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Glenoid component lucencies are associated with poorer patient-reported outcomes following anatomic shoulder arthroplasty

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Background: High rates of radiographic glenoid loosening following anatomic total shoulder arthroplasty (TSA) are documented at midterm follow-up. Small studies remain conflicted on the impact of lucent lines on clinical outcomes. This study assesses the impact of radiolucent lines on function and patient-reported outcomes (PROs) following TSA.

Methods: We retrospectively evaluated 492 primary TSAs performed between February 2005 and April 2016. Radiographs were evaluated for glenoid loosening according to the Lazarus grade at a mean of 5.3 years (range, 2-12 years). Clinical outcome measures included range of motion and American Shoulder and Elbow Surgeons, Constant, University of California–Los Angeles, Simple Shoulder Test, and Shoulder Pain and Disability Index scores. Outcomes were compared between patients with and patients without glenoid lucent lines and in relation to lucency grade.

Results: At most recent follow-up, 308 glenoids (63%) showed no radiolucent lines (group 0) and 184 demonstrated peri-glenoid lucencies (group 1). The groups were similar regarding age, sex, body mass index, comorbidities, and prior surgery. At follow-up, group 1 demonstrated significantly lower improvements in forward elevation ($P = .02$) and all PROs ($P \leq .005$). Subgroup analysis by radiolucency grade showed that forward elevation diminished with increasing radiolucent score and exceeded the minimal clinically important difference (MCID) above grade 2 lucencies. A similar decline in PROs was observed with increasing lucency grade. These differences did not exceed the MCID below grade 5 lucencies.

Discussion: Peri-implant glenoid lucencies following TSA are associated with lower forward elevation and PROs. Lucencies above grade 2 are associated with clinically important losses in overhead motion. However, differences below the MCID are maintained for PROs below grade 5 glenoid lucencies.

Institutional review board approval was received for this study (Western Institutional Review Board study no. 1112376).

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Anatomic total shoulder arthroplasty (TSA) is a reliable operation to provide pain relief and improve function for end-stage primary osteoarthritis of the glenohumeral joint.[6,23] However, there remains a high incidence of radiographic lucencies about the glenoid component at midterm follow-up, with reports showing up to 60% of TSAs being affected.[7,13,15] In more than one-third of cases, components have been shown to be radiographically loose.[7,15] Kilian et al[13] showed similar rates of loosening between pegged and keeled all-polyethylene components. Despite high rates of radiographic loosening, revision rates remain significantly lower, averaging approximately 1% per year.[13,23,24] Given the discrepancy between radiographic loosening and revision rates, it is assumed that many patients tolerate glenoid component loosening. Small studies remain conflicted on the impact of lucent lines on clinical outcomes.[4,8,9,12,16-18,20] The primary objective of this study was to assess the clinical impact of radiolucent lines on functional and patient-reported outcomes (PROs) following anatomic TSA.

Materials and methods

A retrospective review of all primary anatomic TSAs between February 2005 and April 2016 was performed using a prospectively collected multicenter research database. All procedures were performed with a single shoulder arthroplasty system (Equinoxe; Exactech, Gainesville, FL, USA). This system offers 3 glenoid options, which include an all-polyethylene keeled component, an all-polyethylene peg, and a central ingrowth peg with peripherally cemented pegs. All operations were performed by fellowship-trained surgeons from 14 centers across the world. The glenoid component type was chosen based on surgeon preference and availability at the time of implantation. The exclusion criteria included central ingrowth pegs, augmented glenoid components, revision surgery, an active diagnosis of infection, and radiographic follow-up of less than 2 years. Central ingrowth peg components were eliminated because of their later introduction, shorter follow-up, and lower rates of radiolucent lines.[10]

All shoulders were evaluated by the operating surgeon using a standardized radiographic follow-up template. A minimum of 2 views were routinely obtained (Grashey and axillary lateral) (Fig. 1). Glenoid lines were graded according to the Lazarus scale.[14] For keeled components, shoulders were deemed

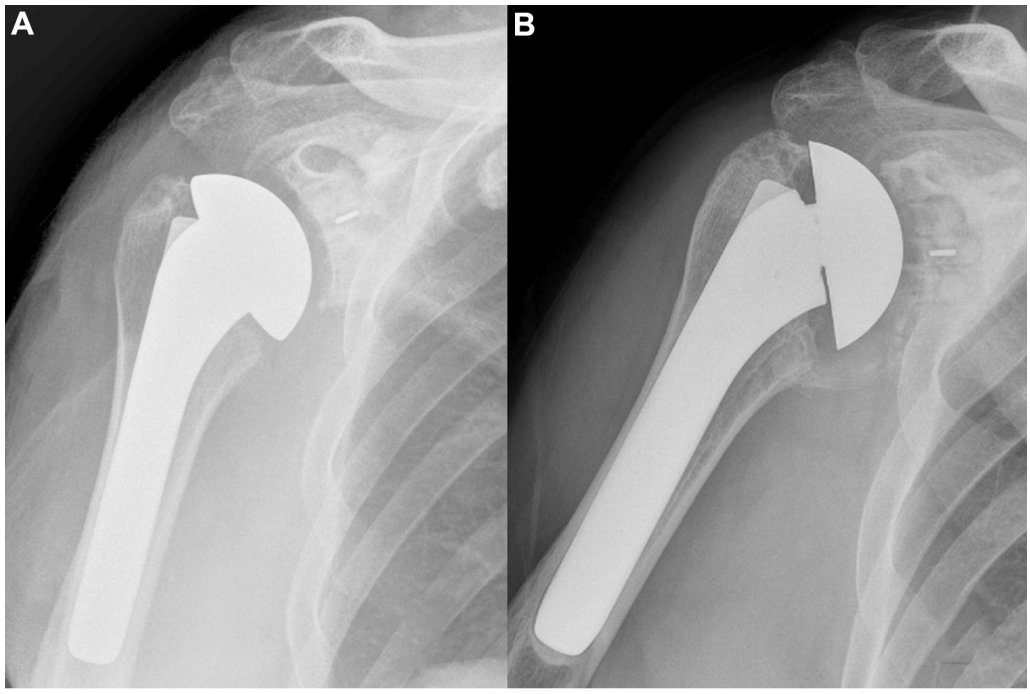

Figure 1 Early postoperative **(A)** and 5-year postoperative **(B)** radiographs showing a grade 5 lucency about the all-polyethylene pegged glenoid.

Table I IR scale

Active range of IR	IR score
0°	0
15° of IR or motion to hip	1
30° of IR or motion to buttock/PSIS/SI joint	2
45° of IR or motion to sacrum	3
60° of IR or motion to L4 to L5	4
75° of IR or motion to L1 to L3	5
90° of IR or motion to T8 to T12	6
>90° of IR or motion to T7 or above	7

IR, internal rotation; *PSIS*, posterior superior iliac spine; *SI*, sacroiliac; *L*, lumbar vertebra; *T*, thoracic vertebra.

grade 0 (no radiolucency), grade 1 (radiolucency at superior, anterior, and inferior flange), grade 2 (incomplete radiolucency at keel), grade 3 (complete radiolucency ≤ 2 mm around keel), grade 4 (complete radiolucency > 2 mm around keel), or grade 5 (gross loosening or shift in component position). For pegged components, shoulders were deemed grade 0 (no radiolucency), grade 1 (incomplete radiolucency around 1 or 2 pegs), grade 2 (complete radiolucency 2 mm wide around only 1 peg with or without incomplete radiolucency around another peg), grade 3 (complete radiolucency 2 mm wide around ≥ 2 pegs), grade 4 (complete radiolucency > 2 mm wide around ≥ 2 pegs), or grade 5 (gross loosening or shift in component position). Shoulders were then separated based on the presence or absence of glenoid component lucencies. Humeral loosening was assessed according to Sanchez-Sotelo et al.[21,22]

The database was queried for demographic data including age, sex, and body mass index. Data were collected on the administration of a prior corticosteroid injection or prior surgery. The performing surgeons and/or their associated research teams evaluated patients independently both prior to and following primary shoulder arthroplasty. Shoulders were evaluated clinically for active range of motion (ROM), including forward elevation, external rotation with the arm at the side, and internal rotation. Forward elevation and external rotation were measured in degrees. Internal rotation was measured according to the level reached by the thumb. This value was categorized as described by Flurin et al,[5] as detailed in Table I. At the time of clinical follow-up, patients also completed PRO scores including the following: American Shoulder and Elbow Surgeons score, Constant score, University of California–Los Angeles score, Simple Shoulder Test score, and Shoulder Pain and Disability Index score. Improvements in ROM and PRO measures were also compared with the minimal clinically important difference (MCID) to assess the clinical implications of differences found between groups.[25] Complications and reoperations were recorded. Shoulders undergoing revision surgery were included in the clinical analysis using the most recent data prior to revision surgery.

Statistical analysis

Continuous variables were evaluated using the Welch 2-sample t test or 1-way analysis of variance with the Tukey honestly significant difference post hoc test for multiple comparisons of means. Because of low counts for some categorical variables, the Fisher exact test was used for comparisons. Other categorical variables were analyzed using the χ^2 test. The α level for significance was set at $P < .05$. SPSS software (version 17.0; IBM, Armonk, NY, USA) and the R program (version 3.5.1; R Foundation for Statistical Computing, Vienna, Austria) were used for statistical analyses.

Table II Demographic characteristics with preoperative and postoperative ROM and PROs

Characteristic	No lines (n = 308)	Lines (n = 184)	*P* value
Age, yr	67 (8.7)	67 (9.5)	.3
M/F sex, n	130/178	76/108	.9
BMI	30.1 (6.5)	29.5 (6.3)	.4
Prior surgery, n	39	20	.6
Injection, n	111 (56%)	49 (36%)	.03
Follow-up, mo	59.7 (27.8)	70.6 (29.0)	<.001
Preoperative			
Forward elevation, °	97 (32.5)	98 (30.2)	.7
IR	3.0 (1.5)	2.9 (1.5)	.661
ER, °	15 (19.4)	15 (18.0)	.6
SST score	3.1 (2.6)	4.0 (2.7)	.007
Constant score	35.1 (12.4)	37.6 (13.1)	.1
ASES score	33.1 (15.9)	37.8 (15.8)	.01
UCLA score	13.4 (4.0)	14.3 (4.1)	.07
SPADI score	88.2 (21.2)	82.2 (20.6)	.02
Postoperative			
Forward elevation, °	144 (30.3)	137 (34.0)	.01
IR	5.0 (1.5)	5.1 (1.6)	.6
ER, °	49 (19.4)	47 (19.5)	.2
SST score	10.1 (2.5)	9.4 (3.1)	.006
Constant score	69.8 (14.5)	64.8 (16.2)	.001
ASES score	81.8 (20.7)	74.6 (23.6)	.001
UCLA score	30.0 (5.6)	28.0 (7.2)	.002
SPADI score	19.1 (24.0)	30.0 (29.1)	<.001

ROM, range of motion; *PRO*, patient-reported outcome; *M*, male; *F*, female; *BMI*, body mass index; *IR*, internal rotation; *ER*, external rotation; *SST*, Simple Shoulder Test; *ASES*, American Shoulder and Elbow Surgeons; *UCLA*, University of California–Los Angeles; *SPADI*, Shoulder Pain and Disability Index.
Data are presented as mean (standard deviation) unless otherwise indicated.

Results

Patients

We evaluated 492 TSAs (286 female and 206 male patients). All-polyethylene pegged glenoids were used in 306 shoulders. All-polyethylene keels were used in 186 shoulders. All-polyethylene pegged glenoids were significantly more common in the group with peri-implant lucencies (group 1) (68% vs. 59%, $P = .04$). At most recent follow-up, 308 glenoids (63%) showed no radiolucent lines (group 0). The remaining 184 glenoids demonstrated peri-implant lucencies (group 1) deemed grade 1 in 64 (35%), grade 2 in

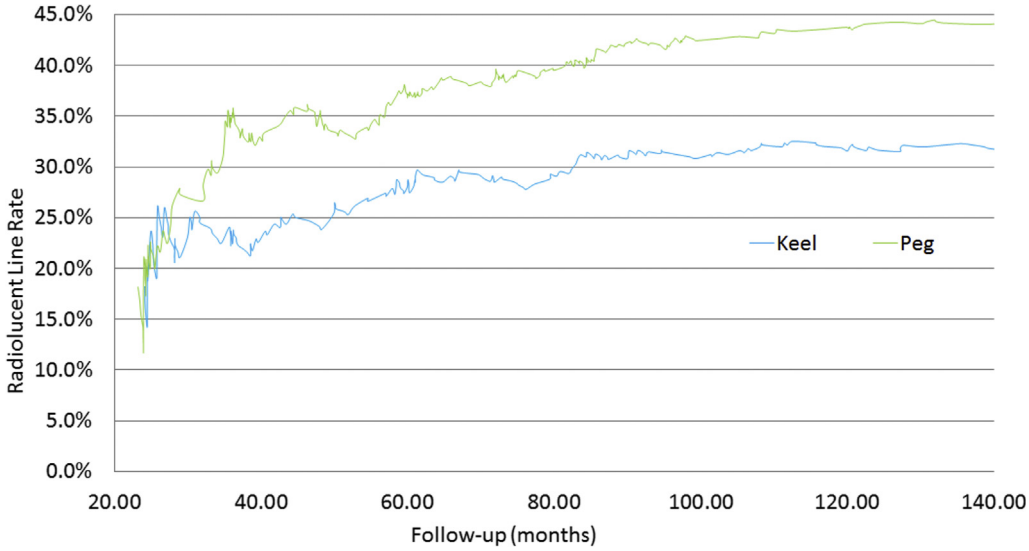

Figure 2 Change in radiolucent glenoid line rate with follow-up duration: comparison of keeled and pegged glenoids.

47 (26%), grade 3 in 38 (21%), grade 4 in 18 (10%), and grade 5 in 17 (9%). Both groups were similar regarding age, sex, body mass index, comorbidities, and history of surgery. Table II shows complete demographic data.

The follow-up period for group 1 (mean, 5.9 years; range, 2-12 years) was significantly longer than that for group 0 (mean, 5.0 years; range, 2-12 years; $P < .001$). When evaluation was performed based on implant type, all-polyethylene pegged and keeled glenoids had similar follow-up periods (63.6 months vs. 64.3 months, $P = .8$). There was a trend toward longer follow-up with increasing radiolucency score, with the percentage of shoulders showing radiolucent lines increasing over time (Fig. 2).

Clinical results

Preoperatively, group 0 and group 1 demonstrated similar ROM and PROs. Preoperative PROs showed statistically significant differences for only Simple Shoulder Test, American Shoulder and Elbow Surgeons, and Shoulder Pain and Disability Index scores between group 0 and group 1. These data are detailed in Table II. Postoperatively, ROM in all planes improved significantly in both groups. When compared according to the presence of glenoid lines, group 1 had lower forward elevation (137° vs. 144°, $P = .01$) and external rotation (47° vs. 49°, $P = .3$). Internal rotation was similar in the 2 groups, averaging 5.1 ($P = .6$). Similarly to overhead ROM, all PRO measures were significantly worse in group 1 ($P < .007$).

When we compared improvement over time, overhead ROM and all PROs remained worse in group 1. Statistically significant differences were noted for forward elevation and all PROs. Table III shows details. However, all ROM and PRO improvements remained greater than the MCIDs, as described by Simovitch et al,[25] compared with the preoperative values for both groups.

Complications and reoperations were more common in group 1 (16% vs. 5% [$P < .001$] and 11% vs. 3% [$P < .001$], respectively). Glenoid component loosening was the most common cause of reoperation in group 1, representing the indication for revision in 14 of 21 reoperations. When eliminating glenoid component loosening, we found similar reoperation rates between groups ($P = .6$).

Comparison of outcomes according to Lazarus grade

A subgroup analysis was performed to assess the impact of radiolucency grade on both ROM and PRO parameters.

Table III Mean improvement in ROM and PROs

Measure	Mean improvement		*P* value
	No lines (n = 308)	Lines (n = 184)	
Forward elevation, °	49 (37.5)	39 (41.7)	.02
IR	2.1 (1.9)	2.0 (2.1)	.6
ER, °	34 (23.0)	31 (20.4)	.1
SST score	7.3 (3.0)	5.6 (3.9)	<.001
Constant score	34.8 (16.3)	28.0 (19.7)	.005
ASES score	49.1 (22.5)	38.1 (27.3)	<.001
UCLA score	16.8 (6.3)	14.0 (8.2)	.003
SPADI score	70.2 (28.4)	52.5 (34.3)	<.001

ROM, range of motion; *PRO*, patient-reported outcome; *IR*, internal rotation; *ER*, external rotation; *SST*, Simple Shoulder Test; *ASES*, American Shoulder and Elbow Surgeons; *UCLA*, University of California–Los Angeles; *SPADI*, Shoulder Pain and Disability Index. Data are presented as mean (standard deviation).

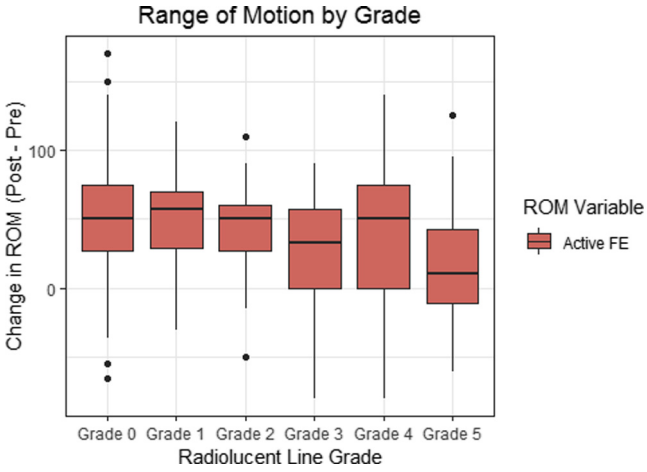

Figure 3 Forward elevation (*FE*) trend by Lazarus grade. *ROM*, range of motion; *Post*, postoperatively; *Pre*, preoperatively.

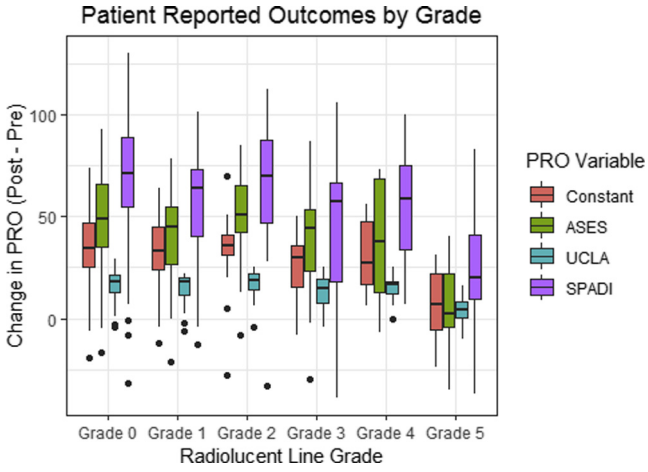

Figure 4 Patient-reported outcome (*PRO*) trend by Lazarus grade. *Post*, postoperatively; *Pre*, preoperatively; *ASES*, American Shoulder and Elbow Surgeons; *UCLA*, University of California–Los Angeles; *SPADI*, Shoulder Pain and Disability Index.

When individual groups were analyzed, there was a trend toward decreased forward elevation and decreased PROs with an increasing Lazarus grade (Figs. 3 and 4). Internal rotation and external rotation were maintained without significant differences in all groups regardless of lucent line grade. However, forward elevation diminished with increasing radiolucent lines, and the differences compared with shoulders without lucent lines exceeded the MCID beyond a grade 2 rating (Table IV). A similar decline in PROs was observed with increasing glenoid lucency grade. However, unlike ROM, these differences did not exceed the MCID until a grade 5 lucency was present.

Discussion

Early failures following TSA are most commonly due to instability and rotator cuff deficiency.[2,24] However, at midterm to long-term follow-up, glenoid component loosening becomes the most prominent mode of failure after TSA.[24] Rates of radiographic lucencies of all-polyethylene glenoid components have been reported to exceed 60% at midterm follow-up, regardless of whether a pegged or keeled design is used.[7,13,15] Despite high rates of radiographic glenoid lucent lines, far fewer shoulders undergo revision surgery. The discordance between the incidence of lucent lines and revision is supported by the results of our study that suggest that radiographic glenoid lucent lines have a progressive worsening effect on both overhead ROM and PROs. However, the negative effect on PROs does not exceed the MCID until a grade 5 lucency is present.

The presence of radiolucent lines has been reported at rates between 0% and 100%.[1,3,6,9,11-13,16,17,19,20,26,28,30,31] At a mean follow-up of 5.3 years, 37% of TSAs in this study had radiolucent lines. This is on the lower end of the historically reported ranges. This may in part be a result of shoulders with a minimum follow-up period of 2 years being included. With longer follow-up, the incidence of radiolucent lines may increase in this cohort. Studies with longer mean follow-up periods have shown higher rates of peri-glenoid lucencies compared with this study. Fox et al[7] reported peri-glenoid lucent lines in 68% of keeled components at an average follow-up of 8.6 years (minimum, 4 years). A similar study by McLendon et al[15] showed a 79% incidence of radiolucent lines at an average follow-up of 7 years for an all-polyethylene in-line pegged component. Multiple studies have shown that radiolucent lines increase over time.[8,12,17] We observed a similar trend, with the Lazarus grade increasing as the average length of follow-up increased.

In shoulders with documented glenoid radiolucencies, improvements in postoperative forward elevation and all PROs were significantly worse than in shoulders without peri-glenoid lucencies. This contrasts with findings of smaller studies that have not shown a correlation between glenoid radiolucencies and PROs.[9,12,17,20] However, these studies were limited by smaller patient cohorts below 100, thereby increasing the chance of a type II (β) error. Larger studies by Walch et al[27] and Young et al[30] have challenged these findings. Walch et al reported on 301 TSAs with a convex-back keeled glenoid at an average of 7.4 years. They found statistically significant correlations with adjusted Constant scores and forward elevation with increasing radiolucent line scores. A similarly designed study by Young et al reported on 217 TSAs treated with flat-back keeled glenoid components using the same methodology as Walch et al. In both studies, the authors only evaluated the presence of a correlation. Specific values

Table IV Mean difference in postoperative improvement by Lazarus grade

Measure	Mean difference					
	Grade 0 vs. grade 1-5	Grade 0 vs. grade 1	Grade 0 vs. grade 2	Grade 0 vs. grade 3	Grade 0 vs. grade 4	Grade 0 vs. grade 5
Forward elevation, °	10.3	0.8	5.7	23.3*	11.8	29.8*
IR	0.1	0.1	0.1	0.5	0.6	0.9
ER, °	3.7	2.1	4.1	1.0	3.9	12.4
SST score	1.7	1.1	0.2	3.0*	1.0	5.4*
Constant score	6.7	3.0	0.9	9.2	3.5	28.9*
ASES score	11.0	9.1	0.9	10.7	10.5	45.4*
UCLA score	2.8	1.5	0.6	4.0	1.8	12.5*
SPADI score	17.6	12.8	4.4	26.9*	15.7	48.6*

IR, internal rotation; *ER*, external rotation; *SST*, Simple Shoulder Test; *ASES*, American Shoulder and Elbow Surgeons; *UCLA*, University of California–Los Angeles; *SPADI*, Shoulder Pain and Disability Index.

* Difference above minimal clinically important difference.[25]

for each group were not provided, and lucencies were grouped into only 3 groups (no loosening, possible loosening, and definite loosening).[27,30] In addition, these prior studies did not assess the effect of radiolucent lines on external rotation or internal rotation. By evaluating groups according to Lazarus grade, we were able to show a progressive effect of radiolucencies on both ROM and PROs. These scores were then able to be compared with those of shoulders without a radiolucency and assessed for clinically meaningful differences.

Although statistically significant differences were noted between patients with and patients without glenoid lines, none of these exceeded the MCID. However, on the basis of our subgroup analysis, the majority of the detrimental effect caused by peri-glenoid lines was caused by shoulders with higher Lazarus grades. When evaluation by Lazarus grade was performed, the clinical significance of radiolucent lines became more apparent. Clinically significant loss in overhead motion was not apparent until a Lazarus grade above 2 was observed. Beyond grade 2, improvements in forward elevation did not exceed the MCID, indicating that clinically meaningful differences were identified compared with shoulders without peri-glenoid radiolucent lines. Despite clinically significant loss in overhead ROM, shoulders maintained clinically meaningful improvements in function with a Lazarus grade below 5. Improvements in all PROs remained above the MCID until a grade 5 lucency was observed and clinically meaningful loss of function was observed. The observed maintenance of function, as assessed by multiple PROs, may explain the discordance of radiolucent lines and revision surgery shown in prior studies.[7,13,15] We are unaware of any other study evaluating the effect of radiographic loosening in relation to MCIDs.

The strength of this study is the large population that was assessed using prospectively collected data. A post hoc power analysis demonstrated that our study was powered to detect all differences in PROs but was underpowered to detect differences in ROM measurements. In addition, the use of multiple surgeons in multiple countries increases the generalizability of the study findings across patient populations.

Our study has multiple limitations. First, operations were performed at 14 separate centers, leading to variation in surgical techniques and choice of implants (pegged vs. keeled). However, this also increases the generalizability of the study findings. Second, the surgeons performing the index arthroplasty were responsible for grading the postoperative radiographs, leading to the risk of self-evaluation bias. To limit interobserver variations, all surgeons performed the review using a standardized form. Third, postoperative reviews were conducted using orthogonal plain-film radiographs. It is possible that all lucencies were not visualized; however, postoperative computed tomography scans have been shown to correlate with plain-film loosening scores.[29] Finally, radiographs were reviewed only at the time of most recent follow-up. Although we did document an overall trend of increased Lazarus grade with increased follow-up time, this was not assessed for each individual patient over time.

Conclusion

The presence of peri-implant lucencies about the glenoid component following anatomic shoulder arthroplasty is associated with lower ROM and PROs compared with shoulders without glenoid lines. Both overhead ROM and PROs worsen as the Lazarus grade increases. Differences in PROs above the MCID are most likely to occur with grade 5 lucencies.

Disclaimer

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References

1. Arnold RM, High RR, Grosshans KT, Walker CW, Fehringer EV. Bone presence between the central peg's radial fins of a partially cemented pegged all poly glenoid component suggest few radiolucencies. J Shoulder Elbow Surg 2011;20:315-21. https://doi.org/10.1016/j.jse.2010.05.025
2. Bohsali KI, Bois AJ, Wirth MA. Complications of shoulder arthroplasty. J Bone Joint Surg Am 2017;99:256-69. https://doi.org/10.2106/JBJS.16.00935
3. Churchill RS, Zellmer C, Zimmers HJ, Ruggero R. Clinical and radiographic analysis of a partially cemented glenoid implant: five-year minimum follow-up. J Shoulder Elbow Surg 2010;19:1091-7. https://doi.org/10.1016/j.jse.2009.12.022
4. Collin P, Tay AKL, Melis B, Boileau P, Walch G. A ten-year radiologic comparison of two-all polyethylene glenoid component designs: a prospective trial. J Shoulder Elbow Surg 2011;20:1217-23. https://doi.org/10.1016/j.jse.2011.06.012
5. Flurin P-H, Marczuk Y, Janout M, Wright TW, Zuckerman J, Roche CP. Comparison of outcomes using anatomic and reverse total shoulder arthroplasty. Bull Hosp Jt Dis (2013) 2013;71(Suppl 2):101-7.
6. Foruria AM, Sperling JW, Ankem HK, Oh LS, Cofield RH. Total shoulder replacement for osteoarthritis in patients 80 years of age and older. J Bone Joint Surg Br 2010;92-B:970-4. https://doi.org/10.1302/0301-620X.92B7.23671
7. Fox TJ, Foruria AM, Klika BJ, Sperling JW, Schleck CD, Cofield RH. Radiographic survival in total shoulder arthroplasty. J Shoulder Elbow Surg 2013;22:1221-7. https://doi.org/10.1016/j.jse.2012.12.034
8. Gazielly DF, Scarlat MM, Verborgt O. Long-term survival of the glenoid components in total shoulder replacement for arthritis. Int Orthop 2015;39:285-9. https://doi.org/10.1007/s00264-014-2637-y
9. Greiner S, Berth A, Kääb M, Irlenbusch U. Glenoid morphology affects the incidence of radiolucent lines around cemented pegged polyethylene glenoid components. Arch Orthop Trauma Surg 2013;133:1331-9. https://doi.org/10.1007/s00402-013-1813-7
10. Grey SG, Wright TW, Flurin P-H, Zuckerman JD, Friedman R, Roche CP. Preliminary results of a novel hybrid cage glenoid compared to an all-polyethylene glenoid in total shoulder arthroplasty. Bull Hosp Jt Dis (2013) 2015;73(Suppl 1):S86-91.
11. 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
12. Kasten P, Pape G, Raiss P, Bruckner T, Rickert M, Zeifang F, et al. Mid-term survivorship analysis of a shoulder replacement with a keeled glenoid and a modern cementing technique. J Bone Joint Surg Br 2010;92:387-92. https://doi.org/10.1302/0301-620X.92B3.23073
13. Kilian CM, Morris BJ, Sochacki KR, Gombera MM, Haigler RE, O'Connor DP, et al. Radiographic comparison of finned, cementless central pegged glenoid component and conventional cemented pegged glenoid component in total shoulder arthroplasty: a prospective randomized study. J Shoulder Elbow Surg 2018;27:S10-6. https://doi.org/10.1016/j.jse.2017.09.014
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. McLendon PB, Schoch BS, Sperling JW, Sánchez-Sotelo J, Schleck CD, Cofield RH. Survival of the pegged glenoid component in shoulder arthroplasty: part II. J Shoulder Elbow Surg 2017;26:1469-76. https://doi.org/10.1016/j.jse.2016.12.068
16. 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(Suppl 1):S29-34. https://doi.org/10.1007/s12306-009-0008-4
17. Merolla G, Ciaramella G, Fabbri E, Walch G, Paladini P, Porcellini G. Total shoulder replacement using a bone ingrowth central peg polyethylene glenoid component: a prospective clinical and computed tomography study with short- to mid-term follow-up. Int Orthop 2016;40:2355-63. https://doi.org/10.1007/s00264-016-3255-7
18. Mileti J, Boardman ND, Sperling JW, Cofield RH, Torchia ME, O'Driscoll SW, et al. Radiographic analysis of polyethylene glenoid components using modern cementing techniques. J Shoulder Elbow Surg 2004;13:492-8. https://doi.org/10.1016/j.jse.2004.03.001
19. Rahme H, Mattsson P, Wikblad L, Nowak J, Larsson S. Stability of cemented in-line pegged glenoid compared with keeled glenoid components in total shoulder arthroplasty. J Bone Joint Surg Am 2009;91:1965-72. https://doi.org/10.2106/JBJS.H.00938
20. Raiss P, Schmitt M, Bruckner T, Kasten P, Pape G, Loew M, et al. Results of cemented total shoulder replacement with a minimum follow-up of ten years. J Bone Joint Surg Am 2012;94:e1711-10. https://doi.org/10.2106/JBJS.K.00580
21. Sanchez-Sotelo J, O'Driscoll SW, Torchia ME, Cofield RH, Rowland CM. Radiographic assessment of cemented humeral components in shoulder arthroplasty. J Shoulder Elbow Surg 2001;10:526-31.
22. Sanchez-Sotelo J, Wright TW, O'Driscoll SW, Cofield RH, Rowland CM. Radiographic assessment of uncemented humeral components in total shoulder arthroplasty. J Arthroplasty 2001;16:180-7.
23. Schoch B, Schleck C, Cofield RH, Sperling JW. Shoulder arthroplasty in patients younger than 50 years: minimum 20-year follow-up. J Shoulder Elbow Surg 2015;24:705-10. https://doi.org/10.1016/j.jse.2014.07.016
24. Schoch B, Werthel JD, Schleck CD, Harmsen WS, Sperling J, Sánchez-Sotelo J, et al. Optimizing follow-up after anatomic total shoulder arthroplasty. J Shoulder Elbow Surg 2017;26:997-1002. https://doi.org/10.1016/j.jse.2016.10.024
25. Simovitch R, Flurin P-H, Wright T, Zuckerman JD, Roche CP. Quantifying success after total shoulder arthroplasty: the minimal clinically important difference. J Shoulder Elbow Surg 2018;27:298-305. https://doi.org/10.1016/j.jse.2017.09.013
26. Throckmorton TW, Zarkadas PC, Sperling JW, Cofield RH. Pegged versus keeled glenoid components in total shoulder arthroplasty. J Shoulder Elbow Surg 2010;19:726-33. https://doi.org/10.1016/j.jse.2009.10.018

27. Walch G, Young AA, Melis B, Gazielly D, Loew M, Boileau P. Results of a convex-back cemented keeled glenoid component in primary osteoarthritis: multicenter study with a follow-up greater than 5 years. J Shoulder Elbow Surg 2011;20:385-94. https://doi.org/10.1016/j.jse.2010.07.011
28. Wirth MA, Loredo R, Garcia G, Rockwood CA, 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. https://doi.org/10.2106/JBJS.J.01400
29. Yian EH, Werner CML, Nyffeler RW, Pfirrmann CW, Ramappa A, Sukthankar A, et al. Radiographic and computed tomography analysis of cemented pegged polyethylene glenoid components in total shoulder replacement. J Bone Joint Surg Am 2005;87:1928-36. https://doi.org/10.2106/JBJS.D.02675
30. Young A, Walch G, Boileau P, Favard L, Gohlke F, Loew M, et al. A multicentre study of the long-term results of using a flat-back polyethylene glenoid component in shoulder replacement for primary osteoarthritis. J Bone Joint Surg Br 2011;93-B:210-6. https://doi.org/10.1302/0301-620X.93B2.25086
31. Zilber S, Radier C, Postel J-M, Van Driessche S, Allain J, Goutallier D. Total shoulder arthroplasty using the superior approach: influence on glenoid loosening and superior migration in the long-term follow-up after Neer II prosthesis installation. J Shoulder Elbow Surg 2008;17:554-63. https://doi.org/10.1016/j.jse.2007.12.004