COMPARISON OF PREOPERATIVE RADIOGRAPHS AND INTRAOPERATIVE FINDINGS OF FIXATION OF HEMISPHERIC POROUS-COATED SOCKETS

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Background: The radiographic criteria for identification of loose cementless acetabular components have not been well established. The purpose of this study was to compare the radiographic appearance of a hemispheric porous-coated cementless cup fixed with screws with the intraoperative findings with regard to the fixation status.
Methods: The quality of the cup fixation was evaluated at fifty-two hip revisions that were performed, for reasons other than infection, at an average of 89.9 months (range, 33.8 to 150.1 months) after the primary operations. The fixation status at the revision surgery was compared with the findings on sequential anteroposterior and lateral radiographs of these sockets. Sequential radiographs of an additional 100 total hip replacements that had not required a reoperation and that had been followed for an average of 121 months were also measured.
Results: Loosening of the socket was radiographically identified by (1) radiolucent lines that initially appeared after two years, (2) progression of radiolucent lines after two years, (3) radiolucent lines in all three zones, (4) radiolucent lines 2 mm or wider in any zone, or (5) migration. The sensitivity of these criteria was 94%, and the specificity was 100%. The criteria had a positive predictive value of 100% and a negative predictive value of 97%.
Conclusions: The most predictive radiographic findings for early diagnosis of loosening of a hemispheric porous-coated cup were progression of radiolucent lines more than two years after the operation and any new radiolucent line of 1 mm or wider that appeared more than two years postoperatively. Sequential anteroposterior and lateral radiographs are necessary to assess the time of onset and progression of radiolucent lines in order to identify loose hemispheric porous-coated cups accurately.

Hodgkinson et al.[1] established an association between radiographic demarcation at the bone-cement interface of cemented sockets and a surgical finding of loosening. The importance of radiolucent demarcation around cementless sockets remains uncertain. It has been assumed that a complete 2-mm-wide demarcation between the bone and the metal cup or migration of the cup of ≥3 mm indicates loosening of the cup[2,3]. Schmalzried and Harris[4] reported an association between an initial radiolucent gap and subsequent progressive radiolucent lines, but no socket with screw fixation was loose in their study so the ultimate outcome was not known. Dorr et al.[5] found that postoperative gaps did not lead to progressive radiolucent lines adjacent to cups without screws.

The purpose of our study was to evaluate radiographic demarcations about hemispheric porous-coated cementless sockets fixed with screws and to compare these findings with the operative findings with regard to the adequacy of fixation.

Materials and Methods

Intraoperative evaluation of the primary acetabular component was performed during fifty-two revision total hip arthroplasties. All of the original sockets had been fixed with 6.5-mm cancellous screws. Every socket was routinely tested for loosening intraoperatively by removing all screws and applying firm blows with a mallet and a bone tamp to the socket edge. Any movement at the bone-socket interface was considered evidence of loosening. The fixation status of the socket at the operation was then compared with its preoperative radiographic findings.

The fifty-two hips (fifty patients) had undergone the primary total hip arthroplasty between February 1985 and September 1988. The time from the primary operation to the revision ranged from 33.8 to 150.1 months (average [and standard deviation], 89.9 ± 31.4 months). Each of these hips had been operated on and followed by us, and each had complete clinical and radiographic follow-up. We continued to follow well-fixed sockets after the revision surgery to determine whether subsequent radiographic signs of loosening developed. The well-fixed sockets were followed for an average of 136.8 ± 18.1 months (range, 102.3 to 165.4 months) following the primary operation.

The radiographs of an additional 100 primary total hip

TABLE I Comparison Between Sockets with Patches of Porous Coating and Those with a Circumferential Porous Coating

Parameter	Patches of Porous Coating (N = 32)	Circumferential Porous Coating (N = 20)	P Value
Harris hip scores* *(points)*			
2-yr	93.93 ± 8.97	89.10 ± 13.46	0.169
Last follow-up	81.11 ± 17.50	79.18 ± 19.36	0.739
Gaps†	11	10	0.264
Radiolucent lines†	20	9	0.216
Onset at >2 yr	2	3	0.298
Progressive at <2 yr	1	0	0.425
Progressive at >2 yr	8	3	0.390
Involving 3 zones	4	1	0.372
Width of ≥2 mm	2	1	0.851
Pelvic osteolysis†	3	1	0.565
Loosening†	12	5	0.350

*The values are given as the mean and the standard deviation. †The values are given as the number of hips.

replacements (in eighty-seven patients) that were functioning well after a follow-up interval of 121.0 ± 18.1 months were measured to corroborate the data on the hips that required a reoperation. The 100 unrevised hips had been treated, between February 1985 and November 1988, with the same socket and implantation technique as had been used in the fifty-two hips that underwent revision. Each of the 100 hips had sequential radiographic follow-up, and the presence of radiographic gaps or radiolucent lines was recorded in the same manner as it was for the fifty-two revised hips.

The revision group consisted of twenty-six women and twenty-four men. The age at the time of the primary operation averaged 53.4 ± 14.3 years (range, 22.6 to 75.6 years). The initial diagnosis was osteoarthrosis in thirty-two hips; avascular necrosis in seven; developmental dysplasia of the hip in seven; septic arthritis in two; and ankylosing spondylitis, spontaneous fusion secondary to infection, slipped capital femoral epiphysis, and rheumatoid arthritis in one hip each.

All patients had an Anatomic Porous Replacement hemispheric acetabular component (APR; Sulzer Medica, Austin, Texas). The acetabular component was manufactured from Ti-6Al-4V alloy. Holes allowed fixation with 6.5-mm titanium-alloy screws. In the first thirty-two hips treated in the study, the prosthesis had patches of porous coating. In November 1986, sockets with a circumferential porous coating were available, and these were used in the next twenty hips (Fig. 1). There was no significant difference in the clinical or radiographic outcomes between the sockets with patches of porous coating and those with a circumferential coating (Table I). The posterior approach was used for both the primary operations and the revision operations. The acetabulum was prepared with use of hemispheric al reamers that were an average of 1 mm smaller than the actual component.

Harris hip scores[5] were obtained preoperatively and at the two-year and final follow-up visits before the reoperation. An anteroposterior radiograph of the pelvis centered over the pubic symphysis and including the proximal part of the femur as well as a modified 17-in (43.2 cm) Lowenstein lateral radio-

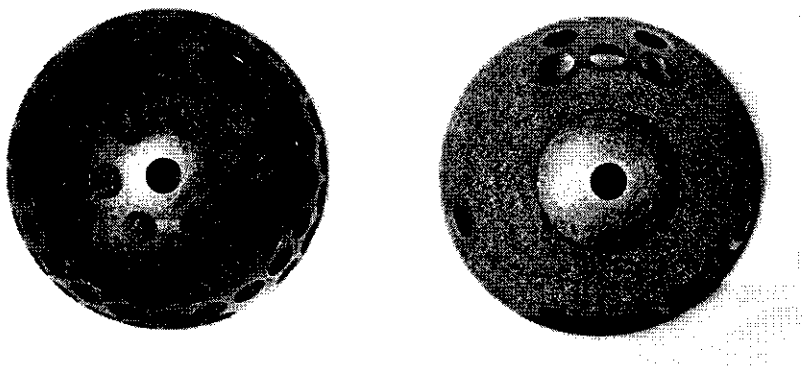

Fig. 1

Photograph showing acetabular components with patches of porous coating (left) and with a circumferential porous coating (right).

TABLE II Association of Radiographic Findings with Loosening*

Parameter	Well-Fixed Cups (N = 35)	Loose Cups (N = 17)	P Value
Gap	14 (40%)	7 (41%)	0.935
Radiolucent line	14 (40%)	15 (88%)	0.001
Nonprogressive	13 (37%)	4 (24%)	0.326
Onset at >2 yr	0	5 (29%)	0.001
Progressive at <2 yr	1 (3%)	0	0.482
Progressive at >2 yr	0	11 (65%)	0.000
Involving 3 zones†	0	5 (29%)	0.001
Width of ≥2 mm†	0	3 (18%)	0.010
Migration	0	7 (41%)	0.000

*The values are given as the number of hips. †Radiolucency included gaps and radiolucent lines.

graph of the hip were used for the radiographic examination. The modified Lowenstein lateral radiograph is similar to an oblique radiograph of the pelvis because the patient is turned onto the affected hip at least 45° and as much as necessary to allow the lower limb to be in abduction and external rotation and to be flat on the x-ray table, which provides a lateral view of the acetabular subchondral bone and the cup after implantation (Figs. 2-A and 2-B). The radiographs were measured by two observers (P.U. and Z.W.) who had no knowledge of the operative findings or the clinical care of the patients. Each radiograph was also reviewed by one observer (P.U.) on two separate occasions, one year apart, to determine the intraobserver reproducibility.

Interobserver reliability and intraobserver reproducibility were determined with calculation of the kappa coefficient[6]. A value of <0.5 indicates poor agreement, and a value of >0.75

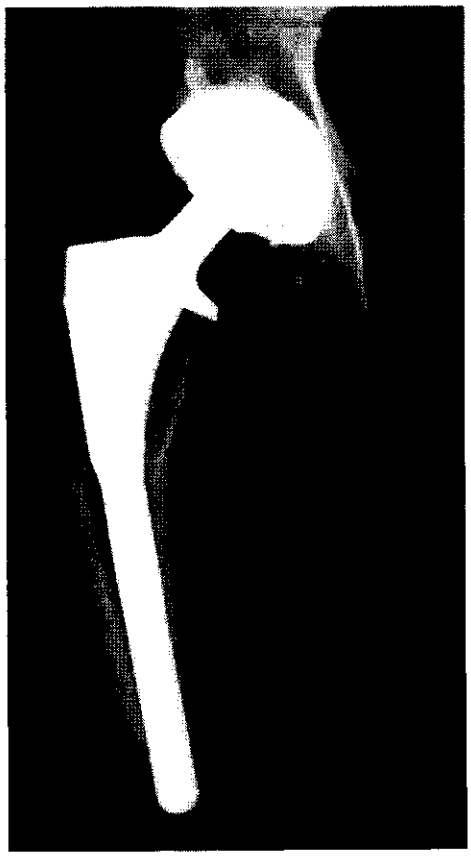

Fig. 2-A

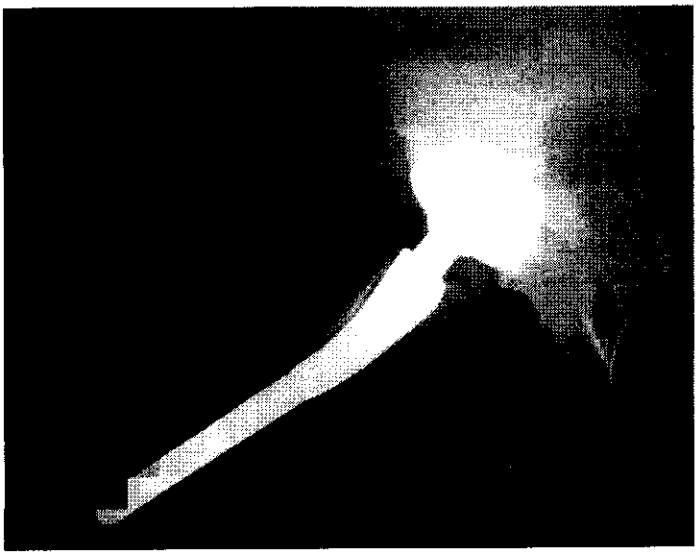

Fig. 2-B

Radiographs demonstrating the differences between the anteroposterior view (Fig. 2-A) and the lateral view (Fig. 2-B) of the acetabulum, obtained with the patient in the modified Lowenstein position.

indicates excellent agreement. Measurements were performed on the preoperative, immediate postoperative, three-month, and twelve-month radiographs and then on the radiographs made at each return visit until the hip was revised. The magnification of the radiographs was corrected according to the known diameter of the femoral head. On the three-month anteroposterior radiographs, the angle of inclination of the socket and the percentage of the surface of the component in contact with bone were measured[3,7]. Evidence of acetabular migration, either linear or rotational, was measured on serial radiographs; a linear change of >3 mm or a rotational change of ≥8° was considered to indicate migration[8].

Postoperative gaps, radiolucent lines, and osteolysis were each identified according to the three zones described by DeLee and Charnley[9] on the anteroposterior pelvic and modified Lowenstein lateral radiographs. Gaps were defined as areas where the surface of the acetabular component was not in contact with bone on the immediate postoperative radiographs; radiolucent lines appear on subsequent radiographs in zones where no gaps initially had existed or after the gaps had disappeared[3].

The width of the gaps and radiolucent lines were measured with use of a digimatic caliper (Mitutoyo, Tokyo, Japan). Progression of a radiolucent line was defined as an increase in the number of zones and/or an increase in the width of the line to ≥2 mm on sequential radiographs. Gaps or radiolucent lines were recorded as decreased if fewer were observed. The size of an osteolytic area was measured on the anteroposterior pelvic radiograph as the longest diameters of the lesion in the horizontal and vertical axes. Screw breakage was also recorded. All data were analyzed with use of SPSS software (SPSS, Chicago, Illinois).

Continuous variables including age and Harris hip scores were compared with use of the independent Student t test. The minimum level of significance was $p < 0.05$.

Results

Findings in Fifty-two Hips with Revision

Seventeen sockets were found to be loose and thirty-five were found to be well fixed at the revision. The preoperative radiographs of ten of the loose sockets were interpreted as showing migration (seven), a continuous radiolucent line in all three zones (two), or a discontinuous radiolucent line in three zones (one). In addition, one of the sockets that migrated had a three-zone radiolucent line prior to migration, and one of the seven sockets that was not diagnosed as loose because of a missed diagnosis by the physician at the time of the clinical evaluation had a discontinuous three-zone radiolucent line. Also, three hips had a 2-mm-wide radiolucent line in a single zone. The patients who had a loose cup at the time of the reoperation were younger on the average and had a lower average Harris hip score than those with a well-fixed socket.

The immediate postoperative radiograph of fourteen of the thirty-five hips with a well-fixed socket and seven of the seventeen with a loose socket showed gaps, all measuring ≤0.5 mm, at the socket-bone interface; no hip had gaps in all three zones. At the end of the study, the gaps were unchanged in four of the hips with a well-fixed socket and were not visible in ten; the gaps were unchanged in two of the hips with a loose socket, were decreased in one, and were not visible in four. Both in the hips with a well-fixed socket and in those with a loose socket, the gaps that disappeared did so at an average of 3.4 ± 2.7 years (range, one to eight years) after the surgery.

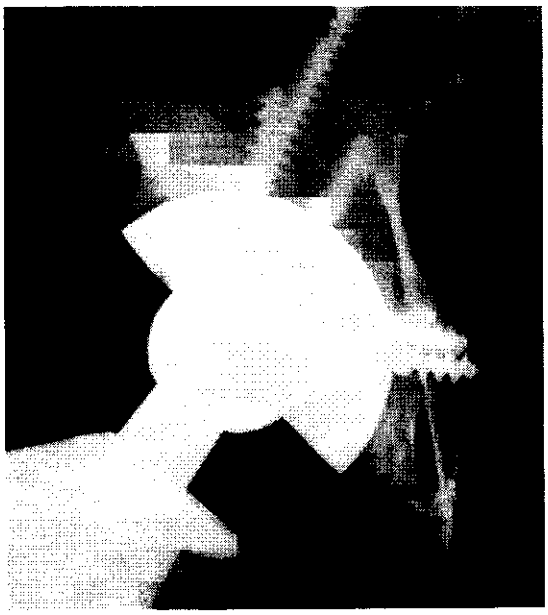

Fig. 3-A

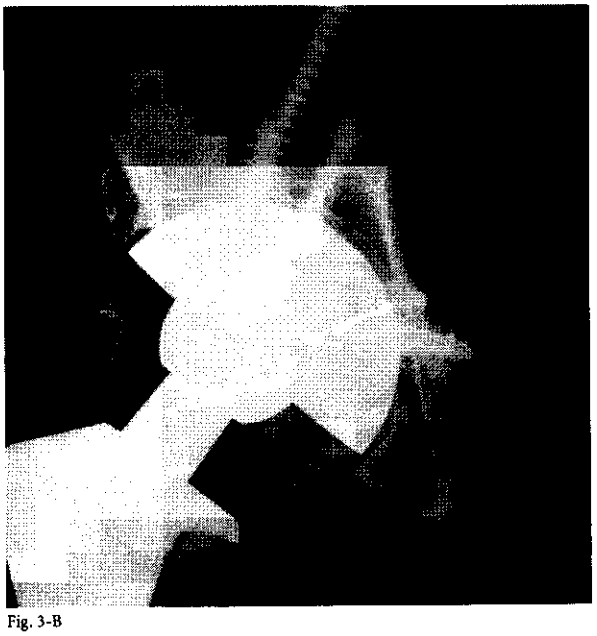

Fig. 3-B

Fig. 3-A Two-year anteroposterior pelvic radiograph showing a 0.5-mm-wide radiolucent line in zone 1. **Fig. 3-B** Two years later, the radiolucent line has progressed in both width and extent, now involving all three zones. This socket was found to be loose at the revision operation.

Eleven of the thirty-five hips with a well-fixed socket and fifteen of the seventeen hips with a loose socket had radiolucent lines identified in the first two years after the operation. These lines initially measured <1 mm and averaged 0.4 mm (range, 0.3 to 0.7 mm) in the hips with a well-fixed socket, whereas they initially averaged 0.9 mm (range, 0.4 to 2.0 mm) in the hips with a loose socket.

None of the hips with a well-fixed socket had a radiolucent line in all three zones, whereas five hips with a loose socket had such a line. At the end of the study, the radiolucent lines had progressed in one hip with a well-fixed socket (only in the first two years), were unchanged in three, and were not visible in ten, whereas all zone-1 radiolucent lines in the hips with a loose socket persisted until the time of the reoperation. No well-fixed socket had subsequently loosened at the latest follow-up evaluation after the revision.

At the time of the reoperation, the radiolucent lines associated with the fifteen loose sockets that had such a line were most common in zone 3; they were progressive in nine of these hips, unchanged in three, decreased in one, and not visible in two. In the two hips in which the lines were not visible, the lines had been progressive until they were obliterated by migration of the socket. Seven of the seventeen loose sockets migrated, at an average of five years (range, two to eight years) postoperatively. Four were associated with progressive radiolucent lines after two years, which preceded the migration.

In the hips with a loose socket, all of the radiolucent lines that progressed did so only after two years postoperatively (Figs. 3-A and 3-B). Progression of a radiolucent line after two years was suggested by the width of the line on the initial postoperative radiograph. The initial width of the radiolucent lines that later progressed averaged 1.0 mm (range, 0.4 to 2.0 mm) compared with 0.6 mm (range, 0.3 to 1.6 mm) for those that did not later progress ($p = 0.04$). Five hips had radiolucent lines only after two years postoperatively (average, five years; range, three to seven years); three of these five had additional progression (Table II).

At the time of the reoperation, four loose sockets did not have radiolucent lines. Two of the four had migrated, obliterating the previously observed radiolucent lines. The other two also had migrated; one of them had had a gap on the immediate postoperative radiograph, but this gap was not evident during the follow-up period (perhaps because of the migration). The fourth cup never had any radiolucency before the revision.

Findings in One Hundred Hips without a Reoperation

Initial postoperative gaps were seen on the radiographs of thirty of the 100 hips. All gaps measured ≤0.5 mm. Gaps were seen in one zone in twenty-two hips, in two zones in seven, and in all three zones (discontinuous) in one. At an average of 121.0 ± 18.1 months, the gaps were unchanged in six hips, decreased in four, and not visible in twenty. Gaps most commonly persisted in zone 1 on the anteroposterior radiograph. Radiolucent lines were observed in the first two years in twenty-two of these hips. At the latest follow-up evaluation, these radiolucent lines were unchanged in three hips, decreased in two, and not visible in seventeen. The radiolucent lines initially measured an average of 0.4 mm (range, 0.3 to 0.6 mm). They were most commonly seen in zone 1 on the anteroposterior radiograph. No socket had a radiolucent line in all three zones, and no lines were progressive.

At the final follow-up evaluation, radiolucent lines were seen around fifteen sockets. Ten of these lines were persistent gaps that had been seen on the initial postoperative radiograph, and five were persistent, nonprogressive radiolucent lines that had been first seen by two years postoperatively. All involved only one zone, and the average width was 0.4 mm (range, 0.3 to 0.6 mm). No socket migration or screw breakage was detected.

The two observers agreed on the radiographic appearance at the bone-socket interface in 142 (93%) of the 152 hips in the entire series (kappa coefficient, 0.76). One observer's first and second reviews, separated by a one-year interval, agreed with regard to the appearance in 147 hips (97%) (kappa coefficient, 0.89). These values indicated excellent interobserver and intraobserver agreement on the measurements. The criteria had a positive predictive value of 100% and a negative predictive value of 97%.

Discussion

Surgeons need criteria with which to make the diagnosis of cup-loosening in a patient with a painful total hip replacement. In this study, we found five radiographic criteria that suggested loosening of the Anatomic Porous Replacement, a cementless hemispheric titanium-alloy porous-coated socket with screws. These criteria, which were best judged on sequential radiographs, were (1) the occurrence of radiolucent lines after two years (2) progression of radiolucent lines after two years (3) radiolucent lines in all three zones (even if they are not continuous), (4) radiolucent lines 2 mm or wider in any zone, and (5) migration.

Our study showed that postoperative gaps were not associated with the subsequent presence of radiolucent lines, progressive radiolucent lines, or socket-loosening. We underreamed the bone by 1 mm compared with the size of the metal shell in these hips. The vast majority of these gaps adjacent to both the well-fixed and the loose sockets as well as in the hips that did not undergo a reoperation disappeared by an average of 3.3 years postoperatively. In a ten-year follow-up study of 188 Harris-Galante hemispheric porous-coated cups (Zimmer, Warsaw, Indiana) that had been implanted by Harris, some association between postoperative gaps and radiolucent lines was reported[10]. At ten years, radiolucent lines were identified around forty-seven (46%) of 102 sockets that had not been associated with postoperative gaps compared with twenty-five (29%) of eighty-six sockets that had been associated with gaps.

Ranawat et al.[11] and Ritter et al.[12] both demonstrated that postoperative demarcation of a cemented cup portends revision by ten years. In contrast, we found that immediate postoperative gaps had no association with cup-loosening. Hodgkinson et al.[1] found that the pattern of radiolucent lines around cemented cups at one year postoperatively was predic-

tive of loosening. In our study, the findings on radiographs of hemispheric porous-coated cups were not predictive until after two years postoperatively. The importance of demarcation (gaps and radiolucent lines) of a cemented cup in the first year after implantation appears to be different from that of such demarcation of a hemispheric porous-coated cup.

The most important radiographic determinants of loosening were the measurements of radiolucent lines after two years postoperatively. Radiolucent lines that *progressed* after two years postoperatively and radiolucent lines of ≥1 mm in *thickness* that appeared after the second year were both 100% predictive of loosening.

A ≥2-mm-wide radiolucent line has traditionally been thought to indicate loosening. A ≥2-mm-wide radiolucent line in one zone was predictive of loosening both in our study and in that by Kobayashi et al.[13]. Hodgkinson et al.[1] found that a 1-mm wide radiolucent line in one zone had predicted the loosening of five of twenty-seven loose cemented cups, and we found that it had predicted the loosening of five of seventeen loose hemispheric titanium-alloy porous-coated cups. A 1-mm radiolucent line in two zones that appeared after two years postoperatively was progressive in five of six hips in our study compared with twenty of twenty-five in the series of Hodgkinson et al.[1]. Schmalzried and Harris[4] found an association between gaps of 1 mm in thickness and the development of progressive radiolucent lines in hips with a Harris-Galante socket fixed with screws. These findings suggest that a 1-mm demarcation between the cup and bone, especially if it is in more than one zone, is predictive of loosening.

The findings in the current study provide radiographic criteria with which to diagnose loosening of one cup design fixed with screws. Because this cup is a 3-mm porous-coated titanium-alloy shell, as are many designs, these criteria may be useful for judging loosening of other cup designs fixed with screws. Implant retrieval studies have confirmed that the pattern of loosening does not differ among different cup designs[14-16]. It is important to make sequential radiographs because progressive radiolucent lines and radiolucent lines of ≥1 mm in thickness after two years postoperatively indicate that the socket is likely to loosen. Hopefully, if sequential radiographs are made, this socket can be identified and revised before extensive migration occurs, so that acetabular bone stock can be preserved. ■

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