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The effects of prosthetic humeral head shape on glenohumeral joint kinematics during humeral axial rotation in total shoulder arthroplasty

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Background: A non-spherical humeral head has been shown to influence kinematics and stability of the glenohumeral joint; yet, most prosthetic humeral head components are designed to be a perfect sphere. The effect of humeral head shape on prosthetic joint kinematics after total shoulder arthroplasty is not well understood. We hypothesized that prosthetic joint kinematics during humeral axial rotation is dependent on humeral head shape, regardless of joint conformity.
Methods: Four prosthetic configurations were investigated using a spherical and a non-spherical prosthetic humeral head articulated with a conforming and a non-conforming glenoid component. Testing was performed in the coronal, scapular, and forward flexion plane at 0°, 30°, and 60° of abduction. Prosthetic joint kinematics was measured in 10° intervals during a 100° arc of humeral axial rotation. Glenohumeral translation patterns, net glenohumeral translation, and averaged glenohumeral translation were compared for each of 4 configurations.
Results: Non-spherical head configurations increased the net glenohumeral translation during humeral axial rotation in multiple test positions compared with spherical head configurations ($P < .05$). Spherical head configurations resulted in a relatively small amount of glenohumeral translation, less than 2 mm. The radius of curvature of the glenoid component alone did not affect the net glenohumeral translation within each of the 2 head groups ($P > .05$).
Conclusion: During humeral axial rotation, the non-spherical humeral head shape contributes to increased glenohumeral translation during humeral axial rotation. However, the spherical head shape does not show significant glenohumeral translation during humeral axial rotation, regardless of glenoid conformity.
Level of evidence: Basic Science Study; Biomechanics

Keywords: Humeral head shape; conformity; kinematics; translation; center of rotation; total shoulder arthroplasty

Investigations were performed at Orthopaedic Biomechanics Laboratory at VA Long Beach Healthcare System and University of California, Irvine. Institutional Review Board approval is not applicable because this is a basic science study.

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A primary biomechanical goal of anatomic total shoulder arthroplasty (TSA) is to restore normal glenohumeral joint kinematics by replacing the pathologic bones with prosthetic humeral head and glenoid components. Biomechanical studies have investigated the influence of prosthetic joint conformity and constraint on translational forces and torque,[17] the effect of articular conformity and size of the humeral head on laxity and motion,[3] glenohumeral joint translation without capsular contracture under passive and active loading before and after TSA,[11] prosthetic positioning,[7,24] and micromotion of the glenoid component.[16,19] Findings from these studies suggest that using less conforming and less constrained glenoid component designs will allow humeral head translation before edge loading occurs and will reduce translational forces, frictional torques, and micromotion of the glenoid component. The disadvantages of using a less conforming joint configuration[20-22] are increased contact pressures and an increased risk of eccentric loading of the humeral head onto the glenoid component, which contribute to the current clinical problems of glenoid component wear and loosening, respectively. A biconcave (a conforming center zone surrounded by a non-conforming zone) glenoid component[23,26] has been introduced (Zimmer, Warsaw, IN, USA) to increase the contact area with less glenohumeral translation during mid ranges of motion within the conforming zone but to allow translation at the extremes of range of motion from a non-conforming zone. It is important to note that almost all the prostheses are designed using a perfectly spherical humeral head to allow for humeral head translation on a non-conforming (larger radius of curvature than the humeral head) glenoid component.

Unlike current prosthetic humeral heads, which are perfect spheres, the native humeral head is not a perfect sphere.[4,6,27] Only a few studies have investigated the effects of a non-spherical humeral head shape on joint stability and kinematics. A biomechanical study showed that a non-spherical prosthetic head increased native glenohumeral joint stability.[13] Recently, using cadaveric specimens, we showed that a non-spherical prosthetic head significantly increased range of motion and restored glenohumeral joint kinematics close to those of the native glenohumeral joint during humeral axial rotation under simulated muscle loading after hemiarthroplasty compared with those of a spherical prosthetic head.[8] To our knowledge, there is no study that has investigated the effects of a non-spherical head on prosthetic joint kinematics during humeral axial rotation. We believe that the use of a non-spherical head that accurately replicates the native humeral head shape would result in increased glenohumeral translation during humeral axial rotation, which has been shown for the native glenohumeral joint.

The purpose of this study was to investigate the effect of humeral head shape on prosthetic joint kinematics during humeral axial rotation. Specifically, we hypothesized that a non-spherical humeral head would increase glenohumeral translation during humeral axial rotation compared with a spherical humeral head. To test this hypothesis, we compared the net glenohumeral translation during humeral axial rotation in multiple arm positions and the averaged net glenohumeral translation among different prosthetic configurations.

Materials and methods

Geometric characteristics of prostheses and prosthetic configurations used in study

For the spherical head, we used a commercially available humeral head (Global AP; DePuy Synthes, Warsaw, IN, USA) with a radius of curvature of 26 mm (Fig. 1, *A*). The

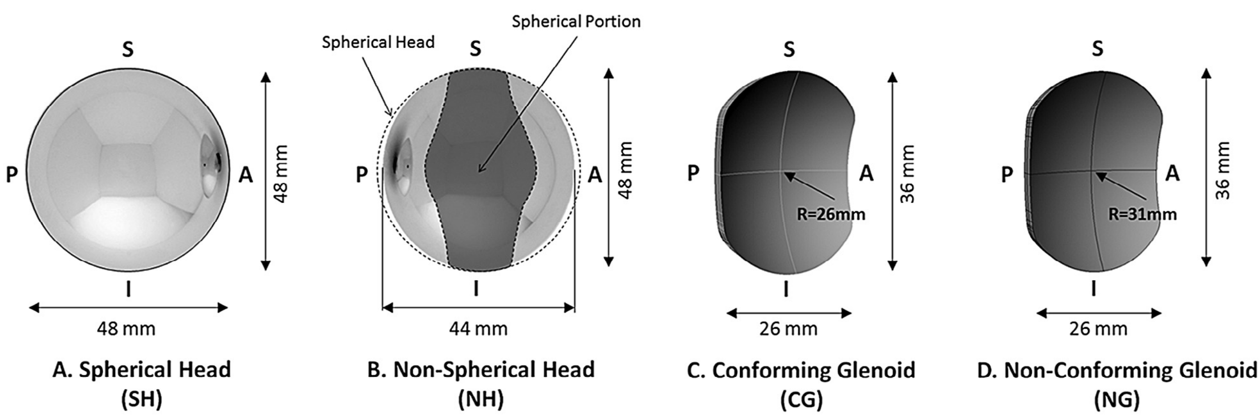

Figure 1 Comparison of prostheses used in study: spherical head with radius of curvature of 26 mm (**A**), non-spherical head with radius of curvature of 26 mm for spherical portion (**B**), conforming glenoid component with radius of curvature of 26 mm (**C**), and non-conforming glenoid component with radius of curvature of 31 mm (**D**). The non-spherical head was custom-made based on a previous anatomic study.[6] The *dashed circular outline* indicates the dimension of the spherical head for comparison purposes. The spherical portion (central 30% and superior-to-inferior direction) is marked in *gray*. Its anterior-posterior dimension gradually decreases by 4 mm (44-mm width for non-spherical head vs. 48-mm width for spherical head). *A*, anterior; *I*, inferior; *P*, posterior; *S*, superior.