Glenoid resurfacing: What are the limits to asymmetric reaming for posterior erosion?

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Eccentric posterior glenoid erosion is a common condition in osteoarthritis. No limits have ever been placed on the degree of eccentric erosion that can be corrected while still maintaining sufficient bone stock to implant a glenoid securely. Five cadaveric scapulae were dissected. Posterior glenoid erosion was created to simulate retroversion of 15° or more. A computed tomography (CT) scan confirmed the degree of glenoid retroversion. The glenoid was then reshaped to correct the glenoid retroversion to neutral, and a glenoid component with central and peripheral pegs was inserted. A second CT scan confirmed the correction to neutral and also evaluated the fit of the component into the glenoid. In all 5 experimental cases, at least 1 of the 4 pegs penetrated the glenoid vault. In 1 case, there was a fracture of the anterior rim. Glenoid retroversion of 15° or more cannot be satisfactorily corrected simply by reaming to lower the anterior edge of the glenoid and restore neutral version when using a glenoid component with peripheral pegs. (J Shoulder Elbow Surg 2007;16:843–848.)

In individuals with glenohumeral osteoarthritis, the pattern of eccentric posterior glenoid erosion and anterior soft tissue contracture is not uncommon. Surgical technique generally includes correction of glenoid orientation to neutral and anterior soft tissue releases. Biomechanically, this will balance the forces across the joint and promote more normal biomechanical loads across the glenoid, as well as a better range of motion. Despite these goals, correcting severe posterior glenoid erosions when implanting a total shoulder may be challenging. Three potential solutions exist for implanting a glenoid component and restoring proper version[2,3,23]: (1) posterior cement augmentation/custom implant with augments, (2) posterior bone grafting, and (3) asymmetric reaming of the anterior glenoid to lower the high side and correct retroversion.

No quantitative limits, however, have ever been determined for the degree of posterior glenoid wear that can be corrected by eccentric reaming and still allow for sufficient bone stock to implant a glenoid component. Only guidelines have been suggested based on empirical experience. Therefore, the aim of this study was to define the limits of eccentric glenoid erosion that can be corrected by reaming to neutral, while still maintaining adequate bone stock for secure placement of a glenoid component.

MATERIAL AND METHODS

Five healthy shoulders from 5 fresh-frozen cadavers were used. These specimens had no evidence of glenoid dysplasia, arthritis, or former surgery. The mean age of the donors (4 women and 1 man, 4 right and 1 left) was 64.4 years.

Dissections were done after overnight thawing at room temperature. The soft tissues of the shoulder were removed, and only the scapula and the proximal humerus were retained. The glenoid and the humeral head sizes were measured so that the correct glenoid component might be selected to match the anatomic reconstruction of the humeral head. This is based on the manufacturer's guidelines to obtain a proper mismatch of glenoid to humeral head radius of curvature (Anatomical Shoulder, Zimmer-Centerpulse, Wintatur, Switzerland). Each scapula was fixed in a block of epoxy to permit stable fixation of the specimen for power reaming.

Creation of posterior glenoid erosion

The Anatomical Shoulder cannulated guide system was centered on the glenoid and used to create a posterior glenoid defect to simulate erosion such as might be encountered in a patient with osteoarthritis. The center of the glenoid was determined as superoinferior alignment of the Kirschner wire was done under visual monitoring, as well as anteroposterior alignment, so that the positioning instrument perfectly fit to the glenoid (Figure 1). A 3-mm Kirschner guidewire was introduced using the cannulated positioning goniometer. The angle of introduction was 20° of retroversion. This guide system allowed control of glenoid reaming and provided a reference point in each specimen in order to create a posterior erosion of 20° retroversion.

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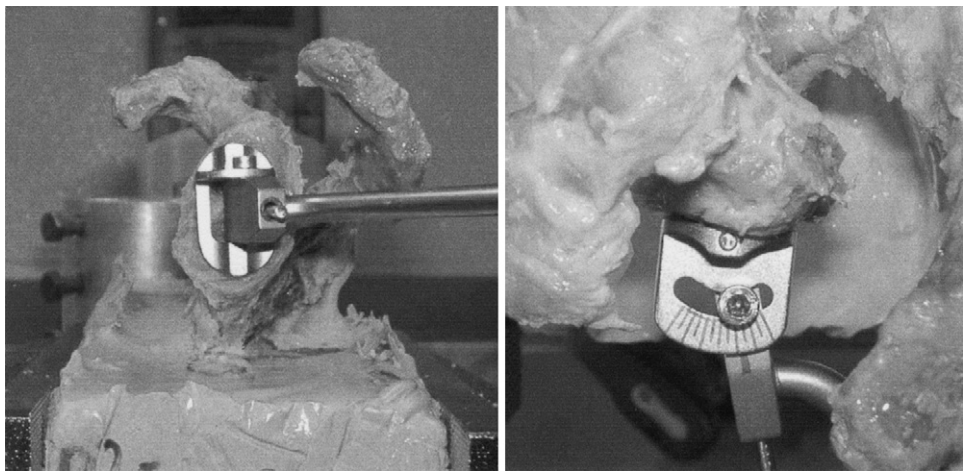

Figure 1 A, A 3-mm Kirschner guide wire is introduced using the cannulated positioning goniometer. **B**, The angle of introduction is of 20° of retroversion.

The created glenoid retroversion was then measured with a computed tomography (CT) scan.[21] Contiguous sections of 1 and 3 mm were obtained, allowing reconstructions in all planes as well as 3-dimensional (3D) reconstructions. The glenoid version was measured, as described by Friedman et al,[10] by using the computerized instrument of the CT scan machine. With computerized measurement, the retroversion of each scapula was determined on the first film on which the tip of the coracoid process was not visible:

1. A line was drawn between the anterior and posterior osseous margins of the glenoid fossa.
2. The transverse axis of the scapula was drawn parallel to the scapular body from the medial border of the scapula to the center of the glenoid (middle of the line extending from the anterior to the posterior edges of the glenoid). A line drawn perpendicular to this was defined as a line of neutral version.
3. A line drawn perpendicular to transverse axis of the scapula was defined as a line of neutral version.
4. The angle between the line of neutral version and the line connecting the anterior and posterior margins of the glenoid was measured and recorded as the degree of retroversion created (Figure 2, *A*).

This measurement technique should be done preoperatively; only the edges of the glenoid are taken into account and not eventual osteophytes.

Correction of retroversion by glenoid reaming

According to Anatomical Shoulder glenoid instrumentation and standard surgical technique, the glenoid was prepared for reaming using the Anatomical Shoulder cannulated positioning goniometer.[22] The correction angles corresponded to the angle measured on the CT scan. This corrected angle was then entered on the glenoid positioning instrument, on which 1 graduation line corresponds to 5°. The 3-mm Kirschner wire guided the cannulated reamers. In all cases, reaming started with the small reamer and progressed to the appropriate final size for the selected glenoid (small, medium, or large). The end point for reaming was uniform contact of the reamer and confirmation of a congruent concave glenoid with a special glenoid template without pegs (Figure 3).

The glenoid drill guide was then positioned along the 3-mm Kirschner wire so that it lay on the glenoid surface. The glenoid drill was used to drill the upper hole with a diameter of 6.2 mm, as far as the stop on the glenoid drilling guide. This drilled hole was fixed with a centering pin. That maneuver was repeated for both inferior holes. The 3-mm Kirschner wire was then removed, so that the central hole was drilled. A pegged glenoid component of appropriate size was then inserted based on initial measurements of the humeral head and glenoid. The liner has 4 pegs in an inverted T-shape fashion, 1 of 11.7 mm centering the implant and 3 of 7 mm (one 11 mm above the central peg and 2 located 9.5 mm below it; Figure 4). These measurements are constant whatever the size of the component (small, medium, or large). Each glenoid was prepared after reaming as follows: a central and 3 peripheral drill holes with a diameter of 6.2 mm were made by using a drill guide.

A second CT scan was then performed with the same protocol as the first to confirm the correction of glenoid version to neutral (with the protocol described above) and to evaluate the fit of the component into the glenoid vault. Complications were an anterior or posterior malposition, a bone fracture, or a polyethylene break out, as shown in Figure 2, *B*.

RESULTS

Preoperative glenoid measurement indicated that 2 small, 2 medium, and 1 large glenoid would fit. The humeral head size measured extended from 40 to 48 mm. In every case, the glenoid size measured by comparison with the trial component, corresponded to the humeral head size measured.

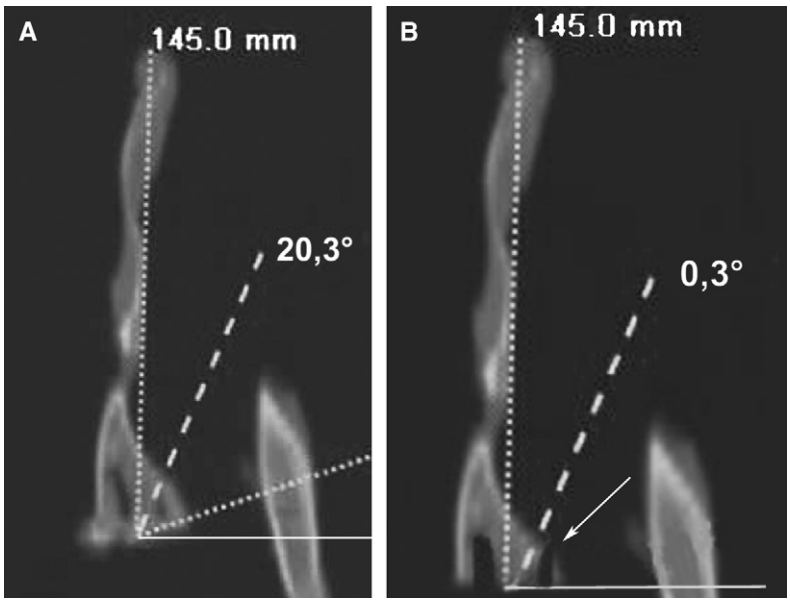

Figure 2 A, A computed tomography scan of the lesion shows a posterior retroversion of 20.3° (*dotted lines*: first between the anterior and posterior margins of the glenoid fossa and second, transverse axis of the scapula; *plain line:* perpendicular line to the transverse axis of the scapula). The break-off line shows the angle measured by the computer. **B**, A control computed tomography scan fracture of the posterior vault and image of polyethylene breakout *(arrow)*.

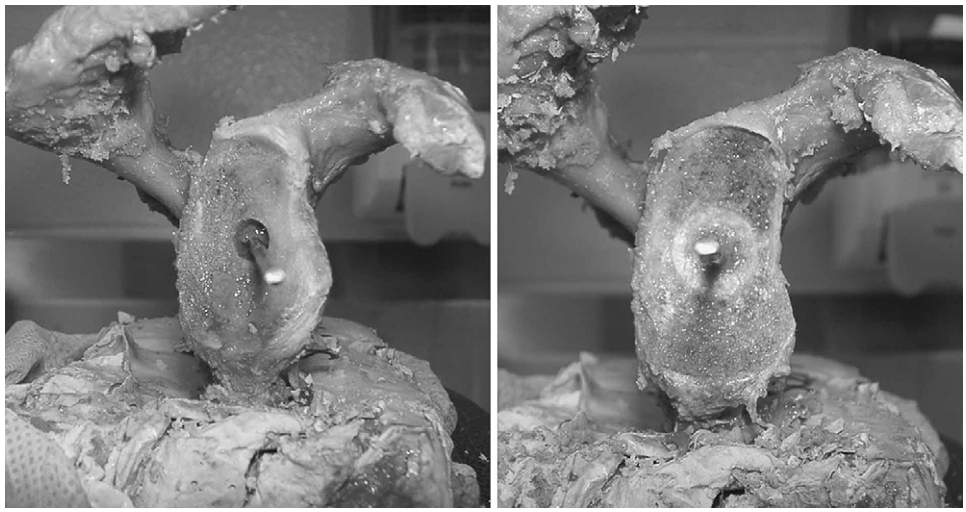

Figure 3 Glenoid before and after asymmetric reaming to restore the normal version. The end point for reaming was uniform contact of the reamer and confirmation of a congruent concave glenoid with a special glenoid template without pegs.

The mean created defect, calculated with the CT scan, was of 24° (from 15° to 31°). In all 5 experimental cases, the glenoid version was corrected to neutral after the asymmetric reaming, restoring the normal version.[5] At least 1 peg of the 4 penetrated the glenoid vault, not only the drill hole but also the peg itself. In 1 case, 3 of 4 pegs penetrated the glenoid vault (Figure 5).

A fracture of the anterior glenoid rim after reaming occurred in 1 case where a 20° retroversion had been corrected to neutral. In another case, although a medium size glenoid was appropriate for the diameter of the humeral head, a small glenoid was the only size that could fit on the remaining glenoid surface after reaming (Figure 2, *B*; Figure 5).

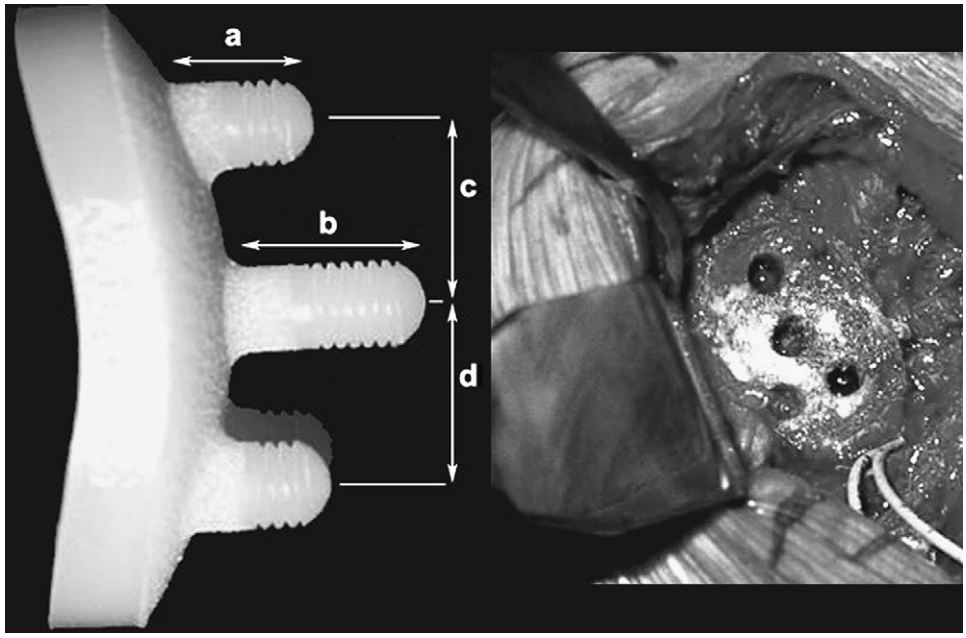

Figure 4 Sample of a medium glenoid component. Four pegs in an inverted T-shape fashion: 1 of 11.7 mm **(A)** centering the implant and 3 of 7 mm **(B)** and **(C)** 11 mm above the central one, and **(D)** 2 located 9.5 mm below it.

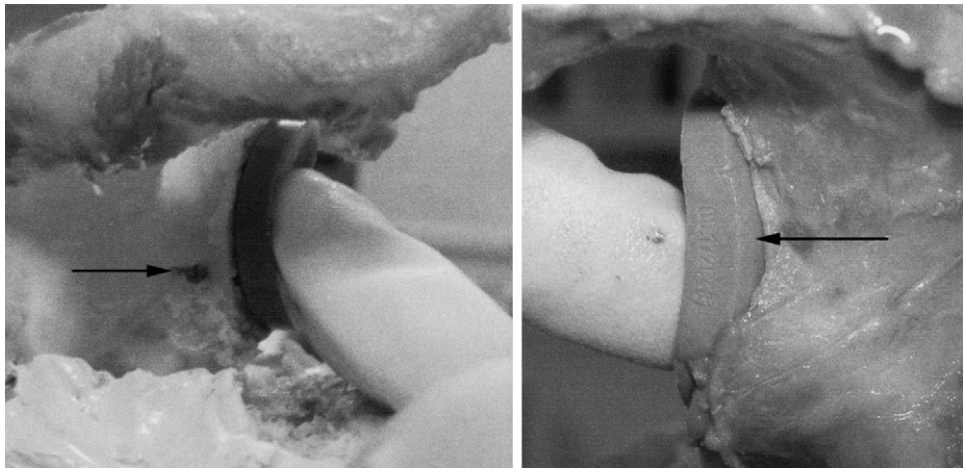

Figure 5 Left: penetration of the glenoid vault and neck by a pin (arrow); Right: the normal glenoid component is oversized (arrow).

DISCUSSION

Posterior glenoid bone loss through progressive erosion may occur in some patients who require total shoulder arthroplasty for arthritis. This can be associated with an acquired retroversion and, in some patients, posterior subluxation of the humeral head.[27,28] Although most patients have only mild degrees of posterior erosion, failure to correct glenoid orientation to neutral in the more severe cases can result in a suboptimal outcome with hemiarthroplasty or glenoid loosening with total shoulder arthroplasty.[2,6,8,9,19,23] Thus, several authors[2,8,19,20,22,26] have recommended correction of the bony deformity. The most common method for correction of the glenoid orientation is to ream the anterior (high side) to neutral; however, no guidelines exist for the extent of reaming that is possible to achieve this goal.

Iannotti et al[14] defined severe posterior bony erosion of the glenoid as more than 10 mm of bone loss. This definition does not adapt to all scapulae, because the retroversion resulting from this bone loss will

vary in proportion to the original size of the glenoid. Walch et al[28] developed a classification for degrees of bony erosion and posterior subluxation of the humeral head and correlated this to outcome after total shoulder replacement. Nyffeler et al[22] demonstrated that the risk of loosening is significantly enhanced by placement of the glenoid component in an orientation of more than 5° retroversion.

For the purposes of our study, we selected more than 15° of retroversion as the definition of severe glenoid erosion or wear. We attempted to define the limits of correction to neutral orientation through reaming of the glenoid and placement of a commercially available glenoid component that has both central and peripheral pegs. We chose to use this component design on the basis of biomechanical data that suggest that a peg design with peripheral pegs is more stable than a central keel component design.[1] Our results cannot be extrapolated to other component designs, such as keel or pegs in-line. In fact, there may be glenoid geometry problems that lend themselves to these designs better than to a component with peripheral pegs.

There is a range of normal glenoid version. Friedman et al[10] found an average value of 2° of retroversion, whereas Saha[24,25] showed that glenoid orientation may vary from 0° to 7.5°. In our study, the defect was added to each glenoid, thus a potentially retroverted glenoid might have been further retroverted through reaming and then corrected to neutral version. That means that the correction we achieved may have been more than what was normal for that specimen. This is 1 shortcoming of our study.

The rationale for correcting glenoid retroversion to neutral is based on clinical experience that positioning the glenoid component with more retroversion leads to unsatisfactory results.[3,9,18] Moreover, biomechanical work from Nyffeler et al has demonstrated that failure to restore glenoid version within 5° will result in significant shear loads across the glenoid, with increased risk of glenoid loosening from edge loading.[22] Hopkins et al[13] found similar results in a finite-element model simulating glenoid retroversions.

We observed that, using a component with a central and peripheral pegs, fracture of the glenoid or penetration of peripheral pegs through the glenoid vault were limiting factors when attempting to correct more than 20° of retroversion. The option in these situations is to perform a posterior bone graft[3,4,7,12,16,17,19,26] before placement of the glenoid component or perhaps to use a component with either a keel or central peg design. We did not, however, study the limits for use of these kinds of components. Unfortunately, no good guidelines are available to determine what size of glenoid osseous deficiency requires bone grafting.

Another alternative is to accept glenoid correction to less than neutral. This might compromise forces across the joint, while allowing secure glenoid component fixation. It is not clear if this will have clinical ramifications; moreover, little clinical experience with this technique has been reported.[12,18,26]

Asymmetric reaming of the anterior glenoid bone to correct excessive glenoid retroversion remains the simplest technique and is also the most widely used. This technique has the advantages of reorienting the joint surface and medializing the center of rotation of the joint. Theoretically, this protects the soft tissue reconstruction (subscapularis tendon) and reduces joint compression, which might otherwise add to polyethylene wear. The results of this study show that this solution is acceptable in cases with small or mild defects. Indeed, this study clearly demonstrated that our assumption that more than 15° retroversion was severe was reasonable, because in every experimental subject, the glenoid vault was compromised by at least 1 peg hole.

Biomechanical and animal work has shown that pegs have some advantages in neutrally oriented glenoids.[11,13,15,29] Whether a keeled glenoid would be better than a glenoid with peripheral pegs in the setting of severe retroversion remains unanswered, although theoretically, if more than 16 mm of bone is left in the center of the glenoid, most of the existing keeled glenoid may be implanted, and probably some custom glenoid with pegs in a vertical line.

We conclude that in cases where glenoid erosion exceeds 15°, the surgeon should consider bone grafting as an alternative to reaming the anterior glenoid. We believe that this study emphasizes the need to obtain a CT analysis of the glenoid preoperatively to understand the 3D anatomy of the glenoid, to evaluate for defects, and to be prepared to address the defects with appropriate glenoid preparation and component implantation.

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