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ORIGINAL ARTICLE

Humeral head osteotomy in shoulder arthroplasty: a comparison between anterosuperior and inferoanterior resection techniques

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Background: The best chance that a shoulder arthroplasty will restore motion and muscle balance across the glenohumeral joint is by closely replicating natural articular morphology. Defining the humeral osteotomy plane along clear landmarks at the anatomic neck is critical. We hypothesized that a new osteotomy, based on alternative landmarks on the anatomic neck, would restore 3-dimensional humeral head morphology more reliably than the traditional osteotomy.
Methods: The anatomic neck was digitized in 30 human cadaver shoulders and compared with its 3-dimensional computed tomography reconstruction. Two different osteotomy techniques were virtually performed: the traditional, following the anterosuperior anatomic neck; and a new technique, defined by the inferoanterior anatomic neck. The length-width difference and orientation (retroversion, inclination) of the resection area were compared between the techniques and with native anatomy.
Results: Length-width difference of the anterosuperior resection area was higher than in the inferoanterior osteotomy (6 ± 2 mm vs. 3 ± 1 mm; $P < .001$). Retroversion of the anterosuperior resection plane was higher than the native head (50° ± 12° vs. 37° ± 11°; $P < .001$), whereas retroversion after the inferoanterior osteotomy (32° ± 12°) did not differ from native ($P = .057$). Inclination differed after the anterosuperior osteotomy (129° ± 5°) and the inferoanterior osteotomy (127° ± 4°) compared with the native head (134° ± 4°; $P \leq .001$).
Conclusion: The inferoanterior referenced osteotomy generated a more circular resection area, matching the native humeral head retroversion more closely than in the anterosuperior technique. This study suggests that in shoulder arthroplasty, the humeral resection level should be referenced at the inferoanterior rather than the anterosuperior anatomic neck. Further studies should investigate the biomechanical effects of this alternative resection plane.
Level of evidence: Basic Science Study; Surgical Technique Using Cadaver and Imaging

Keywords: Shoulder; arthroplasty; osteotomy; anatomy; humerus; geometry; orientation

This study is exempt from Institutional Review Board approval by University of Utah IRB #11755, "Biomechanical Testing of Orthopaedic Devices Using Decedent Tissue Models."

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Shoulder arthroplasty (SA) is an effective treatment to reduce pain and to restore function in patients with end-stage shoulder osteoarthritis.[8,23,32] Yet a 31% revision rate, mainly on the glenoid side, was observed in a long-term follow-up after adaptable third-generation SA.[33] Although failure after shoulder replacement is likely to be multifactorial,[6,13] component malpositioning[24,37,38,40] or the use of nonanatomic prosthesis designs[29] might play an important role in glenoid failure.[6,13,25,26]

Third- and fourth-generation adaptable prosthetic systems are based on the assumption that the articular segment resected at the level of the anatomic neck corresponds to a spherical segment with an equal cross-sectional length and width, which is identically oriented in inclination and retroversion to the native humeral head.[1] Therefore, defining the osteotomy plane along clear anatomic landmarks is a necessary and critical step in SA. Following a line along the anterosuperior portion of the anatomic neck to perform the humeral head osteotomy has been recommended as a surgical guideline and is considered the "gold standard."[1,16,31]

In contrast, several studies using cadaveric and computational models demonstrated that the humeral head is not spherical but instead has an ovoid-like shape with a larger superoinferior than anteroposterior diameter.[11,16,19] Recent evidence also showed that retroversion varies at different levels from the most inferior to the most superior portion of the proximal articular surface.[12,14] That said, the surgeon may select an oversized or undersized prosthetic head and overestimate or underestimate the true retroversion, depending on where the cut is referenced.

The precise benefits of replicating the patient's anatomy in clinical practice have not yet been established.[33,35] However, biomechanical investigations demonstrated that anatomic reconstruction restores motion and muscle balance across the joint, thus limiting eccentric loading of the glenoid.[2,19] Previous reports suggested that radius of curvature of the glenohumeral joint in SA should be reproduced within 2 to 3 mm.[16,20] In their cadaveric study, Jun et al[19] proposed to reconstruct the humeral head with an asymmetric rather than a symmetric prosthetic head. They showed that a length-width difference in prosthetic head size of only 4 mm leads to significant changes in glenohumeral joint kinematics and rotational range of motion.

Modifying the osteotomy technique is another approach proposed to improve anatomic reconstruction.[10,28] In a graphical model, Harrold et al[10] showed that an osteotomy plane referenced along the posterior anatomic neck improved recovery of humeral head geometry in SA. However, this osteotomy plane was individually calculated on models using 3 points of least deviation between the new osteotomy plane and the digitized anatomic neck to simulate the osteotomy. How this concept could be transferred into clinical practice remains unclear, knowing that the humeral head is severely deformed in end-stage osteoarthritis[21] and the posterosuperior anatomic neck cannot be exposed directly by the standard deltopectoral approach.

Therefore, the purpose of this study was to determine the morphologic implications of an osteotomy technique guiding the surgeon along the inferoanterior anatomic neck. We hypothesized that an osteotomy along the inferoanterior anatomic neck would result in a more circular resection area with a smaller length-width difference compared with an osteotomy performed along the anterosuperior anatomic neck. Furthermore, we hypothesized that the retroversion and inclination of the inferoanterior osteotomy plane would not differ with respect to the native anatomy of the humerus, in contrast to the anterosuperior osteotomy plane.

Materials and methods

Specimen preparation

A total of 30 fresh frozen cadaveric upper extremities were included in this study. There were 10 males and 5 females with a mean ± standard deviation age of 58 ± 6 years. All 30 specimens were from matched pairs that had not undergone a previous surgical procedure. The shoulders were disarticulated and all soft tissues removed. To test the study hypothesis in a well-controlled manner, shoulders were excluded if degenerative changes consistent with osteoarthritis or full-thickness rotator cuff tears were detected. By use of 2 nylon screws, marker clusters with three 3-mm beads were affixed to the humerus just distal to the bicipital groove. These marker clusters defined a local coordinate system of the bone in both computed tomography (CT) reconstructions and the laboratory.

Three-dimensional modeling and digitizing of the anatomic neck

Before dissection, each specimen was placed in a supine position and axial CT images of the whole specimen were obtained using a Siemens (Malvern, PA, USA) SOMATOM Definition Flash CT Scanner (100 kV, 35 mAs, 512 × 512 acquisition matrix, 0.6-mm slice thickness with 0.5-mm increments, 0.6 pitch, DICOM format). The humerus surface, the medullary canal, and the beads were semiautomatically segmented from the CT slices using Amira (v5.4; Visage Imaging, San Diego, CA, USA), and 3-dimensional (3D) reconstructions were generated.[18,21,34,39]

After the CT scan, specimens were rigidly mounted on a jig, fixing the humerus in reference to a digitizing probe. Determination of the anatomic neck at the cartilage-metaphyseal border was performed by consensus of 2 board-certified, fellowship-trained orthopedic surgeons (T.S., A.G.P.). The circumference at the anatomic neck and each bead on the marker clusters were digitized using a MicroScribe G2X (±0.23-mm accuracy; Solution Technologies, Oella, MD, USA). The anatomic neck was continuously digitized in autoscan mode (every 1 mm), and beads were digitized by selecting 10 points on each of their surfaces. The anatomic neck was divided into 12 points representing a clock face, with 12 o'clock corresponding to the most superior point at the insertion of the supraspinatus tendon and 6 o'clock corresponding to the lowest point of the articular surface at the cartilage-metaphyseal interface (Fig. 1, *A*).[10] Clockwise and counterclockwise reference numbers were used for right and left specimens, respectively.