Primary Cementless Total Hip Arthroplasty with an Alumina Ceramic-on-Ceramic Bearing

Results After a Minimum of Twenty Years of Follow-up

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Background: The biological problems related to wear debris after total hip arthroplasty have stimulated renewed interest in alternatives to metal-on-polyethylene bearing surfaces.

Methods: We retrospectively evaluated the clinical and radiographic results of 100 patients who had undergone a total of 109 primary total hip arthroplasties with a cementless alumina ceramic-on-ceramic prosthesis between January 1985 and December 1989. The mean age of the patients at the time of the index arthroplasty was forty-six years. Clinical evaluation was performed with use of the Charnley modification of the Merle d'Aubigné-Postel scale. Seventy-eight patients who had had a total of eighty-five arthroplasties were available for follow-up evaluation at an average of 20.8 years. The patients' average age at the time of the latest follow-up was 66.8 years.

Results: Six hips (six acetabular cups and one femoral stem) in six patients underwent revision. Aseptic loosening of the cup combined with focal osteolysis was the cause of all six revisions. In one patient, the stem was also revised because of aseptic loosening. At the time of final follow-up, the result was excellent (according to the Merle d'Aubigné-Postel scale) in 68% of the hips, good in 19%, fair in 9%, and poor in 4%. The mean Merle d'Aubigné-Postel score improved from 7.9 points preoperatively to 16.9 points postoperatively ($p < 0.001$). The cumulative rate of survival of the prostheses was 84.4% at 20.8 years.

Conclusions: The results of these cementless ceramic-on-ceramic total hip arthroplasties continued to be satisfactory at a minimum of twenty years postoperatively. The improved design of contemporary prostheses and the new generation of ceramic-on-ceramic bearing surfaces may lead to even better long-term results.

Level of Evidence: Therapeutic Level IV. See Instructions to Authors for a complete description of levels of evidence.

There is continuing controversy regarding the ideal bearing surfaces to use in total hip arthroplasty[1]. Alumina ceramic-on-ceramic bearing surfaces are an attractive alternative to metal-on-polyethylene bearing surfaces[2,3], mainly because of the biological inertness[4-6] and the superb tribological properties of the material, which result in excellent wear resistance[4,7].

The aim of this study was to update our previous report on patients who were followed for a minimum of seven years after a total hip arthroplasty with the alumina ceramic-on-ceramic Autophor 900-S prosthesis (Osteo, Selzach, Switzerland)[8]. We now report the clinical, radiographic, and functional results after a minimum duration of follow-up of twenty years.

Materials and Methods

This study was approved by our institution's scientific research board, and it was conducted in accordance with the World Medical Association Declaration of Helsinki of 1964 as revised in 1983 and 2000. All patients were informed about the study in detail and provided written informed consent before their enrollment.

Between January 1985 and December 1989, a total of 109 alumina ceramic-on-ceramic cementless Autophor 900-S

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prostheses were implanted in a consecutive series of 100 patients who were sixty years old or younger and were undergoing primary total hip arthroplasty. Two surgeons performed all of the operations. A cementless Autophor 900-S fully porous-coated femoral stem made of cobalt-chromium-molybdenum ENDOCAST alloy (ThyssenKrupp, Dusseldorf, Germany) was implanted with a press-fit technique. A 38-mm BIOLOX femoral head (Feldmühle Aktiengesellschaft, Plochingen, Germany) made of aluminum-oxide ceramic and a cementless tapered threaded BIOLOX cup made of aluminum-oxide ceramic with grooves at the circumference were used in all hips.

The original cohort consisted of 100 patients (109 involved hips), including sixty-eight women and thirty-two men, with an average age (and standard deviation) of 46 ± 7.96 years (range, nineteen to sixty years). The indication for surgery was congenital hip disease in fifty-two hips (48%), osteonecrosis in twenty-six (24%), primary osteoarthritis in twenty (18%), pseudarthrosis following femoral neck fracture in four, ankylosing spondylitis in three, and other reasons in the remaining four.

The Hardinge[9] transgluteal direct lateral approach was used with the patient in the supine position. A second-generation cephalosporin and an aminoglycoside were administered an hour preoperatively and during the first three postoperative days. All patients were also given a four-week postoperative course of low-molecular-weight heparin as a means of thromboprophylaxis; no prophylaxis against heterotopic ossification was used. Following removal of the standard drainage tubes on the second postoperative day, toe-touch weight-bearing with the aid of a walker was allowed. Partial weight-bearing was allowed at six weeks, with a gradual increase to full weight-bearing by twelve weeks postoperatively.

The patients were examined preoperatively; at three, six, and twelve months postoperatively; and yearly thereafter. At their latest follow-up visit, all patients had a physical examination and plain radiographs (an anteroposterior radiograph of the pelvis with the patient in the standing position and a frog-leg lateral non-weight-bearing radiograph of the hip) were made. All radiographs were reviewed specifically to determine the presence of subsidence of the femoral component, migration of the acetabular component, changes in the center of rotation of the hip, resorption of the calcar, radiolucencies around the components, and osteolysis. Osteolysis was defined as any focal endocortical erosion of either the femoral canal or the acetabulum progressing over time[10] and accompanied by a change in the position of the prosthesis. The functional outcomes were evaluated according to the Merle d'Aubigné-Postel scale[11] as modified by Charnley[12].

Statistical Analysis

Significance was set at $p < 0.05$. With use of revision of the femoral stem and/or acetabular cup for any reason as well as losses to follow-up as the end point, a Kaplan-Meier survivorship analysis was performed with calculation of 95% confidence intervals. Censored patients were those who died and those who reached the end of the trial[13,14]. The 95% confidence intervals were determined by using the Rothman equation[14].

Source of Funding

There was no external funding source in support of this study.

Results

Summary of Previous Study[8]

Two hundred and twenty patients underwent a total of 233 ceramic-on-ceramic total hip arthroplasties. The mean age of the patients at the time of the index arthroplasty was 47.5 years (range, nineteen to sixty-five years). A cementless threaded ceramic cup was implanted in eighty-five hips, and a cementless threaded titanium cup was placed in the remaining 148. A 32-mm ceramic head was used in all patients. One hundred and ninety-five patients (205 hips) were available for a follow-up evaluation at an average of 13.5 years (range, seven to seventeen years). One femoral stem combined with a ceramic cup was revised because of septic loosening, and two femoral stems combined with ceramic cups were revised because of aseptic loosening. Nine more cups (two ceramic and seven titanium) were also revised, because of aseptic loosening in the presence of focal osteolysis. Thus, the total revision rate was 5.9%. An excellent or good result (according to the Merle d'Aubigné-Postel scale[11] as modified by Charnley[12]) was found in 92.7% of the hips. The cumulative rate of survival of the femoral stem was 90.0% (Table I).

Current Study

From March 2008 until September 2008, we reevaluated seventy-eight patients (eighty-five hips). There were no dislocations and no reports of squeaking. Six patients (six total hip arthroplasties) underwent revision at an average age of 53.3 years (range, forty to fifty-nine years). With the numbers available, the preoperative diagnosis (congenital dislocation in three patients, osteonecrosis in two, and osteoarthritis in one) was not associated with the rate of survival of the prostheses ($p = 0.82$). Aseptic loosening of the acetabular cup in the presence of focal osteolysis was the cause of the revision in all hips. All six hips were revised with use of a new acetabular cup (a press-fit Duraloc porous-coated cup [DePuy Orthopaedics, Warsaw, Indiana] stabilized with two screws). In one of the six hips, the femoral stem was also revised (with an AML 5/8 porous-coated stem; DePuy Orthopaedics) because of aseptic loosening (Table I).

The age at the time of the operation of the patients who subsequently died was not significantly different from that of the patients who returned for the final follow-up visit ($p = 0.636$). The patients who were lost to follow-up, however, were significantly younger (mean age, 56.9 years) than the patients who were available for final follow-up ($p < 0.01$).

The clinical result[11,12] was excellent in fifty-eight hips (68%), good in sixteen (19%), fair in eight (9%), and poor in three (4%) (Table I). The mean Merle d'Aubigné-Postel score[11], as modified by Charnley[12], improved from 7.9 points preoperatively to 16.9 points postoperatively ($p < 0.001$; t test). The mean pain score improved to 5.7 points, from 2.7 points

TABLE I Comparison of the Results of Our Current and Our Previously Published Study[8]

Parameter	Current Study	Previous Study[8]
Patient data		
Patients who underwent operation *(no.)*	100 (68 women, 32 men)	220 (156 women, 64 men)
Patients available for latest follow-up visit *(no.)*	78 (60 women, 18 men)	195 (150 women, 45 men)*
Mean age (range) at index operation *(yr)*	46 (19-60)	47.5 (19-65)
Total hip arthroplasties performed *(no.)*	109	233
Hips available at latest follow-up visit *(no.)*	85	205
Mean duration of follow-up (range) *(yr)*	20.8 (20-24)	13.5 (7-17)
Postoperative complications *(no. [% of total hip arthroplasties initially performed])*		
Intraoperative fracture of greater trochanter	2 (1.8)	5 (2.1)
Postoperative deep-vein thrombosis	2 (1.8)	6 (2.6)
Postoperative peroneal nerve paresis	1 (0.9)	0
Postoperative superficial wound infection	2 (1.8)	2 (0.9)
Thigh pain during the 1st postoperative year	7 (6.4)	18 (7.7)
Hip dislocation	0	0
Outcomes		
Cumulative survival rate *(% of hips available at latest follow-up visit)*	84.4	90.0
Score according to Charnley[12] modification of Merle d'Aubigné-Postel scale[11] *(no. of hips [% of hips available at latest follow-up visit])*		
Excellent	58 (68.2)	153 (74.6)
Good	16 (18.8)	37 (18.0)
Fair	8 (9.4)	12 (5.9)
Poor	3 (3.5)	3 (1.5)
Aseptic loosening *(no. of hips [% of hips available at latest follow-up visit])*		
Femoral stem	1 (1.2)	2 (1.0)
Acetabular cup	6 (7.1)	Not mentioned
Radiographic features at latest follow-up visit *(no. of hips [% of hips available at latest follow-up visit])*		
Subsidence of femoral stem of ≥2 mm	3 (3.5)	4 (2.0)
Partial resorption of femoral calcar	9 (10.6)	15 (7.3)
Radiographic appearance of endosteal plug	4 (4.7)	6 (2.9)
Radiolucency of ≤2 mm adjacent to femoral stem	9 (10.6)	20 (9.8) (radiolucency >1 mm)
Radiolucency of >2 mm adjacent to femoral stem†	1 (1.2)	
Radiolucency of ≤2 mm adjacent to acetabular cup	61 (71.8)	Not mentioned
Radiolucency of >2 mm adjacent to acetabular cup‡	6 (7.1)	Not mentioned
Hypertrophic femoral diaphysis	16 (18.8)	35 (17.1)
Protrusio of acetabular cup	13 (15.3)	Not mentioned
Revisions *(no. of hips [% of hips available at latest follow-up visit])*		
Femoral stem	1 (1.2) due to aseptic loosening	3 (1.5): 1 due to septic loosening, 2 due to aseptic loosening
Acetabular cup	6 (7.1) due to aseptic loosening + focal osteolysis	12 (5.9): 1 ceramic due to septic loosening, 4 ceramic and 7 titanium due to aseptic loosening + focal osteolysis*

*Information not published. †Stem was revised. ‡Cups were revised.

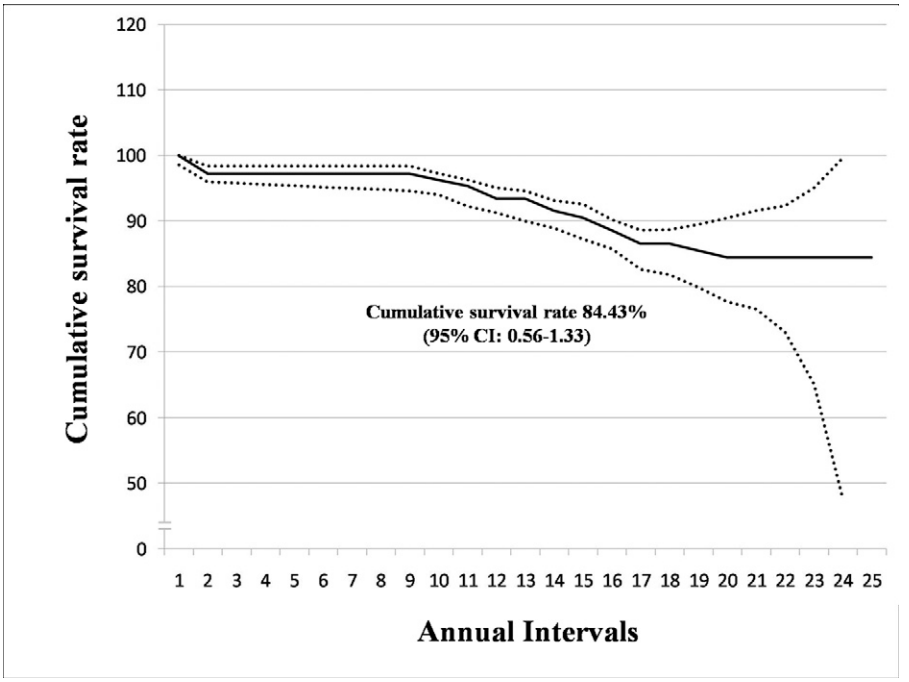

Fig. 1

Survival curve, and 95% confidence intervals, with use of revision of any component performed for any reason and loss to follow-up as the end points. The cumulative probability of survival of the total hip prosthesis was 84.4% (95% confidence interval, 0.56 to 1.33).

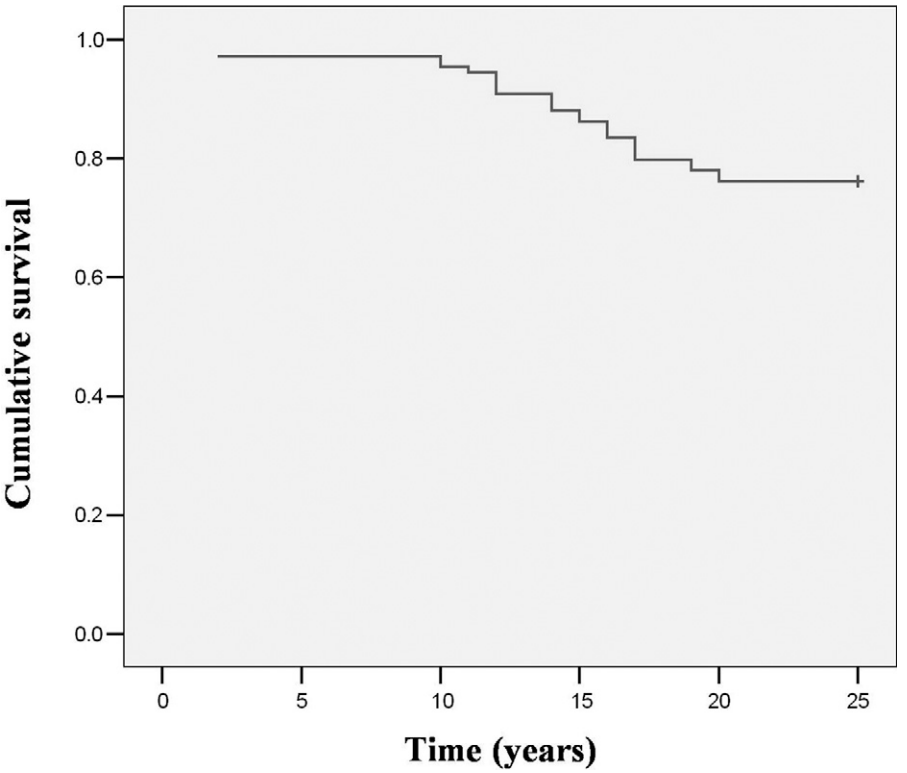

Fig. 2

Kaplan-Meier survivorship probability curve at a minimum of twenty years postoperatively. The curve indicates the probability of having revision surgery over time (mean survival time, 22.25 years [95% confidence interval, 21.22 to 23.28 years]).

preoperatively; the mean range-of-motion score improved to 5.6 points, from 2.7 points; and the mean walking-ability score improved to 5.6 points, from 2.5 points. The mean score (at the latest available follow-up visit) was 16.4 points (range, 15 to 18 points) for the patients who died and 15.3 points (range, 14 to 17 points) for those who were lost to follow-up.

No significant association was found between a fair or poor clinical result (in eleven patients) at the latest follow-up visit and radiographic findings of possible loosening (femoral stem subsidence: $p = 0.497$, calcar resorption: $p = 0.863$, endosteal plug: $p = 0.628$, femoral radiolucency: $p = 0.479$, femoral diaphyseal hypertrophy: $p = 0.953$, acetabular radiolucency: $p = 0.596$, and protrusio: $p = 0.960$; chi-square test). The cumulative probability of survival of the total hip prosthesis was 84.4% at 20.8 years (Figs. 1 and 2).

Discussion

Perhaps the major barrier to increasing the survival of modern total hip prostheses is the need to develop optimal bearing surfaces. Among the most promising bearing surfaces is alumina (Al_2O_3) ceramic on ceramic[4-7].

In this study, we evaluated several issues[10] regarding the long-term clinical results in relatively young patients who had undergone total hip arthroplasty with use of the Autophor 900-S ceramic-on-ceramic prosthesis. At a minimum of twenty years postoperatively, the functional outcomes of our patients were comparable with those reported in our previous study of patients evaluated at a minimum of seven years following a total hip arthroplasty with the same prosthesis[8] (Table I). The cumulative probability of survival of the total hip prostheses in the current series was 84.4% and is comparable with the cumulative probability of survival (90.0%) in our previous study[8] (Table I). Our results are also similar to those reported by Mittelmeier and Heisel[15], who originally developed this prosthesis, and those reported by Hamadouche et al.[16] (85.6% for the acetabular cup and 84.9% for the femoral stem), who performed a similar study in a non-homogeneous group of relatively older patients.

The absence of hip dislocation and prosthetic fracture in this series of patients compares favorably with results reported in the literature[17-19]. Of interest, our patients, who underwent total hip arthroplasty with the use of first-generation ceramic-on-ceramic bearing surfaces, did not report squeaking[20-22]. With the exception of the five acetabular cups and the one complete prosthesis (the cup and femoral stem) that had to be revised because of aseptic loosening and concurrent focal periacetabular osteolysis, there were no instances of either clinical or radiographic evidence of loosening.

Radiolucent lines (<2 mm wide) were noted in the majority (79%) of the reevaluated cases. However, these lines were apparent at the evaluation performed at one year, and they had not progressed, as of the latest follow-up visit, in sixty-one of the sixty-seven hips[23-25]. Protrusio of the acetabular cup was also apparent in thirteen cases. Since it was not accompanied by rotation of the prosthesis or clinical symptoms, none of those patients has required surgical intervention.

Nonprogressive subsidence of the femoral stem of ≥2 mm was seen in three hips (four in our previous series[8]). We believe that subsidence of the femoral stem of 1 to 4 mm during the early postoperative period may allow the stem to attain a more secure position within the femoral canal, and it may still allow bone ingrowth to occur. As a result, early subsidence is still compatible with durable implant fixation[8].

This study has certain limitations. Comparison with another study group treated with different bearing surfaces would have strengthened our findings. Measuring the wear rates of the total hip arthroplasty components would have also been useful, especially in consideration of the relatively long follow-up period. However, as has been reported in similar studies[26], this seems to be extremely difficult (if not impossible) because most of the techniques that have been described in the literature focus on hemispherical acetabular cups and consequently are not appropriate for use with the conical (trapezoidal) Autophor ceramic acetabular component[7]. Another problem when trying to evaluate the wear rate of the Autophor prosthesis is the difficulty in accurately identifying the outer border of the acetabular component because of the increased bone density at the component's periphery secondary to bone remodeling[7,10]. Still another issue is the inability to differentiate the femoral head from the cup on radiographs, even when third-generation ceramic-on-ceramic bearing surfaces were used[26]. Furthermore, the average annual wear rate of this particular type of ceramic-on-ceramic prosthesis has been repeatedly studied and reported to be as low as 0.016 mm in vivo[7] and 0.005 mm in vitro[2]. This is the reason why most ceramic-on-ceramic bearing surfaces seem to have wear rates ranging from ten to 4000 times less than that of metal-on-polyethylene combinations[7,24]. Therefore, we believe that, when reevaluating patients who underwent total hip arthroplasty with the use of ceramic-on-ceramic bearing surfaces (even first-generation ceramic-on-ceramic surfaces), detecting the actual wear rate is important but not as important as evaluating other issues (the dislocation rate, radiographically or clinically evident loosening, the fracture rate, and squeaking).

To the best of our knowledge, we are the first to examine the long-term results (i.e., at a minimum of twenty years) of patients (relatively young at the time of the index operation) who underwent cementless total hip arthroplasty with the use of a single type of alumina ceramic-on-ceramic prosthesis. The design of the socket, head-neck junction, and femoral stem of the Autophor 900-S prosthesis is considered to be poor, and the implant consists of relatively low-quality first-generation alumina components[27]. Nevertheless, the long-term clinical results were surprisingly positive since the cumulative rate of survival of the prosthesis (84.4%) was excellent even when the failed cases were added to all of those lost to follow-up.

Our study demonstrates that total hip arthroplasty with use of alumina ceramic-on-ceramic bearing surfaces can be reliable and effective in a generally young and active patient population. Given the progress achieved in total hip arthroplasty design and the recent introduction of the fourth generation of alumina ceramic-on-ceramic bearing surfaces[27], the

future of ceramic-on-ceramic prostheses appears to be extremely promising. ■

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