J Shoulder Elbow Surg (2020) 29, 2571–2577

ELSEVIER

Journal of Shoulder and Elbow Surgery

www.elsevier.com/locate/ymse

Outcomes of anatomic shoulder arthroplasty performed on B2 vs. A1 type glenoids

Mihir M. Sheth, MD[a], Brent J. Morris, MD[b,c,d], Mitzi S. Laughlin, PhD[c,d,*], Jacob L. Cox, MD[d], Stephen Jones, MD[b], Hussein A. Elkousy, MD[b,c,d], T. Bradley Edwards, MD[b,c,d]

[a]*Department of Orthopaedic Surgery, Baylor College of Medicine, Houston, TX, USA*
[b]*Fondren Orthopedic Group, Texas Orthopedic Hospital, Houston, TX, USA*
[c]*Fondren Orthopedic Research Institute (FORI), Houston, TX, USA*
[d]*Texas Education and Research Foundation for Shoulder and Elbow Surgery, Inc. (TERFSES), Houston, TX, USA*

Background: Glenoid component malpositioning and glenoid component retroversion have been associated with higher rates of radiolucencies, raising concerns about its implications on glenoid loosening and ultimate failure of anatomic total shoulder arthroplasty (TSA). Although there is literature regarding the relative advantages of techniques to address posterior glenoid bone loss, we are not aware of studies comparing outcomes of TSA on these challenging Walch type B2 glenoids vs. more common A1 glenoids. The purpose of this study is to compare outcomes of TSA performed on A1 glenoids and B2 glenoids treated with asymmetric glenoid reaming.

Methods: We identified 1045 shoulders that had primary TSAs performed for osteoarthritis in a prospective shoulder arthroplasty registry. Two hundred eighty-nine shoulders met inclusion criteria of a preoperative Walch type A1 (178) or B2 (111) glenoid morphology, treatment with TSA, asymmetric reaming in the B2 group, and a minimum of 2-year clinical and radiographic follow-up. Postoperative radiographs were assessed for lucencies, and patient-reported outcome measures were collected at all follow-up visits.

Results: Follow-up averaged 40 ± 15 months for all patients, and more men presented with a B2 glenoid (80 of 111; 72%) compared with A1 (101 of 178; 57%) ($P = .009$). Age at surgery ($P = .166$), dominant-sided surgery ($P = .281$), body mass index ($P = .501$), smoking ($P = .155$), preoperative opioid use ($P = .154$), and diabetes ($P = .331$) were not significantly different between groups. Both groups had similar Constant Strength scores preoperatively (A1: 4.7 ± 7.1, and B2: 4.3 ± 7.3) but the B2 group improved significantly more at final follow-up (A1: 10.3 ± 6.2 vs. B2: 12.7 ± 6.7, $P = .005$). The Total Constant score was also significantly better at follow-up in the B2 glenoid group ($P = .039$). All other Constant subscales, American Shoulder and Elbow Surgeons Standardized Shoulder Assessment Form (ASES), and Single Assessment Numerical Evaluation (SANE) measures showed significant improvement preoperatively to final follow-up (all $P < .001$) but there were no significant differences between the A1 and B2 glenoid groups (all $P > .05$). A similar proportion of patients rated their satisfaction as either very satisfied or satisfied between the A1 (160; 90%) and B2 (100; 90%) ($P = .613$). Lazarus scores were also similar between the A1 and B2 groups ($P = .952$) as were the rates of humeral radiolucent lines ($P = .749$) and humeral osteolysis ($P = .507$).

Conclusions: Although patients with B2 glenoids may present a more technically challenging anatomic total shoulder arthroplasty, treatment with concurrent asymmetric glenoid reaming produced similar, successful clinical and radiographic early to midterm

The Texas Orthopedic Hospital's Institutional Review Board committee approved this study (TOH215e).

*Reprint requests: Mitzi S. Laughlin, PhD, Fondren Orthopedic Research Institute (FORI), 7401 South Main Street, Houston, TX 77030, USA.

E-mail address: Mitzi.Laughlin@fondren.com (M.S. Laughlin).

https://doi.org/10.1016/j.jse.2020.03.050

outcomes for patients undergoing TSA compared with A1 glenoids. Additional follow-up on this cohort will be important to confirm the durability of these early results.

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

Keywords: Anatomic total shoulder arthroplasty; glenohumeral joint osteoarthritis; Walch glenoid type; patient-reported outcome measures; patient satisfaction; radiographic outcomes

Aseptic glenoid loosening remains the most common cause of revision for anatomic total shoulder arthroplasty (TSA).[2] Numerous studies have demonstrated that excessive glenoid retroversion, generally defined as greater than 15°, is correlated with eccentric loading of the glenoid component,[3,5,10,30] radiolucencies,[14] poor functional outcome,[17,26,33] and higher revision rates[33] compared with less retroverted glenoids.

Numerous strategies have been proposed to correct retroversion, including asymmetric reaming, posterior glenoid bone grafting, posteriorly augmented glenoid components, and reverse shoulder arthroplasty. Although eccentric reaming was historically the most common treatment method, Walch et al[34] found that aggressive reaming is associated with glenoid component subsidence and posterior tilt thought to be secondary to a reduction in subchondral bone support and joint line medialization reducing the surrounding soft tissue's ability to create a stable fulcrum. Computer-based studies suggest that eccentric reaming should be limited to glenoids with less than 15° of preoperative retroversion.[4,25] Although there is no consensus, the current evidence suggests that glenoids with retroversion greater than 15° may be better addressed with glenoid bone grafting, augmented glenoid components, or reverse shoulder arthroplasty (RSA).

However, limitations to each of these alternative methods exist. The results of bone grafting have been mixed, with reports of high complication rates.[19,28,33] There are few reports on the mid- and long-term clinical and radiographic outcomes of augmented glenoids and RSA, and RSA is known to be associated with higher complication rates than TSA. Conversely, clinical data on outcomes of TSA with asymmetric reaming regardless of preoperative retroversion have not consistently reflected concerns about the technique at midterm follow-up.[7,15,27]

The purpose of this study was to report the outcomes of TSA with asymmetric reaming performed on retroverted, biconcave (Walch type B2) glenoids compared with TSA in nonpathologically retroverted (Walch type A1) glenoids. We hypothesize that eccentric reaming of B2 glenoid can produce equivalent outcomes to routine TSA in short- to midterm follow-up. Additionally, these data may provide a baseline from which to understand the outcomes of newer methods of treatment for severe retroversion, such as RSA and augmented glenoids.

Methods

Patient inclusion criteria and demographics

Our investigation identified all primary TSAs performed for primary osteoarthritis from 2004-2016 in a prospectively collected shoulder arthroplasty registry. Patients who were identified with an A1 or B2 glenoid were selected for this study. All operations were performed at a single, high-volume shoulder arthroplasty center by a single surgeon (T.B.E.). A minimum of 2 years of clinical follow-up was required for inclusion in this study.

We identified 1045 shoulders that had primary TSA performed for primary osteoarthritis in a prospective shoulder arthroplasty registry. Two hundred eighty-nine shoulders met inclusion criteria of a preoperative Walch type A1 (n = 178) or B2 (n = 111) glenoid morphology and with 2-5 years of clinical follow-up. Glenoid morphology was identified prospectively by the senior author, and then 2 independent reviewers confirmed the designation of a B2 glenoid retrospectively based on the classification by Walch et al.[32] Preoperative computed tomography (CT) scans were available for 61% of patients. For the remaining 39%, the classification was made based on outside hospital CT scans that were not available for retrospective review. The designation was further confirmed intraoperatively.

Patient demographics, clinical characteristics, and patient- and clinician-reported outcomes were collected prospectively in the shoulder arthroplasty registry. Specific demographic and clinical characteristics included age, sex, body mass index, shoulder dominance, smoking status, preoperative opioid use, chronic back pain, depression, diabetes, heart disease, and insurance type. Patient and clinician outcome measures were collected preoperatively and at final follow-up and included the Constant score,[6] the American Shoulder and Elbow Surgeons Standardized Shoulder Assessment Form (ASES) score,[23] the Single Assessment Numeric Evaluation (SANE),[36] and active mobility measurements.

Surgical technique

The Aequalis, Aequalis Ascend, and Aequalis Ascend Flex (Wright Medical, Memphis, TN, USA) anatomic total shoulder arthroplasty systems were used. The TSA technique used is well described for more standard symmetric glenoid reaming as well as corrective reaming of B2 glenoids.[9] Asymmetric glenoid wear in the B2 glenoids was treated with corrective reaming to eliminate the biconcavity and restore a single concavity and concentric glenoid. The glenoid reaming required preferential reaming of the anterior glenoid or "high side" until a single concavity was achieved. The goal was to restore a more anatomic or neutral

Table I Demographic and preoperative clinical characteristics

	A1 glenoid (n = 178)	B2 glenoid (n = 111)	*P* value
Age at surgery, yr, mean ± SD	67.5 ± 9.1	65.9 ± 8.9	.166
Male sex	101 (56.7)	80 (72.1)	.009
BMI, mean ± SD	30.2 ± 5.9	29.8 ± 5.5	.501
Dominant shoulder	83 (46.6)	59 (53.2)	.281
Current smoker	3 (1.7)	5 (4.5)	.155
Preoperative opioid use	52 (29.2)	24 (21.6)	.154
Chronic back pain	83 (46.6)	28 (25.2)	<.001
Depression	20 (11.2)	4 (3.6)	.022
Diabetes	11 (9.6)	7 (6.3)	.331
Heart disease	17 (9.6)	12 (10.8)	.729
Insurance			.258
Private	60 (33.9)	47 (42.3)	
Government (Medicare, Medicaid, Tricare, Workers Compensation)	117 (66.1)	64 (57.7)	

BMI, body mass index; *SD*, standard deviation.
Unless otherwise noted, values are n (%).

glenoid version when possible. A standardized postoperative rehabilitation protocol was followed.[9,22]

Clinical assessment

Patients were prospectively enrolled in a shoulder arthroplasty outcomes registry and monitored clinically. Complete clinical examinations were performed by the senior surgeon (T.B.E.) preoperatively, then postoperatively at 12 months and annually thereafter. Patient-reported outcome measures were collected preoperatively and postoperatively starting at 12 months. All intraoperative and postoperative complications were recorded along with all revision procedures. Postoperative radiographs were obtained at the initial postoperative visit and annually thereafter and included anteroposterior in the scapular plane, scapular "Y," and axillary views. Radiographic assessment of glenoid components was performed in a fashion similar to previously published studies at our institution.[8,12] Radiographs were obtained at yearly visits, using fluoroscopic and magnification-controlled techniques to ensure that the beam was perpendicular to the bone-implant interface. Lucency about the glenoid component was graded according to the classification of Lazarus et al,[21] which was a modification of the original classification proposed by Franklin et al.[11] Active mobility measurements were determined using a goniometer, and strength of abduction was measured with a handheld digital dynamometer (Chatillon Digital Force Gauge 200 lbf; AMETEK Inc., Largo, FL, USA).

Statistical analysis

Patient demographics and preoperative clinical characteristics were tested for significant differences between A1 and B2 glenoid groups. As appropriate, independent group *t* tests or Fisher exact tests were performed to determine if differences existed in age, sex, comorbidities, and insurance type between glenoid types. To evaluate the impact of glenoid type on outcome measures, repeated measures analysis of variance was used to test for post-surgical improvement between patients with A1 or B2 glenoid groups. Patient satisfaction, revision, and complication rates and the presence of radiolucent lines at the final follow-up were evaluated by Fisher exact tests to determine if a difference existed between glenoid types.

Results

Demographics and preoperative clinical characteristics by glenoid type are recorded in Table I for the 289 patients included in this study with an A1 (n = 178) or B2 (n = 111) glenoid. The average follow-up for both groups was 40 ± 15 months. There was no statistically significant difference in age at TSA between the A1 (67.5 ± 9.1 years) and B2 (65.9 ± 8.9 years) groups ($P = .166$). In total, there were 181 men (63%) in the 2 groups. More men presented with a B2 glenoid (80 of 111; 72%) compared with A1 (101 of 178; 57%) ($P = .009$). The rate of dominant-sided surgery ($P = .281$), body mass index ($P = .501$), smoking ($P = .155$), preoperative opioid use ($P = .154$), diabetes ($P = .331$), heart disease ($P = .729$), and having private vs. government insurance ($P = .258$) were not significantly different between groups. However, the A1 glenoid group did report significantly more chronic back pain (A1, 46.6%, and B2, 25.2%; $P < .001$) and depression (A1, 11.2%, and B2, 3.6%; $P = .022$). Preoperative CT scans were available for review in 61% of the B2 group, and the average glenoid retroversion was 15° ± 6°.

The evaluation of the impact of glenoid type on outcome measures showed that both glenoid groups improved significantly from preoperative to final follow-up (Tables II and III). Both groups had similar Constant Strength scores preoperatively (A1: 4.7 ± 7.1, and B2: 4.3 ± 7.3), but the B2 group improved significantly more at final follow-up (A1: 10.3 ± 6.2, vs. B2: 12.7 ± 6.7; $P = .005$). The Total Constant score was also significantly better at

Table II Outcome scores

	A1 glenoid		B2 glenoid	
	Preoperative, mean ± SD	Follow-up, mean ± SD	Preoperative, mean ± SD	Follow-up, mean ± SD
Constant—Pain	3.8 ± 3.1	12.3 ± 3.9	4.0 ± 3.0	13.1 ± 3.2
Constant—Activity	7.8 ± 4.2	16.7 ± 4.4	7.4 ± 3.4	17.1 ± 4.7
Constant—Mobility	12.1 ± 8.8	35.2 ± 6.7	11.2 ± 7.0	35.5 ± 5.6
Constant—Strength	4.7 ± 7.1	10.3 ± 6.2	4.3 ± 7.3	12.7 ± 6.7
Constant—Total	28.5 ± 18.0	74.6 ± 15.4	26.8 ± 15.0	78.4 ± 14.9
Constant—Adjusted	36.6 ± 22.0	100.4 ± 22.6	33.4 ± 17.4	102.2 ± 20.2
ASES	37.5 ± 18.4	85.8 ± 19.0	39.8 ± 18.2	88.8 ± 18.6
ASES—Pain	5.9 ± 2.5	13.5 ± 20.5	5.6 ± 2.8	13.0 ± 20.6
SANE	32.3 ± 26.3	77.4 ± 31.5	30.3 ± 22.1	76.0 ± 33.5
External rotation	13.5 ± 14.3	47.9 ± 13.9	10.7 ± 14.3	45.5 ± 12.1

ASES, American Shoulder and Elbow Surgeons Standardized Shoulder Assessment Form; *SANE*, Single Assessment Numerical Evaluation; *SD*, standard deviation.

follow-up in the B2 glenoid group ($P = .039$). All other Constant subscales, ASES, and SANE measures showed significant improvement preoperatively to final follow-up (all $P < .001$), but no significant differences existed between the A1 and B2 glenoid groups (all $P > .05$).

Patient satisfaction was evaluated both preoperatively and at final follow-up (Table IV). No patients were satisfied with their shoulder preoperatively, and a similar percentage of patients rated their satisfaction postoperatively as either very satisfied or satisfied between the A1 (160; 90%) and B2 (100; 90.1%) ($P = .993$).

The Lazarus grade of glenoid radiolucent lines was also similar between the A1 and B2 groups (Table V; $P = .952$), and no statistically significant differences existed in the presence of humeral radiolucent lines ($P = .749$) and humeral osteolysis ($P = .507$). Postoperative complications occurred in 8 shoulders (7%) in the B2 group and 8 shoulders in the A1 group (5%) ($P = .588$). The revision rates were also similar between the B2 (6 patients; 5%) and A1 (6 patients; 3%) groups ($P = .916$).

In the B2 group, 3 patients suffered a posterior dislocation at 1 week, 2 weeks, and 3 years, respectively, after TSA. The posterior dislocation at 3 years occurred in a 78-year-old man after a high-speed motor vehicle accident and was revised to RSA. The patient who dislocated at 2 weeks was a 53-year-old woman. She was initially treated with a closed reduction, but then she redislocated 2 weeks later. At that point, she underwent posterior capsulorrhaphy and revision of the humeral component into a more anteverted position. The remaining posterior dislocation occurred in a 72-year-old woman at 1 week from TSA, and she was revised to RSA at that time. One patient experienced aseptic glenoid loosening 11 years after the TSA and underwent a 2-stage revision to RSA for an uncontained glenoid bone defect. The remaining complications in the B2 group were subscapularis failures without instability

Table III Comparison of changes in patient shoulder function scores from the preoperative assessment to the final follow-up using analysis of variance

	Preoperative to final follow-up differences, *P*	A1 and B2 group differences, *P*	Preoperative to final follow-up changes between groups, *P*
Constant—Pain	<.001	.109	.300
Constant—Activity	<.001	.933	.241
Constant—Mobility	<.001	.799	.320
Constant—Strength	<.001	.176	.005
Constant—Total	<.001	.441	.039
Constant—Adjusted	<.001	.787	.188
ASES	<.001	.118	.825
ASES—Pain	<.001	.730	.956
SANE	<.001	.168	.501

ASES, American Shoulder and Elbow Surgeons Standardized Shoulder Assessment Form; *SANE*, Single Assessment Numerical Evaluation.

Table IV Patient satisfaction results

	A1 glenoid		B2 glenoid	
	Preoperative, n (%)	Final follow-up, n (%)	Preoperative, n (%)	Final follow-up, n (%)
Very dissatisfied	117 (69.2)	6 (3.4)	81 (74.3)	2 (1.8)
Dissatisfied	52 (30.8)	11 (6.2)	28 (25.7)	9 (8.1)
Satisfied	—	45 (25.4)	—	23 (20.7)
Very satisfied	—	115 (65.0)	—	77 (69.4)

Satisfaction rated as "satisfied" or "very satisfied" at follow-up was not significantly different between A1 and B2 glenoid types ($P = .993$).

(n = 2) that did not require revision and periprosthetic joint infections (n = 2) that underwent 2-stage revision to RSA.

In the A1 group, 4 patients developed aseptic glenoid loosening at 19 months, 3 years, 8 years, and 9 years following TSA; all were revised to RSA. One patient had traumatic glenoid loosening at 1 year after TSA and was revised to another anatomic TSA. Two patients experienced subscapularis failure with anterior subluxation at 2 and 3 years, respectively, after TSA and were revised to RSA at that time. The 2 remaining complications were a periprosthetic joint infection that underwent staged revision to RSA at 6 years after TSA and a transient axillary nerve palsy.

Discussion

This study is a cohort comparison of the clinical and radiographic outcomes for TSA with eccentric reaming for Walch type B2 glenoids to TSA in Walch type A1 glenoids. We found no difference in active mobility, strength, functional outcomes, complication rates, revision rates, or radiolucencies at early to midterm follow-up (mean, 40 ± 15 months). However, importantly, 3 posterior dislocations occurred in the B2 group.

Increased preoperative retroversion has gained attention as a potentially correctable source of glenoid component wear or loosening, which continues to be the most common reason for TSA failure.[2,31] Prior studies have shown that patients with >15° retroversion are more likely to develop osteolysis around the central glenoid peg,[14] and retrieved implants show posteroinferior polyethylene edge deformation when implanted in retroversion.[33] Cadaveric studies have similarly demonstrated that retroverted glenoid components experience asymmetric loading and eccentric wear.[30]

Table V Radiographic outcomes at final follow-up

Glenoid component	A1 glenoid, n (%)	B2 glenoid, n (%)	*P* value
Lazarus score			
0	115 (65)	70 (63)	.952
1	48 (27)	32 (29)	
2	6 (3)	5 (5)	
3	4 (2)	3 (3)	
4	0 (0)	0 (0)	
5	3 (2)	1 (1)	
Humeral component			
Radiolucent line	47 (26.7)	31 (28.4)	.749
Osteolysis	21 (12.1)	16 (14.8)	.507

Controversy exists about the optimal method and extent of version correction. The patients in this study all received asymmetric glenoid reaming to more anatomic or neutral version when sufficient bony support was available, or partial correction in cases of more severe deformities in which correction to anatomic version would have substantially compromised subchondral bone support. Alternative methods include posterior glenoid bone grafting, the use of augmented glenoid components, and the use of reverse shoulder arthroplasty. A complete comparison of these techniques is beyond the scope of this study. However, it should be noted that the degree of correction attainable with asymmetric reaming is limited by glenoid bone stock. Loss of subchondral support with overly aggressive reaming has in some studies been associated with implant loosening,[34] and multiple in vitro studies[16,25,30] have suggested that correction should be limited to less than approximately 15° to avoid peg perforation and preserve adequate bone support.

However, clinical data on outcomes of TSA with asymmetric reaming have not consistently reflected these concerns at midterm follow-up. Orvets et al[27] retrospectively reviewed outcomes of TSA with partially corrective glenoid reaming in 59 patients at a mean 50-month follow-up and found no difference in patient-reported outcome measures between patients with more or less than 20° retroversion. Devito et al[7] also reported no difference in functional outcomes in a case-control study including 40 and 80 patients with greater or less than 20° retroversion, respectively, at approximately 4 years' follow-up. Hussey et al[15] in a comparison between 148 eccentrically worn and 196 concentrically worn glenoids at approximately 4 years' follow-up found a similar lack of difference between eccentric and concentric glenoids. Thus, although compelling evidence exists that severe retroversion can affect the longevity of the glenoid component, asymmetric

reaming to anatomic or partial correction can achieve functional results indistinguishable from routine TSA in concentric or less retroverted glenoids.

Conversely, reports on the presence of radiolucencies around the glenoid component and the complication profile in B2 glenoids differ. Hussey et al[15] found a statistically significant difference in the radiographic evidence of gross glenoid loosening (12% vs. 6%), and Devito et al[7] reported 3 cases of gross loosening in their >20° group compared with zero in the <20° group. This study and others did not find differences in radiographic glenoid loosening. With regard to complications and revisions, no case-control study (including ours) has demonstrated a statistically significant difference in rates of glenoid loosening, instability, or revision based on the severity of preoperative retroversion or the eccentricity of wear. However, our study included 3 posterior dislocations that all required revision, and longer-term follow-up is required on these cohorts to confirm the similarity of glenoid loosening rates.

The outcomes of alternative procedures, such as augmented glenoids or RSA, should be placed within the context of these results. Augmented glenoids have recently attracted attention as a means of correcting version while avoiding joint line medialization and thereby improving soft tissue tension. Biomechanical and early-term clinical outcome studies have demonstrated greater preservation of bony support[18,20,29] and, in some studies, lower stresses across the implant.[1,13] However, long-term radiographic and clinical outcomes for these implants is lacking, and no large studies have compared results to other techniques, such as eccentric reaming. In addition, some augmented component designs have demonstrated higher strain at the bone-implant interface than standard components implanted by eccentric reaming,[35] and their benefit must also be weighed against added implant cost.

RSA has also been proposed to manage B2-type glenoids because it offers improved fixation and constraint compared with an anatomic prosthesis. Mizuno et al[24] reported 27 patients with a mean age of 74 years who underwent RSA with a mean follow-up of 54 months. The mean preoperative retroversion was 32°, and the mean subluxation of the humeral head with respect to the scapular axis was 87%. They found significant improvements in clinical outcome measures alongside a 15% complication rate. At this time, most authors agree that RSA should be reserved for patients with severe erosion and subluxation and used sparingly in younger patients because of its incompletely understood longevity and poor salvage options.

This study is limited by its retrospective design. With the data available, we were unable to examine whether the severity of retroversion with the B2 classification affected the outcome. CT scans were available at the time of surgery for the senior author to classify as B2 glenoids; however, some of the CT scans from outside hospitals are no longer available and prevented our independent radiographic reviewers from being able to review the degrees of retroversion in these cases. In addition, all operations were done by a single, high-volume shoulder arthroplasty surgeon and therefore may not be generalizable. Lastly, the follow-up for this study was relatively short at a mean 40 months, and it is possible that these patients will still develop relatively early glenoid component loosening.

Conclusions

Although patients with B2 glenoids may present a more technically challenging anatomic total shoulder arthroplasty, treatment with concurrent asymmetric glenoid reaming produced similar, successful clinical and radiographic early to midterm outcomes for patients undergoing TSA compared with more common A1 glenoids. Additional follow-up on this cohort will be important to confirm the durability of these early results.

Disclaimer

No direct funding was received for this study; however, Wright Medical, Inc. supports the shoulder arthroplasty registry used in this study and the Fondren Orthopedic Research Institute (FORI) supports part of the study team (MSL).

Brent J. Morris and T. Bradley Edwards received financial support (Tornier, Inc.) for the database that was used to collect results for the study and have received intellectual property royalties/work as a consultant for Wright Medical Technology, Inc. T. Bradley Edwards also works as a paid consultant, presenter, or speaker for DJ Orthopedics and Smith & Nephew and receives royalties from DJ Orthopedics. None of the commercial entities were involved in any aspect of the study. All the other authors, their immediate families, and any research foundations with which they are affiliated have not received any financial payments or other benefits from any commercial entity related to the subject of this article.

References

1. Allred JJ, Flores-Hernandez C, Hoenecke HR, D'Lima DD. Posterior augmented glenoid implants require less bone removal and generate lower stresses: a finite element analysis. J Shoulder Elbow Surg 2016; 25:823-30. https://doi.org/10.1016/j.jse.2015.10.003
2. Bohsali KI, Bois AJ, Wirth MA. Complications of shoulder arthroplasty. J Bone Joint Surg Am 2017;99:256-69. https://doi.org/10.2106/JBJS.16.00935
3. Bryce CD, Davison AC, Okita N, Lewis GS, Sharkey NA, Armstrong AD. A biomechanical study of posterior glenoid bone loss and humeral head translation. J Shoulder Elbow Surg 2010;19:994-1002. https://doi.org/10.1016/j.jse.2010.04.010

4. Clavert P, Millett PJ, Warner JJP. Glenoid resurfacing: what are the limits to asymmetric reaming for posterior erosion? J Shoulder Elbow Surg 2007;16:843-8. https://doi.org/10.1016/j.jse.2007.03.015
5. Collins D, Tencer A, Sidles J, Matsen F. Edge displacement and deformation of glenoid components in response to eccentric loading. The effect of preparation of the glenoid bone. J Bone Joint Surg Am 1992;74:501-7.
6. Constant CR, Gerber C, Emery RJH, Søjbjerg JO, Gohlke F, Boileau P. A review of the Constant score: modifications and guidelines for its use. J Shoulder Elbow Surg 2008;17:355-61. https://doi.org/10.1016/j.jse.2007.06.022
7. DeVito P, Agyeman KD, Judd H, Moor M, Berglund D, Malarkey A, et al. Outcomes of anatomic total shoulder arthroplasty in patients with excessive glenoid retroversion: a case-control study. J Shoulder Elbow Surg 2019;28:1948-55. https://doi.org/10.1016/j.jse.2019.03.012
8. Edwards TB, Labriola JE, Stanley RJ, O'Connor DP, Elkousy HA, Gartsman GM. Radiographic comparison of pegged and keeled glenoid components using modern cementing techniques: a prospective randomized study. J Shoulder Elbow Surg 2010;19:251-7. https://doi.org/10.1016/j.jse.2009.10.013
9. Edwards TB, Morris BJ. Shoulder arthroplasty. 2nd ed. Philadelphia, PA: Elsevier; 2018.
10. Farron A, Terrier A, Büchler P. Risks of loosening of a prosthetic glenoid implanted in retroversion. J Shoulder Elbow Surg 2006;15:521-6. https://doi.org/10.1016/j.jse.2005.10.003
11. Franklin L, Barrett WP, Jackins SE, Matsen FA. Glenoid loosening in total shoulder arthroplasty. J Arthroplasty 1988;3:39-46.
12. Gartsman GM, Elkousy HA, Warnock KM, Edwards TB, O'Connor DP. Radiographic comparison of pegged and keeled glenoid components. J Shoulder Elbow Surg 2005;14:252-7. https://doi.org/10.1016/j.jse.2004.09.006
13. Hermida JC, Flores-Hernandez C, Hoenecke HR, D'Lima DD. Augmented wedge-shaped glenoid component for the correction of glenoid retroversion: a finite element analysis. J Shoulder Elbow Surg 2014;23:347-54. https://doi.org/10.1016/j.jse.2013.06.008
14. Ho JC, Sabesan VJ, Iannotti JP. Glenoid component retroversion is associated with osteolysis. J Bone Joint Surg Am 2013;95:e82. https://doi.org/10.2106/JBJS.L.00336
15. Hussey MM, Steen BM, Cusick MC, Cox JL, Marberry ST, Simon P, et al. The effects of glenoid wear patterns on patients with osteoarthritis in total shoulder arthroplasty: an assessment of outcomes and value. J Shoulder Elbow Surg 2015;24:682-90. https://doi.org/10.1016/j.jse.2014.09.043
16. Iannotti JP, Greeson C, Downing D, Sabesan V, Bryan JA. Effect of glenoid deformity on glenoid component placement in primary shoulder arthroplasty. J Shoulder Elbow Surg 2012;21:48-55. https://doi.org/10.1016/j.jse.2011.02.011
17. Iannotti JP, Norris TR. Influence of preoperative factors on outcome of shoulder arthroplasty for glenohumeral osteoarthritis. J Bone Joint Surg Am 2003;85:251-8. https://doi.org/10.2106/00004623-200302000-00011
18. Kersten AD, Flores-Hernandez C, Hoenecke HR, D'Lima DD. Posterior augmented glenoid designs preserve more bone in biconcave glenoids. J Shoulder Elbow Surg 2015;24:1135-41. https://doi.org/10.1016/j.jse.2014.12.007
19. Klika BJ, Wooten CW, Sperling JW, Steinmann SP, Schleck CD, Harmsen WS, et al. Structural bone grafting for glenoid deficiency in primary total shoulder arthroplasty. J Shoulder Elbow Surg 2014;23:1066-72. https://doi.org/10.1016/j.jse.2013.09.017
20. Knowles NK, Ferreira LM, Athwal GS. Augmented glenoid component designs for type B2 erosions: a computational comparison by volume of bone removal and quality of remaining bone. J Shoulder Elbow Surg 2015;24:1218-26. https://doi.org/10.1016/j.jse.2014.12.018
21. Lazarus MD, Jensen KL, Southworth C, Matsen FA. The radiographic evaluation of keeled and pegged glenoid component insertion. J Bone Joint Surg Am 2002;84:1174-82. https://doi.org/10.2106/00004623-200207000-00013
22. Liotard J-P, Edwards BT, Padey A, Walch G, Boulahia A. Hydrotherapy rehabilitation after shoulder surgery. Tech Shoulder Elbow Surg 2003;4:44. https://doi.org/10.1097/00132589-200306000-00002
23. Michener LA, McClure PW, Sennett BJ. American Shoulder and Elbow Surgeons Standardized Shoulder Assessment Form, patient self-report section: reliability, validity, and responsiveness. J Shoulder Elbow Surg 2002;11:587-94. https://doi.org/10.1067/mse.2002.127096
24. Mizuno N, Denard PJ, Raiss P, Walch G. Reverse total shoulder arthroplasty for primary glenohumeral osteoarthritis in patients with a biconcave glenoid. J Bone Joint Surg Am 2013;95:1297-304. https://doi.org/10.2106/JBJS.L.00820
25. Nowak DD, Bahu MJ, Gardner TR, Dyrszka MD, Levine WN, Bigliani LU, et al. Simulation of surgical glenoid resurfacing using three-dimensional computed tomography of the arthritic glenohumeral joint: the amount of glenoid retroversion that can be corrected. J Shoulder Elbow Surg 2009;18:680-8. https://doi.org/10.1016/j.jse.2009.03.019
26. Nyffeler RW, Sheikh R, Atkinson TS, Jacob HAC, Favre P, Gerber C. Effects of glenoid component version on humeral head displacement and joint reaction forces: an experimental study. J Shoulder Elbow Surg 2006;15:625-9. https://doi.org/10.1016/j.jse.2005.09.016
27. Orvets ND, Chamberlain AM, Patterson BM, Chalmers PN, Gosselin M, Salazar D, et al. Total shoulder arthroplasty in patients with a B2 glenoid addressed with corrective reaming. J Shoulder Elbow Surg 2018;27:S58-64. https://doi.org/10.1016/j.jse.2018.01.003
28. Sabesan V, Callanan M, Ho J, Iannotti JP. Clinical and radiographic outcomes of total shoulder arthroplasty with bone graft for osteoarthritis with severe glenoid bone loss. J Bone Joint Surg Am 2013;95:1290-6. https://doi.org/10.2106/JBJS.L.00097
29. Sabesan V, Callanan M, Sharma V, Iannotti JP. Correction of acquired glenoid bone loss in osteoarthritis with a standard versus an augmented glenoid component. J Shoulder Elbow Surg 2014;23:964-73. https://doi.org/10.1016/j.jse.2013.09.019
30. Shapiro TA, McGarry MH, Gupta R, Lee YS, Lee TQ. Biomechanical effects of glenoid retroversion in total shoulder arthroplasty. J Shoulder Elbow Surg 2007;16:S90-5. https://doi.org/10.1016/j.jse.2006.07.010
31. Somerson JS, Hsu JE, Neradilek MB, Matsen FA. Analysis of 4063 complications of shoulder arthroplasty reported to the US Food and Drug Administration from 2012 to 2016. J Shoulder Elbow Surg 2018;27:1978-86. https://doi.org/10.1016/j.jse.2018.03.025
32. Walch G, Badet R, Boulahia A, Khoury A. Morphologic study of the glenoid in primary glenohumeral osteoarthritis. J Arthroplasty 1999;14:756-60.
33. Walch G, Moraga C, Young A, Castellanos-Rosas J. Results of anatomic nonconstrained prosthesis in primary osteoarthritis with biconcave glenoid. J Shoulder Elbow Surg 2012;21:1526-33. https://doi.org/10.1016/j.jse.2011.11.030
34. Walch G, Young AA, Boileau P, Loew M, Gazielly D, Molé D. Patterns of loosening of polyethylene keeled glenoid components after shoulder arthroplasty for primary osteoarthritis: results of a multicenter study with more than five years of follow-up. J Bone Joint Surg Am 2012;94:145-50. https://doi.org/10.2106/JBJS.J.00699
35. Wang T, Abrams GD, Behn AW, Lindsey D, Giori N, Cheung EV. Posterior glenoid wear in total shoulder arthroplasty: eccentric anterior reaming is superior to posterior augment. Clin Orthop Relat Res 2015;473:3928-36. https://doi.org/10.1007/s11999-015-4482-8
36. Williams GN, Gangel TJ, Arciero RA, Uhorchak JM, Taylor DC. Comparison of the Single Assessment Numeric Evaluation method and two shoulder rating scales. Am J Sports Med 1999;27:214-21.