seen in 56.1% (n=69), followed by an inverted comma shape in 35.0% (n=43), oval shaped in 6.5% (n=11) and triangular in 2.4% (n=3). In contrast, the glenoid was found to be pear-shaped, oval, and an inverted comma in 50% (n=30), 31.66% (n=19) and 18.33% (n=11) of scapulae, respectively (Vardhan et al., 2019), whereas, Sahana et al. (2018) observed that the glenoid was pear-shaped in 52.8% (n=38), an inverted comma shape in 29.2% (n=21) and oval in 18% (n=13). In contrast, Singh et al. (2019) reported that 44% (n=44) were pear-shaped, 34% (n=34) were oval and 22% (n=22) were inverted comma shaped.

The shape of the lower glenoid has been investigated suggesting that it is circular; however, a difference in the percentage of circular and non-circular fossae has been reported. Aigner et al. (2004) observed that 50% (n=10) were circular, while in the remaining 50% (n=10) the inner margin of the glenoid labrum was circular and the fossa was oval. In the same year De Wilde et al. (2004) reported that the inferior quadrants of the glenoid fossa were circular with an average radius of 14.7 mm (range 12 – 18 mm) to the peripheral articular rim. Later Huysmans et al. (2006), in an investigation of 40 scapulae with no sign of wear and tear or reference to sex or race, found that in 39 scapulae the inferior glenoid was circular with a diameter of 24.7 ± 2.1 mm to the glenoid cartilage rim, and 30.5 ± 2.6 mm to the bony rim. However, in an assessment of 90 patient shoulders, Jeske et al. (2009) observed that the inferior glenoid was circular in all shoulders, with no significant difference in shape between the sexes, but with males being on average 3.6 mm larger in diameter than females.

Notch

Prescher and Klumpen (1997) have suggested that the tendon of subscapularis as it passes anterior to the glenoid cavity could cause atrophic pressure on the bone, leading to the formation of a glenoid notch. Merrill et al. (2009) observed the presence of a notch in 80.4% (n=148) of female and 57.6% (n=184) of male scapulae. Consequently, they suggested a classification system based on the type of glenoid notch present: in type I the notch is curved, being the most common type in both sexes (52.2% females, 46.2% males); in type II the notch is notched (26% females, 10.3% males); in type III it is scalloped (2.2% females, 1.1% males). Merrill et al. (2009) also highlight that the location of the notch differs between females and males, with the average width of the glenoid fossa at the level of the glenoid notch for males and females being 17.6 mm and 19.7 mm, respectively. Recently, Alashkham et al. (2017) developed a new classification system for assessing the glenoid notch based on its severity: mild (type I) was observed in 34% (n=48), moderate (type II) was observed in 28% (n=39), and severe (type III) was present in 38% (n=53): glenoid notch type was significantly associated with sex, with females being significantly more likely to have type I or II , while males were significantly more likely to have type III (Figure 2).

Height and Width

Glenoid height is taken as the distance between the most superior and inferior points on the glenoid fossa (Rajendra et al., 2016; Vardhan et al., 2019). Based on sex, side, and method of determination mean glenoid height varies (Table 1). It has been observed to be greater in males than females, with the difference being significant in some studies (Mallon et al., 1992; Churchill et al., 2001; Chercoun et al., 2002; Merrill et al., 2009; Alashkham et al., 2016), but not others (Iannotti et al., 1992; Bicknell et al., 2007). No difference in height between different races has been reported (Churchill et al., 2001; Merrill et al., 2009), with Bicknell et al. (2007) also reporting no difference in individuals with osteoarthritis. In contrast, Misir et al. (2019) observed a significant difference between right and left glenoid height.

In an assessment of 12 scapulae, with measurements taken directly from bone and from 3D CT scans Kwon et al. (2005) observed that direct measurements were smaller than those from 3D CT scans, with a confidence limit of < 2.12 mm. These authors therefore propose that glenoid fossa measurements using 3D CT scans are accurate, and could be used in preoperative evaluation of the glenoid fossa.

Glenoid width is the distance between the most anterior and posterior points on the glenoid fossa (Rajendra et al., 2016; Vardhan et al., 2019). Based on sex, side and method of determination, mean glenoid width has been shown to vary (Table 2). Not surprisingly, mean width of the lower half of the fossa is greater than that of the upper half, with a ratio of 1: 0.80

± 0.01 (Iannotti et al., 1992). Significant differences in width between sexes has been reported by Mallon et al. (1992), Churchill et al. (2001, 2002), and Merrill et al. (2009); however, no difference was observed between races by Churchill et al. (2001) and Merrill et al., (2009). De Wilde et al. (2004) reported a correlation between glenoid length and width (r = 0.77). In contrast, Misir et al. (2019) have reported a significant difference between right and left glenoids regarding width. However, unlike the findings with respect to glenoid height, Kwon et al. (2005) observed that direct measurement from bone resulted in larger widths than did measurements taken from 3D CT scans: nevertheless, they reiterate that the accuracy of measurement from 3D CT scans is reliable.

Table 1 placement

Table 2 placement

Surface area and Volume

The mean surface area of the inferior glenoid has been reported as being 32.0 ± 0.6 mm^2 (Jeske et al., 2009), with the mean diameter of the glenoid cavity being greater in males than in females, being 29.8 ± 2 mm and 26.2 ± 2 mm, respectively. These authors also reported an appreciable size difference (1.8% ± 1.9%) between right and left sides in inferior glenoid surface areas in the same individual. The surface area of the articular surface (hyaline cartilage) of the whole glenoid fossa is 60.3 mm^2 (range 44.7 – 86.0 mm^2), with a mean circumference of 91.2 mm^2 (range 78 – 108 mm^2) (Aigner et al., 2004). Using 3D CT scans, Kwon et al. (2005) reported similar mean surface areas of 87 ± 27 mm^2 (range 70 – 142 mm^2). However, Soslowsky et al. (1992), in an evaluation of 32 cadaveric shoulders, earlier reported smaller mean articular surface areas in both males and females, 57.9 ± 16.9 mm^2 and 46.8 ± 9.3 mm^2 respectively. In contrast, Misir et al. (2019) reported that the overall glenoid surface area in males and females were 959.4 mm^2 (range 570.6 – 1316.3 mm^2) and 759.6 mm^2 (range 580.6 – 910.2 mm^2) respectively, with a significant difference between sides being observed.

In assessments of the volume and morphology of the glenoid vault, 3D CT scans give a volume varying from 71 to 216 mm^3, depending on the size of the scapula. Kwon et al. (2005) reported a significant, but consistent, difference between glenoid surface area and the glenoid vault, with a mean difference of 14 mm^3. In an assessment of glenoid vault morphology, its shape was found to be rectangular in coronal section and triangular in transverse section (Bicknell et al., 2007). Furthermore, Codsi et al. (2008), in a study of 61 scapulae using 3D CT scans, observed that the shape of the glenoid vault was triangular in all cases, leading them to suggest 5 sizes of implant that would fit any scapula. Furthermore, the range of surface areas of the triangular glenoid vault varied between 140.8 – 221.7 mm^2 (Codsi et al., 2008).

Version

Glenoid version is defined as the orientation of the axis of the glenoid articular surface to the transverse axis of the scapula (Misir et al., 2019). A number of studies have reported the version to be posterior (retroversion), however the degree of retroversion is variable (Table 3). Glenoid morphology has been classified into three types by Walch et al. (1999): type A (59%, n=49), with a mean retroversion of 11.5° in which the humeral head is centrally placed; type B (32%, n=18), with a mean retroversion of 18° in which the humeral head is posteriorly subluxated; and type C (9%, n=10), with a mean glenoid retroversion of 35° in which the humeral head is either centrally placed or posteriorly subluxated. Couteau et al. (2000) also classified patients into three groups: group A (33.3%, n=4), who had a mild rotator cuff tear, in which glenoid retroversion was 17° (range 12 – 22°); group B (50%, n=6), who had primary osteoarthritis, in which retroversion was 27° (range 4 – 48°); and group C (16.7%, n=2,) who had rheumatoid arthritis, in which reroversion was 31° (range 25° – 31°). In a later study, Couteau et al. (2001) concluded that version was more specific regarding age and sex, again classifying patients into three groups. Group A (15 patients) had a mild rotator cuff tear and glenoid retroversion of 8° (range 2° – 17°); group B (13 patients) had primary osteoarthritis and retroversion of 16° (range 0.2° – 50°); and group C (4 patients) had rheumatoid arthritis and retroversion of 15° (range 6° – 22°). Churchill et al. (2001) used two methods to determine glenoid version: one method used the transverse axis of the scapula, while the second placed the scapula in the coronal plane, with version measured perpendicular to the glenoid inclination. Although a difference in retroversion was observed between races, no difference between males and females of the same race were observed. Nyffeler et al. (2003) reported significant differences (6.5°, range 0° – 21°) between version measured from CT scans and from conventional radiographs, leading them to conclude that measurements of glenoid version from standard axillary radiographs, either pre- or post-operatively, are not reliable and that CT scans should be used. Kwon et al. (2005) also reported that measurements of glenoid version from 3D CT scans were slightly smaller than direct scapula measurement: however, there was no significant difference between the two sets of measurements. More recently, Rouleau et al. (2010) assessed glenoid version in symptomatic patients using both the Friedman method and the scapular body method. The Friedman method uses a line drawn between the anterior and posterior glenoid margins, with the transverse axis of the scapula evaluated by drawing a line from the mid-glenoid fossa to the medial margin of the scapula: neutral version is when the transverse axis line is perpendicular to the anteroposterior line of the glenoid margin. In the scapula body method, the angle of version is the complementary angle between the transverse axis of the scapula and the anteroposterior line of the glenoid margin: in retroversion, the posterior margin of the glenoid fossa is medial to the anteroposterior line of the glenoid margin, while in anteversion, the anterior margin is medial. The authors reported that mean glenoid version using the scapula body axis was significantly smaller than using the Friedman method. Despite the reliability of both methods, Rouleau et al. (2010) suggest that using the Friedman method is easier in individuals with curved scapulae for all glenoid types. In all of the above studies it is assumed that degree of glenoid version is the same throughout the glenoid. That this is not the case is proven by Lewis and Armstrong (2011), who reported that the superior part of the glenoid fossa is more retroverted than the inferior part by as much as 5.5°.

Earlier, Monk et al. (2001) reported that more than one angle of version is associated with each glenoid fossa: at the equatorial line (mid-glenoid anteroposterior line) the fossa could be either retroverted or anteverted, with a range of 8.3°: the mean difference between the superior and inferior aspects of the fossa was 11.2°. As a result, they conclude that the superior glenoid fossa is retroverted while the inferior is anteverted. This could account for the loosening of glenoid components in both total and hemi shoulder arthroplasty as the component rocks between retro- and ante-version. Misir et al. (2019) have also observed that the glenoid version is significantly different between right and left sides.

Table 3 placement

Inclination

Inclination of the glenoid fossa is described as tilting of the articular surface about the transverse axis of the scapula (Misir et al., 2019). Churchill et al. (2001) reported a mean glenoid inclination for males and females of 4° superiorly (range 7° inferiorly, 15.8° superiorly) and 4.5° superiorly (range 1.5° inferiorly to 15.3° superiorly), respectively. They also noted that the angle of inclination varied significantly between race and sex: mean glenoid inclination of their combined (i.e. men and women) black and combined white patients was 3.9° and 4.6° superiorly respectively, while for the white men and women, it was 4.4° and 5.3° superiorly respectively, and for the black men and women, it was 3.6° and 4.2° superiorly respectively. It has been suggested that superior inclination of the glenoid cavity is a predisposing factor for rotator cuff pathogenesis (Wong et al., 2003), with Konrad et al. (2006) stating that a decrease in superior inclination results in a significant reduction in superior movement of the humeral head against the glenoid fossa, therefore decreasing the risk of a rotator cuff tear. Using 3D CT scans of the inferior glenoid plane, De Wilde et al. (2010) reported a difference in inclination between females (mean 22.3^0) and males (mean 20.3^0). In contrast, Misir et al. (2019) observed the overall glenoid inclination in males and females to be 6.8° ± 4.6° and 7.5° ± 3.9°, with no significant difference between side and sex. Bishop et al. (2009) observed no significant association between increasing glenoid inclination and superior-inferior translation at the glenohumeral joint, concluding that superior inclination is not correlated with superior humeral translation, thereby enhancing subacromial impingement. These authors also observed a difference in glenoid inclination between surgically repaired rotator cuff tears and contralateral shoulders.

Bare area of the glenoid cavity and the Tubercle of Assaki

There is some controversy over the definition of the bare area and the Tubercle of Assaki. The bare area is defined as thinning of the central area of the hyaline cartilage of the glenoid cavity (Kim, 2009). However, it is also considered to be a focal centrally located cartilaginous defect of the glenoid cavity considered to be a normal variation in adults (Ly et al., 2004).

An Assaki Tubercle is defined as a thinning of the middle of the articular cartilage and thickening of the subchondral bone (Al–Mulhim, 2013), located in the centre of the inferior glenoid cavity (Burkhart et al., 2002). However, according to Warner et al. (1998) the Tubercle of Assaki is the thickest region of subchondral bone of the glenoid fossa due to constraint of the humeral head against the articular surface. Others have reported the Tubercle of Assaki to be the bare area of the glenoid labrum (Paturet, 1951, cited in De Wilde et al., 2004). The bare area of the glenoid was named the ‘Tubercle of Assaki’ by Lugo et al. (2008). In 2002 the bare area was considered to be a constant reference point when evaluating the amount of anterior bone loss from the glenoid rim (Burkhart et al., 2002).

The number of specimens showing a bare area, which is known as a bare spot in the literature, has been observed to be as high as 88% in adults (Resnick et al., 2007). In contrast, the incidence of the bare spot, assessed by MRI, in children is very low: children up to 10 years had no evidence of a bare area, while a small number of those aged 11 to 20 years showed either central or eccentric bare spots in the inferior glenoid cavity (Kim et al., 2010). A shoulder MRI of a 14-year old boy after a football injury showed a bare spot at the centre of the glenoid (Kim, 2009), while another MRI on a 14-year old with a traumatized shoulder revealed a 4 mm central area of hyaline cartilage loss of the glenoid fossa (diagnosed as glenoid bare spot) without changes in the subchondral bone (Gagliardi and Carino, 2013). No bare spots were observed in 51 foetal shoulders (Fealy et al., 2000).

The bare spot in glenohumeral joints appears to be constant, but variable in shape, and mostly present in an eccentric position within the inferior glenoid cavity (Aigner et al., 2004; Alashkham et al., 2017; Hachem et al., 2019). This constant appearance is assumed to be the result of the distribution of hyaline cartilage in the glenoid cavity, therefore it cannot be taken as a marker for operative measurement (Aigner et al., 2004). De Wilde et al. (2004) support this statement in determining the correlation between the bare spot and Tubercle of Assaki. They reported that the Tubercle of Assaki was round to oval in shape with an average diameter of 6 mm: in 98.9% (n=97) of specimens where the centre of the inferior glenoid was in the anterosuperior quadrant of the surface area of Assaki's Tubercle. However, Huysmans et al. (2006) observed a bare spot in 87.5% (n=35) of scapulae examined, all of which were located in the centre of the inferior glenoid: no significant difference between the measurement from the bare spot to the anterior, inferior or posterior cartilage rim or bony rim was observed. This suggests that the bare spot is the centre of both the articular surface of the inferior glenoid and the bony inferior glenoid except for a small difference to the inferior bony rim. Recently, Alashkham et al. (2017) observed the bare spot in 80.7% (n=113) of shoulders, being more common in males than females, with an overall mean length and width of 7.2 mm and 6.2 mm respectively.

In an analysis of the distribution of mineralization in the subchondral bone of 28 shoulder joints of throwing athletes using CT osteoabsorptiometry, the glenoid labrum was divided into one central and 6 peripheral areas: the mechanical stress was found to affect the peripheral regions (anterior, anteroinferior, posterior and posteroinferior) more than the central region (Mochizuki et al., 2005). However, in an assessment of 44 shoulders by CT osteoabsorptiometry to evaluate the distribution of mineralization of the subchondral bone plate, Schulz et al. (2002) observed that maximum density localization showed that long-term stress distribution is in the periphery and is often bicentric.

HUMERAL HEAD

The humeral head comprises two-fifths of a sphere, which faces superiorly, medially and posteriorly (Figure 1). Regardless of glenohumeral joint position, only one third of the humeral head is in contact with the articular surface of the glenoid fossa at any time (Soames and Palastanga, 2019). A number of studies have shown that humeral head shape, size, diameter, inclination and version are variable (Figure 3). Retroversion of the humeral head varies markedly, not only between individuals, but also between the right and left sides in the same individual. Depending on factors such methodology, sex, and sport type, retroversion of the humeral head ranges between -2 and 60° (Osbahr et al., 2002; Pearl, 2005; Murachovsky et al., 2007; Thomas et al., 2012; Mastumura et al., 2014; Reagan et al., 2014; West et al., 2017; Oh et al., 2017; West et al., 2018) (Table 4). Humeral and glenoid retroversion are significantly greater on the dominant compared to the non-dominant side, and are also larger in males than females (Mastumura et al., 2014). According to Reagan et al. (2014) there is a significant difference in external and internal rotation between dominant and non-dominant arms in baseball players, which is also significantly correlated with an increase in retroversion of the humeral head. Osbahr et al. (2002) observed that the dominant arms of players all had greater external rotation, less internal rotation and greater retroversion, with the differences being significant between dominant and non-dominant arms. Furthermore, in the dominant arm the correlation between retroversion and external rotation was significant. Murachovsky et al. (2007), in a study of handball players, reported a significant difference in retroversion between dominant and non-dominant arms, being larger on the dominant side. A linear relationship was also noted between increasing retroversion and increasing external rotation. Thomas et al. (2012) also reported that the dominant arm was significantly more retroverted than the non-dominant arm, with a negative relationship between humeral retroversion and humeral head internal rotation being reported. In a cadaveric study using a surface laser scanner, Harrold and Wigderowitz (2012) reported that, depending of the level of the plane of the measurement, the angle of retroversion was variable, and increased moving superiorly (22.5° ± 11.9°), and decreased moving inferiorly (14.3° ± 9.4°). The mean retroversion of the head of the humerus at its midpoint, i.e. between the inferior and superior margins, was 18.6°: the authors consequently suggest that the articular cartilage is not circular. Investigating 60 patients with severe osteoarthritis using 3D CT imaging, Sabesan et al. (2014) reported that the relationships between the centre of the humerus and glenoid retroversion with respect to its relation to the scapular central line was strong and linear; however, no strong correlation was observed in the relation between humeral head alignment to the glenoid plane. Mean humeral scapular alignment was - 2.3%.

According to Harrold and Wigderowitz (2012) the diameter of the articular surface of the humerus is 23.9 ± 1.4mm; however, Boileau and Walch (1997) report values ranging between 37.1 mm and 56.9 mm (mean 46.2 mm), with the articular surface diameter ranging from 36.5 mm to 51.7 mm (mean 43.3 mm). Milner et al. (2012) gave mean humeral head diameter in males as 49 mm and females 42.1 mm. Mean humeral head retroversion through the trans-epicondylar axis was 17.9° and through the tangent elbow axis 21.5° (Boileau and Walch, 1997). Inclination of the articular humeral head in relation to the humeral shaft ranged from 30° to 55° (Pearl, 2005), while Boileau and Walch (1997) report a range of 123.2° to 135.8° (mean 129.6°).

Table 4 placement

GLENOID DEFORMITY IN OSTEOARTHRITIS AND ITS SURGICAL MANAGEMENT

Glenohumeral arthritis is the sequela of variable pathological shoulder processes, with primary glenohumeral osteoarthritis being the most common, but could also be secondary to post-traumatic arthritis, inflammatory arthritis and rotator cuff tear arthropathy. Patients with glenohumeral arthritis commonly show patterns of humeral and glenoid bone wear, with the erosion and deformity being caused by the etiology of the arthritis (Neer 1974; Darrow et al., 2019; Grogan and Jobin, 2019). The magnitude of degenerative arthritis of the glenoid vary considerably and is based on the type of the arthritic process affecting the glenohumeral joint (Walch et al., 1988; Cofield, 2007; Matsen et al., 2007; Ansok and Muh, 2018).

Primary glenohumeral osteoarthritis commonly causes posterior glenoid wear, secondary glenoid retroversion and posterior humeral head subluxation, whereas inflammatory osteoarthritis is occasionally associated with central and symmetric glenoid erosion which could be associated with the existence of glenoid vault cysts (Cofield and Edgerton, 1990; Ansok and Muh, 2018; Grogan and Jobin, 2019). Glenoid involvement, as well as its morphology, have been shown to vary accordingly. Neer (1974, 1988) has reported a frequent posterior subluxation of the humeral head and posterior erosion of the glenoid, whereas, Friedman et al. (1992) and Mullaji et al. (1994) have reported an extensive glenoid retroversion. Walch et al. (1999) classified the glenoid morphological changes in primary osteoarthritis and identified three types (A, B, and C). In type A (59%) the humeral head was centred with balanced distribution of strength against the glenoid surface; in type B (32%) the humeral head subluxated posteriorly with asymmetrical load distribution, and was implicated in the development of primary glenohumeral osteoarthritis; in type C (9%) the glenoid morphology was defined by a retroversion of more than 25°: regardless of glenoid wear the retroversion was dysplastic in origin, thus explaining the early onset of primary osteoarthritis.

Varying degrees of posterior subluxation of the humeral head associated with posterior glenoid erosion is considered to be the most common pattern of presentation in primary glenohumeral osteoarthritis (Cofield, 2007; Matsen et al., 2007). Individuals with posterior glenoid tear were noted to have an internal rotation contracture as their condition progressed, as well as posterior glenohumeral joint instability (Neer et al., 1982; Cofield and Edgerton, 1990; Moeckel et al., 1993; Iannotti et al., 2005).

One option in the treatment of either primary glenohumeral joint osteoarthritis, post-traumatic arthritis or inflammatory arthritis is shoulder arthroplasty, which has been shown to reduce pain and improve joint function significantly (Norris and Iannotti, 2002; Leung et al., 2012; Papadonikoakis et al., 2013; John, 2019; Bell et al., 2020; Sean et al., 2020; Stavrev et al., 2020). The number of shoulder arthroplasty and hemiarthroplasty procedures has increased in the last two decades, with glenohumeral joint osteoarthritis being the primary diagnosis for

43% and 77% of hemiarthroplasties and total shoulder arthroplasties respectively (Kim et al., 2011; Papadonikoakis et al., 2013; Bell et al., 2020; Sean et al., 2020). As the prevalence of shoulder arthroplasty increases, the prevalence of shoulder revision procedures has also dramatically increased (Day et al., 2010; Kim et al., 2011). Apart from the cost of revision surgery there are other potential risks, including poor bone quality and risk of infection, leading to a significant burden on health-care systems. Enhancing the survivorship of shoulder arthroplasty components may decrease this burden.

One of the most challenging issues in the treatment of glenohumeral joint osteoarthritis is glenoid bone loss. In such individuals total shoulder arthroplasty associated with either bone grafting (including the coracoid, distal clavicle, iliac crest and allograft distal tibia), or augmented glenoid component implantation aiming to correct version, or structural bone grafting, or metallic augmentation of the bone deficiency are available treatment options (Sabesan et al., 2014; Rabinowitz et al., 2017; John, 2019; Bell et al., 2020; Sean et al., 2020). Therefore, a thorough history, physical, laboratory and radiographic examination are keys to understanding the etiology of arthritis, as well as any associated secondary humeral and glenoid bone deformity. In addition, understanding the pathoanatomy and pattern of glenoid bone wear will help surgeon not only to formulate a successful treatment plan, but also to improve the durability of shoulder arthroplasty. The evaluation of both humeral and glenoid bone deformity in glenohumeral arthritis has profound clinical implications and is considered to be fundamental for successful shoulder arthroplasty.

Conclusion

Total shoulder arthroplasty is a common treatment for shoulder joint osteroathritis. In addition to the glenoid anatomical variations, one of the most challenging issues for surgeons is glenoid bone loss, causing postoperative pain, limitation of function, and potentially, the need for revision surgery. This article reviewed the current state of knowledge on the anatomy of the glenoid fossa, the humeral head and deformity of the glenoid in osteoarthritis, as well as its surgical management.

CONFLICT OF INTEREST

The author report no conflict of interest

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Figures legends

Figure 1: (A) Coronal section of the shoulder joint showing the articular surfaces, glenoid labrum, fibrous capsule and synovial membrane; (B) Posterior view of the right shoulder joint showing the fibrous capsule; (C) Lateral view of the right shoulder. The humerus has been removed to expose the fibrous capsule and glenoid fossa (Soames R and Palastanga N, 2019)

Figure 2: Lateral view of the right scapula showing the three types of glenoid notch which are mild, moderate and severe (Alashkham et al., 2017)

Figure 3: The angles of inclination (A) and retroversion (B) of the humeral head (Soames and Palastanga N, 2019)

Table 1: Comparison of glenoid height (mm) reported in different studies.

Study	No	Method	Mean length (range) mm
Mallon et al. (1992)	28	Scapulae	M: 38 (43 – 45); F: 36.2 (33 – 45)
Iannotti et al. (1992)	140	Patients and scapulae	39 (30 – 48)
Churchill et al. (2001)	172	Scapulae	M:37.5 (30.4 – 42.6); F:32.6 (29.4 – 37)
Checroun et al. (2002)	412	Scapulae	37.9 (31.2 – 50.1)
De Wilde et al. (2004)	98	Scapulae	35.6
Kwon et al. (2005)	12	Scapulae and 3D CT scans	Scapulae: 37.8 (30 – 47) 3D CT scans: 39.1 (31 – 48)
Bicknell et al. (2007)	72	Scapulae	41 ± 6.1
Codsi et al. (2008)	11	Scapulae	35 (33 – 45)
Merrill et al. (2009)	363	Scapulae	M:37.01; F: 33.83
Rajendra et al. (2016)	123	Scapulae	136.43 (123.12 – 149.74)
Alashkham et al. (2016)	140	Scapulae	38.94 (32.7 – 46.07)
Misir et al. (2019)	200	CT scan	M:39.1 ± 2.5 ; F:34.5 ± 1.8
Vardhan et al. (2019)	60	Scapulae	36.77 ± 3.03

M: males; F: females; No: number

Table 2: Comparison of glenoid width (mm) reported in different studies.

Study	No	Method	Mean length (range)
Mallon et al. (1992)	28	Scapulae	M: 28.3 (24 – 32); F: 23.6 (17 – 27)
Churchill et al. (2001)	172	Scapulae	M: 27.8 (24.3 – 32.5); F: 23.6 (19.7 – 26.3)
Checroun et al. (2002)	412	Scapulae	29.3 (22.6 – 41.5)
De Wilde et al. (2004)	98	Scapulae	25.8
Kwon et al. (2005)	20	Scapulae and 3D CT scans	Scapulae: 26.8 (22 – 35) 3D CT scans: 25.2 (21 – 34)
Bicknell et al. (2007)	72	Scapulae	22.9 ± 4.6
Merrill et al. (2009)	363	Scapulae	M: 28.56; F: 23.67
Rajendra et al. (2016)	123	Scapulae	99.14 (90.93 – 107.35)
Alashkham et al. (2016)	140	Scapulae	30.50 (23.03 – 36.82)
Vardhan et al. (2019)	60	Scapulae	23.93 ± 2.55
Misir et al. (2019)	200	CT scan	M:27.7 ± 2.2 ; F:23.6 ± 1.6

M: males; F: females; No: number

Table 3: Comparison of glenoid retroversion in different studies

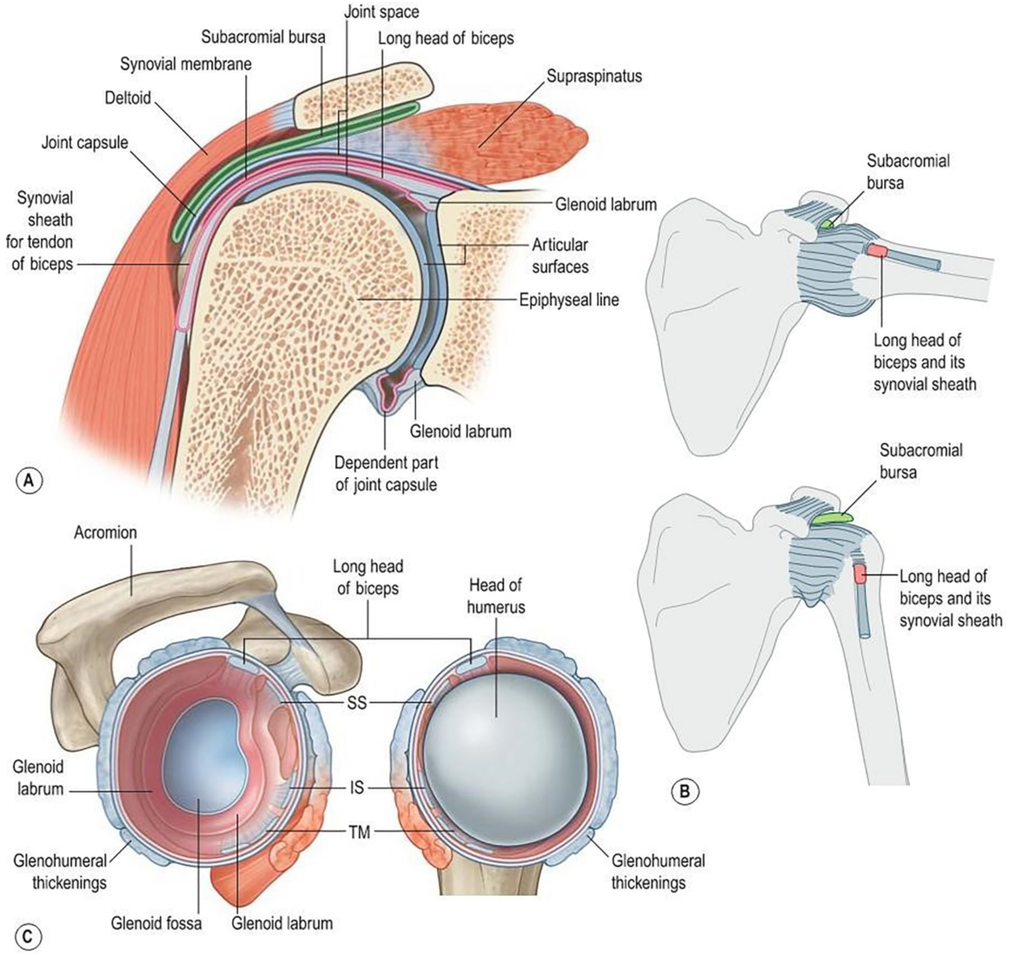
Study	No	Method	Mean retroversion (range) (°)
Mallon et al. (1992)	28	Roentgenogram and CT scan	6° (– 2° ± 13°)
Walch et al. (1999)	113	Friedman method	16° (– 12° to 50°)
Churchill et al. (2001)	172	Transverse axis and coronal plane of the scapula	1.2°
Nyffeler et al. (2003)	25	CT scans	3° (–7° to 16°)
Kown et al. (2005)	12	3D CT scans	1.0° ± 5.4°
Kown et al. (2005)	12	Direct scapula measurement	1.6° ± 5.5°
Rouleau et al. (2010)	116	Scapula body axis	14.8° ± 12.7° (–58.0° to 8.0°)
Rouleau et al. (2010)	116	Friedman method	17.9° ± 12.8° (– 56.0° to 12.0°)
Iannotti et al. (2012)	13	3D surgical simulator	13° (1° – 42°)
Misir et al. (2019)	200	CT scans	M:6.7° ± 3.4° ; F:4.4° ± 3.7°

No: number.

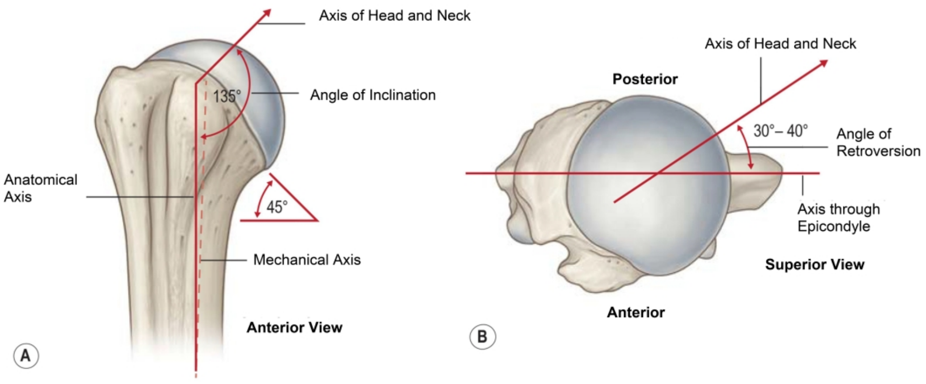
Table 4: Comparison of humeral head version reported in different studies.

Study	No	Method	Retroversion in Dominant	Retroversion in Non-dominant	Relation
Reagan et al. (2014)	54 baseball players	X-ray	36.6°± 9.8°	26° ± 9.4°	P=0.001
Thomas et al. (2012)	24 baseball players	Ultrasound	- 0.3° ± 12.53°	16.13° ± 11.53°	P=0.0001
Osbahr et al. (2002)	19 baseball players	Soderlund technique	33.2° ± 11.4°	23.1° ± 9.1°	P=0.001
Murachovsky et al. (2007)	17 handball players	X-ray	30.59°	27.53°	P=0.018
Mastumura et al. (2014)	270 non-players	CT scan	28° ± 11°	25 °± 11°	P<0.001

No: number.


Joint space
Subacromial bursa
Long head of biceps
Synovial membrane
Supraspinatus
Deltoid
Joint capsule
Synovial sheath for tendon of biceps
Glenoid labrum
Articular surfaces
Epiphyseal line
Glenoid labrum
Dependent part of joint capsule
A
Subacromial bursa
Long head of biceps and its synovial sheath
Subacromial bursa
Long head of biceps and its synovial sheath
B
Acromion
Long head of biceps
Head of humerus
SS
Glenoid labrum
IS
TM
Glenohumeral thickenings
Glenohumeral thickenings
Glenoid fossa
Glenoid labrum
C


Type I
Type II
Type III


Axis of Head and Neck
Angle of Inclination
135°
Anatomical Axis
45°
Mechanical Axis
Anterior View
A
Axis of Head and Neck
Posterior
30°– 40°
Angle of Retroversion
Axis through Epicondyle
Superior View
Anterior
B