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Introduction: 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. The number of shoulder arthroplasty procedures performed in the United States continues to increase and the indications for RTSA continue to expand. However, one of the most common complications following RTSA is glenoid component loosening or failure. Considering that the average age of patients undergoing RTSA is greater than 70 years, accurate baseplate screw placement and maximal peripheral locking screw purchase is paramount to prevent glenoid component failure in this osteoporotic-prone patient population. 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. Our study utilizes three-dimensional computer-aided design software to calculate optimal baseplate rotation using CT DICOM images from eighteen (18) arthritic human scapulae with osteoarthritis and 3D CAD representations of the Biomet Comprehensive reverse total shoulder arthroplasty system. Optimal peripheral locking screw placement was calculated for the three major bony corridors of the scapula: the spine, coracoid, and inferior pillars.

Methods: After obtaining institutional review board approval, eighteen arthritic scapulae (5 left, 13 Right) were scanned and reconstructed using computed tomography. Each scapula was then imported into Autodesk Inventor Professional 2014 (Autodesk Inc., San Rafael, California, USA). Once in the program, 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 sagittal plane. On the defined glenoid sagittal plane, a line to bisect the glenoid was drawn from the most superior to the most inferior point. This was then converted into a 2-D object to aid in component placement. 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 10 degree tilt relative to vertical. The scapula, along with the generated plane, mini baseplate, 50 mm screw, and guide were then imported into the Assembly portion of Inventor. 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 degrees inferiorly. With this done the guide was unable to rotate in any direction. The 50 mm peripheral locking screw was 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 would then verify anatomical reference points, and position the mini-baseplate within its defined constraints. The same orthopedic surgeon would rotate the mini-baseplate to position the screw in the spine, inferior, and coracoid pillars. Screws breaching cortical bone by more than 50% of their thread diameter prior to achieving purchase in their scapular pillars were designated as “in-out-in” screws. (Figure 1). In-out-in screws were then reassessed to determine the maximum screw length prior to breaching cortical bone (see Table 1). The angle formed by the most superior aspect of the glenoid rim, the geometric center of the mini-baseplate, and the geometric center of the screw-hole was projected onto the face of the mini-baseplate and measured to determine optimal baseplate rotation.

Results: Optimal baseplate rotational placement was referenced in internal rotation (clockwise for right shoulders and counterclockwise for left shoulders) from the previously marked most superior aspect of the glenoid. The mean positions for optimal screw placement were as follows: 10 ± 3 degrees (mean ±SEM) for the coracoid pillar, 194 ± 3 degrees for the inferior pillar, and 288 ± 4 degrees degrees for the scapular spine pillar. Of note, 78% (14/18) of the screws attempting to obtain purchase in the scapular spine pillar were unable to be placed without an in-out-in configuration. For these in-out-in screws, the most common screw length before glenoid perforation was <15mm (see Table 1).

Discussion: Our results demonstrate the ideal baseplate rotation for this RTSA system to obtain maximum peripheral locking screw purchase. These rotational measurements not only serve to guide the shoulder surgeon for optimal peripheral locking screw placement, but also will be useful in future product design efforts. In addition, these results highlight the difficulty in obtaining safe purchase in the scapular spine pillar, as 78% of our scapulae were unable to achieve purchase without an “in-out-in” trajectory.
Significance: The number of shoulder arthroplasty procedures performed in the United States continues to increase and the indications for RTSA continue to expand. The results of this study will influence the reverse shoulder arthroplasty surgeon regarding ideal placement of the baseplate’s peripheral screws. Better screw purchase would result in more stable baseplate fixation and potentially superior patient outcomes.

Acknowledgments: We thank Biomet Inc, for providing CAD files of their Comprehensive Reverse Total Shoulder system as well as the CT images of the 18 arthritic human scapulae.

References:
Figure 2: Baseplate orientation with 10 degrees inferior tilt relative to the plane of the glenoid articular surface. Note that our model does not account for the glenoid reaming process, which would change the accuracy of our screw length measurement; however, current surgical technique involves minimal reaming, thereby reducing the effect on this measurement.

Figure 3: Measurement of spinal pillar screw rotational alignment.
Figure 4: Graphic representation of mean and 95 percent confidence interval of baseplate rotations.

<table>
<thead>
<tr>
<th>Summary of Fixture Rotation</th>
<th>Spine (deg)</th>
<th>Inferior (deg)</th>
<th>Coracoid (deg)</th>
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<tbody>
<tr>
<td>Average(deg)</td>
<td>274.4</td>
<td>193.6</td>
<td>19.2</td>
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<td>SD (deg)</td>
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<td>9.1</td>
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<td>SEM (deg)</td>
<td>8.6</td>
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<tr>
<th>Maximum Screw Lengths Before Bicortical Glenoid Vault Perforation</th>
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<tbody>
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