The Effectiveness Of Ct To Determine Bone Graft Resorption After Bio-Rsa

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Introduction: Bony increased-offset reverse shoulder arthroplasty (BIO-RSA) has recently gained popularity due to its ability to reduce scapular impingement and notching, providing effective treatment for patients with rotator cuff tear arthropathy. The surgical technique requires a cylindrical bone graft harvested from the humeral head be placed between a reverse shoulder arthroplasty baseplate and the native glenoid. The long-term efficacy of this procedure is dependent on osseointegration between the bone graft and the glenoid, and between the bone graft and the baseplate. Bone on-growth requires contact at the graft-baseplate interface. Failure of on-growth between graft and baseplate may occur due to bone graft resorption, micromotion due to improper fixation, or angled bone grafts.

Post-operative patient computed tomography (CT) is the primary tool for surgeons to image the bone graft to determine the level of osseointegration and/or resorption. Although CT can be an effective imaging tool, image quality is often degraded by metal artifact produced by implants. While algorithms for reducing implant metal artifact exist and can be used clinically, these methods do not completely eliminate artifact. Hence, metal artifact may decrease the ability of surgeons to detect bone graft resorption, which may present as a gap between the base of the baseplate and the bone graft.

The purpose of this study was (1) to determine if a simulated bone graft resorption gap is detectable at the graft-baseplate interface of a BIO-RSA, and (2) to quantify the accuracy and reliability of two observers in measuring gaps using CT.

Methods: Four fresh-frozen cadaveric shoulders (mean age: 56 ± 18) with preserved soft tissues and the humerus resected at the midshaft were used for this imaging study. An 8 mm thick cylindrical bone graft was harvested from the humeral head and a BIO-RSA was performed on each specimen by an experienced shoulder surgeon using an AequalisTM Reversed II Shoulder System (Tornier Inc., Amsterdam, NL). A 29 mm diameter baseplate with an extended 25 mm post was implanted with a 36mm glenosphere.

Six bone resorption gaps of varying width were simulated at the graft-baseplate interface of each specimen using precision machined (±0.05 mm) plastic spacers. Resorpton gaps were simulated in decreasing order (i.e. 8, 6, 4, 2, 1, 0 mm). The plastic spacers were used to confirm the desired gap, but were removed prior to CT scanning.

In order to simulate the density of joint fluid and to avoid high contrast caused by air, each specimen was placed in a plastic container filled with a buffered saline solution (Nerl Blood Bank Saline, Thermo Fisher Scientific). The specimen was secured in the container to avoid movement during scanning. Scanning was performed using a multi-slice scanner (GE Discovery CT750 HD) with clinical settings (140 Kvp, 250 mm field of view, 1 mm slice increment, 1.25 mm slice thickness, resolution of 512x512 and 0.488 mm pixel size). These settings are standard to minimize metal artifact for patients with shoulder implants.

Computed tomography images in digital imaging in communications and medicine (DICOM) format were uploaded to medical imaging software (Mimics V. 15.01, Materialize, Leuven, BE). All identifying information was removed from the file names in order to blind observers. Separately, two experienced observers viewed blinded and randomized specimen files to radiographically measure the simulated gap distance between the bone graft and baseplate using the built-in linear distance measurement tool. Examples can be seen in Figures 1,2,3.

Statistical analysis was performed using a Fisher Exact test to determine if each observer could determine a gap when present. A paired samples t-test was used for quantification of observer accuracy, and an inter-item paired-samples correlation was used to compare if each observer was able to determine gaps in the same simulated resorption gap images.

Results: Experienced observers were unable to determine if a simulated bone resorption gap existed (Table 1). Observers tended to report no gap (0 mm) existed for most images (75% of known 1 mm simulated gaps, 75% of 2 mm gaps, 50% of 4 mm gaps, 50% (observer 1) and 75% (observer 2) of 6 mm gaps, and 50% of 8 mm gaps).

A significant difference was found between the actual gap distance and gap measured by each observer, although there was no significant difference between observer 1 and observer 2 (Table 2).

There was a correlation between each observers ability to determine gaps in the same simulated resorption gap images (Inter-item paired samples correlation, R2 = 0.690, p < 0.001).

Discussion: This is the first known study of the ability of experienced observers to determine if a simulated bone resorption gap exists and the accuracy of gap measurement at the graft-baseplate interface of a BIO-RSA. It was found that experienced observers are not able to determine if a gap is present at the graft-baseplate interface of a BIO-RSA. Observers did not perform better with large gaps (4 to 8 mm) compared to small gaps (1 to 2 mm). It is clear that metal artifact prevented gap identification, and that without a visible gap, the observers most often believed there was no gap. Metal artifact reduction
algorithms may improve identification of large gaps, but are not likely to be effective for small gaps. This illustrates the need for a more effective imaging technique to determine if bone graft resorption has occurred following BIO-RSA.

**Significance:** This study elucidates the limitations of using post-operative CT imaging to identify bone graft healing following BIO-RSA. Imaging protocols should be reviewed and re-evaluated in the context of BIO-RSA for detecting bone graft resorption behind the implant back.

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<table>
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<tr>
<th>Gap Sizes (mm)</th>
<th>p-value</th>
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<tr>
<td>0, 1, 2</td>
<td>0.631</td>
</tr>
<tr>
<td>0, 1, 2, 4, 6, 8</td>
<td>0.240</td>
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*Table 1: Gap size and associated p-values for experienced observers’ ability to determine if a simulated bone resorption gap exists for the smallest gaps and all gaps tested (Fisher Exact test).*

<table>
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<tr>
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<th>Mean ± SD (mm)</th>
<th>p-value</th>
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<tbody>
<tr>
<td>Actual – Observer 1</td>
<td>1.83 ± 3.27</td>
<td>0.011</td>
</tr>
<tr>
<td>Actual – Observer 2</td>
<td>2.53 ± 2.62</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Observer 1 - Observer 2</td>
<td>0.70 ± 1.82</td>
<td>0.073</td>
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*Table 2: Observer accuracy in gap size measurement (mean ± standard deviation) and associated p-values (Paired samples t-test).*

**Figure 1:** A CT image in the coronal plane of a specimen with no gap (0mm simulated resorption gap). The absence of the gap was accurately identified by both observers.
Figure 2: A coronal CT image of a specimen with a 4mm simulated resorption gap, which was incorrectly reported by both observers as having no gap (0mm).

Figure 3: 4mm simulated resorption gap in the coronal plane between bone graft and baseplate accurately measured by both observers using Mimics linear measurement tool.