



Total shoulder arthroplasty in patients with a B2 glenoid addressed with corrective reaming: mean 8-year follow-up

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Background: The management of Walch B2 glenoid deformities in primary glenohumeral osteoarthritis is frequently debated. Previous literature has shown that the treatment of B2 glenoids with high-side reaming and anatomic total shoulder arthroplasty (aTSA) perform well in the short-term but is associated with an increased glenoid component failure rate in severe deformities. Therefore, many have explored alternative options, including augmented anatomic glenoid components and reverse shoulder arthroplasty. Our goal in this study is to provide mid-term radiographic and clinical outcomes after high-side reaming and aTSA for B2 glenoids.

Methods: Patients were followed both clinically and radiographically. Preoperative computed tomography scans were used for retrospective analysis of deformity. Both preoperative and postoperative visual analog scale pain, American Shoulder and Elbow Surgeons score, and Simple Shoulder Test scores were collected. Radiographs were analyzed preoperatively and postoperatively for humeral head decentering relative to the glenoid vault, immediate glenoid seating, and final glenoid peg radiolucency.

Results: Of the original cohort of 59 patients (6 now deceased) reported at a mean radiographic follow-up of 3.4 years, 34 shoulders in 33 patients with B2 glenoids (mean retroversion 18.9°, range 4°–32°) were available for follow-up at a mean of 8.6 years (range 5.5–11.2) after high-side glenoid reaming with aTSA. Three (5.1%) of the original 59 shoulder were revised. At final follow-up, 3 of 30 (10.0%) shoulders had radiographic glenoid component failure, but were unrevised. Glenoid component failure was associated with worse initial glenoid component seating (mean Lazarus score 1.2 vs. 2.0, $P = .002$). Glenoid failure was also associated with increased posterior humeral head subluxation at 2–4 year follow-up (mean 5.6% vs. 12.6%, $P = .045$) and at final follow-up (mean 7.0% vs. 21%, $P = .002$). There was no association between glenoid component failure and preoperative retroversion, inclination, or humeral head subluxation (all $P > .05$). Glenoid component failure was associated with worse American Shoulder and Elbow Surgeons (88 vs. 73) and visual analog scale pain (0.8 vs. 2.1) scores (both $P = .03$).

Conclusions: At a mean of 8.6 years, 88% of shoulders available for follow-up had well-fixed glenoid components. Glenoid component failure was associated with poor initial glenoid component seating, with failed components having an average of 25% of the glenoid component not seated. Preoperative deformity such as glenoid retroversion, inclination, or humeral head subluxation did not predict glenoid component failure. This study supports that initial glenoid component seating and recurrence of posterior humeral head subluxation may be the most important factors for mid-term glenoid component survival in aTSA in patients with B2 glenoids.

Level of evidence: Level IV; Case Series; Treatment Study

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Patients with primary glenohumeral osteoarthritis (GHOA) and a glenoid retroversion deformity present a controversial treatment challenge today. Early reports demonstrated a relatively high failure rate of anatomic total shoulder arthroplasty (aTSA) for patients with Walch B2 glenoids.¹³ However, some historic surgical techniques used in previous publications, such as the use of a bone graft behind the glenoid component, are used less commonly today. Therefore, these studies may not be generalizable to current surgical techniques and treatment strategies of managing glenoid deformities in shoulders with B2 glenoids.

More recently, reverse shoulder arthroplasty (RSA) utilization has increased, due in part to expanded indications which now include shoulders with primary GHOA with a glenoid retroversion deformity. As such, the use of aTSA has undergone a proportional decrease even though the total number of shoulder arthroplasties has increased, as many surgeons have shifted to using RSA instead.^{1,2} However, there is limited evidence so far to support this change, as there are limited mid-term and long-term studies on the clinical and radiographic outcomes of the use of aTSA for primary GHOA with a Walch B2 glenoid retroversion deformity.

Our goal in this study is to present our mid-term clinical and radiographic outcomes of patients with primary GHOA and a B2 deformity that underwent aTSA with a cemented all-polyethylene glenoid placed after corrective reaming without the use of augmented components or bone graft at a single institution. This study includes mid-term clinical and radiographic data at an average of 8.6 years and is a follow-up of our previously published study, which included a mean of 50 months of follow-up.¹¹ We hypothesized that patients would have a low radiographic failure rate and good clinical outcomes at mid-term using the techniques described in this study.

Materials and methods

We performed a retrospective review of patients that underwent an aTSA between 2007 and 2014. As described in our previous publication, patients underwent an aTSA for the indication of primary GHOA.¹¹ Our inclusion criteria included all Walch B2 glenoids, without any defined preoperative glenoid retroversion deformity limit. Exclusion criteria included: 1) Lack of preoperative shoulder computed tomography (CT) scan, 2) Diagnosis other than osteoarthritis of the glenohumeral joint, 3) Glenoid deformity addressed with bone grafting, and 4) Less than 5 years follow-up post-surgery.

Preoperative radiographs and CT scans were available on all patients. All CT scans were reformatted in the plane of the scapula using Osirix software (Geneva, Switzerland) to calculate the glenoid retroversion angle, glenoid inclination angle, and percentage of humeral head subluxation using a previously described technique.³ Additionally, humeral head decenting relative to the

glenoid face as described by Matsen, et al was measured preoperatively, postoperatively at 2-4 years follow-up, and at final follow-up (see Table I).¹⁰ Initial glenoid component seating was measured on true AP and axillary radiographs obtained at the first postoperative visit as described by Lazarus, et al.⁹ Glenoid peg lucency was then measured at final follow-up on true AP and axillary radiographs, also as described by Lazarus, et al.⁹ Measurements were completed by 2 of the authors (J.D.K. and R.E.H.) and an average of the 2 measurements was used. Glenoid components were considered loose radiographically when the Lazarus score was 4 or greater or there was gross subsidence of the glenoid component. Any shoulder revised for glenoid loosening was assigned a Lazarus grade 5. Where any differences existed in radiolucent line grading and implant seating assessment, the case was reviewed and a consensus was reached.

The following clinical data collected preoperatively and at final follow-up was included: visual analog scale (VAS) pain score, American Shoulder and Elbow Surgeons (ASES) score, and Simple Shoulder Test (SST) score.

Surgical technique

We performed an aTSA using our previously reported technique by 1/4 shoulder and elbow fellowship-trained surgeons at a single institution.¹¹ To summarize, all patients had a deltopectoral approach and the subscapularis managed with a lesser tuberosity osteotomy. A cemented all-polyethylene, in-line pegged glenoid implant was used with a cemented or noncemented humeral stem (Zimmer, Warsaw, IN, USA). A preoperative CT scan helped define the deformity. We planned for an estimated glenoid retroversion correction to 10°-15° of neutral. Glenoid reaming was performed by first sounding the glenoid vault using a small caliber drill bit at an angle that would remove the ridge between the neoglenoid and paleoglenoid and partially correct the retroversion deformity through high-side reaming. Though we would accept 80% seating to prevent excessive reaming, we tried to obtain as close to 100% glenoid component seating as possible in all cases. In the setting of severe retroversion deformity, glenoid reaming to >15° retroversion was allowed to prevent excessive bone removal that would occur at a more anteverted reaming angle. Severe retroversion deformity was defined as a deformity that could not be corrected to 10°-15° of neutral with nearly 100% seating, without perforating the subchondral plate. Reaming angles and degree of version correction were estimated intraoperatively.

Manual cement pressurization was performed carefully and meticulously in all cases prior to glenoid component implantation. To pressurize, we used a large syringe to fill and pressurize cement into the drilled peg holes, followed by manual pressurization/packing using an edge of a sponge on a narrow hemostat-like instrument. This process was repeated 2-3 times for each drill hole, followed by final cement filling, implant insertion, and impaction. No cement was placed on the backside of the implant.

Humeral preparation was done to match native humeral version and a head selected to match the native head to greater tuberosity height. Humeral stems were implanted in 20°-40° of retroversion, and no attempt was made to change proximal humeral version unless it was outside of this range. In this cohort, eccentric humeral heads were used to help recreate anatomy, but we did not dial the head center anteriorly to augment stability.

Table I Summary of radiographic outcomes (n = 30^{*})

Variable	Preoperative		2-4 Years postoperative [†]		Final postoperative [‡]	
	Mean (SD)	Range	Mean (SD)	Range	Mean (SD)	Range
HH subluxation (glenoid vault method)	8.7% (6.1%)	−5% to 21%	6.5% (6.5%)	−2 to 25%	8.8% (8.7%)	−3% to 37%
HH subluxation (Friedman's line method)	67.6% (8.7%)	46%-86%	-	-	-	-
Glenoid retroversion (corrected 2D CT)	18.9° (6.7°)	4°-32°	-	-	-	-
Glenoid inclination (corrected 2D CT)	6.2° (6.7°)	−10° to 23°	-	-	-	-

SD, standard deviation; HH, humeral head; CT, computed tomography.

^{*} Radiographs unavailable on 4 shoulders.

[†] Mean follow-up of 3.4 years.

[‡] Mean follow-up for 8.6 years.

Table II Summary of clinical outcomes (n = 30^{*})

	Preoperative		Postoperative (mean 8.6 yr)		Change	
	Mean (SD)	Range	Mean (SD)	Range	Mean	Range
VAS pain	7.1 (1.7)	2-10	1.0 (1.5)	0-6	−6.1 (2.1)	−1 to −10
ASES score	37.8 (15.5)	15-90	86.0 (15.5)	40-100	48.2 (16.4)	2-80
SST	4.9 (2.5)	0-12	9.5 (2.6)	3-12	4.7 (2.6)	0-11

VAS, visual analog scale; ASES, American Shoulder and Elbow Surgeons; SST, Simple Shoulder Test.

^{*} Four patients did not complete follow-up surveys.

Statistical analysis

Two-tailed Student *t*-test was used to compare continuous variables. A multivariate linear regression analysis was performed to determine correlations and Pearson probability of correlation between variables. Statistical analysis was completed using JMP software (Cary, NC, USA).

Results

Demographics

Of the 59 subjects that participated in the prior study, 6 were deceased, leaving 53 subjects eligible for further clinical follow-up at this time point. Despite multiple attempts to contact each patient, we were able to contact and recruit 33 of the eligible 53 subjects (62.2%, 34 shoulders) to participate in the present study. The mean subject age at the time of surgery was 65.5 years (range 38-83) and the median age was 65.9 years. 38% of the subjects were female. Surgery was done on the dominant side for 74% of patients. The mean age at the time of surgery of the 26 subjects not included in this study was 63.9 years and was not significantly different ($P = .67$).

Subjects were followed for a mean of 8.6 years (range 5.5-11.2) after high-side glenoid reaming with aTSA. At final follow-up, radiographs were available on 30 of 34 shoulders (88%) and clinical data (VAS pain, ASES, and

SST) were available for 30 (88%) shoulders. Three of 30 shoulders (10.0%) with available radiographs in the cohort of 34 shoulders were classified as radiographically loose, but were unrevised. One shoulder (2.9%) in the cohort of 34 shoulders was revised and was excluded from radiographic and clinical outcome analysis after revision, but was accounted for in the implant survivorship calculations. Therefore, a total of 4 of 34 shoulders (11.8%) can be considered as having a clinical or radiographic glenoid failure. Of the original cohort of 59 shoulders, a total of 3 (5.1%) were revised based on clinical follow-up or remote follow-up by phone.

Revision summary

One patient was revised 3 years and 10 months after the primary surgery to a RSA for a large rotator cuff tear involving the supraspinatus and subscapularis. The primary surgery was done at age 84. A second patient was revised to an RSA for a loose glenoid 7.0 years after the primary surgery, which was done at age 62. This revision required a bulk femoral head allograft and was ultimately complicated by baseplate loosening and failure. A third patient had a partial revision for a subjective sense of posterior instability by changing the original prosthetic humeral head to an anteriorly offset humeral head. This was done 8 years and 4 months after the index surgery. The index procedure was done at age 39. They were seen in clinic 2 years and

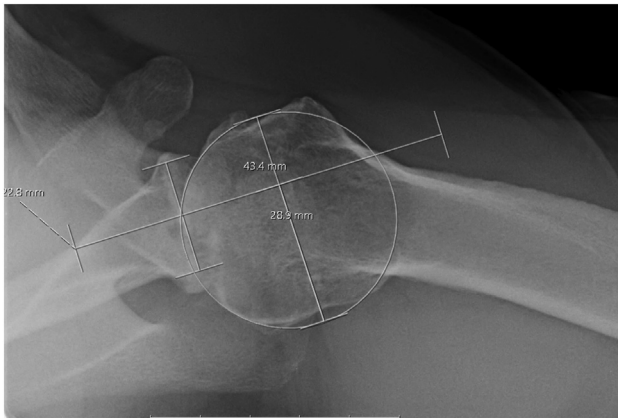


Figure 1 An example patient preoperative x-ray.

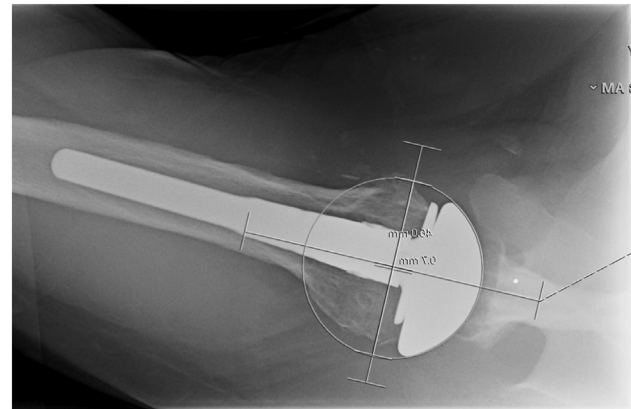


Figure 3 An example patient's first postoperative axillary x-ray, 2 weeks after surgery.

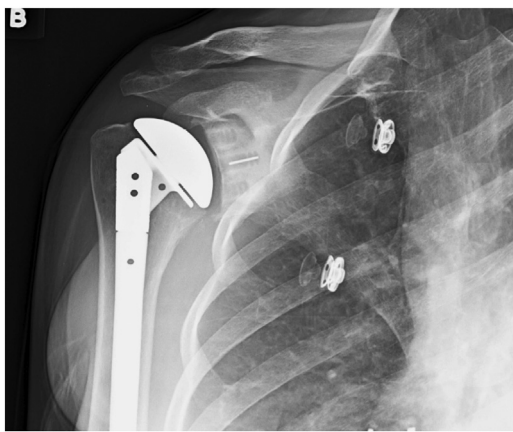


Figure 2 An example patient's first postoperative true AP x-ray, 2 weeks after surgery.



Figure 4 An example patient's 9-year follow-up true AP x-ray.

5 months after the partial revision and the patient was doing well.

Clinical outcomes

Clinical data were available on 30 subjects (88%) at final follow-up. The mean VAS pain score improved on average from 7.1 preoperatively to 1.0 postoperatively. The mean ASES score improved from 37.8 to 86.0, and the mean SST score improved on average from 4.9 to 9.5 at final follow-up (see [Table II](#)). All patient-reported clinical outcomes were significantly improved compared to preoperative values.

Radiographic outcomes

Radiographic outcomes are presented in [Table I](#) and sample patient radiographs are shown in [Figures. 1-5](#). All subjects

had a preoperative B2 glenoid deformity, and the mean preoperative retroversion was 23.0° (range 10° - 39°). Pre-operative humeral head subluxation relative to the glenoid vault was a mean of 8.7%, 6.5% at intermediate follow-up, and 8.8% at final follow-up. There was no significant difference in preoperative and postoperative humeral head subluxation at final follow-up ($P = .16$). We found a correlation between preoperative glenoid retroversion and preoperative humeral head subluxation, where each additional degree of glenoid retroversion was associated with 0.65% additional humeral head posterior subluxation ([Fig. 6](#)).

Lazarus grading of radiolucent line progression is presented in [Table III](#). At final follow-up, the mean Lazarus score assessing glenoid radiolucencies was 1.0 ($n = 30$) compared to 0.56 ($n = 34$) at 3.4 years follow-up ([Table III](#)). Three unrevised shoulders were classified as radiographically loose. Including the one shoulder revised for



Figure 5 An example patient's 9-year follow-up axillary x-ray.

glenoid loosening, the rate of aseptic glenoid loosening in this cohort was 4/34 (11.8%) at a mean of 8.6 years. The initial Lazarus glenoid seating scores are provided in [Table IV](#).

Correlations

We performed a multivariate linear regression analysis to determine correlations between preoperative patient factors and postoperative radiographic and clinical outcomes ([Table V](#)). We noted a moderate but significant ($r = 0.44$, $P = .02$) correlation between immediate glenoid component seating and glenoid peg radiolucency at final follow-up. There was a moderate but significant ($r = 0.46$, $P = .01$) correlation between glenoid peg radiolucency and humeral head subluxation at final follow-up. These were the most notable and clinically significant findings of this study.

We also noted significant and moderate correlations between glenoid peg radiolucency at final follow-up and lower clinical improvements in VAS pain score ($r = 0.42$, $P = .03$), VAS pain delta ($r = 0.47$, $P = .02$), and ASES score delta ($r = -0.44$, $P = .03$).

Subgroup analysis: failed glenoid components

A subgroup analysis of failed glenoid components is summarized in [Table VI](#). Failed glenoid components ($n = 4$) were defined as a Lazarus score of 4-5 or shoulders requiring revision for glenoid component failure. Failed glenoid components had the following clinically and statistically significant findings: worse initial glenoid component seating, higher posterior humeral head subluxation at 2-4 year and final follow-up, higher VAS pain scores, and lower ASES scores.

Discussion

Performing an aTSA in patients with a Walch B2 glenoid deformity has recently become increasingly controversial.

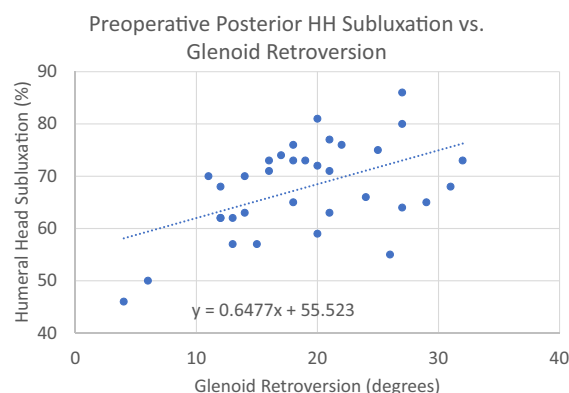


Figure 6 Correlation between preoperative glenoid retroversion and posterior HH subluxation, where each additional 1.0° of glenoid retroversion corresponds to 0.65% additional HH posterior subluxation. HH, humeral head.

Given the increasingly popular use of reverse arthroplasty for the treatment of GHOA, it is incumbent to understand the rate of glenoid failure in shoulders with B2 glenoids treated with aTSA at longer follow-up periods. This is especially true given the majority of previous studies only provide short-term data. It has been our experience that many patients with B2 glenoids do well clinically after aTSA performed with a high-side reaming technique and a pegged, cemented, nonaugmented, all-polyethylene glenoid component. Therefore, we were motivated to first study and then report our mid-term clinical and radiographic outcomes.

The most important findings from our study were that complete initial glenoid component seating was significantly associated with better radiographic ($P = .02$) glenoid component survival at mid-term and better clinical ($P = .03$) outcome scores. Additionally, there was a moderate but significant ($r = 0.46$, $P = .01$) correlation between glenoid peg radiolucency and humeral head subluxation at final follow-up. We also found that increasing glenoid peg radiolucency at final follow-up correlated with worse ASES and VAS pain scores. Surprisingly, in our multivariate linear regression analysis we did not find that preoperative glenoid deformity as defined retroversion, humeral head subluxation, or glenoid inclination were associated with an increased rate of glenoid component failure or poorer clinical outcomes.

The patients in our study were older (mean 65.1 years, range 38-83) and had a variety of retroversion deformities (mean 23° , range 10° - 39°), making our results more broadly generalizable. The above findings in this patient demographic should encourage us to continue to offer aTSA to appropriately indicated patients, regardless of age, with biconcave glenoid deformities and mild or moderate retroversion deformities. Importantly, a strong emphasis was placed on near complete glenoid component seating (80%-100%) and a meticulous cement pressurization technique. We feel strongly that these factors are important

Table III Glenoid component peg radiolucency measurements

Lazarus grade	2-4 year follow-up (n = 34)	Final follow-up (mean 8.6 yr, n = 30 [*])
Grade 0	23	19
Grade 1	6	4
Grade 2	2	3
Grade 3	3	0
Grade 4	0	0
Grade 5	0	4 [†]
Mean	0.56	1.00

^{*} Radiographs unavailable on 4 shoulders.

[†] Includes revisions due to glenoid loosening.

in achieving good long-term durability with aTSA. However, the recurrence of preoperative humeral subluxation and the progression of radiolucent lines in these shoulders raise concern for the long-term durability of these implants and further study is needed to define the long-term durability and, more importantly, the limits of glenoid deformity that can be addressed with high-side reaming.

Walch et al in 2012 described their outcomes of aTSA for biconcave glenoid deformities.¹⁴ At a mean follow-up of 6.4 years, they observed glenoid loosening in 20.6% and a revision rate of 16.3%. We observed a 12% glenoid loosening rate and a 4% revision rate at a mean of 8.6 years. Their mean patient age was 68 years vs. 65 years in our cohort and they had a mean neoglenoid retroversion of 25° (9°-48°) vs. 23° (range 10°-39°) in our cohort. Despite similar patient age and shorter length of follow-up in their study, their revision and glenoid loosening rate is a higher than ours. It's important to note several differences in study design and surgical technique between studies. They measured glenoid deformity using uncorrected 2D CT scans. Gantry correction has shown to significantly affect both glenoid retroversion and inclination deformity assessment.³ The glenoid implant in our study has a convex back with 3 inline pegs. The Walch study utilized keeled glenoid implants and 61% of the glenoids placed had a flat-back design. In terms of surgical technique, Walch et al planned for a glenoid retroversion correction to 0°-10°, in contrast to our target of 10°-15°. When they were not able to achieve correction to 10°, a posterior bone graft was used in 7 patients (7.6% of their cohort). No bone grafts were used in our cohort, as these have been associated with poorer outcome in several studies.⁵ A posterior capsulorraphy was used in 9 patients (9.8%) for static posterior humeral head instability in the Walch et al study, vs. none in our cohort. It is possible we did not experience this same level of posterior instability by using our technique of permitting greater final glenoid retroversion during reaming.

Several studies have tried to determine the maximum allowable glenoid retroversion after reaming. In 2013 Iannotti et al showed an increase in glenoid central peg osteolysis and Lazarus score with postoperative

Table IV Glenoid component initial seating (n = 34)

Lazarus grade	Count
Grade A	25
Grade B	8
Grade C	1
Grade D	0
Grade E	0

retroversion of >15° at an average follow-up of 3.8 years.⁶ As in our study, they did not find a correlation of glenoid component loosening with preoperative retroversion. However, unlike our study, they did not find a correlation between central peg osteolysis and clinical outcome scores. By attempting to limit postoperative glenoid retroversion to <15°, it is possible we reduced the amount of glenoid radiolucencies in our study group.

Matsen et al reported data in 2017 that contrast the findings of Iannotti and others. They published on a group of 71 patients that underwent aTSA with a minimum 2-year clinical and radiographic follow-up.¹² They compared glenoid components implanted in either <15° or >15° of final retroversion. They also performed a subgroup analysis for the 39 patients that had B-type glenoids. Except for increased peg perforation in the more retroverted group, there was no difference in clinical or radiographic outcomes in either the combined A-type and B-type group or in the B-type subgroup analysis. In comparing their A-type to B-type glenoids, they showed similar SST score (9.4 vs. 9.5) and similar Lazarus glenoid radiolucency scores. They did have 3 revisions which all occurred in the B-type group. However, none were for glenoid loosening; one was for postoperative shoulder stiffness and 2 were for traumatic subscapularis tears. They acknowledge that their study is smaller and with shorter follow-up but that they were able to obtain good outcomes with aTSA performed in patients with B-type glenoids and reaming to >15° of retroversion when the patient's anatomy necessitated it.

Augmented glenoid components have been marketed as a bone-preserving alternative to high-side reaming. Garriques et al reported a short-term follow-up of a retrospective case series of 86 patients with retroverted glenoids treated with posteriorly augmented glenoid polyethylene components.⁴ Mean preoperative retroversion was 19.3°. Forty-eight of eighty-six had either a B2 or B3 glenoid. With 2-year minimum follow-up, they noted that 68/72 pegged glenoid components had a Lazarus score of 0 and 4/72 had a score of 1 or 2. These results are encouraging, but 5-10 year follow-up data will be needed to assess trends in durability of these new implants. Given the recurrence of posterior humeral head subluxation seen in some of our shoulders, further studies are needed to better understand the potential role of augmented glenoids to maintain head centering, as we demonstrated head decentering to correlate with glenoid radiolucencies.

Table V Correlations and probability, multivariate linear regression analysis (n = 30^{*})

	Glenoid peg radiolucency		SST score		ASES score		VAS pain		SST score delta		ASES score delta		VAS pain delta		Final HH subluxation	
	r value	P value	r value	P value	r value	P value	r value	P value	r value	P value	r value	P value	r value	P value	r value	P value
Preoperative glenoid version	0.03	.86	0.22	.24	0.22	.26	0.01	.97	0.28	.13	0.18	.35	-0.06	.77	0.27	.16
Preoperative glenoid inclination	0.04	.846	0.26	.19	-0.11	.60	0.08	.71	0.19	.32	-0.17	.41	0.11	.60	0.11	.61
Preoperative HH sublux. (Friedman's line method)	0.01	.96	-0.13	.51	0.09	.66	0.01	.97	-0.05	.80	-0.01	.96	0.00	.99	0.27	.17
Preoperative HH sublux. (glenoid vault method)	-0.11	.58	-0.08	.67	-0.02	.91	0.14	.48	0.04	.84	-0.10	.63	0.11	.57	0.18	.35
Immediate glenoid seating (Lazarus)	0.44	.02	-0.23	.22	-0.07	.71	0.00	.98	-0.24	.21	-0.33	.09	0.24	.21	0.23	.24
Postoperative HH sublux. 2-4 yr (glenoid vault)	0.34	.08	0.13	.50	-0.21	.30	0.38	.06	-0.01	.96	-0.22	.29	0.29	.16	0.75	<.0001
Postoperative HH sublux. final f/u (glenoid vault)	0.46	.01	-0.03	.88	-0.13	.56	0.32	.13	-0.13	.51	-0.31	.14	0.41	.05	-	-
Glenoid peg radiolucency, final f/u (Lazarus)	-	-	-0.05	.81	-0.35	.08	0.42	.03	-0.08	.69	-0.44	.03	0.47	.02	0.46	.01

HH, humeral head.

^{*} Four patients did not complete clinical follow-up scores.

Kohan et al reported on a retrospective cohort of 39 patients with B3 glenoids that underwent aTSA with either a standard glenoid component and high-side corrective reaming, or an augmented component with a mean follow-up of 8.7 years.⁸ Preoperative glenoid retroversion was 24° in the standard cohort and 29° in the augmented cohort. They found no difference in ASES, single assessment numeric evaluation (SANE), percent satisfaction, forward elevation, or external rotation. They also noted that all patients stated they would undergo the same procedure again, and none were revised during their study period. A major limitation of their study is a lack of postoperative radiographs that may have detected early or ongoing glenoid failure.

Augmented glenoid components have been designed to minimize bone removal and subchondral plate penetration while generating a desired retroversion correction. However, there is no definitive data available on the impact of subchondral plate perforation on implant durability and revision-free survival. Our philosophy in glenoid preparation is to ream into but to fully avoid any subchondral plate perforation. We believe violating the subchondral plate with cancellous bone exposure may lead to early glenoid component subsidence and early loosening. Although this may not have been shown definitively in the literature, in our opinion there is no reason to introduce subchondral bone penetration as a potential failure mode for the glenoid component. Therefore, we make every effort to never ream through the subchondral bone plate.

We believe our data show good clinical outcomes and an acceptably low revision rate when using aTSA for B2 glenoids with a high-side reaming technique, a cemented, nonaugmented, all-polyethylene glenoid component. Although some advocate for RSA instead of aTSA for patients with primary GHOA to avoid glenoid component loosening, the complication rates remain relatively low. Additionally, the complication rates unique to RSA including acromial stress fracture and dislocation should not be discounted as these are much rarer complications after aTSA, yet often as equally challenging to manage as glenoid component failure. Further study is needed to define the limits of glenoid deformity than can be addressed with high-side reaming.

Limitations

Our study is not without limitations. Perhaps the most significant of which is that version correction may have been variable and without a patient specific guide or postoperative CT scan, it is not possible to precisely quantify either degree of intraoperative correction or final component retroversion. Postoperative CT scans were not obtained and we elected not to measure postoperative glenoid component retroversion, as even with the best radiographs version may be overestimated by up to 9.9°. We felt this level of error could

Table VI Subgroup analysis, by final glenoid component condition (n = 30)

	Intact glenoid component (n = 30)*	Failed glenoid component (n = 4)†	P value
Preoperative glenoid retroversion	18.6°	20.5°	.61
Preoperative glenoid inclination	6.3°	5.2°	.74
Preoperative HH sublux. (Friedman's line method)	68%	68%	.88
Preoperative HH sublux. (glenoid vault method)	9.1%	5.4%	.27
Immediate glenoid seating (Lazarus‡)	1.2	2.0	.002
Postoperative HH sublux. 2-4 yr (glenoid vault)	5.6%	12.6%	.045
Postoperative HH sublux. final f/u (glenoid vault)	7.0%	21%	.002
Glenoid peg radiolucency (Lazarus)	0.4	5	.001
VAS pain	0.8	2.1	.03
ASES score	88	73	.03
SST	10.8	10	.39

HH, humeral head; VAS, visual analog scale; ASES, American Shoulder and Elbow Surgeons; SST, Simple Shoulder Test.

‡ Lazarus seating is expressed here as a continuous variable 1-5 (rather than A-E).

* Intact glenoid defined as Lazarus glenoid peg lucency of 0-3.

† Failed glenoid defined as Lazarus glenoid peg lucency of 4-5 (no grade 3 or 4 were present in this group).

produce inaccurate conclusions.⁷ Another important limitation was our loss to follow-up. Despite our best attempt to locate patients with multiple phone calls, letters, and emails, some did not respond or refused to participate. Our significant loss to follow-up resulted in a much smaller cohort to study. This study highlights the very significant challenges experienced when trying to follow older patients after shoulder arthroplasty, which has been a challenge for other authors as well. Lastly, this study may have been under powered to determine if preoperative glenoid retroversion and inclination, and humeral head subluxation are predictive of glenoid component failure.

Conclusions

At a mean of 8.6 years, 88% of patients had intact glenoid components and there was a 12% radiographic failure rate that was associated with poorer clinical results. The most important finding from our study was that glenoid component failure was associated with poorer initial glenoid component seating, with failed components having an average of 25% of the glenoid component not seated. There was also a significant and moderate correlation between glenoid peg radiolucency and humeral head subluxation at final follow-up. Surprisingly, preoperative glenoid retroversion, inclination, or humeral head subluxation did not predict glenoid component failure.

This study supports that complete glenoid component seating may be the most important factor for mid-term glenoid component survival in aTSA in patients with B2 glenoids. Importantly, complete glenoid component seating is a modifiable variable within the surgeon's

control and could be improved with careful surgical technique to extend the durability of the glenoid component in aTSA.

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