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Treatment of B2 type glenoids with anatomic vs. reverse total shoulder arthroplasty: a retrospective review

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Background: Patients with glenohumeral arthritis with Walch B2 glenoid morphology present a challenge for shoulder surgeons. Poor outcomes have been demonstrated in patients with anatomic total shoulder arthroplasty (aTSA) left in retroversion. Reverse total shoulder arthroplasty (rTSA) yields good midterm results. There is a paucity of studies comparing aTSA to rTSA in patients with glenohumeral arthritis and B2 glenoids. The purpose of this study was to compare the results of aTSA vs. rTSA in patients with glenohumeral arthritis with B2 glenoid morphology.

Methods: We performed a retrospective review of patients who underwent total shoulder arthroplasty by a single surgeon. Preoperative computed tomography was used to determine glenoid type based on the modified Walch classification. Patients with B2 glenoid morphology were included in the study. Patients who had evidence of a rotator cuff tear or less than two years of follow-up were excluded. Patients were categorized by procedure type (aTSA vs. rTSA). Preoperative glenoid version, glenoid inclination, and posterior humeral head subluxation were measured using computed tomography. Patient reported outcome measures, active range of motion, and complications requiring revision (instability, rotator cuff insufficiency, infection, component loosening) were recorded. Postoperative glenoid version, glenoid inclination, and evidence of humeral head decentering were evaluated on standard shoulder radiographs. Statistical analysis was performed and results are presented as mean ± standard deviation.

Results: A total of 224 patients were included. One hundred sixty-two patients underwent aTSA and 62 underwent rTSA. The mean length of follow-up was 25.6 ± 1.95 months for the rTSA group and 32.8 ± 2.27 for the aTSA group ($P = .002$). Patients who underwent rTSA were significantly older ($P < .001$) and had a significantly higher proportion of females ($P = .019$). Postoperatively patients in the aTSA group had significantly better external rotation ($P < .001$) and internal rotation (IR) compared to the rTSA group ($P < .001$). There were no differences in patient reported outcome measures between the two groups. No patients in the aTSA group had recurrent posterior humeral head subluxation. Eight complications requiring revision occurred, 4 in each group. One patient who underwent aTSA had evidence of glenoid loosening. There was no evidence of glenoid loosening in the rTSA group.

Conclusions: aTSA and rTSA can produce good results in patients with B2 glenoid morphology with low rates of revision with appropriate patient selection. aTSA may result in improved range of motion that may not be clinically relevant.

Glenohumeral arthritis is a common problem worldwide with operative treatment options including hemiarthroplasty, anatomic total shoulder arthroplasty (aTSA), and reverse total shoulder arthroplasty (rTSA). Patients with posterior wear with a biconcave glenoid and posterior humeral head subluxation (Walch B2) pose a challenge for shoulder arthroplasty surgeons on how to address glenoid bone loss and correct glenoid version.[31] The decision to perform aTSA or rTSA in patients with B2 glenoid morphology can be difficult.

Walch B2 glenoid morphology occurs in 11% of patients presenting for shoulder arthroplasty.[26] There are many options to address glenoid bone loss in patients with biconcave glenoid wear.

This study was approved by University at Buffalo Institutional Review Board (IRB), IRB study approval number: STUDY0000691.

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Hemiarthroplasty can be performed without glenoid reaming or reaming to a single concave surface (ream and run). Glenoid options in aTSA and rTSA include placing the glenoid component in retroversion or correcting version using high-side reaming (HSR), structural bone graft, or an augmented glenoid component.[9,12,25,28] Recently there has been a trend towards preference to perform rTSA over aTSA for patients with B2 type glenoids. However, it remains unclear if rTSA has superior outcomes to aTSA for treatment for these patients.

Poor outcomes have been shown in patients with posterior glenoid wear who have underwent aTSA with the glenoid component left in retroversion greater than 10°.[5,17] It is preferable to correct glenoid version to neutral to prevent these issues associated with a retroverted implant.[12] Use of aTSA with HSR in patients with posterior bone loss has been shown to be an acceptable option to correct up to 15° of glenoid retroversion.[3] Results of this procedure have been shown to have poor outcomes in patients with greater than 15° of glenoid retroversion.[3] Excessive eccentric reaming can cause joint line medialization which may result in poor soft tissue tension, use of a smaller glenoid component, medial cortex perforation, and component subsidence as well as recurrent posterior subluxation.[1,2,8] Iannotti et al demonstrated a 3 fold increase in risk of component loosening in patients who underwent aTSA with HSR and a nonaugmented glenoid baseplate.[15] Walch et al also demonstrated a high rate of glenoid loosening (6.5%) and overall complications (16.3%) for patients with posterior glenoid bone loss who underwent aTSA with nonaugmented glenoid component.[32]

Structural bone grafting of the posterior glenoid during aTSA has been associated with high rates of glenoid loosening (11% at 5 year follow-up), graft failure (29%), and unsatisfactory results (anywhere from 47% to 71%).[1,13,21,29,32] These studies have a high heterogeneity in patient population, as well as types of components and baseplate fixation method used, making them difficult to compare. More recently, augmented baseplates have gained popularity in aTSA. Midterm clinical results have been favorable but studies have been small and long-term follow-up is lacking at this point.[6]

Given the relatively high rates of complications and unsatisfactory outcomes in patients with B2 glenoids treated with aTSA, rTSA has become a popular treatment option. The semiconstrained design of the reverse prosthesis prevents static posterior instability, and screw fixation of the glenoid component provides a more stable construct to prevent glenoid component loosening.[1,13,21,29,32] Mizuno et al reported on 27 patients with B2 type glenoids who underwent rTSA with or without additional humeral head allograft with favorable results.[20] One concern with use of rTSA in treatment of younger patients is implant longevity.[4] Additionally, rTSA has been shown to have greater limitation with range of motion (ROM), particularly rotation, compared to patients with aTSA.[1]

Prior studies comparing treatment of patient with B2 glenoids have been limited by patient follow-up, population size, and patient group demographic matching.[1,18,24,29,32] Additionally, prior studies have been limited by their assessment of rotator cuff status, which may have impacted implant selection and confounded results.[3] Polisetty et al performed a matched retrospective cohort analysis comparing patients with B2 and B3 glenoids who underwent aTSA vs. rTSA at two years follow-up. They found that patients who underwent rTSA had significantly lower VAS pain scores compared to aTSA, and patients in the aTSA group had significantly better internal rotation (IR) compared to those who underwent rTSA. They concluded that rTSA is comparable to aTSA at 2 year follow-up in patient with Walch B2 and B3 type glenoids.[23] A recent systematic review demonstrated optimal treatment method for management of B2 glenoids is not currently conclusive and higher quality comparative studies are required.[25] The primary aim of this study is to compare clinical and functional outcomes in patients with Walch B2 glenoid morphology treated with aTSA and rTSA at minimum of two year follow-up.

Methods

Patient selection

A retrospective review was performed of all patients who underwent total shoulder arthroplasty by a single shoulder and elbow fellowship-trained orthopedic surgeon from January 2011 to December 2020 identified via Current Procedural Terminology codes. Preoperative computed tomography was used to identify patients with glenohumeral arthritis and a biconcave glenoid morphology with posterior wear and posterior subluxation of the humeral head consistent with Walch B2 type glenoid according to the Walch classification.[31]

Inclusion criteria were (1) patients aged 18 and older with Walch B2 type glenoid morphology, (2) treated with primary aTSA or rTSA, (3) with an intact rotator cuff, and (4) with a minimum of 2 years of clinical and radiographic follow-up data available.

Exclusion criteria were (1) inability to accurately classify preoperative glenoid morphology, (2) any patient identified to have a rotator cuff tear on preoperative imaging, prior history of rotator cuff repair surgery, or any intraoperative evidence of full-thickness rotator cuff tear, (3) any patient with lack of 2-year follow-up data, and (4) any form of secondary shoulder arthritis including post-traumatic, septic, or Charcot arthropathy.

Patients were separated into groups based on those who were treated with aTSA and those who were treated with rTSA and evaluation of clinical and patient reported outcome measures (PROMs) was performed preoperatively and at the time of final follow-up.

Operative technique

All operations were performed by a single fellowship-trained orthopedic surgeon. Preoperative planning was performed on all patients with 3D planning software with the goal being to restore glenoid version to within 5° of neutral. The decision to perform aTSA vs. rTSA was made by the senior author based on glenoid morphology on preoperative planning and patient specific factors including age, gender, and bone quality. aTSA was preferred in patients with adequate bone stock on preoperative planning to support an anatomic glenoid component with a hybrid bone ingrowth central peg using the following criteria; > 90% backside contact of the component, no evidence of central peg penetration through the glenoid vault, no more than one peripheral peg penetrated through the glenoid vault, <5° of retroversion, and <5 mm of joint line medialization of the final component. If this was unable to be achieved, rTSA was performed. A flow-chart of the treatment algorithm is demonstrated in Figure 1. One-hundred percent backside contact and neutral version of the glenoid component was preferred, but > 90% backside contact and version correction to within 5° of neutral was accepted to avoid complications associated with over medialization of the joint and compromise of implant fixation. Figures 2 and 3 demonstrate examples of patients with B2 glenoid morphology who were treated with aTSA and rTSA, respectively.

A standard deltopectoral approach with subpectoral biceps tenodesis was used. Direct visualization and assessment of the rotator cuff was performed intraoperatively and was recorded in the operative record. For patients who underwent aTSA, a subscapularis tenotomy was performed. For patients who underwent rTSA, a subscapularis peel was performed. The subscapularis was repaired at the conclusion of the procedure in all cases.

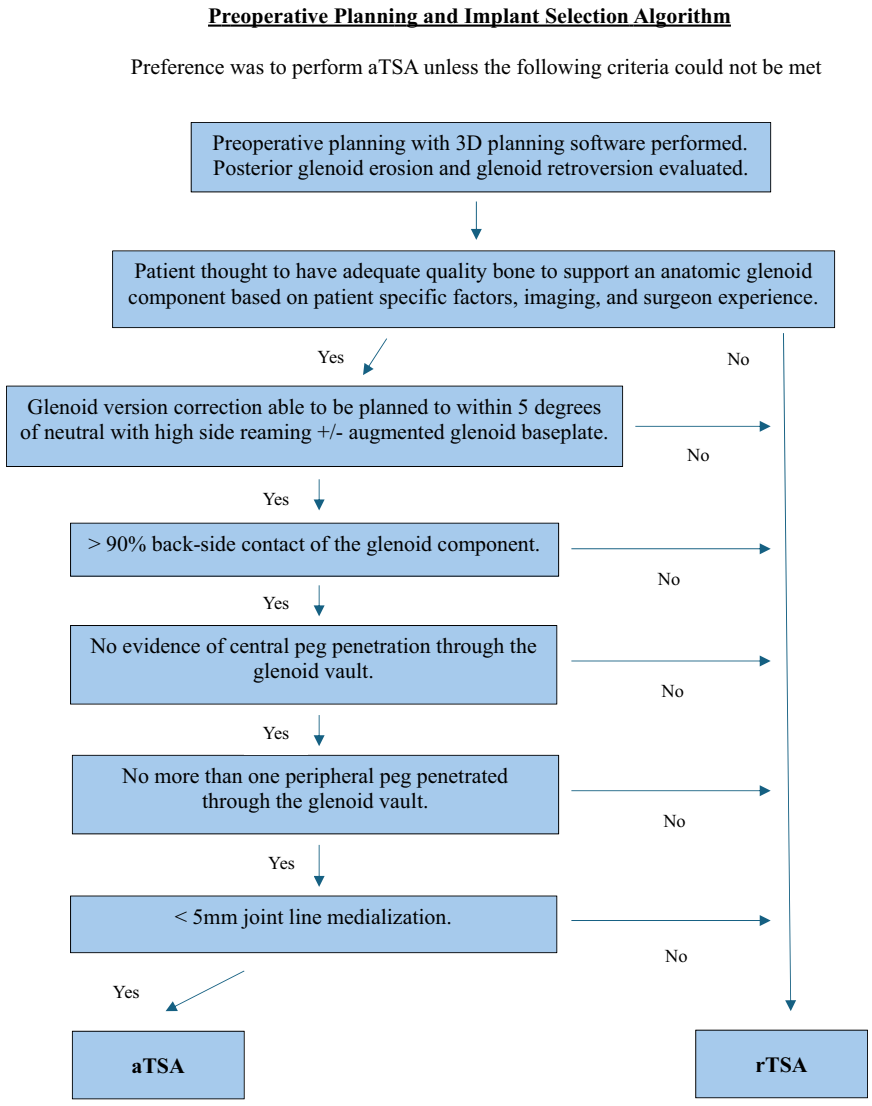

Figure 1 Treatment algorithm for implant selection based on 3D preoperative planning software. *aTSA*, anatomic total shoulder arthroplasty; *rTSA*, reverse total shoulder arthroplasty.

Patients who underwent aTSA were treated with a standard press-fit humeral component with a 135° head shaft angle and a hybrid glenoid component consisting of a polyethylene implant with a porous-coated central peg for bony ingrowth and cemented peripheral pegs (Comprehensive total shoulder; Zimmer Biomet, Warsaw, IN, USA). Use of HSR or augmented glenoid baseplate was determined based on degree of posterior wear and preoperative glenoid retroversion. In patients who glenoid version correction could be achieved with HSR only (less than 15° retroversion preoperatively), a standard implant was used. In patients with retroversion greater than 15°, a combination of HSR and augmented implant or structural bone grafting was used.

Patients who underwent rTSA were also treated with a standard press-fit humeral component with a 135° head shaft angle and onlay type design. The glenoid consisted of a porous-coated glenoid component with one central screw and 4 peripheral screws and a glenosphere designed to have a lateralized center of rotation (Comprehensive total shoulder; Zimmer Biomet, Warsaw, IN, USA). Use of HSR and augmented glenoid baseplate was determined in a similar fashion to those who underwent aTSA. Glenosphere size and humeral tray were determined based on size of the patient and intraoperative assessment of component stability.

All patients underwent the same standard postoperative rehabilitation protocol which consisted of immobilization in a shoulder-immobilizer and subsequent progressive ROM and strengthening in a guided physical therapy program.

Patient demographic and clinical outcomes

The electronic medical record and a shoulder arthroplasty registry maintained at the University at Buffalo (Research Electronic Data Capture; Vanderbilt University, Nashville, TN, USA) were queried. Patient demographic data including age, sex, height, weight, body mass index, race, smoking status, and hand dominance were recorded. Active ROM including forward flexion (FF), abduction (ABD), and external rotation (ER) were performed preoperatively and at each postoperative visit using a goniometer. Active IR was measured based on the highest vertebral level reached by the thumb. This was further divided into three groups: those who could reach L5 or below, those who could reach L1-L5, and those who could reach T12 and above. PROMs evaluated include Quick Disabilities of Arm, Shoulder and Hand score, American Shoulder and Elbow Surgeons score, Single Assessment Numeric Evaluation Score, visual analog scale (VAS) shoulder pain

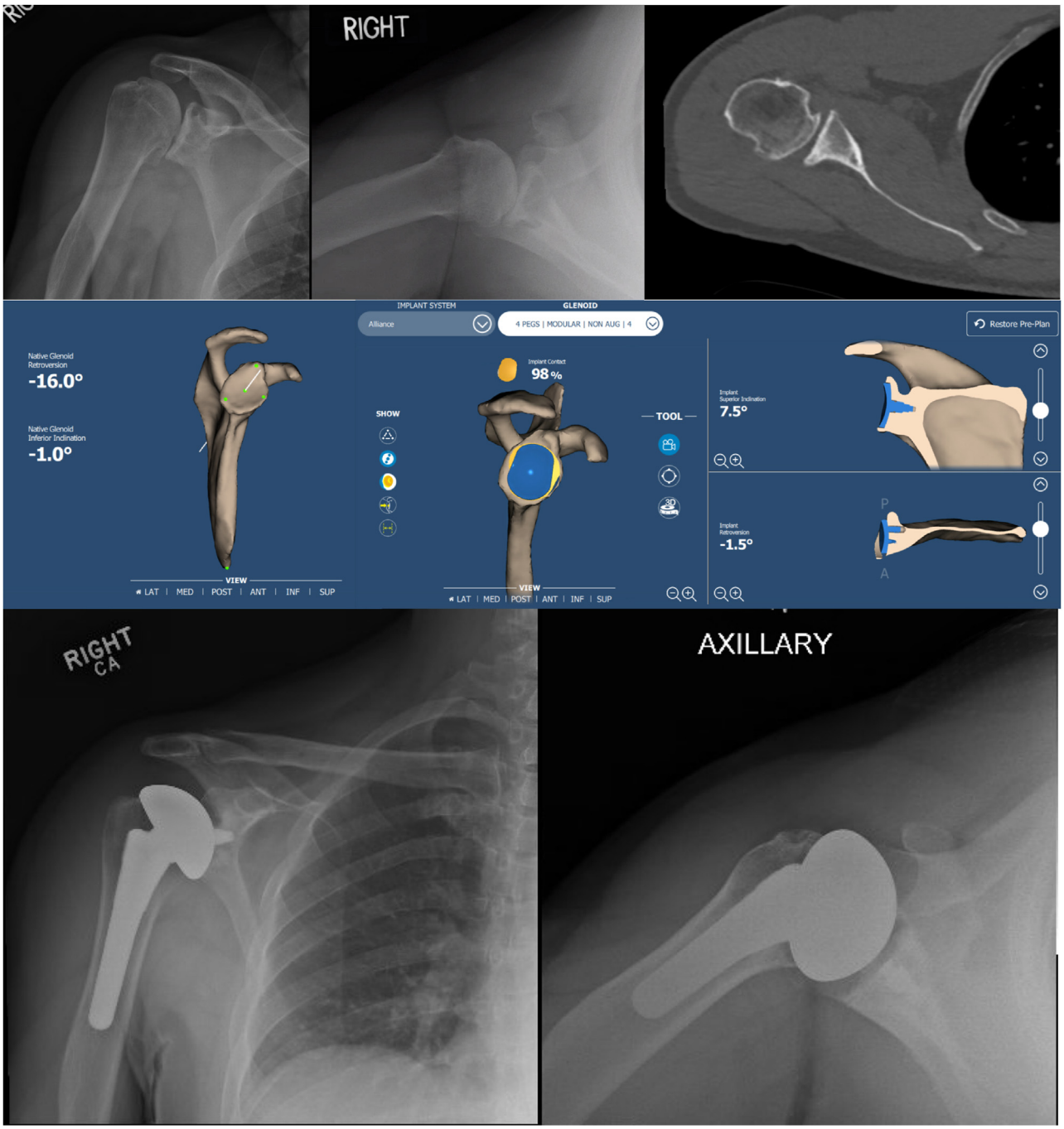

Figure 2 Preoperative radiographs, computed tomography (CT) scan, 3D planning, and postoperative radiographs for a patient who underwent aTSA with high-side reaming for treatment of glenohumeral arthritis with B2 glenoid morphology and 16° of retroversion. *aTSA*, anatomic total shoulder arthroplasty.

score, and VAS shoulder physical function score. Active ROM and PROMs were compared between the two groups preoperatively and at time of final follow-up. Additionally, all complications requiring revisions were recorded and compared.

Radiographic evaluation

Radiographic evaluation was performed by two investigators and discrepancies were reviewed and consensus was reached with input from the lead author. Walch classification and preoperative measurements were determined by review of preoperative computed tomography scans. Glenoid version was measured using the Friedman's line method.[7] Glenoid inclination was measured as described by Gerber et al.[19] Humeral head subluxation was measured using the method previously described by Walch et al and modified by Siebert et al[27,31] Postoperatively standard 3-view shoulder radiographs including Grashey, axillary, and scapular-y views were obtained at each follow-up visit. Glenoid version and inclination were measured on postoperative radiographs as described above. Any evidence of humeral head decentering was evaluated. Radiographs were reviewed for presence of radiolucent lines around the humeral and glenoid components as well as any change in implant position to evaluate for component loosening.

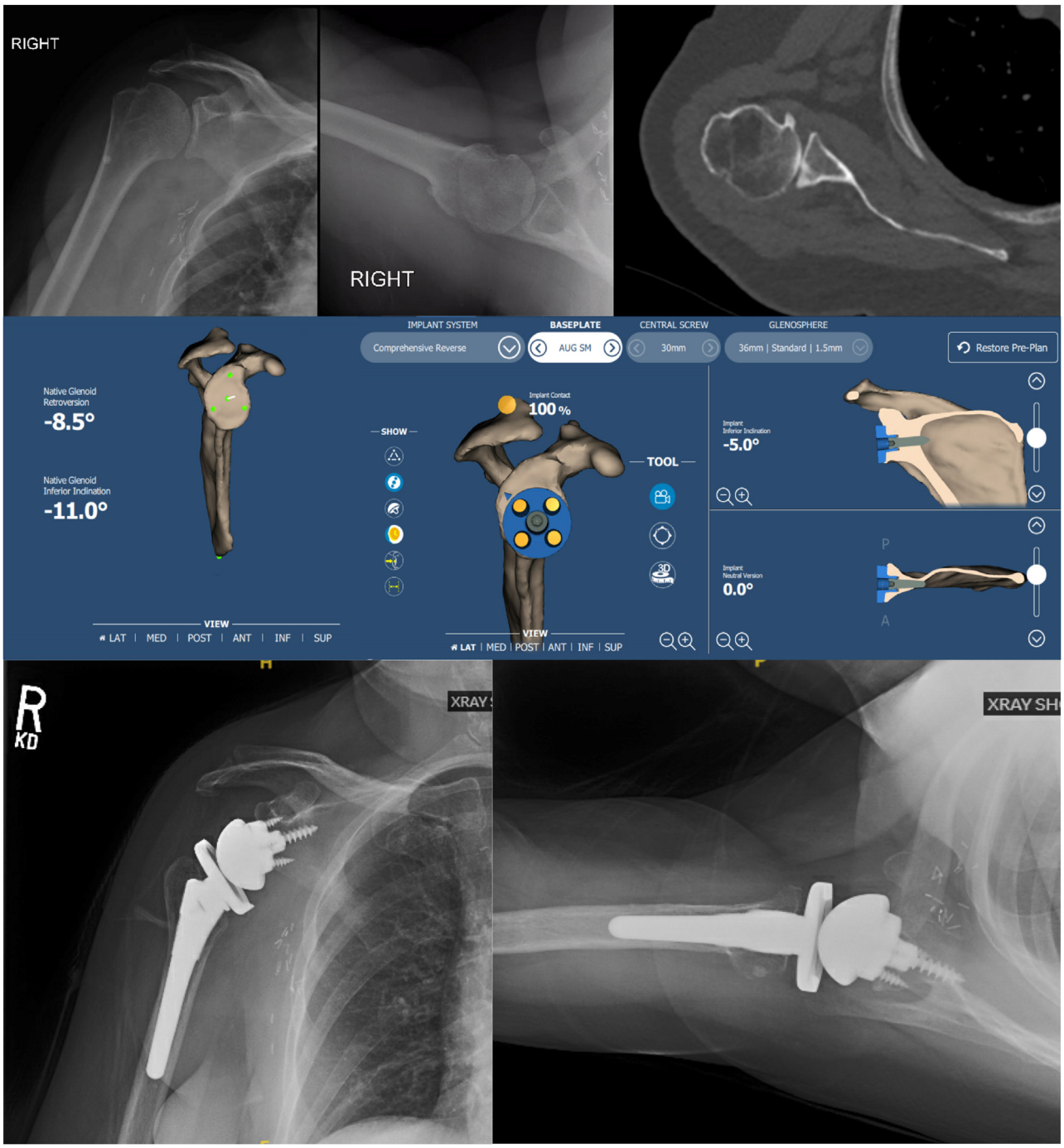

Figure 3 Preoperative radiographs, computed tomography (CT) scan, 3D planning, and postoperative radiographs for a patient who underwent rTSA with high-side reaming and a small glenoid augment for treatment of glenohumeral arthritis with B2 glenoid morphology and 8.5° of retroversion. *rTSA*, reverse total shoulder arthroplasty.

Statistical analysis

Continuous variables were reported as means and standard deviations and categorical variables were reported as frequencies and percentages. The data met the assumption of normality. Independent-sample *t* tests were used to evaluate continuous variables and chi-squared analysis was used to compare categorical/binary variables between the groups who underwent aTSA and those who underwent rTSA. A *P* value of <.05 was considered significant.

Results

The final patient population included 224 patients with Walch B2 type glenoid wear and an intact rotator cuff who underwent shoulder arthroplasty surgery. One hundred sixty-two of these patients underwent aTSA and 62 underwent rTSA. The mean length of follow-up was 25.6 ± 1.95 months for the rTSA group and 32.8 ± 2.27 for the aTSA group ($P = .002$). The patients in the rTSA group were older than those in the aTSA group (75.7 ± 7.27 vs. 68.26 ± 7.59, $P < .001$) and there were more female patients in the

Table I
Demographics of each group.

	rTSA	aTSA	*P* value
Sample size (n)	62	162	
Age (years)	75.70 ± 7.27	68.26 ± 7.59	<.001
Height (cm)	169.85 ± 11.94	169.85 ± 11.94	.037
Weight (kg)	87.33 ± 21.89	92.79 ± 19.74	.077
BMI	30.08 ± 5.90	30.62 ± 5.06	.506
Final follow up (months)	25.6 ± 1.95	32.8 ± 2.27	.002
Operative side (n)			
Left	31	88	.562
Right	31	74	
Sex (n)			
Female	30	49	.019
Male	31	101	
Not reported	1	12	
Race (n)			
American Indian/Alaska Native	0	1	.757
Black/African American	2	8	
White	59	152	
Not reported	1	1	
Smoking status (n)			
Smoker	3	11	.854
Former smoker	20	50	
Never smoker	34	92	
Not reported	5	9	
Hand dominance (n)			
Left	4	11	.68
Right	46	128	
Not reported	12	23	

rTSA, reverse total shoulder arthroplasty; *TSA*, total shoulder arthroplasty; *BMI*, body mass index.

rTSA group (30 vs. 49, $P = .019$). All other patient demographics were similar between the two groups (Table I). Breakdown of operative technique used to correct glenoid version is demonstrated in Table II.

Preoperative and postoperative ROM is demonstrated in Table III. Both the rTSA and aTSA group had significant improvement in ROM in all planes postoperatively compared to preoperative state. Patients in the aTSA group had significantly better FF (110.19 ± 36.51 vs. 97.26 ± 38.96, $P = .021$), ABD (101.49 ± 34.54 vs. 83.63 ± 38.63, $P = .001$), and ER (28.92 ± 18.5 vs. 23.36 ± 17.6, $P = .045$) preoperatively compared to those who underwent rTSA. There was also a larger number of patients who could internally rotate from L1-L5 and from T12 and above preoperatively in the aTSA group compared to the rTSA group, although this did not reach statistical significance ($P = .08$). Postoperatively there was no difference in FF ($P = .145$) and ABD ($P = .808$) between the rTSA and aTSA groups at final follow-up. The patients in the aTSA group had significantly better ER compared to the rTSA group (53.28 ± 12.26 degrees vs. 39.22 ± 18.18 degrees, $P < .001$) and also had a significantly higher number of patients who could reach higher vertebral levels corresponding to better IR ($P < .001$).

There was no difference in baseline PROMs between the two groups (Table IV). Both the aTSA and rTSA groups improved significantly in all PROM scores compared to preoperative levels. There was no statistically significant difference in the two groups in postoperative PROMs at final follow-up (Table IV).

On radiographic analysis, the patients who underwent rTSA had increased glenoid retroversion preoperatively compared to the aTSA group (16.68 ± 6.89 degrees vs. 14.24 ± 6.83 degrees, $P = .018$). Glenoid inclination and posterior humeral head subluxation was not different between the two groups preoperatively (Table V). There was no difference in glenoid version postoperatively ($P = .561$). The patients who underwent aTSA had higher glenoid inclination compared to those who underwent rTSA (4.54 ± 4.26 vs. 2.25 ± 5.8 degrees, $P = .015$). No patients in the rTSA or aTSA group experienced any resubluxation or posterior humeral head decentering postoperatively. One patient in the aTSA group had radiographic evidence of glenoid loosening and was found to have a grossly loose glenoid component intraoperatively at the time of revision. There was no evidence of humeral-sided loosening in either group.

Table II
Operative technique to correct glenoid version.

	Total	HSR	HSR + augment	Structural bone graft
aTSA (n)	162	138	14	10
rTSA (n)	62	21	41	0

aTSA, anatomic total shoulder arthroplasty; *rTSA*, reverse total shoulder arthroplasty.

There were 8 complications requiring revision recorded in 8 patients, 4 in the rTSA group, and 4 in the aTSA group (Table VI). Three patients in the rTSA group experienced instability postoperatively. All were successfully treated with single-stage revision arthroplasty with modular component exchange of the glenoid and humeral components. Stability was achieved in all three patients after the revision surgery with no further revisions required. One patient in the rTSA group was diagnosed with infection which was successfully treated with single-stage revision arthroplasty with irrigation and débridement and complete component exchange. Two patients in the aTSA group were diagnosed with infection, also treated successfully with single-stage revision arthroplasty with irrigation and débridement and conversion to rTSA. Two patients in the aTSA group had rotator cuff insufficiency requiring conversion to rTSA, and one of these patients had evidence of glenoid component loosening intraoperatively.

Discussion

Traditionally, aTSA was the treatment of choice for patients with glenohumeral arthritis and Walch B2 type glenoid morphology with an intact rotator cuff. Prior studies have shown poor clinical results and higher rates of glenoid loosening in patients who were treated with aTSA with glenoid component left in retroversion.[8,10,14,17] Due to this, rTSA has gained popularity and has become the preferred treatment for many arthroplasty surgeons when managing patients with B2 glenoids. In a retrospective matched cohort study Kirsch et al found similar PROMs and complication rates for patients who underwent aTSA compared to rTSA for treatment of glenohumeral arthritis with intact rotator cuff. Patients who underwent aTSA had significantly better ROM postoperatively than those who underwent rTSA.[16] Another retrospective matched cohort study demonstrated no difference in patient satisfaction and average cost effectiveness ratio for patients undergoing aTSA and rTSA, although the group who underwent aTSA had a 2.4% revision rate for glenoid loosening compared to no revisions for glenoid loosening in the rTSA group.[22]

Few studies have directly compared aTSA to rTSA for treatment of patients with glenohumeral arthritis with B2 glenoid morphology and have been limited by evaluation of rotator cuff status. Polisetty et al recently performed a matched retrospective cohort analysis comparing patients with B2 and B3 glenoids who underwent aTSA vs. rTSA at minimum of two years follow-up. rTSA patients had significantly lower VAS pain scores compared to aTSA, and aTSA patients had significantly better IR compared to those who underwent rTSA.[23] In our study we compared patients with glenohumeral arthritis with B2 type glenoid morphology and an intact rotator cuff treated with aTSA and rTSA. We hypothesized that with glenoid version correction to within 5° of neutral and appropriate patient selection based on the algorithm previously described (Fig. 1), both groups would have similar outcomes.

Table III
Preoperative and postoperative range of motion.

	Preoperative			Postoperative (final follow-up)		
	rTSA	aTSA	*P* value	rTSA	aTSA	*P* value
Forward flexion (degrees)	97.26 ± 38.96	110.19 ± 36.51	.021	155.25 ± 29.52	161.11 ± 25.16	.145
Abduction (degrees)	83.63 ± 38.63	101.49 ± 34.54	.001	155.17 ± 29.07	156.34 ± 32.25	.808
External rotation (degrees)	23.36 ± 17.60	28.92 ± 18.50	.045	39.22 ± 18.18	53.28 ± 12.26	<.001
Internal rotation (n)						
T12 and above	2	7	.08	8	48	<.001
L1-L5	6	35		16	65	
Below L5	51	108		23	16	

aTSA, anatomic total shoulder arthroplasty; *rTSA*, reverse total shoulder arthroplasty.

Table IV
Preoperative and postoperative patient reported outcome measures.

	Preoperative			Postoperative (final follow-up)		
	rTSA	aTSA	*P* value	rTSA	aTSA	*P* value
QuickDash	48.73 ± 19.83	47.32 ± 17.11	.703	22.00 ± 22.87	14.38 ± 16.40	.134
ASES	44.04 ± 18.71	47.95 ± 17.52	.2	83.56 ± 19.43	83.58 ± 16.44	.794
SANE	27.88 ± 23.98	27.05 ± 18.28	.859	77.18 ± 29.76	75.46 ± 28.41	.814
VAS shoulder pain	5.85 ± 2.41	5.74 ± 2.24	.771	1.35 ± 2.25	1.53 ± 2.25	.733
VAS shoulder physical function	3.60 ± 1.63	3.86 ± 1.89	.425	7.43 ± 3.54	7.67 ± 2.81	.749

rTSA, reverse total shoulder arthroplasty; *aTSA*, anatomic total shoulder arthroplasty; *QuickDASH*, Quick Disabilities of the Arm, Shoulder, and Hand score; *ASES*, American Shoulder and Elbow Surgeon score; *SANE*, Single Assessment Numeric Evaluation score; *VAS*, visual analog scale.

Table V
Preoperative and postoperative patient radiographic measures.

	Preoperative			Postoperative (2 year follow-up)		
	rTSA	aTSA	*P* value	rTSA	aTSA	*P* value
Glenoid retroversion (degrees)	16.68 ± 6.89	14.24 ± 6.83	.018	1.81 ± 2.66	1.54 ± 2.37	.561
Glenoid inclination (degrees)	10.66 ± 6.55	8.74 ± 6.62	.053	2.25 ± 5.8	4.54 ± 4.26	.015
Posterior humeral head subluxation (%)	78.68 ± 15.81	82.42 ± 11.01	.052			
Posterior humeral head decentering (n)*				0	0	

rTSA, reverse total shoulder arthroplasty; *aTSA*, anatomic total shoulder arthroplasty.
*Posterior humeral head decentering was recorded as a yes or no value in the postoperative radiographic analysis. No patients in the anatomic or reverse total shoulder arthroplasty group demonstrated any evidence of posterior humeral component decentering at 2 year follow-up.

Table VI
Complications requiring revision.

	Instability	Infection	Rotator cuff insufficiency	Component loosening
rTSA (n)	3	1	0	0
aTSA (n)	0	2	2	1*

rTSA, reverse total shoulder arthroplasty; *aTSA*, anatomic total shoulder arthroplasty.
*One patient who underwent total shoulder arthroplasty who had both rotator cuff insufficiency and glenoid component loosening.

Both groups experienced significant improvement in ROM and PROMs compared to preoperative levels. There was no significant difference in PROMs at final follow-up in the patients treated with aTSA compared to those treated with rTSA. This is consistent with prior studies comparing aTSA to rTSA in patients with glenohumeral arthritis and an intact rotator cuff.[16,22,23] There was no difference in ROM in FF, ABD, and IR between the two groups, despite the aTSA group having significantly better ROM preoperatively. There was a trend towards more patients in the aTSA groups' ability to reach higher vertebral levels correlating with IR and humeral extension. aTSA patients were found to have significantly higher ER at final follow-up compared to those who underwent rTSA (53.28 ± 12.26 degrees vs. 39.22 ± 18.18 degrees, $P < .001$). This is similar to prior studies which have demonstrated better rotational motion postoperatively in patients who have undergone aTSA compared to rTSA for cuff-intact glenohumeral arthritis.[16,23] While this is statistically significant, this may not be clinically relevant as the ROM measurements performed in the office were performed with the arm fixed at the side and do not account for any scapulothoracic movement.

Radiographically, patients who underwent rTSA had significantly more retroversion preoperatively compared to those who underwent aTSA (16.68 ± 6.89 degrees vs. 14.24 ± 6.83 degrees, $P = .018$). This was likely not a clinically relevant difference between the two groups. There was no difference between glenoid version postoperatively with both groups achieving close to neutral version. No patients in either group demonstrated any evidence of posterior humeral head decentering postoperatively. In the rTSA group, there was no evidence of radiolucent lines or component loosening postoperatively at final follow-up. In the aTSA group, one patient had radiographic evidence of glenoid loosening and anterior-superior escape associated with rotator cuff insufficiency. This patient was confirmed to have a grossly loose glenoid component intraoperatively at the time of revision surgery.

There was a low rate of complications requiring revision, with 4 complications requiring revision occurring in each group. The aTSA group underwent revision for infection (2), rotator cuff insufficiency (1), and rotator cuff insufficiency with glenoid component loosening (1). The rTSA group underwent revision for instability (3) and infection (1). All patients were treated successfully with single stage revision and did not require further operation.

The complication rate for patients who underwent rTSA was similar to recent studies.[20] In a recent systematic review Heifner et al found that rTSA in patients who had glenohumeral arthritis with intact rotator cuff and glenoid bone loss resulted in significant improvement in Constant score with a low overall complication rate (4.7%).[11] Virk et al demonstrated a 4.5% complication rate with no glenoid component loosening at mean follow-up of 40 months for patients treated with augmented glenoid baseplate with either B2 or B3 glenoid deformity.[30]

In our study for patients who underwent aTSA the complication rate (2.4%) and rate of glenoid loosening (0.6%) was substantially lower than historically reported by Walch et al.[32] This may suggest that in patients undergoing total shoulder arthroplasty for B2 type glenoid morphology, achieving close to neutral glenoid version with combination of HSR with or without augmented glenoid components or structural bone grafting based on preoperative planning may result in similarly low rates of both overall complications and glenoid component loosening in both aTSA and rTSA

Our study is not without limitation. The data presented in our study reflects the experience of a single high-volume shoulder arthroplasty surgeon and therefore may not be generalizable. The aTSA group had significantly longer follow-up compared to the rTSA group. Due to this, complications may develop over time in the rTSA group that were missed by the shorter follow-up period. Additionally, there is inherent selection bias due to the retrospective nature of this study. Selection of aTSA vs. rTSA for these patients was performed by the lead author based on both radiographic and clinical patient characteristics, prior literature, and overall clinical expertise. In general, the lead author's preference was to perform aTSA in patients with intact rotator cuff with adequate bone stock to support an anatomic glenoid component based on preoperative planning. The requirements for this included the central peg to be fully seated with no penetration through the glenoid vault, no more than one peripheral peg penetrated through the vault, > 90% backside support of the glenoid component, < 5 degrees of retroversion of the final implant, and < 5 mm joint line medialization. 100% backside contact of the glenoid component is preferred and was the goal in every anatomic TSA case. However, we are willing to accept 90% surface contact to avoid over medialization of the joint or compromise of the implant fixation in cases that require significant version correction. If these parameters were unable to be achieved with a combination of HSR with standard or augmented glenoid component, then the preference was to perform a rTSA. The patients who underwent rTSA were significantly older and had a significantly higher proportion of females compared to those who underwent aTSA. This may reflect a preference of the lead author to perform rTSA in older female patients.

Overall this study represents a large sample size of patients who underwent total shoulder arthroplasty for primary glenohumeral arthritis with B2 glenoid morphology and an intact rotator cuff at minimum two-year follow-up. It adds useful information to the relatively limited literature comparing aTSA to rTSA for treatment of these patients. Our data suggests that, despite the historically high complication rate of aTSA for treatment of glenohumeral arthritis with B2 glenoid morphology, aTSA may perform similarly to rTSA with low complication rates and good outcomes when version is able to be corrected to within 5 degrees of neutral and proper patient selection is performed.

Conclusion

aTSA and rTSA can produce comparable results with low rates of revision and significant clinical benefit in patients with glenohumeral arthritis and B2 type glenoid morphology when proper patient selection is performed. aTSA may result in improved ROM, although this may not be clinically relevant. Further studies are needed to determine the long-term clinical outcomes, implant longevity, and the superiority of one treatment over the other.

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