J Shoulder Elbow Surg (2015) ■, 1-6

ELSEVIER

Journal of Shoulder and Elbow Surgery

www.elsevier.com/locate/ymse

Outcomes of anatomic shoulder arthroplasty in primary osteoarthritis in type B glenoids

Paul C. Chin, MD, PhD[a], Michael E. Hachadorian, BS[b], Pamela A. Pulido, BSN[b], Michelle L. Munro, BS[b], Gokhan Meric, MD[b,c], Heinz R. Hoenecke Jr, MD[b,d,*]

[a]*Sterling Ridge Orthopaedics and Sports Medicine, The Woodlands, TX, USA*
[b]*Shiley Center for Orthopaedic Research and Education at Scripps Clinic, La Jolla, CA, USA*
[c]*Department of Orthopaedic Surgery, Balikesir University, Balikesir, Turkey*
[d]*Division of Orthopaedics, Scripps Clinic, La Jolla, CA, USA*

Background: Primary glenohumeral osteoarthritis with posterior wear of the glenoid and posterior subluxation of the humerus (Walch type B) presents a challenge to the treating surgeon. Our hypothesis was that glenoids with biconcavity (B2) would be associated with worse outcomes (functional scores and complications) than B1 glenoids.
Materials and methods: We retrospectively analyzed prospectively collected data on 112 anatomic total shoulder arthroplasties (104 patients) with B glenoids. Preoperative computed tomography identified 64 B1 glenoids and 48 B2 glenoids (50 and 37 available for follow-up).
Results: A significant difference between B1 and B2 glenoids was noted in average retroversion (11° vs. 16°; $P < .001$) and average posterior humeral subluxation (65% vs. 75%; $P < .001$). No significant difference was seen in mean age (69.5 vs. 69.2 years) or body mass index (28.5 vs. 27.4) at time of surgery. At average follow-up of 60 months (range, 23-120 months), glenoid component radiolucencies (51.6%, B1; 47.9%, B2), range of motion, preoperative and postoperative scores of the shortened Disabilities of the Arm, Shoulder, and Hand questionnaire, and patient satisfaction were not significantly different between the 2 groups. Four revisions (4.6%) were documented for acute postoperative infection (2.3%), subscapularis failure (1.1%), and glenoid loosening (1.1%).
Conclusions: Although biconcave glenoids commonly have more severe retroversion and posterior subluxation of the humerus, we were unable to find a clinical or radiographic difference in outcome of patients with B1 or B2 glenoids treated with anatomic total shoulder arthroplasty at intermediate-term follow-up. Continued clinical and radiographic follow-up of these cohorts will be necessary to assess any future divergence in outcome.
Level of evidence: Level III, Retrospective Cohort Design, Treatment Study.

Keywords: Anatomic total shoulder arthroplasty; primary osteoarthritis; biconcave glenoid; type B glenoid

Primary shoulder osteoarthritis is a debilitating condition characterized by progressive loss of shoulder function and pain. Roughly 20,000 to 25,000 total shoulder arthroplasties (TSAs) were performed in the United States

This study received approval from the Scripps Institutional Review Board: No. IRB-13-6297. All patients consented to participate.

*Reprint requests: Heinz R. Hoenecke, Jr., MD, 10666 N Torrey Pines Rd, MS 116, La Jolla, CA 92037, USA.

E-mail address: hhoenecke@gmail.com (H.R. Hoenecke Jr.).

1058-2746/$ - see front matter © 2015 Journal of Shoulder and Elbow Surgery Board of Trustees.
http://dx.doi.org/10.1016/j.jse.2015.05.052

in 2007, with the potential to reach >40,000 procedures by 2015.[2] Initial descriptions recognized that glenohumeral arthritis often involved posterior erosion of the glenoid and posterior subluxation of the humeral head, which led to a classification of type B glenoids.[16,17,21] Although modifications have been made to prosthesis design leading to a history of good to excellent clinical outcomes in the majority of cases, a subset of patients remain who have poor outcomes leading to revision surgery.[11,12,22] As of 2004, the revision burden in the United States was roughly 7%, but it will continue to increase as the rate of primary arthroplasties increases.[2] Revision surgeries are necessary for a variety of factors including stiffness, polyethylene wear, periprosthetic fracture, infection, instability, rotator cuff tears, and component loosening.[12,20]

Prior work has documented the various morphologies of arthritic glenoids before surgical replacement and has recognized that roughly 32% of patients have a type B glenoid shape characterized by posterior subluxation of the humeral head and posterior wear of the glenoid.[21] Type B glenoids are composed of groups, B1 and B2. Biconcave glenoids (type B2) generally have more severe retroversion and posterior subluxation of the humerus. Attempts to correct the abnormal wear during implantation of the total shoulder prosthesis may lead to abnormal mechanics and joint reaction forces that may predispose the glenoid component to loosen and subsequently to fail.[7,8,11,12] Recently, Walch noted a 16% rate of revision surgery at an average follow-up of 77 months in patients treated with TSA for arthritis with biconcave glenoids. In that report, B2 glenoids with a neoglenoid retroversion of >27° carried a 44% risk of complication.[22]

Thus, elucidating a preoperative clinical or radiographic measure to predict the likelihood of failure would add tremendous benefit to treating patients with shoulder osteoarthritis.[9,10,13]

The purpose of this study was to assess the radiographic characteristics and clinical outcomes of anatomic TSA in patients with primary osteoarthritis with type B glenoids. Our hypothesis was that glenoids with biconcavity (B2) would be associated with worse outcomes, including decreased functional scores and higher rates of component loosening, complications, and revisions.

Methods

A retrospective analysis of prospectively collected data was used to identify 2 patient cohorts with type B glenoids (B1 and B2) who underwent anatomic TSA with a minimum follow-up of 24 months or until time of revision. Exclusion criteria included patients with type A and type C glenoid morphologies; patients with secondary causes of arthritis, including inflammatory disease, osteonecrosis, cuff tear arthropathy, and fracture; and shoulders without a preoperative computed tomography (CT) scan. Between 2004 and 2011, the senior author (H.R.H.) performed TSA for primary glenohumeral osteoarthritis on 170 shoulders (146 patients). This included 53 shoulders with type A glenoids (36, A1; 17, A2), 112 shoulders (104 patients) with type B glenoids, and 5 shoulders with type C glenoids. We identified 64 B1 glenoids and 48 B2 glenoids. Of these, 87 shoulders (81 patients) had at least 2 years of follow-up with complete records and were included for analysis (50 B1 glenoids and 37 B2 glenoids). Eighteen shoulders (18 patients) were lost to follow-up, and 7 shoulders (6 patients) were deceased with unknown revision status at 2 years postoperatively. The mean clinical follow-up was 60 months (range, 23-120 months). Our series included 37 women (45.7%) and 44 men (54.3%) with an average age at surgery of 69 years (range, 48-85 years). Preoperative clinical data collection included the shortened Disabilities of the Arm, Shoulder, and Hand questionnaire (QuickDASH) and range of motion testing. According to standard preoperative protocols, all patients had preoperative radiographic images including anteroposterior, Grashey, axillary, and scapular Y views as well as a CT scan of the affected extremity.

Measurements of version and subluxation were determined from the CT scan axial plane image corresponding to the center of glenoid on the sagittal and coronal plane images. Humeral head subluxation was determined relative to the scapular axis as described by Walch and colleagues.[12] Subluxation ratios between 0.45 and 0.55 are considered normal (centered), whereas shoulders with subluxation ratios >0.55 are considered to be posteriorly subluxated. Shoulders with posterior subluxation ratios >0.55 were classified as B1 glenoids, and shoulders with posterior subluxation ratios >0.55 and with a posterior cupula or biconcavity were considered B2 glenoids.[21] For B2 glenoids, the intermediate glenoid and the neoglenoid version angles were measured according to previous published reports[4,12,19]; however, the intermediate glenoid represents the most reliable and clinically useful angle.[19]

All patients underwent anatomic TSA by a deltopectoral approach. Three implant systems were used during the study period: the PROMOS shoulder system (Smith & Nephew, Cordova, TN, USA) with either a cemented all-polyethylene pegged or keeled glenoid component; the Aequalis shoulder system (Tornier Inc., Edina, MN, USA) with either a cemented all-polyethylene pegged or keeled glenoid component; and the Aequalis Ascend shoulder system (Tornier) with a cemented all-polyethylene anchor pegged glenoid component. The PROMOS and Aequalis systems have standard humeral and glenoid components; the Aequalis Ascend system has a short humeral stem design and anchor pegged glenoid. We looked at the difference in results between the 3 implants.

To address either severe retroversion or a biconcave glenoid, the anterior glenoid was asymmetrically reamed to try and achieve retroversion between 0° and 10° with the limitation of removing less than 5 mm of bone. No glenoids in this cohort required structural posterior bone grafting procedures or an augmented glenoid component. Patients were routinely given a postoperative sling with an abduction pillow to wear for 4 weeks and participated in postoperative rehabilitation.

Postoperative evaluations included clinical and telephone follow-up. For clinical follow-up, range of motion testing, QuickDASH score, and a subjective satisfaction question were obtained. A telephone interview of all available patients included QuickDASH score, a question about any reoperations, and a subjective satisfaction question. No data on range of motion were obtained in the telephone interview. In addition, routine

Table I Demographic data

Descriptor	Type B1	Type B2	Significance
	N = 64	N = 48	
Age (years)	68.9	68.7	$P = .82$
Body mass index	28.5	27.3	$P = .14$
Gender (male/female)	50%/50%	39.4%/60.6%	$P = .35$

postoperative radiographic evaluation included Grashey, axillary, and scapular Y views to assess for radiographic lucencies or component migration. Glenoid radiolucencies were scored as reported previously by Franklin et al and Lazarus et al.[3,14] Humeral radiolucencies were classified by the zonal method according to the classification by Matsen et al.[15] Complications and reoperations were recorded.

Continuous variables such as age, body mass index (BMI), range of motion (forward flexion, abduction, and external rotation), and QuickDASH scores were assessed with Levene test for equality of variances and Student *t* test. Categorical variables such as gender, revision status, patient satisfaction, range of motion (internal rotation), and radiographic loosening were assessed with χ^2 tests. Analysis of the neoglenoid angle and resultant loosening was performed with Mann-Whitney test because of small sample size by grouping of loosening grade (G0, G1, and G2 vs. G3, G4, and G5). Results are reported as mean and standard deviation unless otherwise noted. Statistical significance was set at $P < .05$. SPSS 13.0 was used for all analyses (SPSS Inc., Chicago, IL, USA).

Results

The mean retroversion of all B1 glenoids (11° ± 7°) was significantly less than the mean retroversion of all B2 glenoids (17° ± 8°; $P < .001$). The mean posterior subluxation of the humerus was significantly less for B1 glenoids (65% ± 7%) than for B2 glenoids (75% ± 9%; $P < .001$). Of the B1 glenoids and B2 glenoids with clinical follow-up, retroversion (11° ± 8° and 16° ± 8°, respectively; $P = .002$) and posterior humeral subluxation (65% ± 7% and 75% ± 10%, respectively; $P < .001$) were also significantly different. Of the B2 glenoids, the average neoglenoid retroversion angle was 11° ± 7° (range, 2°-28°).

No significant demographic differences were observed between the B1 glenoid and B2 glenoid cohorts with regard to the average age at the time of TSA, gender, or BMI at the time of surgery (Table I). Four intraoperative complications were noted, including 1 greater tuberosity fracture, 1 glenoid fracture, 1 midsubstance deltoid tear, and 1 small humeral shaft fracture, but these did not affect eventual clinical outcome. The average follow-up, either clinical or by phone, was 60 months (range, 23-120). We identified 4 revisions (4.6%) during the study period (3 in B1 glenoids). Three revisions were acute (2 infections in B1 glenoids and 1 failed subscapularis repair in a B2 glenoid) at an average of 2 months from TSA. The fourth revision was due to glenoid loosening at 56 months after TSA.

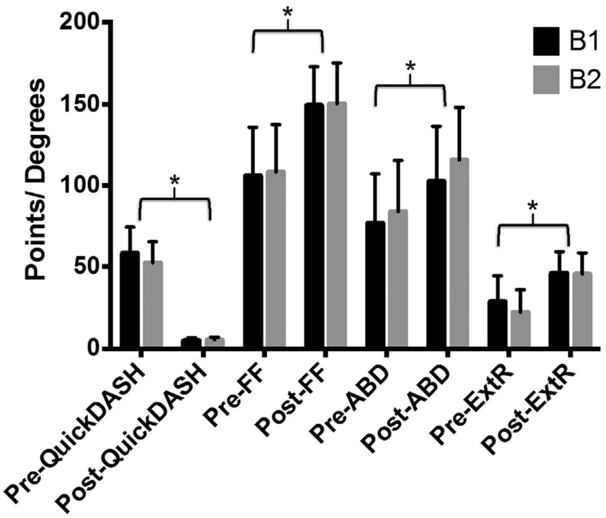

Figure 1 Chart illustrating mean and standard deviation of preoperative and postoperative data. *Significant differences were observed in comparing preoperative with postoperative data. However, no differences were observed between B1 and B2 glenoids. *FF*, forward flexion; *ABD*, abduction; *ExtR*, external rotation.

We observed significant differences in QuickDASH scores between preoperative and postoperative measures when comparing the entire cohort; however, there was no significant difference in QuickDASH scores by comparing glenoid morphology (B1 to B2; Fig. 1). Significant improvements in preoperative to postoperative range of motion were seen in the entire cohort (forward flexion, abduction, external rotation; Fig. 1); however, there were no significant differences in comparing B1 glenoid improvements to B2 glenoid improvements with regard to change in ranges of motion. Responses to the subjective satisfaction question (63 responses of 81 unrevised patients who were available for clinic follow-up) revealed that no patient was "dissatisfied" with the outcome. Of the responses, 94% (58 of 62) were either "very satisfied" or "satisfied," whereas only 6.5% (4 of 62) were "somewhat satisfied."

Radiographic characteristics

Roughly 62% of the radiographs demonstrated changes in zone 7 (medial calcar) of the humerus. These changes represented a spectrum from rounding of the calcar under the stem to frank osteolysis of the medial calcar. However, no stem had evidence of gross loosening. With regard to the glenoid components, 51.5% of the B1 glenoids and 47.9% of the B2 glenoids demonstrated some evidence of glenoid loosening from incomplete radiolucent lines around 1 peg or flange of the keel to gross loosening (Fig. 2). No evidence of significant difference in loosening between B1 and B2 glenoids was present. Furthermore, examination of loosening grades as a function of neoglenoid angle revealed

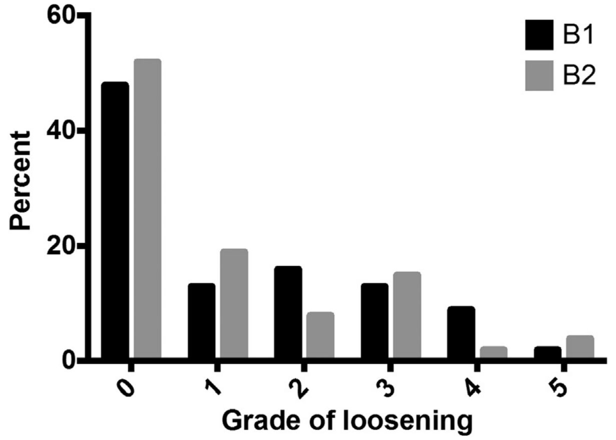

Figure 2 Radiolucency grade distribution by glenoid morphology. No significant differences were observed between B1 and B2 glenoids.

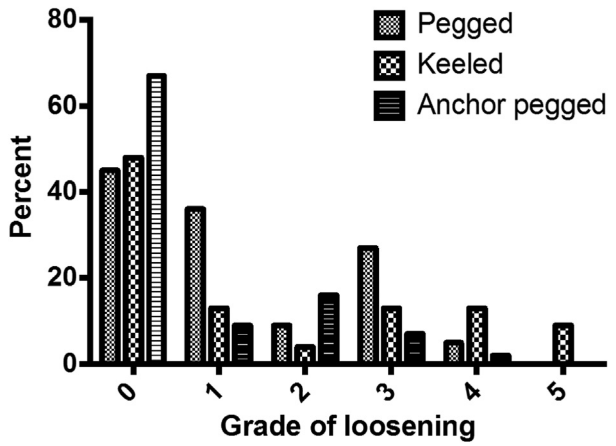

Figure 3 Radiolucency grade distribution by glenoid component design. No significant differences were seen between the glenoid component types.

no significant difference in neoglenoid angle ($P = .376$). In comparing the type of glenoid component (pegged, keeled, or anchor pegged), no significant difference in loosening was present (Fig. 3). The average radiographic follow-up of the pegged components was 53.1 $\pm$ 26.4 months; the keeled components, 48.5 $\pm$ 21.9 months; and the anchor pegged components, 25.1 $\pm$ 13 months.

Discussion

We sought to assess the radiographic characteristics and clinical outcomes of TSA in patients with primary osteoarthritis with type B glenoids and at least 2 years of follow-up. Characterizing radiographic qualities and clinical outcomes, specifically failures of treatment, in patients with type B1 and B2 glenoids will allow parameters to be established for the successful use of TSA. This is the first study attempting to differentiate the radiographic and clinical outcomes of 2 of the most common pathologic variants encountered in glenohumeral arthritis. Much debate exists in the literature about the ideal preoperative assessment of patients with type B glenoids. The challenge of identifying posterior subluxation of the humerus and glenoid retroversion is not without controversy. The options of plain radiography and 2-dimensional or 3-dimensional CT each have their advantages and disadvantages, but neither has attained universal acceptance in addressing the problems at the time of TSA.[4,8,9] The senior author (H.R.H.) routinely obtains a 3-dimensional CT scan for preoperative planning to assess the morphology of the glenoid, scapula, and humeral position.[8-10,13]

Prior large shoulder arthroplasty series have documented excellent functional outcomes, pain relief, patient satisfaction, and durability.[6,17,18] Our series in patients with posterior humeral subluxation, retroversion, and posterior wear demonstrates excellent functional outcomes, low revision rate, pain relief, good intermediate durability, and excellent patient satisfaction. The B1 and B2 glenoid cohorts that we identified demonstrated no difference in preoperative demographics, including age at the time of arthroplasty, gender, and BMI. Preoperative CT demonstrated significant differences in retroversion and posterior subluxation of the humerus. Contrary to our hypothesis, we observed no differences in QuickDASH score, range of motion, or complications between the B1 and B2 groups. In average follow-up of 60 months, we also found no postoperative radiographic differences in humeral or glenoid component loosening. In this population of challenging pathology, our data reflect a 4.6% (4 of 87) revision rate.

Iannotti and Norris in 2003 demonstrated that patients with posterior subluxation of the humerus had lower American Shoulder and Elbow Surgeons scores, more pain, and less active external rotation.[11] They deemed posterior subluxation associated with glenoid bone loss the most severe situation in advanced arthritis, and 7 of 9 of their failures were in this group. Boileau et al published a prospective, double-blind, randomized trial comparing uncemented metal-backed and cemented polyethylene glenoid components, and 3 of only 4 failures were in the metal-backed group in patients with preoperative biconcave glenoids and posterior humeral subluxation.[1] Gerber et al in 2009 investigated a series of shoulders that had static posterior subluxation of the humeral head before TSA.[5] They found, however, excellent clinical outcome and patient satisfaction and reported no failures.

Recently, Walch et al demonstrated results of clinical outcomes in a population of B2 glenoids.[22] Although the clinical outcomes were acceptable, the revision rate was high at 16%. Walch and colleagues noted loose glenoids in 20.6% of their cohort by radiolucent line scores >12. Similarly, in our cohorts, combining radiolucency grades 3, 4, and 5 yields loosening present in 23.4% of B1 glenoids and 20.8% of B2 glenoids. Furthermore, these combinations of radiolucency grades yield no significant difference when B2 neoglenoid version angles are examined. For loose glenoids in the Walch study, the average time to revision was 96 months. When the neoglenoid was 27° or more, they observed 73% of their complications. Despite this large neoglenoid retroversion, Walch and colleagues no longer recommend the use of concomitant bone grafting procedures with TSA because of a high complication rate. We present this series without the need for posterior bone grafting. In the study of Walch et al, there were 92 B2 glenoids, and the average neoglenoid angle was 25° with a range of 9° to 48°.[22] In our series, the average neoglenoid version angle was 11° with a range of 2° to 28°. This difference may help explain the decreased complication rate that we have observed, given Walch's observation that neoglenoid angles >27° are associated with a 44% risk of complication.

A new morphologic classification of B type glenoids with posterior subluxation and retroversion has recently been proposed (Gilles Walch, personal communication). This classification (B3 glenoid) attempts to identify a subset of arthritic glenohumeral morphology that poses a great treatment difficulty. We identified 7 B3 glenoids using preoperative CT measurement parameters of retroversion >12° and posterior subluxation of the humerus >70% in glenoids without biconcavity that, compared with our B1 and B2 cohorts, had significantly worse radiographic loosening on follow-up images (data not shown). Combined with Walch and colleagues' previous work with biconcave glenoids,[22] identification of the glenohumeral changes that present the biggest surgical challenges continues to evolve.

Walch et al in 2012 reported grade 5 loosening (radiolucency of >2 mm over the entire bone-cement interface) in 32% of keeled glenoid components in a multicenter study with >60 months of follow-up.[23] These results underscore the importance of maintaining good subchondral support for glenoid components to prevent loosening. In our B1 and B2 glenoid cohorts with a keeled glenoid component follow-up of 48.5 months, we observed grade 5 loosening in 9% of the keeled glenoid components.

Wirth et al, in 2012, published a series of shoulders undergoing TSA with an anchor pegged glenoid design.[24] They demonstrated significant improvements in clinical outcome scores and radiographic loosening (grade 5) of only 3% at an average follow-up of 4 years. Our experience with anchor pegged glenoids is similar, with no evidence of grade 5 loosening but with 16% that demonstrated osteolysis around the central peg (grade 2). Hence, these are glenoids that we will monitor closely for evidence of clinical or further radiographic deterioration.

The limitations of our study are apparent. First, we performed a retrospective review of our database to compare only the B1 and B2 glenoids. Although it is a large cohort, the ability to define a clinically significant difference between the 2 groups may require a larger cohort or longer follow-up. The preferred implants, including the humeral stems and glenoid components, changed multiple times through the duration of the study, which may have affected our results. However, 1 surgeon with a consistent surgical technique was a reliable constant in compiling the study database. Unfortunately, we were unable to compare preoperative retroversion and subluxation with postoperative measurements because CT scans were not done routinely in the postoperative period. Nevertheless, the strength of this study is the large samples of B1 and B2 glenoids that demonstrate excellent clinical and radiographic clinic outcome at intermediate follow-up.

Conclusion

Our retrospective comparative study of patients with glenohumeral osteoarthritis with type B1 and B2 glenoids undergoing TSA has demonstrated excellent clinical outcome. We found no difference in either clinical outcome or radiographic outcome between the B1 glenoids and B2 glenoids. We found no significant difference in the utilization of different humeral or glenoid component designs. Our follow-up at this time is intermediate at an average of 60 months, so continued follow-up will be important to assess any further divergence in outcomes.

Acknowledgment

The authors wish to acknowledge Scripps Clinic Medical Group grant funding and Joshua M. Matthews, MD (San Diego Arthroscopy and Sports Medicine Fellowship), for CT scan analysis.

Disclaimer

Heinz R. Hoenecke is a consultant for and receives royalties from Tornier. All the other authors, their immediate families, and any research foundation 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. Boileau P, Avidor C, Krishnan SG, Walch G, Kempf JF, Mole D. Cemented polyethylene versus uncemented metal-backed glenoid components in total shoulder arthroplasty: a prospective, double-blind, randomized study. J Shoulder Elbow Surg 2002;11:351-9. http://dx.doi.org/10.1067/mse.2002.125807

2. Day JS, Lau E, Ong KL, Williams GR, Ramsey ML, Kurtz SM. Prevalence and projections of total shoulder and elbow arthroplasty in the United States to 2015. J Shoulder Elbow Surg 2010;19:1115-20. http://dx.doi.org/10.1016/j.jse.2010.02.009
3. Franklin JL, Barrett WP, Jackins SE, Matsen FA 3rd. Glenoid loosening in total shoulder arthroplasty. Association with rotator cuff deficiency. J Arthroplasty 1988;3:39-46.
4. 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.
5. Gerber C, Costouros JG, Sukthankar A, Fucentese SF. Static posterior humeral head subluxation and total shoulder arthroplasty. J Shoulder Elbow Surg 2009;18:505-10. http://dx.doi.org/10.1016/j.jse.2009.03.003
6. Godeneche A, Boileau P, Favard L, Le Huec JC, Levigne C, Nove-Josserand L, et al. Prosthetic replacement in the treatment of osteoarthritis of the shoulder: early results of 268 cases. J Shoulder Elbow Surg 2002;11:11-8. http://dx.doi.org/10.1067/mse.2002.120140
7. 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
8. Hoenecke HR Jr, Hermida JC, Dembitsky N, Patil S, D'Lima DD. Optimizing glenoid component position using three-dimensional computed tomography reconstruction. J Shoulder Elbow Surg 2008;17:637-41. http://dx.doi.org/10.1016/j.jse.2007.11.021
9. Hoenecke HR Jr, Hermida JC, Flores-Hernandez C, D'Lima DD. Accuracy of CT-based measurements of glenoid version for total shoulder arthroplasty. J Shoulder Elbow Surg 2010;19:166-71. http://dx.doi.org/10.1016/j.jse.2009.08.009
10. Hoenecke HR Jr, Tibor LM, D'Lima DD. Glenoid morphology rather than version predicts humeral subluxation: a different perspective on the glenoid in total shoulder arthroplasty. J Shoulder Elbow Surg 2012;21:1136-41. http://dx.doi.org/10.1016/j.jse.2011.08.044
11. Iannotti JP, Norris TR. Influence of preoperative factors on outcome of shoulder arthroplasty for glenohumeral osteoarthritis. J Bone Joint Surg Am 2003;85-A:251-8.
12. Kidder JF, Rouleau DM, Pons-Villanueva J, Dynamidis S, DeFranco MJ, Walch G. Humeral head posterior subluxation on CT scan: validation and comparison of 2 methods of measurement. Tech Shoulder Elbow Surg 2010;11:72-6. http://dx.doi.org/10.1097/BTE.0b013e3181e5d742
13. Landau JP, Hoenecke HR. Genetic and biomechanical determinants of glenoid version: implications for glenoid implant placement in shoulder arthroplasty. J Shoulder Elbow Surg 2009;18:661-7. http://dx.doi.org/10.1016/j.jse.2008.11.012
14. Lazarus MD, Jensen KL, Southworth C, Matsen FA 3rd. The radiographic evaluation of keeled and pegged glenoid component insertion. J Bone Joint Surg Am 2002;84-A:1174-82.
15. Matsen FA 3rd, Iannotti JP, Rockwood CA Jr. Humeral fixation by press-fitting of a tapered metaphyseal stem: a prospective radiographic study. J Bone Joint Surg Am 2003;85-A:304-8.
16. Neer CS 2nd. Replacement arthroplasty for glenohumeral osteoarthritis. J Bone Joint Surg Am 1974;56:1-13.
17. Neer CS 2nd, Watson KC, Stanton FJ. Recent experience in total shoulder replacement. J Bone Joint Surg Am 1982;64:319-37.
18. 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
19. 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
20. Sperling JW, Hawkins RJ, Walch G, Zuckerman JD. Complications in total shoulder arthroplasty. J Bone Joint Surg Am 2013;95:563-9.
21. Walch G, Badet R, Boulahia A, Khoury A. Morphologic study of the glenoid in primary glenohumeral osteoarthritis. J Arthroplasty 1999;14:756-60.
22. 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
23. Walch G, Young AA, Boileau P, Loew M, Gazielly D, Mole D. Patterns of loosening of polyethylene keeled glenoid components after shoulder arthroplasty for primary osteoarthritis: results of a multicenter study with more than five years of follow-up. J Bone Joint Surg Am 2012;94:145-50. http://dx.doi.org/10.2106/JBJS.J.00699
24. Wirth MA, Loredo 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