Advantages of a Wedge-Shaped Glenoid Prosthesis to Correct Retroversion in Total Shoulder Arthroplasty

INTRODUCTION

Severe arthritis of the shoulder is frequently associated with retroversion of the glenoid articular surface. Surgical correction of glenoid version is recommended during total shoulder arthroplasty especially when the deformation is greater than 10°. Uncorrected retroversion can result in an unstable glenohumeral joint and mechanical failure of prosthetic components due to edge-loading.1-3 Glenoid retroversion is typically corrected by reaming to remove more bone from the anterior aspect of the glenoid articular surface, which results in a more neutral alignment of the glenoid component. However, this method of correcting retroversion also mediolizes the implant, reduces the amount of available bone stock for structural support, and increases the risk of cortical bone perforation by the component fixation features (e.g., pegs or keels).8

A wedge-shaped glenoid component can compensate for a retroverted glenoid without medialization, loss of glenoid bone, or increasing the risk for perforation. However, the effects of such a design change on the stresses in the cement and bone are not known. We postulated that a wedge-shaped design would reduce any excessive stresses generated in an uncorrected retroverted glenoid component and would result in a more normal distribution of the forces. We tested this hypothesis in a finite element analysis of a shoulder arthroplasty.

METHODS

Fig 1: A finite element model of a total shoulder arthroplasty was constructed in Abaqus v6.7.

Bone Geometry: A cadaveric shoulder of median size, neutral glenoid version, and absence of visible arthritis was imaged using qCT. The CT scan was segmented to generate surface meshes for the cortical and cancellous bone using MIMICS (Materialise, Leuven, Belgium) and solid meshes (4-node tetrahedral elements) in Hypermesh (Altair Engineering, Troy, Michigan). To simulate surgical reaming and drilling for peg fixation, retroverted models of the scapula were later generated by Boolean subtraction of an oriented sphere from the glenoid articular surface (Fig 2).

Implant Geometry: A standard pegged glenoid ultrahigh molecular weight polyethylene (UHMWPE) component and a 1-mm thick cement mantle were meshed with hexahedral elements from CAD models and virtually implanted in the scapular model in 0° and 15° of retroversion relative to the scapular axis. To correct retroversion without medialization a wedge-shaped glenoid component was designed with increased thickness posteriorly and the pegs were aligned with the scapular axis. The humerus head was modeled as a rigid sphere with radius of curvature of 24 mm.

Material Properties: qCT data were used to convert the CT units (Hounsfield) into bone density (ρ). The following relationship was used to assign a Young’s modulus (E) to the material properties for each bone element.4,5

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\text{Trabecular bone } E = 0.06 + 0.9\rho^2; \text{ Cortical bone } E = 0.9\rho^{1/4}
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Poisson’s ratio (v) for bone was 0.3. UHMWPE was modeled as a linear isotropic elastic material (E = 1.0 GPa; v = 0.4); and the cement mantle was modeled as linear isotropic elastic material (E = 2.9 GPa; v = 0.35). Boundary conditions: A force of 625N was applied across the humeral head to simulate shoulder abduction.6 Fixed boundary conditions were applied at muscle attachment sites to simulate muscle reaction forces.

RESULTS

Fig 3: Peak stresses were higher in the retroverted condition and were restored to below normal levels with the wedge-shaped design.

DISCUSSION

Excessive retroversion of the glenoid may increase failure of the glenoid component as suggested by experimental1 and numerical studies. Correction of retroversion greater than 10° is typically recommended.1,2 In our study, 15° of uncorrected glenoid retroversion greatly increased stresses, especially in the bone, and shifted the stress distribution posteriorly. These results agree well with results from other finite element studies.3,5 Awedged-shaped design decreased peak stresses substantially in bone, cement, and polyethylene compared to the standard glenoid component in the retroverted condition. The peak stresses in the bone were even lower than those seen in the neutral condition. We increased the polyethylene thickness in the standard glenoid component to the average thickness of the wedge component. While peak stresses in the polyethylene remained the same, increasing polyethylene thickness reduced peak stresses in the underlying cement and bone (Fig 3). Thus, the increased thickness provided by a wedge-shaped prosthesis has an additional beneficial effect on stress distribution in bone and cement.

We simulated retroversion in a normal scapula. An arthritic scapula with pre-existing retroversion is more relevant but would preclude simulation of neutral version. We only analyzed a single static load during simulated shoulder abduction, other activities could generate different magnitudes and distribution of peak stresses.

The surgical advantage of a wedge-shaped glenoid component is preservation of bone stock, reduced need for medialization to correct retroversion, and decreased risk of cortical penetration by the fixation pegs6. Our results support biomechanical advantages of a wedged glenoid insert in reducing the stresses generated in a retroverted glenoid.

REFERENCES