

CEMENTLESS HEMISPHERIC POROUS-COATED SOCKETS IMPLANTED WITH PRESS-FIT TECHNIQUE WITHOUT SCREWS: AVERAGE TEN-YEAR FOLLOW-UP

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Background: Press-fit implantation of a porous-coated hemispheric acetabular component without screws is an option for primary total hip replacement. The purpose of the present study was to evaluate the results of this technique after an average duration of follow-up of ten years to determine if there was any loss of fixation or increase in osteolysis over time.

Methods: From June 1988 to November 1990, 132 primary total hip replacements were performed with a porous-coated socket that was implanted with use of a press-fit technique. Twenty-two hips were excluded because the patient had died or had been lost to follow-up, leaving 110 hips (103 patients) available for inclusion in the study after an average duration of follow-up of 10.2 ± 1.0 years. The average age of the patients at the time of operation was 60.7 years (range, 23.7 to 86.2 years). Radiographs were evaluated with regard to initial gaps, radiolucent lines, migration, polyethylene wear, and osteolysis. Kaplan-Meier survivorship analysis was performed to calculate the rate of survival of the acetabular component.

Results: One hip (0.9%) had revision of the socket because of aseptic loosening, and four hips (4%) had revision of a stable socket. With the numbers available, the presence of gaps on the initial postoperative radiographs was not associated with the occurrence of radiolucent lines ($p = 0.039$). Pelvic osteolysis was seen in four hips, with an average time to radiographic appearance of six years. Increased wear was directly related to an abduction angle of $>40^\circ$. The twelve-year survival rate was 99.1% with revision because of failure of fixation of the metal shell as the end point, 95.3% with revision for any reason as the end point, and 79.6% with exchange of the liner as the end point.

Conclusions: The fixation of this press-fit socket did not deteriorate over time and was associated with a low rate of osteolysis. The most common reasons for reoperation were wear and dissociation of the polyethylene insert.

Press-fit implantation of a porous-coated acetabular component without screws has the technical advantage of providing initial intrinsic stability. The avoidance of screws saves operative time and eliminates the risk of vascular or nerve injury due to the screw as well as the possibility of fretting wear between the screw and the metal shell. The press-fit implantation technique with underreaming of the acetabulum has been reported to provide better surface contact at the bone-implant interface at the periphery of the socket in com-

parison with a line-to-line reaming technique^{1,4}, although some cadaveric studies have demonstrated that fractures occurred when the acetabulum was underreamed by ≥ 2 mm^{5,6}.

The five to six-year results of press-fit implantation^{1,4,7} have been promising, with a rate of mechanical failure (defined as revision for aseptic or radiographic loosening) of 0% (zero of 115 hips¹) to 1% (two of 213 hips⁷) and a prevalence of pelvic osteolysis of 0% (zero of 122 hips³) to 2% (two of 115 hips¹). However, in our experience, most acetabular components begin to fail after five to six years postoperatively⁸. Therefore, the purpose of the present study was to evaluate the average ten-year results of press-fit insertion of a titanium porous-coated hemispheric acetabular component without screws to determine if



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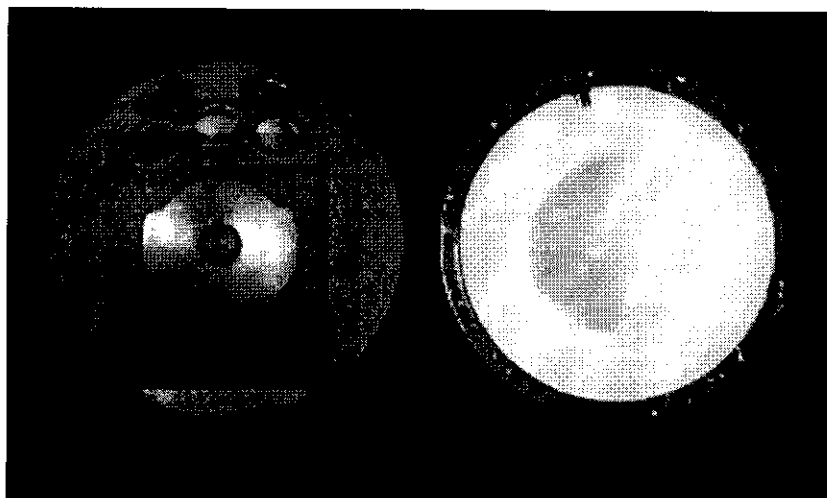


Fig. 1

The Anatomic Porous Replacement hemispheric porous-coated socket. Note the screw holes that can be used when stable fixation cannot be achieved in an osteoporotic acetabulum.

there had been any loss of fixation or any increase in the prevalence of osteolysis since the time of our previous study of the six-year results¹.

Materials and Methods

From June 1988 to November 1990, 132 primary total hip replacements in 123 patients were selectively performed with use of a press-fit technique without adjunctive screw fixation. Initially, only hips without osteoporotic bone were treated with this technique. By the third year, all hips were treated with the press-fit technique, but 7% required screws. Although seventy-two other acetabular components were implanted during that time-period, the present report includes all sockets that were implanted without screws or cement fixation. All of the operations were performed by one surgeon (L.D.D.). Fifteen patients (sixteen hips) died at an average of 4.8 years (range, two to eight years) after the operation. None of these patients had had a reoperation, and all had had satisfactory fixation of the acetabular component as seen on radiographs made within one year before death. Five patients (six hips) were lost to follow-up at an average of 3.3 years (range, one to four years) after the operation. These patients had no radiographic evidence of loosening at the time of the last follow-up. Thus, 110 hips (103 patients) were available for inclusion in the present report after an average duration of follow-up of 10.2 ± 1.0 years (range, 7.0 to 11.9 years), with the date of the last clinical and radiographic examination (and for five hips, revision of the index metal shell) used as the end point of the study.

Sixty-three patients (sixty-seven hips) were men, and forty patients (forty-three hips) were women. The mean age at the time of the index operation was 60.7 years (range, 23.7 to 86.2 years). The mean weight of the patients was 81 kg (range, 48 to 148 kg). The reason for the operation was osteoarthritis in ninety-two hips, avascular necrosis of the femoral head in eight, rheumatoid arthritis in four, developmental dysplasia of the hip in four, and traumatic arthritis in two.

The Anatomic Porous Replacement hemispheric porous-

coated metal shell (APR; Sulzer Orthopedics, Austin, Texas) was used in all hips (Fig. 1). This metal shell is manufactured from Ti-6Al-4V alloy and has a pure titanium porous coating referred to as *cancellous structured titanium*. The porous coating is heat sintered to the alloy with a pore size of 490 μm and 55 volume percent ingrowth available. The thickness of the acetabular shell is 3 mm. The modular polyethylene inserts used in these hips were circumferentially incongruent with the metal shell by 0.5 to 0.75 mm (that is, there was a gap between the metal shell and the polyethylene) and had rotatory motion of 0.5 mm. The design of the acetabular component did not change during the time-period of this study, and this metal shell is still used with inserts with an improved congruence and locking mechanism (Converge; Sulzer Orthopedics).

The Anatomic Porous Replacement I femoral stem (Sulzer Orthopedics) was implanted in fifty-two hips (including thirty-one that had fixation without cement and twenty-one that had fixation with cement), and the Anatomic Porous Replacement II femoral stem (Sulzer Orthopedics) was implanted in fifty-eight hips (including fifty-four that had fixation without cement and four that had fixation with cement). The femoral head was cobalt-chromium, and three head sizes (26 mm, 28 mm, and 32 mm) were used.

All procedures were performed through a posterior approach with the patient in the lateral position. The acetabulum was reamed progressively with hemispheric reamers to obtain circumferential bone contact with bleeding cancellous or subchondral bone. The final reamer was inclined firmly under the superior aspect of the acetabular rim to ream the bone to a hemisphere from its normal sloped anatomy. The final reamer size was determined by complete contact between the reamer and the acetabular rim, and a trial shell that was the same size as the final reamer was then inserted. If this trial shell appeared to be loose, the next size of trial shell was inserted. If the second trial shell could not be seated fully, only the rim of the acetabulum was reamed with that size reamer, and this usually allowed full seating of the trial prosthesis.

With use of this technique, the acetabulum was underreamed by 1 to 3 mm in every hip. The intraoperative stability of fixation was confirmed by checking for movement after hitting the socket edge with a metal bone tamp and mallet and by trying to pull the metal shell out of the acetabulum with use of the attached insertion tool (pull-out test). No intraoperative or postoperative fractures were identified.

Clinical evaluation was performed with use of a patient self-assessment questionnaire at the time of the final follow-up. All patients were asked to complete a modified version of the Short Form-36 (SF-36) questionnaire, which had twenty-three questions regarding overall function and hip-specific issues (Orthographics, Salt Lake City, Utah).

Radiographic examination included an anteroposterior radiograph of the pelvis, made with the beam centered over the pubic symphysis and with inclusion of the proximal part of the femur, and a 17-in (43-cm) modified Lowenstein lateral radiograph of the hip. The magnification of the radiographs was corrected with use of the known diameter of the metal femoral head. Radiographic measurements were made on the preoperative, three-month, two-year, six-year, and final follow-up radiographs. In cases in which the acetabular shell required revision, measurements were made on the radiograph made prior to revision. The abduc-

tion angle of the acetabular component as well as the percentage of the surface of the component that was in contact with bone was measured on the postoperative radiographs. In patients with unilateral involvement, the center of rotation of the normal, contralateral hip was used as the reference, whereas in patients with bilateral involvement, the center of the femoral head was approximated as described by Pagnano et al.⁹ Evidence of socket migration (both linear and rotational) was measured on serial radiographs, and a linear change of >3 mm or a rotational change of $\geq 8^\circ$ was considered migration¹⁰.

Postoperative gaps, radiolucent lines, and osteolysis were identified in the three zones described by DeLee and Charnley¹¹ on the anteroposterior and Lowenstein lateral radiographs. The width of the gaps and radiolucent lines was measured by a single observer who had not participated in the operation or other care of the patients. The measurements were performed with use of a Digimatic caliper (Mitutoyo, Tokyo, Japan). Regions in which the surface of the acetabular component was not in contact with bone on the immediate postoperative radiographs were classified as gaps, to distinguish them from radiolucent lines that appeared on subsequent radiographs in areas in which no gaps had existed initially or in which gaps had disappeared¹³. Progression of a radiolucent line was defined as an increase in the number of zones of involvement 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 such areas were observed on subsequent radiographs, and they were classified as "not visible" if they disappeared (and remained absent) on subsequent radiographs. An acetabular component was considered radiographically loose when migration had occurred

or a complete radiolucency of ≥ 2 mm could be measured. The size of the area of osteolysis was measured on the anteroposterior pelvic radiograph as the greatest diameter of the lesion in the horizontal and vertical axes.

Linear polyethylene wear was measured with use of the technique described by Dorr et al.⁸ Femoral head displacement (penetration) that was measured on the three-month radiograph was primarily considered creep, and subsequent displacement was primarily considered wear.

The quality of stem fixation was classified with use of the A, B, C, and D grading scale developed by Barrack et al.¹² for cemented stems and with use of the method developed by Dorr et al.¹³ for cementless stems.

Statistical analysis was performed with use of SPSS software (SPSS, Chicago, Illinois). The Student t test and multiple linear regression analysis were used to evaluate the relationships between the rate of polyethylene wear and the variables of age, weight, gender, polyethylene thickness, center of rotation of the hip, abduction angle of the socket, and presence of radiolucent lines. The chi square test was used to analyze the association between the development of radiolucent lines and the use of bone graft and that between the development of radiolucent lines and the presence of an initial gap. Kaplan-Meier survivorship analysis was performed to calculate the rate of survival of the acetabular component.

Results

One (0.9%) of the 110 hips was revised because of aseptic loosening of the acetabular metal shell at eighty-four months postoperatively. This hip had a rheumatoid protrusio deformity that required particulate bone-grafting, and progressive radiolucent lines were observed five years after the index operation. Four hips (4%) had revision of a stable acetabular component at an average of 8.5 years (range, 7.7 to 9.2 years) after the index operation. In two of these hips, the metal shell was revised because of recurrent dislocations. In the other two hips, the shell was revised at the time of polyethylene liner exchange because the position of the cup was not considered acceptable for the prevention of dislocation postoperatively. All four of these hips were revised with use of a cementless socket that was fixed with screws.

The self-assessment questionnaire was completed by ninety-eight patients (105 hips) who still had the index acetabular component in place at the time of the final follow-up. Eighty-six patients (ninety-two hips; 88%) rated the outcome of the index operation as excellent or very good, ten patients (eleven hips; 10%) rated the outcome as good, and two patients (two hips; 2%) rated the outcome as fair. Radiographs of both of the hips that received a rating of fair showed no evidence of migration or radiolucency around the acetabular component.

Thirty-seven hips (34%) had a gap around the socket on the initial postoperative radiographs; of these, nineteen hips had a gap in two zones and eighteen had a gap in one zone. The width of these gaps was almost always <0.5 mm and was never >1 mm. The number of visible gaps decreased at each

follow-up interval. At the time of the final follow-up of 105 intact cups, radiolucent lines were observed in four of thirty-seven hips that had had a gap on the initial postoperative radiographs compared with four of the sixty-eight hips that had not had a gap on the initial postoperative radiographs ($p = 0.039$). The presence of a gap was not associated with the subsequent occurrence of radiolucent lines.

At an average of two years postoperatively, new radiolucent lines around the socket were identified on the anteroposterior and lateral radiographs of three hips. All of these lines measured ≤ 0.5 mm in width. There were no loose sockets; hence, the mechanical failure rate was 0%.

At an average of six years postoperatively, no new radiolucent lines were observed to have developed since the second year, thirteen hips had persistent gaps, and three hips had stable radiolucent lines. There were no loose sockets; hence, the mechanical failure rate remained 0%.

At the time of the latest follow-up examination, performed at an average of 10.2 years postoperatively, eight hips (7%) had radiolucent lines around the socket. Four hips had persistent gaps that had been seen on the initial postoperative radiograph, three hips had new radiolucent lines measuring no greater than 0.5 mm in width, and one hip had progression of a preexisting radiolucent line that had progressed to all three zones. The latter hip had revision of the cup. No hip had a radiolucent line that was >1 mm wide, and no hip had evidence of socket migration in any of the three follow-up periods (Figs. 2-A and 2-B). The mechanical failure rate at ten years was 0.9% (one of 110). The twelve-year rate of survival of the acetabular component was 99.1% (95% confidence interval, 97.3% to 100%) with revision or recommended revision for aseptic loosening (mechanical failure) as the end point and 95.3% (95% confidence interval, 91.2% to 99.3%) with revision of the metal shell for any reason as the end point.

Overall, the mean rate of linear wear of the original polyethylene liners



Fig. 2-A

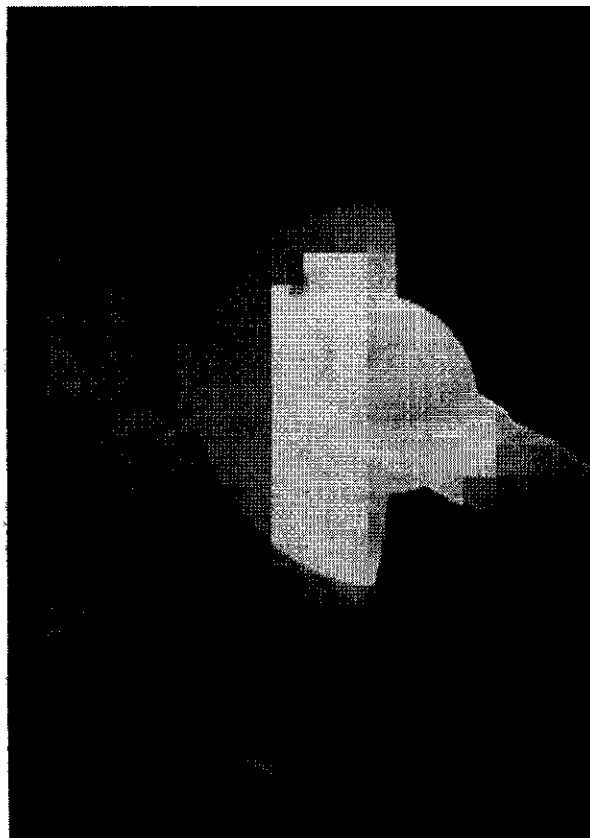


Fig. 2-B

Anteroposterior (Fig. 2-A) and lateral (Fig. 2-B) radiographs, made ten years after insertion of a press-fit acetabular component without screws. These radiographs demonstrate the typical appearance of the fixation at ten years, with evidence of osseous attachment to the socket and no evidence of radiolucency at the bone-socket interface.

was 0.16 ± 0.13 mm/yr and the mean rate of volumetric wear was 107.40 ± 95.36 mm³/yr. In ninety-six hips that did not require reoperation for excessive

wear, the rate of polyethylene wear was 0.14 ± 0.10 mm/yr. With the numbers available, linear wear was not significantly different between the hips treated with 26-mm femoral heads (0.19 mm/yr), 28-mm femoral heads (0.13 mm/yr), and 32-mm heads (0.21 mm/yr) ($p < 0.1$). Focal osteolysis of the acetabulum was seen in four hips (4%) at an average of six years postoperatively, and this finding was confined to the ilium.

Eighteen hips had an exchange of the polyethylene insert because of complications related to the insert. In thirteen asymptomatic hips, the polyethylene liner and the femoral head were exchanged because of excessive wear. The average linear wear in these hips was 0.32 mm/yr (range, 0.16 to 0.62 mm/yr), the average time between the index operation and the reoperation was 6.9 ± 2.6 years (range, 3.5 to 10.1 years), and the average polyethylene thickness at the time of the index operation was 10.3 ± 1.9 mm (range, 8.5 to 14.5 mm). One additional symptomatic hip had such excessive wear that the polyethylene liner was worn through and had fractured. This hip was treated with exchange of the liner and the metal femoral head. Four hips had a reoperation because of dissociation of the polyethylene liner, and again only the polyethylene liner and the femoral head were exchanged. The rate of survival of the polyethylene insert was 79.6% (95% confidence interval, 70.1% to 89.1%) with revision because of wear or disassociation as the end point.

Nine hips had revision of the femoral stem because of aseptic loosening at an average of 7.4 ± 2.0 years postoperatively. In addition, two hips had revision of the stem because of a periprosthetic femoral fracture and one hip had revision of the stem because of severe femoral osteolysis. These twelve hips (11%) had an incidental exchange of the polyethylene liner at the time of the femoral revision. In the present study, the amount of wear that was measured was not correlated to whether the stem was fixed or loose.

Overall, thirty hips had a polyethylene liner exchange, including the eighteen hips that had the exchange because of complications related to the liner and the twelve that had an incidental exchange at the time of femoral revision. The metal shell was determined to be stable in all thirty hips at the time of the liner exchange, but it was revised in two hips because its position was not thought to be acceptable for the prevention of dislocation following the exchange.

Multiple regression analysis showed that the volumetric and linear wear rates were significantly associated with the age of the patient ($p = 0.009$ and 0.034 , respectively) and the abduction angle of the socket ($p = 0.004$ and 0.012 , respectively) (Table I). A higher linear wear rate was seen in patients who were fifty years of age or younger (0.28 ± 0.22 mm/yr). Patients who were seventy years of age or older had a linear wear rate of 0.10 ± 0.07 mm/yr. Hips with an abduction angle of the socket of $>40^\circ$ also had higher wear rates (Table I).

Discussion

A hemispheric porous-coated socket that is inserted with a press-fit technique, without the use of adjunctive screw fixation, provides results that are comparable with those

TABLE I Polyethylene Wear Rate in Sockets with Different Abduction Angles

Abduction Angle (deg)	No. of Hips	Linear Wear (mm/yr)	Volumetric Wear (mm ³ /yr)
≤ 40	21	0.07 ± 0.05	43.85 ± 29.84
41-45	33	0.15 ± 0.09	98.95 ± 56.54
46-50	33	0.19 ± 0.13	117.69 ± 93.98
> 50	23	0.21 ± 0.18	160.35 ± 136.10

achieved with use of a cementless cup that is fixed with screws. Two other reports on the ten-year results associated with cementless sockets are available for comparison. Clohisy and Harris¹⁴ reported the average ten-year results for patients who had had fixation of the Harris-Galante porous-coated acetabular component (Zimmer, Warsaw, Indiana) with screws, and Engh et al.¹⁵ reported the average eleven-year results for patients who had had fixation of the anatomic medullary locking prosthesis (AML; DePuy, Warsaw, Indiana) with pegs. Those two studies involved consecutive series of patients, whereas the present study was selective. The selective nature of the present study was necessary because we were using a new technique in which we needed to gain trust and, secondly, because in our estimation some sockets will always require screw fixation. Screw fixation is necessary for patients who have soft bone due to osteoporosis, a dysplastic socket with an absent anterior wall that also does not permit coverage of the superior aspect of the cup with bone, and mechanical instability of the cup at the time of surgery.

The rate of revision of the socket for any reason was nearly the same for hips in which the Harris-Galante prosthesis was fixed with screws (4.6%; nine of 196)¹⁴, those in which the anatomic medullary locking prosthesis was fixed with pegs (4.6%; eight of 174)¹⁵, and those in the present study, in which the Anatomic Porous Replacement prosthesis was fixed without screws (4.5%; five of 110). The rate of revision for loosening of the socket was 0%, 2%, and 0.9%, respectively; the rate of radiographic loosening of the socket was 0%, 1.5%, and 0%, respectively; and the rate of mechanical failure was 0%, 4.0%, and 0.9%, respectively.

The stable fixation of press-fit sockets at an average of ten years postoperatively seems to provide clinical confirmation of the findings of the cadaveric study by Kwong et al.¹⁶. Those authors found that there was no difference in the stability of Harris-Galante porous-coated acetabular components that had been inserted with a 1-mm press-fit with or without supplementary screws. They also found that exact-fit reaming with screw fixation yielded less stability at the rim of the acetabular component than did 1-mm underreaming and press-fit fixation. In our study, we used underreaming and we did not observe any fractures of the acetabulum as have been observed in cadaveric bone^{5,6}.

The complications associated with these uncemented

sockets were a consequence of their modularity. Reoperation because of wear was necessary for fourteen (13%) of the 110 hips in this study. The high rate of reoperation for wear was likely a result of the 0.5 to 0.7-mm gap between the polyethylene and the metal shell¹ as well as the philosophy of the senior surgeon to operate on hips with excessive linear wear (>0.3 mm/yr) in order to avoid osteolysis. In the present study, the thickness of the polyethylene insert did not appear to contribute to accelerated wear as it had with the porous-coated anatomic socket¹⁷ (Howmedica, Rutherford, New Jersey) and the use of 32-mm femoral heads did not seem to contribute to accelerated wear as was suggested by Engh et al.¹⁵.

We found the abduction angle of the cup to be an important technical factor contributing to the amount of wear. Cups with an abduction angle of $\leq 40^\circ$ had the lowest annual rates of linear and volumetric wear, and cups with an abduction angle of $>50^\circ$ had the highest rates of wear (Table I). Cups with an abduction angle of $>50^\circ$ had an average volumetric wear rate of 160 mm³/yr, which exceeds the critical rate of 150 mm³/yr that can be expected to result in osteolysis and loss of fixation¹⁸. This accelerated wear in cups with an abduction angle of $>50^\circ$ was also reported by Schmalzried et al.¹⁹.

We have confidence in this method of fixation because of the low prevalence of radiolucent lines, particularly progressive radiolucent lines. We strive to keep the abduction angle of the cup at $\leq 40^\circ$, and we use 28-mm heads almost exclusively. We do use 22-mm heads for socket sizes of ≤ 49 mm so that the liner is at least 8 mm thick. ■

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