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Early to midterm outcomes of anatomic shoulder arthroplasty performed on dysplastic glenoids

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Background: Treatment of primary osteoarthritis with glenoid dysplasia or Walch type C glenoids remains controversial. There is scant literature available on patient outcomes after anatomic shoulder arthroplasty in patients with Walch type C glenoids. The purpose of this study was to evaluate the outcomes of total shoulder arthroplasty (TSA) for Walch type C dysplastic glenoids with standard (nonaugmented) glenoid components compared with TSA for glenoids with concentric wear and minimal erosion (Walch type A1). We hypothesized that TSA performed for Walch type C dysplastic glenoids with standard glenoid components can reliably produce successful results at short- to midterm follow-up.

Methods: We identified all patients who had primary anatomic TSA performed for osteoarthritis in a prospective shoulder arthroplasty registry collected from 2004 to the present time. Twenty-nine patients met inclusion criteria of a preoperative Walch type C dysplastic glenoid, treatment with TSA using standard (nonaugmented) glenoid components, and a minimum of 2-year clinical follow-up. A matched cohort of 58 patients with a type A1 glenoid and minimum of 2-year clinical follow-up for anatomic shoulder arthroplasty served as the control group. The American Shoulder and Elbow Surgeons (ASES) score, the Single Assessment Numeric Evaluation (SANE), patient satisfaction, complications, and revisions were evaluated in both cohorts.

Results: The mean follow-up for this study was 4.5 years (standard deviation, 2.6 years; range, 2-10 years). Baseline measures were not significantly different between the Walch type C dysplastic group and the matched type A1 cohort (all $P > .05$). Both groups showed significant improvements in ASES, ASES pain, and SANE scores from baseline to the final follow-up (all $P < .001$). The Walch type C group had no significant differences in ASES score ($P = .118$), ASES pain ($P = .730$), or SANE score ($P = .168$) compared with the matched type A1 cohort. The complication rate of patients with a type C glenoid was 14% (4 of 29) with a 7% (2 of 29) revision rate. Similarly, the complication rate for the A1 matched cohort was 17% (10 of 58) with a 12% (7 of 58) revision rate. Both groups had high patient satisfaction without statistical differences ($P = .549$). In addition, there were no differences in the rate of radiographic lucencies or Lazarus scores ($P = .222$).

Conclusions: Anatomic TSA reliably produced clinically significant improvements in pain and function and similar short- to midterm outcomes in patients with Walch type C dysplastic glenoids compared with patients with type A1 glenoids. Anatomic TSA with standard (nonaugmented) glenoid components should remain an option in patients with Walch type C dysplastic glenoids despite emerging treatment options including augmented glenoid components and reverse TSA.

The Texas Orthopedic Hospital's institutional review board committee approved this study (TOH217e).

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Glenoid dysplasia is a developmental abnormality that results in bony deficiency of the posteroinferior glenoid[5] and severe glenoid retroversion. The prevalence of glenoid dysplasia and the number of patients who develop end-stage glenohumeral arthritis are unknown, largely owing to the number of patients who are asymptomatic[5,10,16] or respond to nonoperative treatment.[21]

Nevertheless, glenoid dysplasia has been recognized in arthroplasty literature. According to Walch et al,[19] dysplastic glenoids are type C and described as having greater than 25° of retroversion in their original classification of glenoid morphology for primary osteoarthritis (OA). The Walch classification has been subsequently clarified to differentiate from severe retroversion due to posterior subluxation and eccentric wear (type B glenoids). Walch type C dysplastic glenoids are defined by severe retroversion without humeral head subluxation and with the presence of hypertrophic posteroinferior soft tissue structures.[1,8,18]

There are very few studies examining the outcomes of arthroplasty in patients with Walch type C dysplastic glenoids. Allen et al[2] and Edwards et al[6] reported series of 22 and 15 patients, respectively, treated with either hemiarthroplasty (HA) or anatomic total shoulder arthroplasty (TSA). In total, these 2 series contained 25 patients treated with TSA for Walch type C dysplastic glenoids. The series by Allen et al demonstrated that there may be an increase in the frequency of glenoid component issues requiring revision compared with other glenoid morphologies, and the authors concluded that there may be a role for alternative treatments.[2] However, our current understanding of treatment outcomes in patients with Walch type C dysplastic glenoids continues to be limited by low patient numbers.

The purpose of this study was to evaluate the outcomes of TSA for the treatment of Walch type C dysplastic glenoids with standard (nonaugmented) glenoid components compared with TSA for glenoids with concentric wear and minimal erosion (Walch type A1). We hypothesized that anatomic TSA performed on a Walch type C dysplastic glenoid can reliably produce successful results at short- to midterm follow-up and should remain a viable treatment option.

Methods

Patient selection

All patients completed informed consent before enrolling in our prospectively collected, single-surgeon shoulder arthroplasty registry from 2004 to 2018. We identified 31 primary TSAs in our shoulder arthroplasty registry performed for primary OA in patients with Walch type C dysplastic glenoids and included 29 who had a minimum of 2 years of follow-up. We excluded all patients for whom TSA was a revision from a prior arthroplasty. Type C morphology was defined as having a uniconcave glenoid with greater than 25° of retroversion and characteristic features, including hypoplasia of the posteroinferior glenoid or capular neck and reduced glenoid depth. Glenoid morphology was assessed by the senior author on the preoperative computed tomography (CT) scan based on the original classification by Walch et al.[19] Two blinded radiographic reviewers (JLC and SLJ) retrospectively reviewed all preoperative CT scans at the time of this study to confirm that each case involved a Walch type C dysplastic glenoid rather than the recently described B3 glenoid. In addition, the 2 blinded reviewers assessed the final follow-up x-ray and determined the Lazarus score.

A matched cohort was created from the registry with patients diagnosed with primary OA and undergoing primary anatomic TSA with an A1 glenoid. Each of the 29 Walch type C dysplastic glenoid cases was matched with 2 control cases (A1 glenoid) using propensity scoring. This technique allows subject matching based on baseline characteristics that in this study were age, gender, body mass index (BMI), shoulder dominance, and surgery date. A propensity score was calculated for the 29 type C cases and all type A1 primary OA cases in the registry. Then each type C case was matched to 2 type A1 cases so as to minimize the total within-pair propensity score differences. This optimal matching was performed without replacement of cases, so each type C case is matched to 2 unique type A1 cases.

Data collection

Patients were examined preoperatively by the senior surgeon (TBE) and postoperatively at 1 week, 6 weeks, 3 months, 6 months, 12 months, and then annually. Patient demographic and clinical characteristics reviewed included age, gender, BMI, shoulder dominance, duration of follow-up, and preoperative opioid use as well as a history of smoking, depression, diabetes, chronic back pain, and cardiovascular disease. Patient-reported outcome measures were collected preoperatively and at yearly postoperative visits and included the American Shoulder and Elbow Surgeons (ASES),[13] Single Assessment Numeric Evaluation (SANE),[20] and patient satisfaction measures. Radiographs from all patients were obtained at each clinical visit and included anteroposterior in the plane of the scapula, scapular Y, and axillary views. These radiographs were reviewed for radiolucent lines around the humeral and glenoid component by the primary surgeon prospectively at the time of follow-up. In addition, all intraoperative and postoperative complications were recorded.

Table I Subject demographic and preoperative clinical characteristics

	Type C (n = 29)	Type A1 (n = 58)	*P* value
Male gender	22 (76)	44 (76)	.999
Age at surgery (yr), mean ± SD	61.0 ± 10.1	61.6 ± 9.5	.700
Dominant shoulder	18 (62)	36 (62)	.999
BMI, mean ± SD	30.2 ± 5.3	30.2 ± 5.4	.993
Follow-up years, mean ± SD	4.6 ± 2.4	4.4 ± 2.7	.623
Current smoker	1 (3)	2 (3)	.999
Preoperative opioid use	2 (7)	6 (10)	.600
Chronic back pain	5 (17)	4 (7)	.135
Depression	3 (10)	5 (9)	.793
Diabetes	3 (10)	4 (7)	.577
Cardiovascular disease	1 (3)	2 (3)	.999

SD, standard deviation; *BMI*, body mass index.
Data are presented as n (%) unless otherwise specified.

Operative technique

All cases were performed through a deltopectoral approach, using our published anatomic TSA technique.[7] The subscapularis was tenotomized along the anatomic neck in all cases. A cemented standard (nonaugmented) all-polyethylene glenoid (pegged or keeled) with a press-fit humeral stem was used in all cases. No effort was made to correct glenoid version through reaming or posterior bone graft. In addition, no patients underwent posterior capsulorrhaphy. The humeral components used included Aequalis (10), Ascend (3), and Ascend Flex (2) (Tornier/Wright Medical, Memphis, TN, USA). The glenoid components used included standard nonaugmented all-polyethylene components: Perform Cortiloc pegged (7), Aequalis pegged (4), and Aequalis keeled (4) (Tornier/Wright Medical). There were 2 intraoperative fractures, one of the humerus during canal preparation and the other of the glenoid rim; both fractures were small and did not require repair or additional treatment.

Statistical analysis

Baseline patient characteristics such as age, gender, BMI, and comorbidities were evaluated for differences in the type A1 and type C patients with independent sample *t* tests and χ^2 tests as appropriate. Mixed linear models were used to evaluate differences in preoperative, final follow-up, and preoperative to final follow-up change (ie, improvement) in patient-reported outcome measures between patients with A1 and type C glenoids. The mixed model analysis accounted for the 1:2 matching of the type C patients to type A1 patients. Patient satisfaction, revision and complication rates, and the presence of radiolucent lines at the final follow-up were evaluated by Fisher's exact tests to determine if a difference existed between glenoid types.

Results

Baseline patient characteristics

There were no statistical differences between the type C and A1 glenoid subject characteristics regarding gender, age at surgery, BMI, and dominant side shoulder surgery (all $P < .05$, Table I). Furthermore, comorbidities between glenoid types were not significantly different for a history of smoking, chronic back pain, depression, diabetes, or cardiovascular disease. The average clinical follow-up for the entire cohort was 4.5 years (standard deviation, 2.6 years; range, 2-10 years).

Complications and revisions

In the patients with a type C glenoid, there were 4 postoperative complications in 4 of 29 patients including 1 patient who required revision to reverse shoulder arthroplasty (RSA) and 1 patient whose revision to RSA was recommended, giving an overall complication rate of 14% and revision rate of 7%. The complications were aseptic glenoid loosening (2), isolated subscapularis failure (1), and superior migration of the humeral head (1).

The first patient with a complication in the type C group was a 45-year-old man who developed aseptic glenoid loosening and associated subscapularis failure that was identified 3 years after TSA for a Walch type C glenoid. He underwent revision HA with removal of the glenoid component and bone grafting of an uncontained glenoid defect at that time. This patient ultimately developed rotator cuff failure and was later revised to RSA 11 years after the index TSA. The second patient with a complication was a 78-year-old woman who developed aseptic glenoid loosening identified 10 years after the index TSA. She was scheduled for revision to RSA; however, the patient passed away due to unrelated medical comorbidities before the revision. The third patient with a complication suffered an isolated subscapularis failure that was identified at 3 years from TSA. This patient's symptoms resolved with a trial of physical therapy, and the patient is now 6 years from TSA without revision. The fourth complication included a patient with a painful TSA at 4 years postoperatively with

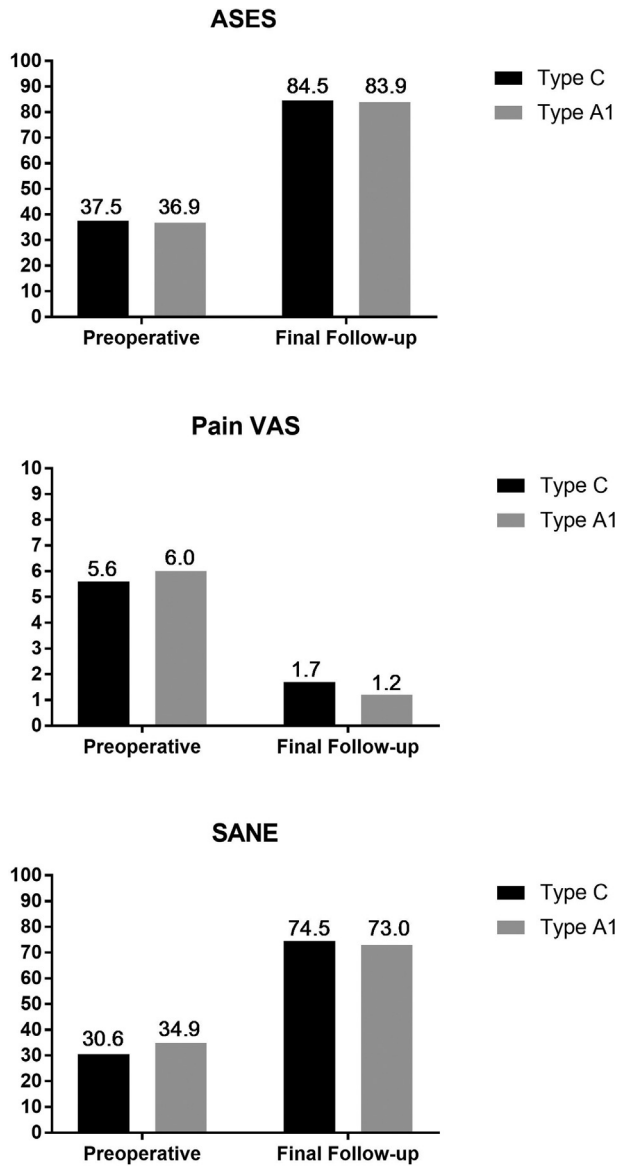

Figure 1 Patient-reported outcome measures were not significantly different between glenoid types. *ASES*, American Shoulder and Elbow Surgeons; *VAS*, visual analog scale; *SANE*, Single Assessment Numeric Evaluation.

superior migration on radiographs; the rotator cuff tendons were found to be intact on CT arthrogram and her infection workup (aspiration) was negative. The patient ultimately elected to be treated nonoperatively and was prescribed physical therapy and has not returned to the clinic in 10 months.

In the matched cohort patients with a type A1 glenoid, there were 10 postoperative complications in 10 patients with 7 revisions to RSA, resulting in a 17% complication rate and a 12% revision rate. All 7 revisions were to RSA for aseptic glenoid loosening at a mean of 7 years from index TSA (range, 3-10 years). Three of these 7 patients required glenoid bone grafting at the time of revision. In addition, 2 patients were found to have nerve palsies after surgery; one had a partial brachial plexopathy presenting as mild biceps and hand weakness that resolved at 2 months, and the other an axillary nerve palsy in which motion and strength returned at 6 months but sensation has not returned at 5 years.

Outcome measures

No significant differences were noted between the 2 groups for preoperative ASES, pain visual analog scale, or SANE measures. Both groups improved significantly on the ASES, ASES pain, and SANE measures between preoperative and final follow-up (all $P < .001$, Fig. 1). The absolute improvement from preoperative to final follow-up was nearly identical between the 2 groups, demonstrating similar improvements after surgery regardless of glenoid type (all $P > .05$).

All patients rated that they were either very dissatisfied or dissatisfied with their shoulder preoperatively (Table II). At the final follow-up, 83% of type C patients and 77% of type A1 patients were satisfied or very satisfied. This small difference in satisfaction was not statistically significant ($P = .549$). Radiographic images at the final follow-up were retrospectively evaluated by 2 independent reviewers for glenoid radiolucent lines and Lazarus grade. The scoring agreement between the 2 reviewers was considered excellent (ICC = 0.953). The Lazarus grade for glenoid radiolucent lines was similar between the type C and A1 groups (Table III; $P = .222$), and no statistically significant differences existed in the presence of humeral radiolucent lines ($P = .590$) and humeral osteolysis ($P = .691$).

Discussion

Our study examined a single surgeon's experience with TSA in primary OA for Walch type C dysplastic glenoids compared with a matched cohort of more routine TSA in concentrically worn A1 glenoids. In slight contrast to other series on Walch type C dysplastic glenoids and the growing focus on version correction, no attempt was made at correction of retroversion in our series. We found that TSA, without any corrective reaming for type C glenoids, reliably produced clinically significant improvements in function, pain, and satisfaction, which were similar to results for type A1 glenoids. There were 2 cases of aseptic glenoid loosening in the Walch type C dysplastic glenoid group, one of which occurred 3 years from the index surgery and the other developed 10 years from the index surgery. In addition, only 2 patients demonstrated radiolucent lines at final radiographic follow-up. Although this study is limited in sample size, these findings did not demonstrate a higher rate of glenoid-sided complications despite the preoperative glenoid retroversion when compared with TSAs in concentrically worn (A1) glenoids.

Table II Patient satisfaction results

	Type C glenoid		Type A1 glenoid	
	Preoperative	Final follow-up	Preoperative	Final follow-up
Very dissatisfied	18 (62)	1 (3)	38 (68)	4 (7)
Dissatisfied	11 (38)	4 (14)	18 (32)	9 (16)
Satisfied	–	6 (21)	–	16 (28)
Very satisfied	–	18 (62)	–	28 (49)

Satisfaction rated as "satisfied" or "very satisfied" at the final follow-up was not significantly different between C and A1 glenoid types ($P = .549$). Data are presented as n (%).

Table III Radiographic outcomes at final follow-up

Glenoid component	Type C glenoid	Type A1 glenoid	*P* value
Lazarus score			.222
0	6 (21)	24 (42)	
1	3 (10)	5 (9)	
2	8 (28)	8 (14)	
3	5 (17)	2 (4)	
4	7 (24)	14 (25)	
5	0 (0)	4 (7)	
Humeral component			
Humeral radiolucent line	5 (25)	10 (19)	.590
Osteolysis	2 (10)	7 (13)	.691

Data are presented as n (%).

The glenoid fossa develops from 2 ossification centers: the subcoracoid center and the secondary glenoid center. The subcoracoid center forms the upper ring of the glenoid and base of the coracoid; this center appears and fuses at approximately 10 and 15 years of age, respectively. The secondary glenoid center develops at puberty to deepen the glenoid cavity. Glenoid dysplasia is thought to occur due to failed ossification of this center.[1,12,21] This theory is supported by thickened inferior cartilage and hypertrophic posterior labrum seen on advanced imaging[9,11] and arthroscopically.[14] These soft tissue changes may help center the humeral head in the retroverted glenoid, and thereby partially explain why many patients with glenoid dysplasia remain asymptomatic for years.[1] In addition, this anatomic variation provides a basis for not needing to correct retroversion at the time of TSA. Our general treatment of Walch type C dysplastic glenoids has been to "play it where it lies" without correction of the glenoid retroversion. The glenoid retroversion is congenital and not acquired over time, so we have elected to treat Walch type C dysplastic glenoids with standard (nonaugmented) glenoid components and without version correction with reaming.

There is no consensus on whether glenoid dysplasia will naturally progress to end-stage OA. Prior studies have demonstrated that even patients with degenerative changes can respond to physical therapy.[21] However, there is a known subset of these patients with unremitting symptoms that progress to arthroplasty. Walch et al[19] reported a 9% incidence of type C glenoids in their original series, and a prior multicenter study by Edwards et al[6] reported dysplastic glenoids in 3.5% of patients undergoing TSA.

HA has been reported as a treatment option Walch type C dysplastic glenoids, with variable results. Bonnevialle et al[4] reported outcomes in 10 shoulders at 6-year follow-up, and only 1 patient had significant postoperative pain. By contrast, Allen et al[2] found that 4 of 8 patients who underwent HA had no reduction in their pain, and Edwards et al[6] found better postoperative mobility scores in patients who underwent TSA compared with HA. Despite the lack of strong evidence against HA, there is some consensus that TSA is more reliable.

vThe 2 prior reports on TSA in Walch type C dysplastic glenoids had notable differences in technique and results. Edwards et al[6] reported outcomes of TSA and HA in 15 shoulders at a mean 37-month follow-up. These authors made no attempt to perform eccentric reaming, posterior capsulorrhaphy, or glenoid bone grafting. In the 11 patients who underwent TSA, 10 had significant improvements in all functional outcome scores and rated their outcome as "excellent" or "good." The remaining patient was the only revision in the series, whose glenoid component became loose at 12 months from TSA due to, what the authors felt, the poor cementing technique (a small radiolucent line was present around the keel on initial postoperative radiographs).

Allen et al[2] also reported on 22 Walch type C dysplastic glenoids that underwent HA or TSA at a mean 6-year follow-up. By contrast, these authors attempted to correct glenoid version with as much anterior reaming as possible to still subjectively maintain 12.5-15 mm of glenoid vault depth. Five of 14 shoulders originally treated with TSA underwent revision for deep infection (2), glenoid polyethylene wear at 39 months (1), glenoid loosening at 10 years (1), or glenoid implant fracture (1) at 15.5 years. No functional outcome scores were obtained; however, the outcomes of TSA were graded as unsatisfactory in 6 patients by the Neer result rating. Radiographic review revealed 6 glenoid components with grade 1 radiolucency, 2 of which required revision; of note, both were metal-backed glenoid components. The authors concluded that patients with TSA and glenoid dysplasia experienced more glenoid-sided complications than in patients with more

typical concentric OA, and that alternative treatment methods should be explored.

RSA has been proposed as an alternative to TSA, with the theoretical advantage of diminishing glenoid-sided complications such as early loosening. There is limited evidence examining RSA for primary OA and dysplastic glenoids. Sperling [17] reported 12 cases of RSA for Walch type C dysplastic glenoids. At a mean 28-month follow-up, the mean ASES score was 74 (standard deviation, 20); in addition, there were no reoperations or radiographic loosening. However, 3 patients were unsatisfied with their outcome and there were no improvements in shoulder rotation. Moreover, the potential benefits of RSA should be weighed against its poorly understood longevity and limited salvage options, as well as the reliable outcomes of TSA demonstrated in this study.

Overall, the results of our study align more with the successful outcomes reported by Edwards et al.[6] This may be explained by longer follow-up in the study by Allen et al,[2] which could have recognized complications not yet seen in the other 2 series.[6] In addition, the 3 revisions for glenoid-sided complications in the study by Allen et al[2] occurred in metal-backed glenoids (Cofield type), which, separate from glenoid dysplasia, are known to be associated with higher failure rate than all-polyethylene components.[3,15] Lastly, the difference in glenoid preparation technique could have contributed. Allen et al used some degree of corrective reaming, compared with no attempt in the other 2 series.

Our study is limited by its retrospective design and small patient cohort, both of which stem from the rarity of this condition. In addition, all operations were performed by a single, high-volume shoulder arthroplasty surgeon and therefore may not be generalizable. Nonetheless, this series provides valuable information on treating these patients with more contemporary arthroplasty designs.

Conclusions

Anatomic TSA reliably produced clinically significant improvements in pain and function and similar short- to midterm outcomes in patients with Walch type C dysplastic glenoids compared with patients with type A1 glenoids. Anatomic TSA with standard (nonaugmented) glenoid components should remain an option in patients with Walch type C dysplastic glenoids despite emerging treatment options including augmented glenoid components and reverse TSA.

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