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Do glenoid retroversion and humeral subluxation affect outcomes following total shoulder arthroplasty?

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A R T I C L E I N F O

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

Background: Glenoid retroversion and humeral head subluxation have been suggested to lead to inferior outcomes after total shoulder arthroplasty (TSA). There are limited data to support this suggestion. We investigated whether preoperative glenoid retroversion and humeral head subluxation are associated with inferior outcomes after TSA and whether change of retroversion influences outcomes after TSA.
Methods: Patients undergoing TSA with minimum 2-year follow-up were included from a prospectively collected institutional shoulder arthroplasty database. Retroversion and humeral head subluxation before and after surgery were measured on axillary radiographs. Postoperative radiographs were -evaluated for glenoid component loosening and compared between groups. Spearman correlations were determined between retroversion measurements and American Shoulder and Elbow Surgeons Standardized Shoulder Assessment Form (ASES) scores. Patients were analyzed in groups based on retroversion and humeral head subluxation.
Results: There were 113 patients (50% follow-up rate) evaluated at 4.2 years postoperatively. The mean preoperative retroversion (15.3° ± 7.7°) was significantly higher than postoperative retroversion (10.0° ± 6.8°; $P < .0001$). There was no correlation between postoperative glenoid version or humeral head subluxation and ASES scores. For patients with preoperative retroversion of >15°, there was no difference in outcome scores based on postoperative retroversion. There were no differences in preoperative or postoperative version for patients with or without glenoid lucencies.
Discussion: We observed no significant relationship between postoperative glenoid retroversion or humeral head subluxation and clinical outcomes in patients following TSA. For patients with preoperative retroversion >15°, change of retroversion during TSA had no impact on their clinical outcomes at short-term follow-up.

Total shoulder arthroplasty (TSA) allows for reduced pain and improvements in function and quality of life for patients with glenohumeral arthritis.[2,28] Recent estimates suggest that a total of 39,000 TSAs are performed annually in the United States, with a growth rate of approximately 5%-9% per year.[33] With this increasing utilization of TSA, it is necessary to understand the role of various preoperative factors on patient outcomes and shoulder function.

Morphologic changes at the glenohumeral joint may be responsible for inferior outcomes after shoulder arthroplasty. Neer observed that posterior glenoid wear and posterior subluxation of the humeral head were present in patients with primary glenohumeral osteoarthritis.[23] Walch classified the morphology of glenohumeral joint arthritis based on glenoid retroversion, humeral head subluxation, and glenoid wear.[37] The B2 glenoid, with posterior glenoid wear and posterior humeral head subluxation, may have inferior biomechanics, poor clinical outcomes, increased complications, and increased rates of glenoid loosening.[16,38] Surgical techniques have been introduced to correct glenoid retroversion, including asymmetric reaming of the glenoid,[4,7,38] augmented glenoid components,[29,40] and bone grafting.[17,30,34] Clinical studies have shown that outcomes may still not be satisfactory.[19] Recently, some have recommended that patients with significant glenoid retroversion may be better treated with a reverse shoulder arthroplasty.[22] Novel augmented glenoid components and computer-guided planning systems have been introduced to allow for correction of glenoid retroversion.[1]

This study was approved by the University of California, San Francisco Committee on Human Research (no. 17-23836).

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Although cadaveric biomechanical studies show that glenoid component retroversion and eccentric humeral head loading lead to increased contact forces, excessive glenoid component wear, and glenoid component loosening,[6,26,32,36] the clinical outcomes following TSA with retroverted glenoids are controversial.[11,27,31,38] It is still questionable how correction of glenoid retroversion at the time of TSA influences postoperative outcomes.

The primary purpose of this study was to evaluate the influence of preoperative and postoperative glenoid retroversion and humeral head subluxation on outcomes following TSA. The second objective was to evaluate the relationship between the change in glenoid retroversion and its impact on clinical outcomes in patients with a retroverted glenoid. We hypothesized that the amount of preoperative and postoperative glenoid retroversion and the magnitude of correction would have no influence on postoperative patient-reported outcomes. We also hypothesized that preoperative and postoperative glenoid retroversion would have no influence on eventual radiographic glenoid loosening.

Methods

Study design and participants

A retrospective cohort study was performed using a prospectively collected database of shoulder replacement patients from a single tertiary referral center. The study data were collected and managed using REDCap[10] electronic data capture tools hosted at our institution. We included all patients treated with primary anatomic total shoulder arthroplasty using cemented pegged glenoid between July 2006 and July 2016 (n = 247). Exclusion criteria were lack of postoperative radiographs (n = 13), low-quality images where the glenoid vault and/or glenoid component could not be visualized (n = 14), or patients who lacked a minimum 2-year follow-up (n = 96). All TSAs were performed by 1 of 3 fellowship-trained surgeons.

Surgical technique

A standard deltopectoral approach with a subscapularis tenotomy was used for exposure with a humeral head osteotomy performed at 30° of retroversion. The glenoid was reamed for an inline, 3-peg glenoid component. For patients with severe retroversion, as defined by the treating surgeon's evaluation of preoperative imaging and intraoperative assessment, retroversion was corrected by reaming down the anterior glenoid until satisfactory implant support was achieved. There was no specific targeted amount of retroversion that was deemed acceptable, and the treating surgeon sought to ream the glenoid to allow for stable placement with more than 80% bony contact of the glenoid component. All glenoid components and humeral stems (Zimmer, Warsaw, IN, USA) were cemented. The subscapularis was repaired through bone tunnels with soft tissue repair. Postoperatively, patients were immobilized in an abduction sling for 6 weeks with physical therapy starting after 7-10 days. Active range of motion (ROM) started after 6 weeks and strengthening at 12 weeks. Patients were followed at 6 weeks, 3 months, 6 months, and annually.

Study variables

Demographic variables, including age, body mass index (BMI), and sex, were collected. Postoperative patient-reported outcomes were measured using the American Shoulder and Elbow Surgeons Standardized Shoulder Assessment Form (ASES) scores at the most recent follow-up. ROM was recorded by a trained research assistant, using a goniometer to measure active forward flexion, abduction, and external rotation with the arm at the side. In the event that a patient later required revision shoulder replacement, the indication for revision surgery was noted and the patient was excluded from final analysis.

Standardized preoperative and postoperative axillary radiographs were collected within a year before and after surgery. Glenoid retroversion was evaluated using the methodology of Service et al,[31] and humeral head subluxation was evaluated according to Walch et al[38] on preoperative (Fig. 1) and postoperative (Fig. 2) radiographs. Radiographic retroversion measurements were made by 2 independent reviewers (EC and WX). A subset of the most recent available radiographs at a minimum of 2 years after surgery were evaluated by 2 reviewers (EC and DAL) for glenoid lucency and graded from 0-5 according to Lazarus et al.[18] Individual intraclass correlation coefficients were 0.81 for glenoid retroversion measurements and 0.80 for glenoid lucency evaluation. An average measurement between reviewers was used for glenoid retroversion and glenoid lucency grade.

Statistical analysis

Statistical analyses were performed with Stata (version 14, StataCorp LP, College Station, TX, USA). Descriptive statistics, including means, standard deviations, and frequencies were calculated. Spearman correlation tests tested relationships between retroversion measurements and outcome scores. Patients were separated into 3 groups based on glenoid retroversion: group 1, <15°; group 2, 15°-25°; and group 3, >25°. Patients were also separated into 3 groups based humeral head subluxation: group 1, <0.45; group 2, 0.45-0.55; and group 3, >0.55. For both glenoid retroversion and humeral head subluxation, patients were grouped and analyzed based on the preoperative value and the postoperative value. Outcome scores and ROM were compared between groups. Patients with preoperative retroversion of >15° were separated into 3 groups based on postoperative glenoid retroversion using the same criteria, and outcomes and ROM were compared between these groups. Glenoid lucency grades were grouped as no glenoid loosening (mean lucency <2) or advanced glenoid loosening (≥2). Preoperative and postoperative retroversion and subluxation measurements were compared between groups. Patients were divided into 2 groups based on the Patient Acceptable Symptom State after TSA (ASES score = 76).[3] Retroversion and subluxation measurements were compared between these groups. One-way analysis of variance with Bonferonni corrections, Student *t* tests, or Fisher exact tests were used for comparing differences between groups. Significance was defined as P <.05.

Results

There were 124 patients (67 female) available for analysis (age: 66.5 ± 9.3 years, BMI: 29.2 ± 6.4, follow-up: 4.2 ± 2.1 years, at a 50% follow-up rate). The preoperative retroversion (15.3° ± 7.6° [range: 2°-33.5°]) was significantly higher than the postoperative retroversion (9.7° ± 6.7° [−1.5° to 33.5°]; P < .0001).

The overall complication rate was 11.3% (N = 14/124), including 5 periprosthetic joint infections, 3 with glenoid loosening, 2 rotator cuff failures, 2 periprosthetic fractures, 1 patient with stiffness treated with lysis of adhesions, and 1 patient with recurrent posterior instability after treatment with shoulder replacement after a locked posterior dislocation. Eleven of these patients underwent component revision. There was no observed difference between patients with or without revision surgery for either preoperative retroversion (15.2° ± 5.5° [6°-23°] for failures vs. 15.3°

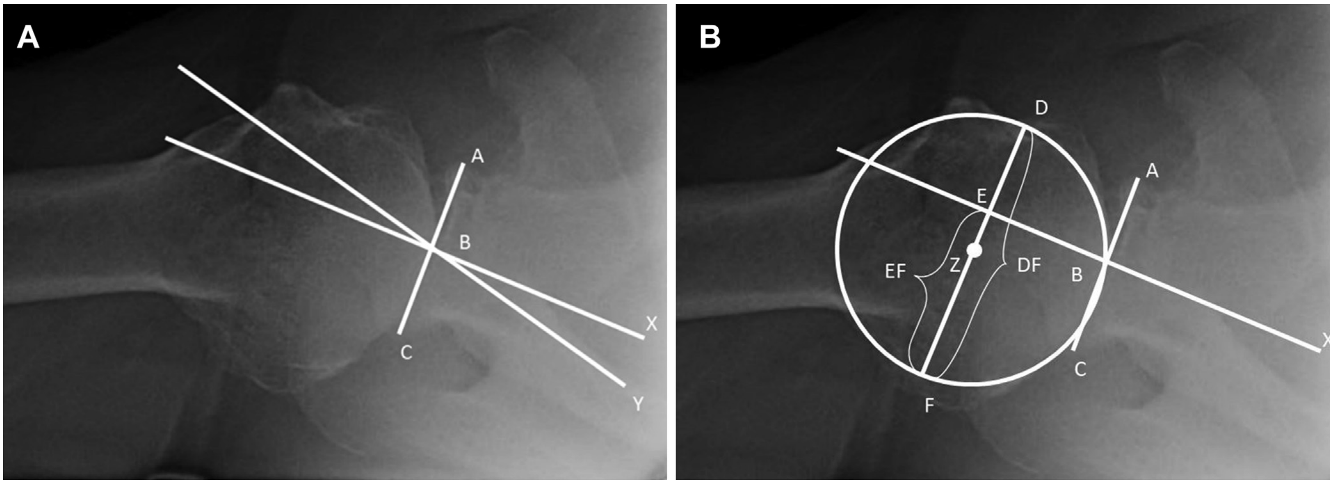

Figure 1 (**A**) Assessment of preoperative glenoid retroversion. Line A-C represents the glenoid plane, which is drawn connecting the anterior (A) and posterior (C) rims of the glenoid. Line B-Y represents the scapular plane. Line B-X is the perpendicular bisector of line A-C. The retroversion of glenoid is defined as the angle between lines B-X and B-Y. (**B**) Assessment of preoperative subluxation. The same lines A-C and B-X are drawn. The humeral head circle is drawn with point Z at the center. Line segment D-F marks the humeral diameter, parallel to line A-C. Point E is the intersection between lines D-F and B-X. Subluxation is defined as the percentage of the humeral head posterior to line B-X, and is calculated as (E-F)/(D-F) × 100%.

± 7.7° [2°-33.5°] for nonfailures; P = .95) or postoperative retroversion (7.1° ± 5.2° [2°-19°] vs. 10.0° ± 6.8° [−1.5° to 33.5°]; P = .17). For the patients with eventual glenoid loosening, the preoperative retroversion was 15° and 17° in 2 of the 3 patients (third patient did not have available preoperative imaging) and the postoperative retroversion was 19°, 8°, and 6°. The preoperative subluxation was 0.64 and 0.60, whereas postoperative subluxation was 0.58, 0.49, and 0.48. The 11 patients with component revision were excluded from the analysis below.

Our final analysis included 113 patients (62 females) with a mean final ASES score of 80.0 ± 20.6 (range: 23.3-100), significantly increased from the preoperative ASES score of 39.0 ± 20.5 (range 1.7-85) (P < .0001). The mean preoperative glenoid retroversion (15.3° ± 7.7°) was significantly higher than the postoperative glenoid retroversion (10.0° ± 6.8°; P < .001). Humeral head subluxation was 0.52±0.06 (posterior of center) (range 0.36-0.72) preoperatively and decreased to 0.49 ± 0.04 (range 0.42-0.61) postoperatively (P < .001).

Preoperative measurements

We observed no difference in postoperative ASES scores, ROM measurements, age, or BMI based on preoperative retroversion groups (Table I). There was no observed difference in ASES scores between groups based on preoperative humeral head subluxation (Table I). Forward flexion was 12.7° higher in group 3 relative to group 2 (P = .048). We observed no difference in other ROM, age, BMI, or gender distribution between groups.

Postoperative measurements

We observed no significant correlation between postoperative glenoid retroversion and ASES scores (rho = 0.098, P = .30). We found no significant correlation between the absolute change in retroversion and final ASES score (rho = 0.06, P = .50) or the absolute change in retroversion and change in ASES score from before surgery to final follow-up (rho = 0.06, P = .59). There was no

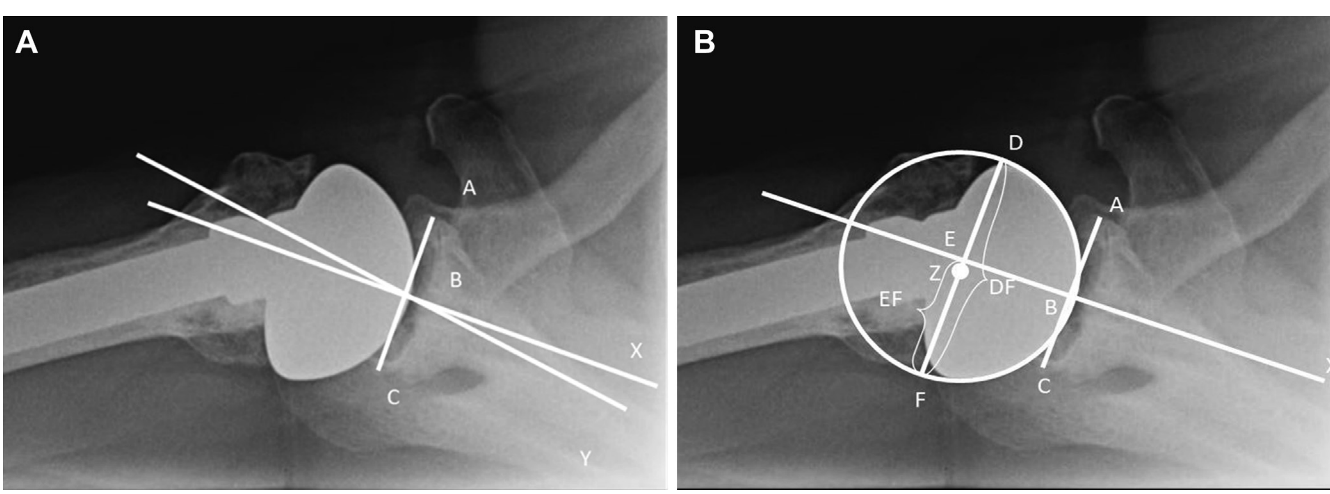

Figure 2 (**A**) Assessment of postoperative glenoid retroversion. Line A-C represents the glenoid plane, which is drawn connecting the anterior (A) and posterior (C) rims of the glenoid. Line B-Y represents the scapular plane. Line B-X is drawn along the central peg metal marker of the glenoid component. The retroversion of glenoid component is defined as the angle between lines B-X and B-Y. (**B**) Assessment of postoperative subluxation. The same line A-C is drawn. The humeral circle is drawn with point Z at the center. Line segment D-F marks the humeral diameter, parallel to line A-C. Line B-X is drawn along the metal marker of the glenoid component. Subluxation is calculated as (E-F)/(D-F) × 100%.

Table I
Preoperative retroversion and subluxation

	Group 1 (<15°) (n = 61)	Group 2 (15°-25°) (n = 37)	Group 3 (>25°) (n = 15)	*P* value
Preoperative retroversion				
Age, y	65.9 ± 9.2	68.9 ± 8.1	67.9 ± 4.9	.23
Body mass index	29.7 ± 7.5	28.1 ± 5.3	29.7 ± 4.7	.48
Sex, n (%)				
Male	21 (41.2)	19 (37.3)	11 (21.5)	.02
Female	40 (64.5)	18 (29.0)	4 (6.5)	
Preoperative retroversion, degrees	9.4 ± 3.5 (2-14.5)	19.4 ± 2.8 (15-24.5)	29.3 ± 2.5 (25.5-33.5)	<.001
Postoperative ASES score	77.2 ± 22.0 (23.3-100)	84.1 ± 17.6 (30-100)	81.2 ± 21.3 (48.3-100)	.27
Forward flexion, degrees	137.2 ± 27.9 (40-180)	143.9 ± 21.1 (96-180)	142.6 ± 20.3 (105-170)	.41
Abduction, degrees	129.2 ± 35.1 (42-180)	136.9 ± 30.2 (48-175)	144.3 ± 25.4 (83-177)	.21
External rotation, degrees	61.2 ± 18.9 (−30 to 90)	55.6 ± 13.7 (30-80)	60.7 ± 11.1 (45-85)	.26
	Group 1 (<0.45°) (n = 10)	Group 2 (0.45-0.55) (n = 71)	Group 3 (>0.55°) (n = 32)	
Preoperative subluxation				
Age, y	70.0 ± 10.3	66.6 ± 9.1	67.5 ± 6.1	.48
Body mass index	27.5 ± 6.8	29.2 ± 6.6	29.5 ± 6.4	.70
Sex, n (%)				
Male	4 (7.8)	33 (64.7)	14 (27.5)	.92
Female	6 (9.7)	38 (61.3)	18 (29.0)	
Preoperative retroversion, degrees	11.8 ± 7.8 (5-26)	14.8 ± 7.4 (2-33)	17.5 ± 8.1 (3.5-33.5)	.08
Postoperative ASES score	85.7 ± 18.2 (41.7-100)	78.4 ± 21.5 (23.3-100)	81.8 ± 19.4 (36.7-100)	.49
Forward flexion, degrees	144.9 ± 20.6 (115-170)	135.7 ± 27.9 (40-180)	148.4 ± 15.5 (115-180)*	.044
Abduction, degrees	140.5 ± 32.4 (90-170)	128.1 ± 34.3 (42-180)	144.2 ± 26.2 (85-180)	.051
External rotation, degrees	53.2 ± 32.2 (−30 to 83)	60.0 ± 12.4 (25-90)	59.8 ± 15.1 (40-85)	.82

ASES, American Shoulder and Elbow Surgeons Standardized Shoulder Assessment Form.
Unless otherwise noted, values are mean ± standard deviation, with ranges of values in parentheses.
* Significant difference compared with group 2 (*P* = .048).

observed difference in ASES scores between groups based on postoperative glenoid retroversion at most recent follow-up (Table II). We observed no differences between groups in ROM measurements, age, BMI, or gender distributions.

We observed no difference in age and BMI between groups based on postoperative humeral head subluxation, though female patients were more frequently in group 2 relative to male patients (*P* = .012). We observed no difference in ASES scores or ROM measurements between groups. Only 17.7% patients had abnormal humeral head subluxation postoperatively (<0.45 or >0.55), which was significantly lower compared with 37.2% patients preoperatively (*P* = .001).

Preoperative glenoid retroversion >15°

Fifty-two patients had preoperative glenoid retroversion of >15° (group 1: <15° postoperative retroversion [n = 37], group 2: 15°-25° postoperative retroversion [n = 11], group 3: >25°

Table II
Postoperative retroversion and subluxation

	Group 1 (<15°) (n = 93)	Group 2 (15°-25°) (n = 16)	Group 3 (>25°) (n = 4)	*P* value
Postoperative retroversion				
Age, y	66.8 ± 8.5	69.4 ± 8.7	67.3 ± 3.6	.53
Body mass index	29.1 ± 6.6	29.4 ± 6.7	29.0 ± 3.1	.99
Sex, n (%)				
Male	40 (78.4)	7 (13.7)	4 (7.9)	.09
Female	53 (85.5)	9 (14.5)	0 (0)	
Postoperative version, degrees	7.6 ± 4.2 (−1.5 to 14)	19.5 ± 2.3 (16-23.5)	28.4 ± 2.7 (25.5-31.5)	<.001
ASES score	79.6 ± 20.2 (25-100)	82.1 ± 19.0 (23.3-100)	76.9 ± 24.6 (53.3-98.3)	.89
Forward flexion, degrees	137.7 ± 25.3 (40-180)	150.3 ± 22.3 (105-180)	155.3 ± 5.5 (150-160)	.08
Abduction, degrees	130.3 ± 32.6 (42-180)	146.5 ± 30.5 (83-180)	163.0 ± 9.6 (155-177)	.03*
External rotation, degrees	58.7 ± 17.2 (−30 to 90)	62.4 ± 12.8 (38-80)	60.5 ± 13.7 (50-80)	.94
	Group 1 (<0.45) (n = 13)	Group 2 (0.45-0.55) (n = 93)	Group 3 (>0.55) (n = 7)	
Postoperative subluxation				
Age, y	66.1 ± 8.1	67.4 ± 8.7	65.9 ± 6.5	.79
Body mass index	30.9 ± 6.3	28.9 ± 6.7	29.5 ± 4.2	.56
Sex, n (%)				
Male	9 (17.6)	36 (70.6)	6 (11.8)	.01
Female	4 (6.5)	57 (91.9)	1 (1.6)	
Postop retroversion, degrees	6.5 ± 3.5 (1-13.5)	10.1 ± 6.8 (−1.5 to 29.5)	14.9 ± 8.0† (7-31.5)	.026
ASES score	69.6 ± 31.2 (25-100)	80.8 ± 18.9 (23.3-100)	88.8 ± 13.5 (63.3-100)	.095
Forward flexion, degrees	131.8 ± 22.6 (96-180)	141.0 ± 25.9 (40-180)	143.9 ± 11.8 (130-160)	.42
Abduction, degrees	132.8 ± 30.6 (90-180)	133.0 ± 33.7 (42-180)	145.3 ± 18.0 (116-175)	.63
External rotation, degrees	60.8 ± 15.7 (25-80)	59.4 ± 17.0 (−30 to 90)	55.6 ± 10.8 (40-70)	.91

ASES, American Shoulder and Elbow Surgeons Standardized Shoulder Assessment Form.
Unless otherwise noted, values are mean ± standard deviation, with ranges of values in parentheses.
* No significant post hoc comparisons between groups (*P* > .14 for all).
† Significance compared to group 1 (*P* = .023).

Table III
Outcomes of patients with preoperative retroversion >15°

	Group 1 (postoperative retroversion <15°) (n = 36)	Group 2 (postoperative retroversion 15°-25°) (n = 11)	Group 3 (postoperative retroversion >25°) (n = 4)	*P* value
Preoperative retroversion, degrees	21.8 ± 4.8 (16-32)	21.5 ± 5.4 (16.5-33)	29.6 ± 3.9* (24.5-33.5)	.012
Postoperative retroversion, degrees	9.6 ± 3.6 (2.5-14)	20.3 ± 2.1 (16-23.5)	28.4 ± 2.7 (25.5-31.5)	<.001†
Version change, degrees	12.2 ± 6.1‡ (2.5-27)	1.2 ± 6.5 (−5 to 11.5)	1.3 ± 6.0 (−5 to 8)	<.001
Postoperative humeral head subluxation	0.49 ± 0.04 (0.42-0.56)	0.49 ± 0.02 (0.45-0.52)	0.54 ± 0.05§ (0.50-0.61)	.045
ASES score	83.2 ± 19.9 (30-100)	82.9 ± 15.4 (58.3-100)	84.2 ± 21.3 (53.3-98.3)	.99

ASES, American Shoulder and Elbow Surgeons Standardized Shoulder Assessment Form.
Values are mean ± standard deviation, with ranges of values in parentheses.
* Significance compared to group 1 ($P = .01$) and group 2 ($P = .02$).
† All comparisons between groups are $P < .001$.
‡ Significance compared to group 2 ($P < .001$) and group 3 ($P = .004$).
§ Trend toward significance compared with group 1 ($P = .058$) and group 2 ($P = .050$).

postoperative retroversion [n = 4]). We observed no significant correlation between retroversion change and ASES scores (rho = 0.21, $P = .15$). Group 3 had a trend toward significantly higher posterior subluxation relative to group 1 ($P = .058$) and group 2 ($P = .050$). We observed no significant difference in ASES scores between groups at final follow-up (Table III).

Glenoid lucencies

Eighty-one patients had appropriate radiographs more than 2 years postoperatively (4.7 ± 2.1 years). There were 52 patients (64.2%) with grade 0-1 lucency and 29 patients (35.8%) with grade 2 or higher lucencies (Fig. 3). We observed no difference in preoperative or postoperative retroversion or humeral head subluxation between these groups of radiographic lucencies (Table IV). There were 2 patients with grade 4 lucency. The preoperative retroversion measurements was 10° and 19°, and preoperative humeral head subluxation was 0.52 and 0.53; the postoperative retroversion was 2° and 13°, and postoperative humeral head subluxation was 0.47 and 0.53.

ASES Patient Acceptable Symptom State score

There were 38 patients with a postoperative ASES score less than 76, and 75 patients with an ASES score of greater than 76. We observed no significant differences in age, BMI, or sex between groups. We observed no difference in preoperative or postoperative glenoid retroversion between groups (Table V). We observed no difference in preoperative or postoperative humeral head subluxation between groups, or in the absolute difference of preoperative or postoperative subluxation from centered (0.50).

Discussion

We observed no difference in outcomes following anatomic total shoulder arthroplasty based on postoperative measurements of glenoid retroversion and humeral head subluxation. In patients with glenoid retroversion greater than 15°, postoperative retroversion did not influence the outcome measures. At mean 4.7 years, we observed no differences in glenoid retroversion for patients based on degree of radiographic glenoid lucencies. Preoperative and postoperative retroversion were not different for patients above or below the ASES Patient Acceptable Symptom State score of 76. Factors reported in other studies, such as patients' preoperative mental health score and patients' comorbidities, seem to have a stronger effect on patient outcomes.[20,39]

There has been increased interest in correcting excessive glenoid retroversion during TSA with a surge of surgical techniques, implant designs, and bone grafting. Asymmetric reaming can compromise subchondral bone and may lead to peg penetration in the glenoid vault.[5,8] Bone grafting is technically demanding, and nonunion, resorption, or subsidence are frequently observed.[15,24]

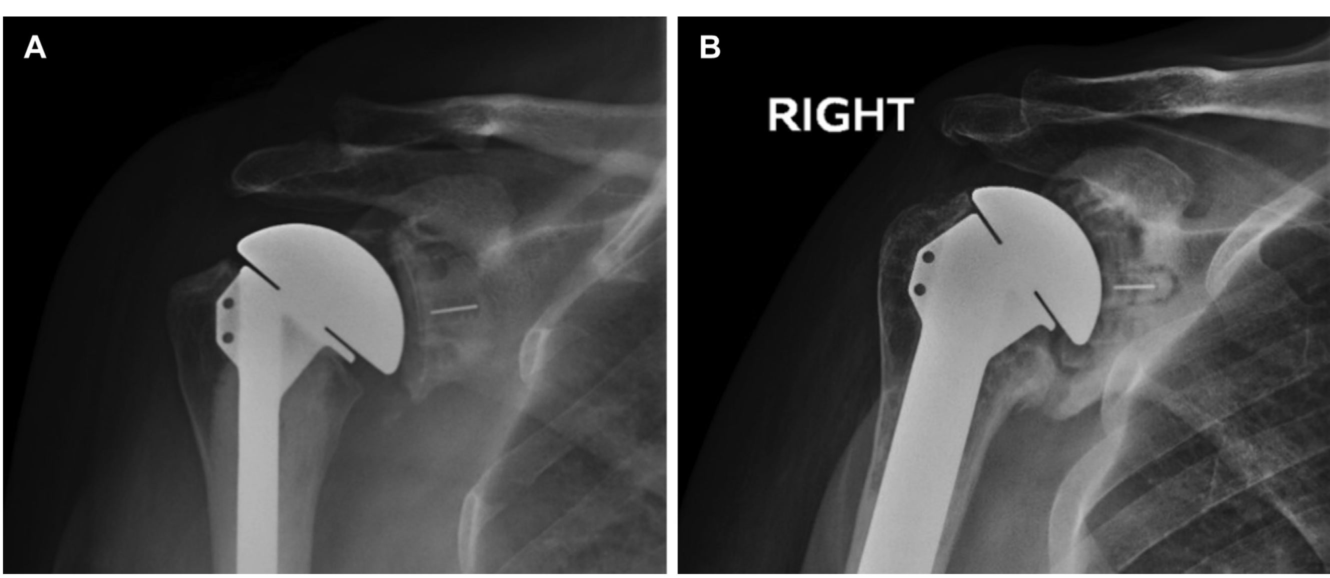

Figure 3 Postoperative Grashey radiographs are shown at final follow-up for 2 patients with (**A**) no evidence of glenoid loosening and (**B**) advanced glenoid loosening (grade 4).

Table IV
Analysis of glenoid radiolucency, glenoid version, and humeral head subluxation

	Group 1 (mean lucency <2), (n = 29)	Group 2 (mean lucency ≥2), (n = 52)	*P* value
Follow-up	4.8 ± 2.2	4.6 ± 2.1	.72
Preoperative retroversion, degrees	16.2 ± 7.7 (5.5-31.5)	15.5 ± 8.2 (4-33.5)	.72
Postoperative retroversion, degrees	9.9 ± 6.4 (−1.5 to 31.5)	10.1 ± 8.1 (1.5-27)	.90
Preoperative subluxation	0.52 ± 0.06 (0.36-0.66)	0.52 ± 0.06 (0.42-0.65)	.87
Postoperative subluxation	0.50 ± 0.03 (0.42-0.56)	0.49 ± 0.04 (0.43-0.61)	.78

Values are mean ± standard deviation, with ranges of values in parentheses.

Although posteriorly augmented glenoid components have been introduced recently, long-term data are not available yet. Augmented glenoids have been widely marketed as a solution for patients with retroversion to improve outcomes and preserve bone. An augmented glenoid may be justified for bone preservation, though we would caution early adoption without longer follow-up on aggressive correction of retroversion. We used asymmetric reaming for the severely retroverted glenoids and careful intraoperative soft tissue balancing (Fig. 4). We did not observe an effect of postoperative retroversion on patient-reported outcomes, even when isolating patients with preoperative glenoid retroversion higher than 15°.

Prior studies have reported that preoperative glenoid retroversion may not be associated with worse outcomes after TSA. Keener et al[27] found no difference in the progression of glenoid radiolucencies for patients with a B2 glenoid when comparing preoperative glenoid retroversion of ≤20° with glenoid retroversion of >20°. Matsen grouped 71 preoperative TSA patients into nonretroverted (<15°) and retroverted (≥15°). There was no significant difference between the 2 groups in outcomes at 2-year follow-up.[31] Recent reports using CT scans to evaluate preoperative glenoid retroversion have also shown no clinical differences.[4] We observed that the change in retroversion was not associated with better clinical outcomes and that final clinical outcomes were not dependent on postoperative glenoid retroversion.

These clinical observations are in contrast to results from biomechanical studies. Compared with a neutral glenoid, placement of the glenoid component in 15° of retroversion significantly decreased glenohumeral contact area and increased contact pressure, which might result in eccentric loading of the glenoid component and possibly lead to wear and loosening.[32,36] These biomechanical studies, however, use a model with the glenoid placed in retroversion relative to the native glenoid, which may not accurately reproduce joint mechanics with a prolonged history of muscle and soft tissue adaptation.

Humeral head position may influence postoperative outcomes after TSA. Gerber et al[7] has reported excellent results despite the degree of preoperative subluxation, whereas Iannotti et al[16] found inferior ASES scores and greater pain in patients with >75% posterior subluxation. In our cohort, outcome scores were no different for patients with a centered, anteriorly subluxed, or posteriorly subluxed head preoperatively. Regardless of preoperative head position, most patients in our cohort were centered following surgery (83%), also similar to prior reports.[7,9] Recurrence of posterior subluxation can occur and was not evaluated at long-term follow-up, though posterior instability has been shown even after correction of retroversion.[38]

Glenoid component failure is of primary concern following TSA. In a retrospective cohort of 92 TSA with a preoperative biconcave glenoid, Walch et al[38] found that intermediate glenoid retroversion was associated with glenoid loosening. However, structural bone grafting was used in 7 shoulders whose glenoid retroversion could not be corrected using asymmetric reaming, and only 2 were successful. Jason et al[11] correlated osteolysis around the central peg with component retroversion greater than 15°. We observed 2 patients in our cohort with advanced glenoid lucency, though their postoperative retroversion (2° and 13°) and postoperative humeral head subluxation (0.47 and 0.53) were not abnormal. The presence of mild to moderate or advanced lucency also showed no relationship with measurements of glenoid retroversion. The complication rate among our group was 5.2%, with a component revision rate of 2.6%, in line with prior reports.[4,14] Further long-term follow-up is warranted to monitor if adverse outcomes are noted because of increased risk of component wear or loosening.

Axillary lateral radiographs were used to evaluate glenoid retroversion and component positioning. Although 3-dimensional imaging with CT scans offers superior evaluation of the complex anatomy of the shoulder, this imaging modality may not be practical for routine clinical follow-up or larger research studies.[12,13,21,25] Intraclass coefficients of correlation have been reported from 0.67-0.69 between radiographs and CT scans for patients undergoing shoulder arthroplasty.[12,25] Glenoid retroversion may be overestimated by axillary lateral radiographs, though this limitation would not impact our findings in a meaningful manner as there was no amount of glenoid retroversion that seemed to negatively influence patient outcomes.

There are several other limitations in our study. First, although we included a sample size of 113, we acknowledge that we are still underpowered to detect potential true small differences between groups. Our sample size allows for detection of Spearman correlation of 0.25 at alpha of 0.05 with power of 0.8. Nearly all differences are under the minimally clinically important difference of 21 points for the ASES score after TSA.[35] Second, of 247 eligible patients, 124 (50%) were included in our study, and radiographic follow-up after 2 years was available for 81 patients (33%). There could be bias between the study group and patients lost to follow-up, but our

Table V
Radiographic analysis by ASES scores

	ASES score <76 (n = 38)	ASES score >76 (n=75)	*P* value
ASES score	54.4 ± 13.9 (23.3-73.3)	92.9 ± 6.3 (76.7-100)	<.001
Preoperative glenoid version, degrees	14.3 ± 8.5 (4.5-33)	15.8 ± 7.4 (2-33.5)	.34
Postoperative glenoid version, degrees	9.0 ± 6.4 (−1.5 to 25.5)	10.5 ± 6.9 (−1.5 to 31.5)	.24
Preoperative subluxation	0.52 ± 0.06 (0.36-0.72)	0.52 ± 0.06 (0.4-0.66)	.67
Postoperative subluxation	0.49 ± 0.03 (0.42-0.56)	0.50 ± 0.04 (0.42-0.61)	.18

ASES, American Shoulder and Elbow Surgeons Standardized Shoulder Assessment Form.
Values are mean ± standard deviation, with ranges of values in parentheses.

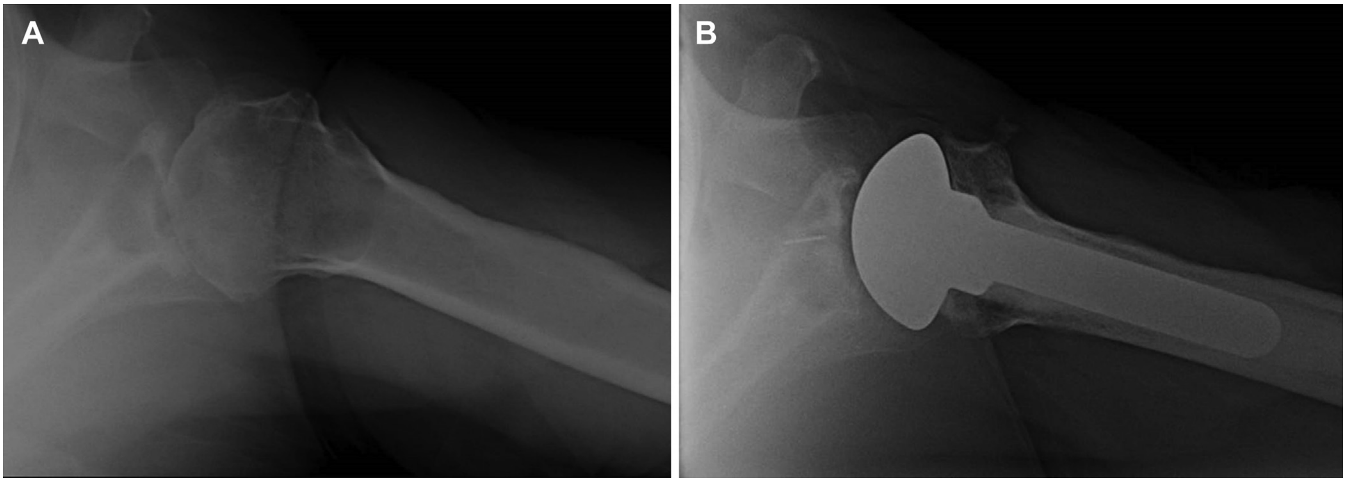

Figure 4 An example of a patient with advanced glenoid retroversion both before and after total shoulder arthroplasty. (**A**) The preoperative axillary radiograph showed retroversion of 38°, whereas (**B**) the postoperative axillary radiograph showed retroversion of 36°. The ASES score at 5-year follow-up was 98.33. *ASES*, American Shoulder and Elbow Surgeons Standardized Shoulder Assessment Form.

follow-up rate is comparable to other studies.[16,31] Third, our mean follow-up is 4.2 years, though the TSA survival is expected to exceed 10 years. Longer follow-up is needed to provide more information on the relationship between radiographic measures, clinical outcomes, and implant longevity. Fourth, we did not have a specific target for retroversion correction and are unable to measure the amount of seating of the glenoid component. Future studies may aim to answer questions related to these factors. Finally, these replacements were performed by fellowship-trained surgeons at a tertiary center. The results may not be generalizable to all orthopedic surgeons, though we do believe that this approach to patients with retroverted glenoids could be adapted into practice by shoulder replacement surgeons regardless of practice location.

Conclusion

We observed no significant relationship between postoperative glenoid retroversion or humeral head subluxation on clinical outcomes in patients following TSA with standard cemented pegged glenoid components. For patients with more severe retroversion, change of retroversion had no impact on their outcomes at short-term follow-up, suggesting that correction of retroversion may not be necessary for achieving successful outcomes after TSA. Long-term follow-up may be necessary to assess whether future divergence in outcomes exist.

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