7 Standard Glenoid Replacement

Jonathan Levy

Introduction

Since the first introduction in 1974, total shoulder arthroplasty (TSA) has become a reliable and reproducible treatment for end-stage arthritis that has failed to respond to nonoperative measures [18, 19, 25, 43, 57]. The utilization of TSA continues to expand at exponential rates with a 319 % increase in TSA procedures between 1993 and 2007 [17]. Analysis of outcomes following shoulder arthroplasty suggests that the addition of a glenoid component improves pain relief and outcomes [24, 47], suggesting significant advantages of TSA over hemiarthroplasty. This observation as resulted in a moderate strength recommendation to perform a total shoulder arthroplasty over a hemiarthroplasty for patients with glenohumeral joint osteoarthritis (AAOS). Nonetheless, glenoid component loosening has been shown to be the most common middle-term and long-term complication of TSA and is one of the most common causes of revision surgery [6, 10, 27, 50, 51, 74, 75]. Glenoid implant loosening has been associated with worse functional outcomes, worse pain, and inferior strength [59, 76]. Improvements in preoperative surgical planning, intraoperative instrumentation, surgical technique, and implant designs have all helped to improve the ability to properly and securely implant a glenoid component which will likely contribute to improved long-term results of total shoulder arthroplasty.

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Glenoid Anatomy

A basic understanding of the variations in glenoid anatomy is critical for optimal utilization of glenoid components. Glenoid height, width, inclination, version, and vault size all play influential roles in surgical planning. Recent literature has shed greater light into the complexities of glenohumeral anatomy in the setting of arthritis.

Glenoid Height

Glenoid height can be measured from the distance from the most superior and inferior points on the glenoid (Fig. 7.1). Checroun et al. [9] reported a mean height of 37.9 mm using an analysis of 412 cadavers, Iannottii et al. [30] reported a mean height of 39 mm using an analysis of 140 shoulders, and Churchill observed an average height of 37.5 mm for men and 32.6 mm for women [11]. Analysis of the glenoid height helps to define glenoid component size during glenoid component

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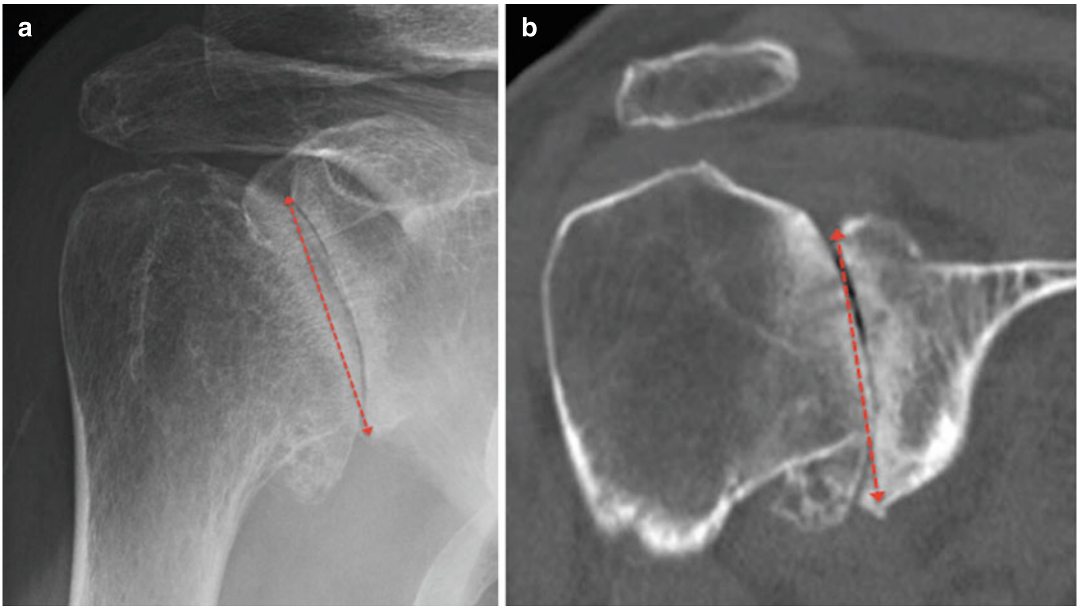

Fig. 7.1 *Glenoid height* – the *double arrows* are intended to outline the measurement of glenoid height on a AP radiograph (**a**) and CT coronal reconstruction (**b**). The *double arrows* in (**a**) seems to have been a bit shortened as it shoulder reach the top of the glenoid

preparation and implantation and is typically performed on coronal reconstruction of CT images.

Glenoid Width

Glenoid width can be measured from the most anterior and posterior points on the glenoid and is often influenced by osteophyte and wear patterns (Fig. 7.2). Variations in glenoid shape (Fig. 7.3) can influence the glenoid width, as pear-shaped and oval-shaped glenoids may have different variations in width. As an illustrative point, Ianottii [30] reported an average upper width of 23 mm and an average lower width of 29 mm. Others have reported averages of glenoid width without taking into consideration differences in shape. Kwon et al. [35] reported an average width of 26.8 mm, and Churchill et al. [11] reported an average width of 27.8 mm. Appreciation of the glenoid width also helps to define glenoid component size, as efforts should be made to prevent excessive overhang of the implant. Accurate measurement is often made difficult, as osteophytes and bone erosion often obscure the identification of the native glenoid limits.

Glenoid Inclination

Glenoid inclination is defined as the slope of the glenoid articular surface measured in the superior to inferior axis and can be measured both on AP radiographs and coronal reconstruction CT images (Fig. 7.4). Maur et al. found the angle between the glenoid fossa line (line from the superior to inferior tip of the glenoid), and the floor of the supraspinatus fossa was most reliable at measuring glenoid inclination [42]. Average inclination can range from 2.2° of inferior tilt to 4.2° of superior tilt with reported ranges from 12° of inferior tilt to 15° degrees of superior tilt [46]. Churchill et al. [11] found male patients to have an average of 4° of inferior tilt, whereas females had an average superior tilt of 4.5°. The observed range of inclination varied between 7° of inferior tilt to 15.8° of superior tilt. Appreciation of the glenoid inclination becomes important during

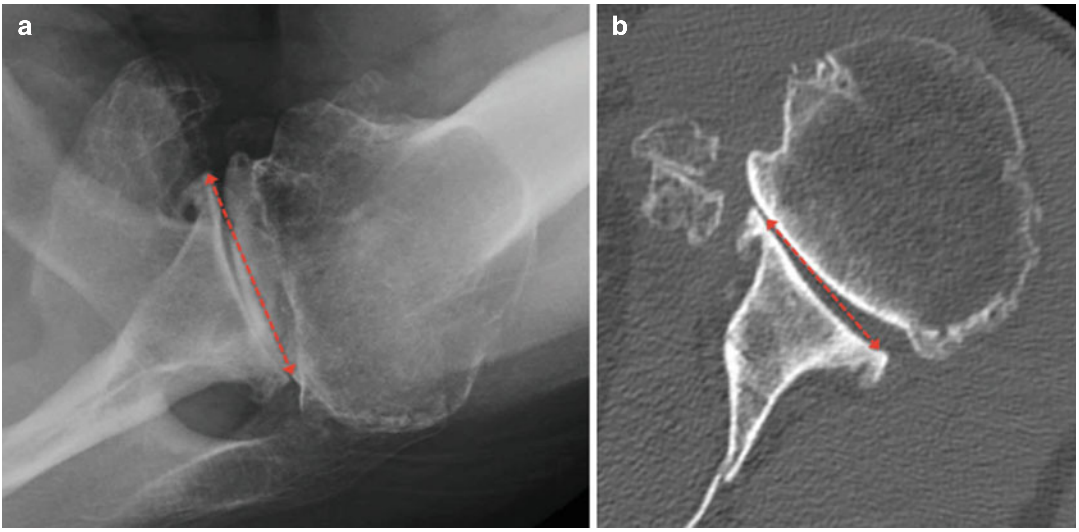

Fig. 7.2 *Glenoid width* – glenoid width can be measured from the most anterior and posterior points on the glenoid. This can be measured both on an AP radiograph (**a**) and CT coronal reconstruction image (**b**) (Note the osteophytes seen anteriorly and posteriorly which can overestimate the glenoid width)

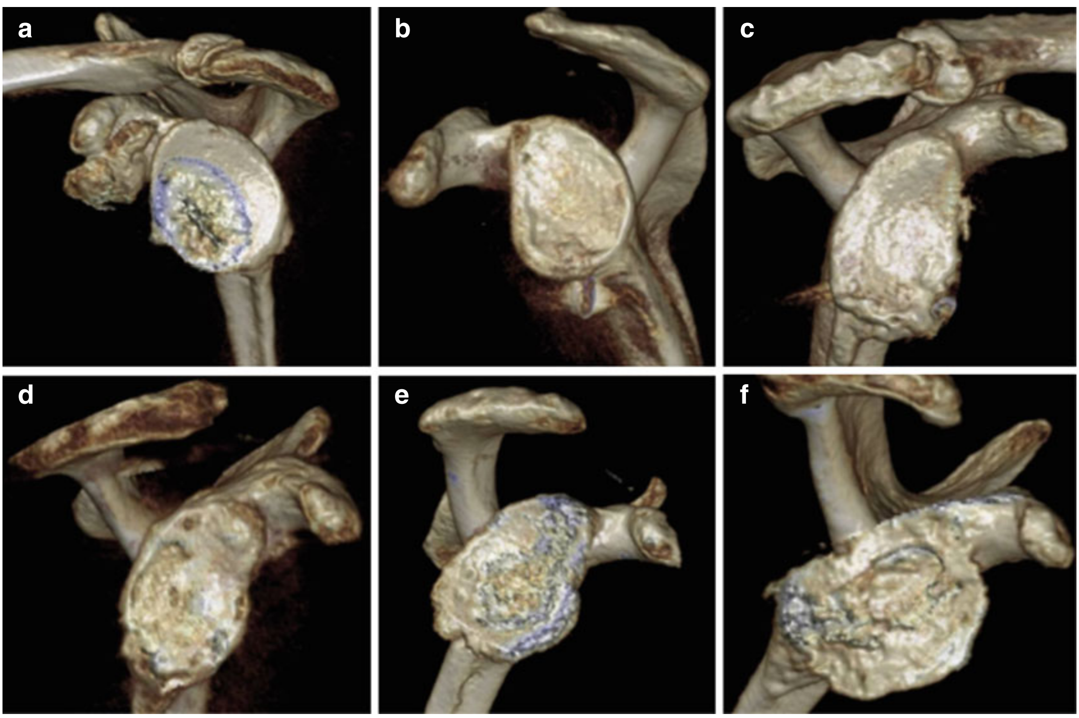

Fig. 7.3 *Glenoid shape* – variations in glenoid shape can be appreciated best by 3D CT reconstruction images. Osteophytes and wear patterns influence this shape. (**a**) Oval-shaped glenoid; (**b**) Pear-shaped glenoid with anterior-inferior osteophyte; (**c**–**e**). Pear-shaped glenoid with inferior osteophytes; (**f**) Posterior-superior glenoid wear alters the glenoid shape

glenoid implantation, as placement of the component with superior tilt has been associated with a greater incidence of rotator cuff disease postoperatively [78].

Glenoid Version

Glenoid version has gained a great deal of attention, as much of the pathologic changes in glenohumeral arthritis result in alterations in glenoid version. Glenoid version is most commonly calculated on axial CT images using the Friedman method [22], which is measured based on the glenoid axis (anterior to posterior rim of the glenoid) and the scapular axis (line connecting the medial boarder of the scapula and the center of the glenoid line) (Fig. 7.5). Alternatively, the vault method [41] is referenced based on the glenoid axis and the glenoid vault axis (line connecting the tip of the scapular vault to the glenoid axis) (Fig. 7.6). Matsumura et al. reported that both methods demonstrated high intra- and inter-rater reliability with normal glenoids having 1.1° ± 3.2° retroversion with the conventional method and 8.9° ± 2.7° retroversion with the vault method. In contrast, arthritic glenoids had average glenoid retroversion of 10.8° ± 9.3° measured with the conventional method and 18.2° ± 9.1° with the vault method. Variation in glenoid version in normal shoulders has been reported to average from

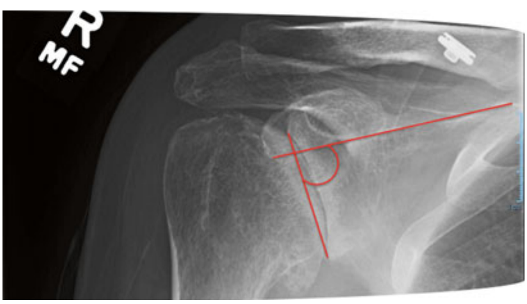

Fig. 7.4 *Glenoid inclination* – glenoid inclination can be measured by the angle between the glenoid fossa line (*vertical line*) and a horizontal scapular reference. This can be measured on radiographs as well as CT reconstructed images. Maur et al. found the angle between the glenoid fossa line (line from the superior to inferior tip of the glenoid) and the floor of the supraspinatus fossa was most reliable at measuring glenoid inclination [42]

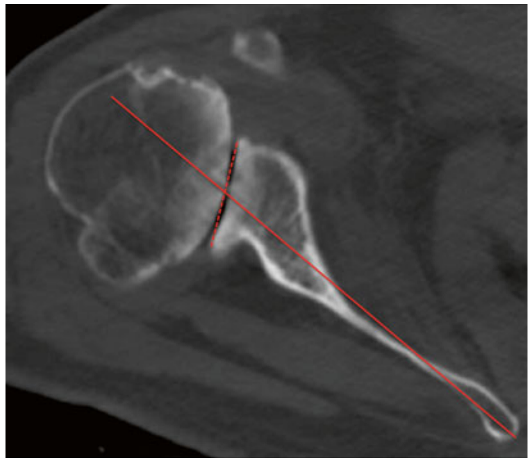

Fig. 7.5 *Glenoid version* – glenoid version can be measured using the Friedman method which defines glenoid version based on the relationship between the glenoid axis (*dotted line*; anterior to posterior rim of the glenoid) and the scapular axis (*solid line*; line connecting the medial boarder of the scapula and the center of the glenoid line)

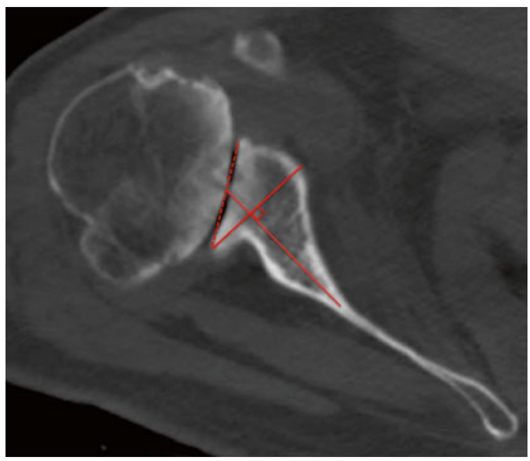

Fig. 7.6 *Glenoid version* – glenoid version can be measured using the vault axis method which defines glenoid version based on the relationship between the glenoid axis (*dotted line*; anterior to posterior rim of the glenoid) and the glenoid vault axis

2° of anteversion to 9° of retroversion [11, 22, 39, 45], with greater degrees of average retroversion seen in arthritic shoulders [22] with wear patterns showing preferential wear in the posterior-inferior glenoid [12]. There has been criticism of the accuracy of 2D CT scans in calculating glenoid version due to alterations in pathologic anatomy, orientation of the scapula for axial cuts, and wear patterns of the glenoid. Recently, Scalise et al. utilized 3D CT reconstructions to assess glenoid version and observed an average retroversion of 15.6° in the arthritic shoulder and 7° in the normal shoulder [51]. Using 3D CT reconstructions, the plane of the scapula is defined by three points: inferior tip of the scapula, scapula trigonum, and the center of the glenoid. Once the plane of the scapula is defined, 2D images are made in the axial, coronal, and sagittal planes to help calculate glenoid version and inclination [51]. While 3D CT reconstructions may provide a more accurate assessment of glenoid version, utilization of 3D reconstructions to define the scapular plane and then create a new 2D axial image along this plane resulted in no significant differences in glenoid version measurements between 3D and 2D images [8]. Appreciation of glenoid version is important as reports have suggested inferior outcomes when glenoid components are implanted in excessive retroversion [29, 53, 77].

Glenoid Vault

The glenoid vault has gained recent attention based on the work of Iannotti and Williams [15, 23, 48–51, 68]. The concept, first described by Ianotti and Williams [68], relates to opportunities for glenoid component fixation when glenoid wear and bone loss becomes significant. While this scenario is more common in the revision setting, pathologic patterns of arthritic wear and joint destruction may allow for preferential glenoid component fixation within the vault and rim rather than the typical subchondral bone surface. Codsi et al. utilized a custom software program to measure variations in glenoid vault anatomy in 61 cadaveric specimens. A group of 5 sized glenoid vault implants were created, representing the consistent triangular anatomy observed in the glenoid vault. Appreciation of the glenoid vault helps to anticipate the ability of the glenoid component to fit within the glenoid vault rather than violating the medial cortex of the glenoid. Moreover, by understanding the glenoid vault anatomy, it is possible to recognize the alterations in glenoid anatomy and facilitate reconstruction efforts aimed at restoring normal version without medialization of the joint.

Subchondral Bone Density

Nearly all glenoid components rely on the subchondral support of the glenoid. Violation of this subchondral surface during glenoid preparation has been shown to result in subsidence of the glenoid implant [66, 67]. It has thus been advocated that the subchondral plate be preserved during glenoid reaming. Simon et al. recently reported an analysis of 3D CT osteoabsorptiometry on 21 patients with concentric glenoid wear and 21 patients with eccentric glenoid wear [52]. They observed differences in subchondral bone patterns for concentric and eccentric wear patterns, with greater density in the posterior zone for eccentric glenoids, whereas concentrically worn glenoids had a homogeneous pattern of bone density. In evaluating CT scans, attention should be directed to the thickness of the subchondral bone. This can assist in preoperative planning when eccentric reaming is necessary.

Subluxation Index

Subluxation of the glenohumeral joint in the setting of arthritis is rather common. Walsh et al. [62] described a method for calculating the subluxation index by measuring the percent subluxation of the humeral head on axial CT images. Using the midpoint of the glenoid axis (line between the anterior and posterior limits of the glenoid), the distance between this center point and the posterior limit of the humeral head is divided by the distance between the anterior and posterior limits of the humeral head (Fig. 7.7). A centered head has a subluxation index of 35–65 %. Posterior subluxation is defined as a subluxation index of greater than 65 % and anterior subluxation as less than 35 %. Appreciation of the amount of subluxation seen on both axillary

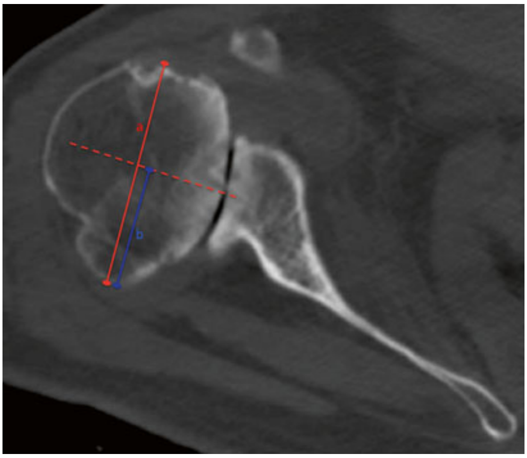

Fig. 7.7 *Subluxation* – subluxation of the humeral head can be appreciated best on axial CT images. Using the midpoint of the glenoid axis (line between the anterior and posterior limits of the glenoid), the distance between this center point and the posterior limit of the humeral head (*line b*) is divided by the distance between the anterior and posterior limits of the humeral head (*line a*). The glenohumeral relationship can then be classified as centered (35–65 %), posteriorly subluxated (>65 %), or anteriorly subluxated (<35 %)

radiographs and CT scans helps to understand wear patterns and formulate strategies for glenoid preparation.

Glenoid Morphology

Recognition of patterns of wear and the glenoid morphology is one of the most important aspects of surgical planning for glenoid component placement.

The most widely referenced classification of glenoid morphology was described by Walch et al. [61, 62] (Fig. 7.8). Five patterns of glenoid wear were described in a series of patients with osteoarthritis. Type A glenoids have a central pattern of wear with minor erosion (A1) and major erosion (A2). Type B glenoids have posterior subluxation without erosion (B1) and with posterior rim erosion (B2). B2 glenoids are commonly described as having a biconcave glenoid deformity. Type C glenoids have glenoid retroversion of more than 25° and are typically considered dysplastic glenoids. While this classification is typically observed on axial radiographs, axial CT images and 3D CT images help clarify the glenoid morphology.

Recently, Walch introduced the concept of the B3 glenoid, based on the recognition that as glenoid erosion advances in the setting of posterior subluxation, a biconcave wear pattern becomes difficult to recognize. This glenoid morphology typically has posterior subluxation of more than 70 %, retroversion of more than 10°, and no clear margin between the neoglenoid and paleoglenoid (CSSES Meeting, Tampa 2015).

Glenoid morphology patterns are different in the setting of rheumatoid arthritis. Levigne and Francheschi described a glenoid morphology classification based on a series of 50 shoulders treated with shoulder arthroplasty [36] (Fig. 7.9). Stage 1 represented an intact or minimally deformed subchondral bone plate. Stage 2 showed erosion reaching the base of the coracoid. Stage 3 patients demonstrated erosion beyond the coracoid base.

Surgical Plan

Common logic suggests that placement of the glenoid component in an ideal location should provide the best chance for long-term survivability of the implant. Ideally, the glenoid face should be prepared to perfectly match the backside of the glenoid component without overhang of the glenoid component or reaming past the subchondral bone. The fixation pegs or keels should be contained within the glenoid vault. The component should be placed in neutral to slight inferior inclination, specifically avoiding superior tilt. While there is no defined ideal version correction that has been shown to improve long-term fixation or wear, Iannotti et al. suggested that glenoid version should be corrected to within 5° of a plane perpendicular to the plane of the scapula [30]. Unfortunately, with increasing glenoid deformities, the ability to accurately place the glenoid component can be challenging [30], both in terms of planning and execution of the surgical plan.

Advances in imaging capabilities, integration of surgical planning software, improvements in

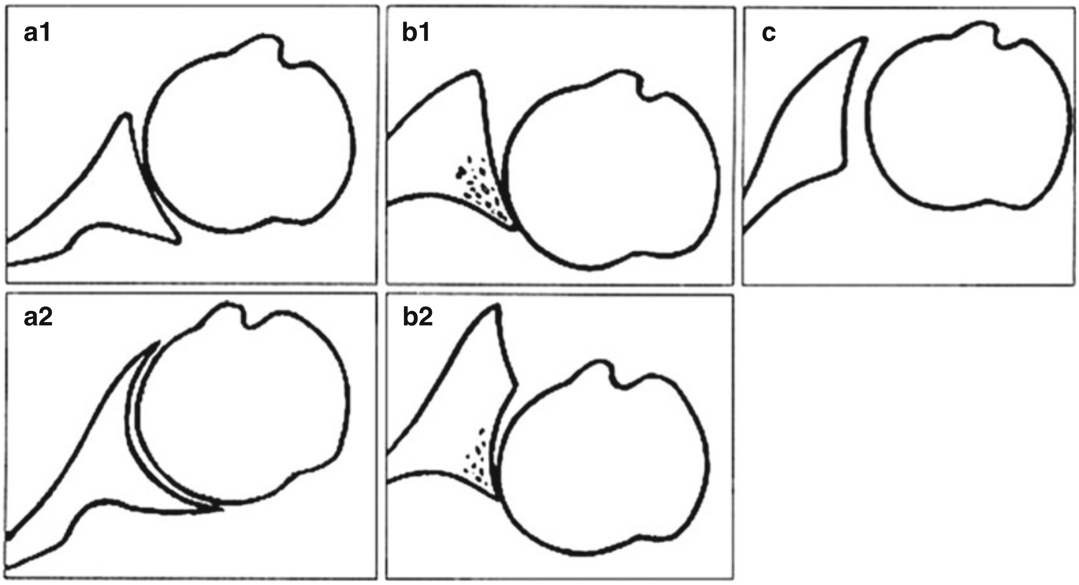

Fig. 7.8 *Glenoid wear morphology in osteoarthritis* – the most commonly referenced classification of glenoid morphology of glenohumeral osteoarthritis as described by Walch et al. [62]. The figure represents the Walch classification, (**a1**) centered humeral head with mild glenoid erosion. (**a2**) centered humeral head with major erosion, (**b1**) posterior subluxation with no erosion, (**b2**) posterior erosion with biconcave glenoid. (**c**) severe retroversion

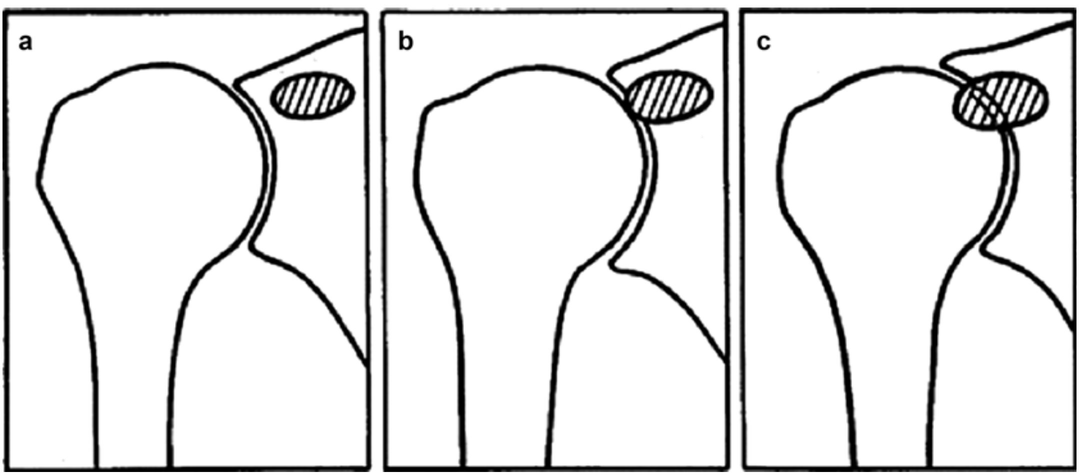

Fig. 7.9 *Glenoid morphology in rheumatoid arthritis* – stage 1 (**a**) intact or minimally deformed subchondral bone plate; stage 2 (**b**) erosion reaching the base of the coracoid; stage 3 (**c**) erosion beyond the coracoid base

implant innovation, and a greater understanding of glenoid anatomy and wear patterns have all contributed to the advancements in surgical planning of glenoid component implantation. The introduction of patient-specific instrumentation together with 3D modeling software developments has facilitated precise surgical planning with opportunities to carry out that plan with a high level of accuracy.

Radiographs continue to be the gold standard for the evaluation of glenohumeral arthritis. Properly oriented anteroposterior (AP) and axillary lateral views of the glenoid are critical [28, 69]. While properly performed axillary radiographs can be sufficient in evaluating glenoid wear patterns, the value of CT scan imaging with two- and three-dimensional reconstructions has become invaluable in surgical planning for glenoid component implantation.

2D reconstructed CT scan images allow the analysis of several key components of shoulder anatomy that are critical in preoperative planning of glenoid component implantation. Axial images are used to calculate the glenoid version, humeral head subluxation, eccentric wear patterns, glenoid width, subchondral bone density and location, location of osteophytes, depth of the glenoid vault, analysis of the quality of the subscapularis muscle and tendon, and identification of bone defects which may be present. Coronal reconstructions help to appreciate the glenoid height, inclination angle, superior humeral head subluxation, and quality of the supraspinatus and infraspinatus muscle and tendons. Sagittal reconstructions help to appreciate muscle atrophy of the rotator cuff musculature. Using two-dimensional images, glenoid planning can be performed [31]. The central axis point can be estimated which will serve for the axis of glenoid reaming. The amount of glenoid reaming necessary to restore appropriate version can be estimated as well.

The introduction of 3D reconstructions with humerus subtraction has helped to better understand the limitations of 2D CT imaging as well as gain a better appreciation of the location of wear patterns in pathologic glenoids. Not only can calculations of version, inclination, and subluxation be performed more accurately [60], but the actual location of glenoid wear patterns can be appreciated. In recent years, 3D printing technology has become more widely available. Printing scapular models of patient anatomy brings the understanding of glenoid anatomy to the next level and is now a part of most patient-specific instrumentation platforms currently available. The recent interest in patient-specific instrumentation has taken surgical planning to a high level of precision [31, 37, 38, 58, 64, 65]. The combination of virtual surgical planning, 3D printing of the scapula, and instrumentation developed specifically for reproducing the virtual surgical plan has improved the accuracy of carrying out the surgical plan for glenoid component placement to within a few degrees of error. With accurate planning, it is now possible to place the glenoid component accurately in the properly planned location, correct deformities of version and inclination, define the appropriate component rotation on the face of the glenoid, and properly size the glenoid components to avoid medial vault penetration.

Implant Selection

There are numerous variations in glenoid implant designs. Differences are seen in component shape, radial mismatch, backside curvature, keel and peg size and orientation, and method of fixation. It is important to understand the rationale behind each of these implant features.

Glenoid Shape

Most of the original glenoid component designs were oval shaped despite the pear shape of the native glenoid. The surgeon was often left with a decision of how to best size the prosthetic glenoid component, as proper sizing of the inferior glenoid often resulted in implant overhang superiorly. With the advent of the Aequalis (Tornier, Edina, MN) and the Solar (Stryker, Kalamazoo, MI), attention was focused on more closely matching the glenoid anatomy using a pear-shaped design [9]. Several glenoid implants have since been introduced with a more anatomic glenoid shape. The theoretical risk of the anatomically matched glenoid component is increased instability [1, 16]; however, to date there are no reports of greater instability seen with anatomically shaped glenoid components. It is generally accepted that the optimal glenoid component size is one that most closely matches the prepared glenoid surface without allowing for the component to hang off the glenoid bone.

Radius of Curvature Mismatch

Nearly all glenoid components have a mismatch between the radius of curvature of the humeral head and the glenoid. This is based on the rationale that normal glenohumeral mechanics result in translations between the humeral head and glenoid. In a cadaveric analysis, Karduna et al. observed that active translations seen in normal joints were best reproduced with glenoid components that were less conforming and determined that a radial mismatch of 4 mm best represents this relationship [32]. In a multicenter analysis of flat-back cemented polyethylene glenoids, Walch et al. observed that glenohumeral mismatch significantly influenced the incidence of radiolucent lines and described an ideal mismatch between 6 and 10 mm [63]. However, no study has defined the ideal radial mismatch for a glenoid component based on effects on outcomes, and variations in the radial mismatch remain common among different implant designs.

Glenoid Fixation

Critical to the long-term success of the glenoid component is implant fixation. There are several methods of component fixation that have been utilized in glenoid implant designs. Pegged and keeled designs are certainly the most common and have historically been cemented into the glenoid. Metal-backed glenoid components with polyethylene inserts allow for enhanced fixation using screws, pegs, and ingrowth metals. Recently, hybrid combinations of cemented and uncemented pegs have been utilized as methods of enhancing component fixation into the bone.

Fully cemented pegged and keel designs have been utilized since the first total shoulder arthroplasties performed by Charles Neer in the early 1970s. While keel designs remain the most popular worldwide, Edwards et al. reported significantly higher rates of radiolucent lines surrounding keeled implants than pegged implants both on initial postoperative radiographs and 2-year follow-up [20]. All cemented peg and keel designs vary with differences observed in the shape of the keel and the orientation and number of pegs.

The effect of cement technique on glenoid component fixation has been studied. Terrier et al. used an FEA to assess the stress interaction between the cement and glenoid bone and concluded that a 1.0 mm cement mantle thickness is ideal [55]. Nyffler performed axial pullout testing of variable glenoid component designs and observed that threaded pegs demonstrated higher pullout force than notched pegs, which were both higher than smooth pegs [45]. Additionally, they noted that increasing the cement mantle thickness from 0.1 to 0.6 mm increased the pullout force [45]. Roughened backside surface finish of glenoid components has also been shown to improve component stability in all-cemented glenoids [2, 45]. Finally, cement pressurization during glenoid component implantation has been associated with a low incidence of early radiolucent lines [4, 34].

Recently, enhanced fixation glenoids which support bone growth into or around pegs have gained interest based on improved biologic fixation. Early results are quite promising with high rates of bone growth observed between the flutes on the pegs [72, 73] in studies with up to 5-year follow-up [13]. With greater initial fixation of the component [14] and opportunity for biologic fixation of the pegs, enhanced fixation polyethylene glenoids may ultimately help to lower rates of radiolucent lines suggestive of glenoid loosening.

Metal-backed uncemented glenoid implants have lost popularity based upon a historical experience of high complications. The original designs utilized a metal casing secured with screw fixation and an exchangeable polyethylene insert. High rates of screw breakage, excessive polyethylene wear, dissociation, and high revision rates have been reported [40, 54]. Recently, new uncemented metal-backed designs utilizing modern fixation technologies have been introduced. These include implants with ingrowth metals and improved screw fixation methods that may help avoid the historical failures. However, to date there are no reports to suggest that the history of loosening and catastrophic failure has been avoided using these newer designs.

Glenoid Materials

As glenoid component fixation improves, initial failure modes may shift from component loosening due to loss of fixation to polyethylene wear and osteolysis. Cross-linked, ultrahigh molecular weight polyethylene is typically used for most glenoid components [71]. While polyethylene wear has been clearly linked with osteolysis in total hip arthroplasty, there are few reports of similar reactions following total shoulder arthroplasty [33, 79]. Osteolysis after TSA has been reported to be as high as 23 % [79] and has been shown to be more common with metal-backed glenoids [5, 33]. Wirth et al. evaluated the polyethylene debris particle size in retrievals of three failed total shoulder arthroplasties that were revised for aseptic loosening with osteolysis and compared them to failed total hip components revised for similar reasons. The wear debris was found to be larger and more fibrillary than the particles from failed total hip arthroplasty [70], suggesting a different mechanism of wear in shoulders than in hips. Differentiating between mechanical loosening from loss of fixation and osteolysis may ultimately be difficult as osteolytic regions can contribute to mechanical loosening.

Recently, the addition of vitamin E into highly cross-linked polyethylene has been introduced into total shoulder arthroplasty. This has been based on the success seen in total hip arthroplasty, which has demonstrated oxidative stability, low wear rates, and improved strength with the addition of vitamin E [7]. With enhanced fixation of glenoid components, efforts at utilizing this and other polyethylene materials with improved wear and strength properties will continue. Given the recent introduction of this technology, there is no clinical data supporting the use of these alternative polyethylene materials in total shoulder arthroplasty.

Surgical Execution

Proper glenoid exposure remains the critical step for placement of a glenoid component. This necessitates appropriate soft tissue releases, placement of retractors, and sufficient bone resections to allow clear visualization of the glenoid. Once the glenoid is exposed, all total shoulder arthroplasty systems now have instrumentation designed to prepare the glenoid surface to match the backside of the glenoid and precisely drill peg holes or a keel vault to match the selected glenoid component.

Glenoid Preparation

All glenoid components are defined based on a central axis. This axis, defined during surgical planning, defines all corrections in version, inclination, and translation. Once this axis is defined, glenoid reaming can be performed using glenoid reamers. These reamers are either cannulated based on a wire that has been placed down the central axis or non-cannulated utilizing a tip that fits within a hole in the central axis point on the glenoid face. The goal of glenoid preparation is to prepare a matching surface to the backside of the glenoid component. Early flat-back glenoid designs often required significant glenoid reaming, whereas concave glenoid designs typically require less glenoid reaming during preparation. A critical principle of glenoid preparation is to avoid reaming past the subchondral bone plate into more cancellous bone as this has been associated with early component subsidence [66, 67].

Once the glenoid is reamed to match the back surface of the glenoid component, the peripheral pegs or keels are created. For glenoids designed to utilize cement, the peg or keel preparation anticipates creating a cement mantle which is typically 1.0 mm [55]. Glenoid designs, which utilize pegs without the need for cement, create peg holes designed for a press fit.

The rotation of the glenoid component is defined during this step. Most TSA systems provide precision jigs which help to create the peripheral pegs or keel vault; however, the surgeon must define the rotation of the component. By referencing the biceps insertion on the supraglenoid tubercle, the proper rotation of the glenoid component can be selected. Patient-matched instrumentation systems have the capacity to integrate this step into a guide that is used during surgery, defining both the central axis for reaming and a peripheral peg hole to maintain the accuracy of glenoid component rotation in addition to version, inclination, and translation position [56].

Glenoid Implantation

Most all-polyethylene glenoid components utilize cement for component fixation. Modern cement techniques have evolved with most emphasizing drying the glenoid [21], cement mantle thickness of 1.0 mm [55], and cement pressurization either by injection into the peg hole or keel vault using a syringe [4, 34] or weep-hole vacuum assistance [26]. Use of additional cement on the back of the glenoid component is more controversial based on concerns regarding fracture and fragmentation of thin areas of cement and associated risk of third-body wear from dislodged cement particles. Once the glenoid component is placed, all extruded cement must be removed from the periphery of the glenoid component.

Conclusion

Modernization of total shoulder arthroplasty has greatly improved the understanding and appreciation of variations in glenoid anatomy in severely arthritic shoulders. Appreciation of both normal and abnormal glenoid anatomy has helped the surgeon understand patient pathology and has enhanced glenoid component design and surgical technique. Collectively, the surgeon now has a greater understanding of how to appreciate anatomical variations, properly plan glenoid placement, and accurately execute standard glenoid component placement during total shoulder arthroplasty.

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