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Baseplate retroversion does not affect postoperative outcomes after reverse shoulder arthroplasty

Randa Elmallah, MD[a], Daniel Swanson, BS[b], Kiet Le, PA-C[b,c], Jacob Kirsch, MD[b,c], Andrew Jawa, MD[b,c,*]

[a]*Department of Orthopaedic Surgery, Massachusetts General Hospital, Harvard Medical School, Boston, MA, USA*
[b]*Boston Sports and Shoulder Center, Waltham, MA, USA*
[c]*Department of Orthopaedic Surgery, New England Baptist Hospital, Boston, MA, USA*

Background: There is concern that excessive glenoid component retroversion leads to altered biomechanics and baseplate failure in reverse shoulder arthroplasty (RSA). However, much of this has been rooted in the total shoulder arthroplasty experience. In the current literature, it is not well defined whether glenoid baseplate positioning in reverse arthroplasty affects functional outcomes. Our practice has been to preserve glenoid bone stock without aiming for a certain degree of retroversion. We aimed to evaluate the correlation between pre- and postoperative retroversion in a cohort of RSAs and determine the effect of glenoid retroversion on functional outcomes, range of motion, and postoperative complications.

Methods: A retrospective review of patients who had an RSA between 2017 and 2019 was performed. Preoperative computed tomography scans were used to assess preoperative retroversion, and axillary radiographs were used for postoperative retroversion. Outcome measures included American Shoulder and Elbow Surgeons score, visual analog scale for pain score, Single Assessment Numeric Evaluation score, range of motion, radiographic lucency, and complications.

Results: A total of 271 patients were eligible for the study. There was a 76.9% 2-year follow-up rate. In total 161 patients had postoperative retroversion $\leq 15^\circ$ (group A), and 110 patients had retroversion $>15^\circ$ (group B). There were no significant differences in American Shoulder and Elbow Surgeons, visual analog scale, or Single Assessment Numeric Evaluation scores. There were also no significant differences in postoperative range of motion. There was 1 baseplate failure in each group, and there was 1 patient in group B with asymptomatic radiographic loosening (baseplate at risk). The mean change in pre- to postoperative retroversion was 1° and 4° in groups A and B, respectively.

Conclusion: There was no significant difference in postoperative functional outcomes, range of motion, or complications between patients who had baseplate retroversion $\leq 15^\circ$ vs. those who had retroversion $>15^\circ$.

Level of evidence: Level III; Retrospective Cohort Comparison; Prognosis Study

Keywords: Reverse total shoulder arthroplasty; glenoid retroversion; clinical outcome

It has been postulated that failure to restore glenoid component version to acceptable ''normal'' values may lead to suboptimal joint biomechanics and subsequent component failure.[5] In particular, there has been an emphasis on the use of eccentric reaming or augmented baseplates and bonegraft for erosion $>15^\circ$.[3,14] However,

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*Reprint requests: Andrew Jawa, MD, Boston Sports and Shoulder Center, 840 Winter Street, Waltham, MA 02451, USA.

E-mail address: andrewjawa@gmail.com (A. Jawa).

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many of the concerns for component failure are rooted in total shoulder arthroplasty (TSA). The inherent instability of the glenoid component in anatomic TSA suggests that eccentric loading may lead to early glenoid component failure with increased cement stress, increased posterior glenohumeral peak stresses, and micromotion at the cement-bone interface.[6,18,23] This has led to the common approach of correcting "excessive" retroversion.

Regardless of implant, there are complications associated with excessive correction of native retroversion. In reverse shoulder arthroplasty (RSA), it may be associated with baseplate failure, possibly due to inadequate central or peripheral screw purchase in the remaining native bone. The use of large bone grafts to correct version may lead to increased likelihood of resorption, or excessive reaming into cancellous bone may predispose to micromotion as well as potential component medialization.[11] In addition, the guidelines for the use of augmented baseplate or bone graft in correcting retroversion are unclear, which raises the question of whether or not correction is indicated.[9,24] It has been shown that there is considerable variability between surgeons in baseplate positioning and when augments are used, irrespective of the severity of glenoid deformity. This further demonstrates that there is little consensus on optimal baseplate positioning.[21]

The semiconstrained design of the RSA can mitigate soft tissue asymmetric tensioning associated with posterior glenoid wear and provide more robust glenoid fixation, and therefore it does not require as much correction of glenoid retroversion. Although the use of baseplate augmentation to decrease retroversion has demonstrated improvements in functional scores,[2,14] it is unclear whether this is directly correlated to correction of version or just a function of undergoing a successful pain-relieving RSA.[4,16,20] In the current literature, it is not well defined whether glenoid baseplate positioning in RSA affects functional outcomes, and it has been our practice to preserve glenoid bone stock without aiming for a certain degree of retroversion. As a result, the purpose of our study was to evaluate the correlation between pre- and postoperative retroversion in a cohort of RSAs and determine the effect of baseplate retroversion on functional outcomes, range of motion (ROM), and postoperative complications.

Methods

Patient selection

After approval from the institutional review board, a retrospective review of a prospectively maintained TSA database (OBERD, Columbia, MO, USA) was performed to identify all patients who underwent primary RSA between 2017 and 2019. All procedures were performed by a single high-volume shoulder and elbow surgeon. Inclusion criteria consisted of patients who underwent primary RSA with preoperative computed tomography (CT) scans and minimum 2-year clinical and radiographic follow-up with complete preoperative and postoperative outcome scores, including patient-reported outcome measures and ROM. Exclusion criteria consisted of patients who: (1) did not undergo primary RSA, (2) did not have minimum 2-year clinical or radiographic follow-up, (3) had inadequate postoperative axillary lateral X-rays to allow for accurate measurements, and (4) had incomplete documented patient-reported outcome measures or ROM.

Surgical technique

All surgeries were performed by the senior author through a standard anterior deltopectoral approach. In all cases, the biceps tendon was tenodesed to the pectoralis major, and a subscapularis peel was performed. This or any remaining capsular tissue was subsequently repaired at the end of the procedure, if possible. During glenoid reaming, the aim was to preserve glenoid bone stock and ream to a single concavity. A noncemented inlay or onlay design humeral stem was used in all patients. The onlay prosthesis used was either the Zimmer Anatomical (Zimmer Biomet, Warsaw, IN, USA) or the Tornier Aequalis Ascend Flex (Wright Medical, Memphis, TN, USA). The inlay prosthesis used was the DJO surgical Altivate Reverse prosthesis (DJO; LLC, Lewisville, TX, USA). The postoperative rehab protocol was consistent, which included complete immobilization of the shoulder with no external rotation past neutral, and then a home exercise program with progressive ROM beginning at weeks 2-6, depending on patient condition. No internal rotation behind the back was allowed for the first 6 weeks. After this, a gradual progression of active ROM and strengthening was started.

Radiographic evaluation

Preoperative retroversion measurements were assessed using CT scans that were uploaded onto online preoperative planning software (Materialise Surgicase). Standard anteroposterior Grashey and axillary lateral radiographs were used to assess implant position and glenoid component retroversion postoperatively. Implant retroversion was assessed on the axillary view. Using a method previously described,[24] a parallel line overlying the center screw of the glenoid component and a line parallel to the body of the scapula were drawn. The angle between these 2 lines was used to determine the glenoid version (see Fig. 1). X-rays were used to measure postoperative glenoid version as routine postoperative CT scans are costly and expose patients to excessive radiation. In addition, using high-quality axillary X-rays (minimal space between the acromion and glenoid and no humeral head rotation), no statistically significant differences in version measurements have been found when compared with CT scans, and they can be accurate to within 1° to 3° with excellent correlation.[12,19] A value of 15° of retroversion was used as our cutoff based on prior studies looking at TSA.[24] Lucency around the baseplate or central screw was assessed on postoperative radiographs. A baseplate failure was defined as radiographic evidence of a change in hardware position or broken screws, as well as onset of symptoms, such as increased pain or decreased function. A baseplate at risk was defined as radiographic lucency without any change in hardware position in asymptomatic individuals. Radiographic assessments were performed by a single reviewer and subsequently by a

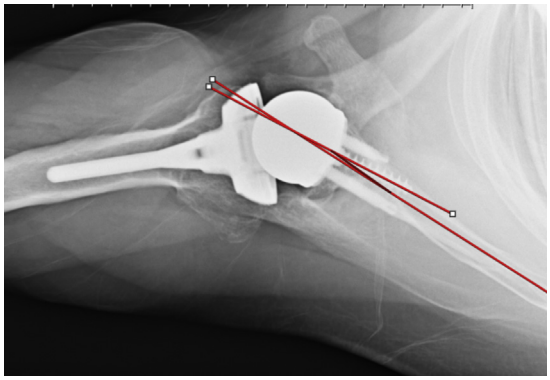

Figure 1 Measurement of baseplate version. The angle between a parallel line overlying the center screw of the glenoid component and a line parallel to the body of the scapula.

second reviewer who was blinded to the results. The interobserver correlation coefficient was 0.59 (95% confidence interval, 0.52-0.65), indicating moderate consensus. Any discrepancies were then reviewed by the senior author.

Clinical evaluation

A standardized clinical assessment was used for all patients, which included a survey to assess functional outcome scores at every visit, as well as evaluation of active ROM. The outcome scores that are used are the visual analog pain score (VAS), the American Shoulder and Elbow Surgeons shoulder assessment (ASES), and the Single Assessment Numeric Evaluation score (SANE). The VAS is measured on a scale of 1-10. The ASES is measured on a scale of 0 (worst) to 100 (best) and incorporates pain and ability to perform activities of daily living. The SANE scoring system is a 1-question subsequent assessment of their shoulder compared with normal (scale of 0-100).[1]

The ROM evaluation included forward flexion, external rotation at zero degrees of abduction, and internal rotation. Internal rotation was determined by the uppermost vertebral level reached by the thumb of the affected extremity. A scoring system was then assigned to the vertebral levels reached. Zero was assigned to internal rotation to the hip, 1 to internal rotation to the sacrum, 2 to the L5 vertebra, 3 to the L4 vertebra, and each sequential number assigned to the next cephalad vertebra. All measurements were performed by the senior surgeon.

Statistical analysis

Descriptive statistics were determined and expressed as means, standard deviations (SD), and percentages. Statistical tests including the Student *t*-test, Mann-Whitney *U*-test, and χ^2 test for independence were used, depending on data type and distribution, to analyze preoperative and postoperative clinical outcomes. Univariate analysis was used to compare baseline demographic characteristics including age, body mass index, and American Society of Anesthesiologists classification. Improvements in ASES scores were compared with threshold minimally important clinical differences, which was defined as a difference of 10.3 points (SD, 3.3), and substantial clinical benefit, which was defined as a difference of 25.9 points (SD, 2.9), as reported by Simovitch et al.[25,26] The minimally important clinical difference is defined as the smallest difference in a value that leads to patient-perceived meaningful clinical improvement. The substantial clinical benefit is defined as a value that exceeds the minimal threshold and demonstrates substantial improvement. The alpha risk was set to 0.05 to estimate statistical significance. All statistical analysis was performed using R statistical software (Version 4.1.1; R, Vienna, Austria).

Results

This is a retrospective case series of 472 patients who had RSAs with 2-year minimum follow-up. After exclusion of patients who did not have a primary RSA at our institution and those who had incomplete functional outcome data, 299 patients remained. We further excluded 27 patients who did not have adequate postoperative X-rays, as described above, leaving a total of 272 patients eligible for the study. There was a 76.9% 2-year follow-up rate. A total of 162 patients had postoperative retroversion $\leq 15^\circ$ (group A), and 110 patients had retroversion $>15^\circ$ (group B) (Table I).

Functional outcome measures

Patients in both groups had an improvement in VAS, SANE, and ASES scores at follow-up. In group A, the mean VAS improvement was −4.5 points at the final follow-up (range, −7.3 to −1.9) compared with −4.8 points in group B (range, −7.5 to −2.1) ($P = .419$). In addition, there was no statistically significant difference in VAS scores between the groups at any time point (Table II).

The SANE scores improved by 54.6 points in group A (range, 27.1-82.7) compared with 54.5 points in group B (range, 26.2-82.8) ($P = .998$). Similarly, the ASES improved by 43.5 points in group A (range, 21.8-65.8)

Table I Demographic information separated by group

	Retroversion $\leq 15^\circ$	Retroversion $>15^\circ$	*P* value
	n = 162	n = 110	
Age (yr)	70.3 ± 6.1	71.1 ± 6.4	.272
Follow-up	25.9 ± 3.6	25.5 ± 4.1	.430
Female sex, n (%)	103 (63.6)	53 (48.2)	.017*
ASA, n (%)			
1	6 (3.7)	4 (3.6)	1.000
2	116 (71.6)	81 (73.6)	
3	37 (22.8)	25 (22.7)	
BMI	30.1 ± 6.1	30.2 ± 5.9	.904
Prior surgery, n (%)	59 (36.4)	33 (30.0)	.333
Radiographic lucencies, n (%)	1 (0.6)	2 (1.8)	.568

ASA, American Society of Anesthesiologists; *BMI*, body mass index.
* Signifies significant values with alpha risk set at .05.

Table II Impact of retroversion on clinical outcomes

	Retroversion ≤15	Retroversion >15	*P* value
	n = 162	n = 110	
VAS pain			
Pre	5.4 ± 2.4	5.5 ± 2.3	.651
Post	0.7 ± 1.6	0.7 ± 1.3	.815
Change	−4.5 ± 2.7	−4.8 ± 2.7	.419
SANE			
Pre	31.6 ± 21.9	30.1 ± 19.6	.539
Post	86.2 ± 17.7	84.6 ± 20.1	.664
Change	54.6 ± 28.0	54.5 ± 28.3	.998
ASES			
Pre	38.7 ± 15.8	38.6 ± 17.7	.979
Post	82.1 ± 18.5	85.0 ± 14.8	.327
Change	43.5 ± 22.4	46.4 ± 23.9	.314
MCID, n (%)	148 (91.4)	100 (90.9)	1.000
SCB, n (%)	129 (79.6)	92 (83.6)	.501
Forward elevation			
Pre	89 ± 28	89 ± 26	.923
Post	137 ± 22	137 ± 23	.883
Change	48 ± 29	48 ± 26	.981
External rotation			
Pre	29 ± 15	26 ± 14	.142
Post	54 ± 21	50 ± 20	.108
Change	25 ± 23	23 ± 21	.594
Internal rotation			
Pre	1.3 ± 1.9	1.1 ± 1.8	.129
Post	3.1 ± 2.1	2.7 ± 2.2	.089
Change	1.7 ± 2.4	1.6 ± 2.6	.741
Complications, n (%)	7 (4.3)	5 (4.5)	1.000

VAS, visual analog scale; *SANE*, Single Assessment Numeric Evaluation; *ASES*, American Shoulder and Elbow Surgeons; *MCID*, minimal clinically important difference; *SCB*, substantial clinical benefit.

compared with 46.4 points in group B (range, 22.5-70.3) ($P = .314$). There were no significant differences in scores between the groups at any time point (Table II).

A total of 148 patients (91.4%) in group A and 100 patients in group B (90.9%) demonstrated an improvement in ASES scores that met the minimally important clinical difference as defined previously. In regard to substantial clinical benefit, 129 patients (79.6%) in group A and 92 patients (83.6%) in group B met this criterion (Table II).

Range of motion

Forward flexion, external rotation at zero degrees of abduction, and internal rotation were assessed for each patient. There was a similar mean improvement in forward flexion at the final follow-up for both groups (48°), and the difference between the groups was not statistically significant ($P = .981$) (Table II).

External rotation improved by a mean 25° in group A (range, 2°-48°) compared with 26° in group B (range, 2°-44°) ($P = .594$). Using the previously mentioned scaling system for internal rotation, the mean improvement was 1.7 points in group A compared with 1.6 points in group B ($P = .741$). There was no statistically significant difference in mean ROM between the groups at any time point (Table II).

Table III Demographics for those with preoperative computed tomography scans

	Retroversion ≤15°	Retroversion >15°	*P* value
	n = 115	n = 84	
Age (yr)	70.8 ± 6.4	70.9 ± 6.0	.867
BMI	30.8 ± 6.0	30.6 ± 5.8	.795
ASA, n (%)			
1	3 (2.6)	3 (3.6)	.706
2	78 (67.8)	62 (73.8)	
3	31 (27.0)	19 (22.6)	
Female sex, n (%)	70 (60.9)	35 (41.7)	.011*
Retroversion			
Pre	−9 ± 8	−19 ± 10	<.001*
Post	−8 ± 4	−23 ± 6	<.001*
Change	1 ± 9	−4 ± 10	<.001*

BMI, body mass index; *ASA*, American Society of Anesthesiologists.
* Signifies significant values with alpha risk set at .05.

Radiographic lucency

One radiolucency was found in patients with less than 15° of retroversion, and this was classified as a baseplate failure. Two lucencies were found in the group with >15° of retroversion and were classified as a baseplate failure and baseplate "at risk" ($P = .568$) (Table I).

Change in preoperative to postoperative retroversion

One hundred and ninety-nine patients had preoperative CT scans available for analysis. There were 115 patients (70 women and 45 men) in group A and 84 patients (35 women and 49 men) in group B. The mean age for both groups was 71 years. There were no statistically significant differences in age, body mass index, or American Society of Anesthesiologists classification between the groups. In this cohort of patients, the mean preoperative retroversion in group A was 9° (range, 1°-17°) vs. 19° in group B (range, 9°-29°). The mean change in preoperative to postoperative retroversion in groups A and B was 1° and 4°, respectively (Table III).

Complications

There were 7 complications in group A (4.3%). These included intraoperative fracture, traumatic scapular spine

fracture, 2 hematomas of which 1 had a deltoid rupture, wound healing issue, baseplate failure, and acromial stress fracture. In group B, there were 5 complications (5.4%). These included dislocation/instability, nerve injury, intraoperative fracture, traumatic hardware failure, which was the baseplate failure reported above, and infection (Table II).

Discussion

The importance of correcting glenoid retroversion in RSA is not well defined. In our cohort of patients, glenoid baseplate positioning was based on maximizing bony contact and therefore often similar to the native retroversion. As a result, we found that patients with a mean higher preoperative version tended to have a mean higher postoperative retroversion. There were no significant differences in postoperative functional outcomes, ROM, or complications between those who had retroversion $\leq 15^\circ$ and those who had retroversion $>15^\circ$.

The relationship between preoperative and postoperative retroversion was also demonstrated by Gregory et al.[10] They evaluated 29 TSA CT scans and assessed the relationship between preoperative and postoperative glenoid retroversion. They noted that there was a statistically significant correlation between the values. Specifically, patients with greater native glenoid retroversion had a glenoid component that was placed in greater retroversion as well. This was due to the concern of vault perforation in severely eroded glenoids if an excessive attempt was made to correct retroversion. Although clinical outcomes were not evaluated, it was hypothesized that retroversion of the glenoid component would be more favorable compared with the complication of risking vault perforation.[10]

To our knowledge, there is another study by Lansdown et al[15] that assessed the effect of postoperative glenoid retroversion in RSA on functional outcomes. In their cohort of 177 patients, they compared patients who had less than 10° of retroversion with those who had greater than 10° and found that there were no statistically significant differences in ASES scores or forward flexion, abduction, external rotation, or internal rotation.[15]

Several studies have evaluated baseplate position using finite element analysis and mechanical testing. Friedman et al[8] conducted a finite element analysis evaluating the effect of varying baseplate retroversion angles on micromotion and fixation of the baseplate. They noted that although there was a significant increase in micromotion and stress with increased retroversion angles, these were well within the threshold to still allow for bone ingrowth, even at retroversion angles up to 25°.[8] In contrast, Favre et al[7] evaluated the effect of glenoid version on RSA instability using mechanical testing. Glenoid version was from 20° of retroversion to 20° of anteversion. It was noted that glenoid positioning did not have a significant effect on instability compared with humeral positioning, except at 20° of glenoid retroversion, when there was a significant drop in instability at the resting arm position.[7] Permeswaran et al[22] assessed the effect of glenoid and humeral retroversion on impingement-free ROM in finite element analysis. They noted that increasing glenoid retroversion was associated with a smaller impingement-free arc of motion as well as subluxation.[22]

Furthermore, Keener et al[13] conducted an ROM analysis on 10 CT scans with varying degrees of glenoid component retroversion. The effect of increased retroversion had inconsistent effects on ROM, with significant limitations in external rotation and extension only. Retroversion of the glenoid component was associated with increased internal rotation and flexion ROM, with no significant effect on abduction and adduction.[13] Even in biomechanical analyses, the results remain inconclusive.

Excessive version correction may also predispose to failure. Ho et al[11] conducted a study assessing bone graft failure in patients who had RSA. Of the 44 patients evaluated, 11 had radiographic and clinical evidence of bone graft failure, indicated by significantly worse SANE scores. Patients who had baseplate failures had a larger correction in glenoid retroversion compared with those who did not (mean 11° vs. 0° of correction; $P = .02$), highlighting potential detrimental effects of excessive correction of native glenoid retroversion.[11]

Most studies assessing the clinical outcomes of glenoid retroversion have been performed on TSA patients. Service et al[25] evaluated the effect of glenoid component positioning in 201 TSAs. Similar to our technique, they did not strive to address preoperative glenoid retroversion, but rather conserve bone by only reaming to a single concavity. When comparing patients with postoperative glenoid retroversion greater than and less than 15°, simple shoulder test and percent maximal possible improvement outcomes were similar between the groups at 2-year follow-up. In addition, there were similar rates of central peg lucency between the retroverted and nonretroverted glenoids (19% vs. 12%; $P = .4$). None of the patients had revisions for glenoid component failure.[8] Ma et al[17] demonstrated similar findings in their study of 124 TSA patients. The authors did not attempt to correct retroversion but aimed to have 80% bony contact of the component. The preoperative retroversion ranged between 7.7° and 22.9°, whereas the mean postoperative retroversion ranged from 3.0° to 16.4°. They found no significant correlation between pre- or postoperative glenoid retroversion and ASES scores or radiographic lucency.[17]

There are several limitations in this study. First, our cohort had a minimum 2-year follow-up. Component lucency and failure may occur many years after this, in addition to changes in clinical and functional outcomes. Furthermore, different imaging modalities were used for the pre- and postoperative measurements. Many of the preoperative X-rays were not adequate for the measurement of glenoid retroversion due to a combination of patient pain

and lack of ROM from advanced arthritis, preventing the arm positions needed for good views. In addition, using postoperative CT scans instead of X-rays to maintain consistency are costly and provide unnecessary radiation exposure. Therefore, postoperative version measurements were assessed on axillary radiographs, of which the quality is more variable. We did attempt to mitigate variability in X-rays by only including high-quality radiographs. In addition, to try to limit bias, all preoperative measurements were done on CTs and all postoperative measurements were done on X-rays. Furthermore, we did not incorporate glenoid morphology classification in our assessment, and it would be valuable to include this in future studies. Lastly, we did not have 100% follow-up of our patients, which may have also affected our outcomes.

Conclusion

In our practice, we prioritize preserving bone stock without aiming for a specific degree of retroversion correction. Using this method in our study of 271 RSA patients, there was no significant difference in postoperative functional outcomes, ROM, or complications between patients who had baseplate retroversion $\leq 15^{\circ}$ vs. those who had retroversion $>15^{\circ}$.

Disclaimers:

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Conflicts of interest: Andrew Jawa is a board/committee member of the American Academy of Orthopaedic Surgeons and the American Shoulder and Elbow Surgeons Society. He is a member of the editorial/governing board of the *Journal of Shoulder and Elbow Surgery*; reports IP royalties and stock/stock options from Ignite Orthopaedics; and is a paid consultant and paid presenter/speaker for and reports research support from personal fees from DJO Global.
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