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Mid- to long-term outcomes of augmented and nonaugmented anatomic shoulder arthroplasty in Walch B3 glenoids

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Background: In cases of severe osteoarthritis, posterior glenoid wear leads to acquired retroversion of the glenoid. Surgical treatment of glenoids with acquired retroversion and posterior humeral subluxation with anatomic total shoulder arthroplasty (aTSA) is controversial. The purpose of this study was to determine mid- to long-term outcomes and reoperation rates of augmented and nonaugmented aTSA for treatment of glenohumeral osteoarthritis with Walch B3 glenoid deformity.

Methods: This observational cohort study reviewed patients with a Walch B3 glenoid undergoing aTSA at a single institution between 2007 and 2014. Patients were contacted to complete updated patient-reported outcome measures at a minimum of 6 years postoperatively. Outcome measures collected included the American Shoulder and Elbow Surgeons Standardized Shoulder Assessment Form (ASES) score and Single Alpha Numeric Evaluation (SANE) score. Secondary outcomes included any additional surgery on the operative shoulder, patient satisfaction, and willingness to undergo aTSA again.

Results: Thirty-nine patients met inclusion criteria, and thirty-five (89.7%) were able to be contacted for final outcomes evaluation. Mean follow-up was 8.7 years (range 6-13) after surgery. Sixteen patients were treated with an augmented glenoid component, and 19 patients were treated with a standard glenoid component. Of those with standard components, all were partially corrected with asymmetric reaming. At final follow-up, there were no statistically significant differences between those with augmented and standard glenoid components for mean ASES score (93.3 vs. 85.7, $P = .217$), ASES pain score (47.2 vs. 41.6, $P = .161$), SANE score (87.8 vs. 86.0, $P = .692$), and percentage patient satisfaction (95.6% vs. 96.8%, $P = .735$), forward elevation (148° vs. 149°, $P = .852$), or external rotation (36° vs. 39°, $P = .202$). No patient in either group had undergone revision surgery of the operative shoulder over the study period and all patients stated that they would undergo the same surgery again.

Discussion: Both augmented and standard aTSA can provide satisfactory and sustained improvements in patient-reported outcomes in patients with acquired glenoid retroversion due to glenohumeral osteoarthritis. Despite a trend toward alternative treatment options, anatomic shoulder arthroplasty should remain a surgical consideration even in the setting of a Walch B3 glenoid deformity.

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

Keywords: Glenohumeral osteoarthritis; shoulder; arthroplasty; outcomes; Walch; B3; glenoid; survival

Asymmetric posterior glenoid wear is present in up to 50% of patients presenting for shoulder arthroplasty and represents a challenge to surgical reconstruction of the shoulder.[14] Shoulders with posterior subluxation of the humeral head and/or posterior glenoid bone loss were

This study has been approved under Thomas Jefferson University Institutional Review Board (protocol 17D.668).

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originally identified by Walch as B1 or B2 glenoids.[26] However, recent evidence suggests that the natural history of these eccentric glenoids is progressive bone loss into a retroverted, monoconcave, and medialized glenoid.[13,27] Although not included in the original Walch classification, the B3 glenoid was later defined as having eccentric posterior glenoid wear with monoconcavity, not caused by dysplasia, with retroversion >15° or posterior humeral head subluxation >70%, or both.[1] This definition was selected based on literature showing eccentric reaming of glenoids with retroversion >15° would not allow for implantation of standard anatomic glenoid components without perforating the glenoid vault.[1,3,7,10,15,18]

Since its recognition, outcomes following the treatment of complex B3 glenoids with an intact rotator cuff has been of particular interest to shoulder surgeons. Surgical options for glenohumeral osteoarthritis with acquired glenoid retroversion include anatomic total shoulder arthroplasty (aTSA) with standard glenoid components, either with or without partial version correction via asymmetric anterior glenoid reaming, aTSA with a posteriorly augmented glenoid component, aTSA with posterior bone graft, and reverse total shoulder arthroplasty (RTSA).[4-6,9,11,12,14,16,17,19,21-23,25,28]

Asymmetric reaming of the anterior glenoid can partially correct version; however, this technique can lead to further joint line medialization, loss of subchondral bone, peg perforation, and difficulty with soft tissue balancing when attempting to correct 15° or ≥20° of retroversion.[3,7,18] Walch experienced a 16% revision rate and 21% rate of glenoid loosening at mean 6-year follow-up treating B2 glenoids with aTSA with a standard glenoid component and asymmetric reaming of the anterior glenoid.[27] This experience led Walch to recommend the more constrained reverse shoulder arthroplasty in the setting of posterior humeral head subluxation.[4] Although promising midterm results have been reported for RTSA treating B3 glenoids,[4] there are unique complications to consider including scapular spine fractures, inferior glenoid notching, subcoracoid impingement, and internal rotation dysfunction.[20]

To avoid the potential pitfalls of asymmetric reaming and reverse shoulder arthroplasty, some authors have used aTSA with standard glenoid components and minimal version correction or posteriorly augmented glenoids. Matsen et al[14] recently reported on 66 shoulders with a B2 or B3 glenoid treated with a standard glenoid component inserted without changing retroversion and found excellent patient-reported outcomes and survival of all glenoid components at a mean 3-year follow-up. Ho et al[9] reported their encouraging short-term experience (median 2.4 years) treating 71 shoulders with a posterior augmented glenoid and no glenoid failures. Though the short-term results of these techniques are promising, there is particular interest in the mid- to long-term survival of the glenoid component.

The purpose of this study was to evaluate mid- to long-term patient-reported outcomes and reoperation rates of augmented and nonaugmented aTSA for treatment of glenohumeral osteoarthritis with B3 glenoid deformity at a single institution.

Methods

Institutional review board approval was obtained before the initiation of the study. This study was a retrospective observational cohort study. We retrospectively identified all patients undergoing total shoulder arthroplasty by 3 fellowship-trained shoulder surgeons at a single tertiary hospital between January 2007 and December 2014. Inclusion criteria were patients undergoing aTSA in the setting of acquired posterior glenoid bone loss with a monoconcave glenoid and retroversion greater than 15° or posterior humeral head subluxation >70% (Walch B3), either with or without an augmented glenoid component. Patients were excluded for diagnoses other than glenohumeral osteoarthritis, glenoid morphology other than Walch B3, having undergone reverse shoulder arthroplasty or hemiarthroplasty, were undergoing revision procedures, or had undergone a concomitant procedure (ie, rotator cuff repair). Fifty-one patients met inclusion criteria, and of those eligible, 12 were deceased, leaving 39 available for follow-up. Of these, 35 patients completed the follow-up questionnaires and represented our final cohort (89.7% of those available). Patients meeting inclusion and exclusion criteria are shown in Figure 1.

Surgical methods

All patients underwent a TSA with a standard deltopectoral approach. The subscapularis was managed with a lesser tuberosity osteotomy in all cases. Glenoid type was confirmed via intraoperative visualization of retroversion and monoconcavity. All 19 patients with standard glenoid components were asymmetrically reamed for partial version correction, and pegged glenoid components were used. All patients in the augmented cohort received a stepped component. Standard or augmented glenoid component use was at the discretion of the operating surgeon, based on the amount of posterior bone loss, joint line medialization, and surgeon training/philosophy in management. After glenoid preparation, cement was pressurized in all anchor holes and the glenoid components were held in place until the cement cured. In the case of perforation of the central hole, bone graft was placed into the hole and cement was placed but not pressurized in that hole.

On the humeral side, the Global AP shoulder system (DePuy Synthes, Warsaw, IN, USA) or Ascend Flex system (Wright Medical, Memphis, TN, USA) was used. On the glenoid side, the Anchor Peg Glenoid (DePuy Synthes), Affiniti glenoid (Wright Medical), or StepTech glenoid (DePuy Synthes) was used. Implant system was at the discretion of the operating surgeon. The lesser tuberosity osteotomy was repaired in all cases. Implant characteristics and sizes are shown in Table I.

Patients were seen for routine follow-up at 2 weeks, 6 weeks, and 3 months postoperatively. If patients were doing well at the 3-month visit, they were recommended for routine yearly follow-up thereafter.

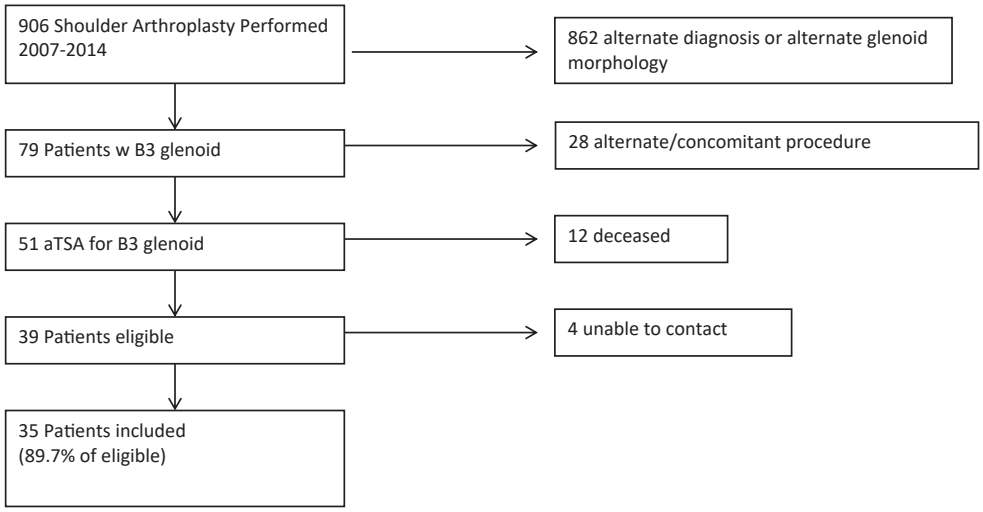

Figure 1 Inclusion and exclusion criteria.

Table I Surgical characteristics

	Standard glenoid component (n = 19)	Augmented glenoid component (n = 16)
Humeral system/size	DePuy Global AP: 13	DePuy Global AP: 13
	- Size 10: 3	- Size 10: 3
	- Size 12: 9	- Size 12: 8
	- Size 16: 1	- Size 14: 2
	Tornier Ascend: 6	Tornier Ascend: 3
	- Size 4: 1	- Size 4: 1
	- Size 6: 4	- Size 5: 1
	- Size 9: 1	- Size 7: 1
Glenoid system/size	DePuy Anchor Peg: 13	DePuy StepTech: 16
	- Size 44: 2	- Size 44 + 7: 1
	- Size 48: 5	- Size 48 + 3: 4
	- Size 52: 5	- Size 48 + 5: 3
	- Size 56: 1	- Size 52 + 3: 2
		- Size 52 + 5: 5
	Tornier Affiniti: 6	- Size 52 + 7: 1
	- Size 48: 2	
	- Size 52: 4	
Central peg hole penetration	No: 14	No: 7
	Yes: 5	Yes: 9
Postoperative complications:	Pulmonary embolism: 1	Axillary neuropathy: 1
	Ulnar neuropathy: 1	Periprosthetic humeral shaft fracture: 1
	Superficial infection: 1	Superficial infection: 1

Data collection

Patient charts were reviewed to collect demographics including age, sex, body mass index, and age-adjusted Charlson Comorbidity Index.[2] Surgical records were reviewed by 2 shoulder and elbow fellows to record surgical approach, subscapularis management, implant selection, and glenoid component selection (standard vs. augmented). Indication for standard vs. augmented glenoid was at

the discretion of the operating surgeon. Postoperative notes were reviewed to record postoperative range of motion.

Patients were contacted to complete updated patient-reported outcome measures at a minimum of 6 years postoperatively. Outcome measures collected included the American Shoulder and Elbow Surgeons Standardized Shoulder Assessment Form (ASES) score,[20] visual analog scale for pain, and Single Assessment Numeric Evaluation (SANE) score.[8] Patients were also asked if they have had any additional surgery on the operative shoulder, to rate how satisfied they were with their surgery on a scale from 0-100, and if they would undergo the same procedure again.

Radiographic analysis

The preoperative radiographs of all eligible patients were reviewed by 1 fellowship-trained shoulder surgeon and 2 orthopedic shoulder fellows. All preoperative radiographs were within 12 months of surgery except for 1 patient, who obtained radiographs 2 years preoperatively. Glenoid morphology was graded according to the modified Walch classification.[1] Computed tomographic scans or magnetic resonance images were used to assist in glenoid classification when available. If there was disagreement between the reviewers about the glenoid morphology, the radiographs were reviewed together and a consensus was reached.

Preoperative axillary lateral radiographs or computed tomographic scans (when available) were evaluated to measure glenoid retroversion. Preoperative glenoid version was defined by the angle formed between the scapular axis (Friedman line) and a line perpendicular to the native glenoid face, excluding osteophytes (Fig. 2).

Statistical analysis

No a priori power analysis was performed as patients were identified retrospectively and all available patients were included. Data normality was assessed using the Shapiro-Wilk test. Equality of variance between groups was assessed with the Levene test. Standard and augmented glenoid component cohorts were compared with independent sample t tests or Mann-Whitney U tests based on data normality for preoperative glenoid version, postoperative range of motion, and postoperative ASES, visual analog scale, SANE, and percentage satisfaction scores. Chi-square or Fisher exact test was performed to evaluate the incidence of additional surgery and if patients would undergo the same TSA again between those with an augment and those without. A P value of less than .05 was considered to be significant. Post hoc power analysis was performed based on the clinical outcomes collected.

Results

Of the 35 patients included, 19 patients received a standard glenoid component and 16 received an augmented glenoid component. Average follow-up was 9.3 years (range 6-13) in the standard group and 8.0 years (range 6-10.5) in the augmented group. Patient demographics are shown in Table II.

There were no statistically significant differences in preoperative retroversion between patients with standard and augmented glenoid components. Preoperative glenoid retroversion was 24° ± 8.6° (range 11.2°-41.8°) in the standard cohort and 29° ± 5.8° (range 18.5°-37.5°) in those who received augmented glenoid components ($P = .06$).

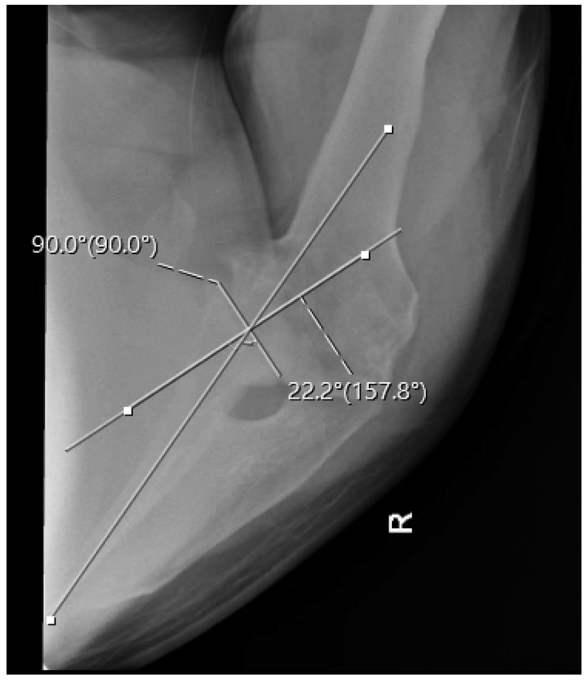

Figure 2 Preoperative glenoid retroversion measurement. Preoperative glenoid retroversion was measured as the angle between the scapular axis (Friedman line), and a line perpendicular to the native glenoid face, excluding osteophytes.

At the time of glenoid preparation, there was anterior perforation of the central peg hole in 5 patients in the standard component cohort and 9 patients in the augmented component cohort. There were no intraoperative complications in either cohort. There were 3 postoperative complications in each cohort. Postoperative complications are listed in Table I. The 2 patients with superficial infections were managed with antibiotics; 2 patients with neuropathies were observed and the nerves recovered spontaneously; and the periprosthetic humeral shaft fracture occurred after a fall and was managed nonoperatively.

Over the follow-up period, none of the included patients had any secondary surgeries on the operative shoulder and all patients would want to undergo the same surgery again. Comparing those with standard and augmented glenoid components, there were no statistically significant differences in range of motion, ASES score, visual analog scale score, SANE score, or satisfaction (Table III).

Discussion

The management of B3 glenoids provides a number of challenges to the treating surgeon, including how best to manage glenoid retroversion, posterior glenoid bone loss,

Table II Patient demographics

	Standard (n = 19)	Augmented (n = 16)
Sex, n		
Male	16	15
Female	3	1
Age	68.4 ± 8.6	70.0 ± 8.7
Follow-up length	9.3 ± 2.0	8.0 ± 1.5
Body mass index	29.1 ± 4.0	29.3 ± 5.2
Age-adjusted Charlson Comorbidity Index	3.7 ± 1.3	4.1 ± 1.7

Unless otherwise noted, values are mean ± standard deviation.

Table III Postoperative patient-reported outcomes scores

Outcome measure	Glenoid component	n	Mean	SE	*t* or *z* score	*P* value
ASES score	No augment	19	85.7	3.7	−1.3	.217
	Augment	16	93.3	1.5		
ASES pain	No augment	19	41.6	2.6	−1.5	.161
	Augment	16	47.2	0.9		
SANE score	No augment	19	86.0	3.9	−0.4	.692
	Augment	16	87.8	2.4		
Percentage satisfaction	No augment	19	96.8	2.7	0.3	.735
	Augment	16	95.6	1.6		
Postoperative forward elevation	No augment	19	149°	3.7°	−0.2	.852
	Augment	16	148°	4.7°		
Postoperative external rotation	No augment	19	39°	2.2°	−1.4	.202
	Augment	16	36°	2.3°		

ASES, American Shoulder and Elbow Surgeons Standardized Shoulder Assessment Form; *SANE*, single alpha numeric evaluation; *SE*, standard error.

joint line medialization, and posterior subluxation of the humeral head. In the current study, we report the results of 36 patients with glenohumeral osteoarthritis and a B3 glenoid wear pattern managed with anatomic shoulder arthroplasty, either with or without a posteriorly augmented glenoid component. We found that using both standard and augmented glenoid components reliably produced excellent survivorship, patient satisfaction, and patient-reported outcome scores at mid- to long-term follow-up.

In our cohort of B3 glenoids, 19 patients were successfully treated with aTSA with a standard glenoid component. Matsen et al[14] recently reported their clinical and radiographic outcomes treating 26 B3 glenoids with TSA with a nonaugmented all-polyethylene glenoid component without attempting to normalize glenoid version. At a mean follow-up of 3 years, the mean Simple Shoulder Test score improved from mean 3.0 ± 2.5 ''yes'' responses preoperatively to mean 9.4 ± 2.1 ''yes'' responses postoperatively ($P < .001$). In their supplemental data, they reported a mean follow-up of 4 years on 52 B3 glenoids with a mean postoperative SANE score of 86 ± 13, which is very similar to our results. Two patients underwent manipulation within the first 3 months after surgery for shoulder stiffness, and no patients underwent revision of the components. Radiographic review showed that minimal correction of glenoid retroversion was performed at surgery with values of −26° ± 7° preoperatively to −23° ± 7° postoperatively. They reported bone integration into the central peg of 81% for B3 glenoids, which was not inferior to other glenoid types. Anterior penetration of the glenoid neck by the central peg was observed in 23% of the B3 glenoids in their series, which did not significantly affect postoperative mean Simple Shoulder Test score. DeVito et al[5] reviewed their clinical experience treating 40 patients with severe glenoid retroversion (>20°) with aTSA with nonaugmented glenoid component with the goal of creating a concentric surface to match the backside of the glenoid component with partial correction of glenoid retroversion without violating the subchondral bone. At a mean follow-up of 53 months (range, 24-129 months), they observed significant improvements in preoperative to postoperative mean Simple Shoulder Test score (3.7 ± 2. to 9.5 ± 2.8), SANE score (44.4 ± 24.6 to 80.6 ± 22.5), and ASES total score (34.9 ± 15.4 to 84.8 ± 18.9). Three patients (8%) were observed to have gross glenoid component loosening on radiographic review; however, no revision procedures were performed. They compared these results to a matched cohort of 80

patients with glenoid retroversion <20° treated with aTSA and found no difference in postoperative patient-reported outcome scores, range of motion, or radiographic findings.

In our series, patients treated with aTSA with a posterior augmented glenoid component also had durable results at a mean 8-year follow-up. Our findings were consistent with previous studies reporting short-term outcomes. Ho et al[9] reported on 71 shoulders with B2 (65%) or B3 (35%) glenoids treated with a posteriorly stepped augmented glenoid component with a minimum 2-year follow-up. They found significant improvements from preoperative to postoperative functional outcomes scores (median Penn Shoulder Score 30-94), range of motion, humeral centering (16%-85%), and correction of glenoid retroversion ($-24° \pm 7°$ to $-11° \pm 6°$). Central peg osteolysis was present in 15% at latest follow-up and associated with greater preoperative joint-line medialization and posterior glenoid bone loss, and worse functional outcomes scores were associated with greater preoperative posterior humeral head subluxation.[9] Priddy et al[21] evaluated 37 full-wedge posterior augmented glenoid components (including 5 B3 glenoids) and matched to 37 control shoulders without posterior augmented glenoids (including 7 B3 glenoids). At a mean follow-up of 3.2 years, both groups demonstrated similar improvements in pain, range of motion, and functional outcome scores. Radiographic review at final follow-up demonstrated lucencies in 54% of augmented glenoids compared with 46% in standard glenoid component. Two cases of augmented glenoids (5%) required reoperation, one for deep infection and one for symptomatic glenoid loosening.

The limitations of this study include its retrospective design and the relatively small patient cohort. The patients in this study all had surgery at a single tertiary hospital, so arthroplasties performed at other hospitals within our institution may have been missed. Given that this was performed at a high-volume single institution, it may not be generalizable to all surgeons performing shoulder arthroplasty. Multiple implant systems were used in the study population, so the groups are not uniform; however, all standard glenoid components were pegged and all augmented components had a stepped design. Additionally, given the small number of patients, we were unable to perform a subgroup analysis between those with relatively mild B3 glenoids (<20° retroversion) and those with more significant glenoid deformity (>20° retroversion). All patients available were included, although a post hoc power analysis showed that a sample size of approximately 140 patients would be needed to obtain statistical power of 0.80. Given the rarity of anatomic shoulder arthroplasty performed in the setting of a B3 glenoid deformity, a larger patient series would require a multicenter design. However, this is the largest reported series of aTSA with both augmented and standard glenoid components in this patient population. Additionally, even if the nonsignificant results would be significant with appropriate statistical power, the differences would not be clinically significant per the minimal clinically important difference for ASES score.[24]

Another limitation includes the lack of universal preoperative advanced imaging to measure glenoid version and the lack of long-term radiographic follow-up to assess for central peg osteolysis or loosening. Patients doing well often did not return for evaluation beyond the immediate postoperative period, and patients were contacted via telephone to collect updated clinical outcome scores for this study. It is possible that patients may have evidence of subclinical glenoid loosening that would be identified radiographically without affecting clinical outcome scores. A further limitation of the study is the absence of a control group of patients undergoing aTSA with concentric glenoid wear without posterior subluxation or posterior glenoid wear; however, the patient-reported outcome scores in our cohort are similar to those reported in previous studies.

Conclusion

Both augmented and standard aTSA can provide satisfactory and sustained improvements in patient-reported outcomes in patients with acquired glenoid retroversion due to glenohumeral osteoarthritis. Despite a trend toward alternative treatment options, anatomic shoulder arthroplasty should remain a surgical consideration even in the setting of a Walch B3 glenoid deformity.

Disclaimer

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