Inferior glenoid baseplate tilt relative to the coronal axis of the scapular body has been associated with improved results and fewer postoperative complications in reverse shoulder arthroplasty. However, the native glenoid surface is not always a reliable reference for the true scapular axis. Digital preoperative planning software and advanced imaging now allow surgeons to more precisely determine optimal glenoid placement. The purpose of this study was to evaluate the accuracy of the subchondral smile and cannulated surface guide techniques in achieving inferior glenoid baseplate tilt by using 3-dimensional preoperative planning software. Virtual glenoid baseplate preparation and implantation was performed using computed tomography scans of 16 shoulders with rotator cuff deficiency. Two techniques were used: a subchondral smile technique that preferentially reams the interior glenoid, resulting in the appearance of a smile, and a cannulated surface guide technique that references the native glenoid face to place the baseplate in 10° of inferior tilt. Using the subchondral smile technique, the glenoid baseplate was implanted at a mean of 8.9° of superior tilt relative to the transverse scapular axis. Using the surface guide technique, the glenoid baseplate was implanted at a mean of 2.8° of superior tilt. Neither the subchondral smile technique nor the 10° cannulated surface guide technique is a reliable method to produce inferior glenoid tilt relative to the transverse axis of the scapula. Three-dimensional preoperative planning software is a useful tool when attempting to achieve optimal glenoid baseplate positioning in reverse shoulder arthroplasty. [Orthopedics. 2016; 39(4):e615-e620.]

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Dr Dilisio has no relevant financial relationships to disclose. Dr Warner holds stock in Imascap. Dr Walch receives royalties from Tornier and Wright and holds stock in Imascap.

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Received: July 16, 2015; Accepted: November 25, 2015.

doi: 10.3928/01477447-20160610-04
10° to 15° of inferior glenoid tilt intraoperatively, which can be difficult because there are few reliable anatomic landmarks available for surgeons to reference. Many RSA systems have cannulated surface guides that allow surgeons to reference the glenoid surface to prepare the glenoid baseplate in inferior inclination relative to the transverse axis of the scapula. The subchondral smile technique also has been proposed; this technique directs surgeons to preferentially ream the inferior glenoid, resulting in the appearance of a smile of bleeding cancellous bone along the inferior aspect of the glenoid.

However, the native glenoid surface is not always a reliable reference for the true scapular axis, which prior gleno-sphere placement optimization studies were predicated. Digital preoperative planning software and advanced imaging now allow surgeons to more precisely determine optimal glenoid placement customized to each individual patient’s anatomy and in reference to the scapular axis. The purpose of this study was to use 3-dimensional preoperative planning software to address the following question: Are the subchondral smile and cannulated surface guide techniques accurate in achieving inferior glenoid baseplate tilt? The hypothesis was that neither the subchondral smile technique nor the cannulated surface guide technique is a reliable method to produce inferior glenoid tilt relative to the transverse axis of the scapula.

The transverse axis of the scapula was defined by a line between the trigonum of the scapula and the center of the glenoid fossa. The scapular trigonum was defined as the intersection of the scapular spine and medial scapular border. Glenoid inclination was defined by the angle formed by the intersection of the transverse axis of the scapula and the plane perpendicular to the face of the glenoid fossa.

Figure 1: The 10° inferior tilt surface guide method was performed to simulate glenoid preparation with a generic surface referencing guide that uses a guide pin and cannulated reamers to place the glenoid baseplate in 10° of inferior tilt relative to the native glenoid surface (top images). The 29-mm reamer was first aligned 10° inferior from a line perpendicular to the surface of the native glenoid. Virtual reaming then was performed in 0.5-mm increments in this trajectory until the reamer came into contact with 80% of the glenoid surface. In this shoulder, 83% seating of the glenoid component was achieved with this technique (bottom images).

Materials and Methods

Plain radiographs and Digital Imaging and Communications in Medicine (DICOM) sequences of computed tomography (CT) scans of 16 shoulders with the radiographic diagnosis of a massive rotator cuff tear as defined by Hamada et al were included in the study. The images were analyzed using Glenosys software (Glenosys 1.3; Imascap, Brest, France) for preoperative 3-dimensional shoulder arthroplasty planning. The radio-

graphs of each shoulder were classified according to Hamada for massive rotator cuff tears. The coronal glenoid morphology on the CT scans was classified according to the classification of Favard et al for glenohumeral osteoarthritis with a massive rotator cuff tear.

Using the Glenosys software, virtual preparation of the glenoid was performed to accept a 29-mm diameter glenoid baseplate with a 15-mm central post for the Tornier Aequalis Reversed Shoulder Arthroplasty system (Tornier Inc, Montbonnot Saint Martin, France). The coronal inclination of the native glenoid, axial version of the native glenoid surface, and posterior subluxation of the humeral head were recorded for each shoulder prior to glenoid preparation.

Two methods of virtual glenoid preparation were performed. For both methods, the glenoid component was placed so that the inferior aspect of the baseplate was within 1 mm of the inferior and central aspect of the glenoid and perpendicular to the native glenoid axial version.

First, the 10° inferior tilt surface guide method was performed to simulate glenoid preparation with a generic surface referencing guide that uses a guide pin and cannulated reamers to place the glenoid baseplate in 10° of inferior tilt relative to the native glenoid surface (Figure 1). The 29-mm reamer was aligned, and
then virtual reaming was performed in 0.5-mm increments in this trajectory until the reamer came into contact with 80% of the glenoid surface. By convention, the senior author (G.W.) uses a minimum value of 80% to define acceptable glenoid baseplate seating as there is currently minimal published clinical or biomechanical data that define the amount of glenoid baseplate seating required in reverse shoulder arthroplasty.

Second, the subchondral smile technique was performed by reaming the glenoid at the appropriate coronal inclination that would result in the appearance of a “smile” of reamed bone of at least 120° (Figure 2). With this technique, reaming was first trialed perpendicular to the coronal inclination of the native glenoid face. If no smile was produced, reaming was restarted with an additional 1° of coronal inferior tilt. The process was repeated in 1° increments until a smile was achieved. At this point, additional reaming was performed in 0.5-mm increments until at least 80% baseplate seating was achieved similar to the 10° surface guide method. The 1° and 0.5-mm reaming refinements are the minimum adjustments allowed by the software.

After virtual implantation by both methods, the resultant baseplate coronal tilt relative to the transverse scapular axis, baseplate coronal tilt relative to the native glenoid surface, maximal reaming depth (in mm), and percent of final baseplate seating were recorded.

Statistical Analysis

Means, ranges, standard deviations, and 95% confidence intervals (CIs) were calculated for all continuous data obtained. The Mann-Whitney test for continuous, nonparametric data was used to test the null hypothesis that there was no difference in coronal glenoid baseplate tilt and maximal reaming depth between the surface guide and subchondral smile virtual glenoid baseplate implantation techniques.

RESULTS

Sixteen shoulders in 16 patients were included in the analysis. Mean native glenoid retroversion was 13.94° (range, 0°-30°; 95% CI, 9.35-18.53), and mean superior inclination was 12.81° (range, 2°-31°; 95% CI, 9.30-16.32). Mean posterior subluxation was 66.63% (range, 30%-92%; 95% CI, 58.52-16.32). Coronal glenoid morphology as defined by Favard was type 1 in 8 patients, type 2 in 5 patients, and type 3 in 1 patient. Two patients could not be classified according to the Favard classification because no glenohumeral arthrosis or osteonecrosis was present. Two patients were classified as Hamada type 1, 1 patient as type 2, 5 patients as type 4A, 7 patients as type 4B, and 1 patient as type 5 (Table 1).

Virtual glenosphere baseplate implantation by the 10° surface guide technique resulted in a mean superior inclination of 2.81° relative to the transverse axis of the scapula (range, -8 to 21; 95% CI, -0.70
to 6.32°) and 10° of inferior tilt relative to the native glenoid surface. There was no variation in the coronal tilt measurements relative to the glenoid surface because the surface guide technique references the glenoid face to prepare the glenoid surface for baseplate implantation. Maximal reaming depth was a mean of 7.33 mm (range, 3.7-9.5 mm; 95% CI, 6.47-8.18). Baseplate seating was 84.13% (range, 80%-96%; 95% CI, 82-86.26) (Table 2). Virtual glenosphere baseplate implantation by the subchondral smile technique resulted in a mean superior tilt of 8.94° relative to the transverse axis of the scapula (range, 0°-24°; 95% CI, 5.61-12.26) and a mean superior tilt of 3.88° relative

<table>
<thead>
<tr>
<th>Patient No.</th>
<th>Native Glenoid Retroversion</th>
<th>Native Glenoid Superior Inclination</th>
<th>Posterior Subluxation</th>
<th>Favard Classification</th>
<th>Hamada Classification</th>
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<tr>
<td>1</td>
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<td>61%</td>
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<td>13.94°</td>
<td>12.81°</td>
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</table>

Abbreviation: n/a, not applicable.

### Table 2
Results of Virtual Glenosphere Implantation Using the Surface Guide and Subchondral Smile Techniques

<table>
<thead>
<tr>
<th>Measurements</th>
<th>10° Surface Guide Technique</th>
<th>Subchondral Smile Technique</th>
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<tr>
<td></td>
<td>Mean</td>
<td>Range</td>
<td>95% CI</td>
</tr>
<tr>
<td>Baseplate coronal tilt, relative to scapular axis</td>
<td>2.81°</td>
<td>-8° to 21°</td>
<td>-0.70° to 6.32°</td>
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<tr>
<td>Baseplate coronal tilt, relative to native glenoid surface</td>
<td>-10°</td>
<td>-10°</td>
<td>-10°</td>
</tr>
<tr>
<td>Maximal reaming depth, mm</td>
<td>7.33</td>
<td>3.7 to 9.5</td>
<td>6.47 to 8.18</td>
</tr>
<tr>
<td>Baseplate seating</td>
<td>84.13%</td>
<td>80% to 96%</td>
<td>82.00% to 86.26%</td>
</tr>
</tbody>
</table>

Abbreviation: CI, confidence interval.

*Mann-Whitney test.
to the glenoid face (range, -11° to 0°; 95% CI, -5.81 to -1.94). The maximal reaming depth using the subchondral smile method was 5.33 mm (range, 3.67-7.6 mm; 95% CI, 4.76-5.89), and baseplate seating was 88% (range, 80%-100%; 95% CI, 85.36-90.64) (Table 2).

A statistically significant difference was found between the mean coronal tilt of 2.81° of superior glenoid baseplate inclination by the surface guide method and 8.94° of superior tilt by the subchondral smile technique (P=.016). A significant difference also was found between the 2 methods regarding maximal reaming depth (P<.001). No significant difference was found regarding baseplate seating (P=.085).

**Discussion**

The principal results of the current study demonstrate that with the 10° surface guide technique, the glenoid baseplate was implanted at a mean of 2.8° of superior tilt relative to the scapular axis. With the subchondral smile technique, the glenoid baseplate was implanted at a mean of 8.9° of superior tilt; this difference between the 2 methods was statistically significant. The mean glenoid baseplate position therefore was superiorly inclined for both methods, which would be considered poorly positioned from the current understanding of optimal glenoid inclination.3-7,9,19 These results support the study hypothesis that neither the subchondral smile technique nor a generic cannulated surface guide is a reliable method to produce inferior glenoid tilt relative to the transverse axis of the scapula.

Several biomechanical and clinical studies have investigated optimal glenoid positioning, with most authors agreeing that inclining the baseplate inferior to the transverse axis of the scapula is advantageous.3-7,9,19-21 Gutiérrez et al17 performed several biomechanical studies and found not only does inferior tilt maximize humeral impingement-free range of motion, but it also may reduce the incidence of mechanical baseplate failure by improved stability on the glenoid face.4 In these studies, the authors concluded that 15° of inferior tilt was optimal, which is a mean of almost 18° and 24° off from the surface guide and subchondral smile methods that were used in the current study, respectively.

Randelli et al8 demonstrated a reduced risk of RSA glenohumeral dislocation when the baseplate was oriented at 10° of inferior tilt compared with neutral tilt. Simovitch et al7 found an association between scapular notching and superior tilt of the glensphere. Scapular notching has been associated with a worse Constant score, worse subjective shoulder value, decreased range of motion, decreased strength, and increased radiolucent lines around the humeral and glenoid prostheses.5,7 Although other authors have questioned the relevance of a more superiorly tilted glenoid or scapular notching,7 most evidence suggests it should be avoided if possible. The results of the current study demonstrate that surgeons should not rely on a fixed surface guide or the subchondral smile method alone to avoid superior baseplate tilt and any associated negative consequences.

In contrast to the current study, Bries et al9 found that using a surface guide intended to produce 15° of inferior inclination resulted in 8.5° of inferior inclination when comparing preoperative radiographs to the postoperative glenoid baseplate position. The authors postulated the possible reasons for the inaccuracy in producing slightly more than half of the intended inferior tilt as possible freehand technique, bending the guide pin, surgeon underappreciation of the native glenoid deformity, or purposeful underreaming due to fear of losing glenoid bone stock.19

The current study differs primarily from the study by Bries et al9 in that 3-dimensional CT reconstructions and digital preoperative planning software were used to precisely place and measure glenoid baseplate position. Several authors have concluded that both plain radiographs22 and 2-dimensional CT23-25 are less accurate than 3-dimensional CT in assessing glenoid morphology and version. Regardless, Bries et al19 still found that their surface guide placed the glenoid component a mean of 7.5° less than expected when using a 15° guide.

In the current study, when using the surface guide method, a mean of 7.3 mm of reaming was required to obtain at least 80% glenoid baseplate seating. In comparison, 5.33 mm of reaming was required with the subchondral smile technique. This is likely due to the tendency to ream more perpendicular to the native glenoid face using the subchondral smile technique without the obligate 10° of inferior tilt with the surface guide method. As a result, more inferior reaming is performed with more inferior tilt, which may be why the surface guide method removed more bone.

Although this study highlights the theoretical precision that can be achieved with 3-dimensional preoperative planning software, the clinical utility of this technology has yet to be defined. Computer-navigated arthroplasty and custom patient-specific cutting guides are becoming more popular throughout the field of orthopedics. However, although this technology can assist surgeons in more accurately achieving precise component alignment, there is little evidence that these techniques can improve the clinical outcome.26-29 The actual value of this technology in regard to outcome in relationship to cost remains to be determined.

The current study has several limitations. Primarily, DICOM sequences of a random selection of 16 shoulders were chosen to analyze from a database of several hundred shoulders that had undergone RSA. Including additional shoulders with a greater variety of glenoid morphologies may have demonstrated different results. The same size and type of glenoid baseplate was used throughout the analysis, and the results may have been different if
additional types of RSA baseplates were used. Finally, the transverse axis of the scapula is precisely measured with the use of the Glenosys software, but there can be variability in the way in which surgeons define the scapular axis.

Conclusion

Neither the subchondral smile technique nor a 10° cannulated surface guide is a reliable method to produce inferior glenoid tilt relative to the true transverse axis of the scapula. Using the surface guide technique, the glenoid baseplate was implanted at a mean of 2.8° of superior tilt relative to the scapular axis. Using the subchondral smile technique, the glenoid baseplate was implanted at a mean of 8.9° of superior tilt. Surgeons should not rely on generic surface guides or the subchondral smile method alone to avoid superior baseplate tilt and any associated negative consequences. Three-dimensional preoperative planning software is a useful tool when attempting to achieve optimal glenoid baseplate positioning in RSA.

References


