J Shoulder Elbow Surg (2015) 24, 1367-1371

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Journal of Shoulder and Elbow Surgery

www.elsevier.com/locate/ymse

Optimal baseplate rotational alignment for locking-screw fixation in reverse total shoulder arthroplasty: a three-dimensional computer-aided design study

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Background: Baseplate loosening in reverse total shoulder arthroplasty (RTSA) remains a concern. Placing peripheral screws into the 3 pillars of the densest scapular bone is believed to optimize baseplate fixation. Using a 3-dimensional computer-aided design (3D CAD) program, we investigated the optimal rotational baseplate alignment to maximize peripheral locking-screw purchase.

Methods: Seventy-three arthritic scapulae were reconstructed from computed tomography images and imported into a 3D CAD software program along with representations of an RTSA baseplate that uses 4 fixed-angle peripheral locking screws. The baseplate position was standardized, and the baseplate was rotated to maximize individual and combined peripheral locking-screw purchase in each of the 3 scapular pillars.

Results: The mean ± standard error of the mean positions for optimal individual peripheral locking-screw placement (referenced in internal rotation) were 6° ± 2° for the coracoid pillar, 198° ± 2° for the inferior pillar, and 295° ± 3° for the scapular spine pillar. Of note, 78% (57 of 73) of the screws attempting to obtain purchase in the scapular spine pillar could not be placed without an in-out-in configuration. In contrast, 100% of coracoid and 99% of inferior pillar screws achieved full purchase. The position of combined maximal fixation was 11° ± 1°.

Conclusions: These results suggest that approximately 11° of internal rotation is the ideal baseplate position for maximal peripheral locking-screw fixation in RTSA. In addition, these results highlight the difficulty in obtaining optimal purchase in the scapular spine.

Level of evidence: Basic Science Study, Computer Modeling.

Keywords: Reverse total shoulder arthroplasty; baseplate; locking screws

Reverse total shoulder arthroplasty (RTSA) has emerged as a reliable treatment option for elderly patients with rotator cuff-deficient glenohumeral arthritis and low functional demands.[7,17] RTSA does, however, have a

This study was exempt from Investigational Review Board approval.

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1058-2746/$ - see front matter © 2015 Journal of Shoulder and Elbow Surgery Board of Trustees.
http://dx.doi.org/10.1016/j.jse.2015.01.012

higher complication rate than traditional shoulder arthroplasty.[5] Historically, glenoid loosening or failure was a frequent complication after RTSA,[4,7] especially in patients with rheumatoid arthritis, in whom a mechanical failure rate as high as 25% has been reported.[15] These complications were associated with early RTSA baseplate designs; modern baseplates with advances such as a central post and hydroxyapatite coating have not demonstrated significant baseplate failures.[1,6] Nevertheless, optimal screw placement is believed to be important to maximize initial baseplate stability and encourage bony ingrowth in this elderly and often osteoporotic population.[17] Screw and baseplate positioning is the primary surgeon-controlled means of influencing bony ingrowth onto the baseplate, which has been associated with preventing baseplate failure.[13]

Inferior placement of the baseplate has been shown to minimize scapular notching,[16] which has been associated with poorer outcomes.[11] Despite a clinical study that failed to demonstrate a significant difference in patient outcomes,[3] implantation of the glenoid component in inferior tilt has been suggested to reduce the frequency of biomechanical failure in RTSA by providing more uniform compressive forces and less micromotion at the baseplate-glenoid interface.[8] In a radiologic analysis of 12 cadaver scapulae, DiStefano et al[2] examined the optimal screw placement into the areas of thickest cortical bone (lateral aspect of suprascapular notch, scapular spine base, anterior/superior aspect of inferior pillar, and junction of the glenoid neck with the scapular spine), determining the screw lengths and trajectories that resulted in optimal and safe fixation. In a study of 12 scapulae, Parsons et al[14] demonstrated that baseplates rotated 20° toward the scapular spine (external rotation) yielded shorter screw lengths than those positioned at 0° of rotation and 20° toward the coracoid. No study to date has examined the relationship between continuous sagittal baseplate rotation and maximal screw purchase.

The purpose of our study was to determine the optimal rotation (referenced in degrees of internal rotation measured from the 12 o'clock position of the glenoid) of the RTSA baseplate with fixed-angle locking screws that obtains maximal screw purchase in the 3 bony pillars of the scapula (coracoid, scapular spine, and inferior). Our study used a three dimensional (3-D) representation of an RTSA Comprehensive Mini-Baseplate (Biomet Warsaw, IN, USA) that includes a nonlocking 6.5-mm central compression screw through a porous-coated hydroxyapatite central post with 4 peripheral fixed-angle locking screws. In addition, the uniaxial peripheral locking screws are set to 5° of divergence. Finally, the baseplate studied was a "mini" baseplate, because this plate allows maximal preservation of glenoid bone stock and allows the locking screws to be more central in the glenoid vault to optimize screw length and fixation.

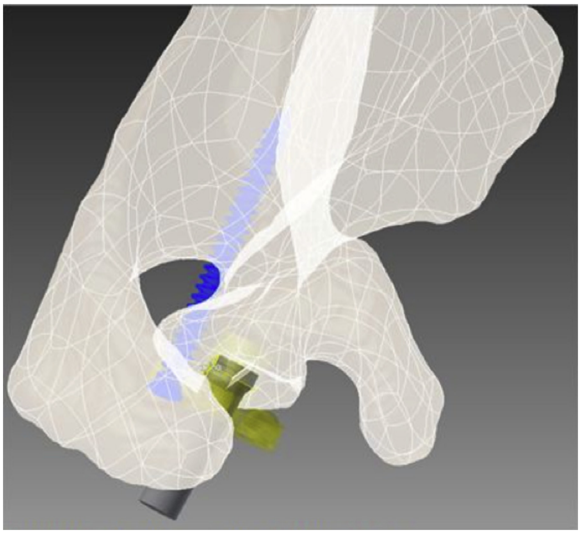

Figure 1 Axial projection demonstrates an "in-out-in" configuration of scapular spine baseplate screw.

Materials and methods

Seventy-three scapulae (43 left, 30 right) underwent initial radiographic screening for glenohumeral arthritis and were then scanned and reconstructed using 3-D computed tomography. Each scapula was imported into AutoDesk Inventor Professional 2014 software (Autodesk Inc, San Rafael, CA, USA), and a plane was generated using the most superior or inferior point of the glenoid rim and the most anterior and posterior points. The use of superior or inferior point was influenced by the default coordinate system in which the glenoids were scanned; the point chosen allowed for the best representation of the glenoid articular surface in the sagittal plane. On this defined glenoid sagittal plane, a line bisecting the glenoid was drawn from the most superior to the most inferior point. This was then converted into a 2-D object projecting out of the glenoid plane to aid in component placement. The 3-D representations of the RTSA 25-mm baseplate with fixed-angle peripheral locking screws were then imported into the AutoCad Inventor (Autodesk Inc). A custom-made guide was constructed in AutoCad Inventor to ensure the mini baseplate had a 10-degree inferior tilt with respect to the plane of the glenoid articular surface. This was done by constructing a cylinder with the same diameter as the central hole in the baseplate, protruding out of the center of a cube at a 10° tilt relative to vertical.

The scapula, along with the generated plane, mini baseplate, locking screws, and guide, was imported into the assembly portion of AutoDesk Inventor. The square base of the guide was first constrained to translate only along the glenoid sagittal plane. It was additionally constrained to translate with the 2-D object passing through the midpoint of the cube with the cylinder tilted 10° inferiorly. With this step complete, the guide was unable to rotate in any direction. The peripheral locking screws were constrained so that the threads aligned with the locking threads of the mini baseplate. The mini base plate was then constrained to rotate and translate along the guide cylinder.

An orthopedic surgeon (T.W.T.) then verified the anatomical reference points and positioned the mini baseplate within its