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The glenoid in shoulder arthroplasty

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Total shoulder arthroplasty is a common treatment for glenohumeral arthritis. One of the most common failure modes of total shoulder arthroplasty is glenoid loosening, causing postoperative pain, limitation of function, and potentially, the need for revision surgery. The literature has devoted considerable attention to the design of the glenoid component; efforts to better understand the biomechanics of the reconstructed glenohumeral joint and identify factors that contribute to glenoid component loosening are ongoing. This article reviews the current state of knowledge about the glenoid in total shoulder arthroplasty, summarizing the anatomic parameters of the intact glenoid, variations in component design and fixation, the mechanisms of glenoid loosening, the outcomes of revision surgery in the treatment of glenoid component failure, and alternative treatments for younger patients.
Level of evidence: Review Article.

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Since the introduction of humeral head replacement in the 1950s as a treatment for complex proximal humeral fractures, and the subsequent addition of a glenoid resurfacing component, the indications for total shoulder arthroplasty (TSA) have expanded.[51,52,82] Currently, the most common shoulder pathology managed with TSA is glenohumeral osteoarthritis, accounting for approximately 20,000 cases annually in the United States.[61,82] For appropriately selected patients, TSA decreases pain and improves shoulder function.[34,54] In a recent meta-analysis of 23 clinical studies comparing TSA with humeral head replacement for treatment for primary glenohumeral osteoarthritis, Radnay et al[61] reported that TSA resulted in significantly better pain relief, postoperative range of motion, and patient satisfaction, with a lower revision rate compared with hemiarthroplasty.

Current indications for glenoid resurfacing include patients with painful glenohumeral incongruity, adequate glenoid bone stock, and an intact and functioning rotator cuff.[64] Typical pathologies that fit these indications include primary and secondary glenohumeral osteoarthritis and selected patients with inflammatory arthritis. Glenoid resurfacing is contraindicated in patients with irreparable rotator cuff tears and inadequate glenoid bone stock. Active infection, neuropathic arthropathy, and paralysis of the periscapular musculature are contraindications for both hemiarthroplasty and TSA.[64]

Considerable attention has been devoted in the literature to the attributes of the glenoid component. To date, the

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most common middle-term and long-term complication of TSA is glenoid component loosening, causing post-operative pain, limitation of function, and potentially, the need for revision surgery.[76,82,83] Efforts to better understand the biomechanics of the reconstructed glenohumeral joint and identify factors that contribute to glenoid component loosening are ongoing.

This article reviews the current state of knowledge about the glenoid in TSA, summarizing the anatomic parameters of the intact glenoid, variations in component design and fixation, the mechanisms of glenoid loosening, the outcomes of revision surgery in the treatment of glenoid component failure, and alternative treatments for younger patients.

Glenoid anatomy

Anatomic parameters of the glenoid relevant to prosthesis design include glenoid height, width, articular surface area, inclination, vault size and shape, and version (Figure 1). An emphasis will be placed on glenoid version because this has been the focus of numerous recent studies. A number of cadaveric studies have demonstrated considerable natural variability in these parameters; this variability affects prosthesis design, instrumentation, and intraoperative implantation techniques. The reader is reminded, that care should be taken when interpreting and comparing data from multiple studies, because each uses different methodologies that are associated with their own inherent accuracy and precision.

Glenoid height is defined as the distance from the most superior and inferior points on the glenoid. In an evaluation of 412 cadaveric scapulae, Checroun et al[10] reported a mean glenoid height of 37.9 mm (range, 31.2-50.1 mm). In an evaluation of 140 shoulders of patients who were a mean age of 75 years, Iannotti et al[33] reported a mean glenoid height of 39 mm (range, 30-48 mm). In an evaluation of 5 shoulders from donors aged 66 to 84 years old, Sharkey et al[68] reported a mean glenoid height of 35.1 mm (range, 29.9-38.8 mm). In an evaluation of 12 cadaveric scapulae, Kwon et al[40] reported a mean glenoid height of 37.8 mm (range, 30-47 mm). Churchill et al[13] found a gender difference in specimens in an evaluation of 344 cadaveric scapulae, reporting a mean glenoid height of 37.5 mm (range, 30.4-42.6 mm) for men compared with 32.6 mm (range, 29.4-37 mm) for women. There was no difference in glenoid height between specimens from white and black patients. A smaller but similar gender difference in glenoid height was found by Mallon et al[43] in their evaluation of 28 cadaveric scapulae. They reported a mean glenoid height of 38 mm (range, 33-45 mm) for men compared with 36.2 mm (range, 32-43 mm) for women.

Glenoid width is defined as the distance from the most anterior and posterior points on the glenoid. Glenoid width is a function of the overall shape, which has been observed to be more pear-shaped than elliptical or oval. Checroun et al[10] reported that 71% of the 412 glenoids were pear-shaped; the remainder were elliptical. Pear-shaped glenoids have an upper width that is smaller than their lower width. Concerning this point, Iannotti et al[33] reported a mean upper glenoid width of 23 mm (range, 18-30 mm) and a mean lower glenoid width of 29 mm (range, 21-35 mm). Kwon et al[40] reported a mean glenoid width of 26.8 mm (range, 22-35 mm). Churchill et al[13] reported a difference in mean glenoid width of 27.8 mm (range, 24.3-32.5 mm) in male specimens compared with 23.6 mm (range, 19.7-26.3 mm) in female specimens. Once again, there was no difference in glenoid width between specimens from white and black patients. Mallon et al[43] reported a mean glenoid width of 28.3 mm (range, 24-32 mm) in male specimens compared with 23.6 mm (range, 17-27 mm) in female specimens.

As expected by the reported variability in glenoid height and width, glenoid articular surface area is reported with similar variation. In an evaluation of 32 cadaveric scapulae, Soslowsky et al[69] reported a mean articular surface area of 5.79 cm^2 in male specimens and 4.68 cm^2 in female specimens. Kwon et al[40] reported a mean articular surface area of 8.7 cm^2 (range, 7.0-14.2 cm^2).

Glenoid inclination is defined as the slope of the glenoid articular surface along the superior-inferior (SI) axis. Churchill et al[13] reported considerable variability in glenoid inclination. In male specimens, the glenoid was superiorly inclined by 4° (range, 7° inferior-15.8° superior inclination) compared with the glenoid being superiorly inclined by 4.5° in female specimens (range, 1.5° inferior-15.3° superior inclination). White patients tended to have slightly greater glenoid inclinations (mean, 4.6° superior inclination) than black patients (mean, 3.9° superior inclination).

Glenoid vault shape and size has been reported by Codsi et al.[15] They evaluated variations in glenoid vault shape and size from 3-dimensional (3D) computed tomography (CT) reconstructions of 61 cadaveric scapulae. By normalizing the measured glenoid vault geometry relative to the SI glenoid height, they were able to construct a normalized glenoid vault model. A review of this model revealed that the vault is approximately triangular for its entire length in the SI dimension. From this, Codsi et al proposed a family of 5 sizes of triangular implant prototypes that approximate the shape of each assessed scapula.

Glenoid version is defined as the angular orientation of the axis of the glenoid articular surface relative to the long (transverse) axis of the scapula; a posterior angle is denoted as retroversion. Numerous studies have assessed glenoid version in recent years; most cite a normal range varying from 2° anteversion to 9° retroversion and note changes in version in the presence of glenohumeral pathology.[13,26,57,62] Churchill et al[13] reported a mean glenoid retroversion of 1.2° (range, 9.5° anteversion-10.5° retroversion). Glenoids from men tended to be slightly more retroverted than those from women (mean, 1.5° compared with 0.9°, respectively) while those from white patients were significantly more retroverted than those from black (mean, 2.7° compared with 0.2°; $P < .00001$). Mallon et al[43] reported a mean glenoid retroversion of 6° (range, 2° anteversion-13° retroversion).