Clinical outcomes, especially range of motion, after reverse shoulder arthroplasty depend on technical and implant factors. Together, the non-anatomic design of reverse shoulder arthroplasty and the pathoanatomic changes associated with the disease process may contribute to postoperative functional limitations. Specifically, loss of external and internal rotation can occur. Humeral component version, defined as the position of the humeral head component relative to the frontal axis of the elbow joint, is a known variable that affects rotation and may affect clinical outcomes.

Effect of Humeral Component Version on Outcomes in Reverse Shoulder Arthroplasty

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Abstract

Although reverse shoulder arthroplasty provides excellent clinical results in appropriately selected patients, loss of external and internal rotation may occur. Component selection, design, and placement affect postoperative results. Recent studies considered the effect of humeral component version on functional results. The current study investigated whether humeral stem retroversion affects the outcomes of reverse shoulder arthroplasty with a retrospective review of a multisurgeon, industry-sponsored, prospectively gathered database of a single reverse shoulder arthroplasty implant. All patients had at least 2-year follow-up. Clinical outcomes, including American Shoulder and Elbow Surgeons score, visual analog scale pain score, Short Form-12 Mental and Physical Component scores, range of motion, and internal rotation function, were compared between patients with humeral retroversion of 10° or less (group A) and those with humeral retroversion of 20° or greater (group B). Radiographic outcomes were compared. The analysis included 64 patients (group A, 29 patients; group B, 35 patients). No clinical or statistically significant difference was found in American Shoulder and Elbow Surgeons scores. Both groups showed statistical and clinical improvement vs preoperative scores, with group A averaging 77.8 and group B averaging 79.2 at final follow-up. No differences were found between groups in range of motion or ability to perform tasks that require shoulder internal rotation. Patients can expect good clinical improvement after reverse shoulder arthroplasty. No difference was found in clinical or radiologic outcomes based on humeral component retroversion. Despite the theoretical increase in external rotation when the humeral component is placed closer to native retroversion, the results did not show this effect. [Orthopedics. 2017; 40(3):179-186.]
During the past decade, reverse shoulder arthroplasty has provided excellent clinical results in appropriately selected patients. Initially, general indications for reverse shoulder arthroplasty were limited to patients with rotator cuff arthropathy. However, as surgeons became more experienced with the prosthesis, indications expanded to include severe primary glenohumeral arthritis, proximal humerus fracture, and revision shoulder arthroplasty.

Specific recommendations for humeral component version placement are varied and are based mostly on expert opinion. Historically, with earlier reverse shoulder arthroplasty designs, experts suggested placing the humeral component at 0° version to minimize glenoid component complications. With these Grammont-style humeral components, experts have warned against placing the humeral component in retroversion to avoid increasing instability, and some have even suggested placing the component in some anteversion. More recently, device manufacturers have designed humeral stems with more varus alignment to improve functional outcomes. Biomechanical studies of these components confirmed that increasing humeral retroversion increases impingement-free external rotation at the expense of internal rotation. The few clinical studies that evaluated the effect of changing the humeral version of these non–Grammont-style humeral components were single-surgeon case series. The current study evaluated 2-year clinical and radiologic outcomes with multiple surgeons to assess whether humeral stem retroversion affects outcomes. The study hypothesis was that greater humeral retroversion (>20°) would increase external rotation and improve clinically validated functional outcome scores or radiographic outcomes.

**Materials and Methods**

This study queried an industry-sponsored database of patients who underwent surgery performed by 12 fellowship-trained shoulder and elbow surgeons with a specific reverse shoulder arthroplasty implant (Zimmer Trabecular Metal Reverse Shoulder System; Zimmer Biomet). Institutional review board approval was obtained, and approval was obtained from Zimmer Biomet and participating surgeons to gather data for research purposes from the database. The database compiles several clinical outcomes at prescribed pre- and postoperative time points. Inclusion criteria for the database included patients 18 years and older who were able to provide written informed consent for reverse shoulder arthroplasty and had a diagnosis of osteoarthritis, rheumatoid arthritis, posttraumatic arthritis, ununited humeral head fracture, acute 3- or 4-part humeral head fracture, avascular necrosis, gross rotator cuff deficiency, or failed shoulder arthroplasty. Patients were excluded if they were pregnant, if they were in prison, if they abused alcohol or drugs, if they were unable to provide and participate in the informed consent process, and if they did not meet the criteria to undergo reverse shoulder arthroplasty. Additional exclusion criteria included significant neurologic injury or disease affecting the brachial plexus or axillary nerve, local or systemic infection, significant proximal bone loss, revision of a hemiarthroplasty, or known allergy to the implanted materials.

Patient selection included all adult patients in the database with at least 2 years of follow-up data. Patients were excluded if intraoperative humeral stem retroversion was not recorded. Humeral stem version was assessed intraoperatively by measuring the angle of the humeral socket component relative to the axis of the forearm at the time of final implantation. Surgeons used specific alignment guides on the handle of the humeral component to assess version, with the forearm used as reference. The version of each humeral component was decided by each individual surgeon at the time of surgery and was not based on matching the patient’s native version. Most patients had humeral stem retroversion of 20° or greater (range, 20°-30°) or 10° or less (range, 0°-10°). All glenoid baseplates were placed without altering the native glenoid version. Patients who had significant glenoid deformities or who required grafting of the glenoid were excluded from analysis.

Overall, 74 patients were eligible for inclusion. Of these patients, 10 had stems placed at 15° and were excluded from analysis to create 2 homogeneous groups for comparison, with a total of 64 patients left for analysis. Basic demographic information included age, sex, race, primary diagnosis, previous open or arthroscopic procedure, and duration of symptoms before surgery. Preoperative clinical outcome scores, including American Shoulder and Elbow Surgeons (ASES) score, visual analog scale score for pain, and Short Form-12 (SF-12) Mental and Physical Component scores were obtained. Postoperative clinical outcome measures included ASES, visual analog scale pain score, and SF-12 Mental and Physical Component scores at 6 months, 1 year, and 2 years of follow-up. Additionally, pre- and postoperative active and passive forward flexion and external rotation, with the arm at the side and at 90° abduction, were obtained. Postoperative radiographic measures included assessment of stem placement, presence of scapular notching (based on the Nerot-Sirveaux system), and evaluation of humeral stem loosening at 6 months, 1 year, and 2 years postoperatively. Additionally, postoperative complications, including the need for revision, were recorded.

Patients were divided into 2 groups based on humeral component retroversion of 10° or less (group A) or 20° or greater (group B). Group A included 29 patients, 9 men and 20 women, with average age at the time of surgery of 69 years. Group B included 35 patients, 16 men and 19 women, with average age at the time of surgery of 69 years. Distributions were similar for primary diagnosis, age, race, and duration of symptoms (Table 1).
The primary outcome measure was the difference in ASES scores between each patient group at each follow-up time point, for which the minimally clinically important difference was 6.4.\textsuperscript{12-14} Secondary outcome measures included postoperative visual analog scale pain scores, SF-12 Mental and Physical Component scores, and postoperative radiographic outcomes, as previously described. A previous clinical study showed decreased ability to perform tasks requiring internal rotation as a result of increased external rotation.\textsuperscript{4} For this reason, the current study analyzed specific components of the ASES score that address activities that require internal rotation, namely, the ability to manage toileting and washing the back, to assess for a difference between the groups. All outcome variables underwent statistical analysis with a random effects model to evaluate for statistical significance, with 2-sided alpha of 0.05 and beta of 0.80. Continuous variables were assessed with independent samples $t$ test, and categorical variables were assessed with chi-square test. Post hoc power analysis was performed to detect a 20-point difference in ASES score, which has been defined as the minimal clinically important difference,\textsuperscript{15} between groups with the statistical parameters and determined that 27 patients would be needed in each group.

**RESULTS**

Overall, no clinical or statistical significance was found for average ASES score for group A vs group B at any postoperative time point (Figure 1). Scores improved from 39.1 to 72.5 for group A and from 40.5 to 71.9 for group B from preoperatively to 6 months postoperatively. Scores showed mild improvement 1 year postoperatively, with group A scores improving to 78.3 and group B scores improving to 80.2. No change was seen at 2-year follow-up compared with 1-year follow-up, with the group A score averaging 77.8 and the group B score averaging 79.2. Scores for both groups showed statistically significant improvement vs preoperative scores at all postoperative time points ($P<.001$ for both groups). No statistically significant difference was found between group A and group B for average ASES score at any time point ($P=.73$).

Significant improvements in all range of motion parameters tested over time were found within both groups (Table 2). Active forward flexion improved for group A from 71° to 138° at 2 years of follow-up, and similar improvements were seen for group B, with findings improving from 77° to 144°. This difference was not statistically significant between groups ($P=.81$). Similar findings were seen with passive forward flexion, with group A improving from 118° to 147° and group B improving from 99° to 153° ($P=.34$).

Active external rotation, both at the side and at 90°, was equivalent at 2-year follow-up between groups. For group A, active external rotation at the side averaged 36° compared with 31° for group B ($P=.46$).

---

**Table 1**

<table>
<thead>
<tr>
<th>Demographic</th>
<th>Group A</th>
<th>Group B</th>
<th>$P$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, mean, y</td>
<td>69.2</td>
<td>68.5</td>
<td>.78</td>
</tr>
<tr>
<td>Sex, male/female, No. (%)</td>
<td>9 (31)/20 (61)</td>
<td>16 (46)/19 (54)</td>
<td>.31</td>
</tr>
<tr>
<td>Operative side, right/left, No. (%)</td>
<td>10 (34)/19 (66)</td>
<td>18 (51)/17 (49)</td>
<td>.44</td>
</tr>
<tr>
<td>Duration of symptoms, mean, d</td>
<td>78.9</td>
<td>80.1</td>
<td>.96</td>
</tr>
<tr>
<td>Diagnosis, No.</td>
<td></td>
<td></td>
<td>.31</td>
</tr>
<tr>
<td>Rotator cuff deficiency</td>
<td>19</td>
<td>18</td>
<td></td>
</tr>
<tr>
<td>Osteoarthritis</td>
<td>7</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>Proximal humerus fracture</td>
<td>1</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Failed arthroplasty</td>
<td>1</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Rheumatoid arthritis</td>
<td>1</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>0</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Previous arthroscopic surgery, No.</td>
<td>10</td>
<td>7</td>
<td>.25</td>
</tr>
<tr>
<td>Previous open surgery, No.</td>
<td>2</td>
<td>5</td>
<td>.44</td>
</tr>
</tbody>
</table>

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**Figure 1:** Pre- and postoperative American Shoulder and Elbow Surgeons (ASES) scores. $P=.73$ between groups. Abbreviation: Pre-op, preoperative.
Similarly, active external rotation at 90° at 2 years was 71° for group A and 64° for group B (P=.56). Passive external rotation at the side was equivalent at 2-year follow-up, with group A averaging 44° and group B averaging 41° (P=.53). Similar findings were noted with passive external rotation at 90°, with a mean value of 79° for group A and 71° for group B (P=.07).

Figure 2 shows the results of visual analog scale pain scores. Preoperatively, both groups had equivalent pain scores (group A, 5.8; group B, 5.1; P=.1) Overall, both groups showed significantly improved visual analog scale pain scores compared with preoperative values (P<.001), with group A reporting an average score of 1.5 and group B reporting an average score of 1.0. No difference was found between groups at final follow-up (P=.1).

Figure 3 and Figure 4 show SF-12 Physical (Figure 3) and Mental Component (Figure 4) scores. Both groups showed statistically significant improvement of SF-12 Physical Component scores postoperatively. The statistical model showed a statistically significant difference between groups at final follow-up, with a score of 43.6 for group A and a score of 46.7 for group B (P=.05). This difference was not clinically important. The SF-12 Mental Component score was the only outcome score that did not show improvement postoperatively compared with preoperatively. At 2-year follow-up, the SF-12 Mental Component score averaged 52.0 for group A and 56.4 for group B. Again, the statistical model found a statistically significant difference between the groups (P=.05), but this small difference was not clinically significant.

Based on available postoperative radiographic assessment by the surgeon, placement of the humeral stem component was considered neutral for 26 patients in group A and 29 patients in group B. Humeral stems were cemented in 38 cases and press-fit in 26 cases. At 2-year follow-up, no humeral components showed evidence of radiographic loosening and no glenoid components showed signs of loosening or superior migration.

The prevalence of scapular notching increased in both patient groups and was limited to grade 1 or 2. The overall prevalence of notching 6 months postoperatively was 10% (6 of 60 available radiographs) and increased to 25% at 2-year follow-up (15 of 59 available radiographs, P=.03). No significant increase in notching was seen between 6-month and 1-year postoperative radiographs (19.6%, 10 of 51 radiographs; P=.4). Table 2 shows the prevalence of grade 1 or 2 notching based on humeral stem retroversion. Both groups showed increased notching at longer follow-up, but no statistically significant difference in the rate of notching was found between groups.

Assessment of the ASES score components that required internal rotation of the shoulder (ability to manage toileting

| Table 2

<table>
<thead>
<tr>
<th>Range of Motion Outcomes</th>
<th>Group A</th>
<th>Group B</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Outcome</strong></td>
<td>Preoperative</td>
<td>Final Postoperative</td>
</tr>
<tr>
<td>Active forward elevation</td>
<td>71°</td>
<td>138°</td>
</tr>
<tr>
<td>Passive forward elevation</td>
<td>118°</td>
<td>147°</td>
</tr>
<tr>
<td>Active external rotation at side</td>
<td>25°</td>
<td>36°</td>
</tr>
<tr>
<td>Passive external rotation at side</td>
<td>33°</td>
<td>44°</td>
</tr>
<tr>
<td>Active external rotation at 90° abduction</td>
<td>29°</td>
<td>71°</td>
</tr>
<tr>
<td>Passive external rotation at 90° abduction</td>
<td>41°</td>
<td>79°</td>
</tr>
</tbody>
</table>

*aBoth groups had statistically significant improvements from preoperative to postoperative motion in all measurements (P<.001).*

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**Figure 2:** Pre- and postoperative visual analog scale (VAS) pain scores. P=.1 between groups. Abbreviation: Pre-op, preoperative.
and ability to wash the back) is detailed in Table 3 and Table 4. For ability to perform toilet tasks, equivalent numbers of patients in both groups showed improvement for this self-reported task at the 2-year postoperative visit compared with preoperatively (Table 3). These improvements were statistically significant compared with preoperative values for individual groups (group A, \( P = .001 \); group B, \( P < .001 \)). Overall, 16 patients in group A (55%) and 19 patients in group B (54%) showed improvement. There was no difference based on humeral component version regarding patients reporting worse outcomes with toileting after surgery (\( P = .24 \)). Additionally, patients showed modest improvement in the ability to wash the back after surgery (Table 4). At the final follow-up visit, 12 patients in group A (41%) and 19 patients in group B (54%) reported improvement. Neither group showed statistically significant improvement compared with preoperative function (group A, \( P = .5 \); group B, \( P = .08 \)). At the final postoperative visit, a higher percentage of patients had worse outcomes in group A compared with group B (7 vs 3 patients), but these differences were not statistically significant (\( P = .08 \)).

Overall, for internal rotation function based on ASES evaluation, all patients showed improvement with toileting compared with preoperative status, with no difference based on humeral component version. The ability to wash the back, which requires more internal rotation than toileting, did not show as much improvement based on preoperative assessment. Again, no difference was found in the ability to perform this task based on humeral version.

Few postoperative complications required revision. Only 2 revision procedures, 1 from each group, were performed in the 2-year follow-up period. One patient in group A who had humeral component version of 10° had recurrent instability of the prosthesis and required revision with exchange for a thicker polyethylene liner. The other complication was an infected prosthesis in a patient in group B (30° version) that required explant with placement of an antibiotic spacer and subsequent revision reverse shoulder arthroplasty.

**Discussion**

This retrospective multicenter study was performed to determine the effects of humeral version on patient-reported outcomes and complication rates 2 years after reverse shoulder arthroplasty. The study hypothesis was that greater humeral retroversion would improve range of motion and patient-related outcomes. Humeral version did not affect patient-related outcomes (ASES score, visual analog scale pain score, or range of motion) or complication rates, including instability and dislocation. The analysis found statistically significant differences in SF-12 Mental and Physical Component scores as well as statistical differences in visual analog scale instability scores, but these differences were not clinically significant.

Outcomes after reverse shoulder arthroplasty are typically excellent. However, certain limitations still exist, most notably, inability to regain internal rotation to the same extent as forward elevation and
external rotation. Theoretically, version of the humeral stem can affect rotational movement. In a large French multicenter trial with a Grammont-style prosthesis, placement of the stem at neutral version was associated with better outcomes in activities of daily living, strength, Constant score, radiographic loosening, and glenoid complications compared with placing the stem at 20°.6,17 Based on the findings of this study, several experts suggested placing the humeral stem at neutral to reduce complications.6 However, other studies of reverse shoulder arthroplasty showed a decrease in external rotation with the stem placed in neutral version.2,18

More recently, in an effort to improve outcomes, humeral component designs have changed to better match native neck shaft angle compared with Grammont-style designs. Similarly, surgeons have postulated that placing humeral components at more retroversion, or even matching native version, may improve outcomes. However, few studies have focused on the effects of humeral component placement. A variety of biomechanical and computer simulation studies have attempted to determine the optimum placement of the humeral component. Table 5 outlines these results, which show that increasing retroversion leads to increased external rotation.3,5,9,10 The results on the effect of humeral version on stability are mixed, with some studies showing increased impingement and instability with increased retroversion.3,5 However, other studies showed no effect of humeral version on stability.

Historical concerns about placement of the humeral component at increased retroversion stemmed from concern about increasing complications and glenoid loosening.6,17 The findings of the current multicenter analysis found a low rate of complications. Only 1 dislocation occurred in the entire cohort, and no component loosening was found. Similarly, scapular notching, which has been reported in 50% to 96%,6,17 of cases, occurred in only 25% of 2-year radiographs, with only low-grade findings. This low rate of complications and radiographic loosening is likely related to a combination of improved component design, with a slightly lateral center of rotation, a more varus neck shaft angle, and a better understand-

### Table 3

<table>
<thead>
<tr>
<th>Ability</th>
<th>Group A</th>
<th></th>
<th>Group B</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Preoperative</td>
<td>Final Postoperative</td>
<td>Preoperative</td>
<td>Final Postoperative</td>
</tr>
<tr>
<td>No difficulty</td>
<td>8 (28)</td>
<td>21 (72)</td>
<td>11 (31)</td>
<td>28 (80)</td>
</tr>
<tr>
<td>Some difficulty</td>
<td>7 (24)</td>
<td>5 (17)</td>
<td>9 (25)</td>
<td>3 (9)</td>
</tr>
<tr>
<td>Very difficult</td>
<td>6 (20)</td>
<td>2 (7)</td>
<td>5 (14)</td>
<td>2 (5.5)</td>
</tr>
<tr>
<td>Unable</td>
<td>8 (28)</td>
<td>1 (4)</td>
<td>10 (29)</td>
<td>2 (5.5)</td>
</tr>
</tbody>
</table>

*Both groups showed statistically significant improvements from preoperative to postoperative function (P = .001).*

### Table 4

<table>
<thead>
<tr>
<th>Ability</th>
<th>Group A</th>
<th></th>
<th>Group B</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Preoperative</td>
<td>Final Postoperative</td>
<td>Preoperative</td>
<td>Final Postoperative</td>
</tr>
<tr>
<td>No difficulty</td>
<td>4 (14)</td>
<td>7 (24)</td>
<td>2 (6)</td>
<td>8 (23)</td>
</tr>
<tr>
<td>Some difficulty</td>
<td>4 (14)</td>
<td>6 (21)</td>
<td>1 (3)</td>
<td>10 (29)</td>
</tr>
<tr>
<td>Very difficult</td>
<td>7 (24)</td>
<td>5 (17)</td>
<td>10 (29)</td>
<td>5 (14)</td>
</tr>
<tr>
<td>Unable</td>
<td>14 (48)</td>
<td>11 (28)</td>
<td>22 (62)</td>
<td>12 (34)</td>
</tr>
</tbody>
</table>

Rhee et al reported clinical results from a retrospective single-surgeon series evaluating functional outcomes with 0° and 20° retroversion. At minimum 2-year follow-up for patients undergoing reverse shoulder arthroplasty for rotator cuff arthropathy, no difference was found for external or internal rotation based on humeral retroversion. Constant scores were equivalent in both groups at final follow-up. These authors also evaluated activities of daily living and found that the 0° retroversion group had significant improvement for activities that involved internal rotation (eg, washing the back, fastening a bra), but otherwise showed no difference. Additionally, they reported only 1 dislocation in the entire series of 62 patients. Scapular notching was found in 24% of cases, with no difference based on humeral version. The current findings concur with those of Rhee et al.4 In the current study, all patients showed improvement in clinical and functional outcomes without the improvement in external rotation seen in biomechanical studies. However, no difference was found in the ability to perform tasks that require more internal rotation based on humeral component version.
ing of proper glenoid baseplate and glenosphere placement.

Limitations

Even though this study included results from a multicenter, prospectively collected database, it had limitations. The current study may be underpowered to show a significant difference in range of motion and clinical outcome variables, given the small differences seen between patient groups. However, this difference in outcome measures likely is not clinically important. Additionally, soft tissue management and fixation of the humeral component were not uniform. Indications were also varied and included some proximal humerus fractures. Further, the database did not include body mass index, which may affect outcomes. However, recent studies showed no effect on short- and intermediate-term outcomes based on body mass index. Humeral component version was based on surgeon preference and not on an attempt to match native humeral version. Despite these limitations, the authors believe that the current study represents a large, wide sampling of reverse shoulder arthroplasty procedures and can have broad applications to drive continued research into optimal component position in reverse shoulder arthroplasty.

CONCLUSION

At 2-year follow-up after reverse shoulder arthroplasty, patients can expect improvements in functional outcomes and range of motion. This study found no difference in clinical or radiologic outcomes based on humeral component retroversion. Despite the theoretical increase in external rotation when the humeral component is placed closer to native retroversion, the study results did not show these findings. Additionally, no difference was found in the ability to perform tasks that require internal rotation based on humeral component version.

REFERENCES


2. Werner CM, Steinmann PA, Gilbart M, Gerber C. Treatment of painful pseudoparesis due to irreparable rotator cuff dysfunction with the Delta III reverse-ball-and-socket to-


