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Posterior glenoid bone grafting in total shoulder arthroplasty for osteoarthritis with severe posterior glenoid wear

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Background: Total shoulder arthroplasty (TSA) in cases with posterior wear can be addressed by eccentric reaming of the anterior glenoid or by augmenting the posterior glenoid with bone grafting or augmented glenoid implants. We report the results of TSA with posterior glenoid bone grafting (PGBG) with humeral head autograft in patients with shoulder osteoarthritis and severe posterior glenoid wear.
Methods: A retrospective review of cases from 2004 to 2014 revealed 34 patients. Preoperative and postoperative radiographs were evaluated for glenoid version and humeral head subluxation as well as component loosening. Patient-reported outcomes were compared preoperatively and postoperatively. Complications and reoperations were also evaluated.
Results: Of the 34 patients, 28 (82.4%) were available at a minimum of 2 years' follow-up. PGBG corrected glenoid retroversion from $-28° \pm 4°$ preoperatively to $-4° \pm 2°$ ($P < .001$). Humeral head subluxation also improved after PGBG with respect to the scapular axis and to the midglenoid face ($P < .001$). Radiographic analysis revealed all PGBGs had incorporated. Radiographically, 3 patients (10.7%) had a total of 5 broken or displaced screws. In addition, 3 patients (10.7%) had a broken metal marker in the center peg of the glenoid component. No patients required component revision surgery by final follow-up. Only 1 reoperation occurred for capsular release. Patients showed significant improvements in all patient-reported outcomes.
Conclusion: Patients undergoing primary TSA with humeral head autograft PGBG showed significant improvements in glenoid version, humeral head subluxation, patient-reported outcomes, and range of motion at an average of 4 years' follow-up. There was a low revision rate and a high rate of graft incorporation.
Level of evidence: Level IV; Case Series; Treatment Study

Keywords: Posterior glenoid bone loss; total shoulder arthroplasty; posterior glenoid bone grafting; humeral head autograft; glenoid wear; glenoid augmentation

Primary osteoarthritis in the shoulder is a debilitating condition for patients, severely limiting their ability to participate in activities of daily living. Total shoulder arthroplasty (TSA) offers patients pain relief and increased range of motion and activity level, with an overall implant survivorship estimated at greater than 85%.[27] Glenoid component failure is

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the most common complication after TSA, with contributing factors including aseptic loosening, component malpositioning, altered joint reactive forces, and insufficient bony support for the component. The degenerative wear pattern of osteoarthritis in the shoulder is frequently characterized by posterior glenoid bone erosion, which results in an increase in glenoid retroversion.[13,28]

Glenoid posterior wear patterns can increase the retroversion angle, result in medialization of the joint line, decrease glenoid vault volume, decrease glenohumeral contact area, and increase contact pressures, thus jeopardizing the long-term component functioning.[11,22] Varying degrees of posterior humeral head subluxation can also accompany the increased retroversion.[2,6,8,20,32] This condition can be further exacerbated by posterior capsular laxity or insufficiency, which can lead to further shoulder posterior extrusion outside the confines of the glenoid. If severe posterior glenoid bone loss is not corrected during a TSA, then the probability of glenoid loosening and instability can be dramatically increased.[4,11,30]

Glenoid bone loss with resultant retroversion of components presents a unique but not uncommon challenge to surgeons. Walch et al[32] classified glenoid bone loss according to the pattern and magnitude of posterior bone erosion that are present. This classification system is beneficial because it allows one to determine how significant the defect is and what surgical interventions may be necessary to re-create normal glenoid anatomy and version. In addition, advanced imaging including computed tomography (CT) scans with 3-dimensional reconstruction can help surgeons to understand the degree of bone loss, degree of retroversion, and amount of humeral head displacement.

In cases with posterior wear, the defect can be addressed by tackling the dilemma by either "lowering the front" or "raising the back." When a large defect is present, eccentric anterior glenoid reaming can lower the front to re-create normal version; however, this can result in inadequate bone support, increasing the risk of incomplete component seating and glenoid vault shortening and penetration.[9,12,27,30] Incomplete seating can also lead to eccentric loading of the implant, increasing stresses at the implant-bone interface, compromising overall stability.[8,19,32] In most cases the posterior glenoid wear pattern is in the posterior-inferior aspect of the glenoid and not a symmetrical or uniform wear pattern.[16-18]

Conversely, when large posterior defects are present, a posterior glenoid bone graft can be used to re-create normal anatomic glenoid version by raising the back. Posterior bone grafting can help to correct retroversion, restore bone stock, and provide a biological basis for healing and can prevent component penetration of the glenoid vault. In addition, bone grafting re-establishes a more "normal" joint position by avoiding medialization, normalizing mechanics and forces about the shoulder, and decreasing the risk of posterior subluxation.[22,30] However, few studies have evaluated the longevity of this option, the outcomes, and the effect on range of motion.[10,15,20,25,29] This article will discuss the surgical technique and results in 28 patients who were treated with posterior glenoid bone grafting (PGBG) with humeral head autograft in conjunction with implantation of a TSA.

Methods

Patient selection

A retrospective review of cases from 2004 to 2014 revealed 34 consecutive patients who underwent primary TSA with PGBG with humeral head autograft for primary shoulder osteoarthritis with severe posterior glenoid wear. The total number of TSA cases performed during this period was 325. In all patients, nonoperative management had failed, including activity modification, oral anti-inflammatories, and in some cases, physical therapy or intra-articular cortisone injections. The inclusion criteria involved glenoid retroversion such that the senior author's assessment was that asymmetrical anterior reaming would result in excessive removal of bone stock and increase the risk of perforation. The range of retroversion in this series was –42° to –20°; thus, we did not have any cases with –15° or less, which has been discussed as a threshold in anatomic studies. Indications for considering PGBG were patients with glenohumeral arthritis, an intact rotator cuff, and significant glenoid posterior wear. Revision and reverse TSAs, as well as surgical indications other than primary osteoarthritis with posterior glenoid wear, were excluded. Patients with missing radiographs were excluded. Only patients with a minimum of 2 years' follow-up were included.

Radiographic measurements

All patients underwent preoperative and postoperative radiographs including a true anteroposterior view of the glenohumeral joint, scapular Y view, and axillary lateral view. Axillary radiographs were evaluated for glenoid version with respect to the scapular axis as per the method of Friedman et al[6] (Fig. 1, *A*). Advanced imaging studies—either magnetic resonance imaging or CT scans—were obtained preoperatively (Fig. 1, *B*). Although the ideal for this study would have been postoperative advanced imaging (CT), this imaging was not obtained postoperatively in that the patients were functioning well and there was no clinical indication for such imaging. The goal was to make the measurements as translational as possible so that the surgeon in the office could correlate preoperative and postoperative plain films in the office. Axillary radiographs were also evaluated for humeral head subluxation relative to the scapular axis and the glenoid face.[24] Postoperative radiographs were evaluated for glenoid version and humeral head subluxation in the same fashion. Postoperative radiographs at most recent follow-up were assessed for PGBG healing, hardware complications, and component loosening. The senior author, a fellowship-trained shoulder surgeon with over 20 years in practice, evaluated all imaging. All measurements were performed in a digital imaging environment with angle measurement software. Incorporation of the graft was evaluated on the axillary radiograph, with comparison to serial radiographs, for osteolysis, lucent lines, or position change.

Surgical technique

TSA is performed through a deltopectoral approach with standard humeral preparation. After glenoid exposure, PGBG is performed

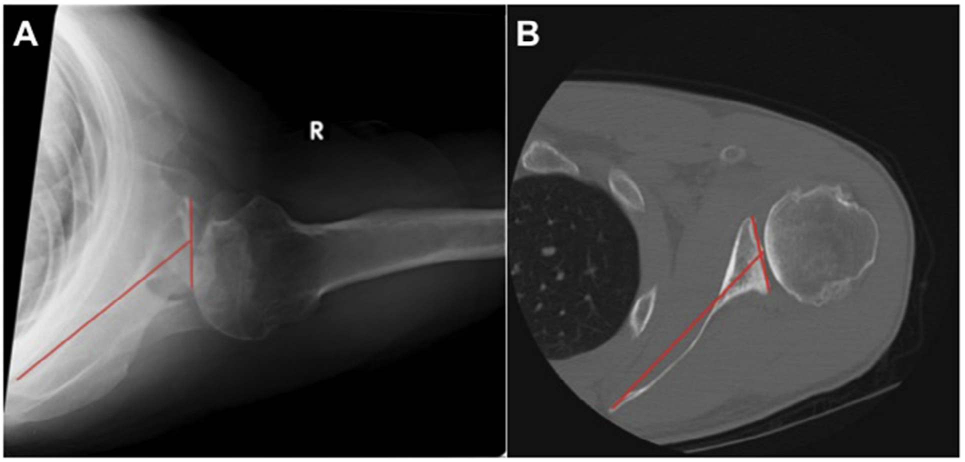

Figure 1 Preoperative axillary radiograph **(A)** and computed tomography scan **(B)** used for measurement of glenoid retroversion. "R" indicates right shoulder.

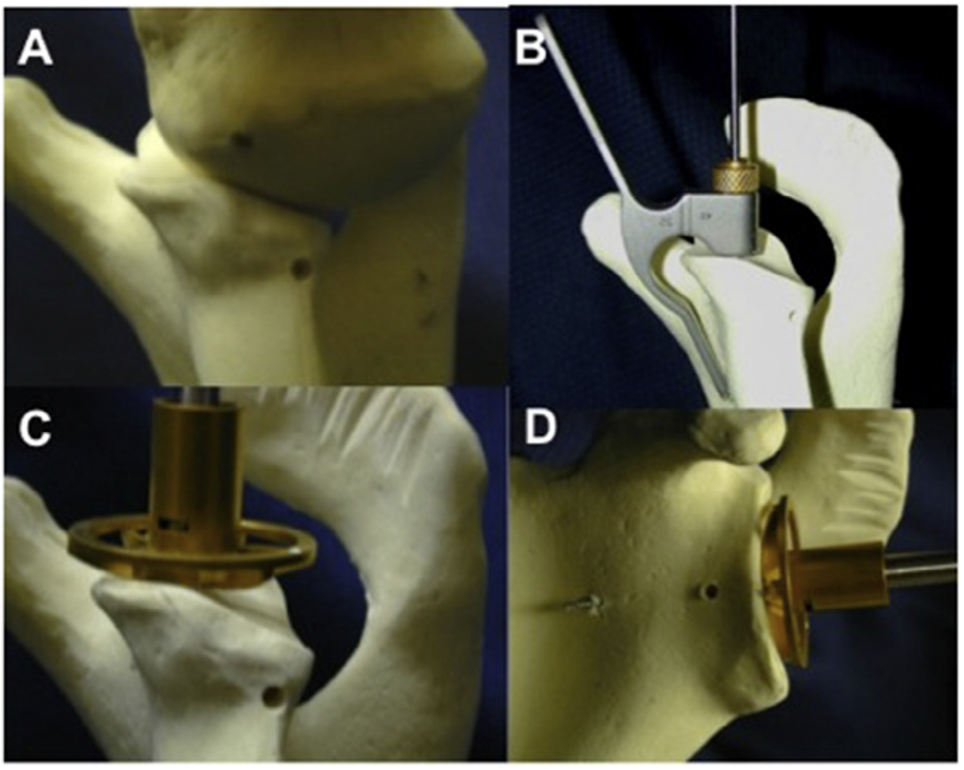

Figure 2 **(A)** Bone model depiction of posterior glenoid wear, showing the humeral head articulating with the posterior-inferior aspect of the glenoid. A patented drill guide allows placement of a guide pin down the center of the glenoid vault **(B)** and cannulated reaming **(C)** to near perpendicular to the long axis of the scapula **(D)**.

as shown in Figures 2-7. In most cases with posterior glenoid wear, the humeral head has been articulating with the posterior-inferior aspect of the glenoid (Fig. 2, *A*) and there is remaining cartilage on the anterior aspect of the glenoid face. This cartilage is removed. With posterior glenoid wear and biconcavity, it can be difficult to place a drill guide and drill a pilot hole properly on the sloped surface. Even if performed satisfactorily, sometimes the glenoid reamer pilot "nose" cannot reach the drill hole because of the prominence of the anterior glenoid rim in relation to the sloped glenoid surface.

We developed a patented drill guide based on anatomic studies from our institution and the literature to allow placement of a guide pin down the center of the glenoid vault (Fig. 2, *B*).[1,6,8,19] This guide and cannulated reamer system are commercially available (Zimmer, Warsaw, IN, USA) and allow the placement of a pin down the glenoid centerline. The glenoid face can be reamed without first drilling a large hole in the glenoid face. The reamer head can also show the surgeon the magnitude of the wear pattern as the reamer is placed down the pin and onto the glenoid face. This allows cannulated

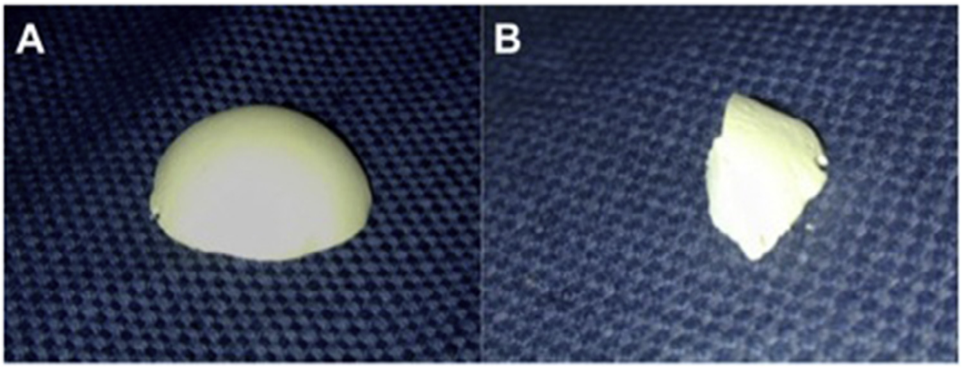

Figure 3 The resected humeral head **(A)** is sized in a fan shape to fit the measured defect in the glenoid **(B)**.

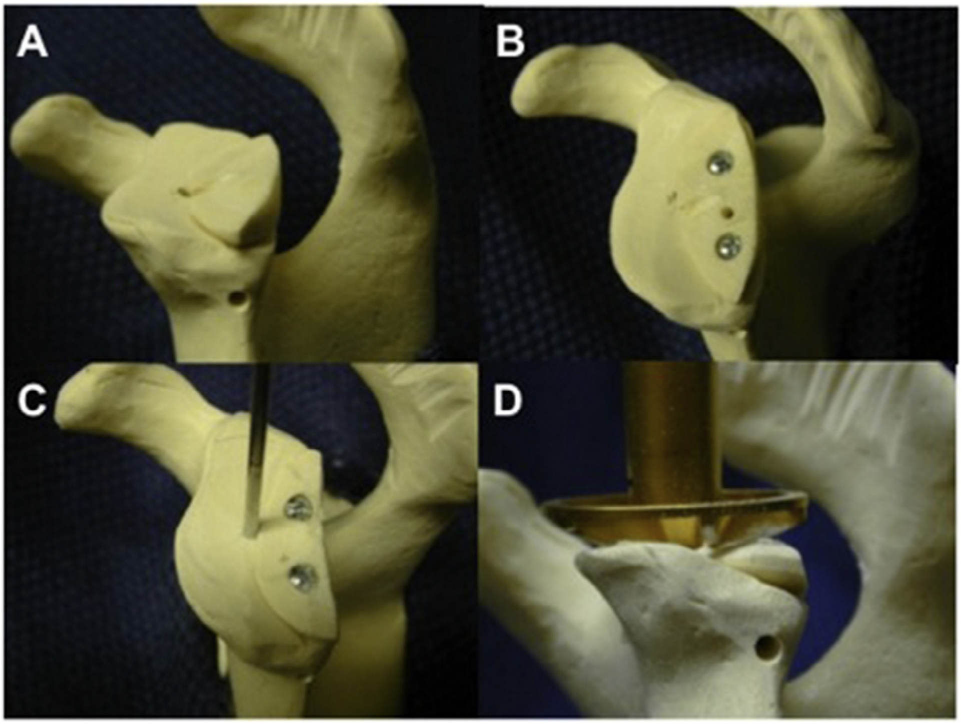

Figure 4 The cortical surfaces are placed flush **(A)**, and the posterior glenoid bone graft head segment is fixed in place with two 3.5-mm cortical screws that are drilled perpendicular to the surface through the graft and into the native glenoid bone **(B)**. The glenoid centering guide can now be placed on the new glenoid surface **(C)** and the center drill hole placed into the native glenoid **(D)**.

reaming to near perpendicular to the long axis of the scapula and has the potential to restore a more normal glenoid version. It also gives the surgeon a visual assessment of the extent of posterior glenoid. The surgeon can then assess whether it is possible to lower the front or whether it will be necessary to raise the back to restore the glenoid joint line position.

The drill guide is placed down the scapular neck and the guide pin placed. It should exit the anterior scapular surface approximately 3 cm medially and just below the crura of the coracoid base. The 2-piece cannulated reamer is now placed over the guide pin, with the reamer head placed first, followed by the cannulated driver (Fig. 2, *C* and *D*). Again, this is a straight-on approach with straight instruments. Typically, the reamer lowers the front to create a curved surface, although this is not an aggressive reaming. The preoperative assessment—and now the intraoperative assessment—of posterior glenoid bone loss confirms the need to also raise the back.

The arthritic joint surfaces are usually very well matched in the radius of curvature. The resected humeral head had been articulating with the most worn area of the glenoid. The size of the worn glenoid area is measured for length and width and the humeral head marked. With a small oscillating saw, a portion of the humeral head is resected in a straight-line fashion to create the “fan shape” needed to fill the defect (Fig. 3). The cortical surfaces are placed flush, such that they fit with almost no dead space (Fig. 4, *A*). Both surfaces are lightly “scarified” with a burr. The PGBG head segment is fixed in place with a smooth K-wire. Two 3.5-mm cortical screws are drilled perpendicular to the surface through the graft and into the native glenoid bone. They are tightened down through and below the

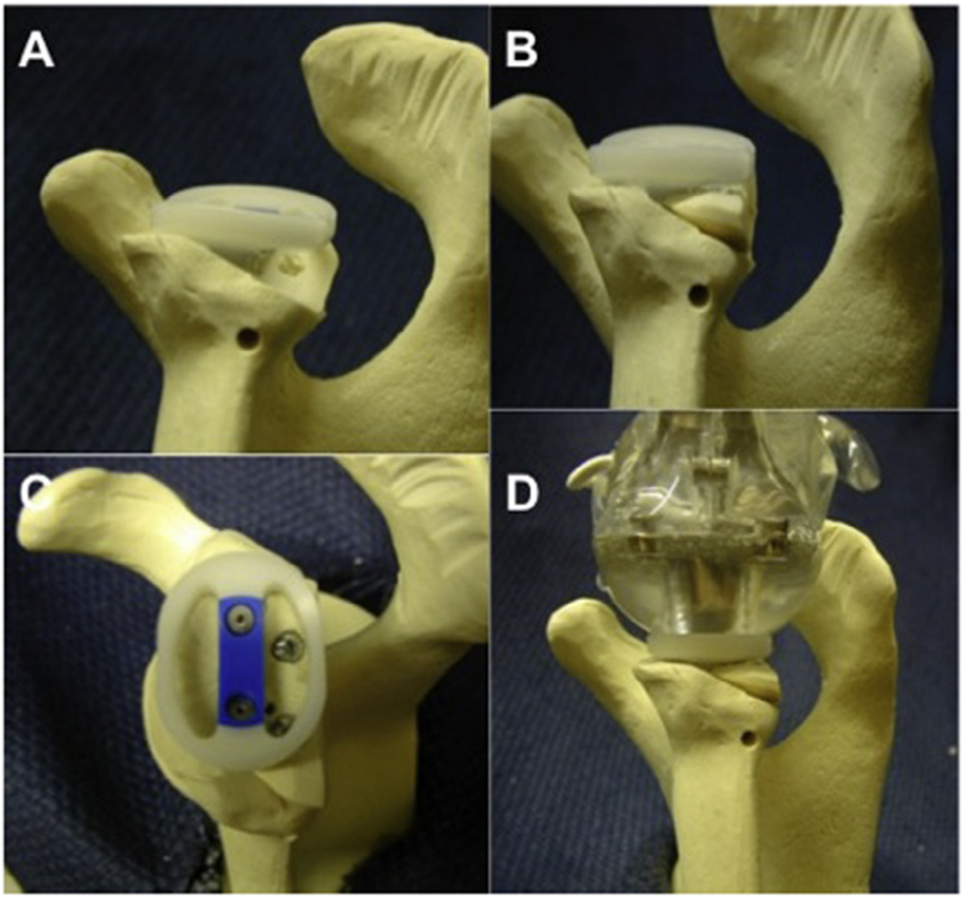

Figure 5 Once the appropriate preparation is completed **(A)** and the glenoid component is cemented into place **(B)**, the final components are placed in the glenoid **(C)** to articulate with the replaced humeral head **(D)**.

cancellous graft surface and onto the underside of the subchondral or endosteal surface of the humeral head graft to avoid screw head prominence (Fig. 4, *B*). The screw heads are below the cancellous surface and compress the endosteal surface (or undersurface of the humeral head cortical bone) onto the matching glenoid surface. In this way the polyethylene contacts the cancellous surface of the posterior glenoid bone graft and the native glenoid but does not contact the screw head.

The guide pin can be placed back into the center hole and the surface lightly reamed if necessary. The glenoid centering guide can now be placed on the "new" glenoid surface and the center drill hole placed into the native glenoid (Fig. 4, *C* and *D*). Either keeled or in-line pegged components can be used. The technique does not lend itself to peripheral peg configurations. The peg holes or keel preparations are placed in the native glenoid bone. The appropriate preparation is completed and the glenoid component is cemented into place, with cement in the native glenoid vault ensuring apposition of the component on the osseous surface of the native glenoid and the posterior glenoid bone graft from the humeral head (Figs. 5 and 6). In this series there were 22 in-line 3-peg glenoids (Zimmer) and 6 keeled glenoids (Tornier, Minneapolis, MN, USA).

An important technical point needs to be repeated: Because of the wear of the humerus on the posterior glenoid, the matching concavity of the glenoid defect and the convexity of the humeral head make an ideal interface for bone graft fixation. As opposed to other previously described glenoid bone grafting techniques, we use this smooth interface and place the cortical portion of the resected humeral head against the cortical portion of the glenoid defect.

Outcomes

Patient demographic characteristics, including age, sex, and laterality, were extracted from medical records. Patient-reported outcomes were collected preoperatively and postoperatively at most recent follow-up. The visual analog scale pain score, Simple Shoulder Test score, and American Shoulder and Elbow Surgeons score were considered. Range of motion, obtained with a goniometer at the senior surgeon's routine preoperative and postoperative physical examinations, was recorded preoperatively and postoperatively. Complications and reoperations were also evaluated.

Statistical analysis

Statistical analysis was performed using SPSS software (version 18; SPSS, Chicago, IL, USA). Descriptive statistics were calculated initially. Data were confirmed to be normal in distribution. Preoperative and postoperative scores and range of motion were compared with paired Student *t* tests. Significance was set at $P < .05$.

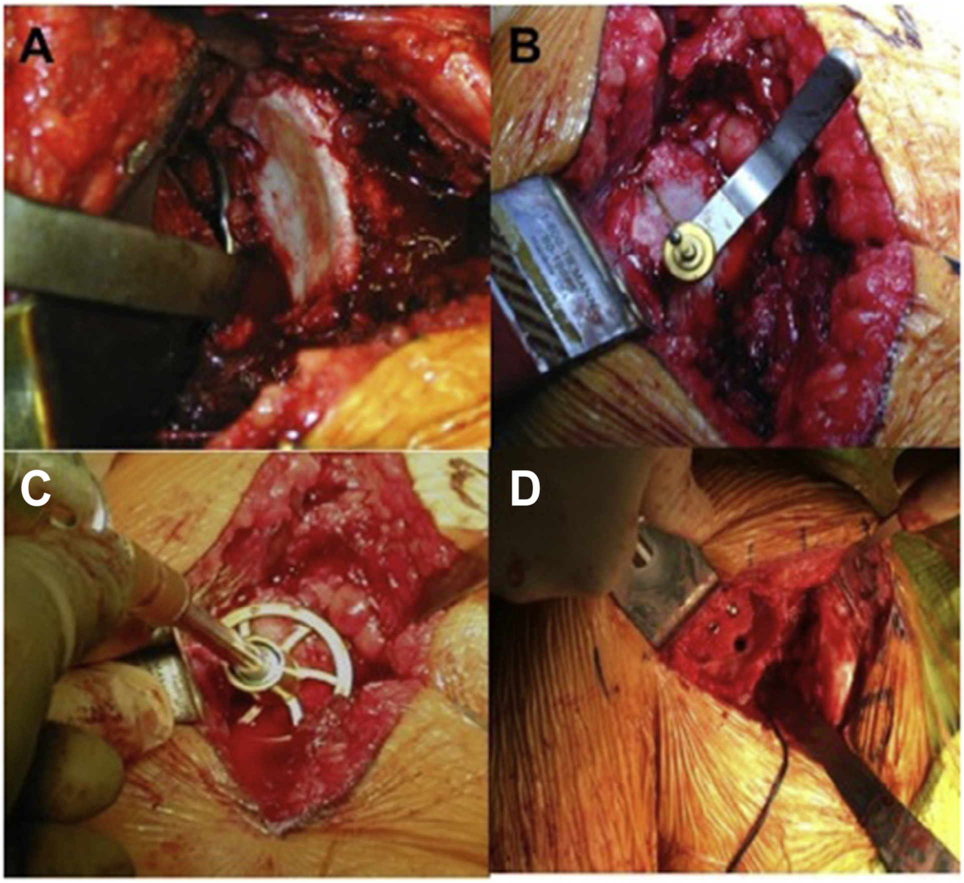

Figure 6 Posterior glenoid bone grafting with humeral head autograft. **(A)** Glenoid exposure revealing severe glenoid posterior wear and retroversion. **(B)** Cannulated drill guide used to place guide pin down center of glenoid. **(C)** Cannulated reamer used to prepare glenoid surface. **(D)** Humeral head fitted to posterior glenoid defect after light decortication and fixed with two 3.5-mm screws buried under cancellous surface. The glenoid component is then cemented in place in typical fashion (not shown).

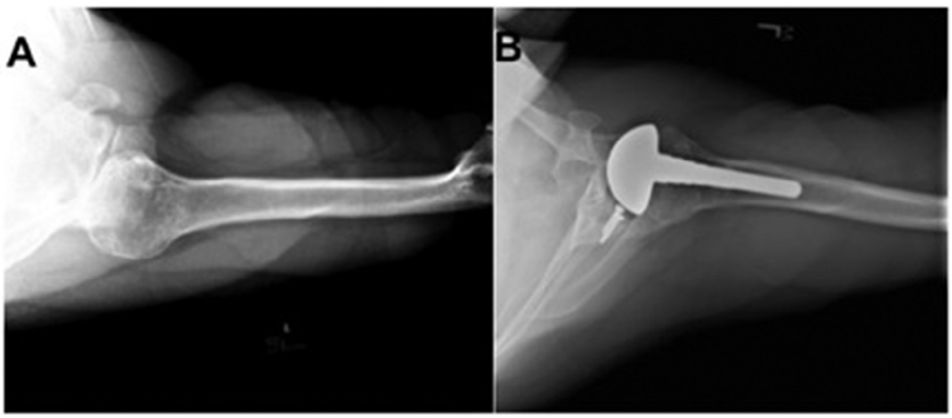

Figure 7 Preoperative **(A)** and postoperative **(B)** axillary radiographs show correction of glenoid retroversion and posterior humeral subluxation with a healed and incorporated graft after posterior glenoid bone grafting.

Results

Of the 34 consecutive patients who underwent TSA with PGBG from 2004 to 2014, 28 (82.4%) met the inclusion and exclusion criteria and were available for minimum 2-year clinical and radiographic follow-up (mean follow-up, 4.0 ± 2.3 years; range, 2-10.5 years). Patients were aged on average 61.4 ± 10.3 years (range, 33-76 years) and were predominantly

Table I Improvements in glenoid retroversion and humeral head subluxation after total shoulder arthroplasty with posterior glenoid bone grafting

	Preoperative	Postoperative	*P* value
Glenoid retroversion, °	28 ± 4	4 ± 2	<.001
Humeral head subluxation, °			
Scapular axis	87 ± 11	60 ± 5	<.001
Midglenoid face	69 ± 5	49 ± 5	<.001

men (26 of 28, 92.9%). Most procedures were performed on the right arm (22 of 28, 78.6%). There were 13 type B1 and 15 type B2 glenoids. No congenital type C dysplastic glenoids were included.

PGBG corrected glenoid retroversion from a preoperative radiographic average of –28° ± 4° (range, –42° to –20°) and advanced imaging average of –28° ± 5° to a radiographic average of –4° ± 2° (range, –9° to 0°) postoperatively ($P < .001$) (Table I). Humeral head subluxation also improved after PGBG with respect to the scapular axis (87° ± 11° to 60° ± 5°, $P < .001$) and to the midglenoid face (69° ± 5° to 49° ± 5°, $P < .001$) (Table I). Radiographs at follow-up revealed all PGBGs had incorporated. Radiographically, 3 patients (10.7%) were observed to have 5 broken or displaced screws (8.9% of all total screws). In addition, 3 patients (10.7%) had a broken center peg metal marker in the glenoid component. There were no progressive lucent lines and no osteolysis, and only 2 glenoids (5.9%) had a 1-mm line around the inferior peg. One patient required a capsular release for stiffness 9 months after the initial surgical procedure. This patient had diabetes and a positive smoking history. He admitted that he did not curtail his nicotine intake or adequately control his insulin levels during the preoperative or postoperative period. No other patients required revision surgery by final follow-up.

Patients showed significant improvements in the visual analog scale pain score ($P < .001$), Simple Shoulder Test score ($P < .001$), functional score ($P < .001$), American Shoulder and Elbow Surgeons score ($P < .001$), and motion (forward flexion, internal rotation, and external rotation; $P < .001$) (Table II).

Table II Patient outcomes and range of motion after total shoulder arthroplasty with posterior glenoid bone grafting

	Preoperative	Postoperative	*P* value
VAS pain score	5 ± 2	1 ± 1	<.001
SST score	4 ± 3	10 ± 2	<.001
Functional score	11 ± 6	25 ± 4	<.001
ASES score	39 ± 18	90 ± 10	<.001
Forward flexion, °	89 ± 24	149 ± 19	<.001
Internal rotation, °	28 ± 14	47 ± 12	<.001
External rotation, °	19 ± 11	56 ± 13	<.001

ASES, American Shoulder and Elbow Surgeons; SST, Simple Shoulder Test; VAS, visual analog scale.

Discussion

Posterior glenoid bone loss occurs in patients with degenerative osteoarthritis, resulting in an increase in glenoid retroversion. The options for patients with severe posterior glenoid wear are to either lower the front or raise the back to prevent early component failure associated with retroversion. Lowering the front would entail significant reaming with loss of glenoid surface and vault. Hemiarthroplasty is also an option for this patient population, and in an older population, reverse TSA has been discussed as an option in severe posterior glenoid wear patterns. More recently, augmented glenoid components have also been used to attempt to raise the back with polyethylene and normalize version. We report average 4-year outcomes of patients undergoing TSA for severe posterior wear using the native humeral head for PGBG. PGBG resulted in significant improvements in glenoid version, humeral head subluxation, patient-reported outcomes, and range of motion. All grafts were incorporated and there were no revisions, although several patients had asymptomatic broken screws and glenoid component pegs.

One of the most common complications of TSA is glenoid loosening as well as instability due to component malposition.[27] Correction of excessive glenoid retroversion with a posterior glenoid bone graft allows a reduction in the amount of edge loading that occurs at the glenoid component–bone interface. Reducing these nonbalanced forces decreases the probability that a glenoid will become unstable and problematic in the future.

Other authors have recognized the posterior glenoid wear pattern, and PGBG has been described.[10,20,25] However, those descriptions have not been specific regarding the details of the technique. In the few series available, there have been a variety of diagnoses and a combination of both posterior and anterior defects that were grafted, both with autografts and with allografts. In the original article and description of Neer and Morrison,[20] the series included patients in whom there were 20 fixed grafts and 45 smaller unfixed grafts, with only 15 posteriorly fixed grafts. Indications for surgery also varied, including rheumatoid arthritis, post-capsulorrhaphy degenerative arthritis, and osteoarthritis. It is difficult to draw conclusions on the posterior glenoid wear pattern treated with PGBG from this series.[20]

Similarly, Hill and Norris[10] reported a series of 17 glenoid bone grafts for glenoid wear or insufficiency. However, they did not have a similar population, with indications including chronic anterior fracture-dislocation, osteoarthritis, capsulorrhaphy degenerative joint disease, and inflammatory joint disease. In addition, they used both humeral head and iliac crest grafts, both anteriorly and posteriorly. In their series, 8 of 17 patients went on to have component failure, requiring revision surgery despite grafting at the time of initial surgery; however, it is difficult to make conclusions on the factors that led to failure given the study's heterogeneous group.

The glenoid component positioning relies on reaming to correct version and adequate bone stock to support the implant. When faced with posterior glenoid bone loss, the anterior glenoid can be reamed to lower the front and level to the posterior surface, re-creating glenoid version. This technique can be used in cases of minor changes in glenoid version; however, if a severe defect is present, this may require excess removal of anterior bone stock, potentially leaving the glenoid in residual retroversion if not leveled. Removing a significant amount of anterior bone stock can also leave the glenoid component at risk of loosening if there is insufficient residual bone to support the implant. Finally, removal of anterior bone stock can lead to medialization of the glenohumeral joint line, altering soft-tissue tension and joint mechanics.[27] Clavert et al[3] in a cadaveric study determined that retroversion greater than 15° cannot be corrected by eccentrically reaming anteriorly; this finding has similarly been echoed in subsequent cadaveric studies and models.[7,21]

In contrast, PGBG can correct version, provide a solid foundation for glenoid component seating, and protect against glenoid vault penetration.[27] PGBG offers the advantage of preserving anterior bone to provide a foundation for implant seating while avoiding vault penetration, maintains joint kinematics, and provides the potential for restoring bone stock to the deficient glenoid. The main disadvantage of PGBG is the potential for the graft to not heal, as a result of either movement, graft dissolution, nonunion, or fixation failure. However, as shown in our study, with the correct indications and technique, PGBG can be a very successful option for treatment of posterior glenoid bone loss and resultant retroversion. The consistent incorporation of the graft in this series may be a result of the cortex-to-cortex matched surfaces of glenoid to humeral head graft, the compression of those surfaces by the screw technique that does not allow any cement to extrude between the surfaces, and the normalization of load on the corrected glenoid version. Newer studies have also begun to examine the use of augmentations for treatment of posterior glenoid bone loss. However, clinical results using augmented glenoid components are just now being reported with over 2 years' follow-up.[23,31,34] In addition, more bone may need to be reamed away posteriorly to create a uniform surface for the augmented component. Augmentations may introduce shear stress across the glenoid-bone interface, compromising stability and leading to early loosening and failure.[5,14,26,33]

Our series of patients represents a homogeneous consecutive group of patients with severe posterior glenoid wear from glenohumeral osteoarthritis, treated with PGBG using humeral head autograft and a consistent fixation technique. We had over 80% follow-up at a mean of 4 years and minimum of 2 years, and the longest-term follow-up was more than 10 years. Our surgical technique provides a reproducible and reliable outcome with limited complications. The ability to use a portion of the humeral head that is already contoured to the shape of the patient's posterior glenoid defect decreases the intraoperative steps and increases one's ability to effectively re-create the patient's correct anatomic version and proper glenoid contour. The placement and internal fixation of the subchondral surface of the glenoid against the subchondral surface of the humeral head offer many advantages over previously described techniques. Leaving the cancellous portion of the humeral head exposed gives the surgeon the ability to countersink 3.5-mm screws beneath the graft while still obtaining secure fixation against the deep subchondral bone. We acknowledge the concern that the subchondral bone of the glenoid against the subchondral bone of the humeral head may not provide as optimal an interface for consolidation; however, this has not been an issue in our series. We attribute this to our surgical technique, which involves significant preparation and scoring of both interfaces prior to screw fixation. The strong compression that is obtained between the 2 subchondral surfaces prevents cement from becoming entrapped between the bone graft and the glenoid, which would decrease overall bone remodeling and healing. To successfully implement this technique, it is critical to perform anterior, posterior, and inferior releases of the surrounding capsule and soft tissues that are adherent to the patient's glenoid. This will allow the necessary exposure needed to place the graft and properly secure it with internal fixation. Removal of glenoid rim osteophytes is also paramount so that the graft is properly sized prior to internal fixation.

There are some limitations to our study. Postoperatively, no advanced imaging was obtained, with glenoid version and humeral subluxation measured from an axillary radiograph. As a result, version preoperatively was also measured from preoperative radiographs for consistency. All patients presented with consolidation of their bone grafts on plain radiographs and well-functioning shoulders, although advanced imaging was not obtained postoperatively for confirmation of graft incorporation. There were 5 broken screws in 3 patients. In one patient, one screw was broken, the other screw was displaced, and the glenoid was displaced 9 years postoperatively after a virulent form of Parkinson disease developed. At 8 years, he had normal radiographs. However, during the next year, the disease developed and the patient had multiple falls. The second patient had one broken screw and a displaced screw at 9 years' follow-up. The glenoid component had shifted position, but the patient remained functional with minimal pain. No revision has been planned. The third patient had one broken screw at 7 years but minimal functional impact. No revision is planned. Three patients had breakage of center peg metal markers but had no associated symptomatic complaints or decreased function, and these radiographic findings are being monitored with annual follow-up. Our level IV retrospective case series of PGBG does not allow us to directly compare results of PGBG with those of eccentric anterior reaming or glenoid component posterior augmentation. Future studies will be needed to compare treatment options for glenohumeral osteoarthritis with severe posterior wear to establish which option provides the best and most durable outcomes. Our study had a high rate of follow-up at a minimum of 2 years and mean of 4 years. Longer-term follow-up will also be required to determine the longevity of PGBG with TSA for glenohumeral osteoarthritis with severe posterior wear.

The salient points from our series are as follows:

- The posterior glenoid wear pattern is not symmetrical and is posterior-inferior and not a 12- to 6-o'clock pattern. It is almost exclusively a male pattern arthritic issue.
- The concave-to-convex surfaces match almost perfectly to allow positioning, screw compression, and healing with no cement extrusion between the surfaces. No further bone removal or reaming is necessary posteriorly with the technique.
- The humeral head graft can be tailored to fit almost any size of defect, but we acknowledge that we do not determine a "minimum" size of defect to graft.
- A glenoid component with an in-line keel or peg configuration should be used with the PGBG technique.
- All grafts were incorporated, and correction of severe retroversion and elimination of posterior humeral head subluxation were maintained.
- Not all patients with posterior glenoid wear patterns are candidates for this technique, but the PGBG technique adds a viable option for the shoulder arthroplasty surgeon.

Conclusion

Posterior glenoid bone erosion in the presence of osteoarthritis is not an uncommon finding prior to TSA. One must be prepared to correct this deformity prior to glenoid implantation or run the risk of early glenoid loosening and instability. Our unique PGBG technique allows one to correct significant glenoid defects with a high rate of incorporation and a low rate of complications. The necessity for this procedure is not frequent, as our overall percentage of patients requiring this technique was only 20% of our TSA population. However, in these specific cases, not performing this technique would have led to suboptimal results. This is a technically demanding procedure that should ideally be performed by surgeons who are well versed in the placement of TSAs.

Disclaimer

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References

1. Bicos J, Mazzocca A, Romeo AA. The glenoid center line. Orthopedics 2005;28:581-5. http://dx.doi.org/10.3928/0147-7447-20050601-14
2. Bryce CD, Davison AC, Okita N, Lewis GS, Sharkey NA, Armstrong AD. A biomechanical study of posterior glenoid bone loss and humeral head translation. J Shoulder Elbow Surg 2010;19:994-1002. http://dx.doi.org/10.1016/j.jse.2010.04.010
3. Clavert P, Millett PJ, Warner JJ. 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
4. Farron A, Terrier A, Buchler 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
5. Favorito PJ, Freed RJ, Passanise AM, Brown MJ. Total shoulder arthroplasty for glenohumeral arthritis associated with posterior glenoid bone loss: results of an all-polyethylene, posteriorly augmented glenoid component. J Shoulder Elbow Surg 2016;25:1681-9. http://dx.doi.org/10.1016/j.jse.2016.02.020
6. 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.
7. Gillespie R, Lyons R, Lazarus M. Eccentric reaming in total shoulder arthroplasty: a cadaveric study. Orthopedics 2009;32:21. http://dx.doi.org/10.3928/01477447-20090101-07
8. Habermeyer P, Magosch P, Luz V, Lichtenberg S. Three-dimensional glenoid deformity in patients with osteoarthritis: a radiographic analysis. J Bone Joint Surg Am 2006;88:1301-7. http://dx.doi.org/10.2106/JBJS.E.00622
9. Hendel MD, Werner BC, Camp CL, Gulotta LV, Walch G, Dines DM, et al. Management of the biconcave (B2) glenoid in shoulder arthroplasty: technical considerations. Am J Orthop (Belle Mead NJ) 2016;45:220-7.
10. 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.
11. Ho JC, Sabesan VJ, Iannotti JP. Glenoid component retroversion is associated with osteolysis. J Bone Joint Surg Am 2013;95:e82. http://dx.doi.org/10.2106/JBJS.L.00336
12. 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;22:1298-308. http://dx.doi.org/10.1016/j.jse.2013.04.014
13. Iannotti JP, Norris TR. Influence of preoperative factors on outcome of shoulder arthroplasty for glenohumeral osteoarthritis. J Bone Joint Surg Am 2003;85:251-8.
14. 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
15. 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

16. Knowles NK, Ferreira LM, Athwal GS. The arthritic glenoid: anatomy and arthroplasty designs. Curr Rev Musculoskelet Med 2016a;9:23-9. http://dx.doi.org/10.1007/s12178-016-9314-2
17. Knowles NK, Ferreira LM, Athwal GS. Premorbid retroversion is significantly greater in type B2 glenoids. J Shoulder Elbow Surg 2016b;25:1064-8. http://dx.doi.org/10.1016/j.jse.2015.11.002
18. 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;24:503-10. http://dx.doi.org/10.1016/j.jse.2014.08.021
19. Meyer NJ, Pennington WT, Ziegler DW. The glenoid center point: a magnetic resonance imaging study of normal scapular anatomy. Am J Orthop (Belle Mead NJ) 2007;36:200-2.
20. Neer CS II, Morrison DS. Glenoid bone-grafting in total shoulder arthroplasty. J Bone Joint Surg Am 1988;70:1154-62.
21. 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
22. Nyffeler RW, Sheikh R, Atkinson TS, Jacob HA, Favre P, Gerber C. Effects of glenoid component version on humeral head displacement and joint reaction forces: an experimental study. J Shoulder Elbow Surg 2006;15:625-9. http://dx.doi.org/10.1016/j.jse.2005.09.016
23. Rice RS, Sperling JW, Miletti J, Schleck C, Cofield RH. 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
24. Rouleau DM, Kidder JF, Pons-Villanueva J, Dynamidis S, Defranco M, Walch G. Glenoid version: how to measure it? Validity of different methods in two-dimensional computed tomography scans. J Shoulder Elbow Surg 2010;19:1230-7. http://dx.doi.org/10.1016/j.jse.2010.01.027
25. 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
26. Sandow M, Schutz C. Total shoulder arthroplasty using trabecular metal augments to address glenoid retroversion: the preliminary result of 10 patients with minimum 2-year follow-up. J Shoulder Elbow Surg 2016;25:598-607. http://dx.doi.org/10.1016/j.jse.2016.01.001
27. Sears BW, Johnston PS, Ramsey ML, Williams GR. Glenoid bone loss in primary total shoulder arthroplasty: evaluation and management. J Am Acad Orthop Surg 2012;20:604-13. http://dx.doi.org/10.5435/JAAOS-20-09-604
28. Shapiro TA, McGarry MH, Gupta R, Lee YS, Lee TQ. Biomechanical effects of glenoid retroversion in total shoulder arthroplasty. J Shoulder Elbow Surg 2007;16:S90-5. http://dx.doi.org/10.1016/j.jse.2006.07.010
29. Steinmann SP. Cause of glenoid rim fracture. Arthroscopy 2009;25:1061-2, author reply 1062. http://dx.doi.org/10.1016/j.arthro.2009.07.003
30. 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;97:251-9. http://dx.doi.org/10.2106/JBJS.N.00566
31. Stephens SP, Spencer EE, Wirth MA. Radiographic results of augmented all-polyethylene glenoids in the presence of posterior glenoid bone loss during total shoulder arthroplasty. J Shoulder Elbow Surg 2017;26:798-803.
32. Walch G, Badet R, Boulahia A, Khoury A. Morphologic study of the glenoid in primary glenohumeral osteoarthritis. J Arthroplasty 1999;14:756-60.
33. Wang T, Abrams GD, Behn AW, Lindsey D, Giori N, Cheung EV. Posterior glenoid wear in total shoulder arthroplasty: eccentric anterior reaming is superior to posterior augment. Clin Orthop Relat Res 2015;473:3928-36. http://dx.doi.org/10.1007/s11999-015-4482-8
34. 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;73(Suppl 1):S79-85.