



# Total shoulder arthroplasty for glenohumeral arthritis associated with posterior glenoid bone loss: results of an all-polyethylene, posteriorly augmented glenoid component

Paul J. Favorito, MD<sup>a,\*</sup>, Robert J. Freed, DO<sup>b</sup>, Angela M. Passanise, DO<sup>c</sup>,  
Maggie Jane Brown, PA-C<sup>a</sup>

<sup>a</sup>Wellington Orthopaedic and Sports Medicine, Cincinnati, OH, USA

<sup>b</sup>Mayo Clinic Health System Mankato, Mankato, MN, USA

<sup>c</sup>Mercy Clinic Orthopedic Surgery, Washington, MO, USA

**Background:** Posterior glenoid bone loss is commonly encountered in total shoulder arthroplasty (TSA). The purpose of our study is to report the clinical and radiographic findings of patients with a minimum of 2 years' follow-up treated with an all-polyethylene, augmented glenoid component.

**Methods:** Twenty-two shoulders with posterior glenoid bone loss were treated by a single surgeon. All underwent primary TSA using a posteriorly augmented, all-polyethylene, stepped glenoid component. Outcome data included visual analog scale, Western Ontario Osteoarthritis of the Shoulder index, and Short Form 36 scores. Radiographic analysis was performed to evaluate bone-cement interface lucency, implant seating, and osseous integration of the central peg.

**Results:** The mean follow-up period was 36 months. Average preoperative retroversion measured with computed tomography scan was 23.5°. In addition to statistically significant increases in forward flexion and external rotation, the visual analog scale score, Western Ontario Osteoarthritis of the Shoulder score, and Short Form 36 physical component summary score all improved significantly ( $P < .001$ ). Twelve shoulders had osseous integration between the central-peg flanges, 6 had bone adjacent to the central-peg flanges but without identifiable osseous integration, and 1 showed osteolysis. The mean Lazarus score was 0.5. All glenoids had perfect seating scores. Two patients sustained a total of 3 episodes of prosthetic instability.

**Conclusions:** Early results of a posteriorly augmented, all-polyethylene, stepped prosthetic glenoid component to address posterior glenoid loss in TSA are encouraging. Continued evaluation will determine prosthetic longevity and maintained clinical improvement.

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

© 2016 Journal of Shoulder and Elbow Surgery Board of Trustees. All rights reserved.

**Keywords:** Augmented glenoid component; glenoid bone loss; shoulder arthroplasty; survival

Institutional review board approval was obtained from The Jewish Hospital of Cincinnati (Study JH No. 12-36).

\*Reprint requests: Paul J. Favorito, MD, Wellington Orthopaedic and Sports Medicine, 7575 Five Mile Rd, Cincinnati, OH 45230, USA.

E-mail address: [pfavorito@wellingtonortho.com](mailto:pfavorito@wellingtonortho.com) (P. Favorito).

Total shoulder arthroplasty (TSA) is an effective and reliable treatment for glenohumeral arthritis.<sup>3,7</sup> Both component positioning and prosthetic stability are important factors in component longevity and favorable patient outcomes. Failure

of TSA is multifactorial, but glenoid component failure remains the single most common reason.<sup>2,24,32,37</sup> Survivorship for TSA in the absence of significant posterior glenoid bone loss is estimated to be greater than 85% at a 15-year minimum follow-up.<sup>5</sup>

Posterior glenoid bone loss is a common finding in advanced glenohumeral arthritis.<sup>33,34</sup> Walch et al<sup>33</sup> classified glenoid wear patterns, and in their series, 24% had erosive changes (types B2 and C) posteriorly. Friedman et al<sup>9</sup> identified a significant difference in the amount of glenoid retroversion between a control group and a severely arthritic group. The optimal management for bone loss is unclear, but failure to address bone loss during TSA will likely lead to suboptimal results.<sup>8,14,35</sup> Farron et al<sup>8</sup> performed a finite element analysis of glenoid components placed in various degrees of retroversion. Increased retroversion resulted in significant increases in stress within the cement mantle and cement-bone interface. They suggested that retroversion greater than 10° should be corrected or if not possible, glenoid implantation should not be performed. Ho et al<sup>14</sup> reviewed 66 TSAs with an all-polyethylene glenoid component. They identified glenoid component osteolysis with component retroversion of 15° or greater. Walch et al<sup>35</sup> reviewed the results of TSA in biconcave glenoids. At a mean of 6 years' follow-up, glenoid loosening occurred in 20.6% and revisions occurred in 16.3% of 92 patients. Glenoid bone loss and increased retroversion were significantly associated with glenoid component loosening.

Re-establishing ideal glenoid version during TSA is particularly challenging in the presence of significant posterior glenoid wear. Restoring anatomic glenoid version improves prosthetic glenoid wear characteristics and reduces failure rates according to biomechanical and finite element studies.<sup>8,26,30</sup> Asymmetrical glenoid reaming is an accepted treatment, but more significant retroversion may not be correctable without excessive medialization and loss of glenoid bone stock resulting in peg perforation or obligate component downsizing.<sup>6,25</sup> Glenoid bone grafting is another purported treatment option but is technically challenging and has been associated with a 10-fold higher rate of prosthetic glenoid failure.<sup>13</sup> Non-union, subsidence, and graft resorption are common causes of failure,<sup>13,28,31,35</sup> with unsatisfactory outcomes in 8% to 47% of patients.<sup>13,18,23,31</sup> Sabesan et al<sup>28</sup> reviewed 12 patients with severe glenoid bone loss with an average retroversion of 44° and reported more favorable outcomes. Ten of the 12 shoulders had graft incorporation without any resorption and 2 had minor bone resorption at an average of 53 months.

Augmented glenoid components offer a theoretical solution to a difficult problem. In recent biomechanical studies, an all-polyethylene, augmented glenoid component with a posterior step performed favorably.<sup>15,17,29</sup> Presently, there are 3 augmented components that are Food and Drug Administration approved and available for use in the United States, with only 1 study in the peer-reviewed literature reporting short-term outcomes.<sup>38</sup> The purpose of our study is to report the clinical and radiologic findings of patients with at least 2 years' follow-up after TSA with a posteriorly augmented, all-

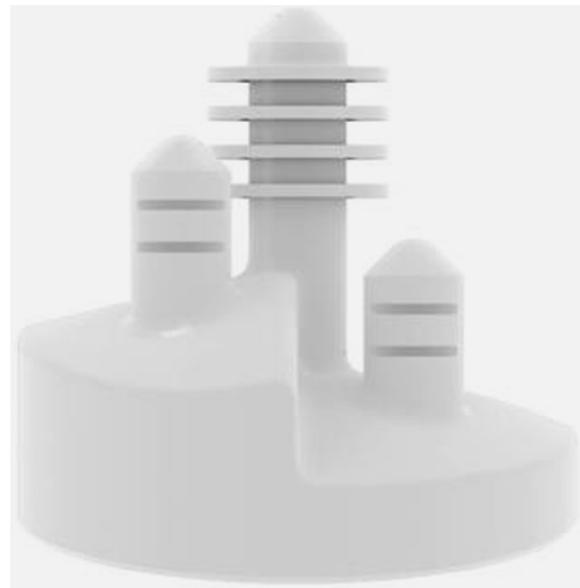
polyethylene, stepped glenoid component. We hypothesized that patients would improve clinically and would have radiographic component survival consistent with previously reported outcomes for non-augmented glenoid components in TSA.

## Materials and methods

This is a retrospective review of a prospectively collected series of consecutive patients with glenohumeral arthritis and posterior glenoid bone loss with retroversion measuring 15° or greater who underwent TSA with an augmented glenoid component. Informed consent was obtained from all patients before participation in the study.

## Patient population

Between May 2011 and January 2013, 22 shoulders in 19 patients (15 men and 4 women) underwent primary TSA by a single surgeon. In all cases, an all-polyethylene, posteriorly augmented, stepped glenoid component (Global StepTech Anchor Peg Glenoid; DePuy Synthes, Warsaw, IN, USA) was implanted (Fig. 1). One patient was lost to follow-up. One patient was unable to undergo follow-up imaging because of a stem cell procedure for a pulmonary disease. Therefore, 20 shoulders in 17 patients had both clinical and radiographic data available for follow-up. The mean follow-up period was 36 months (range, 26-46 months). The mean patient age at the time of surgery was 62 years (range, 44-77 years). All patients were routinely followed up postoperatively at 2 weeks, 6 weeks, 3 months, 6 months, 1 year, and then annually. The same postoperative rehabilitation protocol was prescribed for all patients except for 1 patient who underwent a rotator cuff repair. All patients had a preoperative diagnosis of osteoarthritis except for 1 patient who was diagnosed with rheumatoid arthritis (Table I).



**Figure 1** StepTech Anchor Peg Glenoid augmented glenoid component (GLOBAL® STEPTECH® Anchor Peg Glenoid courtesy of DePuy Synthes Joint Reconstruction).

**Table I** Patient demographic data

Case No.	Surgical side	Sex	Age, y	Diagnosis	Preoperative glenoid retroversion, °	Humeral head size	Stem size + fixation	Glenoid component (diameter + augmentation)	Length of follow-up, mo
1	Right	M	45	OA	37	58 × 18 ecc	10 press fit	48 + 7	46.8
2	Left	M	79	OA	29	52 × 18 ecc	10 press fit	48 + 3	46.9
3	Left	M	63	OA	31	52 × 21 ecc	12 press fit	52 + 5	41.9
4	Right	M	66	OA	23	56 × 21 ecc	12 press fit	52 + 5	44.6
5	Right	F	59	RA	25	48 × 21 ecc	8 press fit	48 + 5	46.3
6	Right	F	69	OA	19	48 × 18 ecc	12 press fit	48 + 5	NA
7	Left	F	68	OA	22	44 × 21 ecc	10 press fit	44 + 3	39.6
8	Left	M	65	OA	18	56 × 21 ecc	12 press fit	52 + 3	39.6
9	Left	F	56	OA	18	44 × 18 ecc	8 press fit	44 + 3	37.2
10	Right	M	70	OA	24	52 × 18 ecc	14 press fit	48 + 5	35.8
11	Right	M	68	OA	27	52 × 18 ecc	12 press fit	52 + 5	34.5
12	Left	F	59	RA	26	44 × 18 ecc	8 cemented	40 + 5	36.6
13	Left	M	62	OA	16	52 × 21 ecc	12 press fit	52 + 5	34.4
14	Right	M	74	OA	26	52 × 21 ecc	12 press fit	52 + 5	34.0
15	Left	M	58	OA	16	52 × 18 ecc	12 press fit	52 + 3	32.8
16	Left	M	61	OA	25	52 × 21 ecc	12 press fit	52 + 5	34.5
17	Right	M	73	OA	21	52 × 18 ecc	12 press fit	48 + 5	33.3
18	Right	M	64	OA	31	52 × 21 ecc	10 press fit	48 + 5	32.4
19	Left	M	46	OA	29	48 × 18 ecc	12 press fit	44 + 5	31.2
20	Left	M	70	OA	18	48 × 21 ecc	14 press fit	48 + 3	29.4
21	Right	M	54	OA	20	52 × 18 ecc	16 press fit	52 + 5	28.3
22	Left	M	64	OA	16	48 × 21 ecc	12 press fit	48 + 3	26.4

ecc, eccentric head; F, female; M, male; NA, not applicable; OA, osteoarthritis; RA, rheumatoid arthritis.

## Clinical evaluation

An electronic medical record was reviewed to obtain all preoperative information. Postoperative clinical examinations were performed at each visit and final data recorded at the most recent evaluation. Active range of motion of the glenohumeral joint was measured by goniometry in forward flexion (seated), external rotation (seated with the arm at the side), and internal rotation (hand up the back and recorded at the spinal level indicated by the thumb).

Muscle strength testing was measured using the Baseline Push-Pull Dynamometer (Fabrication Enterprises, White Plains, NY, USA) and performed as recommended by the manufacturer. Strength was recorded in kilograms in forward flexion, external rotation, and internal rotation and compared with the contralateral extremity.

## Outcome rating scales

Preoperative and postoperative Short Form 36 (SF-36),<sup>20</sup> Western Ontario Osteoarthritis of the Shoulder (WOOS) index,<sup>22</sup> and visual analog scale (VAS) scores were calculated for all patients at their most recent follow-up visit.

## Radiographic evaluation

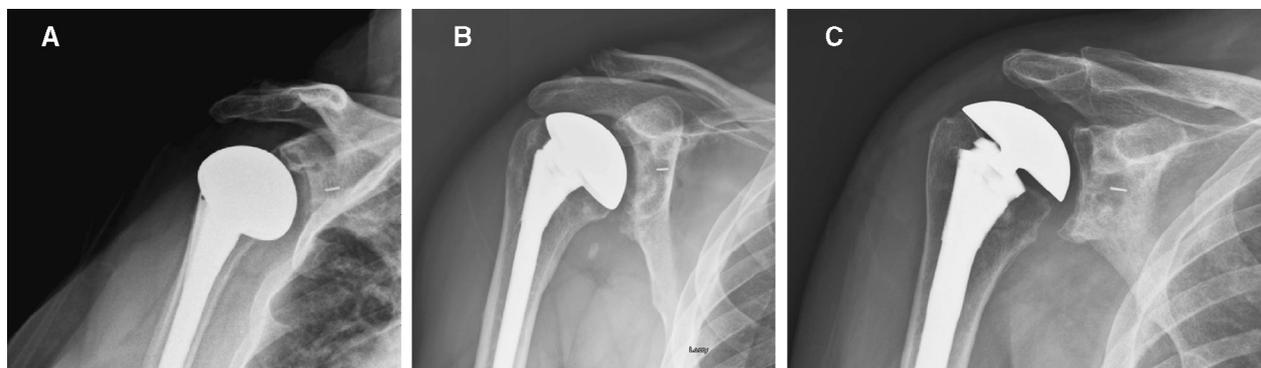
Preoperative computed tomography (CT) scans were reviewed to calculate glenoid retroversion using the neoglenoid line, as described by both Friedman et al<sup>9</sup> and Walch et al.<sup>33</sup> The most recent

postoperative radiographs were evaluated for radiolucency around the pegged components (Fig. 2) and component seating as described by Lazarus et al.<sup>21</sup>

Osseous integration of the central peg was similarly evaluated at final follow-up. The radiographic appearance of the bone adjacent to the periphery of the flanges of the central peg and the radiodensity between the flanges of the central peg were graded on a scale from 1 to 3 as described by Wirth et al.<sup>36</sup> Bone in contact with the periphery of the flanges of the central peg with increased radiodensity between the flanges resulted in a grade of 3. Bone in contact with the periphery of the flanges but with no increase in radiodensity between the flanges resulted in a grade of 2, and osteolysis about the central flanges resulted in a grade of 1.<sup>36</sup> Two independent physicians (a shoulder fellowship-trained orthopedic surgeon [R.J.F.] and a musculoskeletal fellowship-trained radiologist [not an author]) reviewed postoperative radiographs and were blinded to patient outcomes. The average scores were calculated from images independently graded by each physician.

## Surgical technique

The senior author (P.J.F.) performed all procedures with patients in the semi-upright position. Interscalene blocks and general anesthesia were administered. A standard deltopectoral approach was used. If present, the biceps tendon underwent tenodesis distally to the pectoralis major tendon. A lesser tuberosity osteotomy was performed. The subscapularis tendon was separated from the capsule, and with the axillary nerve protected, standard anterior and inferior capsular releases were completed.



**Figure 2** (A) Anteroposterior radiograph showing increased radiodensity between the flanges, suggesting osseous integration. (B) Anteroposterior radiograph showing bone in contact with the periphery of the flanges without radiodensity between the flanges. (C) Anteroposterior radiograph showing osteolysis about the central flange.

Periarticular humeral osteophytes were removed, and the humeral head underwent osteotomy through the anatomic neck using a free-hand technique. The humeral diaphysis was prepared using hand reamers. The appropriately sized broach was seated and a protector plate attached to protect the humerus and lesser tuberosity during glenoid preparation.

The glenoid was exposed, and a sizing disk was used to determine the correct glenoid size. The amount of correction was determined from both the preoperative CT scan and the amount and quality of glenoid bone stock identified intraoperatively. The goal was to achieve as close to neutral but not more than  $7^\circ$  of retroversion. The augmented (variable-height posterior step) pin guide was positioned so that it sat flush on the glenoid. A guide pin was drilled through the sizer and its exit confirmed with digital palpation along the anterior scapular body. The anterior glenoid was power reamed until bone at the level of the guide pin and anterior to it was symmetrically concave. The central drill hole was made.

The posterior guide was secured in place, with care taken to recreate appropriate rotation. Both a power bur and rasp were used to create the posterior step. The 3-hole peripheral guide with post was inserted into the central hole. The peripheral holes were drilled. The augmented glenoid trial was inserted to confirm concentric seating. The trial was removed. The peripheral holes were irrigated to remove debris, and then thrombin-soaked sponges were placed for hemostasis. By use of a bone graft applicator, morselized cancellous bone was applied to the central peg of the final component. Polymethyl methacrylate (Stryker, Mahwah, NJ, USA) was pressurized in the peripheral holes and the final component cemented into place.

The humeral protector plate was removed. The appropriately sized fixed- or variable-angle humeral head (Global Anatomic Prosthesis; DePuy Synthes) was chosen to cover the osteotomy site and properly balance the soft tissue to reproduce glenohumeral stability. The shoulder was placed in neutral flexion and rotation. The humeral head was translated anteriorly, posteriorly, and inferiorly. Approximately 50% translation was desired. The lesser tuberosity was anatomically repaired using sutures placed both through bone and around the humeral component.

A drain was placed if needed. The deltopectoral interval was loosely approximated, and the incision was closed in a standard fashion with absorbable suture.

## Postoperative management

Patients were admitted to the hospital and discharged when medically fit. On the first postoperative day, patients received in-hospital physical therapy and a home exercise program emphasizing protected range of motion and muscle activation. Sling use was discontinued by 2 weeks postoperatively, at which time outpatient physical therapy was instituted.

## Statistical analysis

Changes between the preoperative and most recent postoperative assessments were evaluated with use of a paired *t* test. Relative associations between strength measures and range-of-motion outcomes were evaluated using the Pearson correlation coefficient. Statistical analyses were conducted in Microsoft Excel (Office 2010; Microsoft, Redmond, WA, USA), and statistical significance was established a priori at  $P < .05$ .

## Results

### Clinical findings

The mean VAS score improved from  $7.3 \pm 1.8$  preoperatively to  $1.7 \pm 2.0$  at the latest follow-up ( $P < .001$ ). There was a statistically significant improvement in the WOOS score from  $42.4\% \pm 13.2\%$  to  $85.7\% \pm 16.1\%$  ( $P < .001$ ). The physical component summary score of the SF-36 also saw significant improvement, from  $33.6 \pm 8.0$  to  $45.9 \pm 11.4$  at final follow-up ( $P < .001$ ).

There were statistically significant increases in both forward elevation and external rotation. Mean forward flexion improved from  $110^\circ \pm 42^\circ$  preoperatively to  $136^\circ \pm 26^\circ$  ( $P < .005$ ), and mean external rotation improved from  $9.74^\circ \pm 25.8^\circ$  to  $39.7^\circ \pm 15.8^\circ$  ( $P < .00004$ ). Preoperatively, the highest spinal level seen in internal rotation was L5 in 2 patients, with the rest showing varying degrees of motion to

the side or buttocks. Postoperatively, internal motion improved to an average of T12. The mean postoperative forward flexion, external rotation, and internal rotation strength was 91%, 97%, and 96%, respectively, of the contralateral arm's strength as measured with the dynamometer.

### Radiographic analysis

Preoperative glenoid morphology was graded as Walch type B2 in 20 shoulders and type C in 2 shoulders. Glenoid retroversion averaged 23.5° (range, 16°-37°). The average Lazarus lucency score was 0.53 (Fig. 3). Ten shoulders had a lucency grade of 0. Eight shoulders had a lucency grade of 1, and 1 shoulder showed grade 2 lucency. All shoulders had a perfect component seating grade of A. Central-peg flange osseous integration was seen in 12 shoulders. Six had bone adjacent to the central-peg flanges but without identifiable osseous integration, and 1 showed osteolysis.

### Complications

There were two postoperative complications. One patient had an anterior dislocation noted at the first postoperative evaluation 2 weeks after the index procedure. No injury or mechanism was reported. Closed reduction under anesthesia was unsuccessful. The patient underwent open reduction and was noted to have an intact subscapularis and lesser tuberosity repair. The posterior capsule was released, the medial subscapularis muscle was reapproximated with suture anchors to the anterior glenoid, and the humeral head was revised to a larger component.

The second patient sustained a posterior dislocation 22 months postoperatively while pushing himself up and out of bed. He underwent closed reduction and external rotation bracing for 6 weeks. His shoulder remained stable until 30 months after arthroplasty when another atraumatic posterior dislocation occurred. He was then revised to a reverse TSA.

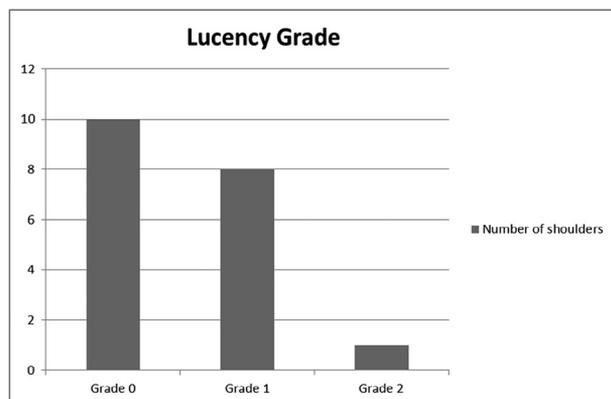


Figure 3 Lucency grading.

During revision surgery, there did not appear to be any bony ingrowth to the glenoid component.

### Discussion

We hypothesized that TSA patients treated with an all-polyethylene, posteriorly augmented component would improve clinically and have radiographic component survival consistent with previously reported outcomes for non-augmented glenoid components in TSA. Our hypothesis was proved. There were statistically significant improvements in both patient-reported and physician-measured outcomes. Postoperatively, pain scores were decreased, motion (forward flexion and external rotation) was significantly improved, and both WOOS and SF-36 scores increased. One case of glenoid component failure resulted in posterior instability requiring revision. Given the small number of patients, the resultant glenoid component failure rate requiring revision was 5%, which is slightly lower than the 7% reported in a meta-analysis of TSA with non-augmented components performed by Bohsali et al.<sup>2</sup>

Posterior glenoid bone loss may present significant challenges during TSA.<sup>28,31,35</sup>

The posteriorly augmented glenoid component is one option to address significant posterior bone loss. The stepped, augmented glenoid used in this study is a modification of the all-polyethylene pegged design that has been evaluated previously.<sup>36</sup> Both the conventional and augmented components have 1 central post designed for osseous ingrowth and 3 peripheral pegs that should be cemented. For each augmented glenoid diameter size between 40 mm and 56 mm, there are 3 options (+3, +5, and +7 mm) for version correction. Anterior reaming (approximately 5° of version correction) is combined with the correction for each version step (+3 = 5°, +5 = 10°, and +7 = 15°). Combining 1 of the 3 prostheses with anterior reaming results in 10° to 20° of version correction. In addition, the posterior step is 77°, not perpendicular, to counteract posterior loading.

Clinical improvement is expected after conventional TSA in the absence of significant posterior glenoid bone loss.<sup>10,12</sup> In our study, patients improved clinically with VAS scores decreasing from 7.3 to less than 2. Statistically significant improvements were seen in the WOOS score, from 42% to 85%, and the physical component summary score of the SF-36. Both forward elevation and external rotation improved to 136° and 39°, respectively. These findings are consistent with outcomes reported by Wirth et al<sup>36</sup> (147° and 44°, respectively), who used a similar non-augmented glenoid prosthesis.

There is little peer-reviewed literature reporting clinical results after implanting augmented prosthetic glenoids. Rice et al<sup>27</sup> used an asymmetrical keel-type design that allowed 4° of version correction. Although early results were promising, a high rate of instability forced them to abandon using the prosthesis.

Youderian et al<sup>38</sup> described their preliminary clinical and radiographic outcomes using the same glenoid component used

in our study. At an average follow-up of 10.8 months, they reported that significant improvements in clinical function and pain levels were shown in 17 of 18 patients. When comparing our results with this patient population and other peer-reviewed literature using augmented glenoids, we are more optimistic.

## Radiographic discussion

Our radiographic results are encouraging. The mean Lazarus lucency score of 0.53 compares favorably with results reported in the study by Youderian et al,<sup>38</sup> in which an augmented, stepped prosthetic glenoid was used. In their series of 24 shoulders, 58% had a Lazarus score of grade 0 or 1 whereas we showed a rate of 95% for these same grades. A multicenter study performed by Lazarus et al<sup>21</sup> reported a lucency score of 1.3 for the glenoid component of the Global Total Shoulder System (DePuy Synthes). Although they used a multi-axial and pegged component, the central post was smooth and not designed for bony ingrowth. The component used in our study allows bony ingrowth and may have contributed to improved fixation and resultant lucency scores.

Wirth et al<sup>36</sup> reported a 73% perfect seating grade using a non-augmented component. In our study, all glenoids had a perfect seating score. Several plausible explanations exist for the discrepancy in results. In addition to differences in interobserver radiographic assessment, slight alterations in exposure technique and improved instrumentation may have contributed to our results.

The glenoid component used in our study is designed for minimal cement application for the peripheral pegs and bony ingrowth around the central peg with flanges. Wirth et al<sup>36</sup> reported a grading system to describe the amount of osseous integration around the central peg of this component design. Using their scale, we identified a mean osseous integration score of 2.5, with only 1 shoulder showing osteolysis about the central peg at 33 months postoperatively. In our study, 63% of components had identifiable osseous integration of the central peg. This is comparable with the 68% rate of osseous integration reported by Wirth et al. Overall, the radiographic results of this augmented component are comparable with those of a similarly designed, non-augmented component.<sup>1,4</sup>

## Complications

There were 2 complications in our study. Although both were instability events, they occurred for different reasons.

### Anterior dislocation for patient 1

One dislocation was anterior and identified at the first postoperative visit and was most likely related to soft-tissue balancing. Approximately 5° of the version correction comes from anterior glenoid reaming.<sup>11</sup> Sabesan et al<sup>29</sup> performed a 3-dimensional computer-simulated correction of glenoid bone

loss comparing eccentric reaming with an augmented component. Correction to neutral version resulted in an average bone removal of 3.8 mm. A +5 step resulted in mean medialization of 6.7 mm to neutral version and 5.4 mm to 6° of retroversion.<sup>29</sup>

In our patient, the humeral head was appropriately sized to re-create the normal humeral anatomy. However, it was insufficient to restore proper soft-tissue balance. At the time of revision surgery, the subscapularis and lesser tuberosity were intact. The humeral head was exchanged for one measuring 44 × 21 mm. Although there has been no recurrence of glenohumeral instability since the revision procedure and the VAS pain score decreased from 10 to 5, the patient has a subjective shoulder score of 40 and an American Shoulder and Elbow Surgeons score of 38.

### Posterior dislocation for patient 2

The second patient had 24° of preoperative retroversion and, at the time of TSA, had a 48 + 5 glenoid implanted (Fig. 4). He sustained an atraumatic posterior dislocation 22 months postoperatively while pushing himself up and out of bed. After closed reduction under anesthesia, his shoulder was stable for 8 months. He ultimately underwent revision to a reverse TSA after a second posterior instability episode at 30 months postoperatively. Serial review of his postoperative radiographs showed gradual subsidence of the posterior bone.

The implantation of a stepped glenoid component requires removal of some posterior bone. In glenoids in which there is both retroversion and glenoid medialization, there may be insufficient subchondral bone, volume, and/or density after preparation to support the posterior component.

There are 2 types of augmented glenoids commercially available that have been biomechanically evaluated: stepped and wedged (full wedge and posterior-only wedge).<sup>15,16,17,19</sup> Several comparison studies have shown that the wedged design removes less posterior bone than the stepped design.<sup>16,19</sup> However, the advantages of a stepped, augmented glenoid include a design that places the component more perpendicular to joint forces (Fig. 5).<sup>15,16,17,29,38</sup> Iannotti et al<sup>15</sup> performed a biomechanical evaluation of 4 augmented glenoid components. They found the stepped glenoid component had lower initial and final liftoff values compared with the non-stepped, augmented devices.

## Limitations

There are several limitations to our study. The prospective cohort is small, and the follow-up is relatively short. Preoperatively, we did not identify the amount of version correction required because there were no preoperative CT scans of the contralateral shoulder to identify native glenoid version specific to each patient. The amount of correction performed at the time of surgery was based on preoperative CT scans with a goal to achieve close to neutral version. Finally, we did not measure postoperative version. Inconsistencies in



**Figure 4** (A, B) Anteroposterior and axillary radiographs at 2 weeks postoperatively. (C, D) Radiographs at 26 months postoperatively showing osteolysis about the central peg. (E, F) Patient’s second dislocation with progression of osteolysis.



**Figure 5** Postoperative axillary radiograph showing the posterior step.

radiographic imaging precluded accurate measurements, and routine postoperative CT scans were not obtained.

**Conclusion**

Early results of an augmented prosthetic glenoid component used to address posterior glenoid loss in TSA are encouraging. Further studies are warranted to determine prosthetic longevity and maintained clinical improvement.

**Acknowledgments**

The authors thank Greg Meyers, PhD, for his assistance with statistical analysis and Richelle Gwin for her administrative assistance.

## Disclaimer

Paul Favorito is a paid consultant for DePuy Synthes but received no compensation for the preparation of this manuscript. All the other authors, their immediate families, and any research foundations with which they are affiliated have not received any financial payments or other benefits from any commercial entity related to the subject of this article.

## References

1. Arnold RM, High RR, Grosshans KT, Walker CW, Fehring EV. Bone presence between the central peg's radial fins of a partially cemented pegged all poly glenoid component suggest few radiolucencies. *J Shoulder Elbow Surg* 2011;20:315-21. <http://dx.doi.org/10.1016/j.jse.2010.05.025>
2. Bohsali KL, Wirth MA, Rockwood CA Jr. Complications of total shoulder arthroplasty. *J Bone Joint Surg Am* 2006;88:2279-92. <http://dx.doi.org/10.2106/JBJS.F.00125>
3. Boileau P, Sinnerton RJ, Chuinard C, Walch G. Arthroplasty of the shoulder. *J Bone Joint Surg Br* 1996;88:562-75.
4. Churchill RS, Zellmer C, Zimmers HJ, Ruggero R. Clinical and radiographic analysis of a partially cemented glenoid implant: five-year minimum follow-up. *J Shoulder Elbow Surg* 2010;19:1091-7. <http://dx.doi.org/10.1016/j.jse.2009.12.022>
5. Cil A, Veillette C, Sanchez-Sotelo J, Sperling JW, Schleck CD, Cofield RH. Survivorship of the humeral component in shoulder arthroplasty. *J Shoulder Elbow Surg* 2010;19:143-50. <http://dx.doi.org/10.1016/j.jse.2009.04.011>
6. Clavert P, Millett P, Warner JJP. Glenoid resurfacing: what are the limits to asymmetric reaming for posterior erosion? *J Shoulder Elbow Surg* 2007;16:843-8. <http://dx.doi.org/10.1016/j.jse.2007.03.015>
7. Cofield RH. Total shoulder arthroplasty with a Neer prosthesis. *J Bone Joint Surg Am* 1984;66:899-906.
8. Farron A, Terrier A, Büchler P. Risks of loosening of a prosthetic glenoid implanted in retroversion. *J Shoulder Elbow Surg* 2006;15:521-6. <http://dx.doi.org/10.1016/j.jse.2005.10.003>
9. Friedman RJ, Hawthorne KB, Genez BM. The use of computerized tomography in the measurement of glenoid version. *J Bone Joint Surg Am* 1992;74:1032-7.
10. Gausden E, Taylor SA, Dines JS, Bedi A, Chin C, Craig EV, et al. Total shoulder arthroplasty for primary osteoarthritis utilizing a mini-stem humeral component-midterm results of the first 100 cases. *J Shoulder Elbow Surg* 2015;24:e116. <http://dx.doi.org/10.1016/j.jse.2014.11.019>
11. Global StepTech Anchor Peg Glenoid: surgical technique. Warsaw, IN: DePuy Synthes; 2014.
12. Gruson KI, Pillai G, Vanadurongwan B, Parsons BO, Flatow EL. Early clinical results following staged bilateral primary total shoulder arthroplasty. *J Shoulder Elbow Surg* 2010;19:137-42. <http://dx.doi.org/10.1016/j.jse.2009.04.005>
13. Hill JM, Norris TR. Long-term results of total shoulder arthroplasty following bone-grafting of the glenoid. *J Bone Joint Surg Am* 2001;83:877-83.
14. Ho JC, Sabesan VJ, Iannotti JP. Glenoid component retroversion is associated with osteolysis. *J Bone Joint Surg Am* 2013;95:e821-8. <http://dx.doi.org/10.2106/JBJS.L.00336>
15. Iannotti JP, Lappin KE, Klotz CL, Reber EW, Swope SW. Lift-off resistance of augmented glenoid components during cyclic fatigue loading in the posterior-superior direction. *J Shoulder Elbow Surg* 2013;22:1530-6. <http://dx.doi.org/10.1016/j.jse.2013.01.018>
16. Kersten AD, Flores-Hernandez C, Hoenecke HR, D'Lima DD. Posterior augmented glenoid designs preserve more bone in biconcave glenoids. *J Shoulder Elbow Surg* 2015;24:1135-41. <http://dx.doi.org/10.1016/j.jse.2014.12.007>
17. Kirane YM, Lewis GS, Sharkey NA, Armstrong AD. Mechanical characteristics of a novel posterior step prosthesis for biconcave glenoid defect. *J Shoulder Elbow Surg* 2012;21:105-15. <http://dx.doi.org/10.1016/j.jse.2010.12.008>
18. Klika BJ, Wooten CW, Sperling JW, Steinmann SP, Schleck CD, Harmsen WS, et al. Structural bone grafting for glenoid deficiency in primary total shoulder arthroplasty. *J Shoulder Elbow Surg* 2014;23:1066-72. <http://dx.doi.org/10.1016/j.jse.2013.09.017>
19. Knowles NK, Ferreira LM, Athwal GS. Augmented glenoid component designs for type B2 erosions: a computational comparison by volume of bone removal and quality of remaining bone. *J Shoulder Elbow Surg* 2015;24:1218-26. <http://dx.doi.org/10.1016/j.jse.2014.12.018>
20. Kosinski M, Keller SD, Hatoum HT, Kong SX, Ware JE. The SF-36 health survey as a generic outcome measure in clinical trials of patients with osteoarthritis and rheumatoid arthritis: tests of data quality, scaling assumptions and score reliability. *Med Care* 1999;37(Suppl):MS10-22.
21. Lazarus MD, Jensen KL, Southworth C, Matsen FA. The radiographic evaluation of keeled and pegged glenoid component insertion. *J Bone Joint Surg Am* 2002;84:1174-82.
22. Lo IK, Griffin S, Kirkley A. The development of a disease-specific quality of life measurement tool for osteoarthritis of the shoulder: Western Ontario Osteoarthritis of the Shoulder (WOOS) index. *Osteoarthritis Cartilage* 2001;9:771-8.
23. Neer CS II, Morrison DS. Glenoid bone-grafting in total shoulder arthroplasty. *J Bone Joint Surg Am* 1988;70:1154-62.
24. Norris TR, Iannotti JP. Functional outcome after shoulder arthroplasty for primary osteoarthritis: a multicenter study. *J Shoulder Elbow Surg* 2002;11:130-5. <http://dx.doi.org/10.1067/mse.2002.121146>
25. Nowak DD, Bahu MJ, Gardner TR, Dyrszka MD, Levine WN, Bigliani LU, et al. Simulation of surgical glenoid resurfacing using three-dimensional computed tomography of the arthritic glenohumeral joint: the amount of glenoid retroversion that can be corrected. *J Shoulder Elbow Surg* 2009;18:680-8. <http://dx.doi.org/10.1016/j.jse.2009.03.019>
26. Nyffeler RW, Jost B, Pfirrmann CW, Gerber C. Measurement of glenoid version: conventional radiographs versus computed tomography scans. *J Shoulder Elbow Surg* 2003;12:493-6. [http://dx.doi.org/10.1016/S1058-2746\(03\)00181-2](http://dx.doi.org/10.1016/S1058-2746(03)00181-2)
27. Rice RS, Sperling JW, Miletti J, Schleck C, Cofield R. Augmented glenoid component for bone deficiency in shoulder arthroplasty. *Clin Orthop Relat Res* 2008;466:579-83. <http://dx.doi.org/10.1007/s11999-007-0104-4>
28. Sabesan V, Callanan M, Ho J, Iannotti JP. Clinical and radiographic outcomes of total shoulder arthroplasty with bone graft for osteoarthritis with severe glenoid bone loss. *J Bone Joint Surg Am* 2013;95:1290-6. <http://dx.doi.org/10.2106/JBJS.L.00097>
29. Sabesan V, Callanan M, Sharma V, Iannotti JP. Correction of acquired glenoid bone loss in osteoarthritis with a standard versus an augmented glenoid component. *J Shoulder Elbow Surg* 2014;23:964-73. <http://dx.doi.org/10.1016/j.jse.2013.09.019>
30. Shapiro TA, McGarry MH, Gupta R, Lee YS, Lee TQ. Biomechanical effects of glenoid retroversion in total shoulder arthroplasty. *J Shoulder Elbow Surg* 2007;16(Suppl):S90-5. <http://dx.doi.org/10.1016/j.jse.2006.07.010>
31. Steinmann SP, Cofield RH. Bone grafting for glenoid deficiency in total shoulder replacement. *J Shoulder Elbow Surg* 2000;9:361-7.
32. Strauss EJ, Roche C, Flurin PH, Wright T, Zuckerman JD. The glenoid in shoulder arthroplasty. *J Shoulder Elbow Surg* 2009;18:819-33. <http://dx.doi.org/10.1016/j.jse.2009.05.008>

33. Walch G, Badet R, Boileau A, Khoury A. Morphologic study of the glenoid in primary glenohumeral osteoarthritis. *J Arthroplasty* 1999;14:756-60.
34. Walch G, Boulahia A, Boileau P, Kempf JF. Primary glenohumeral osteoarthritis: clinical and radiographic classification. The Aequalis Group. *Acta Orthop Belg* 1998;64(Suppl 2):46-52.
35. Walch G, Moraga C, Young A, Castellanos-Rosas J. Results of anatomic nonconstrained prosthesis in primary osteoarthritis with biconcave glenoid. *J Shoulder Elbow Surg* 2012;21:1526-33. <http://dx.doi.org/10.1016/j.jse.2011.11.030>
36. Wirth MA, Loredi R, Garcia G, Rockwood CA Jr, Southworth C, Iannotti JP. Total shoulder arthroplasty with an all-polyethylene pegged bone-ingrowth glenoid component: a clinical and radiographic outcome study. *J Bone Joint Surg Am* 2012;94:260-7. <http://dx.doi.org/10.2106/JBJS.J.01400>
37. Wirth MA, Rockwood CA Jr. Complications of total shoulder replacement arthroplasty. *J Bone Joint Surg Am* 1996;78:603-16.
38. Youderian AR, Napolitano LA, Davidson IU, Iannotti JP. Management of glenoid bone loss with the use of a new augmented all-polyethylene glenoid component. *Tech Should Surg* 2012;13:163-9. <http://dx.doi.org/10.1097/BTE.0b013e318265354d>