J Shoulder Elbow Surg (2021) 30, 1068–1077

ELSEVIER

Journal of Shoulder and Elbow Surgery

www.elsevier.com/locate/ymse

Central-peg radiolucency progression of an all-polyethylene glenoid with hybrid fixation in anatomic total shoulder arthroplasty is associated with clinical failure and reoperation

Jason C. Ho, MD*, Eric T. Ricchetti, MD, Joseph P. Iannotti, MD, PhD

Orthopaedic and Rheumatologic Institute, Cleveland Clinic, Cleveland, OH, USA

Background: Glenoid component loosening is a common cause of failure after anatomic total shoulder arthroplasty. Prior studies of all-polyethylene glenoid implants with hybrid fixation did not show early glenoid radiolucency to be clinically significant. The purpose of this study was to determine the clinical significance of progression of radiolucency around the central peg of the glenoid component.
Methods: We identified 73 shoulders that underwent primary anatomic total shoulder arthroplasty between January 1995 and May 2015 for osteoarthritis with an all-polyethylene pegged glenoid, with a minimum follow-up interval of 2 years between early and late follow-up. Demographic, radiographic (central-peg osteolysis [CPO] and central-peg grading [CPG]), and outcome variables comprising the Penn Shoulder Score (PSS) and revision surgery were collected. Clinical failure was defined as a PSS decrease >11.4 points (ie, PSS failure) or revision surgery.
Results: The average patient age at surgery was 65 ± 7 years, and 63% of patients were men. The median initial follow-up period was 14 months (interquartile range, 12-25 months), and the final median follow-up period was 56 months (interquartile range, 47-69 months). Revision surgical procedures were performed in 4 patients, and 17 PSS failures occurred. We found that CPO at final follow-up, CPG progression, and worse PSS at follow-up were associated with revision surgery ($P < .05$). We also found younger age at surgery, CPO at final follow-up, CPG progression, and greater glenoid component retroversion at final follow-up to be associated with clinical failure (PSS failure or revision surgery) ($P < .05$). Multivariate analysis found only CPG progression to be associated with clinical failure ($P < .001$).
Discussion and conclusion: CPO and CPG progression were associated with clinical failure, defined as decreasing clinical outcome scores or revision surgery.
Level of evidence: Level IV; Case Series; Treatment Study

Keywords: Total shoulder arthroplasty; glenoid loosening; radiolucent lines; pegged glenoid; glenoid failure; arthroplasty outcomes

Glenoid component loosening is a common cause of failure after anatomic total shoulder arthroplasty (TSA).[3,4,7-9] Radiolucent lines in keeled glenoid component designs were associated with worse clinical outcomes and concerning for possible impending failure.[2,24,25] Prior studies have shown the progression of radiolucency in a keeled all–polyethylene (PE) glenoid to be predictive of poor functional scores,[6] and other studies have associated

Cleveland Clinic Institutional Review Board approved this study (no. 6235).

*Reprint requests: Jason C. Ho, MD, Orthopaedic and Rheumatologic Institute, Cleveland Clinic, 9500 Euclid Ave, A40, Cleveland, OH 44195, USA.

E-mail address: hoj@ccf.org (J.C. Ho).

1058-2746/$ - see front matter
https://doi.org/10.1016/j.jse.2020.07.039

this with lower Constant scores but not the need for revision surgery.[10] In studies using the next generation of pegged implants with all-cement fixation, worse radiolucent lines have also been correlated with significantly worse clinical outcomes.[17] Pegged glenoids have demonstrated some potential biomechanical advantages,[18,20] and the hybrid fixation design with bony integration (BI) between the fins of the central anchor peg of an all-PE glenoid has shown some possible histologic and clinical benefits.[28,29] With this type of BI hybrid fixation in a pegged implant, studies have found that glenoid central-peg radiolucency could be a sign of early implant loosening, but it has not been found to be correlated with a deterioration in clinical outcomes with early follow-up.[5,13] However, prior studies have lacked sequential follow-up in large numbers to allow for assessment of the progression of radiolucency over time with this implant design and to determine its clinical significance.[1,5,11,13,22,26,29]

Therefore, the purpose of this study was to evaluate the clinical significance of glenoid central-peg radiolucency progression in an all-PE pegged glenoid component following anatomic TSA in a patient cohort with a minimum 2-year follow-up interval. The primary outcomes of interest in this study were patient-reported outcome scores and revision surgery rates. The secondary goals of the study were to find factors that may be associated with a clinically significant decrease in outcome score and/or revision surgery rate for this type of implant.

Materials and methods

We retrospectively identified 376 shoulders (224 in male patients [60%] and 152 in female patients [40%]) that underwent primary anatomic TSA between January 1995 and May 2015 for glenohumeral osteoarthritis with an all-PE pegged glenoid component with an uncemented central peg having flanges that would allow for BI and a standard-length humeral stem (Fig. 1). The initial radiographic and clinical follow-up period was between 1 and 3 years after surgery. All patients had an intact rotator cuff and received either a non-augmented central pegged glenoid component or an augmented central pegged all-PE glenoid component. From this group, 104 patients who had a Penn Shoulder Score (PSS) <70 points at initial follow-up were excluded because we wanted to evaluate the relationship of central-peg osteolysis (CPO) in patients with high shoulder scores at first follow-up—essentially asymptomatic patients. Another 199 patients were excluded as they did not have a minimum interval of 2 years between the initial clinical and radiographic follow-up and the final follow-up. Patients who underwent revision surgery in this 2-year interval were included for analysis. This left a final cohort of 73 shoulders (Fig. 2).

Operative procedure

All patients were operated on by 1 of 3 fellowship-trained shoulder surgeons and received an all-PE glenoid component with a flanged center peg that would allow for BI (APG [DePuy Synthes, Warsaw, IN, USA], Steptech APG [DePuy Synthes], or Affiniti [Wright-Tornier, Bloomington, MN, USA]) and implantation of a standard-length humeral stem. All components were highly cross-linked PE. All patients underwent a deltopectoral approach and followed a standard postoperative physical therapy regimen that started with home-based active-assisted range of motion immediately after discharge from the hospital, with progressive strengthening at 8 weeks from surgery.

Variables of interest

Demographic variables were obtained from the electronic medical record. The PSS was collected prospectively at each follow-up visit as part of routine care. Radiographic variables comprising central-peg grading (CPG)[14,29] (Fig. 3) and glenohumeral radiographic relationships (glenoid component version, superior migration of the humeral head in the humeral head–glenoid plane, and posterior subluxation of the humeral head in the humeral head–scapular and –glenoid planes) were measured at both early and late follow-up, as previously described,[14] by a single reader (J.C.H.) who was blinded to the PSS or need for revision surgery in a randomized fashion and had extensive experience with this technique. CPG (grade 1, CPO; grade 2, bone growth to the edge of the central-peg flanges; or grade 3, bone growth within the central-peg flanges) and superior migration >1 mm were assessed on Grashey (anteroposterior) views (Fig. 3). For all 73 patients, good-quality Grashey (anteroposterior) views were available to measure CPG and humeral head migration. A good-quality radiograph showed a clear space between the components with a good trabecular bone pattern around the glenoid component and no bony structure obscuring the central peg (eg, ribs). Glenoid component version and humeral head subluxation in the scapular and glenoid planes were measured on axillary views when radiographs demonstrated the central-peg metallic marker with sufficient length of the scapular body to define the plane of the scapular body.[14] Humeral head subluxation in the scapular and glenoid planes was measured on axillary radiographs, and superior

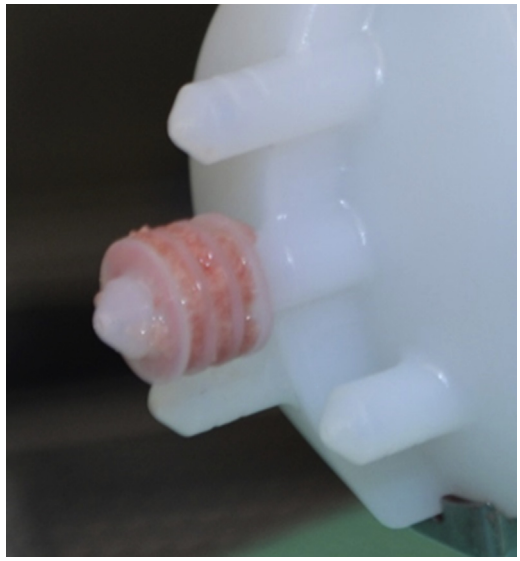

Figure 1 Example of all-polyethylene pegged glenoid component with central peg to allow for bony integration.

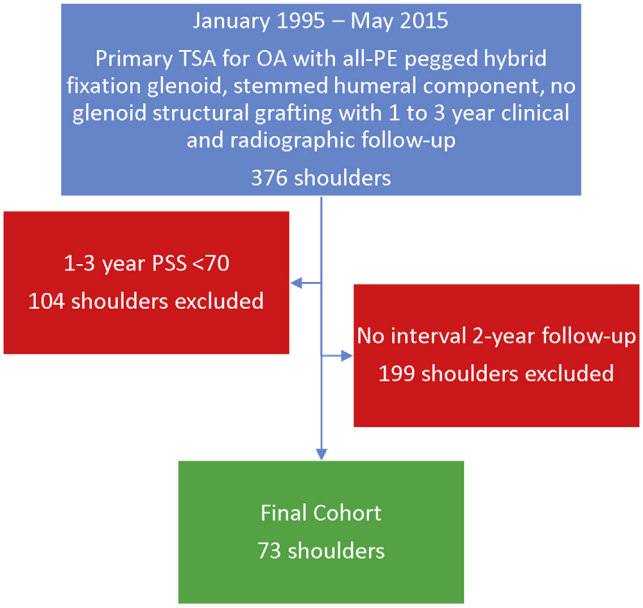

Figure 2 Flowchart showing initial cohort of patients reviewed and exclusions for low early Penn Shoulder Score *(PSS)* and inadequate follow-up between early and late time points. *TSA*, total shoulder arthroplasty; *OA*, osteoarthritis; *PE*, polyethylene.

migration, on Grashey views. If the center of the humeral head, defined by a best-fit circle around the articular surface of the implant, was within 1 mm of a line drawn from the marker on the center peg, then the humeral head was considered centered. Axillary radiographs that did not meet these criteria were excluded from axillary measurements (Table I). A grade of 1 on the CPG scale was defined as CPO. Progression of CPG was considered a change by $\geq$1 grade across the 2 follow-up time points (grade 3 to grade 2, grade 2 to grade 1, or grade 3 to grade 1) or widening of CPO present at initial follow-up (Fig. 3); CPG did not improve in any cases. PSS failure was defined as a decrease >11.4 points, which is the defined minimal clinically important difference,[16] from the early PSS. Clinical failure was defined as PSS failure or revision surgery.

Statistical analysis

The variables of interest were compared across groups based on the primary outcomes of interest, need for revision surgery (yes or no) and clinical failure (yes or no). Continuous variables such as age at surgery and PSS change were displayed as means and standard deviations and were compared across time or between groups using 2-sample *t* tests. Other continuous variables such as time to early or late clinical follow-up, clinical follow-up time, glenoid component version, CPG change, early PSS, and late PSS were presented as medians and interquartile ranges (IQRs) because of non-normal distributions and were compared using the Wilcoxon test. Categorical variables were presented as counts and percentages and were compared using the Pearson χ^2 test or Fisher exact test when appropriate.

To identify the predictors of clinical failure (need for revision surgery or PSS failure), a logistic regression model was built using backward elimination. The following variables were entered into

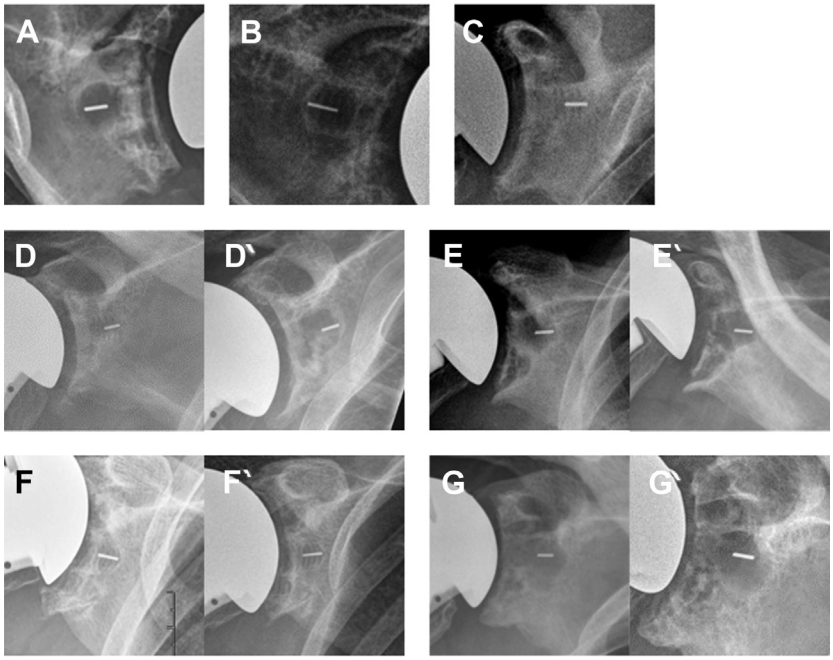

Figure 3 True anteroposterior (Grashey view) radiographs showing central-peg grading *(CPG)* scale for grade 1 (central-peg osteolysis *[CPO]*) **(A)**, grade 2 (bone growth to edge of flanges) **(B)**, and grade 3 (bone growth within flanges) **(C)**. Example of CPG progression from grade 3 **(D)** to grade 1 **(D′)**. Example of CPG progression from grade 1 **(E)** to worsening of grade 1 **(E′)**. One should note the advancement of early sclerotic edges to radiolucency around the central and peripheral pegs **(E′)**. Example of early radiograph showing grade 3 **(F)**, with no change in CPG (ie, stable grade 3) **(F′)**. Example of stable early grade 1 CPO **(G)**, with no progression of CPO and a stable peripheral peg appearance **(G′)**.

Table I Summary statistics (N = 73)

Factor	n	Statistic
Age at surgery, yr	73	65.3 ± 7.4
Sex	73	
Female		27 (37.0)
Male		46 (63.0)
Early radiographic follow-up, mo	73	14.0 [12.0, 25.0]
Radiographic follow-up interval, mo	73	39.3 [25.3, 54.3]
Last radiographic follow-up, mo	73	56.0 [47.0, 69.0]
Glenoid implant	73	
APG		44 (60.3)
Steptech APG		17 (23.3)
Affiniti		12 (16.4)
CPG		
Early follow-up	73	
1		7 (9.6)
2		32 (43.8)
3		34 (46.6)
Late follow-up	73	
1		22 (30.1)
2		28 (38.4)
3		23 (31.5)
CPG progression	73	
No		46 (63.0)
Yes		27 (37.0)
Superior migration		
Early follow-up	73	
No		70 (95.9)
Yes		3 (4.1)
Late follow-up	73	
No		64 (87.7)
Yes		9 (12.3)
Version, degree		
Early follow-up	63	−7.3 [−11.6, −3.2]
Late follow-up	67	−10.1 [−15.5, −3.7]
Posterior subluxation in scapular plane		
Early follow-up	66	
No		46 (69.7)
Yes		20 (30.3)
Late follow-up	67	
No		38 (56.7)
Yes		29 (43.3)
Posterior subluxation in glenoid plane		
Early follow-up	71	
No		60 (84.5)
Yes		11 (15.5)
Late follow-up	70	
No		61 (87.1)
Yes		9 (12.9)
PSS, points		
Early follow-up	73	93.0 [87.2, 98.2]
Late follow-up	73	93.0 [82.1, 98.0]
PSS change, points	73	−4.8 ± 16.6
PSS failure	73	
No		55 (75)
Yes		18 (25)
Revision	73	
No		69 (94.5)
Yes		4 (5.5)

CPG, central-peg grading; *PSS*, Penn Shoulder Score.
Statistics are presented as mean ± standard deviation, median [25th percentile, 75th percentile], or number (column percentage).

the model: CPG at early follow-up, glenoid component version at early follow-up, CPG progression, time to last clinical follow-up, humeral head–scapular plane subluxation at early follow-up, and humeral head–glenoid plane subluxation at early follow-up. After the predictors were selected by the model, the model results correcting for age were presented using odds ratios and corresponding 95% confidence intervals. Data management and data analysis were conducted using SAS software (version 9.4; SAS Institute, Cary, NC, USA). All tests were 2-sided, assuming an α level of .05.

Results

The average age at surgery was 65 ± 7 years, and 46 of 73 (63%) were men (Table I). The median initial follow-up period was 14 months (IQR, 12-25 months), with a median follow-up interval of 39 months (IQR, 25-54 months) and an overall final median follow-up period of 56 months (IQR, 47-69 months) from surgery (Table I). The median initial PSS and final PSS were 93 points (IQR, 87-98 points) and 93 points (IQR, 82-98 points), respectively, with an average change in the PSS of –4.8 ± 16.6 points between follow-up times. We found CPO (grade 1 on CPG scale) in 7 of 73 patients (10%) at initial follow-up and 22 of 73 (30%) at final follow-up ($P < .0001$). We observed CPG progression in 27 of 73 patients (37%). Revision surgical procedures were performed in 4 patients, and 18 clinical failures (revision surgery or PSS failures) occurred (Table I). All revision surgical procedures were performed for a painful TSA owing to aseptic glenoid component loosening. Three shoulders underwent revision to reverse TSA with bone grafting of the glenoid defect, and one underwent revision to a hemiarthroplasty with bone grafting of the glenoid defect as the first stage of a 2-stage revision to reverse TSA. From initial to final follow-up, we measured an average increase in glenoid component retroversion of 3° ($P = .04$), an 8% increase in the number of patients with humeral head superior migration ($P = .01$), and a 13% increase in the number of patients with humeral head posterior subluxation in the scapular plane ($P = .008$) but found no significant change in the number of patients with humeral head posterior subluxation in the glenoid plane ($P = .48$) (Table I).

Univariate analysis at final follow-up showed that CPO ($P = .007$), CPG progression ($P = .016$), and worsening of PSS ($P = .027$) were associated with revision surgery (Table II). CPO at late follow-up ($P = .034$), CPG progression ($P < .001$), and glenoid component version at final radiographic follow-up ($P = .019$) were associated with clinical failure, as defined by the need for revision surgery or PSS failure (Table III). However, CPG was not significantly different at final follow-up ($P = .084$) when clinical failure and non-clinical failure were compared. We also found differences among glenoid implant types, with a higher CPO rate for the Steptech APG implant at early follow-up ($P = .022$) but no difference at late follow-up ($P = .30$). Moreover, a significant difference in radiographic follow-up times was noted ($P = .0005$): APG implants underwent 67.4 ± 21.2 months of follow-up and Affiniti implants underwent 64.8 ± 23.3 months of follow-up, whereas Steptech APG implants only underwent 44.8 ± 9.5 months of follow-up.

Multivariate analysis correcting for age at surgery showed CPG progression as the only significant factor remaining in the model for prediction of clinical failure (need for revision surgery or PSS failure). The odds ratio of clinical failure occurring in patients with CPG progression vs. patients without CPG progression was 7.61 (95% confidence interval, 2.30-25.19; $P < .001$).

Discussion

The purpose of this study was to evaluate the clinical significance (decrease in PSS or revision surgery rate) of CPG progression over a minimum interval of 2 years after anatomic TSA with an all-PE pegged glenoid component having a central peg with flanges to allow for BI. This study demonstrated that the progression of CPG is associated with both revision surgery and a clinically significant decrease in patient-reported outcome scores (PSS). The association of CPG progression with clinical failure was significant on both univariate and multivariate analyses correcting for age. We also found that younger patients were at higher risk of clinical failure, as defined by the need for revision surgery or a clinically significant decrease in the PSS.

Our study did have limitations owing to its retrospective nature. First, two of the implants used to perform anatomic TSA had a similar design. We included all implants that had fluted central pegs to allow for bony ingrowth. Although the Steptech APG augmented glenoid may be different in design, biomechanical studies have found no difference in liftoff resistance when modeling long-term fixation and clinical studies have found a very low rate of radiographic failure at 2- to 6-year follow-up.[12,15] However, our study was not designed to perform an implant-to-implant comparison but rather to evaluate the significance of a single radiographic finding of central-peg BI, and thus, no conclusion can be made about individual implant types based on these data. Second, measurements of glenohumeral relationships and implant placement were made on standard postoperative radiographs, which have decreased accuracy and sensitivity to detect component position, as well as change in component position over time, compared with more advanced imaging techniques. Incomplete plain radiographs were also present at certain time points, resulting in missing data for some of these measurements. Moreover, CPG may be difficult to discern on plain radiographs as compared with advanced imaging (ie, computed tomography); however, we analyzed both CPO vs. non-CPO cases and grade 1 vs. grade 2 vs. grade 3 on

Table II Comparison between shoulders with no revision and shoulders with revision

Factor	No revision (n = 69)		Revision (n = 4)		*P* value
	n	Statistic	n	Statistic	
Age at surgery, yr	69	65.5 ± 7.5	4	60.8 ± 2.3	.21*
Sex	69		4		.62†
Female		25 (36.2)		2 (50.0)	
Male		44 (63.8)		2 (50.0)	
Early radiographic follow-up, mo	69	15.0 [13.0, 25.0]	4	12.0 [12.0, 12.0]	.012‡,§
Radiographic follow-up interval, mo	69	40.5 [25.5, 54.3]	4	31.7 [19.9, 53.2]	.50§
Last radiographic follow-up, mo	69	57.0 [50.0, 69.0]	4	44.0 [32.0, 65.5]	.15§
Glenoid implant					.06†
APG	69	42 (60.8)	4	2 (50.0)	
Steptech APG	69	17 (24.6)	4	0 (0)	
Affiniti	69	10 (14.53)	4	2 (50.0)	
CPG					
Early follow-up	69		4		.41†
1		6 (8.7)		1 (25.0)	
2		31 (44.9)		1 (25.0)	
3		32 (46.4)		2 (50.0)	
Late follow-up	69		4		.007†,‡
1		18 (26.1)		4 (100.0)	
2		28 (40.6)		0 (0.00)	
3		23 (33.3)		0 (0.00)	
Center-peg osteolysis					
Early follow-up	69		4		.34†
No		63 (91.3)		3 (75.0)	
Yes		6 (8.7)		1 (25.0)	
Late follow-up	69		4		.007†,‡
No		51 (73.9)		0 (0.00)	
Yes		18 (26.1)		4 (100.0)	
CPG progression	69		4		.016†,‡
No		46 (66.7)		0 (0.00)	
Yes		23 (33.3)		4 (100.0)	
Superior migration					
Early follow-up	69		4		.99†
No		66 (95.7)		4 (100.0)	
Yes		3 (4.3)		0 (0.00)	
Late follow-up	69		4		.99†
No		60 (87.0)		4 (100.0)	
Yes		9 (13.0)		0 (0.00)	
Version					
Early follow-up	59	−8.2 [−11.9, −4.3]	4	−1.6 [−5.1, −0.50]	.055§
Late follow-up	64	−10.0 [−15.3, −4.1]	3	−16.7 [−23.0, −2.3]	.31§
Posterior subluxation in scapular plane					
Early follow-up	62		4		.99†
No		43 (69.4)		3 (75.0)	
Yes		19 (30.6)		1 (25.0)	
Late follow-up	64		3		.57†
No		37 (57.8)		1 (33.3)	
Yes		27 (42.2)		2 (66.7)	
Posterior subluxation in glenoid plane					
Early follow-up	67		4		.50†
No		57 (85.1)		3 (75.0)	
Yes		10 (14.9)		1 (25.0)	
Late follow-up	67		3		.34†
No		59 (88.1)		2 (66.7)	
Yes		8 (11.9)		1 (33.3)	

(*continued on next page*)

Table II Comparison between shoulders with no revision and shoulders with revision (*continued*)

Factor	No revision (n = 69)		Revision (n = 4)		*P* value
	n	Statistic	n	Statistic	
PSS, points					
Early follow-up	69	94.0 [87.5, 98.3]	4	82.5 [79.0, 87.1]	.027[‡,§]
Late follow-up	69	93.6 [84.4, 98]	4	51.6 [34.2, 82.8]	.011[‡,§]

CPG, central-peg grading; *PSS*, Penn Shoulder Score.
Statistics are presented as mean ± standard deviation, median [25th percentile, 75th percentile], or number (column percentage).
* *P* value calculated by *t* test.
† *P* value calculated by Fisher exact test.
‡ Statistically significant ($P < .05$).
§ *P* value calculated by Wilcoxon rank sum test.

the CPG scale not only to mitigate any error in grading but also to capture any subtle changes that may be observed. Third, a substantial number of patients did not meet the study inclusion criteria because of lack of minimum 2-year follow-up after the initial 1- to 3-year follow-up visit, which presents significant selection bias. As a result, this study was not able to define the incidence of glenoid component loosening, clinical failure, or revision surgery in a population of patients receiving the described type of implant. However, we can evaluate the association of progression of CPG over time with deterioration in the PSS and revision surgery.

Our data demonstrated that progression of CPO in this type of all-PE glenoid component is clinically significant. In addition, CPO is clinically significant when seen ≥3 years after surgery, with a median 56-month follow-up. Prior studies looking at this implant type have found radiolucent lines and CPO but not necessarily clinical deterioration associated with this finding.[1,5,11,13,26,27,29] Only 1 study analyzed sequential follow-up of radiolucent lines past 1 year to allow for assessment of progression of radiolucency over time but was limited by a small sample size of 20 and underpowered to determine its clinical significance.[5] In our study, we looked only at the central-peg BI, as a unique design characteristic of this type of implant that would theoretically support longer-term stability.[28] Prior studies using other designs have found that progression of radiolucent lines was associated with clinically significant decreases in outcome scores.[10,22] Revision rates were not found to be different in studies of earlier implant designs at long-term follow-up,[10,25] but more recent studies suggest that more severe radiolucent lines may be associated with complications and higher revision rates.[22] In addition, we were unable to analyze the effect of glenoid seating, as we did not analyze initial postoperative radiographs to assess the quality of glenoid seating.

We also attempted to measure certain postoperative implant characteristics (glenoid component version, superior migration of the humeral head, and posterior subluxation of the humeral head) in this study. Although prior studies have found that glenoid component retroversion may be a risk factor for CPO,[13] this finding has not been consistently seen across all studies.[19,23] We observed that increased retroversion was associated with clinical failure only at the later follow-up. The clinical significance of this finding is difficult to interpret owing to the small sample size and acknowledged limitations in the sensitivity of plain radiographic measurements. The increase in retroversion from initial to final follow-up in the cases going on to clinical failure could be attributed to a true shift or loosening of the implant or may be within the margin of measurement error (9.9°) on plain radiographs.[14] We also found that more patients had superior migration of the humeral head and posterior subluxation of the humeral head in the scapular plane at final follow-up, although neither of these variables was associated with the need for revision surgery or clinical failure. Again, the clinical significance of these results is unknown at this time. Such changes in humeral head position may be suggestive of possible rotator cuff dysfunction over time or, as with glenoid component version, could represent measurement error using plain radiographs. The change in posterior subluxation in the scapular plane is also closely related to the measurement of version and could be attributable to the change in component version.[21] These possible changes in implant orientation and glenohumeral relationships over time should be investigated further in larger cohorts and/or with more sensitive imaging techniques to better assess their association with clinical outcomes.

On the basis of these results, we believe that the progression of CPG and presence of late CPO are significantly associated with deterioration in clinical outcomes and should be seen as a risk factor for clinical failure and/or revision surgery. This study showed a 37% rate of progression of CPG and a 30% CPO rate at late follow-up. However, this study could not define the incidence of these findings because we did not follow up a consecutive series of patients. This study does define the clinical significance of the progression of radiolucency for the described implant

Table III Comparison between shoulders with no revision or PSS failure and shoulders with revision or PSS failure

Factor	No revision or PSS failure (n = 55)		Revision or PSS failure (n = 18)		*P* value
	n	Statistic	n	Statistic	
Age at surgery, yr	55	66.4 ± 7.2	18	61.9 ± 7.1	.024[*,†]
Sex	55		18		.71[‡]
Female		21 (38.2)		6 (33.3)	
Male		34 (61.8)		12 (66.7)	
Early radiographic follow-up, mo	55	15.0 [13.0, 26.0]	18	13.0 [12.0, 22.0]	.30[§]
Radiographic follow-up interval, mo	55	37.3 [25.0, 54.3]	18	41.8 [28.5, 60.5]	.40[§]
Last radiographic follow-up, mo	55	56.0 [44.0, 69.0]	18	56.5 [51.0, 82.0]	.69[§]
Glenoid implant					.022[†,‖]
APG	55	31 (56.4)	18	13 (72.2)	
Steptech APG	55	15 (27.3)	18	2 (11.1)	
Affiniti	55	9 (16.4)	18	3 (16.7)	
CPG					
Early follow-up	55		18		.88[‡]
1		5 (9.1)		2 (11.1)	
2		25 (45.5)		7 (38.9)	
3		25 (45.5)		9 (50.0)	
Late follow-up	55		18		.084[‡]
1		13 (23.6)		9 (50.0)	
2		22 (40.0)		6 (33.3)	
3		20 (36.4)		3 (16.7)	
Center-peg osteolysis					
Early follow-up	55		18		.99[‖]
No		50 (90.9)		16 (88.9)	
Yes		5 (9.1)		2 (11.1)	
Late follow-up	55		18		.034[†,‡]
No		42 (76.4)		9 (50.0)	
Yes		13 (23.6)		9 (50.0)	
CPG progression	55		18		<.001[†,‡]
No		41 (74.5)		5 (27.8)	
Yes		14 (25.5)		13 (72.2)	
Superior migration					
Early follow-up	55		18		.99[‖]
No		53 (96.4)		17 (94.4)	
Yes		2 (3.6)		1 (5.6)	
Late follow-up	55		18		.68[‖]
No		49 (89.1)		15 (83.3)	
Yes		6 (10.9)		3 (16.7)	
Version					
Early follow-up	47	−7.3 [−13.4, −4.4]	16	−7.0 [−8.9, −2.2]	.16[§]
Late follow-up	53	−9.5 [−13.1, −3.0]	14	−15.5 [−18.7, −8.1]	.019[†,§]
Posterior subluxation in scapular plane					
Early follow-up	50		16		.35[‖]
No		33 (66.0)		13 (81.3)	
Yes		17 (34.0)		3 (18.8)	
Late follow-up	53		14		.24[‡]
No		32 (60.4)		6 (42.9)	
Yes		21 (39.6)		8 (57.1)	
Posterior subluxation in glenoid plane					
Early follow-up	53		18		.99[‖]
No		45 (84.9)		15 (83.3)	
Yes		8 (15.1)		3 (16.7)	
Late follow-up	55		15		.091[‖]
No		50 (90.9)		11 (73.3)	
Yes		5 (9.1)		4 (26.7)	

(*continued on next page*)

Table III Comparison between shoulders with no revision or PSS failure and shoulders with revision or PSS failure (*continued*)

Factor	No revision or PSS failure (n = 55)		Revision or PSS failure (n = 18)		*P* value
	n	Statistic	n	Statistic	
PSS, points					
Early follow-up	55	94.4 [87.3, 99.0]	18	91.0 [84.0, 95.4]	.17[§]
Late follow-up	55	95.9 [88.6, 99.0]	18	66.6 [51.7, 74.6]	.001[†,§]

PSS, Penn Shoulder Score; *CPG*, central-peg grading.
Statistics are presented as mean ± standard deviation, median [25th percentile, 75th percentile], or number (column percentage).
[*] *P* value calculated by *t* test.
[†] Statistically significant ($P < .05$).
[‡] *P* value calculated by Pearson χ^2 test.
[§] *P* value calculated by Wilcoxon rank sum test.
[‖] *P* value calculated by Fisher exact test.

type, and our results suggest the need to investigate the significance of these radiographic findings in a larger prospectively designed study.

Conclusion

Late CPO and CPG progression were associated with clinical failure, defined as decreasing shoulder scores or the need for revision surgery.

Acknowledgments

The authors thank John J. Brems, MD, for contribution of his patients to this study and Yuxuan Jin for her statistical assistance.

Disclaimer

Jason C. Ho is a presenter/speaker for DJO.

Eric T. Ricchetti receives royalties from DJO and is a consultant and presenter/speaker for DJO.

Joseph P. Iannotti receives royalties from Arthrex, DePuy Synthes, DJO, Wright/Tornier, and Wolters Kluwer Health–Lippincott Williams & Wilkins; is a consultant and presenter/speaker for DJO; and receives financial or material support from Wolters Kluwer Health–Lippincott Williams & Wilkins.

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. Barrett WP, Franklin JL, Jackins SE, Wyss CR, Matsen FA. Total shoulder arthroplasty. J Bone Joint Surg Am 1987;69:865-72.
3. Bohsali KI, Wirth MA, Rockwood CA. Complications of total shoulder arthroplasty. J Bone Joint Surg Am 2006;88:2279-92. https://doi.org/10.2106/JBJS.F.00125
4. Chin PYK, Sperling JW, Cofield RH, Schleck C. Complications of total shoulder arthroplasty: are they fewer or different? J Shoulder Elbow Surg 2006;15:19-22. https://doi.org/10.1016/j.jse.2005.05.005
5. 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
6. 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
7. Fox TJ, Cil A, Sperling JW, Sanchez-Sotelo J, Schleck CD, Cofield RH. Survival of the glenoid component in shoulder arthroplasty. J Shoulder Elbow Surg 2009;18:859-63. https://doi.org/10.1016/j.jse.2008.11.020
8. Franklin JL, Barrett WP, Jackins SE, Matsen FA. Glenoid loosening in total shoulder arthroplasty. J Arthroplasty 1988;3:39-46.
9. Franta AK, Lenters TR, Mounce D, Neradilek B, Matsen FA. The complex characteristics of 282 unsatisfactory shoulder arthroplasties. J Shoulder Elbow Surg 2007;16:555-62. https://doi.org/10.1016/j.jse.2006.11.004
10. 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
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. Ho JC, Amini MH, Entezari V, Jun BJ, Alolabi B, Ricchetti ET, et al. Clinical and radiographic outcomes of a posteriorly augmented glenoid component in anatomic total shoulder arthroplasty for primary osteoarthritis with posterior glenoid bone loss. J Bone Joint Surg Am 2018;100:1934-48. https://doi.org/10.2106/JBJS.17.01282
13. Ho JC, Sabesan VJ, Iannotti JP. Glenoid component retroversion is associated with osteolysis. J Bone Joint Surg Am 2013;95:e82. https://doi.org/10.2106/JBJS.L.00336

14. Ho JC, Youderian A, Davidson IU, Bryan J, Iannotti JP. Accuracy and reliability of postoperative radiographic measurements of glenoid anatomy and relationships in patients with total shoulder arthroplasty. J Shoulder Elbow Surg 2013;22:1068-77. https://doi.org/10.1016/j.jse.2012.11.015
15. Iannotti JP, Lappin KE, Klotz CL, Reber EW, Swope SW. Liftoff resistance of augmented glenoid components during cyclic fatigue loading in the posterior-superior direction. J Shoulder Elbow Surg 2013;22:1530-6. https://doi.org/10.1016/j.jse.2013.01.018
16. Leggin BG, Michener LA, Shaffer MA, Brenneman SK, Iannotti JP, Williams GR. The Penn shoulder score: reliability and validity. J Orthop Sports Phys Ther 2006;36:138-51. https://doi.org/10.2519/jospt.2006.36.3.138
17. 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
18. Nuttall D, Haines JF, Trail II. A study of the micromovement of pegged and keeled glenoid components compared using radiostereometric analysis. J Shoulder Elbow Surg 2007;16(Suppl):S65-70. https://doi.org/10.1016/j.jse.2006.01.015
19. Orvets ND, Chamberlain AM, Patterson BM, Chalmers PN, Gosselin M, Salazar D, et al. Total shoulder arthroplasty in patients with a B2 glenoid addressed with corrective reaming. J Shoulder Elbow Surg 2018;27:S58-64. https://doi.org/10.1016/j.jse.2018.01.003
20. Pomwenger W, Entacher K, Resch H, Schuller-Götzburg P. Multipatient finite element simulation of keeled versus pegged glenoid implant designs in shoulder arthroplasty. Med Biol Eng Comput 2015;53:781-90. https://doi.org/10.1007/s11517-015-1286-7
21. Sabesan VJ, Callanan M, Youderian A, Iannotti JP. 3D CT assessment of the relationship between humeral head alignment and glenoid retroversion in glenohumeral osteoarthritis. J Bone Joint Surg Am 2014;96:e64. https://doi.org/10.2106/JBJS.L.00856
22. Schoch BS, Wright TW, Zuckerman JD, Bolch C, Flurin PH, Roche C, et al. Glenoid component lucencies are associated with poorer patient-reported outcomes following anatomic shoulder arthroplasty. J Shoulder Elbow Surg 2019;28:1956-63. https://doi.org/10.1016/j.jse.2019.03.011
23. Service BC, Hsu JE, Somerson JS, Russ SM, Matsen FA. Does postoperative glenoid retroversion affect the 2-year clinical and radiographic outcomes for total shoulder arthroplasty? Clin Orthop Relat Res 2017;475:2726-39. https://doi.org/10.1007/s11999-017-5433-3
24. Szabo I, Buscayret F, Edwards TB, Nemoz C, Boileau P, Walch G. Radiographic comparison of flat-back and convex-back glenoid components in total shoulder arthroplasty. J Shoulder Elbow Surg 2005;14:636-42. https://doi.org/10.1016/j.jse.2005.05.004
25. Torchia ME, Cofield RH, Settergren CR. Total shoulder arthroplasty with the Neer prosthesis: long-term results. J Shoulder Elbow Surg 1997;6:495-505.
26. Vidil A, Valenti P, Guichoux F, Barthas JH. CT scan evaluation of glenoid component fixation: a prospective study of 27 minimally cemented shoulder arthroplasties. Eur J Orthop Surg Traumatol 2013;23:521-5. https://doi.org/10.1007/s00590-012-1126-5
27. Wijeratna M, Taylor D, Lee S, Hoy G, Evans MC. Clinical and radiographic results of an all-polyethylene pegged bone-ingrowth glenoid component. J Bone Joint Surg Am 2016;98:1090-6. https://doi.org/10.2106/JBJS.15.00475
28. Wirth MA, Korvick DL, Basamania CJ, Toro F, Aufdemorte TB, Rockwood CA. Radiologic, mechanical, and histologic evaluation of 2 glenoid prosthesis designs in a canine model. J Shoulder Elbow Surg 2001;10:140-8.
29. Wirth MA, Loredo R, Garcia G, Rockwood CA, Southworth C, Iannotti JP, et al. 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