

The Glenoid Center Line

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abstract

This study sought to define a point on the anterior glenoid surface to serve as a marker for glenoid orientation and to present the concept of a glenoacromial version angle. Twenty fresh-frozen cadaver scapulas were examined. A line perpendicular to the glenoid surface exited the anterior scapular cortex in all specimens at an average distance of 29.3 ± 3.9 mm. The average glenoacromial version angle was $60^\circ \pm 11^\circ$. These numbers may allow better intraoperative assessment of glenoid version.

for the standardization of glenoid component preparation.

This study sought to define a point on the anterior glenoid surface to serve as a marker for determining the glenoid center line and thus direct orientation of the glenoid surface in total shoulder arthroplasties. In addition, the concept of a glenoacromial version angle for defining a consistent anatomical relationship for glenoid surface orientation is presented.

The first shoulder arthroplasty was performed more than 100 years ago by a French surgeon named Pean in 1893.¹ In the 1950s, Neer emerged as the first modern surgeon to perform prosthetic humeral replacements of the glenohumeral joint,^{2,3} and the concept of glenoid resurfacing for total shoulder arthroplasty began approximately 30 years ago.⁴ Since then, total shoulder arthroplasty has become a reliable procedure for pain relief in shoulders with end-stage degenerative joint disease and inflammatory arthropathies at the glenohumeral articulation.^{5,6}

In looking specifically at the glenoid component, the most critical mechanical aspect of glenoid resurfacing is identifying the correct version and inclination of the glenoid, as poor glenoid orientation has been correlated with glenohumeral instability.^{7,8} It is also known that the greater the contact area between two bearing surfaces, the lower the overall force per unit area each of the surfaces will experience.

In total shoulder arthroplasty, maximizing the contact area between the glenoid component and the humeral head serves to decrease the joint contact pressures, thus reducing stress at the prosthetic-bone interface.⁹ Again, this emphasizes the importance of correct component orientation, and while glenoid components have been associated with early loosening and persistence of radiolucent lines on radiographs,^{10,11} the basic principles of proper prosthetic component placement determine the overall clinical result.

Glenoid resurfacing often is challenging because of posterior glenoid wear with osteoarthritis, superior wear with cuff disease,¹² and large osteophytes from end-stage arthritis. In addition, most techniques for glenoid preparation are dependent on the surgeon's experience. The concept of an intraoperative anatomical landmark or consistent anatomical relationship to scientifically define the orientation of the glenoid surface would allow

MATERIALS AND METHODS

Twenty-five fresh-frozen cadaver shoulders with a mean age of 78.8 ± 18.2 years were examined. The shoulders were stripped of soft tissues and disarticulated at the glenohumeral and acromioclavicular joints. Careful attention was paid in removing the glenoid labrum to adequately define the bony glenoid rim.

The glenoid surface was inspected, and any specimen with grade IV arthritic

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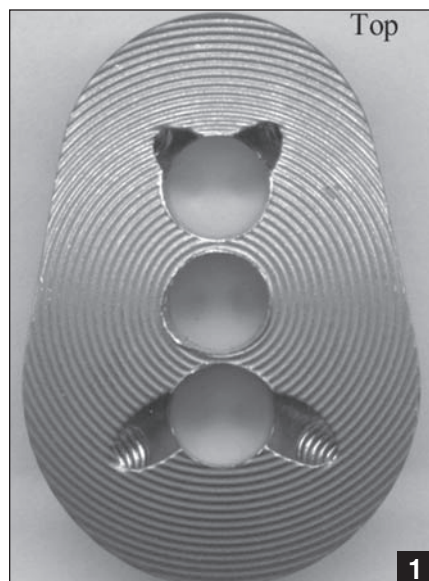


Figure 1: The medium size Tournier guide (Montbonnet, France) was used to construct the templates for glenoid sizing.

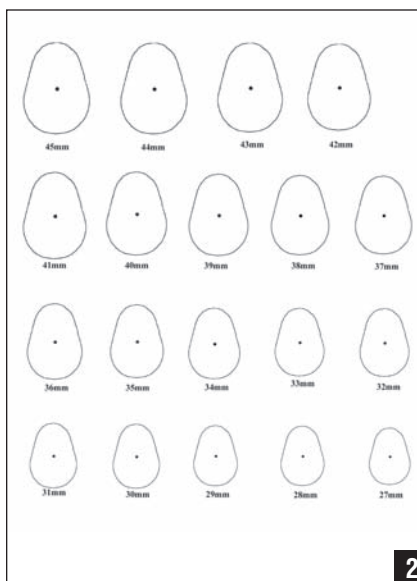


Figure 2: Templates used for glenoid sizing.

changes¹³ or significant (>20%) glenoid articular bony loss was excluded from the study. Therefore, 5 specimens with grade IV arthritic changes were excluded, leaving 20 specimens in the study.

To determine the anatomical center of the glenoid, templates were made referencing the Aequalis Shoulder system (Montbonnet, France) for total shoulder arthroplasty. These consist of small, medium, and large glenoid guides (Figure 1).

The anteroposterior and superoinferior distances of the medium guide were measured, and a 38-mm (superoinferior size) template was constructed, with the outer perimeter similar to the Tournier guide system. The other templates were designed by increasing or decreasing the superoinferior diameter of the 38-mm guide in 1-mm increments and locking the aspect ratio, so that the anteroposterior dimensions of the template were proportional to the superoinferior dimensions.

Template sizes ranged from 27 to 45 mm (Figure 2). The literature shows the average superoinferior glenoid diameter ranges from 30.4 to 42.6 mm in males and 29.4 to 37 mm in females.¹⁴

Each of the templates was marked with

a center dot that was determined by drawing a line parallel to the greatest superoinferior diameter and another line parallel to the greatest anteroposterior diameter. The intersection of these lines was considered to be the geometrical center of the template.

To define a line perpendicular to the glenoid surface, a simple geometrical analysis was used. The glenoid is concave in both the anteroposterior and superoinferior planes. The superoinferior poles of the glenoid rim extend further laterally than the anteroposterior poles. Therefore, a flat

surface could not be placed on the glenoid rim because it would toggle on the high superior and inferior points of the rim.

In addition, because the curvature of each glenoid fossa varied, a single fixed curved guide could not be used. To overcome this, a flexible steel O-ring clamp that conformed to the curvature of any circle or oval was used (Figure 3A).

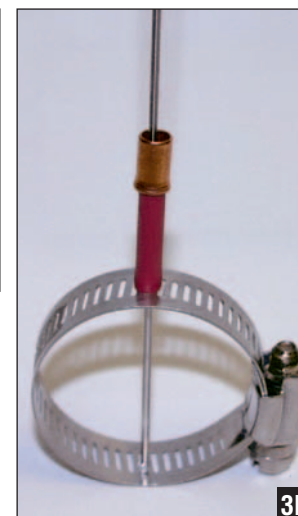
The O-ring was approximately a half inch in width, with slots in the outer perimeter. The width of the O-ring conformed to the overall concavity of the glenoid. Each slot was opposite and parallel to another slot on the other side of the outer perimeter.

By compressing the O-ring, a variable radius of curvature was produced that matched each glenoid specimen. Thus, the slot on the O-ring that corresponded to the marked center of the glenoid was theoretically tangent to the glenoid surface.

To ensure the Kirschner wire was drilled completely perpendicular to the slots in the O-ring clamp, the slots were drilled with holes slightly larger than the diameter of a 0.062-mm K-wire (Figure 3A). In addition, an extender guide (an electrical wire splicing device slightly larger than the diameter of a 0.062-mm K-wire) was used to further ensure the wire drilled was perpendicular to the O-ring clamp (Figure 3B).



Figure 3: An O-ring clamp was used to determine the radius of curvature and the line perpendicular to the surface of the glenoid specimens (A). Note the hole drilled in the slots of the O-ring. The hole is just larger than the K-wires used for drilling. Another hole is drilled in the slot of the O-ring exactly opposite the superior hole. An extender guide (an electrical wire splicing device slightly larger than the 0.062-mm K-wire) was assembled to the O-ring clamp to keep the K-wire perpendicular to the clamp (B).



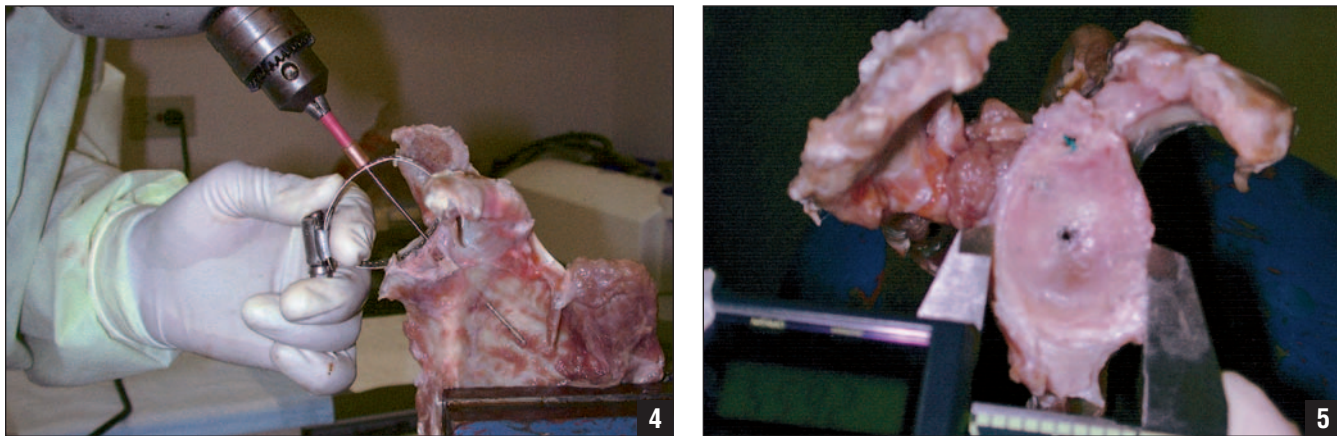


Figure 4: Calipers were used to measure the superoinferior and anteroposterior dimensions of the bony glenoid. **Figure 5:** A 0.062-mm K-wire drilled perpendicular to the glenoid surface exits anteromedially on the scapula.



Figure 6: A standard AO depth gauge was used to measure the distance from the glenoid surface to the point where the K-wire emerged from the anterior cortex (A). Calipers then were used to measure the distance from the superior and inferior margins of the glenoid to the point where the K-wire emerged from the anterior cortex of the scapula (B and C).

Thus, a drill placed through two opposite slots in the O-ring and aimed at the marked center of the glenoid was perpendicular to the ring and also perpendicular to the surface of the glenoid. In this fashion, the O-ring clamp served as a guide in determining a line perpendicular to the glenoid surface.

Each scapula was securely mounted in a vise clamp. Templates (Figure 2) were used to determine the size of the glenoid by matching the outline of the templates to the outline of the bony glenoid rim. A mark then was placed through the center dot of the template to identify the center of the glenoid fossa, and calipers were used to measure the superoinferior and anteroposterior glenoid diameters (Figure 4).

The O-ring clamp was placed on the glenoid fossa, and the center glenoid mark was aligned with one of the perimeter holes of the ring. The O-ring clamp was

compressed so that its radius of curvature matched the curvature of the glenoid fossa. A 0.062-mm K-wire was inserted through the top and bottom hole in the O-ring clamp tangent to the articular surface (both holes were parallel to one another).

The K-wire was then drilled through the glenoid surface, and it was noted where it emerged from the scapula, either on its anterior or posterior cortex (Figure 5). A standard small-fragment AO depth gauge (Synthes Ltd, Paoli, Pa) was used to measure the distance from the glenoid surface to the point where the K-wire emerged from the anterior scapular cortex (Figure 6A). Calipers were used to measure from the most superior and inferior points of the glenoid rim to the point where the K-wire emerged from the anterior scapular cortex (Figures 6B and 6C).

The glenoacromial version angle was defined as the angle between one K-wire placed perpendicular to the glenoid and another K-wire placed along the anterolateral/posterolateral margins of the acromion. The angle measured was viewed from the inferior glenoid looking superiorly and was projected in the axial plane (Figure 7).

All measurements were made by the same investigator.

RESULTS

Superoinferior and anteroposterior glenoid diameter; template size; distance to the anterior, superior, and inferior cortex; and glenoacromial version angle for all 20 specimens are listed in the Table. Average superoinferior diameter was 34.65 mm (range: 26.7-42.5 mm), and average anteroposterior diameter was 25.45 mm

Table

Glenoid Diameter, Template Size, Cortex Distance, and Glenoacromial Version Angle for Scapula Specimens

Specimen No.	Diameter (mm)		Template Size (mm)	Distance to Cortex (mm)			Glenoacromial Version (°)
	Superoinferior	Anteroposterior		Anterior	Superior	Inferior	
1	37.22	25.94	38	27.5	36.8	36.7	56
2	34.08	23.77	34	29	38.03	33.3	64
3	35.5	29.5	35	27.5	38.8	35.4	40
4	31.7	24.18	31	28	33.8	30.2	40
5	35.21	23.55	35	34	37.72	38.21	80
6	31.87	20.54	32	28	37.7	35.4	54
7	37.33	27.3	37	23	35	29.95	74
8	31.92	22.5	32	24	30.92	26.98	56
9	26.7	21.8	27	27	33.08	30.64	64
10	42.46	26.81	42	32	42.01	36.62	72
11	30.1	23.27	30	28	33.07	31.13	72
12	34.27	31.27	39	38	49.18	42.86	62
13	34.11	26.31	34	28	33.8	33	60
14	39.59	26.78	39	36	41.17	38.72	42
15	38.54	30.73	38	29	37.09	34.67	62
16	35.92	27.05	36	25	31.07	30.08	60
17	40.54	27.08	40	28	34.34	33.87	64
18	32.93	23.11	34	29	30.84	29.74	52
19	32.22	26.06	33	35	41.07	41.04	58
20	30.81	21.48	31	30	32.66	30.2	64

(range: 20.54-31.27 mm). Average actual template size used was 35 mm. The correlation coefficient between the template size used and the actual superoinferior diameter was 0.95.

In all 20 specimens, the K-wire perpendicular to the glenoid surface exited through the anterior scapular surface (Figure 5). Average distance to this K-wire was 29.3±3.9 mm from the glenoid surface (Figure 6A), 36.41±4.57 mm from the superior glenoid rim (Figure 6B), and 33.94±4.2 mm from the inferior glenoid rim (Figure 6C). The average glenoacromial version was 60°±11° (Figure 7A).

DISCUSSION

Prosthetic component placement is essential to a successful clinical outcome in total joint arthroplasty. Malpositioned components can lead to abnormal loading at the prosthetic-bone interface and early component failure.

Glenoid resurfacing and component placement in total shoulder arthroplasty is dependent on determining correct glenoid version. Studies have demonstrated the glenoid is normally retroverted between 2° to 12°.7,14-18 Resurfacing often is challenging because of posterior glenoid wear with osteoarthritis, superior wear with cuff disease, and large osteophytes from end-stage arthritis.

It is known a line perpendicular to the glenoid surface exits anterior to the scapular body. The data from this study show this point is approximately 29.3±3.9 mm anteromedial to the glenoid surface. This also is the area within the sulcus created by the superior and inferior crura of the scapula. It is this anatomical point in combination with a theoretical type of “glenoid guide” that could be used to determine the correct glenoid version in challenging total shoulder arthroplasties.

End-stage glenohumeral arthritis can be associated with severe glenoid bony loss, obscuring any normal anatomical landmarks. One study in the literature determined the glenoid-posterior acromion angle adequately defined glenoid version on radiographs.15 However, no study in the literature has examined intraoperative markers to define glenoid version.

Assuming the ability to place a marker perpendicular to the glenoid surface as described in this study, a consistent anatomical relationship between glenoid version and the long axis of the acromion is proposed. The angle in the axial plane between a line perpendicular to the glenoid surface and a line through the anterolateral/posterolateral margins of the acromion subtends 60°±11°.

With this in mind, a guide system could be used to reference the anterolateral/posterolateral margins of the acromion intraoperatively. The guide system then would be rotated approximately 60° in the

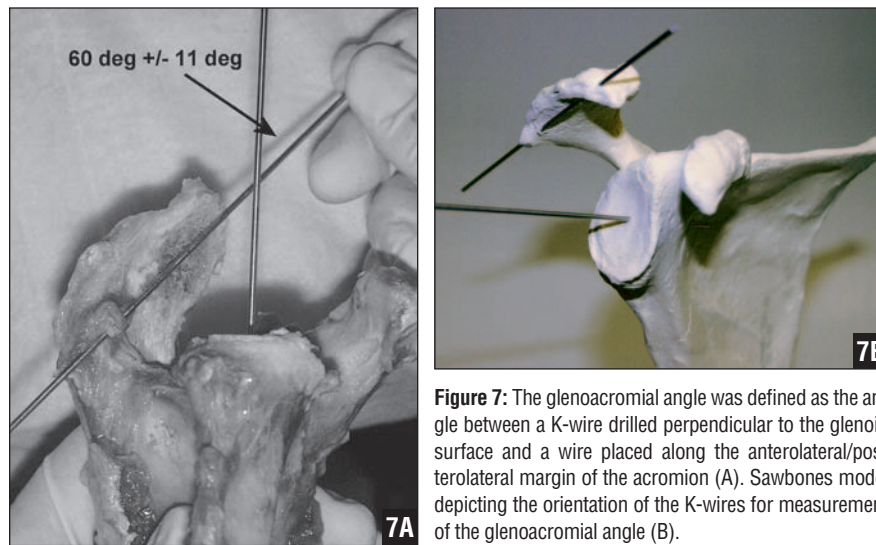


Figure 7: The glenoacromial angle was defined as the angle between a K-wire drilled perpendicular to the glenoid surface and a wire placed along the anterolateral/posterolateral margin of the acromion (A). Sawbones model depicting the orientation of the K-wires for measurement of the glenoacromial angle (B).

What is already known on this topic

■ The most critical mechanical aspect of glenoid resurfacing is identifying the correct version and inclination of the glenoid, as poor glenoid orientation has been correlated with glenohumeral instability in multiple studies.


What this article adds

■ It is known that a line perpendicular to the glenoid surface exits anterior to the scapular body, and our data show that this point is approximately 29.3 ± 3.90 mm anteromedial to the glenoid surface.

■ We propose a consistent anatomical relationship between glenoid version and the long axis of the acromion. The angle in the axial plane between a line perpendicular to the glenoid surface and a line through the anterolateral/posterolateral margins of the acromion subtends $60^\circ \pm 11^\circ$.

axial plane from the reference anterolateral/posterolateral margins and the glenoid surface would be drilled to emerge approximately 29 mm anteriorly on the scapular body from the glenoid.

This anatomical relationship would be independent of acromial morphology (ie, acromial spurs) and could still be applied even in patients with a previous acromioplasty procedure. In addition, the relationship is independent of glenoid wear and glenoid osteoarthritis. The end result

would be an intraoperative solution to glenoid version. Further study is needed to apply these methods to shoulders with significant glenoid wear and examine the data for similar correlations. 

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