

Anatomic Total Shoulder Arthroplasty with All-Polyethylene Glenoid Component for Primary Osteoarthritis with Glenoid Deficiencies

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Background: This study evaluated the ability of shoulder arthroplasty using a standard glenoid component to improve patient self-assessed comfort and function and to correct preoperative humeral-head decentering on the face of the glenoid in patients with primary glenohumeral arthritis and type-B2 or B3 glenoids.

Methods: We identified 66 shoulders with type-B2 glenoids ($n = 40$) or type-B3 glenoids ($n = 26$) undergoing total shoulder arthroplasties with a non-augmented glenoid component inserted without attempting to normalize glenoid version and with clinical and radiographic follow-up that was a minimum of 2 years. The Simple Shoulder Test (SST), the percentage of humeral-head decentering on the glenoid face, and bone ingrowth into the central peg were the main outcome variables of interest. Similar analyses were made for concurrent patients with type-A1, A2, B1, and D glenoid pathoanatomy to determine if the outcomes for type-B2 and B3 glenoids were inferior to those for the other types.

Results: The SST score (and standard deviation) improved from 3.2 ± 2.1 points preoperatively to 9.9 ± 2.4 points postoperatively ($p < 0.001$) at a mean time of 2.8 ± 1.2 years for type-B2 glenoids and from 3.0 ± 2.5 points preoperatively to 9.4 ± 2.1 points postoperatively ($p < 0.001$) at a mean time of 2.9 ± 1.5 years for type-B3 glenoids; these results were not inferior to those for shoulders with other glenoid types. Postoperative glenoid version was not significantly different ($p > 0.05$) from preoperative glenoid version. The mean humeral-head decentering on the glenoid face was reduced for type-B2 glenoids from $-14\% \pm 7\%$ preoperatively to $-1\% \pm 2\%$ postoperatively ($p < 0.001$) and for type-B3 glenoids from $-4\% \pm 6\%$ preoperatively to $-1\% \pm 3\%$ postoperatively ($p = 0.027$). The rates of bone integration into the central peg for type-B2 glenoids (83%) and type-B3 glenoids (81%) were not inferior to those for other glenoid types.

Conclusions: Shoulder arthroplasty with a standard glenoid inserted without changing version can significantly improve patient comfort and function and consistently center the humeral head on the glenoid face in shoulders with type-B2 and B3 glenoids, achieving $>80\%$ osseous integration into the central peg. These clinical and radiographic outcomes for type-B2 and B3 glenoids were not inferior to those outcomes for other glenoid types.

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

There is interest in the management of arthritic shoulders with glenoid retroversion, especially for Walch types B2 and B3^{1,2}. Surgeons have addressed glenoid retroversion with asymmetric reaming of the anterior glenoid bone³⁻¹⁴, posterior bone-grafting¹⁵⁻¹⁹, posteriorly augmented glenoid components²⁰⁻³¹, reverse total shoulder arthroplasty³²⁻³⁶, and the ream-and-run procedure³⁷⁻⁴¹. Although some research indicates a higher rate of glenoid osteolysis when standard components are inserted in retroversion¹⁰, other studies have not

shown inferior outcomes for glenoid components inserted in retroversion of $\geq 15^\circ$ ⁴².

To our knowledge, there has not been a detailed study of the outcomes of the treatment of type-B2 and B3 glenoids using a standard glenoid component inserted with conservative glenoid reaming without attempting to normalize glenoid version. Thus, the objective of the current study was to evaluate the minimum 2-year clinical and radiographic results of standard, non-augmented glenoid components inserted without

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Fig. 1
Type-B2 glenoid. The humeral head is eccentrically posteriorly decentered on the surface of a posteriorly eroded, biconcave glenoid. As defined earlier, type B2 is a shoulder in which the humeral head is eccentrically posteriorly decentered on the surface of a posteriorly eroded biconcave glenoid. We classified this as a type-B2 glenoid because the humeral head was posteriorly decentered in a pathologic concavity. It cannot be a type-A1, A2, or B3 glenoid, because the head is not centered on the glenoid face. It cannot be a type-B1 glenoid because the posterior glenoid is eroded.

substantially changing glenoid version in patients with primary osteoarthritis. Our hypothesis was that the outcomes for shoulders with type-B2 or B3 glenoid morphology treated in this way would not be inferior to those for shoulders with other types of glenohumeral pathoanatomy.

Materials and Methods

Patient Population

From our longitudinally maintained shoulder arthroplasty database, we identified 305 patients meeting the criteria of undergoing a total shoulder arthroplasty for primary glenohumeral osteoarthritis with an intact rotator cuff using a standard, non-augmented, all-polyethylene glenoid component (GLOBAL Anchor Peg; DePuy Synthes) and a standard-length, impaction-grafted humeral stem (GLOBAL ADVANTAGE; DePuy Synthes) performed by an individual surgeon (F.A.M.) between August 24, 2010, and September 18, 2017. Our analysis of these patients was approved by the institutional review board of the University of Washington (#STUDY00007300). For patients undergoing bilateral shoulder arthroplasties, only the first shoulder arthroplasty was entered into the database. Of

these, 272 patients (89%) met the inclusion criterion of a minimum 2-year clinical follow-up using the Simple Shoulder Test (SST); 141 patients (52%) were female; the mean age (and standard deviation) was 69 ± 9 years; and the mean clinical follow-up was 3.2 ± 0.9 years. During the period of this study, no patients were treated by this surgeon with posterior bone-grafting or posteriorly augmented glenoid components.

The preoperative glenohumeral pathoanatomy was assessed on standardized radiographs for all patients⁴¹⁻⁴⁵. The high degree of reproducibility of measurements made on axillary radiographs and their sensitivity to changes after shoulder arthroplasty have been previously demonstrated⁴³. Using a standardized preoperative axillary view, shoulders were categorized into types using the modified Walch classification described in the computed tomography (CT)-based studies of Iannotti et al.², Bercik et al.¹, and Chan et al.⁴⁶. In type A1, the humeral head was concentrically centered on a uniconcave glenoid surface without medial erosion; in type A2, the humeral head was concentrically centered on a uniconcave glenoid surface in $<15^\circ$ of retroversion with medial erosion so that a line connecting the anterior and posterior glenoid edges transected the humeral head; in type B1, the humeral head was eccentrically posteriorly decentered on the surface of a non-eroded glenoid; in type B2, the humeral head was eccentrically



Fig. 2
Type-B3 glenoid. The humeral head is concentrically centered on the uniconcave face of a glenoid with a high degree of glenoid retroversion. As defined earlier, type B3 is a shoulder in which the humeral head is concentrically centered on the uniconcave face of a glenoid with a high degree of glenoid retroversion. This shoulder meets that definition. It cannot be a type-A1 or A2 glenoid because of the high degree of retroversion. It cannot be a type-B1 or B2 glenoid because the humeral head is not decentered on the glenoid.

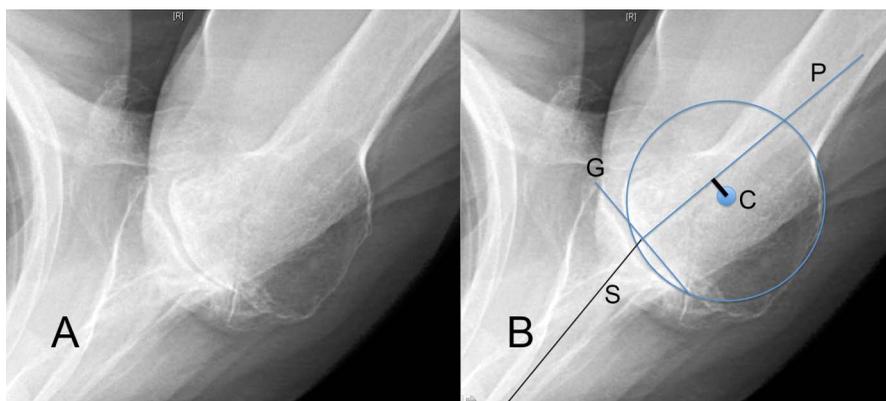


Fig. 3

Fig. 3-A Preoperative axillary view showing the humeral head posteriorly decentered on the face of a biconcave type-B2 glenoid. **Fig. 3-B** Glenoid version is measured as 90° minus the angle between the plane of the scapula (S) and a line drawn through the anterior and posterior edges of the glenoid (G). The percentage of humeral decentering is measured as the distance (heavy black line) between the center of a circle fitted to the humeral head (C) and the perpendicular bisector of the line segment connecting the anterior and posterior edges of the glenoid (P) divided by the diameter of the circle.

posteriorly decentered on the surface of a posteriorly eroded biconcave glenoid (Fig. 1); in type B3, the humeral head was concentrically centered on the unicongave face of a glenoid with a high degree of retroversion (Fig. 2); and in type D, the humeral head was anteriorly decentered on an anteverted glenoid. There were no dysplastic type-C glenoids in this series of total shoulder arthroplasties.

Glenoid version was measured by the angle between a line connecting the anterior and posterior edges of the glenoid and the plane of the scapular body; retroversion was given a negative sign (Fig. 3). Decentering of the humeral head on the glenoid was measured as the percentage of displacement of the humeral-head center with respect to the perpendicular bisector of a line segment connecting the anterior and posterior edges of the glenoid divided by the diameter of the humeral head; posterior decentering was given a negative sign (Fig. 3)^{37,42}. This method is analogous to those used by Ho et al.²³, Iannotti et al.², and Ricchetti et al.⁴⁷, except that our measurements were made on standardized preoperative axillary views (rather than on CT

scans) so that they could be directly compared with the same measurements made on standardized postoperative axillary views (Fig. 4). This avoids the issue identified by Ho et al.²³ of comparing measurements made on preoperative CT scans with measurements made on postoperative axillary radiographs.

Surgical Technique

The total shoulder arthroplasties were performed under general anesthesia without an interscalene block (see Appendix for further details). A deltopectoral approach with a subscapularis peel was used in all patients. The biceps tendon was preserved unless it was frayed or unstable. After any residual cartilage had been removed with a curet, a hole was drilled in the center of the glenoid face, and the short nub on the reamer was inserted into the hole as described by Service et al.⁴². The reamer was oriented so that reaming yielded a smooth concave surface with a 60-mm diameter of curvature (to match the back of the glenoid component) with the removal of the smallest possible amount of bone, without a specific attempt to normalize

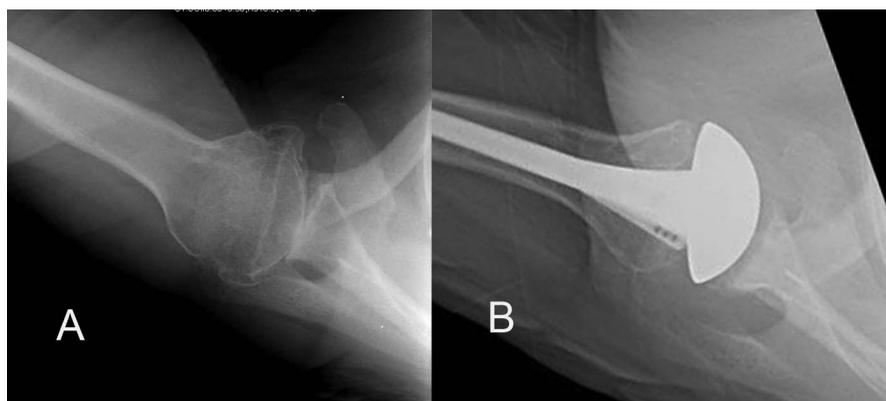


Fig. 4

Preoperative (**Fig. 4-A**) and postoperative (**Fig. 4-B**) standardized axillary views of a shoulder with preoperative posterior decentering of the humeral head on the face of a type-B2 glenoid and postoperative centering of the humeral-head prosthesis on the glenoid component.

TABLE 1 Clinical and Radiographic Characteristics of Patients with Different Glenoid Types*

| Characteristics | Glenoid Type | | | | | |
|--|---------------------|---------------------|---------------------|---------------------|----------------------|---------------------|
| | A1 | A2 | B1 | B2 | B3 | D |
| Clinical follow-up (n = 272) | | | | | | |
| No. of shoulders with clinical follow-up† | 12 (4%) | 97 (36%) | 23 (8%) | 83 (31%) | 52 (19%) | 5 (2%) |
| Age‡ (yr) | 65 ± 8 (54 to 82) | 69 ± 8 (40 to 90) | 67 ± 9 (50 to 82) | 68 ± 9 (42 to 86) | 72 ± 8 (55 to 87) | 69 ± 7 (59 to 76) |
| Follow-up‡ (yr) | 4.8 ± 2.5 (2 to 8) | 3.8 ± 2 (2 to 8) | 2.4 ± 0.8 (2 to 5) | 2.1 ± 0.2 (2 to 3) | 3.9 ± 2.0 (2 to 8) | 2.0 ± 0.4 (2 to 3) |
| Male sex† | 6 (50%) | 36 (37%) | 13 (57%) | 45 (54%) | 31 (60%) | 0 (0%) |
| BMI‡ (kg/m ²) | 32 ± 8 (22 to 51) | 31 ± 7 (20 to 55) | 32 ± 8 (22 to 55) | 30 ± 6 (19 to 49) | 29 ± 5 (22 to 45) | 24 ± 3 (20 to 29) |
| ASA class‡ | 2.4 ± 0.7 (1 to 3) | 2.4 ± 0.6 (1 to 4) | 2.4 ± 0.7 (1 to 4) | 2.2 ± 0.6 (1 to 3) | 2.4 ± 0.6 (1 to 4) | 2.2 ± 0.4 (1 to 4) |
| Work-related problem† | 2 (17%) | 2 (2%) | 2 (9%) | 7 (8%) | 3 (6%) | 0 (0%) |
| Diabetes using insulin† | 0 (0%) | 5 (5%) | 0 (0%) | 2 (2%) | 1 (2%) | 0 (0%) |
| Depression† | 6 (50%) | 18 (19%) | 4 (17%) | 25 (30%) | 7 (13%) | 1 (20%) |
| Prior surgery on shoulder† | 3 (25%) | 10 (10%) | 4 (17%) | 9 (11%) | 9 (17%) | 0 (0%) |
| Preop. measurements for all shoulders | | | | | | |
| Glenoid version‡ (deg) | -8 ± 7 (-20 to 0) | -10 ± 5 (-23 to +4) | -15 ± 8 (-30 to 0) | -21 ± 7 (-36 to -2) | -26 ± 7 (-42 to -16) | 7 ± 2 (6 to 10) |
| Decentering‡ (%) | 1 ± 4 (-7 to +10) | 1 ± 5 (-14 to +13) | -12 ± 5 (-23 to -6) | -14 ± 7 (-42 to 0) | -3 ± 5 (-17 to 3) | 5 ± 8 (0 to 18) |
| Surgical variables | | | | | | |
| Glenoid size§ (mm) | 48 (44 to 56) | 48 (40 to 56) | 48 (40 to 56) | 48 (40 to 56) | 52 (44 to 56) | 48 (44 to 52) |
| Anteriorly eccentric humeral head† | 0 (0%) | 2 (2%) | 1 (4%) | 10 (12%) | 6 (12%) | 0 (0%) |
| Biceps tenodesis† | 3 (25%) | 0 (0%) | 2 (9%) | 7 (8%) | 2 (4%) | 0 (0%) |
| Rotator interval plication† | 0 (0%) | 0 (0%) | 2 (9%) | 0 (0%) | 3 (6%) | 1 (20%) |
| Clinical outcomes | | | | | | |
| Preop. SST‡ (points) | 3.3 ± 2.4 (0 to 6) | 3.3 ± 2.4 (0 to 9) | 3.5 ± 2.9 (0 to 9) | 3.0 ± 2.1 (0 to 8) | 3.0 ± 2.4 (0 to 10) | 3.2 ± 1.9 (1 to 6) |
| Postop. SST‡ (points) | 8.3 ± 2.3 (4 to 12) | 9.6 ± 2.3 (2 to 12) | 9.0 ± 3.1 (0 to 12) | 9.8 ± 2.1 (1 to 12) | 9.8 ± 2.1 (5 to 12) | 9.4 ± 1.5 (9 to 12) |
| P value for change from preop. | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | 0.01 |
| Maximal possible improvement | 58% | 73% | 65% | 76% | 75% | 70% |
| Preop. SANE‡ (points) | 35 ± 24 | 35 ± 22 | 39 ± 19 | 40 ± 19 | 38 ± 23 | 49 ± 25 |
| Postop. SANE‡ (points) | 79 ± 15 | 90 ± 10 | 81 ± 22 | 85 ± 15 | 86 ± 13 | 89 ± 5 |
| P value for change from preop. | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | 0.03 |
| Preop. SF-36 PCS‡ (points) | 32 ± 22 | 33 ± 19 | 40 ± 21 | 39 ± 21 | 29 ± 20 | 32 ± 24 |
| Postop. SF-36 PCS‡ (points) | 61 ± 27 | 55 ± 25 | 50 ± 30 | 59 ± 27 | 56 ± 30 | 49 ± 29 |
| P value for change from preop. | 0.005 | <0.001 | 0.004 | <0.001 | <0.001 | 0.43 |
| Preop. SF-36 MCS‡ (points) | 74 ± 25 | 80 ± 19 | 73 ± 24 | 81 ± 21 | 84 ± 18 | 61 ± 40 |
| Postop. SF-36 MCS‡ (points) | 71 ± 18 | 72 ± 18 | 74 ± 28 | 80 ± 20 | 81 ± 18 | 94 ± 5 |
| P value for change from preop. | 0.19 | 0.33 | 0.87 | 0.64 | 0.72 | 0.63 |
| Surgical revisions† | 2 (17%) | 2 (2%) | 1 (4%) | 0 (0%) | 0 (0%) | 0 (0%) |
| Manipulations† | 0 (0%) | 1 (1%) | 0 (0%) | 2 (2%) | 2 (4%) | 0 (0%) |
| Patients with radiographic follow-up (n = 143) | | | | | | |
| No. of shoulders with radiographic follow-up† | 6 (4%) | 48 (34%) | 19 (13%) | 40 (28%) | 26 (18%) | 4 (3%) |

continued

TABLE 1 (continued)

| Characteristics | Glenoid Type | | | | | |
|--|------------------------|------------------------|----------------------|----------------------|----------------------|----------------------|
| | A1 | A2 | B1 | B2 | B3 | D |
| Shoulders of each type with radiographic follow-up | 50% | 49% | 82% | 48% | 50% | 80% |
| Age† (yr) | 63 ± 5 (54 to 71) | 69 ± 8 (40 to 82) | 67 ± 9 (50 to 81) | 67 ± 10 (49 to 86) | 71 ± 8 (55 to 86) | 67 ± 7 (59 to 76) |
| Follow-up‡ (yr) | 2.9 ± 1.6 (1.9 to 6.3) | 2.7 ± 0.9 (1.9 to 6.1) | 2.9 ± 0.7 (2 to 4.3) | 2.8 ± 1.2 (2 to 7.6) | 2.9 ± 1.5 (2 to 8.5) | 2.4 ± 0.7 (2 to 3.5) |
| Male sex† | 2 (33%) | 18 (38%) | 12 (63%) | 19 (48%) | 16 (62%) | 0 (0%) |
| Preop. SST‡ (points) | 3.8 ± 2.5 (1 to 6) | 3.4 ± 2.2 (0 to 9) | 3.8 ± 2.9 (0 to 9) | 3.2 ± 2.1 (0 to 8) | 3.0 ± 2.5 (0 to 10) | 3.3 ± 2.2 (1 to 6) |
| Postop. SST‡ (points) | 8.7 ± 2.3 (5 to 12) | 9.3 ± 2.2 (4 to 12) | 9.0 ± 3.3 (0 to 12) | 9.9 ± 2.4 (1 to 12) | 9.4 ± 2.1 (6 to 12) | 9.8 ± 1.5 (9 to 12) |
| P value for change from preop. | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Preop. measurements for shoulders with radiographic follow-up | | | | | | |
| Glenoid version‡ (deg) | -9 ± 7 (-20 to 0) | -10 ± 4 (-12 to 0) | -15 ± 8 (-30 to -2) | -21 ± 8 (-36 to -2) | -26 ± 7 (-42 to -16) | 8 ± 2 (6 to 10) |
| Decentering‡ (%) | 1 ± 5 (-7 to +10) | 1 ± 4 (-14 to +10) | -12 ± 5 (-23 to -6) | -14 ± 7 (-42 to 0) | -4 ± 6 (-17 to +8) | 5 ± 9 (0 to 18) |
| Postop. measurements | | | | | | |
| Glenoid version‡ (deg) | -8 ± 5 (-10 to 0) | -10 ± 4 (-20 to 0) | -14 ± 4 (-24 to -5) | -19 ± 8 (-35 to +8) | -23 ± 7 (-38 to -10) | 5 ± 1 (4 to 6) |
| P value for change from preop. | 0.782 | 1.000 | 0.629 | 0.267 | 0.129 | 0.036 |
| Decentering‡ (%) | 0 ± 0 (0 to 0) | 0 ± 1 (0 to 4) | -1 ± 5 (-13 to 13) | -1 ± 2 (-7 to 0) | -1 ± 3 (-9 to 0) | 1 ± 3 (0 to 6) |
| P value for change from preop. | 0.635 | 0.096 | <0.001 | <0.001 | 0.0269 | 0.431 |
| Center peg grading‡ | | | | | | |
| Grade 1: osteolysis | 1 (17%) | 0 (0%) | 0 (0%) | 1 (3%) | 1 (4%) | 1 (25%) |
| Grade 2: bone growth to edge of flanges | 1 (17%) | 7 (15%) | 5 (26%) | 6 (15%) | 4 (15%) | 0 (0%) |
| Grade 3: bone growth within flanges | 4 (67%) | 41 (85%) | 14 (74%) | 33 (83%) | 21 (81%) | 3 (75%) |
| *BMI = body mass index, ASA = American Society of Anesthesiologists, SANE = Single Assessment Numerical Evaluation, SF-36 PCS = Short Form-36 Physical Component Summary score, and SF-36 MCS = SF-36 Mental Component Summary score. †The values are given as the number of patients, with the percentage in parentheses. ‡The values are given as the mean and the standard deviation, with or without the range in parentheses. §The values are given as the median, with the range in parentheses. | | | | | | |

glenoid version. For type-B2 glenoids, the crest between the paleoglenoid⁴⁸ and the neoglenoid was removed with a burr; the glenoid reamer was then oriented equidistant from the anterior and posterior edges of the glenoid. In cases in which there was a large amount of glenoid retroversion, access for reaming was accomplished by a complete resection of osteophytes, careful retraction of the proximal part of the humerus, and positioning of the arm. The all-polyethylene glenoid component used in each case had 3 peripheral cemented pegs and a central fluted peg inserted with cancellous autograft without cement⁴⁹. The component size was selected so that the available glenoid bone was covered. Holes for the central and peripheral pegs were drilled; the holes for the peripheral pegs were sequentially pressurized with cement after drying them with a sterile CO₂ spray (CarboJet; Kinamed). A standard-length, smooth-stemmed humeral component (GLOBAL ADVANTAGE) was inserted in 30° of retroversion with impaction autografting⁵⁰. Centering of the humeral head on the glenoid was achieved by selective anterior soft-tissue releases

and tensioning of the posterior capsule by selecting a humeral-head component thickness that allowed no more than 50% posterior translation and no more than 60° of internal rotation of the abducted arm. Ten (12%) of the shoulders with type-B2 glenoids and 6 (12%) of the shoulders with type-B3 glenoids had anteriorly eccentric humeral-head components used to manage excessive posterior translation identified intraoperatively³⁷. No shoulder required a posterior capsulorrhaphy. The subscapularis peel was repaired to the lesser tuberosity with 6 #2 nonabsorbable braided polyester sutures. All patients started passive range-of-motion exercises on the day of the surgical procedure and began gentle strengthening exercises with the 2-hand press at 6 weeks after the surgical procedure.

Outcome Variables

The principal clinical outcome variable was the final SST score in relation to the preoperative score. The principal radiographic outcome variables were the degree of humeral-head

TABLE II Comparison of the Characteristics of Patients with and without 2-Year Radiographic Follow-up

| | With 2-Year Follow-up | Without 2-Year Follow-up | P Value |
|-----------------------------------|-----------------------|--------------------------|---------|
| No. of patients | 143 | 129 | |
| Age* (yr) | 68.3 ± 8.1 | 69.8 ± 9 | 0.149† |
| Sex‡ | | | 0.715§ |
| Male | 67 (47%) | 64 (50%) | |
| Female | 76 (53%) | 65 (50%) | |
| Glenoid type‡ | | | 0.275§ |
| B2 and B3 | 66 (46%) | 69 (53%) | |
| A1 | 6 (4%) | 6 (5%) | |
| A2 | 48 (34%) | 49 (38%) | |
| B1 | 19 (13%) | 4 (3%) | |
| B2 | 40 (28%) | 43 (33%) | |
| B3 | 26 (18%) | 26 (20%) | |
| D | 4 (3%) | 1 (1%) | |
| Preoperative SST* | 3.2 ± 2.3 | 2.9 ± 2.4 | 0.294† |
| Postoperative SST* | 9.4 ± 2.4 | 9.78 ± 2.2 | 0.176† |
| Retroversion* | -16 ± 10 | -15 ± 8 | 0.367† |
| Percentage posterior decentering* | -6.2% ± 8 | -4.8% ± 8 | 0.151† |

*The values are given as the mean and the standard deviation. †Unpaired t test. ‡The values are given as the number of patients, with the percentage in parentheses. §Fisher exact test.

decentering on the glenoid and the degree of osseous integration into the center peg. Two-year clinical follow-up was available for 272 patients; the mean clinical follow-up for these patients was 4.0 ± 2.2 years (Table I). Of these 272 patients, 143 (53%) were able to return to the office for 2-year standardized

postoperative radiographs; the mean radiographic follow-up for these patients was 2.8 ± 1.1 years. Standardized axillary views could not be reliably obtained on patients who could not return for their 2-year follow-up. The preoperative patient and shoulder characteristics for the 143 patients with 2-year

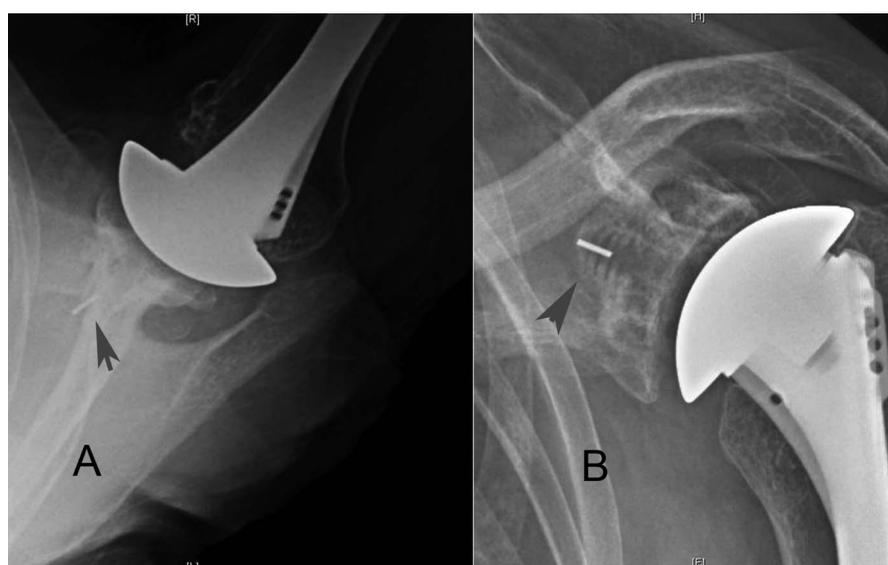


Fig. 5
Postoperative views at 3.5 years after a total shoulder arthroplasty with a standard glenoid component for a type-B3 glenoid. **Fig. 5-A** Axillary view showing anterior penetration of the central peg (arrow). **Fig. 5-B** Grashey view showing secure fixation of the component with osseous ingrowth between the flanges of the central peg (arrowhead).

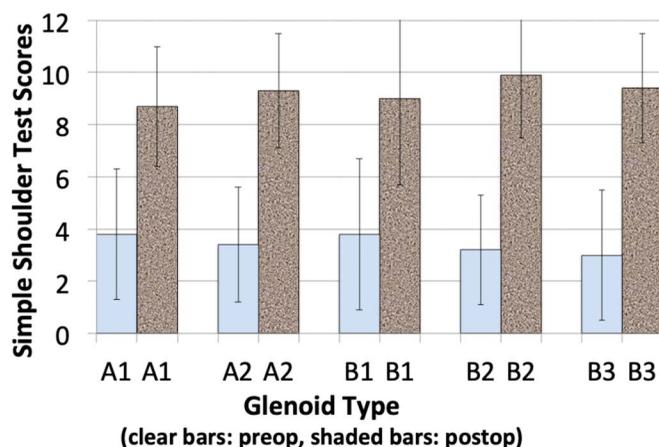


Fig. 6

Fig. 6 The mean SST scores before (light blue bars) and after (brown bars) total shoulder arthroplasty with a standard glenoid component for the different glenoid types. In all cases, the improvement was significant ($p < 0.001$). The error bars represent the standard deviations. These data are for the 143 cases with a minimum 2-year radiographic follow-up. **Fig. 7** The mean glenoid version before (light blue bars) and after (brown bars) total shoulder arthroplasty with a standard glenoid component for the different glenoid types. A negative sign indicates retroversion. In all cases, the change was not significant. The error bars represent the standard deviations. These data are for the 143 cases with a minimum 2-year radiographic follow-up.

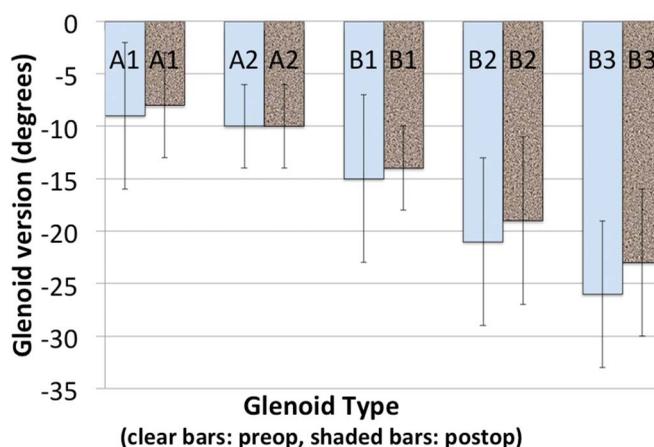


Fig. 7

radiographic follow-up were essentially the same as those for all 272 patients with 2-year clinical follow-up (Table I) and were not different from those for patients without 2-year radiographic follow-up (Table II). The degree of center-peg osseous integration was assessed on the postoperative Grashey view: grade 1 (osteolysis), grade 2 (bone growth to the edge of the flanges), or grade 3 (osseous ingrowth between the flanges) (Fig. 5)^{2,23,42,47,49,51}.

Statistical Analysis

The preoperative and postoperative characteristics of shoulders with each of the glenoid types (A1, A2, B1, B2, B3, D) were characterized as the mean, standard deviation, and range. Significance was set at $p < 0.05$. The paired t test was used to compare preoperative and postoperative values for the SST, glenoid version, and the percentage of humeral-head decentering on the face of the glenoid for each glenoid type.

Results

The clinical results for all patients are shown in Table I. Considering only the patients with a 2-year minimum radiographic follow-up, the mean SST score improved from 3.2 ± 2.1 points preoperatively to 9.9 ± 2.4 points postoperatively ($p < 0.001$) at a mean time of 2.8 ± 1.2 years for the type-B2 glenoids and from 3.0 ± 2.5 points preoperatively to 9.4 ± 2.1 points postoperatively ($p < 0.001$) at a mean time of 2.9 ± 1.5 years for the type-B3 glenoids; these results were not inferior to those for shoulders with other types (Fig. 6). For the B2 and B3 glenoid types, the mean retroversion was a few degrees less after surgical procedures compared with the preoperative values, but these changes were not significant; the mean retroversion was $-21^\circ \pm 8^\circ$ preoperatively and $-19^\circ \pm 8^\circ$ postoperatively ($p = 0.267$) for the type-B2 glenoids and $-26^\circ \pm 7^\circ$ preoperatively and $-23^\circ \pm 7^\circ$ postoperatively ($p = 0.129$) for the type-

B3 glenoids (Fig. 7). The mean preoperative to postoperative changes in the percentage of humeral-head decentering on the glenoid were significant for the type-B2 glenoids, from $-14\% \pm 7\%$ preoperatively to $-1\% \pm 2\%$ postoperatively ($p < 0.001$), and for the type-B3 glenoids, from $-4\% \pm 6\%$ preoperatively to $-1\% \pm 3\%$ postoperatively ($p = 0.027$) (Fig. 8).

The rates of bone integration into the central peg for type-B2 and B3 glenoids were not inferior to those for other glenoid types: 67% for A1, 85% for A2, 74% for B1, 83% for B2, 81% for B3, and 75% for type D. Comparing the rate of

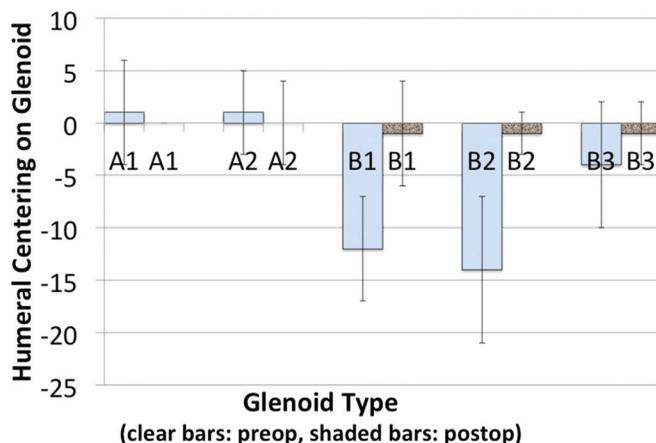


Fig. 8

The mean humeral-head decentering on the face of the glenoid face before (light blue bars) and after (brown bars) total shoulder arthroplasty with a standard glenoid component for the different glenoid types. A negative sign indicates posterior decentering. The change was significant for glenoid types B1 ($p < 0.001$), B2 ($p < 0.001$), and B3 ($p = 0.027$). The error bars represent the standard deviations. These data are for the 143 cases with a minimum 2-year radiographic follow-up.

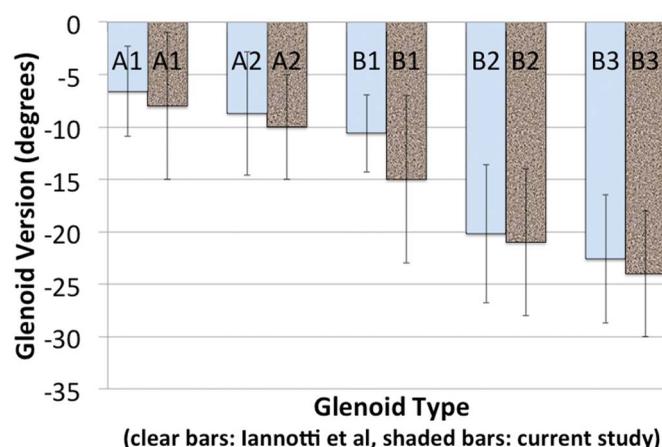


Fig. 9
The mean preoperative glenoid version for the different glenoid types measured on standardized axillary views in the current study (brown bars) and for the measurements made on 3-dimensional reconstructions of CT scans (light blue bars) in the study by Iannotti et al.². Retroversion is indicated by a negative sign. The error bars represent the standard deviations.

bone integration for type-A2 glenoids (85%) with those for type-B2 glenoids (83%; $p = 0.775$) and type-B3 glenoids (81%; $p = 0.743$), the differences were not significant by the Fisher exact test. There were no dislocations and no open revisions. One patient with a type-A2 glenoid, 2 patients with type-B2 glenoids, and 2 patients with type-B3 glenoids had manipulations within the first 3 months after the surgical procedure for refractory shoulder stiffness (Table I).

Anterior penetration of the glenoid neck by the central peg of the glenoid was observed in 2 (11%) of 19 of the type-B1 glenoids, in 6 (15%) of 40 of the type-B2 glenoids, and in 6 (23%) of 26 of the type-B3 glenoids (Fig. 5). Twelve of the 14 shoulders with glenoid neck penetration had ingrowth of bone between the flanges of the central peg with no radiographic evidence of component loosening. The final mean SST score for the 14 shoulders with central peg penetration was 9.4 ± 2.3 points, a value not significantly different ($p = 0.649$) from that for all of the type-B2 and B3 glenoids (9.7 ± 2.2 points).

Discussion

Although surgeons have used other approaches, such as anterior eccentric reaming, posterior bone-grafting, posteriorly augmented glenoid components, reverse total shoulder arthroplasties, and the ream-and-run procedure, for managing shoulders with type-B2 and B3 glenoids, our goal was to investigate the utility of a standard anatomic total shoulder component in the management of these pathologies. Our hypothesis was supported by this investigation: the 2-year outcomes for B2 and B3 glenoid types treated with standard glenoid components without attempting to normalize glenoid version were not inferior to the outcomes for other glenoid types.

The geometry of our type-B2 and B3 glenoids assessed by radiographs appears to be typical. For example, the mean

preoperative measurements of glenoid version for each glenoid type in this study of 272 arthritic shoulders using axillary radiographs were consistent with the mean preoperative measurements on 155 arthritic shoulders reported by Iannotti et al.² using CT scans (Fig. 9) for types A1 ($-9^\circ \pm 7^\circ$ for our study and $-7^\circ \pm 4^\circ$ for the study by Iannotti et al.), A2 ($-10^\circ \pm 4^\circ$ compared with $-9^\circ \pm 6^\circ$), B1 ($-15^\circ \pm 8^\circ$ compared with $-11^\circ \pm 4^\circ$), B2 ($-21^\circ \pm 8^\circ$ compared with $-20^\circ \pm 7^\circ$), and B3 ($-24^\circ \pm 7^\circ$ compared with $-23^\circ \pm 6^\circ$). Our values for the preoperative decentring of the humeral head on the glenoid surface for each glenoid type made on axillary radiographs were consistent with the analogous measurements made on CT scans reported by Iannotti et al.² for types A1 ($1\% \pm 4\%$ compared with $-2\% \pm 5\%$), A2 ($0\% \pm 4\%$ compared with $-1\% \pm 5\%$), B1 ($-12\% \pm 5\%$ compared with $-10\% \pm 1\%$), B2 ($-13\% \pm 7\%$ compared with $-7\% \pm 7\%$), and B3 ($-3\% \pm 5\%$ compared with $-4\% \pm 6\%$) (Fig. 10).

Our minimum 2-year outcomes for 40 shoulders with type-B2 glenoids and 26 shoulders with type-B3 glenoids, analyzed separately, do not appear to be inferior to the minimum 2-year results reported recently by Ho et al. for a combined group of 71 shoulders with type-B2 or B3 glenoid anatomy treated with posteriorly augmented glenoids inserted using preoperative CT scans and 3-dimensional planning software²³. In both series, the clinical scores were significantly improved. The preoperative glenoid version was similar: $-24^\circ \pm 7^\circ$ for the combined type-B2 and B3 glenoids in the study by Ho et al.²³ and $-21^\circ \pm 8^\circ$ for the type-B2 glenoids and $-26^\circ \pm 7^\circ$ for the type-B3 glenoids that were analyzed separately in our series. The mean postoperative glenoid version was $-11^\circ \pm 6^\circ$ in the study by Ho et al., which was substantially changed from the preoperative value, and $-19^\circ \pm 8^\circ$ for our type-B2 glenoids and $-23^\circ \pm 7^\circ$ for our type-B3 glenoids, which were not significantly changed from the preoperative values. In the study by

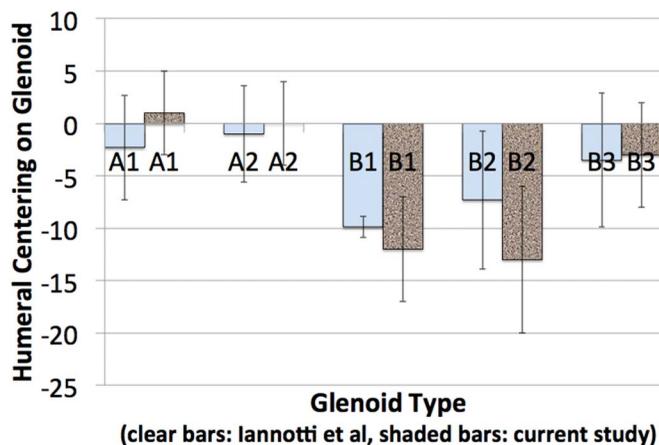


Fig. 10
The mean preoperative humeral decentring for the different glenoid types measured on standardized axillary views in the current study (brown bars) and for the measurements made on 3-dimensional reconstructions of CT scans (light blue bars) in the study by Iannotti et al.². The error bars represent the standard deviations.

Ho et al.²³, the mean decentering of the humeral head on the glenoid face was $-3\% \pm 10\%$ preoperatively and $-3\% \pm 11\%$ postoperatively, with a wide range from -31% (posterior) to $+22\%$ (anterior). In our series, the mean decentering was $-14\% \pm 7\%$ preoperatively and $-1\% \pm 2\%$ (range, -7% to 0%) postoperatively for our type-B2 glenoids and $-4\% \pm 6\%$ preoperatively and $-1\% \pm 3\%$ (range, -9% to 0%) postoperatively for our type-B3 glenoids. Finally, the percentage of central pegs with bone ingrowth between the flanges of the central peg seen on axillary radiographs was 61% in the study by Ho et al. in comparison with 83% for the type-B2 glenoids and 81% for the type-B3 glenoids in our series. Although the observations in the 2 studies were made by different observers and are, therefore, not directly comparable, they suggest that the outcomes in our study using a standard glenoid component are not inferior to those achieved with a posteriorly augmented glenoid component.

The strengths of this study are that all surgical procedures were performed by an individual surgeon using a standard technique and the same type of glenoid component, the results for types B2 and B3 were compared with those obtained by the same surgeon for the other glenoid types using identical outcome measures, our preoperative radiographic characteristics for the new type-B3 glenoids (version of $-26^\circ \pm 7^\circ$ and decentering on the glenoid face of $-3.6\% \pm 5.8\%$) measured on axillary radiographs are consistent with the measurements reported for type-B3 glenoids measured on CT scans by Iannotti et al.² (version of $-23^\circ \pm 6^\circ$ and decentering on the glenoid face of $-3.5\% \pm 6.3\%$), and the preoperative and postoperative radiographic measurements were both made on standardized axillary views (avoiding the problem of comparing preoperative CT measurements with postoperative axillary measurements identified by Ho et al.²³).

The limitations of this study include the relatively small sample size and short duration of follow-up. Although there are many possible additional clinical and radiographic variables that could have been considered in our study, we elected to focus on those that are readily accessible to shoulder surgeons: patient demographic characteristics, patient-reported outcomes using the SST, and straightforward measurements made on standardized radiographs. Finally, this study does not provide a comparison of the merits of the surgical technique described

here for managing the type-B2 and B3 glenoids with other methods, such as the use of posterior bone-grafting, posteriorly augmented glenoid components, reverse total shoulder arthroplasty, and the ream-and-run procedure. Longer follow-up will be needed to compare and validate the outcomes obtained with different treatment strategies for type-B2 and B3 glenoids.

In conclusion, shoulder arthroplasty with a standard glenoid component inserted without changing glenoid version can improve clinical outcomes and recenter the humeral head on the glenoid in shoulders with type-B2 and B3 glenoids at short-term follow-up, with bone ingrowth between the flanges of the central peg of the component in the great majority of cases. The results for the type-B2 and B3 glenoids were not inferior to those achieved for other glenoid types.

Appendix

 Supporting material provided by the authors is posted with the online version of this article as a data supplement at [jbjs.org \(http://links.lww.com/JBJSOA/A218\)](http://links.lww.com/JBJSOA/A218). ■

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