Primary Total-Hip Arthroplasty With the Autophor 900-S Fully Porous Coated Stem in Young Patients

Seven to Seventeen Years of Follow-Up

George E. Petsatodes, MD, John E. Christoforides, MD, Pericles P. Papadopoulos, MD, Anastasios G. Christodoulou, MD, Dimitrios Karataglis, MD, and John D. Pournaras, MD

Abstract: A total of 233 Autophor 900-S fully porous coated stems were implanted in 220 patients with an average age of 47.5 years and an average follow-up of 13.5 years. The mean d' Aubigne-Postel score improved from 7.9 points preoperatively to 16.9 points postoperatively ($P < .001$). The overall result was excellent in 74.6%, good in 18.1%, fair in 5.8%, and poor in 1.5% of cases. One hip was revised for septic and two for aseptic loosening. The overall survival rate of this prosthesis was 98.1% in 17 years. The Autophor 900-S femoral stem has offered a very satisfactory clinical outcome together with considerable prosthesis longevity in the young patient population studied. It combines adequate initial stability, satisfactory subsequent bone ingrowth, smooth load transfer, and low-friction bearing surfaces.
Key words: Autophor 900-S, porous coated stem, total-hip arthroplasty.

Porous coated cementless femoral stems have been widely used during the last 20 years in an effort to improve the long-term results of total-hip arthroplasty (THA), especially in young and active patients. When first-generation cementing technique was used, a rate of loosening as high as 50% within 5 years has been reported in this patient population [1,2].

A number of porous coated cementless femoral stems have been designed, with either proximal or extensive/full porous coating [1,3-8]. One of the first fully porous coated cementless stem designs was the Autophor 900-S stem, introduced by Prof H Mittelmeier replacing the Mittelmeier Mark I and Mark II smooth press-fit stems [9]. It was introduced to address the problem of early loosening that was encountered with the Mittelmeier Mark I and Mark II stems that did not offer adequate initial stability. The stem has a macrotextured surface with particles sized 200 to 300 μm and pore sizes of approximately 150 to 200 μm, so as to enlarge the anchorage surface in the femoral canal and at the same time allow bone micro-ingrowth in an effort to achieve adequate stem stability.

The aim of this study was to evaluate the long-term clinical and radiological outcome of the Autophor 900-S stem in a relatively young patient population.

Patients and Methods

Between 1984 and 1994, a total of 233 Autophor 900-S stems were implanted in 220 patients during a primary hip arthroplasty. The patient population consisted of 156 women (71%) and 64 men (29%)

From the 1st Orthopaedic Department, Aristotelian University of Thessaloniki, "G. Papanikolaou" General Hospital, Thessaloniki, Greece.
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Reprint requests: George E. Petsatodes, MD, 1, Bala str, 55131 Thessaloniki, Greece.

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Table 1. Population

No. of patients	220 (233 hips)
Age (y)	19-65 (average, 47.5)
Sex [female/male, n (%)]	156 females (71)/64 males (29)
Follow-up (y)	7-17 (average, 13.5)
Reason for operation (%)	
Primary OA	76 (32.6)
DDH	69 (29.6)
AVN	65 (27.9)
Rheumatoid arthritis	16 (6.9)
Ankylosing spondylitis	4 (1.7)
Other	3 (1.3)

AVN indicates avascular necrosis; DDH, developmental dysplasia of the hip; OA, osteoarthritis.

with an average age of 47.5 years (range from 19 to 65 years). The indication for surgery was primary osteoarthritis in 76 hips (32.6%), developmental hip dysplasia in 69 (29.6%), avascular necrosis of the femoral head in 65 (27.9%), rheumatoid arthritis in 16 (6.9%), ankylosing spondylitis in 4 (1.7%), and other in 3 (1.3%) (Table 1).

Eight patients (9 hips) died 6 to 12 years postoperatively of unrelated reasons, whereas another 17 patients (19 hips) were lost to follow-up for various reasons. This brings our patient population with a full follow-up to 195 patients (205 hips). Follow-up period ranged from 7 to 17 years (average, 13.5 years).

A fully porous coated Autophor 900-S stem (Osteo AG, Selzach, Switzerland) was implanted with a press-fit technique in all patients. The implant is made of CoCrMo ENDOCAST alloy (Osteo AG) and is fully porous coated with ENDOCAST particles sized 200 to 300 μm touching each other and pore sizes of approximately 150 to 200 μm. The stem is quadrangular, with transverse ribs, a lateral fin, and corrugations below the collar of the shaft. It has rounded, smooth corners, without porous coating and 2 proximal fenestrations. A 32-mm ceramic head (Biolox, Ceramtec, Plochingen, Germany) was used. A cementless threaded ceramic cup was implanted in 85 cases and a cementless threaded titanium cup in 148 cases. Care was taken during preoperative planning for the selection of the proper size of implant.

All operations were performed by one of the first two or the senior author (GEP, JEC, JDP). A transgluteal approach with the patient in the supine position was used in all cases. The cancelous bone of the femoral neck was rasped until the rasp was seen to contact the cortical margin of the bone. The stem was subsequently inserted with a press-fit technique and the fenestrations on the proximal part of it were grafted before insertion, as were any defects left around the most proximal part of the stem.

A second-generation cephalosporin along with aminoglycoside was administered an hour preoperatively and for 3 days postoperatively. Furthermore, all patients were given a 4-week course of low-molecular weight heparin for thromboprophylaxis; no prophylaxis against heterotopic ossification was used. Patients were mobilized the second postoperative day, touch-toe weight bearing with a walker. Partial weight bearing was allowed 6 weeks postoperatively and full weight bearing 3 months after the operation.

Patients were examined both clinically and radiologically preoperatively, 3, 6, and 12 months postoperatively and yearly thereafter. A standard anteroposterior radiograph of the pelvis with the patient standing and a lateral radiograph were taken. Postoperative radiographs were examined to determine any potential migration or subsidence of the femoral component, any changes of the center of rotation, as well as any signs of absorption of the calcar, radiolucencies, or bone remodeling around the prosthesis [6,10]. Clinical evaluation was performed according to the d' Aubigne-Postel scale [11], as modified by Charnley [12].

A 2-tailed Student *t* test was used to evaluate the difference in pre- and postoperative scores in the d' Aubigne-Postel scale. Statistical significance was set at $P < .05$. Using stem revision for any reason as the end point, a life table as well as the corresponding survival curve with 95% confidence intervals (CIs) was plotted and the cumulative stem survival rate was subsequently calculated. As dictated by Murray et al [13,14], a worst-case scenario life table as well as the corresponding survival curve was also plotted, considering revisions as well as losses to follow-up as failures.

Results

According to the d' Aubigne-Postel scale as modified by Charnley, the results were excellent in 153 hips (74.6%), good in 37 (18.1%), fair in 12

Table 2. Results

Mean d' Aubigne-Postel score	Preoperative, 7.9; postoperative, 16.9
Pain score	Preoperative, 2.7; postoperative, 5.7
ROM score	Preoperative, 2.7; postoperative, 5.6
Walking ability score	Preoperative, 2.5; postoperative, 5.6
Overall result [n (%)]	
Excellent	153 (74.6)
Good	37 (18.1)
Fair	12 (5.8)
Poor	3 (1.5)

Table 3. Life Table I (Best-case Scenario: Only Revisions Considered Failures)

Years Since Operation	Number at Start	Revised	Lost	Dead	Censored	Number at Risk	Annual Failure Rate (%)	Annual Success Rate (%)	Cumulative Survival Rate (%)	95% CI	
0 to <1	233	0	0	0	0	233	0	100	100	98.38	100.00
1 to <2	233	1	0	0	0	233	0.43	99.57	99.57	97.61	99.92
2 to <3	232	0	0	0	0	232	0	100	99.57	97.60	99.92
3 to <4	232	0	4	0	0	230	0	100	99.57	97.59	99.92
4 to <5	228	0	4	0	0	226	0	100	99.57	97.56	99.93
5 to <6	224	0	2	1	0	222.5	0	100	99.57	97.53	99.93
6 to <7	221	0	2	4	0	218	0	100	99.57	97.50	99.93
7 to <8	215	0	3	0	23	202	0	100	99.57	97.36	99.93
8 to <9	189	0	2	1	21	177	0	100	99.57	97.10	99.94
9 to <10	165	0	1	1	18	155	0	100	99.57	96.80	99.94
10 to <11	145	2	0	1	20	134.5	1.49	98.51	98.09	94.11	99.40
11 to <12	122	0	0	0	23	110.5	0	100	98.09	93.49	99.46
12 to <13	99	0	0	1	25	86	0	100	98.09	92.54	99.53
13 to <14	73	0	0	0	18	64	0	100	98.09	91.12	99.61
14 to <15	55	0	0	0	19	45.5	0	100	98.09	89.00	99.69
15 to <16	36	0	0	0	18	27	0	100	98.09	84.40	99.80
16 to <17	18	0	0	0	14	11	0	100	98.09	71.38	99.91
17 to <18	4	0	0	0	4	2	0	100	98.09	32.95	99.98
		3	18	9	203						

(5.8%), and poor in 3 (1.5%). This brings the satisfactory results (excellent or good) to a total of 92.7%. The mean d' Aubigne-Postel score improved from 7.9 points preoperatively to 16.9 points postoperatively ($P < .001$). The pain score improved to a mean 5.7 points from 2.7 preoperatively ($P < .001$), the range of motion score to 5.6 from 2.7 preoperatively ($P < 0.001$), and the walking ability score to 5.6 from 2.5 points preoperatively ($P < .001$) (Table 2). Eighteen patients (18 hips) (8.8%) experienced thigh pain during the first postoperative year, but this gradually subsided.

On radiological evaluation, subsidence of the stem of 2 mm or more was recorded in 4 cases (2%), but no cases of distal migration of 5 mm or more, or tilting into varus or valgus of 2° or more were noted. Some degree of absorption of the calcar femoris was seen in 15 cases (7.3%) and an endosteal plug in 6 (2.9%), whereas radiolucent

Table 4. Life Table II (Worst-case Scenario: Revisions + All Cases Lost Considered Failures)

Years Since Operation	Number at Start	Failures (Revised + Lost)	Dead	Censored	Number at Risk	Annual Failure Rate (%)	Annual Success Rate (%)	Cumulative Survival Rate (%)	95% CI	
0 to <1	233	0	0	0	233	0	100	100	98.38	100.00
1 to <2	233	1	0	0	232	0.43	99.57	99.57	97.60	99.92
2 to <3	232	0	0	0	232	0	100	99.57	97.60	99.92
3 to <4	232	4	0	0	228	1.72	98.28	97.85	95.03	99.09
4 to <5	228	4	0	0	228	1.75	98.25	96.14	92.78	97.97
5 to <6	224	2	1	0	223.5	0.89	99.11	95.28	91.65	97.38
6 to <7	221	2	4	0	219	0.91	99.09	94.41	90.53	96.76
7 to <8	215	3	0	23	203.5	1.47	98.53	93.02	88.66	95.78
8 to <9	189	2	1	21	178	1.12	98.88	91.97	87.04	95.13
9 to <10	165	1	1	18	155.5	0.64	99.36	91.38	85.91	94.85
10 to <11	145	2	1	20	134.5	1.49	98.51	90.02	83.79	94.03
11 to <12	122	0	0	23	110.5	0	100	90.02	83.02	94.33
12 to <13	99	0	1	25	86	0	100	90.02	81.88	94.74
13 to <14	73	0	0	18	64	0	100	90.02	80.27	95.24
14 to <15	55	0	0	19	45.5	0	100	90.02	77.98	95.83
15 to <16	36	0	0	18	27	0	100	90.02	73.34	96.73
16 to <17	18	0	0	14	11	0	100	90.02	61.23	98.10
17 to <18	4	0	0	4	2	0	100	90.02	27.88	99.53
		21	9	203						

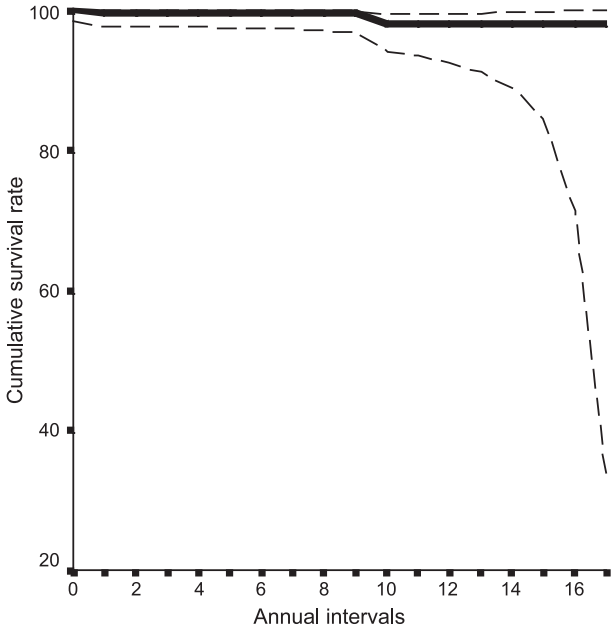

Fig. 1. Survival curve using stem revision for any reason as the end point, with 95% CIs (best-case scenario).

lines 1 mm or more around the prosthesis were noted in 20 cases (9.8%). They never expanded though through more than 2 consecutive Gruen zones, and careful monitoring of those patients has not revealed any progression of the radiolucent lines over time. Hypertrophy of the diaphysis,

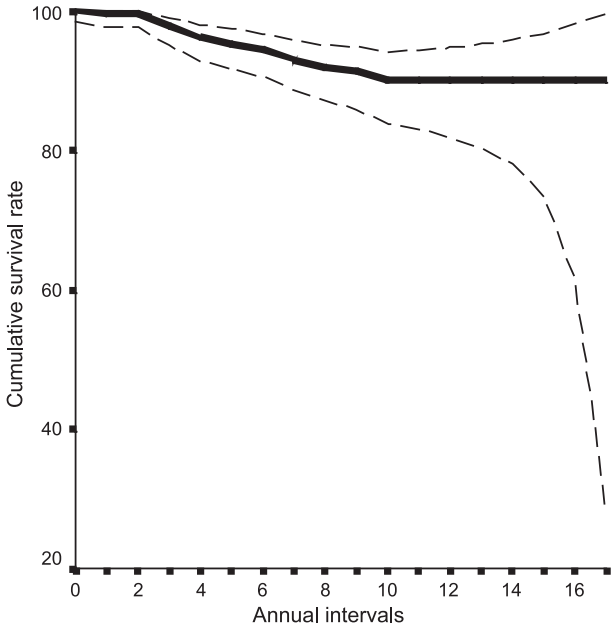

Fig. 2. Survival curve using stem revision and loss to follow-up as the end point, with 95% CIs (worst-case scenario).

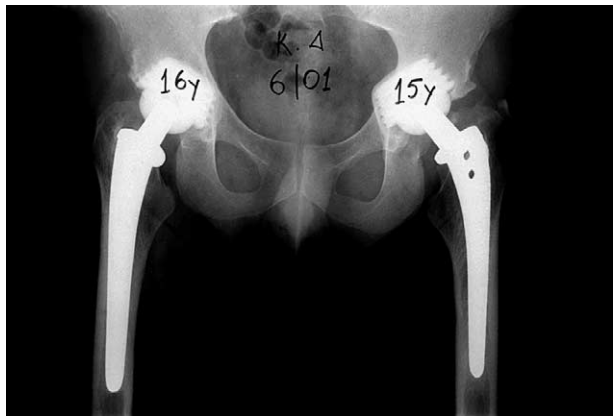

Fig. 3. Bilateral THA with Autophor 900-S prosthesis 16 and 15 years postoperatively.

without any accompanying signs of stress shielding, was recorded in 35 patients (17.1%).

The best-case and worst-case scenario life tables and the corresponding survival curves are shown in Tables 3 and 4 and Figs. 1 and 2, respectively. The cumulative probability of stem survival was 98.09% (95% CI, 39.95%-99.98%) at 17 years in the best-case scenario and 90.02% (95% CI, 27.88%-99.53%) in the worst-case scenario. The greatest majority of patients returned to a high level of daily activities (Fig. 3).

Among the early complications recorded were 6 cases of deep vein thrombosis, 2 superficial wound infections that subsided with antibiotics, and 5 cases of intraoperative fracture of the greater trochanter that were successfully managed with wiring. No dislocations, mechanical fracture of the implant, clinically significant cases of heterotopic ossification, or periprosthetic fractures were recorded. Only 3 out of the 205 stems required revision; 1 for septic loosening 1 year post implantation and 2 for aseptic loosening, both 10 years after the initial operation. Five ceramic and 7 titanium threaded acetabular cups were revised; it should be noted that in all 3 cases where stem revision was required this was combined with acetabular cup revision.

Discussion

The use of femoral implants without cement for primary fixation has been considered a solution to cement disease, especially in arthroplasties performed in young and active patients [2,15-18]. Initially, extensive or even full porous coating of femoral stems was introduced in an effort to

achieve adequate bone ingrowth and lasting implant fixation. Extensive porous coating is thought to allow for micromechanical fixation of the implant over most of its length, potentially leading to fixation stability similar to that offered by cemented stems [6]. Full porous coating though has been implicated with stress shielding resulting to pronounced proximal bone resorption and subsequent failure [19]. This has led to the development of proximally porous coated femoral stems to achieve a more physiological load transfer to the femur [2,20,21]. Proximal fitting designs in turn have been linked with thigh pain, an increased incidence of fractures during insertion, or undersizing that leads to subsidence or early aseptic loosening [2]. A series of changes in various extensively porous coated designs allowed for improved proximal as well as distal canal filling, leading to a smoother load transfer.

Prof H Mittelmeier and his team introduced the Autophor 900-S femoral stem in an effort to address the problem of inadequate osseo-integration and rotational instability. This stem has a fully porous coated surface with pores sized approximately 150 to 200 μm, which is well within the 50- to 400-μm range, which is considered optimal for satisfactory and lasting bone ingrowth [22].

With the exception of the 3 prosthesis that had to be revised because of either aseptic or septic loosening, we had no other cases with reliable signs of either clinical or radiological loosening, such as complete or progressing radiolucent lines wider than 2 mm, progressive subsidence, migration, or tilt of the component [23]. In our series, 20 cases (9.8%) with radiolucent lines wider than 1 mm have been recorded and closely monitored. No signs of significant radiolucent line progression or clinical loosening have been noted though. Subsidence of 2 mm or more was seen in 4 cases but this was in no case either progressing or bigger than the cutoff point of 5 mm. Subsidence of the stem of 1 to 4 mm in the early postoperative period may allow the stem to attain a more stable position within the femoral canal. Bone ingrowth may still occur and therefore early subsidence is still compatible with durable implant fixation [24]. Subsidence seen several months or years after surgery though implies that the implant fixation is unstable. The designer of the prosthesis reports a rate of aseptic loosening of 1% in 1000 cases followed for 1 to 8 years [25].

Stress shielding does not seem to be so significant a problem with the Autophor-900-S stem design as with other extensively porous coated stems. The exact design and shape of the prosthesis, together with the fact that the 4 corners of the quadrangular stem coming in contact with the femoral cortex are rounded as well as omitted from coating, is thought to allow for smooth transfer of the loads, thus eliminating the stress shielding effect [9,25,26]. Mittelmeier and Heisel [25] report stress shielding atrophy of the proximal femoral cortex to have been of no clinical importance in more than 1000 cases. Distal cortical hypertrophy appeared in 35 (17.1%) of our cases, but was not accompanied with significant ipsilateral proximal bone loss and bore no clinical implications. Some degree of absorption of the calcar femoris was recorded in 15 (7.8%) cases, mainly associated with the use of 16-mm or bigger stems. Significant increase in the stiffness of larger stems is thought to result in proximal cortical remodeling [19].

A well-documented early complication of cementless THAs is thigh pain, with a reported incidence of as high as 36% [5,20,27-29]. Thigh pain is associated with both proximal and distal filling porous coated cementless designs inserted with a press-fit technique and is usually a start-up pain that lasts for about a year [30]. It is thought to be due to either micromovements of the stem or microfractures during stem insertion [27]. However, if this type of pain lasts longer, then the clinical suspicion of aseptic loosening should be raised [5,6].

Thigh pain has not been a significant problem in our series. It appeared in 8.8% of cases and gradually subsided within the first year. This could be attributed to the shape and design of the prosthesis, which incorporates 4 rounded corners omitted from porous coating, thus allowing for smoother load transfer. This finding corroborates the results of Mittelmeier and Heisel [25], who reported a rate of remarkable thigh pain of 3% in their series.

The Mittelmeier Mark I and Mark II smooth press-fit stems and the Mittelmeier cementless threaded ceramic cups have been associated with an increased degree of loosening [31,32]. Unlike them, the Autophor 900-S stem, which has been designed to combine the well-known advantages of low-friction ceramic articular surfaces [33] with those of stable cementless fixation based on porous coating [4,6,7], has given very promising early and midterm results [23-25,34]. To our knowledge though, no long-term results of this uncemented implant are yet available.

Long-term results are available for only a limited number of uncemented prostheses. We followed 205 hips for a mean time of 13.5 years (range, 7-17 years). Our results in a young and high-demand

population have been clinically satisfactory in 92.3% of cases and the cumulative probability for stem survival amounted to 98.1% in 17 years (worst-case scenario: stem survival, 90%). Those are very encouraging and compare favorably to the long-term results achieved by other cementless or cemented designs [1,5,17,20,29,35-37].

In conclusion, the Autophor 900-S femoral stem appears to offer a very satisfactory clinical outcome combined with considerable prosthesis longevity for young patients with good bone quality having a cementless hip arthroplasty. Stem design offers a combination of adequate initial stability, satisfactory subsequent bone ingrowth, smooth load transfer, and low-friction bearing surfaces that seem to contribute to a very satisfactory outcome. Survivorship of the prosthesis though, apart from the abovementioned factors, depends also on adequate host-bone quality, careful preoperative planning, and meticulous implantation technique.

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