JSES International 7 (2023) 623–627

Contents lists available at ScienceDirect

JSES International

journal homepage: www.jsesinternational.org

Comparing outcomes of central ingrowth peg vs. noningrowth pegged glenoid components during revision to reverse total shoulder arthroplasty

Samuel K. Simister, BS*, Eleanor H. Sato, MD, Kory Fleming, MPH, Peter N. Chalmers, MD, Robert Z. Tashjian, MD

Department of Orthopaedic Surgery, University of Utah, Salt Lake City, UT, USA

ARTICLE INFO

Keywords:
Shoulder arthroplasty
Total shoulder arthroplasty
Reverse total shoulder arthroplasty
Revision shoulder arthroplasty
Revisions reverse total shoulder arthroplasty
Noningrowth pegged glenoid
Central ingrowth glenoid

Level of evidence: Level III; Retrospective Cohort Comparison; Prognosis Study

Background: One innovation to reduce glenoid loosening in total shoulder arthroplasty (TSA) is a large, central ingrowth peg. However, when bone ingrowth fails to occur, there is often increased bone loss surrounding the central peg which may increase complexity of subsequent revisions. Our goal was to compare outcomes between central ingrowth pegs and noningrowth pegged glenoid components during revision to reverse total shoulder arthroplasty.

Methods: In a comparative retrospective case series, all patients who underwent TSA-to-reverse TSA revision between 2014 and 2022 were reviewed. Demographic varibles as well as clinical and radiographic outcomes were collected. Ingrowth central peg and noningrowth pegged glenoid groups were compared using *t*-test, Mann-Whitney U, Chi-Square, or Fisher's exact tests where indicated.

Results: Overall, 49 patients were included: 27 underwent revision from noningrowth and 22 from central ingrowth components. Females more commonly had noningrowth components (74% vs. 45%, $P = .04$) and preoperative external rotation was higher in central ingrowth components ($P = .02$). Time to revision was significantly earlier in central ingrowth components (2.4 vs. 7.5 years, $P = .01$). Structural glenoid allografting was required more with noningrowth components (30% vs. 5%, $P = .03$) and time to revision in patients ultimately requiring allograft reconstruction was significantly later (9.96 vs. 3.68 years, $P = .03$).

Conclusion: Central ingrowth pegs on glenoid components were associated with decreased need for structural allograft reconstruction during revision; however, time to revision was earlier in these components. Further research should focus on whether glenoid failure is due to glenoid component design, time to revision, or both.

Anatomic total shoulder arthroplasty (TSA) has become the standard of care for managing glenohumeral osteoarthritis in the setting of an intact rotator cuff.[4,8,15,20] However, glenoid component loosening remains one of the most common causes of failure after TSA.[5,17,18] Radiographic evidence of glenoid component loosening has been associated with worse clinical outcomes and increases the risk for revision surgery in long-term follow-up.[5,17,18] Heightened awareness of glenoid component loosening has led to innovations in implant design.[3,11]

Traditionally, an all-polyethylene component was implanted into the glenoid with cement, using either a central keel (keeled) or multiple pegs (pegged). Loosening with these designs led to the introduction of the large, fluted central pegs with several small peripheral pegs. Addition of the larger, central peg theoretically allowed for bony ingrowth between flutes.[22] For the purpose of this study, glenoid components will be discussed as noningrowth (multiple pegs) or central ingrowth (peripheral pegs plus a central peg).

Initial studies of central ingrowth components showed excellent bony integration, including fingerlike projections of bone between flanges.[12] More recently, however, literature has begun to describe radiolucency around the central ingrowth peg and subsequent clinical failure has become a subject of concern with this implant design.[13,19] Furthermore, this design inherently requires more bone removal via drilling to allow for implantation of the larger central

This study was approved by the Division of Electronic Research Integrity and Compliance, The University of Utah (Institutional Review Board 4662).

*Corresponding author: Samuel K. Simister, BS, Department of Orthopaedic Surgery, University of Utah, 847 S. Greenwood Terrace, Salt Lake City, UT 84105, USA.
E-mail address: sam.simister@hsc.utah.edu (S.K. Simister).

https://doi.org/10.1016/j.jseint.2023.03.009

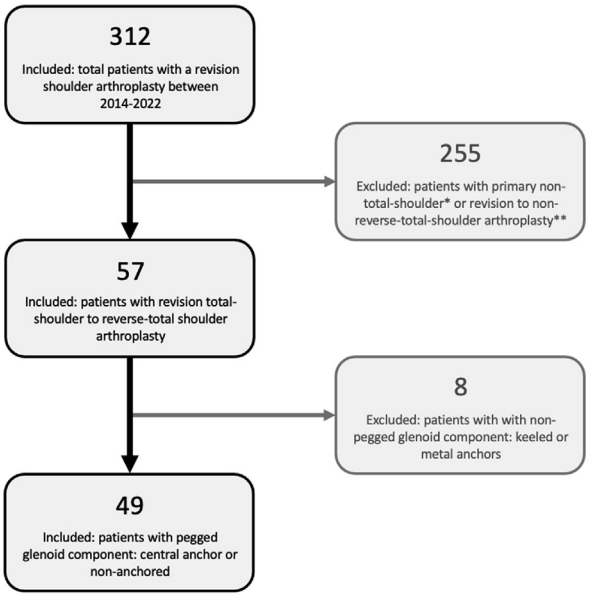

Figure 1 Inclusion and exclusion criteria flowchart. *RTSA*, reverse total shoulder arthroplasty.

peg, which may consequentially lead to an increased difficulty during revision when facing increased bone loss.

Despite these new advances in component design and overall good-to-excellent outcomes of TSA, aseptic loosening of the glenoid component remains one of the primary causes of TSA failure.[12] It remains unknown whether revision of central ingrowth glenoid components complicates revision, as compared to noningrowth pegged glenoid components. The purpose of this study was to compare intraoperative outcomes between central ingrowth vs. noningrowth glenoid components during TSA-to-reverse TSA (rTSA) revision. Our hypothesis was that the revision of central ingrowth glenoid components would be associated with increased surgical complexity compared to noningrowth components, demonstrated by increased operative time and blood loss.

Materials and methods

Patient selection

All patients who underwent a revision TSA between 2014 and 2022 were identified using Current Procedural Terminology code number 23474. All procedures were indicated and performed by 2 Shoulder and Elbow fellowship-trained surgeons at a single institution. A retrospective chart review of the electronic medical record was performed on all patients. All patients with a revision TSA-to-rTSA were included. Utilization of central ingrowth peg vs. noningrowth pegged glenoid components for the primary TSA was determined by operative note review and, when necessary, confirmed via radiographic analysis by the 2 surgeons. On imaging, ingrowth components showed either a fluted central post or a central metal post with ingrowth coating. Exclusion criteria included patients with primary components that were not a standard TSA (patients who underwent revisions from rTSA or hemiarthroplasty), revision to components other than an rTSA, or hardware removal without reimplantation. Patients were also excluded if the glenoid components used in the primary TSA were keeled or metal-backed (Fig. 1). Patients lost to follow-up with no radiographic or clinical follow-up were excluded from this study; however, there was no minimum length of follow-up requirement as intraoperative findings were our primary outcome.

Data collection

For the patients who met the above inclusion/exclusion criteria, a retrospective chart review of the electronic medical record was performed. Demographics, preoperative, intraoperative, and postoperative variables were collected. Demographics included gender, age at surgery, laterality, body mass index, and American Society of Anesthesiologists score. Additional risk factors collected included diagnosis of osteoporosis, current tobacco use, and history of illicit drug use. Indication for revision, including evidence of glenoid loosening, was determined by the primary surgeon via both clinical and radiographic evaluation and confirmed with intraoperative findings. Preoperative variables included range of motion and patient-reported outcomes (PROs) scores were also recorded. PROs included American Shoulder and Elbow Surgeons Shoulder score, visual analog scale pain score, Patient-Reported Outcomes Measurement Information System (PROMIS) physical function, and PROMIS upper extremity scores.[1,2] Intraoperative variables included the use of and type of allograft, baseplate augmentation, skin-to-skin time, blood loss, and intraoperative complications. Need for bone allograft reconstruction was determined intraoperatively. Postoperative variables included most recent follow-up, American Shoulder and Elbow Surgeons, visual analog scale, and PROMIS upper extremity and complications, including hematoma, infection, instability, periprosthetic fracture, nerve injury, and reoperation.

Statistical analysis

Descriptive statistics were calculated for both the central ingrowth and the noningrowth glenoid component groups. Continuous variables were compared between groups using student's *t*-test and Mann-Whitney U test as appropriate depending upon data normality as determined using the Kolmogorov-Smirnov test. Discrete variables were compared between groups using Chi-square tests or Fisher's exact tests as appropriate depending upon cell populations. All analyses were conducted in Excel 16 (Microsoft, Redmond, WA, USA) and SPSS (v 28; IBM, Armonk, NY, USA) with a significance value of $P < .05$.

Results

Patient selection/demographics

A total of 312 patients between 2014 and 2022 were identified by Current Procedural Terminology code alone undergoing revision shoulder arthroplasty. Of these, 255 were excluded as undergoing procedures other than revision TSA-to-rTSA. An additional 8 patients were excluded due to having a primary TSA with a keeled or metal-backed glenoid component. Thus, 49 patients were included in the final analysis.

Overall, 27 (55%) underwent revision from a noningrowth pegged glenoid component and 22 (45%) underwent revision from a central peg ingrowth glenoid component (Fig. 1). Average follow-up time status postrevision rTSA for noningrowth components was 12.6 ± 11 months and for ingrowth components was 16 ± 16 months. Females more commonly had noningrowth glenoid components (74%) compared to ingrowth components (45%) for their primary TSA ($P = .04$, Table I). Patient age, body mass index, American Society of Anesthesiologists score, laterality, diagnosis of osteoporosis, current tobacco use, and history of illicit drug use were similar between groups ($P > .05$).

Intraoperative variables

Structural femoral head allograft was used significantly more frequently in patients who previously had noningrowth glenoid primary component ($P = .03$, Table II). Average time to revision rTSA from anatomical TSA was significantly longer in those requiring allograft (10.0 ± 5.2 years vs. 3.7 ± 4.1 years, $P = .03$). Otherwise, there was no other significant difference in augmentation of baseplate components, use of custom baseplate, operative time, or blood loss between groups. Intraoperative complication rates were similar between groups ($P = .68$).

Clinical outcomes

Revision rTSA occurred significantly earlier in the ingrowth glenoid group at an average of 2.4 years following primary arthroplasty, compared to 7.5 years in the noningrowth glenoid components ($P = .01$). Revision indications based on glenoid loosening included 14% who had noningrowth pegs and 6% with ingrowth pegs, which were nonsignificant ($P = .72$).

Preoperative range of motion including active forward flexion was similar between groups (83 ingrowth, 88 noningrowth), but external rotation in adduction was significantly higher in the ingrowth glenoid component group (67 ingrowth, 41 noningrowth; $P = .02$). Preoperative and postoperative PRO scores were all similar between groups ($P > .05$).

Rates of postoperative infection, periprosthetic fracture, and hematoma were higher in patients with primary noningrowth glenoid components (8%, 8%, and 4%, respectively; Table III) compared to ingrowth components (0%, 0%, and 0%, respectively), although these differences were not significant ($P > .05$). There were no instances of instability in either group. Postoperative nerve deficits were more common in the ingrowth glenoid component group (9% vs. 4%), although this was not significant ($P = .59$). Overall complication and reoperation rates were more common in the noningrowth glenoid component group (33%) compared to the ingrowth group (23%), although this was not significant ($P = .55$).

Table I
Preoperative variables by group reported as mean (SD) or n (%).

Variable	Noningrowth peg (N = 27)	Ingrowth peg (N = 22)	*P* value
Female Sex	74% (20/27)	45% (10/22)	.041
Surgeon 1	22% (6/27)	50% (11/22)	.042
Osteoporosis	26% (7/27)	23% (5/22)	.796
Current Smokers	11% (3/27)	18% (4/22)	.685
History of illicit drug use	7% (2/27)	5% (1/22)	1.000
ASA			.897
2	52% (14/27)	50% (11/22)	
3	48% (13/27)	50% (11/22)	
Right Side	56% (15/27)	45% (10/22)	.482
BMI	32 ± 7	30 ± 5	.546
Age at surgery	68 ± 10	65 ± 7	.335
Active Forward Elevation	88 ± 41	84 ± 52	.761
Adducted External Rotation	41 ± 15	64 ± 38	.016
ASES score	35 ± 17	40 ± 22	.654
VAS Pain Score	9 ± 16	6 ± 3	.696
PROMIS Physical Function	34 ± 18	40 ± 5	.857
PROMIS Upper Extremity	30 ± 7	31 ± 4	.572
Years after primary arthroplasty	7.5 ± 5.2	2.4 ± 3.4	.007
Cuff Failure	19	14	.7142*
Glenoid Loosening	7	3	.7142*

SD, standard deviation; *ASA*, American Society of Anesthesiologists; *ASES*, American Shoulder and Elbow Surgeons; *VAS*, visual analog scale; *PROMIS*, patient-reported outcome measurement information system.
*Fisher's exact test.

Discussion

While polyethylene glenoid component design has been a focus in the field of arthroplasty because of the frequency glenoid component loosening,[16,21] no literature currently explores the downstream effects of these components on subsequent revision rTSA. Our study evaluated the surgical and early postoperative outcomes of revision TSA-to-rTSA, specifically from central ingrowth peg vs. noningrowth pegged primary components. In this, our data showed an increased need for femoral head allografts during revisions of noningrowth pegged components, suggesting our hypothesis was incorrect and increased surgical complexity occurs with noningrowth pegged components. Our data also

Table II
Intraoperative variables by group reported as mean (SD) or n (%).

Variable	Noningrowth peg (N = 27)	Ingrowth peg (N = 22)	*P* value
Structural Femoral Head Allograft	30% (8/27)	5% (1/22)	.030
Allograft chips	7% (2/27)	9% (2/22)	1.000
Augmented baseplate			
Half Wedge	0/22	0/22	NA
Full Wedge	15% (4/27)	27% (6/22)	.311
Custom Baseplate	4% (1/27)	0% (0/22)	1.000
Any Glenoid Augmentation	48% (13/27)	32% (7/22)	.247
Operative time (min)	149 ± 34	157 ± 96	.469
Blood loss (mL)	267 ± 118	282 ± 115	.813

NA, not applicable; *SD*, standard deviation.

Table III
Postoperative complications by group reported as n (%).

Complication	Noningrowth peg (N = 27)	Ingrowth peg (N = 22)	*P* value
Intra-operative	15% (4/27)	9% (2/22)	.678
Hematoma	4% (1/27)	0%	1.000
Infection	8% (2/27)	0%	.493
Dislocation	0%	0%	NA
Fracture	8% (2/27)	0%	.493
Nerve Injury	4% (1/27)	9% (2/22)	.587
Reoperation	11% (3/27)	5% (1/22)	.614
Complication/ reoperation	33% (9/27)	23% (5/22)	.539

NA, not applicable.

showed that the time to revision was significantly longer for noningrowth components, which may contribute to the glenoid vault destruction and need for bony allograft reconstruction.

In the present study, there was no significant association between increased complications and central ingrowth peg glenoid components during revision rTSA. In literature, Chalmers et al outline the complication rates in revision rTSA via a selective review of 9 reports, which showed a weighted average as high as 33%.[6] The present study shows similar rates for noningrowth components (33%) and slightly less for central ingrowth components (22%). This study thus reflects the current literature that revision shoulder arthroplasties are complex surgical procedures with high rates of complications. Additionally, it showed no association of the initial anatomic glenoid component design with intraoperative revision variables, such as operative time, blood loss, or the need for glenoid augmentation. Overall, these results suggest that ingrowth components do not increase complications or surgical complexity at the time of revision arthroplasty if required.

Our study showed a significant association between noningrowth components and glenoid bone loss requiring structural allograft during revision. An example of this bone loss and subsequent femoral head structural grafting in revision of a noningrowth TSA-to-rTSA is demonstrated in Fig. 2. This finding is supported by recent literature, where Klein et al reported 39% of patients with abnormal glenoid morphology during revision procedures, 15% of which required structural allograft.[14] The increased frequency of structural grafting in revision of noningrowth components is likely due to the overall difference in time to revision between noningrowth (7.5 ± 5.2 years) and ingrowth components (2.4 ± 3.4 years). A review of literature reports on the timelines between primary TSA failure and revision rTSA found minimal results, with one study showing a time to revision of 5.8 years,[10] while another was 3.06 years.[7] These reports, however, did not explore glenoid components and thus differ in our report of the potential impact of time to revision with noningrowth components.

When comparing the difference in time until revision between cases requiring glenoid grafting vs. those that did not, the grafted cases were performed in patients with a significantly greater length of time between the initial surgery and revision (10.0 vs. 3.7 years). One explanation for the etiology of this bone loss in noningrowth components includes the potential for increased attritional bone loss due to component micromotion over extended periods of time. Glenoid component shift after anatomic TSA has previously been described by Ricchetti et al, whose results demonstrate no significant association with ingrowth components.[19] Additionally, Dillon et al explored the association between various glenoid component designs, showing differential risks in revision due to glenoid loosening with noningrowth components when compared to ingrowth glenoid components.[9] Thus, the literature supports the hypothesis that increased bone loss may, in part, be due to increased micromotion over time with noningrowth components.

Our study aligns with these theories as the time to revision in our noningrowth glenoid components is significantly longer. This may increase the potential for bone loss, potentially via both micromotion and the increased time to failure, and leads to subsequent intraoperative requirement for glenoid allograft. It is unclear, however, if the increased risk for bone grafting was a result of the noningrowth implants or the longer duration of time from initial surgery but likely it is a combination of both. Additionally, the difference in time to revision may be because ingrowth components have not been available for as long as noningrowth components, creating a lead-time bias. Alternatively, it may be because ingrowth components tend to fail earlier than noningrowth components when bony integration fails to occur because there is less cement fixation of the fluted central peg component.

Limitations

This study has several limitations. First, there is a small sample size. The limited sample size increases the risk for type II error, while also increasing fragility. However, this is a sample collected from a large range of time in a high-volume revision referral center. A larger study may find a statistically significant difference in some of the analyses that were not found to be significant. Second, this was a study of intraoperative factors and the immediate postoperative period, that is, requirement for revision with a graft. A study with longer follow-up may yield additional significant

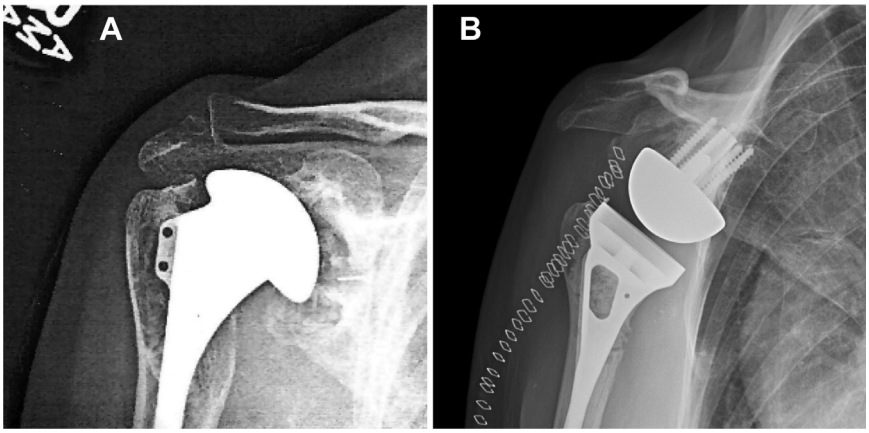

Figure 2 Patient requiring glenoid grafting during revision RTSA secondary to glenoid bone loss, including preoperative (**A**) and postoperative (**B**) radiographic imaging. *RTSA*, reverse total shoulder arthroplasty.

findings regarding complications or reoperations or patient outcomes. Third, this is a 2-surgeon study and is thus relatively homogeneous. In particular, 1 of these 2 surgeons performed a larger percentage of both ingrowth and noningrowth revisions, and thus our findings may not be generalizable outside of that surgeon's practice. Additionally, this bias may apply to the difference in bone loss evaluation, where CT scans for all patients were not available and a reliable radiographic evaluation standard for glenoid bone erosion does not exists.

Conclusion

During revision of TSA to rTSA, central ingrowth peg components do not appear to worsen bone loss as they were associated with decreased need for glenoid structural allograft when compared to noningrowth pegged components. However, ingrowth components were associated with an earlier time to revision. Need for revision and concomitant structural allografting is likely multifactorial and may be a result of the length of time to revision, the primary component design, or both.

Disclaimers:

Funding: No funding was disclosed by the authors.
Conflicts of interest: Robert Z. Tashjian is a paid consultant for Zimmer/Biomet, Stryker, DJO and Depuy-Mitek; has stock in Conextions, INTRAFUSE, Genesis; receives intellectual property royalties from Stryker, DJO, Shoulder Innovations, and Zimmer/Biomet; receives publishing royalties from Springer and the *Journal of Bone and Joint Surgery,* and serves on the editorial board for the *Journal of Bone and Joint Surgery*. Peter N. Chalmers is a paid consultant for Depuy and DJ orthopedics; receives intellectual property royalties from Depuy and Responsive Arthroscopy; receives publishing royalties, financial, or material support from the *Journal of Shoulder and Elbow Surgery*; and is a paid presenter for Depuy. 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. Anthony CA, Glass N, Hancock K, Bollier M, Hettrich CM, Wolf BR. Preoperative performance of the patient-reported outcomes measurement information System in patients with rotator cuff pathology. Arthroscopy 2017;33:1770-1774.e1. https://doi.org/10.1016/j.arthro.2017.04.018.
2. Anthony CA, Glass NA, Hancock K, Bollier M, Wolf BR, Hettrich CM. Performance of PROMIS instruments in patients with shoulder instability. Am J Sports Med 2017;45:449-53. https://doi.org/10.1177/0363546516668304.
3. Bohsali KI, Wirth MA, Rockwood CA Jr. Complications of total shoulder arthroplasty. J Bone Joint Surg Am 2006;88:2279-92. https://doi.org/10.2106/JBJS.F.00125.
4. Bryant D, Litchfield R, Sandow M, Gartsman GM, Guyatt G, Kirkley A. A comparison of pain, strength, range of motion, and functional outcomes after hemiarthroplasty and total shoulder arthroplasty in patients with osteoarthritis of the shoulder. A systematic review and meta-analysis. J Bone Joint Surg Am 2005;87:1947-56. https://doi.org/10.2106/JBJS.D.02854.
5. Buckingham BP, Parsons IM, Campbell B, Titelman RM, Smith KL, Matsen FA. Patient functional self-assessment in late glenoid component failure at three to eleven years after total shoulder arthroplasty. J Shoulder Elbow Surg 2005;14:368-74. https://doi.org/10.1016/j.jse.2004.10.008.
6. Chalmers PN, Boileau P, Romeo AA, Tashjian RZ. Revision reverse shoulder arthroplasty. J Am Acad Orthop Surg 2019;27:426-36. https://doi.org/10.5435/JAAOS-D-17-00535.
7. Constantinescu DLK, Satalich J, Vap A. Time to conversion of hemi/total shoulder arthroplasty to reverse total shoulder arthroplasty: a systematic review of longevity and factors influencing conversion. Arch Rheum Arthritis Res 2021;1. https://doi.org/10.33552/ARAR.2021.01.000517.
8. Dillon MT, Chan PH, Inacio MCS, Singh A, Yian EH, Navarro RA. Yearly trends in elective shoulder arthroplasty, 2005-2013. Arthritis Care Res (Hoboken) 2017;69:1574-81. https://doi.org/10.1002/acr.23167.
9. Dillon MT, Chan PH, Prentice HA, Burfeind WE, Yian EH, Singh A, et al. The association between glenoid component design and revision risk in anatomic total shoulder arthroplasty. J Shoulder Elbow Surg 2020;29:2089-96. https://doi.org/10.1016/j.jse.2020.02.024.
10. Gauci MO, Cavalier M, Gonzalez JF, Holzer N, Baring T, Walch G, et al. Revision of failed shoulder arthroplasty: epidemiology, etiology, and surgical options. J Shoulder Elbow Surg 2020;29:541-9. https://doi.org/10.1016/j.jse.2019.07.034.
11. Gonzalez JF, Alami GB, Baque F, Walch G, Boileau P. Complications of unconstrained shoulder prostheses. J Shoulder Elbow Surg 2011;20:666-82. https://doi.org/10.1016/j.jse.2010.11.017.
12. Groh GI. Survival and radiographic analysis of a glenoid component with a cementless fluted central peg. J Shoulder Elbow Surg 2010;19:1265-8. https://doi.org/10.1016/j.jse.2010.03.012.
13. Ho JC, Ricchetti ET, Iannotti JP. Central-peg radiolucency progression of an all-polyethylene glenoid with hybrid fixation in anatomic total shoulder arthroplasty is associated with clinical failure and reoperation. J Shoulder Elbow Surg 2021;30:1068-77. https://doi.org/10.1016/j.jse.2020.07.039.
14. Klein SM, Dunning P, Mulieri P, Pupello D, Downes K, Frankle MA. Effects of acquired glenoid bone defects on surgical technique and clinical outcomes in reverse shoulder arthroplasty. J Bone Joint Surg Am 2010;92:1144-54. https://doi.org/10.2106/JBJS.I.00778.
15. Lo IK, Litchfield RB, Griffin S, Faber K, Patterson SD, Kirkley A. Quality-of-life outcome following hemiarthroplasty or total shoulder arthroplasty in patients with osteoarthritis. A prospective, randomized trial. J Bone Joint Surg Am 2005;87:2178-85. https://doi.org/10.2106/JBJS.D.02198.
16. Matsen FA 3rd, Clinton J, Lynch J, Bertelsen A, Richardson ML. Glenoid component failure in total shoulder arthroplasty. J Bone Joint Surg Am 2008;90:885-96. https://doi.org/10.2106/JBJS.G.01263.
17. Merolla G, Campi F, Paladini P, Lollino N, Fauci F, Porcellini G. Correlation between radiographic risk for glenoid component loosening and clinical scores in shoulder arthroplasty. Chir Organi Mov 2009;93:S29-34. https://doi.org/10.1007/s12306-009-0008-4.
18. Papadonikolakis A, Neradilek MB, Matsen FA 3rd. Failure of the glenoid component in anatomic total shoulder arthroplasty: a systematic review of the English-language literature between 2006 and 2012. J Bone Joint Surg Am 2013;95:2205-12. https://doi.org/10.2106/JBJS.L.00552.
19. Ricchetti ET, Jun BJ, Jin Y, Ho JC, Patterson TE, Dalton JE, et al. Relationship between glenoid component shift and osteolysis after anatomic total shoulder arthroplasty: three-dimensional computed tomography analysis. J Bone Joint Surg Am 2021;103:1417-30. https://doi.org/10.2106/JBJS.20.00833.
20. Sandow MJ, David H, Bentall SJ. Hemiarthroplasty vs total shoulder replacement for rotator cuff intact osteoarthritis: how do they fare after a decade? J Shoulder Elbow Surg 2013;22:877-85. https://doi.org/10.1016/j.jse.2012.10.023.
21. Williams GR, Abboud JA. Total shoulder arthroplasty: glenoid component design. J Shoulder Elbow Surg 2005;14:122S-8S. https://doi.org/10.1016/j.jse.2004.09.028.
22. Wirth MA, Korvick DL, Basamania CJ, Toro F, Aufdemorte TB, Rockwood CA Jr. Radiologic, mechanical, and histologic evaluation of 2 glenoid prosthesis designs in a canine model. J Shoulder Elbow Surg 2001;10:140-8.