Outcomes of Anatomic Total Shoulder Arthroplasty with B2 Glenoids

A Systematic Review

Colten Luedke, DO

Michael J. Kissenberth, MD

Stefan J. Tolan, MD

Richard J. Hawkins, MD

John M. Tokish, MD

Investigation performed at the Steadman Hawkins Clinic of the Carolinas, Greenville, South Carolina

Abstract

Background: Total shoulder arthroplasty remains an effective procedure for shoulder pain relief. Despite the negative effect of abnormal glenoid morphology and specifically retroverted and posteriorly subluxated glenoids, there is no consensus for management of B2 glenoids in total shoulder arthroplasty. The purpose of this study was to compare the outcomes and complication rates for B2 glenoid techniques so as to provide a baseline understanding of the current state of treatment of this pathology.

Methods: A systematic review evaluating outcomes of total shoulder arthroplasty with biconcave glenoids using PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) methodology included searches up to December 31, 2015, of PubMed, Embase, MEDLINE, Cochrane Reviews, and Google Scholar. Nine articles met inclusion and exclusion criteria.

Results: In this study, 239 total shoulder arthroplasties with B2 glenoids with a mean follow-up of 55.5 months (range, 24 to 91 months) were included. The mean patient age was 63.3 years (range, 55.8 to 68.7 years). Asymmetric reaming was performed in 127 glenoids, posterior bone-grafting was included in 53 glenoids, and 34 received an augmented glenoid component to correct glenoid retroversion and bone loss. Overall, the mean Constant and Neer scores improved from preoperative measures. Fifty-eight percent of patients had no loosening, and 42% had some loosening, although not all of these patients were symptomatic. Despite variation in outcome measures hindering treatment approach comparison, the posteriorly augmented glenoid was generally reported to provide better outcomes with few complications. Although posterior glenoid bone-grafting results in acceptable outcomes, it also represents the highest rate of complications. The revision rate was 15.6% for asymmetric reaming, 9.5% for posterior glenoid bone-grafting, and 0% for posteriorly augmented glenoids.

Conclusions: Surgical treatment of the B2 glenoid remains a challenge to the shoulder surgeon, with worse outcomes and higher complication rates. Longer follow-up, consistent outcome measures, and result stratification based on glenoid type may allow for direct comparison in the future.

Level of Evidence: Therapeutic Level IV. See Instructions for Authors for a complete description of levels of evidence.

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Shoulder arthroplasty has provided durable pain relief and excellent function in patients with glenohumeral arthritis. It is estimated that approximately 25,000 total shoulder arthroplasties were performed in the United States in 2007, and it was projected that this number will have surpassed 40,000 total shoulder arthroplasties by 2015[1,2]. The anatomic glenoid version is noted to range from 2° of anteversion to 8° of retroversion in prior studies[3-7]. In 1999, Walch et al.[8] described 3 main types of glenoid morphologies by reviewing computed tomographic (CT) scans of shoulders with primary glenohumeral osteoarthritis. Type A (59%) was defined as a well-centered humeral head without extensive medial erosion. In type B (32%), posterior subluxation of the humeral head led to asymmetric loads against the posterior (and inferior)[9] aspect of the glenoid. Two subgroups were identified: the B1 type (17%) showed narrowing of the posterior joint space, subchondral sclerosis, and osteophytes, and the B2 type (15%) demonstrated a biconcave aspect of the glenoid with variable posterior subluxation. Type C (9%) was defined by a glenoid retroversion of >25°, regardless of posterior erosion. In their reports, retroversion in type C was primarily of dysplastic origin. Compared with B1 and C glenoids, biconcave (type B2) glenoids generally have more severe retroversion and posterior subluxation of the humeral head.

In type B2 glenoids, the posterior-eroded surface, which is created by the posteriorly subluxated humeral head, is referred to as the neoglenoid. The remaining native anterior aspect is referred to as the paleoglenoid[9]. Placement of the glenoid component in an optimal position is paramount to prevent eccentric loading and higher shear forces on the glenoid implant, ensuring its longevity. The predominant cause for revision of total shoulder arthroplasty is glenoid component loosening, and considerable effort has gone into understanding the contributing risk factors[10-14]. Glenoid component malpositioning has been associated with increased rates of complications, including radiolucencies, loosening, humeral-head subluxation, and revisions[1,3,10,11,13,14].

Several techniques have been established to correct the version in glenoids with posterior osseous erosion. These have included hemiarthroplasty, asymmetric reaming of the high side anteriorly, posterior glenoid bone-grafting, posteriorly augmented glenoid components, and, more recently, reverse shoulder arthroplasty. Painful glenoid wear continues with hemiarthroplasty because it does not correct the glenohumeral posterior subluxation[15]. Asymmetric reaming, although technically straightforward, limits the degree of retroversion correction and >15° of correction can compromise subchondral bone anteriorly and can lead to penetration of pegs in the glenoid vault[3,15-18]. Posteriorly augmented glenoids have a posterior step or wedge built into the component to minimize asymmetric anterior reaming and therefore preserve glenoid bone stock. No long-term data are available on the outcomes of this approach, however. Bone-grafting has been advocated when there is insufficient bone stock for component fixation or an inability to correct component position with glenoid reaming. Concerns with bone-grafting include nonunion, resorption, or subsidence, in addition to the technical demand of graft placement and fixation[19-21]. Finally, reverse shoulder arthroplasty has recently been shown to provide excellent short-term clinical results in elderly patients with B2 glenoids in whom bone stock and posterior humeral subluxation are concerns[22,23]. However, longer-term follow-up and additional research are necessary to determine if this approach is a viable option, especially in younger patients in whom B2 glenoids are common. Outcomes of reverse shoulder arthroplasty for B2 glenoids were not investigated for the purpose of our study.

Despite the considerable amount of literature on the outcomes of anatomic total shoulder arthroplasty, relatively little is known about the specific outcomes in B2 glenoids. To our knowledge, no study has systematically organized the literature to allow a comprehensive assessment of treatment results in this pathology. The primary purpose of our study was to present a review of the literature on results in total shoulder arthroplasty specific to the B2 glenoid.

Materials and Methods

Following the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines (www.prisma-statement.org), we conducted a systematic review of all studies referencing a B2 or biconcave glenoid, published in English up to December 31, 2015. Two reviewers evaluated all relevant studies showing outcomes for total shoulder arthroplasty in patients with a B2 glenoid. Articles were analyzed for the prevalence of radiolucent lines, revisions, postoperative subluxation, and complications. PubMed, Embase, MEDLINE, Cochrane Reviews, and Google Scholar were searched for articles containing "glenoid," "biconcave glenoid," "B2 glenoid," "glenoid bone loss," "outcomes of total shoulder arthroplasty," "bone grafting glenoid," "augmented glenoid," "posterior subluxation," and "glenoid retroversion." In addition, the reference lists of all included articles were reviewed for potentially missed studies.

Exclusion criteria were applied to omit articles with follow-up of <2 years, articles that did not specifically show results stratified by glenoid morphology limited to the B2 glenoid, articles not written in the English language, articles on reverse shoulder arthroplasties, review articles, and nonclinical studies. There were 897 articles in the initial search, and 7 remained after review. Two additional articles were identified and were included after manually reviewing references from qualifying articles, for a total of 9 articles.

Reported outcomes included Constant scores, range of motion, Neer

rating system results, University of California at Los Angeles (UCLA) shoulder scores, the Simple Shoulder Test (SST), Penn scores, and American Shoulder and Elbow Surgeons (ASES) shoulder scores[1,8,15,24-28]. As a secondary outcome, results were stratified according to the technique used to correct glenoid retroversion: asymmetric reaming, posterior glenoid bone-grafting, or an augmented glenoid component. Radiolucent lines were assessed, as well as data on revisions and other complications such as resorption of bone graft, when identified in studies.

Results

Demographic Characteristics

In this study, 239 total shoulder arthroplasties with B2 glenoids were reviewed, with a mean follow-up of 55.5 months (range, 24 to 91 months) (Table I). Asymmetric reaming was performed in 127 of 215 B2 glenoids, posterior bone-grafting was performed in 54 glenoids, and 34 glenoids received an augmented glenoid component for correction of glenoid retroversion and bone loss. The mean patient age was 63.3 years (with the mean ranging from 55.8 to 68.7 years among the studies), and, of the 238 patients studied, there were 132 male patients (55.5%) and 106 female patients (44.5%).

Outcome Measures

The outcome measures varied among the 9 included studies (Table I). Three studies specifically showed Constant scores, with mean ratings of 39.4 points preoperatively and 77.9 points postoperatively. When stratified by technique, Constant scores in the asymmetric reaming group (73 points), the posterior bone-grafting group (79 points), and the posteriorly augmented glenoid group (75 points) were similar. Four of 9 articles showed outcomes with the Neer rating system: patients with a total of 143 B2 glenoids reported 18% excellent results, 56% satisfied or very satisfied results, 17% unsatisfied results, and 8% uncertain results. Stratifying the Neer rating based on methods of correction, we found 66.3% very satisfied or satisfied results in the asymmetric reaming group, 52.5% excellent results in the posterior bone-grafting group, and 36% excellent results in the posteriorly augmented glenoid group. Unfortunately, no excellent ratings were reported for the asymmetric reaming group.

Radiographic Outcomes

Radiolucent lines and/or glenoid loosening data were reported in 5 of 9 articles with 164 total shoulder arthroplasties. Overall, 62 of the patients demonstrated radiolucent lines, although not all were symptomatic. Five of the studies covered loosening, with an overall rate of 6.7% at a minimum of 5 years. The asymmetric reaming technique demonstrated the lowest rate of glenoid radiolucencies at 28%, followed by posterior bone-grafting with 45%, and posteriorly augmented glenoids demonstrated a 64.7% rate of radiolucent lines on radiographs.

Range of Motion

Six of 9 articles reported on the range of motion in 201 shoulders. The mean preoperative forward elevation was 105°. The mean postoperative forward elevation was 148° (range among the studies, 132° to 160°), improving by 43°. The overall abduction improved from a mean preoperative value of 89° to 137°, improving by 48°. External rotation improved from 28° to 49° postoperatively. When stratifying range of motion by technique, only 1 study of 92 shoulders utilizing asymmetric reaming reported the range of motion, with forward elevation improving from 98° to 143° and external rotation improving from 7° to 37°. Three studies, encompassing 47 shoulders, utilizing posterior bone-grafting showed an overall mean of 138° of forward flexion and 50° of external rotation. Posteriorly augmented glenoids had a mean forward flexion of 151° and a mean external rotation of 55°. Internal rotation was only reported in 3 of 9 articles (60 shoulders), which demonstrated, on average, gains from the sacral area to between T8 and T12[24,25,29].

Complications

Complications were variably reported among the 9 included studies, and not all articles described the same complications (Table II). The most common complication was glenoid radiolucent lines, which represented 38% (62) of all 164 complications.

Comparing revision rates by techniques, asymmetric reaming had a revision rate of 15.6%, posteriorly augmented glenoids had 0 revisions, and posterior bone-grafting had a reported revision rate of 9.5%. Additional complications varied by technique, with the lowest prevalence of complications reported in the augmented glenoid group for 1 (3%) of 34 patients, followed by the asymmetric reaming group for 30 (24.6%) of 122 patients. The overall rate of complications in the posterior bone-grafting technique was 30%. Unique to the bone-grafting technique, 4.3% experienced broken screws, 6.4% had bone graft resorption or collapse, and 17% of glenoids shifted in position. Specific complications stratified by technique can be found in Tables III, IV, and V.

Discussion

In comparison with the type-A glenoid, the B2 glenoid presents a difficult reconstructive problem with relatively high failure rates due to glenoid loosening or recurrent posterior instability with the use of anatomic arthroplasty[30]. Type-A glenoids are characterized by a concentric wear pattern, no posterior subluxation, and a well-centered humeral head. By comparison, the B2 morphology is characterized by an asymmetric posterior wear pattern with posterior humeral-head subluxation. Mild deformities may be corrected by asymmetric reaming; however, severe deformities have a high rate of failure at the intermediate-term follow-up with these techniques. Levine et al. reported on 31 shoulders, comparing concentric hemiarthroplasties with those with posterior erosion, and found that the concentric group achieved a satisfactory outcome in 86% of cases compared with

TABLE I Summary of Studies on Total Shoulder Arthroplasties with B2 Glenoid Included*

Study	LOE	Follow-up† *(mo)*	No. of B2 Glenoids at Final Follow-up	Neer Rating	Score‡ *(points)*			
					Constant	UCLA	SST	ASES
Ream								
Chin[1]	III	60 (range, 23 to 120)	37	NR	NR	NR	NR	NR
Walch[33]	IV	77	92	61 (66.3%) very satisfied or satisfied, 15 (16.3%) uncertain, 16 (17.4%) disappointed	32.4 to 68.8	NR	NR	NR
Gerber[26]	IV	42	5	NR	39 to 78; age-adjusted Constant scores improved from 49 to 95	NR	NR	NR
Bone-graft								
Klika[34]	IV	104.4 (8.7 yr) clinical, 91.2 (7.6 yr) radiographic	12	8 excellent, 2 satisfactory, 2 unsatisfactory	NR	NR	NR	NR
Sabesan[27]	IV	53	9	NR	NR	NR	NR	Penn Shoulder score§, 38.7 to 79.4 (of 100): 10 of 12 good or excellent results; SF-12, no significant improvement between preop. and postop. scores
Steinmann[24]	IV	63.6 (5.3 yr)	28	13 excellent, 10 satisfactory, 5 unsatisfactory	NR	NR	NR	NR
Habermeyer[28]	II	24	24	NR	Posterior decentered head, 47.6 improved to 90 (not specifically in B2 glenoids, but in their cohort as a whole)	NR	NR	NR
Augmented								
Rice[29]	IV	60 (5 yr)	14	5 (36%) excellent, 7 (50%) satisfactory, 2 (14%) unsatisfactory	NR	NR	NR	NR
Wright[25]	IV	29.4	20	NR	38.6 improved to 75.6	15.2 improved to 32.1	5 improved to 11	42.6 improved to 91.5
Total: 9 articles	1 Level I, 1 Level III, 7 Level IV	55.5 (range, 24 to 91.2)	239	143 total: 26 (18%) excellent, 80 (56%) satisfied or very satisfied, 25 (17.5%) unsatisfied, 15 (10.5%) uncertain	39.4 improved to 77.9	15.2 improved to 32.1	5 improved to 11	42.6 improved to 91.5

*LOE = Level of Evidence, NR = not reported, and SF-12 = Short Form-12. †The follow-up is given as the mean in months; the minimum follow-up was 2 years. ‡The value is given as the mean. §The Penn Score is very similar to the ASES score, which is why it was reported here.

TABLE II Complications, Radiolucent Lines, and Revisions for Included Studies*

Study	No. of B2 Glenoids at Final Follow-up	Method of Glenoid Version Correction	Complications	Radiolucent Lines	Revisions
Chin[1]	37	Asymmetric glenoid reaming	4 revisions (4.6%): acute postop. infection (2.3%), subscapular failure (1.1%), glenoid loosening (1.1%)	NR	4 (9.2%) of 37 at 60 mo
Walch[33]	92	Asymmetric reaming in 85; humeral-head autograft in 7	15 revisions (16.3%): 6.5% glenoid loosening, 5.5% posterior instability, 4.3% soft-tissue problems, including refractory capsulitis and traumatic subscapularis tear	No radiographic loosening in 66 shoulders (71.7%), possible loosening in 7 (7.6%), and definite radiographic loosening in 19 (20.6%); among 19 shoulders with radiographic loosening, migration of the glenoid component was detected in 11 and revision was performed in 6	15 revisions; 6 (6.5%) of 92 revised for glenoid loosening at 77 mo
Gerber[26]	5	Asymmetric glenoid reaming	NR	NR	NR
Klika[34]	12	Humeral-head autograft	2 revision total shoulder arthroplasties for aseptic glenoid loosening and pain (1 with bone-graft collapse); 6 shoulders had components shifted in position between early postop. and final radiographs	2 shoulders with no radiographic loosening; 20 shoulders with radiolucent lines,10 of which were deemed to be "at risk for clinical failure"	2 (16.6%) of 12 at 8.7 yr
Sabesan[27]	9	Humeral-head autograft	2 patients had broken screws at 1 yr with mild graft resorption; 1 patient at 9 yr required arthroscopic removal of broken screw (graft incorporated)	NR	0 of 9 at 53 mo
Steinmann[24]	28	Humeral-head autograft	2 had symptomatic glenoid loosening; 2 had reoperations for instability; 1 had persistent pain	13 shoulders with no lucencies, 11 with incomplete lucencies, and 4 with complete lucencies (3 of 4 lucencies at least 1.5 mm wide and considered radiographically loose but only 2 of 4 were symptomatic)	NR
Habermeyer[28]	24	Did not distinguish between B1 and B2 glenoids	NR	NR	NR
Rice[29]	14	Posteriorly augmented glenoid	NR	4 shoulders with no lucency, 7 with grade-1 lucency, 1 with grade-5 lucency (glenoid component had shifted in position)	0 of 14 at 5 yr
Wright[25]	20	Posteriorly augmented glenoid	NR	12 shoulders had a radiolucent line with mean radiographic line score of 1.10; 1 glenoid was radiographically but not clinically loose	NR
Totals	239			Of 201 B2s reporting on loosening, 117 (58.2%) had no loosening and 84 (41.8%) had some degree of loosening	5 studies with 164 glenoids reported on revision; 6.4% revised due to glenoid loosening at min. 5 yr

*NR = not reported.

63% of those with posterior erosion[31]. In a subsequent report[32] on 25 shoulders, 42% of concentric glenoids and 13% of nonconcentric glenoids had a satisfactory result. In our meta-analysis, when stratified by the technique of correcting a biconcave glenoid, we found that Neer ratings showed a large difference in outcomes, and Constant

TABLE III Asymmetric Reaming*

	No. of Patients with Reported Outcomes	Outcomes
Neer rating	92	
Very satisfied or satisfied		61 (66.3%)
Uncertain		15 (16.3%)
Disappointed		16 (17.4%)
Constant score *(points)*	90	Mean improved from 35.7 to 73.4
Complications	122	Soft-tissue problem (4.3%); glenoid loosening (7.6%), radiographic loosening (19 [15.6%]); migration of glenoid component (11 [9%], with 6 revised); posterior instability (4.1%); subscapularis failure (1.6%)
Radiolucent lines	92	No radiographic loosening in 66 shoulders (71.7%), possible loosening in 7 (7.6%), and definite radiographic loosening in 19 (20.7%)
Revisions	129	19 revisions (14.7%) at mean of 68.5 mo

*The results were based on the number of reported patients who had undergone asymmetric reaming. Not all studies utilizing the same outcome measures reported the same complications; therefore, the number of reported patients per outcome is different.

scores were similar. A discrepancy between subjective and score-based assessments has previously been reported in the literature, especially for older patients.

The most common technique to address retroversion is asymmetric reaming, in which the glenoid is reamed primarily anteriorly to restore version. It is widely accepted that anterior glenoid reaming beyond 15° risks glenoid vault penetration and may not correct posterior subluxation[16,17,30].

Chin et al.[1] reported on 37 B2 glenoids available for follow-up at a mean of 60 months. All patients treated had primary glenohumeral arthritis and underwent asymmetric reaming for correction of glenoid retroversion. The mean retroversion was 16°, with 75% posterior humeral-head subluxation. Although there were substantial differences between preoperative and postoperative data, no differences were observed between B1 and B2 glenoids. At 60 months, only 1 total shoulder

TABLE IV Humeral-Head Autograft

	No. of Patients with Reported Outcomes	Outcomes
Neer rating	40	
Excellent		21 (53%)
Satisfactory		12 (30%)
Unsatisfactory		7 (18%)
Scores *(points)*		
Constant	24	47.6 to 90 (B1 and B2 cohort as a whole, not stratified by glenoid type)
Penn	9	38.7 to 79.4
Complications	47	11 (23.4%): broken screws, 2 (4.3%); bone-graft resorption or collapse, 3 (6.4%); shift in glenoid position, 8 (17%); persistent pain, 1 (2.1%)
Radiolucent lines	38	No lucencies, 17 (44.7%), incomplete lucency, 13 (34.2%), complete lucency, 8 (21.1%)
Revisions	21	2 (9.5%): 0 at mean follow-up of 42 months

*The results were based on the number of reported patients who underwent humeral-lead autografting for glenoid version correction. Not all studies utilizing the same outcome measures reported the same complications; therefore, the number of reported patients per outcome is different.

TABLE V Posteriorly Augmented Glenoids

	No. of Patients with Reported Outcomes	Outcomes
Neer rating	14	
Excellent		5 (36%)
Satisfactory		7 (50%)
Unsatisfactory		2 (14%)
Scores *(points)*		
Constant	20	38.6 to 75.6
UCLA	20	15.2 to 32.1
SST	20	5 to 11
ASES	20	42.6 to 91.5
Complications	34	1 glenoid shift in position
Radiolucent lines	32	No lucency, 11 (34.4%); radiographic line score of 1.1, 12 (37.5%); lucency 1 mm wide and incomplete, 7; radiographically but not clinically loose†, 1; glenoid shift in position, 1
Revisions	34	0 at mean follow-up of 42 months

*The results were based on the number of reported patients with posterior augmented glenoid used for correction of version. Not all studies utilizing the same outcome measures reported the same complications; therefore, the number of reported patients per outcome is different. †Defined as radiographically loose if radiolucent line score is 12.

arthroplasty was revised for glenoid loosening.

Gerber et al.[26] reported on 23 total shoulder arthroplasties with a mean follow-up of 42 months in which asymmetric reaming was used to address glenoid retroversion and posterior humeral-head subluxation. Five patients had a B2 glenoid, and the remainder had either a B1 or C glenoid. Glenoid retroversion was measured on CT scans by the Friedman method[6], with a mean retroversion of 18°. Friedman et al. described a method of determining glenoid version by drawing a line between the tip of the medial border of the scapula and the center of the glenoid. A line drawn perpendicular to this at the glenoid is defined as neutral version. Asymmetric reaming was performed on B2 glenoids to correct version to a mean of 9°. The mean absolute Constant scores improved from 39 to 78 points, the age-adjusted Constant scores improved from 49 to 95 points, and the Subjective Shoulder Values improved from 40 to 89 points; all changes were significant. Two revision surgical procedures were reported, but the authors did not specify the glenoid morphology.

Walch et al.[33] retrospectively evaluated 92 total shoulder arthroplasties in shoulders with primary osteoarthritis and biconcave glenoids in 72 patients, the largest cohort in the literature. Eighty-five total shoulder arthroplasties had correction of glenoid version with asymmetric reaming, and the other 7 received posterior bone-grafting using a humeral-head autograft. At a mean follow-up of 77 months (range, 14 to 180 months), 15 revisions (16.3%) were performed for glenoid loosening, posterior instability, or soft-tissue problems, with a mean interval from the time of the surgical procedure of 96 months (range, 22 to 192 months). The study did not differentiate outcomes based on the specific technique used for managing biconcave glenoids.

Posterior bone-grafting was performed 7 times, 2 of which were successful; these results were worse than those in other reports[24,27,34]. At the time of the final follow-up of the 92 total shoulder arthroplasties, the Constant scores improved substantially from 32 to 69 points. Subjectively, 66% of patients were very satisfied or satisfied, 17% were disappointed, and 16% were uncertain. Walch et al.[33] recommended against posterior bone-grafting in this specific entity in light of their experience.

Another group of studies investigated results following bone-grafting for correcting glenoid retroversion and posterior subluxation in B2 glenoids[24,26,27,34,35]. Klika et al.[34] evaluated 12 total shoulder arthroplasties in their report, at a mean follow-up of 8.7 years. Glenoid retroversion was corrected utilizing a wedge-shaped autograft harvested from the humeral head and fixed with small screws. Their cohort had mixed etiologies in addition to mixed glenoid components, making definite conclusions difficult. Neer ratings were excellent in 8 and satisfactory in 2. Two had unsatisfactory results and were revised; both had aseptic glenoid loosening and pain, and 1 of the 2 demonstrated bone graft collapse.

Sabesan et al.[27] also reported on bone-grafting for posterior bone loss. The authors prepared the glenoid with a

step-cut and stated that it provided more stability than use of a wedge-shaped graft, especially with the posterior screw fixation. They evaluated 12 total shoulder arthroplasties with a mean follow-up of 53 months (range, 26 to 110 months). Eleven received a polyethylene anchor peg component with humeral-head autograft, and 1 received a keeled implant and autograft. Ten patients had a good or excellent clinical result based on Penn scores, and improvements in range of motion were noted. Two complications were noted in the B2 cohort consisting of 9 patients. Both patients had broken screws seen on radiographs, at 1 year and 9 years after the initial surgical procedure. Despite the small number of patients, the results demonstrated acceptable clinical outcomes. Issues with graft incorporation and resorption continue to be cited among studies with posterior bone-grafting.

Steinmann and Cofield[24] used autogenous humeral-head bone graft fixed with screws for correction of glenoid version for 28 shoulders with posterior bone loss and reported the results at a mean follow-up of 63 months. From these results, it is not clear what type of glenoid component is the best choice after placement of posterior glenoid bone graft as both cemented and uncemented components were used without a clear advantage. Despite these variables, range of motion improved in all planes, and 13 shoulders were rated as excellent, 10 shoulders were rated as satisfactory, and 5 shoulders were rated as unsatisfactory[24]. Neer and Morrison[35] reported on 19 patients who underwent anatomic total shoulder arthroplasty with glenoid bone-grafting. At a mean time of 52.5 months postoperatively, they reported 16 excellent results (84%) and 1 satisfactory result (5%) on the Neer rating system; 2 shoulders were in the limited-goals category (11%). Radiographs demonstrated no radiolucent lines in 13 cases and incomplete radiolucent lines that were <1 mm wide in 6 cases. The grafts were believed to have healed with no loosening or shifting in position of the glenoid prosthesis. Hill and Norris[36] presented data on 17 patients undergoing glenoid grafting. At a mean follow-up of 70 months, there were 3 excellent results (18%), 6 satisfactory results (35%), and 8 unsatisfactory results (47%). They described 4 failures within the first 2 years. Three of these 4 patients developed graft-related problems, which included nonunion, shift in component position, and resorption of the graft. Five patients required a revision surgical procedure for glenoid failure (29%). However, their cohort had a mean glenoid retroversion of 33° and they did not mention a glenoid morphology according to the Walch classification. These 2 studies[35,36] were not included in our analysis, but represent additional populations undergoing posterior bone-grafting and the inherent complications within this population.

In conclusion, these studies indicate that posterior subluxation can be corrected with glenoid bone-grafting, but the technique may be technically difficult and leads to inconsistent results.

Augmented glenoid components were designed as an alternative to asymmetric reaming and bone-grafting to compensate for posterior glenoid bone loss. The design of the augmentation can have a substantial effect on the forces transferred to the implant[22]. The development of a stepped, posteriorly augmented glenoid design places the component perpendicular to the vector of the joint forces and allows for improved biomechanical properties and less shear stress at the implant-bone interface. Posterior glenoid augmentation can improve glenoid version while preventing vault perforation, joint line medialization, and excess subchondral bone loss. Rice et al.[29] reviewed 14 shoulders treated with an asymmetric wedge-shaped posteriorly augmented glenoid component with a mean follow-up of 5 years. Functionally, 5 patients had excellent results, 7 had satisfactory results, and 2 had unsatisfactory results. The range of motion improved in all planes, with forward flexion improving from 90° to 160°, abduction improving from 90° to 160°, external rotation improving from 35° to 56°, and internal rotation improving from the sacrum to the L3 level. Rice et al. concluded that the contribution of the modified wedge-shaped glenoid component to intermediate-term pain relief was satisfactory; however, the overall correction of glenoid wear and posterior humeral instability was marginal, and use of this implant was discontinued[29]. Wright et al.[25] compared 20 shoulders with substantial posterior glenoid wear treated with a posteriorly augmented glenoid with 20 shoulders without posterior glenoid wear treated with a standard all-polyethylene, non-augmented pegged glenoid. Sixty percent of patients with a posteriorly augmented glenoid had a radiolucent line, compared with 33% of patients with a non-augmented pegged glenoid. Despite more radiolucent lines, outcome scores demonstrated comparable results with no statistical clinical differences. When considering non-augmented pegged glenoids and posteriorly augmented glenoids as 1 group, Constant scores improved from a preoperative mean of 38.6 to 75.6 points, UCLA shoulder scores improved from 15.2 to 32.1 points, SST scores improved from 5 to 11 points, and ASES scores improved from 42.6 to 91.5 points. Range of motion also improved in all planes; however, there were no differences in any postoperative clinical outcomes or differences in degree of improvement between the posteriorly augmented glenoid and non-augmented pegged glenoid groups. No revisions were reported at the time of the final follow-up at 29 months. As with other studies in the literature, caution must be exercised in making conclusions on revisions, radiolucencies, and complications of posteriorly augmented glenoids given the short-term follow-up.

The concerning failure rate of posterior bone-grafting and the inability to reliably correct posterior subluxation of the humeral head with an anatomic total shoulder arthroplasty led Mizuno

et al. to investigate the use of a primary reverse shoulder arthroplasty for a B2 glenoid[23]. They performed a retrospective review of 27 reverse shoulder arthroplasties implanted for primary glenohumeral arthritis in shoulders with a B2 glenoid at a mean of 54 months postoperatively. The mean Constant score increased from 31 to 76 points, and no recurrence of posterior instability was observed.

Lastly, this systematic review reports that anatomic total shoulder arthroplasty in the setting of the B2 glenoid can incur a high rate of complications and continues to be a complicated problem to solve. Asymmetric reaming is the least technically difficult method to correct glenoid version. However, attempting to correct >15° of glenoid retroversion carries the risk of vault penetration with the implant. Posterior bone-grafting has also shown satisfactory results in some studies, but is complicated by a more complex surgical technique and issues with bone-graft resorption and glenoid component migration. The relatively recent development of posteriorly augmented glenoids provides a promising solution; however, follow-up has been short term and it remains to be seen if the results will be durable. In elderly, lower-demand patients with posterior erosion, reverse shoulder arthroplasty may be a viable option to restore version and correct posterior subluxation given its constrained design. Longer follow-up, standardized outcome measures, and stratifying results based on glenoid type and surgical techniques will allow a more direct comparison between these techniques in the future.

Colten Luedke, DO[1],
Michael J. Kissenberth, MD[1],
Stefan J. Tolan, MD[2],
Richard J. Hawkins, MD[1],
John M. Tokish, MD[2]

[1]Steadman Hawkins Clinic of the Carolinas, Greenville Health Systems, Greenville, South Carolina

[2]Mayo Clinic, Phoenix, Arizona

E-mail address for J.M. Tokish: jtokish@ghs.org

ORCID iD for J.M. Tokish: 0000-0003-4557-4537

References

1. Chin PC, Hachadorian ME, Pulido PA, Munro ML, Meric G, Hoenecke HR Jr. Outcomes of anatomic shoulder arthroplasty in primary osteoarthritis in type B glenoids. J Shoulder Elbow Surg. 2015 Dec;24(12):1888-93. Epub 2015 Aug 4.

2. Day JS, Lau E, Ong KL, Williams GR, Ramsey ML, Kurtz SM. Prevalence and projections of total shoulder and elbow arthroplasty in the United States to 2015. J Shoulder Elbow Surg. 2010 Dec;19(8):1115-20. Epub 2010 Jun 15.

3. Hsu JE, Ricchetti ET, Huffman GR, Iannotti JP, Glaser DL. Addressing glenoid bone deficiency and asymmetric posterior erosion in shoulder arthroplasty. J Shoulder Elbow Surg. 2013 Sep;22(9):1298-308. Epub 2013 Jun 22.

4. Couteau B, Mansat P, Mansat M, Darmana R, Egan J. In vivo characterization of glenoid with use of computed tomography. J Shoulder Elbow Surg. 2001 Mar-Apr;10(2):116-22.

5. Cyprien JM, Vasey HM, Burdet A, Bonvin JC, Kritsikis N, Vuagnat P. Humeral retrotorsion and glenohumeral relationship in the normal shoulder and in recurrent anterior dislocation (scapulometry). Clin Orthop Relat Res. 1983 May;175:8-17.

6. Friedman RJ, Hawthorne KB, Genez BM. The use of computerized tomography in the measurement of glenoid version. J Bone Joint Surg Am. 1992 Aug;74(7):1032-7.

7. Scalise JJ, Codsi MJ, Bryan J, Iannotti JP. The three-dimensional glenoid vault model can estimate normal glenoid version in osteoarthritis. J Shoulder Elbow Surg. 2008 May-Jun;17(3):487-91. Epub 2008 Feb 20.

8. Walch G, Badet R, Boulahia A, Khoury A. Morphologic study of the glenoid in primary glenohumeral osteoarthritis. J Arthroplasty. 1999 Sep;14(6):756-60.

9. Knowles NK, Keener JD, Ferreira LM, Athwal GS. Quantification of the position, orientation, and surface area of bone loss in type B2 glenoids. J Shoulder Elbow Surg. 2015 Apr;24(4):503-10. Epub 2014 Oct 29.

10. Wirth MA, Rockwood CA Jr. Complications of total shoulder-replacement arthroplasty. J Bone Joint Surg Am. 1996 Apr;78(4):603-16.

11. Torchia ME, Cofield RH, Settergren CR. Total shoulder arthroplasty with the Neer prosthesis: long-term results. J Shoulder Elbow Surg. 1997 Nov-Dec;6(6):495-505.

12. Matsen FA 3rd, Clinton J, Lynch J, Bertelsen A, Richardson ML. Glenoid component failure in total shoulder arthroplasty. J Bone Joint Surg Am. 2008 Apr;90(4):885-96.

13. Cofield RH, Edgerton BC. Total shoulder arthroplasty: complications and revision surgery. Instr Course Lect. 1990;39:449-62.

14. Deshmukh AV, Koris M, Zurakowski D, Thornhill TS. Total shoulder arthroplasty: long-term survivorship, functional outcome, and quality of life. J Shoulder Elbow Surg. 2005 Sep-Oct;14(5):471-9.

15. Walch G, Boulahia A, Boileau P, Kempf JF; The Aequalis Group. Primary glenohumeral osteoarthritis: clinical and radiographic classification. Acta Orthop Belg. 1998;64(Suppl 2):46-52.

16. Gillespie R, Lyons R, Lazarus M. Eccentric reaming in total shoulder arthroplasty: a cadaveric study. Orthopedics. 2009 Jan;32(1):21.

17. Clavert P, Millett PJ, Warner JJ. Glenoid resurfacing: what are the limits to asymmetric reaming for posterior erosion? J Shoulder Elbow Surg. 2007 Nov-Dec;16(6):843-8.

18. Nowak DD, Bahu MJ, Gardner TR, Dyrszka MD, Levine WN, Bigliani LU, Ahmad CS. 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 Sep-Oct;18(5):680-8. Epub 2009 May 31.

19. Neyton L, Walch G, Nové-Josserand L, Edwards TB. Glenoid corticocancellous bone grafting after glenoid component removal in the treatment of glenoid loosening. J Shoulder Elbow Surg. 2006 Mar-Apr;15(2):173-9.

20. Iannotti JP, Frangiamore SJ. Fate of large structural allograft for treatment of severe uncontained glenoid bone deficiency. J Shoulder Elbow Surg. 2012 Jun;21(6):765-71. Epub 2012 Feb 3.

21. Scalise JJ, Iannotti JP. Bone grafting severe glenoid defects in revision shoulder arthroplasty. Clin Orthop Relat Res. 2008 Jan;466(1):139-45. Epub 2008 Jan 3.

22. Stephens SP, Paisley KC, Jeng J, Dutta AK, Wirth MA. Shoulder arthroplasty in the presence of posterior glenoid bone loss. J Bone Joint Surg Am. 2015 Feb 4;97(3):251-9.

23. 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 Jul 17;95(14):1297-304.

24. Steinmann SP, Cofield RH. Bone grafting for glenoid deficiency in total shoulder replacement. J Shoulder Elbow Surg. 2000 Sep-Oct;9(5):361-7.

25. Wright TW, Grey SG, Roche CP, Wright L, Flurin PH, Zuckerman JD. Preliminary results of a posterior augmented glenoid compared to an all polyethylene standard glenoid in anatomic total shoulder arthroplasty. Bull Hosp Jt Dis (2013). 2015 Dec;73(Suppl 1):S79-85.

26. Gerber C, Costouros JG, Sukthankar A, Fucentese SF. Static posterior humeral head subluxation and total shoulder arthroplasty. J Shoulder Elbow Surg. 2009 Jul-Aug;18(4):505-10. Epub 2009 May 29.

27. 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 Jul 17;95(14):1290-6.

28. Habermeyer P, Magosch P, Lichtenberg S. Recentering the humeral head for glenoid deficiency in total shoulder arthroplasty. Clin Orthop Relat Res. 2007 Apr;457:124-32.

29. Rice RS, Sperling JW, Miletti J, Schleck C, Cofield RH. Augmented glenoid component for bone deficiency in shoulder arthroplasty. Clin Orthop Relat Res. 2008 Mar;466(3):579-83. Epub 2008 Jan 8.

30. Denard PJ, Walch G. Current concepts in the surgical management of primary glenohumeral arthritis with a biconcave glenoid. J Shoulder Elbow Surg. 2013 Nov;22(11):1589-98. Epub 2013 Sep 3.

31. Levine WN, Djurasovic M, Glasson JM, Pollock RG, Flatow EL, Bigliani LU. Hemiarthroplasty for glenohumeral osteoarthritis: results correlated to degree of glenoid wear. J Shoulder Elbow Surg. 1997 Sep-Oct;6(5):449-54.

32. Levine WN, Fischer CR, Nguyen D, Flatow EL, Ahmad CS, Bigliani LU. Long-term follow-up of shoulder hemiarthroplasty for glenohumeral osteoarthritis. J Bone Joint Surg Am. 2012 Nov 21;94(22):e164.

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 Nov;21(11): 1526-33. Epub 2012 Mar 23.

34. Klika BJ, Wooten CW, Sperling JW, Steinmann SP, Schleck CD, Harmsen WS, Cofield RH. Structural bone grafting for glenoid deficiency in primary total shoulder arthroplasty. J Shoulder Elbow Surg. 2014 Jul;23(7):1066-72. Epub 2013 Dec 14.

35. Neer CS 2nd, Morrison DS. Glenoid bone-grafting in total shoulder arthroplasty. J Bone Joint Surg Am. 1988 Sep;70(8): 1154-62.

36. Hill JM, Norris T. Long-term results of total shoulder arthroplasty following bone-grafting of the glenoid. J Bone Joint Surg Am. 2001 Jun; 83(6):877-83.