Computed Tomography revealed the correlation between radiolucency and alignment of all-polyethylene pegged glenoid component more than 10 years after total shoulder arthroplasty in the Japanese population

Short title: Long term CT analysis after TSA

Yuki Matsui[1] MD, PhD, Daisuke Momma[2]* MD, PhD, Naoki Suenaga[3] MD, PhD, Atsushi Urita[1] MD, PhD, Chika Yoshioka[3] MD, PhD, Naomi Oizumi[3] MD, PhD, and Norimasa Iwasaki[1] MD, PhD

[1] Faculty of Medicine and Graduate School of Medicine, Department of Orthopaedic Surgery, Hokkaido University, Sapporo, Japan

[2] Center for Sports Medicine, Hokkaido University Hospital, Sapporo, Japan

[3] Orthpaedic Hokushin Hospital, Sapporo, Japan

*Corresponding author: Daisuke Momma

Center for Sports Medicine, Hokkaido University Hospital

Kita 14, Nishi 5, Sapporo, Hokkaido 060-8638, Japan

Tel: +81-11-706-5936; Fax: +81-11-706-6054

E-mail: d-momma@med.hokudai.ac.jp

Disclaimer: The authors, their immediate families, and any research foundations with which they are affiliated have not received any financial payments or other benefits from any commercial entirely related to the subject of this article.

This study was approved by the Institutional Review Board of Hokkaido University Hospital, Japan (#020-0210)

Conflict of Interest

The authors declare no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Abstract

Background: Anatomical total shoulder arthroplasty (TSA) provides successful long-term outcomes but complications can occur after 10 years that require revision. Computed tomography (CT) is a useful tool for assessing radiolucent lines around the glenoid component of TSA; however, the merits of long-term post-TSA follow up with CT are unclear. The purpose of this study was to evaluate the long-term outcomes after TSA of Japanese population and to identify factors related to radiolucency around the glenoid component using CT.

Methods: A retrospective review was conducted of TSA patients who had completed at least 10 years of clinical follow up. Radiographs and CT images of the affected shoulder obtained at the last follow up were evaluated for radiolucent lines around the stem and each peg, superior inclination and retroversion of the glenoid component, subluxation index, and critical shoulder angle (CSA). Shoulder ROM, Constant–Murley score and UCLA score were compared between the preoperative and last follow up period.

Results: Eighteen shoulders in 16 patients met the inclusion criteria. Mean patient age was 61 years, mean follow up period was 137 months, and mean Yian CT score was 19%. CT score was significantly highest in pegs located inferiorly ($p<0.05$). Mean glenoid superior inclination was 12.6°, retroversion was –0.3°, subluxation index was 46%, and CSA was 33.7°. Glenoid superior inclination was significantly lower ($p=0.007$) in shoulders with possible loosening than in cases with no loosening (5.0° vs 15.6°). Mean Constant score and UCLA score improved significantly after TSA, from 25.8 and 10.7 points preoperatively to 70.1 and 28.9 points postoperatively, respectively. Mean shoulder flexion, internal rotation, and external rotation also showed improvement postoperatively.

Conclusion: TSA provides good long-term outcomes. Radiolucency was present most frequently around the inferior pegs of the glenoid component. Glenoid superior inclination may affect the formation of radiolucent lines around glenoid pegs.

Level of evidence: Level IV; Case Series; Treatment study

Introduction

Total shoulder arthroplasty (TSA) is an effective procedure for improving shoulder pain and restoring function. Currently, many shoulder surgeons prefer the 3rd generation TSA system, which has the characteristics of an eccentric humeral head and pegged glenoid component. Several studies have reported excellent clinical and radiographic results for pegged glenoid TSA at short- and middle-term follow up(1-3); however, others have reported primary glenoid humeral osteoarthritis and that the glenoid component was commonly radiographically loose from 10 years after the primary surgery(2, 4). Numerous studies have investigated loosening of the glenoid component, almost all of which evaluated radiographs alone(3, 5-8). Havig et al reported that it is difficult to evaluate the width of radiolucent lines around the glenoid component(9), whereas Yian et al and Agyeman et al recommended computed tomography (CT) for identifying radiolucencies around the pegs of the glenoid component(10, 11).

Glenoid loosening is related to implant position. Excessive glenoid component retroversion, superior inclination, and humeral retroversion have been shown to be related to implant loosening(12-14). A relationship between increasing cortical shoulder angle (CSA) and implant loosening has also been reported(15, 16).

However, no long-term study has evaluated the long-term radiolucency of glenoid component pegs and implant location using CT. This study was first study that has used CT to evaluate radiolucent lines and implant placement at more than 10 years after TSA.

Furthermore, Asian patients exhibited a smaller shoulder morphometrics than Europe and/or American cohort(17-19). TSA implants were designed for Western patients, so the long-term results in Asian patients are not clear.

The purpose of this study was to evaluate the long-term outcomes of all-polyethylene pegged glenoid components after TSA in Japanese patients and to identify risk factors for radiolucency around the glenoid component pegs using CT.

Materials and Methods

Patient selection

We conducted a retrospective case series study to assess the glenoid radiographic findings of TSA surgeries performed at our hospital and related hospitals in our country, between April 2004 and December 2009. The inclusion criteria were (1) implantation of a 3rd-generation cemented pegged glenoid component, (2) diagnosis of osteoarthritis or rheumatoid arthritis, (3) minimum follow-up duration of 10 years, and (4) complete clinical examination and permitted to take CT images 10 years postoperatively. Of 32 prostheses in 30 patients who met the study criteria, 18 prostheses in 16 patients had data available for over 10 years after surgery. Seven patients had died, five patients were lost to follow up, and two patients who underwent revision surgery were excluded (Fig. 1). This study was approved by our institution ethical committee.

Surgical technique

Under general anesthesia, the patient was positioned in the beach chair position. The standard deltopectoral approach was used with subscapularis tenotomy. After capsular release, the joint was exposed. The labrum and any glenoid edge spurs were removed to clarify the shape of the glenoid. The glenoid guide was adjusted and the center hole drilled. After thoroughly cleaning the holes, we tessellated gauze to each peg hole to stop bleeding. We then removed the gauze before injecting pressurized cement into each peg hole. Because placement of cement along the back of the implant can lead to early loosening by increasing the risk of cracking the glenoid, we injected only enough cement at the edge of the holes to sink the pegs. The cement was pressure poured into the trabecular bone through the peg holes in the glenoid with a thick tipped syringe while it was still soft, and the component was placed just before hardened. Peg location was confirmed using an image intensifier. After fixing the glenoid component, we inserted the humeral stem. The impaction bone grafting technique was used for press-fit fixation of the stem after resection of the humeral head.

After surgery, the shoulder was immobilized with an abduction pillow for 2 weeks. Mobilization was commenced as follows: exercise of the glenoid, elbow, hand, and finger at 1 day after surgery; Codman exercise, active range of motion (ROM) exercise in the decubitus position, and isometric exercise without internal rotation at 2 days after surgery; passive ROM exercise at 3 days after surgery; anti-gravity exercise at 2 weeks after surgery; and resistance exercise at 6 weeks after surgery.

TSA was performed in all patients by the same surgeon. Twelve patients were implanted with a Global Advantage (Depuy, Warsaw, IN) shoulder system with an outline peg design, and six patients were implanted with a Bigliani/Flatow (B/F) complete shoulder prosthesis (Zimmer, Warsaw, IN) with an inline peg design.

Clinical evaluation

The clinical results were assessed preoperatively and at the final follow up by Constant–Murley score, UCLA score, and as the active range of shoulder motion (flexion, external rotation, internal rotation).

Radiographic evaluation

Standard true anteroposterior and axillary outlet radiographs and CT (1 mm contiguous slices) of the shoulder were obtained preoperatively and at the final follow up in all patients. Evaluations were performed by three orthopaedics specialists blinded to each other's measurements. We then used the mean values. The presence of radiolucent lines around the glenoid component was classified on radiographs according to the method of Lazarus(6) and on CT scans according to the scoring system of Yian(10). The three inline pegs (inline group) were assessed in five zones around the pegs and between peg and peg scored as 0, 1, 2, or 3 for radiolucent lines of width 0, 1, 2 mm, or gross radiolucency, respectively (Fig. 2a)

The five outline pegs (outline group) were similarly assessed in eight zones with radiolucency around the pegs scored as 0, 1, 2, or 3 for radiolucent lines of width 0, 1, 2 mm, or gross radiolucency, respectively (Fig. 2b).

Yian et al evaluated only four pegs glenoid component, therefore they evaluated six different zones along the glenoid back surface, for a total score ranging from 0 to 18 points. But in this study, we evaluated two different type glenoid components. To unify the values of the outline and inline groups on CT, we evaluated the mean/maximum radiolucency score per zone as the Yian score (%). The degree of loosening was determined based on the radiographic and CT scores. Possible loosening was defined as a Lazarus score of 3 or a Yian score of 33%–67%. Definite glenoid loosening was defined as a Lazarus score of ≥4 or a Yian score of >67%. We then analyzed the appearance of radiolucent lines according to peg location, defined as follows: superior (peg 1 of the inline and outline pegs), middle (peg 2 of the inline pegs and pegs 2, 3, and 4 of the outline pegs), and inferior (peg 3 of the inline pegs and peg 5 of the outline pegs) (Fig. 2).

The grade of glenoid component seating indicates the amount of host subchondral bone directly in contact with the back of the glenoid component. As the surgical ideal is to achieve complete congruency between the back of the component and the host subchondral bone, any section of the component backed by an intervening layer of cement, as evaluated by CT, was deemed to be unsupported. Glenoid component seating was further classified as follows: Grades A, B, and C were defined as “better seating” and grades D and E as “worse seating”.

The degree of humeral stem loosening was classified on radiographs according to the method of Inoue et al(20). The location of bone resorption was divided into 7 zones. The degree of bone resorption was divided into four grades.

Using images obtained at the last follow up, superior inclination and retroversion of the glenoid component, humeral head subluxation index, and rotator cuff fatty infiltration grade were measured on CT, and the critical shoulder angle was measured on radiographs. Glenoid superior inclination was assessed by angle, using the method of Maurrer et al(21). We defined glenoid superior inclination as the angle between the glenoid and a line perpendicular to the floor of the supraspinatus fossa(22) (Fig. 3). Glenoid retroversion was calculated using Friedman’s angle(23) (Fig. 3). The humeral head subluxation index was calculated using the glenoid-based technique described by Walch et al(24). CSA was measured as described by Moor et al(25).

Statistical analysis

The empirical distributions of continuous end points are reported as the mean, standard deviation, minimum, and maximum. Paired t test was used to detect variation over time in paired preoperative and postoperative Constant scores, UCLA scores, shoulder range of motion (flexion, external rotation, internal rotation), and radiographic outcomes.

Statistical comparisons of the data among three groups, appearance of radiolucent lines according to peg location, were performed using ANOVA and Tukey’s protected least significant difference test.

Statistical analyses were performed with JMP 14.0.0. software (SAS Institute Inc., Cary, NC). Statistical significance was set at $P < .05$.

Results

Patient demographics

The mean follow-up period was 137 months (range, 120–179 months). Thirteen of the 16 patients were female, and mean age at surgery was 61 years (range, 50–84 years). TSA was performed for severe shoulder pain or functional disability caused by osteoarthritis (n = 6) or rheumatoid arthritis (n = 12). A B/F shoulder prosthesis was implanted in 6 shoulders and Global Advantage in 12. The demographic data are listed in Table 1.

Clinical outcomes

Our overall results reveal a significant improvement of clinical outcomes following TSA (Table 1). The mean Constant score showed a statistically significant improvement from 25.8 points (range, 12–38 points) preoperatively to 70.1 points (range, 42–93 points) postoperatively ($p<0.001$). The mean UCLA score showed a statistically significant improvement from 10.7 points (range, 8–14 points) preoperatively to 28.9 points (range, 24–35 points) postoperatively ($p<0.001$). Shoulder flexion, internal rotation, and external rotation also improved between pre surgery and post surgery ($p<0.01$).

Radiographic findings

Table 2 lists the individual patient results. In all patients, complete radiographic and CT data from the final follow up were available. The mean radiolucency on CT (Yian score) was 19% ± 15. There was no loosening in 13 shoulders and possible loosening in 5 shoulders. Yian score was significantly higher in patients with RA than in patients with OA (24% vs 6.9%, p = 0.002). However, there were no significant difference between male and female (male 19% vs female 18%, p=0.47), and no significant difference by type of pegs (Inline 22% vs Outline 17%, p=0.26), and no significant difference in age between those over 60 years old and under 60 years old (16% vs 21%, p=0.22).

Mean CT score of the combined inline and outline groups according to peg location was 17 ± 26% for superior pegs, 17 ± 22% for middle pegs, and 48 ± 39% for inferior pegs (Fig. 4). CT score was significantly higher for inferior pegs than for those in other locations (p<0.05). Regarding humeral resorption, grade 1 resorption was seen in seven shoulders (zone 1, n = 5; zone 4, n = 2), and grade 2 in one shoulder (zone 1). Loosening was seen in one patient with RA (grade 4, zone 4). Mean glenoid superior inclination was 12.6 ± 9.9°, retroversion was –0.3 ± 10.4°, and subluxation index was 46.4 ± 5.7%. Regarding seating, all glenoid components were grade A or B, indicating firm seating. Mean CSA was 33.7 ± 8.7°. There were no significant differences in terms of loosening, age, or prothesis type.

Tables 3 and 4 show the results of correlation analysis to identify factors associated with glenoid loosening and possible loosening. Mean Constant score and UCLA score were significantly lower for possible loosening compared with no loosening (55.6 vs 68.2 points and 26.6 vs 29.3 points, respectively) (p = 0.01). Shoulder flexion range was lower for possible loosening than for no loosening (99.0° vs 140.0°) (p = 0.008) (Table 3). Mean Yian CT score was 39 ± 4.4% for possible loosening and 11 ± 8.3% for no loosening. There was no significant difference in loosening in terms of humeral resorption. Glenoid superior inclination values were significantly lower for possible loosening than for no loosening (4.9 ± 5.1° vs 15.6 ± 9.7°) (p<0.01). There was no significant difference between possible loosening and no loosening in terms of glenoid retroversion (–0.16 ± 11.5° vs –0.8 ± 6.7°) (p=0.45) or subluxation index (44.1 ± 5.2% vs 47.3 ± 5.4%) (p=0.16). Mean CSA was 33.3 ± 6.3° for possible loosening and 33.9 ± 9.4° for no loosening (Table 4). We also measured the glenoid superior inclination within 1 month after TSA using radiograph. As a results, similar to the long-term results, glenoid superior inclination values were significantly lower for possible loosening than for no loosening (–3.5° ± 8.3° vs 19.3 ± 6.0°) (p=0.02).

Complications

Among the patients who underwent TSA, revision was performed in three patients, all of whom had RA. In the first patient, revision surgery was performed for stem and glenoid loosening that occurred at 1 year and 5 months after TSA. In the second patient, a first revision surgery was performed 5 years and 5 months after TSA because of stem loosening, and a second glenoid revision surgery was performed 8 years subsequently. In the third patient, humeral stem revision was performed 10 years and 11 months after TSA. There were no neurological complications, periprosthetic infections, fractures, or other complications directly related to the surgical procedure.

Discussion

To the best of our knowledge, this is the first study that has used CT to evaluate radiolucent lines and implant placement at more than 10 years after TSA. Although three shoulders in RA patients required revision surgery, this study demonstrated satisfactory long-term clinical outcomes for the 3rd generation cemented total shoulder system on Japanese patients. Even in implants that were still in position at 10 years after surgery, radiolucent lines were present around the glenoid component. Therefore, we evaluated the presence of radiolucent lines around the glenoid component at last follow up period on CT to clarify the factors that affect glenoid loosening.

TSA is an effective procedure that improves shoulder pain and restores joint function. Papadonikolakis et al performed a systematic review of 3853 TSA surgeries performed between 1976 and 2007. According to their X-ray evaluation, asymptomatic radiolucent lines appeared at a rate of 7.3% per year, symptomatic glenoid loosening occurred at 1.2% per year, and surgical revision occurred at 0.8% per year. Several studies have used CT to evaluate TSA over a medium follow-up period. Yian et al reported possible or definite loosening in 13% of 47 shoulders over a mean follow-up period of 40 months(10). In their study, mean clinical outcomes and ROM were satisfactory at or after the 10-year follow-up; however, the postoperative clinical scores were associated with CT scores. In particular, CT scores were significantly higher around inferior pegs than superior pegs. Wijeratna et al reported that zones around the inferior pegs were the most affected by radiolucency(26). In this study, both radiographic and CT were used for evaluation, and even in cases in which the radiolucent scores appeared to be low on radiographic, there were cases in which possible loosening was observed on CT analysis. We believed that CT should be used for the evaluation of glenoid loosening. In terms of

CT scores, the current results are comparable to those of previous reports of radiolucency. Hence, the CT evaluation system used in the present study could be used as an alternative scoring system for long-term TSA assessment.

CT has previously been used to evaluate bone morphology, implant placement, and radiolucent lines around implant components. Gregory et al reported a protocol for identifying radiolucencies on CT before they can be detected on plain radiographs(27). Asian patients were reported to be exhibited a smaller shoulder morphometrics than Europe and/or American cohort(17-19). Since TSA implants were designed for Western patients shoulder, it is unclear whether they can be properly placed in Asian patients. In the present study, we evaluated glenoid inclination, retroversion, humeral stem inclination, humeral head subluxation, and CSA at the last follow up using CT. Our data showed that lower values for glenoid inclination on postoperative CT were associated with lower postoperative clinical scores. In a previous finite element study, superoinferior misalignment of the glenoid component was predictive of poor outcome(12). Mean values for normal glenoid superior inclination have been reported as 13.2 ± 3.3° by Gracia et al and as 17 ± 4° by Scheiderer et al. In the present study, superior inclination values were 4.9 ±5.1° for possible loosening and 15.6 ± 9.7° for no loosening. These results suggest that the glenoid component should be placed perpendicular to the glenoid surface rather than with inferior tilt.

Bone fragility is greater in RA patients than in OA patients, which may increase the risk of loosening of the humeral stem and glenoid component in RA patients. Raiss et al evaluated 39 arthroplasties in patients with glenohumeral OA and reported a mean Constant score of 27 points (range, 11–54 points) preoperatively and 61 points (range, 21–86 points) postoperatively(2). In the present study, all patients with possible glenoid loosening had RA, and those who required stem revision also had RA.

This study has several limitations. First, it was retrospective in nature. Therefore, we have not been able to evaluate the placement position by CT immediately after surgery. However, superior inclination was able to assess by X-ray immediately after surgery, and the results were similar to those obtained more than 10 years after surgery. Second, few patients had completed a minimum 10 years of follow up. Of the shoulders studied, only five patients were lost to follow up. However, the data of the three shoulders that underwent revision before 10 years and the several patients had died could not be included, which limited our analysis. Third, we used two different prosthetic implants, which were assigned to patients randomly. There was no significantly difference between the two implants with regard to the clinical and radiographic outcomes. Fourth, as our follow-up period was a minimum of only 10 years, the longer-term results are unknown. A larger number of subjects and a longer follow-up period will be required in future to validate the results of the present study.

Conclusions

TSA provided good clinical outcomes according to the results of follow-up at a minimum period of 10 years in Japanese patients; however, several patients with RA required revision. The presence of glenoid radiolucent lines influenced the clinical score. Glenoid radiolucency values were significantly higher in patients with RA than in those with OA. Radiolucency was detected most commonly around the inferior pegs of the glenoid component, and glenoid superior inclination may influence the presence of radiolucent lines around the glenoid pegs.

References

1. Throckmorton TW, Zarkadas PC, Sperling JW, Cofield RH. Pegged versus keeled glenoid components in total shoulder arthroplasty. J Shoulder Elbow Surg2010 Jul;19(5):726-33.

2. Raiss P, Schmitt M, Bruckner T, Kasten P, Pape G, Loew M, Zeifang F. Results of cemented total shoulder replacement with a minimum follow-up of ten years. J Bone Joint Surg Am2012 Dec 5;94(23):e1711-10.

3. Kilian CM, Press CM, Smith KM, O'Connor DP, Morris BJ, Elkousy HA, Gartsman GM, Edwards TB. Radiographic and clinical comparison of pegged and keeled glenoid components using modern cementing techniques: midterm results of a prospective randomized study. J Shoulder Elbow Surg2017 Dec;26(12):2078-85.

4. Sowa B, Bochenek M, Bulhoff M, Zeifang F, Loew M, Bruckner T, Raiss P. The medium- and long-term outcome of total shoulder arthroplasty for primary glenohumeral osteoarthritis in middle-aged patients. Bone Joint J2017 Jul;99-B(7):939-43.

5. McLendon PB, Schoch BS, Sperling JW, Sanchez-Sotelo J, Schleck CD, Cofield RH. Survival of the pegged glenoid component in shoulder arthroplasty: part II. J Shoulder Elbow Surg2017 Aug;26(8):1469-76.

6. Lazarus MD, Jensen KL, Southworth C, Matsen FA, 3rd. The radiographic evaluation of keeled and pegged glenoid component insertion. J Bone Joint Surg Am2002 Jul;84-A(7):1174-82.

7. Parks DL, Casagrande DJ, Schrumpf MA, Harmsen SM, Norris TR, Kelly JD, 2nd. Radiographic and clinical outcomes of total shoulder arthroplasty with an all-polyethylene pegged bone ingrowth glenoid component: prospective short- to

medium-term follow-up. J Shoulder Elbow Surg2016 Feb;25(2):246-55.

8. 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 Am2012 Feb 1;94(3):260-7.

9. Havig MT, Kumar A, Carpenter W, Seiler JG. Assessment of radiolucent lines about the glenoid - An in vitro radiographic study. Journal of Bone and Joint Surgery-American Volume1997 Mar;79a(3):428-32.

10. Yian EH, Werner CM, Nyffeler RW, Pfirrmann CW, Ramappa A, Sukthankar A, Gerber C. Radiographic and computed tomography analysis of cemented pegged polyethylene glenoid components in total shoulder replacement. J Bone Joint Surg Am2005 Sep;87(9):1928-36.

11. Agyeman KD, DeVito P, McNeely E, Malarkey A, Bercik MJ, Levy JC. Comparing the Use of Axillary Radiographs and Axial Computed Tomography Scans to Predict Concentric Glenoid Wear. JB JS Open Access2020 Jan-Mar;5(1):e0049.

12. Hopkins AR, Hansen UN, Amis AA, Emery R. The effects of glenoid component alignment variations on cement mantle stresses in total shoulder arthroplasty. Journal of Shoulder and Elbow Surgery2004;13(6):668-75.

13. Farron A, Terrier A, Buchler P. Risks of loosening of a prosthetic glenoid implanted in retroversion. J Shoulder Elbow Surg2006 Jul-Aug;15(4):521-6.

14. Ho JC, Sabesan VJ, Iannotti JP. Glenoid component retroversion is associated with osteolysis. J Bone Joint Surg Am2013 Jun 19;95(12):e82.

15. Watling JP, Sanchez JE, Heilbroner SP, Levine WN, Bigliani LU, Jobin CM. Glenoid component loosening associated with increased critical shoulder angle at

midterm follow-up. J Shoulder Elbow Surg2018 Mar;27(3):449-54.
16. Wolf M, Bulhoff M, Raiss P, Zeifang F, Maier MW. Effect of the critical shoulder angle on severe cranialization following total shoulder arthroplasty. J Orthop2020 Sep-Oct;21:240-4.
17. Mizuno N, Nonaka S, Ozaki R, Yoshida M, Yoneda M, Walch G. Three-dimensional assessment of the normal Japanese glenoid and comparison with the normal French glenoid. Orthop Traumatol Surg Res2017 Dec;103(8):1271-5.
18. Matsuki K, Sugaya H, Hoshika S, Ueda Y, Takahashi N, Tokai M, Banks SA. Three-dimensional measurement of glenoid dimensions and orientations. J Orthop Sci2019 Jul;24(4):624-30.
19. Cabezas AF, Krebes K, Hussey MM, Santoni BG, Kim HS, Frankle MA, Oh JH. Morphologic Variability of the Shoulder between the Populations of North American and East Asian. Clin Orthop Surg2016 Sep;8(3):280-7.
20. Inoue K, Suenaga N, Oizumi N, Yamaguchi H, Miyoshi N, Taniguchi N, Munemoto M, Egawa T, Tanaka Y. Humeral bone resorption after anatomic shoulder arthroplasty using an uncemented stem. J Shoulder Elbow Surg2017 Nov;26(11):1984-9.
21. Maurer A, Fucentese SF, Pfirrmann CW, Wirth SH, Djahangiri A, Jost B, Gerber C. Assessment of glenoid inclination on routine clinical radiographs and computed tomography examinations of the shoulder. J Shoulder Elbow Surg2012 Aug;21(8):1096-103.
22. Garcia GH, Liu JN, Degen RM, Johnson CC, Wong AC, Dines DM, Gulotta LV, Dines JS. Higher critical shoulder angle increases the risk of retear after rotator cuff repair. J Shoulder Elbow Surg2017 Feb;26(2):241-5.

23. Friedman RJ, Hawthorne KB, Genez BM. The use of computerized tomography in the measurement of glenoid version. J Bone Joint Surg Am1992 Aug;74(7):1032-7.

24. Walch G, Badet R, Boulahia A, Khoury A. Morphologic study of the glenoid in primary glenohumeral osteoarthritis. J Arthroplasty1999 Sep;14(6):756-60.

25. Moor BK, Bouaicha S, Rothenfluh DA, Sukthankar A, Gerber C. Is there an association between the individual anatomy of the scapula and the development of rotator cuff tears or osteoarthritis of the glenohumeral joint? A RADIOLOGICAL STUDY OF THE CRITICAL SHOULDER ANGLE. Bone & Joint Journal2013 Jul;95b(7):935-41.

26. Wijeratna M, Taylor DM, Lee S, Hoy G, Evans MC. Clinical and Radiographic Results of an All-Polyethylene Pegged Bone-Ingrowth Glenoid Component. J Bone Joint Surg Am2016 Jul 6;98(13):1090-6.

27. Gregory T, Hansen U, Khanna M, Mutchler C, Urien S, Amis AA, Augereau B, Emery R. A CT scan protocol for the detection of radiographic loosening of the glenoid component after total shoulder arthroplasty. Acta Orthop2014 Feb;85(1):91-6.

Figure captions

Figure 1

Patient selection flowchart.

Figure 2

Morphology of the two types of glenoid component and area numbers.

(a) Inline type

(b) Outline type

Figure 3

The angles of glenoid placement.

(a) Glenoid component retroversion (α),

(b) Glenoid component superior inclination (β)

Figure 4

Mean CT score (%) of the combined inline and outline groups according to peg location.

Case	Diagnosis	Implant	Implant type	Age	Sex	follow up months	Side	ROM Flexion pre (°)	ROM ER pre (°)	ROM IR pre	Constant Score pre	UCLA score pre	ROM Flexion post (°)	ROM ER post (°)	ROM IR post	Constant Score post	UCLA score post
1	RA	B/F shoulder	inline	50	F	179	L	60	10	buttock	12	10	120	20	T12	74	30
2	RA	B/F shoulder	inline	50	F	176	R	120	20	L5	28	13	110	15	T12	70	28
3	RA	Global advantage	outline	58	F	140	R	120	45	L4	32	9	75	45	L1	50	25
4	OA	Global advantage	outline	83	F	136	R	100	-10	buttock	31	14	160	35	L4	81	31
5	OA	Global advantage	outline	75	M	134	L	50	-20	buttock	14	9	65	-5	L4	42	24
6	RA	B/F shoulder	inline	58	F	150	R	70	20	buttock	16	8	140	30	T12	65	28
7	OA	Global advantage	outline	57	M	131	L	80	-10	buttock	22	14	150	60	T12	61	25
8	RA	B/F shoulder	inline	51	F	132	R	90	0	L2	26	12	100	45	L4	51	27
9	RA	Global advantage	outline	62	F	145	R	80	0	Lateral thigh	13	12	150	35	L4	93	35
10	RA	Global advantage	outline	50	F	130	L	120	20	buttock	26	13	95	25	L2	58	26
11	OA	Global advantage	outline	49	F	120	L	110	10	T11	38	12	160	50	T2	71	27
12	OA	Global advantage	outline	84	F	120	L	120	30	buttock	26	14	145	30	L5	75	30
13	RA	B/F shoulder	inline	67	F	144	R	80	10	buttock	32	8	120	30	L5	72	32
14	OA	Global advantage	outline	66	F	136	L	110	20	L5	34	12	155	45	T12	85	33
15	RA	Global advantage	outline	61	M	130	R	70	10	buttock	31	9	85	35	L5	56	25
16	RA	B/F shoulder	inline	57	F	127	R	80	30	T12	35	8	160	30	T10	86	32
17	RA	Global advantage	outline	60	F	126	L	65	-10	Lateral thigh	21	8	160	30	T10	86	32
18	RA	Global advantage	outline	62	F	120	R	90	10	buttock	27	8	160	35	L4	85	30
mean				61.1		137.6		89.7	10.3	S	25.8	10.7	128.3	32.8	L1	70.1	28.9

RA, Rheumatoid Arthritis; OA, OsteoArthritis; B/F, Bigliani/Flatow; ROM, Range Of Motion; ER, External Rotation; IR, Internal Rotation; UCLA, University of California at Los Angeles.

Table 1

Case	Xp Grade	Seating	CSA (°)	Humeral Bone Resorption Grade/Zone	CT score (%)	Glenoid retroversion (°)	Glenoid inclination (°)	Subluxation index (%)	Goutallier	Warner
1	0	A	49	1/1	20	0.6	27.3	49	1	mild
2	1	B	44	1/1	0	-24	24.6	40	0	none
3	4	A	27	1/1	33	0.9	8.9	49	0	none
4	0	A	32	1/4	0	7.1	1.6	52	2	moderate
5	1	B	27	1/1	21	26.8	7.2	51	2	mild
6	2	A	43	1/1	47	8.6	8.2	43	1	mild
7	0	A	31	0	0	-1.5	18.8	53	0	none
8	1	A	27	0	40	2.4	-0.5	46	0	none
9	1	B	32	0	13	1.3	14.4	43	0	none
10	4	A	33	4/4	38	-4.9	-2.1	34	0	none
11	1	A	30	0	8	10	21.6	55	0	none
12	0	A	29	0	8	-4.2	3.5	50	2	moderate
13	2	A	23	2/1	20	-2	4	39	0	none
14	1	B	32	0	4	2.9	12	39	0	none
15	2	A	38	0	38	-11	10	48	0	none
16	0	A	54	1/1, 1/4	7	-0.8	32	54	2	moderate
17	1	A	38	0	25	-16.2	28.2	44	0	none
18	0	A	20	0	13	-2.7	10.3	47	0	none
mean	1.2		33.8	0.7	18.6	-0.4	12.8	46.4	0.6	

CSA, Critical Shoulder Angle; CT, Computed Tomography.

Table. 2

Table 3

	Glenoid possible loosening	No glenoid loosening	
	(n=5)	(n=13)	
Clinical outcomes	Mean	Mean	P Value
Measured active motion (°)			
Forward flexion	99±22.2	140±27.4	0.008
External rotation	36±8	33.5±17.3	0.35
Internal rotation	buttock	T12	0.11
Clinical scores (points)			
Constant score	56.0±5.4	75.4±12.8	<0.001
UCLA score	26.2±1.2	29.9±3.0	0.001

UCLA, University of California at Los Angeles

Table. 4

Radiographic measurement	Glenoid possible loosening (n=5) Mean	No glenoid loosening (n=13) Mean	P Value
Postoperative radiographs			
Lazarus radiolucency score	2.6±1.2	0.62±0.6	<0.001
Lazarus seating score	5A	9A, 4B	
Critical shoulder angle (°)	33.3±0.4	33.9±9.4	0.44
Inoue humeral bone resorption grade	grade1; 2, grade4; 2	grade1; 5, grade2; 1	
Postoperative CT findings			
CT radiolucency score (%)	39.0±4.4	10.6±8.3	<0.001
Glenoid retroversion (°)	-0.16±11.5	-0.8±6.7	0.45
Glenoid inclination (°)	4.9±5.1	15.6±9.7	0.007
Subluxation index (%)	44.1±5.2	47.3±5.4	0.16
Goutallier	grade 1; 1	grade 1 ;1, grade 2; 4	
Warner	none4, mild1	none8, mild2, moderate3	
Radiographic follow-up, mo	135.6±8.5	138±18.6	0.4

Fig. 1

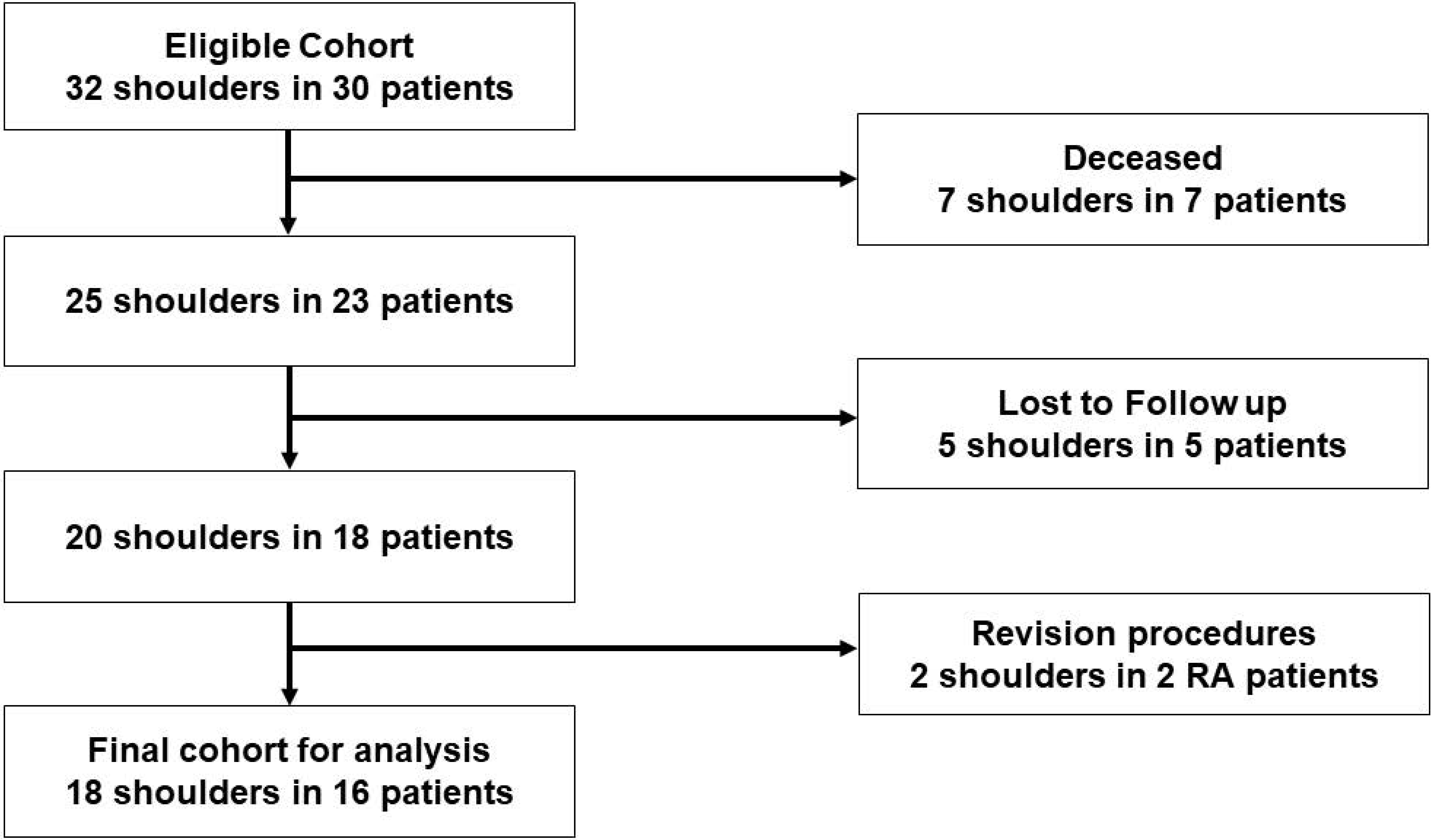
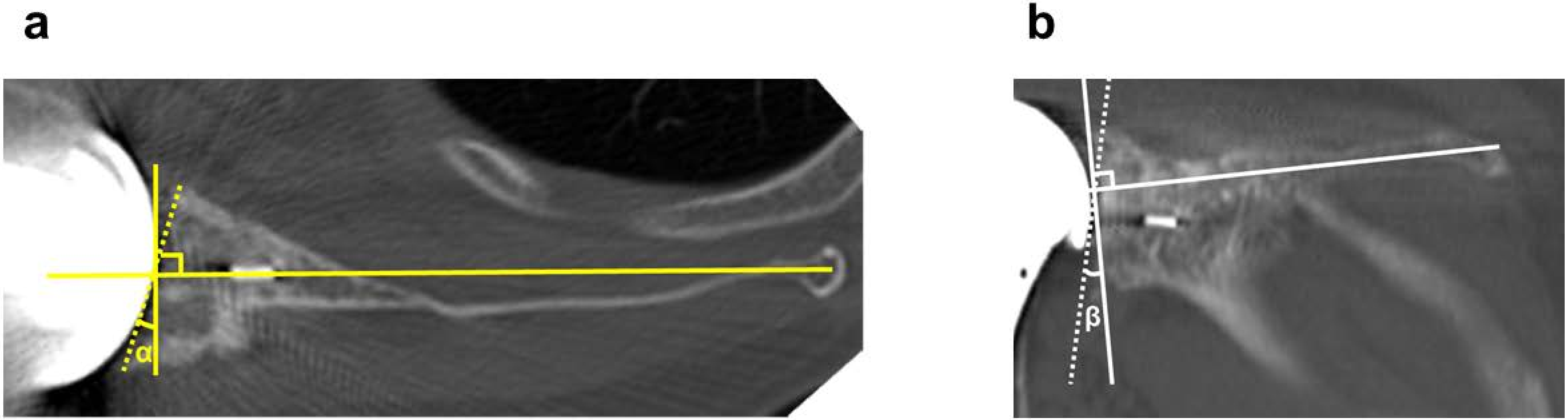
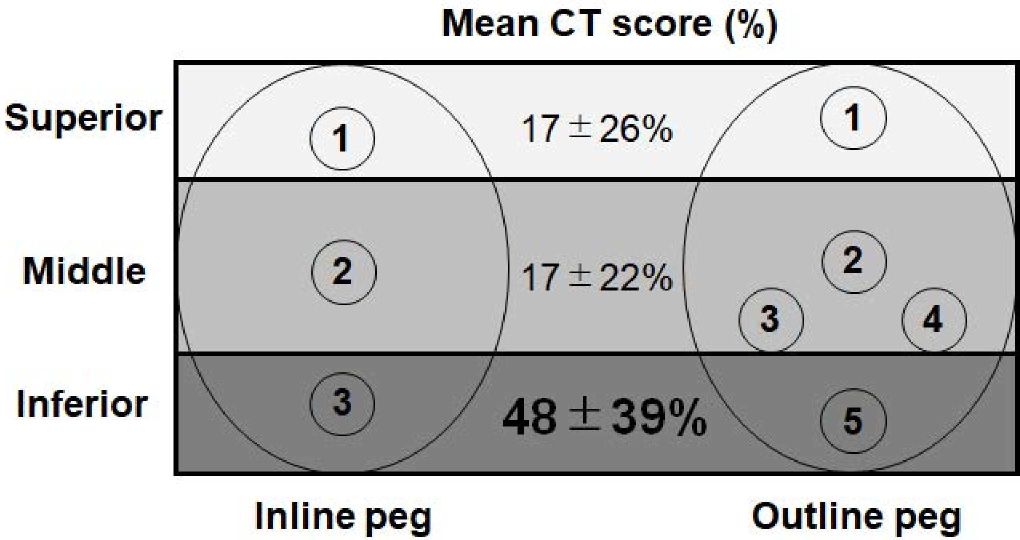

Eligible Cohort
32 shoulders in 30 patients
Deceased
7 shoulders in 7 patients
25 shoulders in 23 patients
Lost to Follow up
5 shoulders in 5 patients
20 shoulders in 18 patients
Revision procedures
2 shoulders in 2 RA patients
Final cohort for analysis
18 shoulders in 16 patients

Fig. 2

Fig. 3




Mean CT score (%)
Superior
Middle
Inferior
17 ± 26%
17 ± 22%
48 ± 39%
1
2
3
1
2
3
4
5
Inline peg
Outline peg