

The Radiographic Evaluation of Keeled and Pegged Glenoid Component Insertion

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Background: Radiolucent lines about the glenoid component of a total shoulder replacement are a common finding, even on initial postoperative radiographs. The achievement of complete osseous support of the component has been shown to decrease micromotion. We evaluated the ability of a group of experienced shoulder surgeons to achieve complete cementing and support in a series of patients managed with keeled and pegged glenoid components.

Methods: We reviewed the initial postoperative radiographs of 493 patients with primary osteoarthritis who had been managed with total shoulder arthroplasty by seventeen different surgeons. One hundred and sixty-five patients were excluded because of inadequate radiographs, leaving 328 patients available for review. Of these, thirty-nine patients had a keeled component and 289 had a pegged component. The method of Franklin was used to grade the degree of radiolucency around the keeled components, and a modification of that method was used to grade the degree of radiolucency around the pegged components. The efficacy of component seating on host subchondral bone was evaluated with a newly constructed five-grade scale based on the percentage of the component that was supported by subchondral bone. Each radiograph was graded four times, by two separate reviewers on two separate occasions.

Results: Radiolucencies were extremely common, with only twenty of the 328 glenoids demonstrating no radiolucencies. On a numeric scale (with 0 indicating no radiolucency and 5 indicating gross loosening), the mean radiolucency score was 1.8 ± 0.9 for keeled components and 1.3 ± 0.9 for pegged components ($p = 0.0004$). After defining categories of "better" and "worse" cementing, we found that pegged components more commonly had "better cementing" than did keeled components ($p = 0.0028$). Incomplete seating was also common, particularly among patients with keeled components. Ninety-five of the 121 pegged components that had been inserted by the most experienced surgeon had "better cementing," compared with eighty-five of the 168 pegged components that had been inserted by the remaining surgeons ($p < 0.00001$).

Conclusions: Perfectly cementing and seating a glenoid replacement is a difficult task. Radiolucencies and incomplete component seating occur more frequently in association with keeled components compared with pegged components. Surgeon experience may be an important variable in the achievement of a good technical outcome.

Total shoulder replacement has been demonstrated to be an effective treatment for end-stage glenohumeral arthritis¹, although the presence of radiolucencies at the glenoid bone-cement interface has been a worrisome finding²⁻²¹. The reported prevalence of this finding has varied from 0% to 96%, and this wide range may be due to a lack of uniformity in grading and follow-up among studies^{22,23}. An association between glenoid radiolucencies and a worse func-

tional outcome has been reported²⁴. For instance, Torchia and colleagues¹⁸ reported that thirty-nine (44%) of eighty-nine glenoids had radiographic signs of loosening after a minimum duration of follow-up of five years and noted that these changes were associated with worsening function.

Often, radiolucent lines at the glenoid bone-cement interface are present on the immediate postoperative radiographs (Table I)^{3,4,7,12,14,15,20,24,25}. All of the current reports that we found in our review of the literature regarding glenoid radiolucencies involved keeled glenoid components. Many contemporary shoulder arthroplasty systems offer a pegged fixation option and, despite widespread use, the prevalence of initial radiolucent lines about pegged glenoid components is unknown.



A video supplement to this article is available from the *Video Journal of Orthopaedics*. A video clip is available at the JBJS web site, www.jbjs.org. The *Video Journal of Orthopaedics* can be contacted at (805) 962-3410, web site: www.vjortho.com.

TABLE I Reported Prevalences of Radiolucencies at the Glenoid Bone-Cement Interface

Study	No. of Glenoids	Prevalence of Radiolucencies	
		Final Follow-up Radiographs (percent)	Initial Postoperative Radiographs (percent)
Neer et al. ¹⁵	194	30.0	28.4
Cofield ⁷	73	83.6	50.7
Barrett et al. ³	40	47.5	42.5
Hawkins et al. ¹²	70	"nearly all"	"nearly all"
Brems ²⁰	69	76.8	69.0
Gartsman et al. ²⁵	24	83.3	62.5

The congruency of the glenoid component on the host bone may have a greater impact on long-term outcome than the presence of radiolucencies does. The laboratory findings reported by Collins et al.²³ demonstrated the importance of complete seating and support of the glenoid prosthesis on subchondral bone. Failure to achieve complete osseous backing for the glenoid component was associated with deforming and rocking forces at the component edge. The extent to which full seating of the glenoid component is attained in the clinical setting has not been reported previously, to our knowledge.

Finally, several investigators have commented on the technical challenge of glenoid resurfacing^{15,19,26}. The addition of pegged fixation may make implantation even more difficult. Most studies on the results of shoulder arthroplasty have been conducted by surgeons who perform a large volume of these procedures and who are very experienced with the technique^{1-4,7,8,10-12,14,15,18,24,27-29}. Although some authors have suggested that there is an association between improved technical outcome and increased surgeon experience^{15,20}, this relationship has not been formally investigated.

The purpose of this study was to examine the validity of the hypotheses that (1) ideal cementing and seating of glenoid

components is inconsistently achieved during shoulder arthroplasty, (2) the serrated, more defined geometry of pegged glenoid components leads to more reproducible cementing and seating, and (3) greater surgical experience contributes to the ability to achieve ideal cementing and seating of the glenoid component.

Materials and Methods

The preoperative and initial postoperative radiographs of patients who had undergone total shoulder arthroplasty because of primary glenohumeral osteoarthritis were collected. These patients were part of a prospective, multicenter study evaluating the functional outcomes achieved with the Global Total Shoulder system (DePuy Orthopaedics, Incorporated, Warsaw, Indiana). Seventeen surgeons participated in the present study; each surgeon was from a different center and each was experienced with shoulder arthroplasty, performing a minimum of twenty-five replacements per year. The all-polyethylene glenoid components were inserted with methylmethacrylate (Fig. 1).

The preoperative radiographs were reviewed, and any that revealed findings that were inconsistent with a diagnosis of primary osteoarthritis were excluded. This initial review



Fig. 1-A



Fig. 1-B

The all-polyethylene keeled (Fig. 1-A) and pegged (Fig. 1-B) components used in this study. (Courtesy of DePuy Orthopaedics, Incorporated, Warsaw, Indiana).

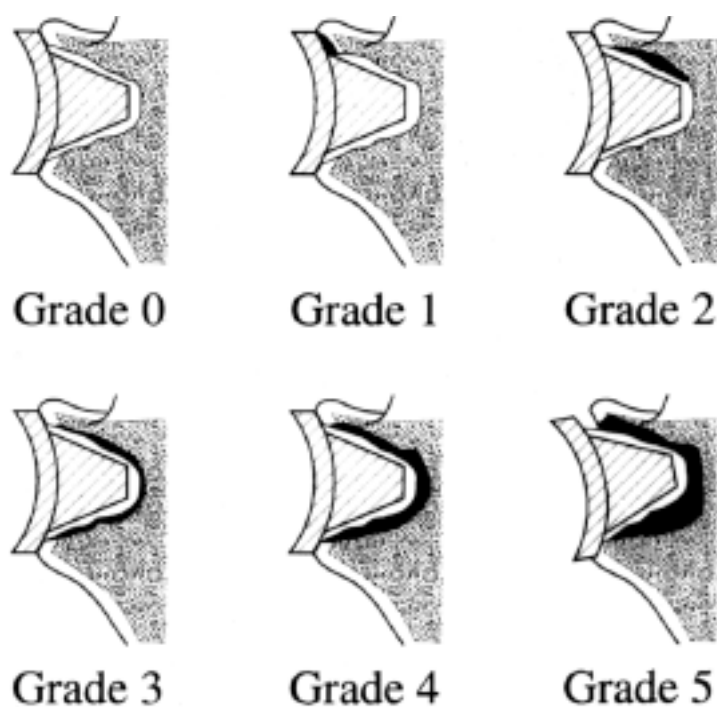


Fig. 2
Illustration depicting the grading system used to assess radiolucencies about keeled glenoid components²².

yielded 493 patients for evaluation. The postoperative radiographs of these patients were then analyzed for sufficient quality. A quality anteroposterior radiograph was defined as one in which a clear space was visible between the prosthetic humeral head and the glenoid component. A quality axillary radiograph was defined as one in which a clear space was visible between the glenoid and the coracoid process anteriorly and the glenoid and the scapular spine posteriorly. On the basis of these criteria, 165 of the 493 patients were excluded and 328 were judged to have acceptable radiographs. Of these 328 patients, thirty-nine had a keeled glenoid component and 289 had a pegged glenoid component.

The radiographs were analyzed and graded according to two separate variables: the presence of radiolucent lines at the bone-cement interface and the contact or seating of the base of the glenoid component on the glenoid surface. Radiolucent lines bordering keeled components were graded according to the method of Franklin et al.²² (Table II and Fig. 2). A modification of the Franklin system was developed to allow for the evaluation and grading of radiolucent lines adjacent to pegged components (Table III and Fig. 3). We further defined grades 0 and 1 as “better cementing” and grades 2 and 3 as “worse cementing.”

The grade of glenoid component seating (Table IV and Fig. 4) reflects the amount of host subchondral bone directly in contact with the back of the glenoid component. Since the surgical ideal is to achieve complete congruency between the back of the component and the host subchondral bone, any section of a component that was backed by an intervening layer of cement was deemed to be unsupported. We further defined Grades A, B, and C as “better seating” and grades D and E as “worse seating.”

Each radiograph was graded four times with each of the two scales (radiolucency and seating); two reviewers read each radiograph twice on viewings performed twenty-four hours apart. The observers had unlimited time to evaluate each radiograph, and the results were recorded by a proctor. The radiographs were shuffled and were identified by random numbers only. The reviewers were blinded with regard to the operative surgeon and to previous grades.

Statistical Analysis

The radiolucency and seating scores for the keeled and pegged components were compared with use of nonparametric analysis. A method for building a composite rating that combined information from the individual ratings, however, was based on parametric assumptions. This was considered appropriate because each scale is clearly ordinal and has aspects of an interval level scale. First, the individual ratings were converted to numerals. Next, the means of the four individual ratings

TABLE II Grading Scale for Radiolucencies About Keeled Glenoid Components

Grade	Finding
0	No radiolucency
1	Radiolucency at superior and/or inferior flange
2	Incomplete radiolucency at keel
3	Complete radiolucency (≤ 2 mm wide) around keel
4	Complete radiolucency (> 2 mm wide) around keel
5	Gross loosening

were calculated. Finally, the composite rating was placed into a scale category. The results are based on these composite scores. Comparisons of these scores were performed with the Fisher two-tailed exact test with significance set at the $p < 0.05$ level. The results for shoulders that had been treated by the most experienced surgeon were then compared with the results for shoulders that had been treated by the other surgeons with use of the Fisher two-tailed exact test. All other statistical comparisons were performed with the Fisher two-tailed exact test with significance set at the $p < 0.05$ level. Finally, the intraobserver and interobserver reliabilities of each grading system were calculated with the Pearson product-moment correlation coefficient and the Cronbach alpha coefficient.

Results

Radiolucencies about the glenoid component were observed on the initial postoperative radiographs of 308 of the 328 shoulders (Fig. 5). Only one of thirty-nine keeled components and nineteen of 289 pegged components were determined to have no radiolucency on all four reviews. There was a clear statistical trend toward a better result for pegged compared with keeled components (Fig. 6). When the radiolucency grade was viewed on a numeric scale of 0 (no radiolucency) to 5 (grossly loose), the mean radiolucency score was 1.8 ± 0.9 for keeled components and 1.3 ± 0.9 for pegged components ($p = 0.0004$). We further defined grades 0 and 1 as “better cementing” and grades 2 and 3 as “worse cementing” and found that pegged components more commonly had “better cementing” than keeled glenoids did ($p = 0.0028$).

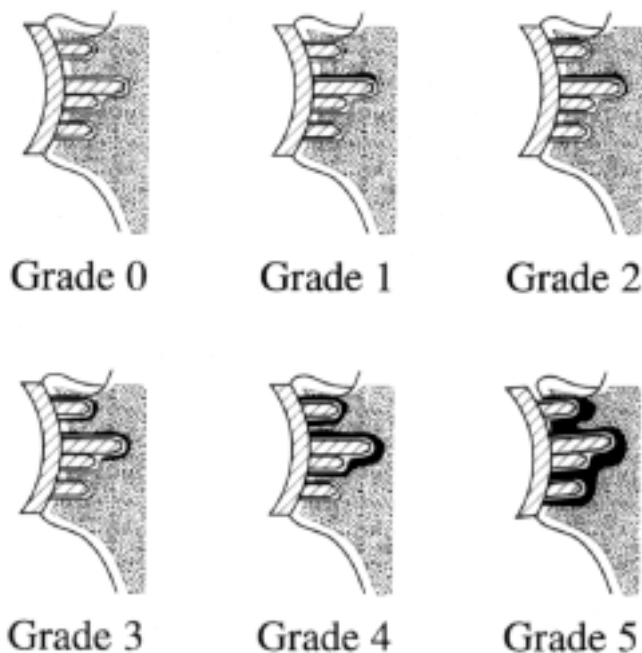


Fig. 3

Illustration depicting the grading system used to assess radiolucencies about pegged glenoid components.

TABLE III Grading Scale for Radiolucencies About Pegged Glenoid Components

Grade	Finding
0	No radiolucency
1	Incomplete radiolucency around one or two pegs
2	Complete radiolucency (≤ 2 mm wide) around one peg only, with or without incomplete radiolucency around one other peg
3	Complete radiolucency (≤ 2 mm wide) around two or more pegs
4	Complete radiolucency (> 2 mm wide) around two or more pegs
5	Gross loosening

TABLE IV Grading Scale for Completeness of Glenoid Component Seating

Grade	Finding
A	Complete component seating
B	$< 25\%$ incomplete contact, single radiograph
C	25-50% incomplete contact, single radiograph
D	$< 50\%$ incomplete contact, both radiographs
E	$> 50\%$ incomplete contact, single radiograph

Incomplete seating of the glenoid component was also common. A frequently seen pattern of incomplete seating was an unsupported posterior rim (Fig. 7). There was a wide range of seating grades, with a clear trend toward greater component seating of pegged compared with keeled components (Fig. 8). We further defined grades A, B, and C as “better seating” and grades D and E as “worse seating.” With this distinction, fifteen (38.5%) of the thirty-nine keeled components and eighty-five (29.4%) of the 289 pegged components had “worse seating.”

When the radiolucency and seating grades were considered jointly, only two of the 328 components were determined to be perfectly cemented and seated on all four reviews. Both of these components were pegged. The correlation between the two evaluation systems was low ($R^2 = 0.13$). Radiolucency scores did not predict seating scores, and vice versa. This finding indicates that the rating systems for radiolucency and seating measured independent features of glenoid implantation.

We also sought to analyze the effect of surgeon experience on the technical result. When the entire group of surgeons was reviewed, there was no correlation between the number of arthroplasties performed per year and the result on

TABLE V Reliability of the Radiographic Ratings of Radiolucencies and Seating

	Radiolucencies			Seating		
	Interobserver Reliability	Intraobserver Reliability	Cronbach Coefficient	Interobserver Reliability	Intraobserver Reliability	Cronbach Coefficient
All components	0.53	0.65	0.84	0.38	0.56	0.76
Pegged components	0.55	0.66	0.85	0.36	0.54	0.75
Keeled components	0.40	0.57	0.76	0.51	0.69	0.84

either scoring system. However, when the most experienced surgeon was compared with all others, there was a highly significant difference. For instance, ninety-five (78.5%) of the 121 pegged components that had been inserted by the most experienced surgeon had "better cementing," compared with eighty-five (50.6%) of the 168 pegged components that had been inserted by the other surgeons ($p < 0.00001$). Similarly, the seating grades achieved by the most experienced surgeon were superior to the grades achieved by the other surgeons: 112 (92.6%) of the 121 pegged components that had been placed by the most experienced surgeon had "better seating,"

compared with ninety (54.2%) of 168 pegged components placed by the other surgeons ($p = 0.001$).

In an attempt to remove surgeon bias from the comparison of keeled and pegged components, we performed a separate analysis of five surgeons who had inserted relatively equal numbers of keeled and pegged components. A total of thirty-six components (nineteen pegged and seventeen keeled) had been inserted by this group. In this group, the average radiolucency score was 1.8 ± 0.9 for the keeled components and 1.2 ± 0.9 for the pegged components ($p = 0.08$).

The reliability of the radiographic interpretations is

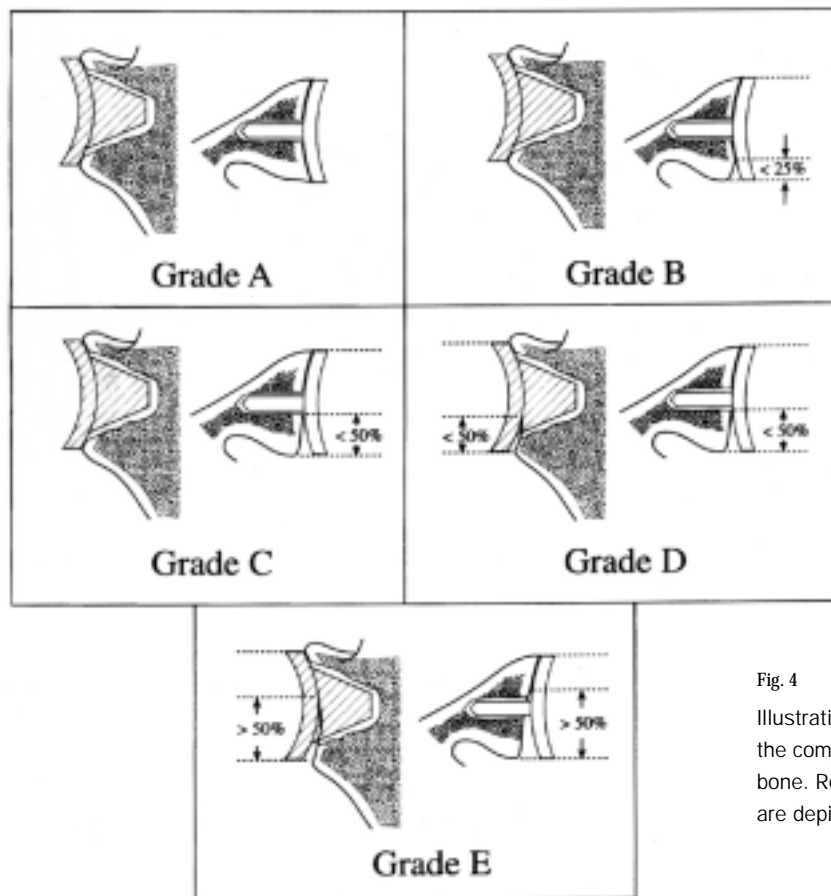


Fig. 4

Illustration depicting the grading system used to assess the completeness of glenoid component seating on host bone. Representative anteroposterior and axillary views are depicted for each grade.

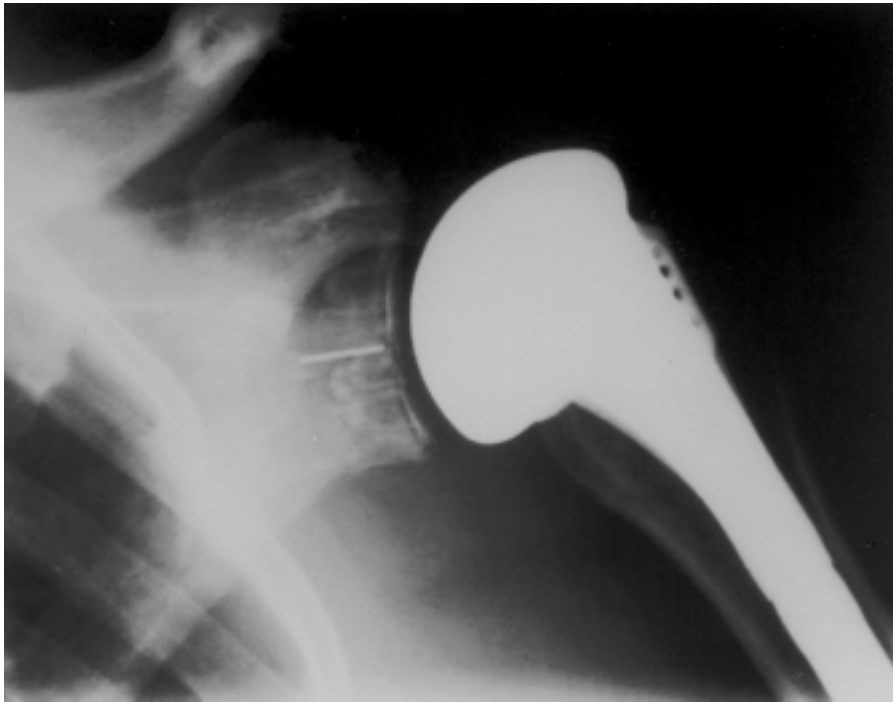


Fig. 5

Radiograph showing grade-3 radiolucency about a pegged glenoid component.

summarized in Table V. As expected, intraobserver reliability was better than interobserver reliability. The interobserver and intraobserver reliability for detecting radiolucencies was slightly better for pegged components than for keeled components. Conversely, the reliability for analyzing component seating was slightly better for keeled components. These differences were not significant. Despite the relatively poor reliability, the observers agreed to within one grade of each other 72.5% of the time during the radiolucency grading and 50.2% of the time during the seating grading.

Discussion

Glenoid bone-cement radiolucencies on immediate postoperative radiographs have been reported and their importance has been debated since the time of the first reports on glenoid component replacement^{7,12,15}. Also, the meaning of these radiolucencies has been questioned, although their presence implies incomplete cementing^{7,15,19,27}. To our knowledge, all previous reports on radiolucency have involved keeled components. A standard classification system

has not been applied to the evaluation of radiolucencies about both keeled and pegged components.

Collins et al.²³, in a cadaveric study, discussed the importance of proper host bone preparation and complete glenoid component seating. Considering the rocking motion of the unsupported components in the study by Collins et al. and the shear forces that are applied to a glenoid component in vivo, it appears that support or seating of the glenoid component may be a more important predictor of long-term durability than the presence of radiolucencies is. This feature of glenoid implantation has not, to our knowledge, been analyzed previously in a clinical setting. Our grading system for seating was designed to consider the percentage of the glenoid component that was unsupported—rather than the width of the unsupported area—as the critical factor because any unsupported amount will permit micromotion of the component rim. In addition, the design of this scale was based on the premise that complete osseous support of the component rim is the surgical goal. If there was an intervening layer of cement between the back of the component and the osseous surface, that section of the component was judged to be unsupported.

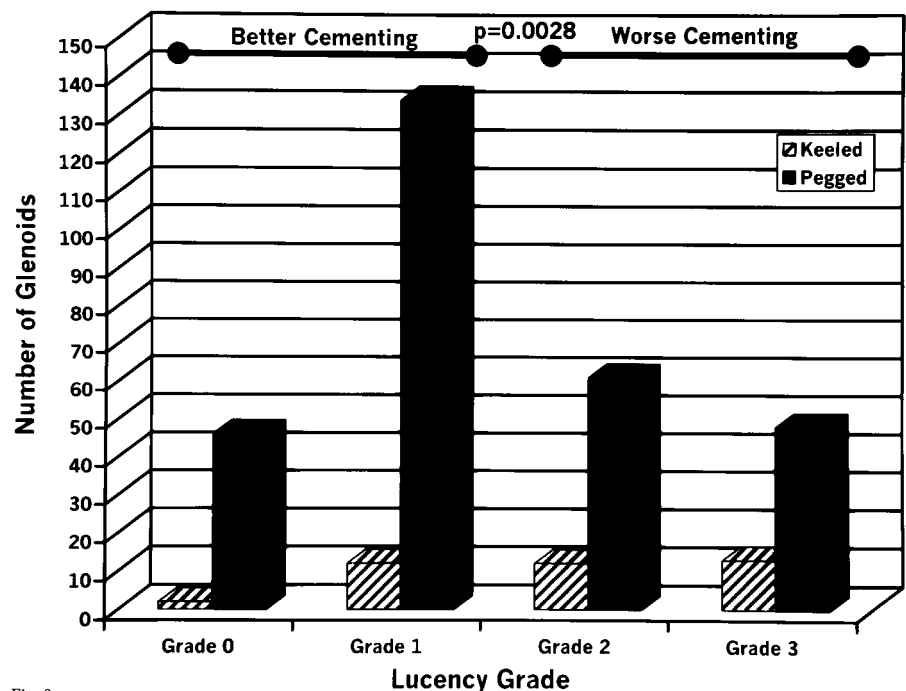


Fig. 6

Illustration depicting the distribution of radiolucency grades for pegged and keeled components.

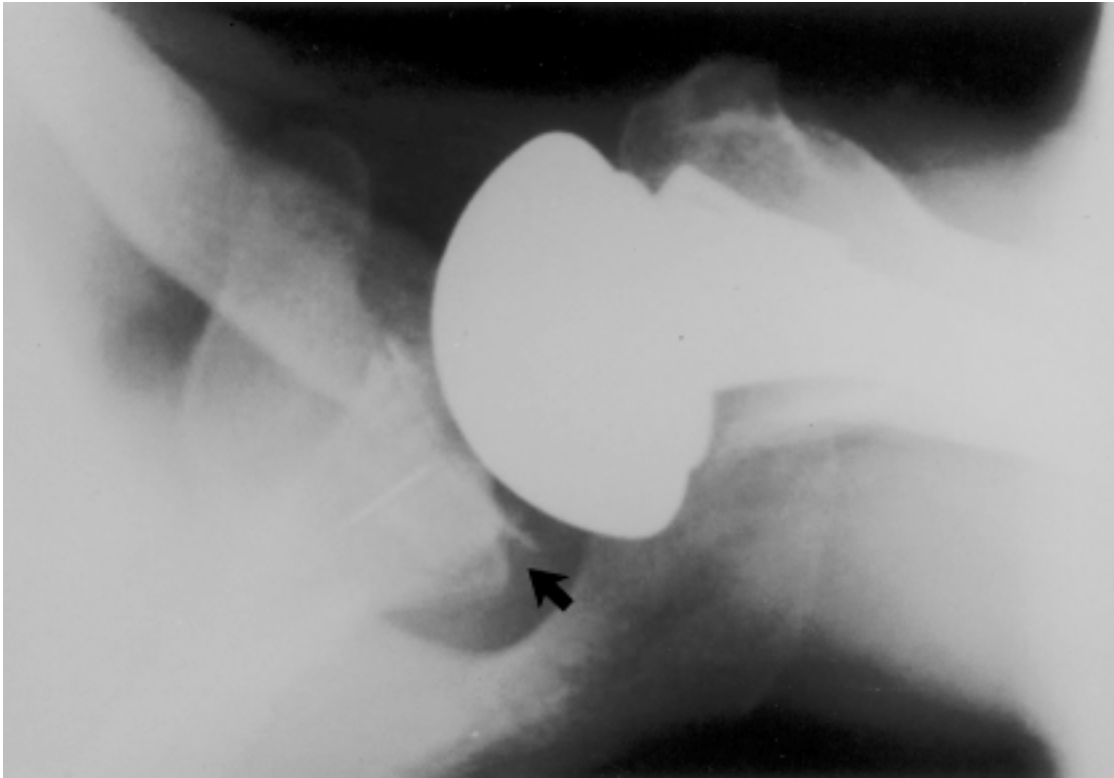


Fig. 7

Radiograph depicting the typical finding of an unsupported posterior rim (arrow).

The present study critically evaluated a surgeon's ability to perfectly cement and fully seat an all-polyethylene keeled or pegged glenoid component. Surprisingly, perfect cementing and seating of the glenoid component was achieved in only two of the 328 shoulders. Both cementing and seating of the component appeared to be technically demanding. Moreover, achieving a good technical outcome in one phase of glenoid component implantation was unrelated to a good technical outcome in the other; that is, cementing outcomes were not related to seating outcomes.

Better component implantation was associated with both prosthesis-related and surgeon-related variables. We observed a clear trend toward improved technical outcomes for pegged components compared with keeled components. Our hypothesis is that a pegged glenoid component has a more fixed geometry than a keeled one, resulting in a more precise fit to host bone. In addition, the instrumentation used for the implantation of a pegged component may be more exact. Finally, the smaller cement volume contained within a peg

bed compared with a keel bed may result in the generation of less heat during cement-curing and a lower risk of adjacent bone necrosis.

Surgeon experience clearly plays an important role in the achievement of a good technical result. Although a significant correlation between surgeon

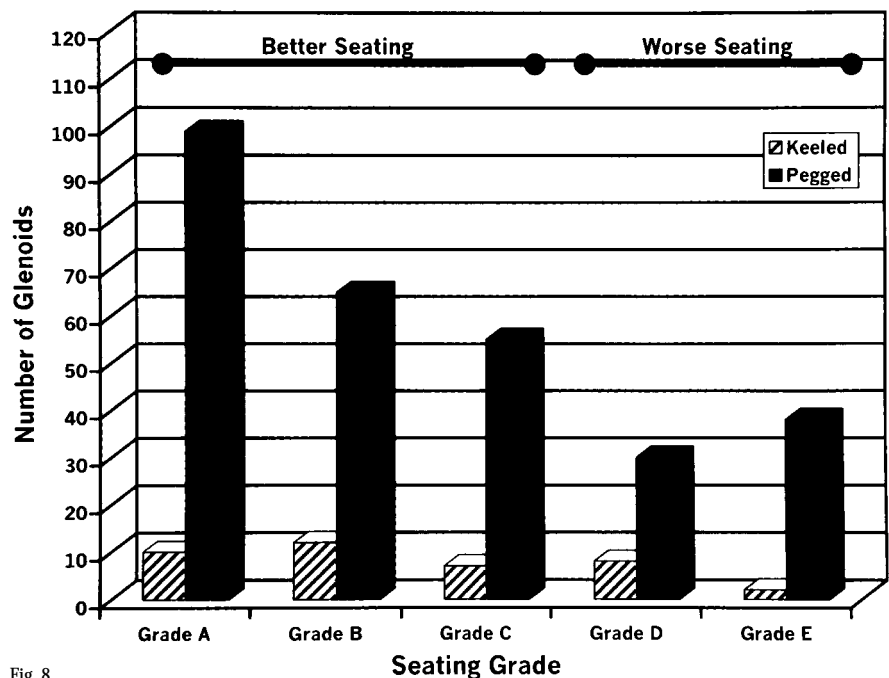


Fig. 8

Illustration depicting the distribution of seating grades for pegged and keeled components.

experience and technical outcome was not observed when the entire group of surgeons was evaluated, the most experienced surgeon fared much better than the group as a whole in terms of both cementing and seating. Given that osteoarthritis is often associated with posterior glenoid wear, it is not surprising that the most common pattern of incomplete component support in this study was an unsupported posterior rim. The components inserted by the surgeon who had performed the highest volume of procedures demonstrated this pattern of incomplete seating less frequently than did those inserted by the group as a whole.

Several aspects of this study make the conclusions tentative. The use of radiographs for the assessment of radiolucent lines in the glenoid has been reported to be somewhat inaccurate^{30,31}. We controlled for this variable by being very selective in determining which patients to include and by excluding a full one-third of the patients because of inadequate radiographs. Furthermore, each final grade was based on four ratings, and the averaging process improved the reliability of the measurements. However, subtle differences between the keeled and pegged glenoid components and between the rating systems that were used for these components may be sources of bias in comparisons.

Several of the surgeons in the study implanted either keeled or pegged components exclusively. Therefore, there may be a bias against a specific prosthetic type because of surgeon-specific variables. We attempted to control for this potential source of bias by performing a separate analysis that included only surgeons who implanted both keeled and pegged components. The results of this analysis still indicated a trend toward better cementing outcomes in the group that received pegged components, despite the low statistical power of the comparison. This secondary analysis, however, may be biased because a surgeon may convert from a preoperatively planned pegged component to a keeled component when there are difficulties in achieving adequate glenoid exposure. Therefore, a larger percentage of technically more difficult arthroplasties may be included in the group that re-

ceived a keeled component. Even when these variables are considered, the results of the present study make it reasonable to conclude that a superior technical outcome will be achieved when a pegged glenoid component is selected.

In conclusion, radiolucencies at the glenoid bone-cement interface and incomplete component seating are extremely common findings on initial postoperative radiographs. Superior technical results are currently associated with pegged components. Surgeon experience may be an important variable in the achievement of a good technical outcome. The present study suggests that improvement in the technical details of glenoid bone preparation and component insertion will increase the surgeon's ability to achieve optimal seating and fixation. ■

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