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Optimizing reverse shoulder arthroplasty component position in the setting of advanced arthritis with posterior glenoid erosion: a computer-enhanced range of motion analysis

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Background: Our study purpose was to determine the optimal glenoid and humeral reverse shoulder arthroplasty (RSA) component design and position in osteoarthritic shoulders with severe glenoid retroversion deformities.
Methods: Computed tomography scans from 10 subjects were analyzed with advanced software including RSA range of motion (ROM) analysis. Variables included glenoid component retroversion of 0°, 5°, 10°, 15°, and 20° and baseplate lateralization of 0, 5, and 10 mm. Humeral variables included 135°, 145°, and 155° angle of inclination (AOI) combined with variable humeral offset.
Results: Glenoid component lateralization had the greatest influence on ROM. In comparing each ROM direction among all lateralization options independently, there were significantly greater adduction, abduction, external rotation, extension, and flexion motions with progressively greater lateralization. Internal rotation motion was greater at 10 mm only.

In analyzing the effects of glenoid version independently, no differences in adduction or abduction ROM were seen. With greater retroversion, decreased external rotation and extension motion was noted; however, greater internal rotation and flexion motion was seen with the exception of flexion at 10 mm of lateralization.

For adduction, external rotation, and extension, a more valgus AOI resulted in less ROM at each progressively greater AOI independent of humeral lateralization. Internal rotation and flexion motions were greater with a more varus AOI but not significant between each inclination angle. Abduction ROM was maximized with a more valgus AOI. Humeral lateralization had no effect on ROM.
Conclusions: In the setting of RSA for advanced glenoid osteoarthritic deformities, optimal ROM is achieved with 10-mm baseplate lateralization and neutral to 5° of retroversion mated to a humeral implant with a varus (135°) inclination angle.
Level of evidence: Basic Science Study; Computer Modeling

Keywords: Reverse shoulder arthroplasty; glenoid deformity; glenohumeral arthritis; range of motion; lateralized glenoid; B2 glenoid

The Washington University in St. Louis Institutional Review Board approved this study: No. 201409158.

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The optimal combination of reverse shoulder arthroplasty (RSA) design features and positioning to maximize range of motion (ROM) in patients with severe glenoid retroversion arthritic deformities is unknown. Glenohumeral osteoarthritis is associated with significant acquired posterior glenoid bone deformities in 35%-40% of shoulders.[5,27] Arthritic shoulders with significant glenoid retroversion deformities are associated with posterior humeral head subluxation and joint line medialization.[1,4,27] These shoulders represent significant challenges in terms of arthroplasty reconstruction, given the relatively high rate of early glenoid component aseptic loosening and instability seen with conventional anatomic total shoulder arthroplasty.[28] Recently, reverse total shoulder arthroplasty has been advocated as a more reliable surgical option for shoulders with severe erosive glenoid deformities.[22] The relatively constrained design and subsequent stability of RSA have been shown to produce reliable clinical outcomes at short-term follow-up in patients with advanced glenoid retroversion deformities.[22]

Previous research has shown that variables such as glenoid component position and glenoid and humeral design features will significantly affect glenohumeral ROM and stability after RSA.[2,10,12,20,30] Adduction impingement with traditional Grammont-type reverse implants with a more valgus angle of humeral inclination and a medialized glenosphere results in a significantly greater rate of scapular notching compared with designs with greater glenosphere lateralization.[7,19,21,24,31] Superior glenosphere placement and increased humeral component angle of inclination (AOI) have been shown biomechanically to increase component adduction impingement,[10,11] whereas glenosphere lateralization will decrease adduction impingement.[12,14,15,30] Reverse humeral implants with a more varus AOI have been shown biomechanically to result in greater glenohumeral adduction, extension, and external rotation motion compared with a more traditional valgus humeral implant.[3,11,16,30]

Previous research related to the biomechanics of RSA has been performed in experimental settings without significant erosive glenoid deformity. The unique bone deformities associated with biconcave and dysplastic osteoarthritic glenoids require significant glenoid reaming or bone grafting to obtain the necessary degree of bone support for glenoid baseplate placement. This results in further medialization of an already eroded glenoid vault, which will likely exacerbate adduction impingement with a traditional hemispheric glenoid unless the baseplate is lateralized. In addition, little is known about the optimal glenosphere version placement in the setting of severe glenoid retroversion deformity. It is likely that the interaction of glenoid component lateralization and version as well as humeral AOI will significantly affect glenohumeral ROM and function when RSA is performed in the setting of severe glenoid retroversion deformities secondary to osteoarthritis.

The purpose of this study was to determine the effects of glenoid component version and lateralization as well as humeral component AOI in shoulders with severe glenoid deformities secondary to primary glenohumeral osteoarthritis based on computer software simulated ROM analysis.

Methods

This is a retrospective diagnostic study. Ten selected shoulders with advanced glenoid bone deformity secondary to primary glenohumeral osteoarthritis were analyzed. All shoulders were planned for primary RSA, given the presence of severe glenoid deformities based on computed tomography (CT) scan analysis. Inclusion criteria included the following: primary glenohumeral osteoarthritis with a Walch B2, B3, or C deformity; glenoid retroversion deformity of ≥25°; posterior humeral head subluxation of ≥80% in relation to the reconstructed scapular plane; and adequate CT scan analysis of the involved shoulder.

Exclusion criteria included inflammatory or post-traumatic glenohumeral arthritis, prior surgery on the involved shoulder, and inadequate or poor-quality CT scan imaging.

CT imaging analysis

CT scans were performed at a single institution. CT scans were performed at 1-mm slice intervals and included the entire scapula. Images were imported into an automated software program (Glenosys; Imascap, Brest, France). Using the raw voxel data as input, this software automatically isolates those voxels that are specific to the glenoid, scapula, and proximal humerus bone anatomy by pattern recognition technology.[23,29] The software then defines a best-fit plane for the scapula and proximal humerus by considering these voxels as a point cloud. It also defines a best-fit sphere for the glenoid to isolate the point cloud of the glenoid fossa. Glenoid version, inclination, and humeral head subluxation are then automatically calculated by the software on the basis of these simulacra (Fig. 1). Humeral head subluxation is calculated on the basis of the ratio of the volume of the humeral head posterior to the plane of the scapula to the volume of the humeral head anterior to the plane of the scapula.

Imascap arthroplasty simulation and ROM analysis

The automated software permits placement of glenoid and humeral shoulder arthroplasty components into the reconstructed models of the scapula and humerus in real time with 6 degrees of freedom. For this analysis, the RSA system used was the Ascend Flex (Tornier; Bloomington, MN, USA) system. Two separate observers performed all test parameters blinded to the results of each other.

Glenoid implant protocol

A 29-mm-diameter glenoid baseplate was positioned in the center of the glenoid in the sagittal plane and in line with the inferior rim of the glenoid, allowing inferior overhang of the glenosphere. In all cases, a 36-mm-diameter glenosphere was used with no eccentric offset. The initial baseplate angle was 0° of retroversion and 0° of inclination. Next, the baseplate was medialized, simulating reaming of the glenoid until there was 50% contact of the baseplate in relation to the native glenoid surface. The amount of glenoid reaming was noted. This glenoid component positioning and reaming sequence was repeated with the glenoid baseplate at 5°, 10°, 15°, and 20° of retroversion in relation to the scapular plane. These 5 initial implant