Two- to 12-Year Evaluation of Cementless Buechel-Pappas Total Hip Arthroplasty

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Abstract: A unique, straight-stemmed, proximally porous-coated, modular hip arthroplasty system, coated with thin-film (5- to 9-μm), titanium-nitride ceramic, was used clinically in 130 hip arthroplasties in 117 patients who were followed over a 2- to 12-year interval (mean, 6.45 years). Harris Hip Scores demonstrated 82.3% excellent, 15.4% good, 2.3% fair, and 0% poor results. Thigh pain that limited activities of daily living was seen in 0.8% (1 of 130) hips. Kaplan-Meier survival estimates using an endpoint of revision of any component for any reason demonstrated an overall survival of 95.5% during the 12-year interval. Cementless fixation survivorship of the acetabular and femoral components was 98.5% during the 12-year interval. **Key words:** Buechel-Pappas-porous-coated, total hip arthroplasty, cementless, titanium-nitride ceramic.

Cementless total hip arthroplasty (THA) researchers, while recognizing the long-term benefits of fixation and function [1], have identified proximal femoral stress shielding as a growing concern for extensively porous-coated prostheses [2,3]. Attempts to reduce proximal stress shielding by limiting the amount of bone ingrowth to the proximal region of the femoral component have met with reasonable success; however, specific design configurations both with and without calcar-loading collars still produce some degree of thigh pain [4–13]. Additionally, osteolysis, femoral component subsidence, and lack of proximal fixation have lessened the appeal for this approach [14–16].

Optimized femoral stem and proximal porous-coating geometries to reduce stress shielding and minimize thigh pain have recently become available [5,17].

Similarly, cementless, hemispherical acetabular components with stable polyethylene bearing liners have been evaluated [18] and used clinically, with good mid-term success after 5 to 10 years [5,19]. Thin-film ceramic surface coatings have also been recently developed and mechanically tested for surface integrity and wear resistance [20–22]. These surfaces, when properly treated, offer significant improvements in wear resistance when used for articulation with ultrahigh-molecular-weight polyethylene (UHMWP) [23]. When used to cover an entire porous-coated prosthesis, the coating greatly reduces the surface exposure of the prosthesis, thus avoiding increased metal ion release without preventing bone ingrowth. In addition, thin-film ceramic coating on a relatively soft substrate like

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Table 1. Patient Demographics

	130 hips in 117 patients	
Diagnosis		
Osteoarthritis	103	
Posttraumatic arthritis	6	
Rheumatoid arthritis	10	
Avascular necrosis	11	
Sex		
Male	52	
Female	78	
	Range	Average
Height (in)	58–76	65.7
Weight (lb)	90–300	180.2
Age at surgery (y)	30.5–90.2	66.3

titanium ($TiAl_6V_4$) alloy hardens the surface against scratching from bone or third-body abrasive particles, thus extending the use of titanium alloys for orthopedic implant fixation without the risks of surface abrasion and metallosis [24].

This study evaluates the use of a totally cementless modular THA, which uses a straight-stemmed femoral component with optimized proximal porous coating and a 30° calcar-loading flange mated to an anatomically shaped, hemispherical acetabular cup.

Clinical, radiographic, and implant survivorship will be compared to standard long-term cemented and cementless hip arthroplasty results to establish the impact of this new technology.

Materials and Methods

From April 30, 1990 to March 31, 1999, there were 141 consecutive hip arthroplasties implanted in 127 patients. Eleven hips in 10 patients were excluded from analysis, because 2 were lost to follow-up immediately postoperatively and the remaining 8 patients expired before the 2-year examination. Of the 130 hips in 117 patients available for examination with a minimum 2-year follow up, 20 hips in 10 patients died at an average of 6.3 years after surgery (range, 2.2–10.8 years), all with well-functioning implants, and 1 was lost to follow-up at 4.6 years after surgery. The patient demographics and diagnoses of patients who survived for a minimum of 2 years are noted in Table 1. All implants used in this study were cementless devices (Buechel-Pappas Integrated Total Hip Replacement System, Endotec, Inc., South Orange, NJ) [24]. The titanium alloy ($TiAl_6V_4$) acetabular cup was hemispherical with inferior extensions and an anatomic inferior cutout (Fig. 1). Cups were available with none, 3, or 5 spherically seated holes for screw fixation, passed through the metallic shell that was porous-coated on its outer surface with sintered commercial pure titanium beads to give an average pore size of 350 μm and a volume porosity of 30% (Biocoat, Endotec, Inc.). $TiAl_6V_4$ 6.5-mm cancellous bone screws (Endotec, Inc.) were used in varying sizes to stabilize the acetabular cup in 17 hips. In the remaining 114 hips, the acetabular cup was press-fit without screws using a 1-mm interference fit for hard bone, such as in osteoarthritis, and a 2-mm interference fit for soft bone, such as in rheumatoid arthritis. A flexible-lipped UHMWP bearing liner was snapped into recessed grooves in the metal shell to complete the assembly. The original design (Mark I) bearing contained several of these flexible lips. A design change was made in 1994 to increase the number of these lips to the full circumference of the bearing (Mark II) to provide more fixation to the metal shell. Acetabular defects were curetted and bone-grafted with autologous femoral head as needed.

The titanium-alloy femoral component was of a straight-stemmed, proportionally sized configuration with an optimized proximal porous coating under the 30° angled collar, on the anterior and posterior surfaces as well as the lateral surface of the component (Fig. 2). The femoral head was made of titanium alloy coated with a polished 6- to 10-μm-thick layer of titanium-nitride ceramic (TiN) (UltraCoat, Endotec, Inc.) applied by means of a proprietary, physical vapor deposition process. The entire femoral stem and porous-coated regions were also coated with UltraCoat, TiN.

Pre- and postoperative clinical evaluations were performed on all patients using the Harris Hip Rat-

Fig. 1. The Buechel-Pappas Acetabular Component with the anatomic design and inferior cutout.

Fig. 2. The Buechel-Pappas Femoral Component with selective proximal porous coating.

ing Scale [25]. Radiographic analyses were performed using the technique of DeLee and Charnley [26] for assessing acetabular radiolucency and the method of Dorr et al [27] for measuring cup migration. The femoral component was evaluated for radiolucencies by the method of Gruen et al [28] and for stress shielding of the calcar by the method of Hamlin et al [5].

Mechanical complications, clinical complications, and mechanisms of failure were recorded and analyzed.

Kaplan-Meier survival analysis [29] was performed using endpoints of revision of any component for any reason, a clinically poor hip score, or radiographic evidence of failure (radiolucency >2 mm in all zones surrounding an implant) or gross implant migration.

The details of this surgical technique performed through a posterior approach were previously reported [30]. Patients were allowed immediate weight-bearing to tolerance on the first postoperative day and progressed with walking aids until independent without them. Anticoagulation, using Warfarin, was performed according to the UCLA protocol [31]. Indocin 25 mg was given 3 times a day for 10 days to inhibit heterotopic bone formation [32]. B-mode ultrasonography was performed on the third to fifth postoperative days to evaluate for proximal and distal venous thrombosis. Suction drains were routinely used for 48 hours until June 1993, when drains for primary hip arthroplasty were discontinued by the senior author.

Results

Preoperative Harris Hip Scores (HHS) averaged 46 (range, 22–60); postoperative HHS averaged 93 (range, 64–100). In patients with longer than 2-year follow-up (average, 6.43 years; range, 2.25–11.2 years) (130 hips in 117 patients), there were 107 (81.7%) excellent, 20 (16%) good, 3 (2.3%) fair, and 0 (0%) poor results noted.

Temporary thigh pain graded as mild and not interfering with activities of daily living was seen in 6 of 130 hips (4.6%), and moderate thigh pain was seen in 1 of 130 hips (0.8%). Mild thigh pain resolved at an average of 2.1 years; moderate thigh pain associated with a traumatic trochanteric fracture resolved after 3.2 years.

Radiographic Analysis

Acetabular Cup. Radiolucencies around the acetabular cup decreased over time, with no cup migrations noted (Table 2). One component was revised elsewhere for possible loosening.

Femoral Stem. Radiolucencies <2 mm were seen around the femoral stem tip in zones 4 on the

Table 2. Acetabular Component Lucencies

Zone	1-y Interval (n = 130)	2-y Interval (n = 99)	3-y Interval (n = 77)	4-y Interval (n = 59)	5-y Interval (n = 47)	6-y Interval (n = 33)	7-y Interval (n = 23)	8-y Interval (n = 17)	9-y Interval (n = 9)	10-y Interval (n = 4)
1	0.022	0.015	0.032	0.017	0.060	0.088	0.135	0.018	0.089	0.275
2	0.023	0.015	0.006	0.075	0.023	0.070	0.065	0.018	0.000	0.050
3	0.023	0.041	0.149	0.122	0.091	0.055	0.043	0.147	0.278	0.000

Average lucencies in millimeters.

Table 3. Femoral Component Lucencies

Zone	1-y Interval (n = 130)	2-y Interval (n = 99)	3-y Interval (n = 77)	4-y Interval (n = 59)	5-y Interval (n = 47)	6-y Interval (n = 33)	7-y Interval (n = 23)	8-y Interval (n = 17)	9-y Interval (n = 9)	10-y Interval (n = 4)
1	0.010	0.069	0.058	0.161	0.096	0.048	0.122	0.000	0.000	0.000
2	0.003	0.010	0.021	0.102	0.021	0.039	0.022	0.018	0.033	0.000
3	0.015	0.048	0.142	0.168	0.079	0.206	0.317	0.224	0.222	0.125
4	0.066	0.342	0.408	0.366	0.402	0.642	0.570	0.482	0.611	0.750
5	0.052	0.124	0.129	0.231	0.123	0.182	0.174	0.176	0.256	0.200
6	0.007	0.010	0.045	0.183	0.085	0.070	0.043	0.088	0.167	0.000
7	0.010	0.010	0.003	0.090	0.021	0.021	0.043	0.000	0.000	0.000

Average lucencies in millimeters.

anteroposterior (AP) and lateral views at the 2-year interval in 75% of cases but did not correlate with thigh pain. Zones 3 and 5 on AP views demonstrated radiolucencies of ≤1 mm in approximately 50% of cases (Table 3). The incidences of zonal radiolucencies ≥1 mm expressed as a percentage from 1 to 10 years' postoperatively are shown in Fig. 3.

Calcar atrophy [5] was minor, being rated as grade 1 (rounding of the calcar medially) in 10% of cases reviewed (90 hips). It was noted to be grade 2 (50% cortical atrophy of the calcar medially under the collar) in 5.6% of cases and grade 3b (100% cortical atrophy medially under the collar with <5 mm of femoral neck atrophy) in 1.1% of cases. No cases of grade 4 (100% cortical atrophy under the collar with femoral neck atrophy of 510 mm) or grade 5 (100% cortical atrophy under the collar with femoral neck atrophy of >10 mm) were seen.

Mechanical Failures and Management

Two Mark I bearing liners dissociated from the acetabular shell after 4.8 and 6.8 years, respectively, in an active 53-year-old osteoarthritic male and in an active 77-year-old osteoarthritic female. Both were replaced with Mark II bearing liners, and both patients resumed normal activities without revising the well-fixed acetabular component. No Mark II bearing liners failed by either dissociation or wear.

Major or Minor Complications

Complications experienced during this study are listed in Table 4.

Postoperative dislocation was observed in 4 patients at 2 to 6 months postoperatively (mean, 3.8 months). One dislocation was traumatic secondary to a fall. The other 3 dislocations occurred by excessive hyperflexion and internal rotation. All dislocations were successfully managed by closed reduction and brace immobilization for 6 weeks. The mean HHS for this group was 98 points (range, 92–100 points) at the latest follow-up.

Peroneal nerve palsy was encountered in the immediate postoperative period in 5 patients. In 3 patients, full recovery was achieved after a mean of 1.4 years (range, 1–2 years). One patient had a partial recovery after 2 years but underwent a posterior tibial tendon transfer to improve her gait. One patient developed a permanent foot drop. No intraoperative complications were noted in any of these patients, but all implants were inserted through a posterior approach. The mean HHS for this group was 85.8 points (range, 65–96 points).

Survivorship Analysis

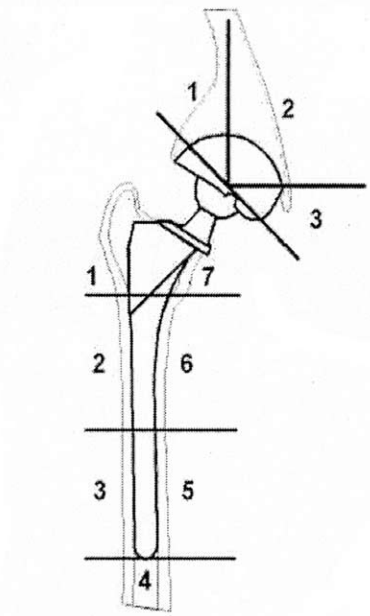
Kaplan-Meier [29] survivorship analysis was performed using several endpoints: 1) revision of any component for any reason; 2) radiographic loosening or clinical loosening of any component. These analyses are shown in Figs. 4 and 5, respectively.

Case Report

Osteoarthritis THA in a Highly Active Patient

A 67-year-old, five-feet-ten-inch (177.8-cm)-tall, 205-lb (93.2-kg), osteoarthritic man developed progressively disabling, weight-bearing pain in his right hip over a 10-year period. Preoperative AP and lateral radiographs (Fig. 6) demonstrated severe degenerative joint disease with complete loss of the articular joint space. He underwent an uneventful, cementless right THA in July 1992. Within 4 months, his HHS was 100 points, and he returned to playing regular platform and doubles tennis without incident. After 9 years, his HHS remained at 100 points. He continues to be an active sports-

Incidence (%) of radiolunciencies ≥ 1 mm from 1 to 10 Year follow-up



Acetabulum Radioluncencies

Zone	1 Year (%) n=130	5 Year (%) n=47	10 Year (%) n=4
1	1.5	2.1	0
2	2.3	0	0
3	1.5	4.3	0

Femoral Stem Radioluncencies

Zone	1 Year (%) n=130	5 Year (%) n=47	10 Year (%) n=4
1	0.8	4.3	0
2	0	2.1	0
3	0.8	5.1	0
4	4.6	27.7	50
5	3.1	4.3	0
6	0.8	2.1	0
7	0.8	2.1	0

Fig. 3. Incidences of zonal radioluncencies ≥1 mm expressed as a percentage from 1 to 10 years postoperatively.

man and deep-sea fisherman. Postoperative AP and lateral radiographs demonstrated excellent bone-prosthesis interfaces around all components, excellent calcar retention, no wear, and no osteolysis after 9 years (Figs. 7 and 8 show 1- and 9-year radiographs).

Discussion

Long-term fixation and function, together with excellent wear resistance, are the prerequisites for successful THA. Survivorship analysis, radiographic analysis, and clinical results are important outcome parameters by which orthopedic surgeons can measure the success or failure of one hip arthroplasty system over another when used in similar patient populations. Primary hip arthroplasty represents the best clinical condition to evaluate a new or improved prosthesis, because the variables of major bone-stock deficiencies associated with revision conditions are minimized or eliminated by study design. In this study, there were 130 primary THAs in 117 patients with minimum 2-year follow-up.

The femoral components used in this study were developed in response to the potential stress-shielding problem posed by the extensively coated AML device developed by Lunceford in the late 1970s [33].

Table 4. Complications Occurring in 130 Buechel-Pappas Primary Hips in 117 Patients

Complication	No.	Percent
Peroneal palsy		
Permanent	1	0.8
Partial recovery	1	0.8
Complete recovery	3	2.3
Wound dehiscence, drainage	2	1.5
Trochanteric bursitis, chronic	1	0.8
Thigh pain		
Mild	6	4.6
Moderate	1	0.8
Abductor pain	1	0.8
Dislocation, all causes	4	3.1
Femoral stem loosening	0	0.0
Trochanteric fracture, traumatic	1	0.8
Sciatica	4	3.1
Acetabular cup loosening	1	0.8
Acetabular bearing dissociation	2	1.5
Femoral stem subsidence	1	0.8
Thrombophlebitis	1	0.8
Deep venous thrombosis	2	1.5
Heel decubitis ulcer	0	0.0
Hematoma, requiring evacuation	1	0.8
Lesser trochanter fracture, traumatic	1	0.8
Pes bursitis	1	0.8
Pulmonary embolism, nonfatal	2	1.5
Deep infection	0	0.0

The femoral components were clinically developed to improve proximal femoral loading strain by means of a 30° angled loading collar and removing porous coating from the proximal medial region [5]. It has been shown by retrieval analysis that proximal medial bone ingrowth into a porous surface causes stress shielding even though the coating has been removed from the distal end of the stem [34]. This finding suggests that removal of the medial proximal porous coating and retention of anterior, posterior, and lateral porous coating represents an ideal ingrowth configuration for maintaining stability while minimizing stress shielding [34]. Finite-element analysis of this improved stem and coating geometry concurs with clinical observations [35]. Clinically, the worst case of calcar resorption in this study was seen in 1.1% of cases with grade 3b resorption [5]. This type of resorption correlates to second-degree resorption (rounding off of the proximal medial neck combined with loss of medial cortical density) described by Engh and Bobyn [2].

Hemispherical, porous-coated acetabular cups have demonstrated excellent mid-term and long-term stability [5,19]. Their use in THA may represent a fixation improvement over cemented components [36]. However, premature wear, bearing dissociation, and osteolysis have been reported with some of these devices [37–39], which casts some doubt as to whether these new devices are really improvements over the cemented Charnley acetabular cup, which has documented superior survivorship [40]. Recent analysis of the acetabular-cup geometries of currently available cementless devices has revealed that the optimal polyethylene liner geometry that maintains spherically congruent articulation with the metallic acetabular shell has not been universally adopted [18]. The acetabular cup used in this study uses the spherically congruent, articulating-connection principles for the assembled cup and bearing liner [5]. This articulation has demonstrated superior stability and satisfactory wear resistance when articulated with polished titanium-nitride-ceramic femoral components in reciprocal, high-cycle simulation [21]. The current study provides clinical evidence to support the stability and durability of this cementless hemispherical acetabular component *in vivo*. One metallic acetabular cup was removed for reported loosening, and 2 Mark I (incomplete flexible lips) bearing liners were replaced (1.5%) after traumatic dissociation from the metallic cup. No Mark II bearing liners (complete flexible lips) were seen to dissociate from the metal cups.

The one acetabular cup that was revised elsewhere because of reported loosening of the acetabular component occurred 5.3 years after surgery. To date, the authors have not been able to review the radiographs or obtain specific reasons for the revision, with the caveat that the femoral stem was solidly fixed and retained.

The radiographic findings in the current study document the qualitative improvement in proximal bone density and lack of calcar atrophy with selective proximal porous coating over extensively coated devices. Engh et al [2] reported results showing that the amount of bone resorption was clearly related to the extent of the porous coating. One-third–coated stems had an incidence of 12.1% second- or third-degree bone resorption, two-thirds–coated stems had 33%, and fully coated stems resulted in 54.3%. No cases in the current study were severe enough to be in the Engh Type II calcar stress-shielding category, which is a marked improvement over the AML prosthesis, which demonstrated 36 of 381 hips (9%) with Engh type II stress shielding [7]. These findings concur with a similar study in which the optimal femoral component was made of $TiAl_6V_4$ alloy [5] and used a similar proximal porous-coating geometry. Further quantification of the actual bone density using the DEXA bone densitometry examination scanning

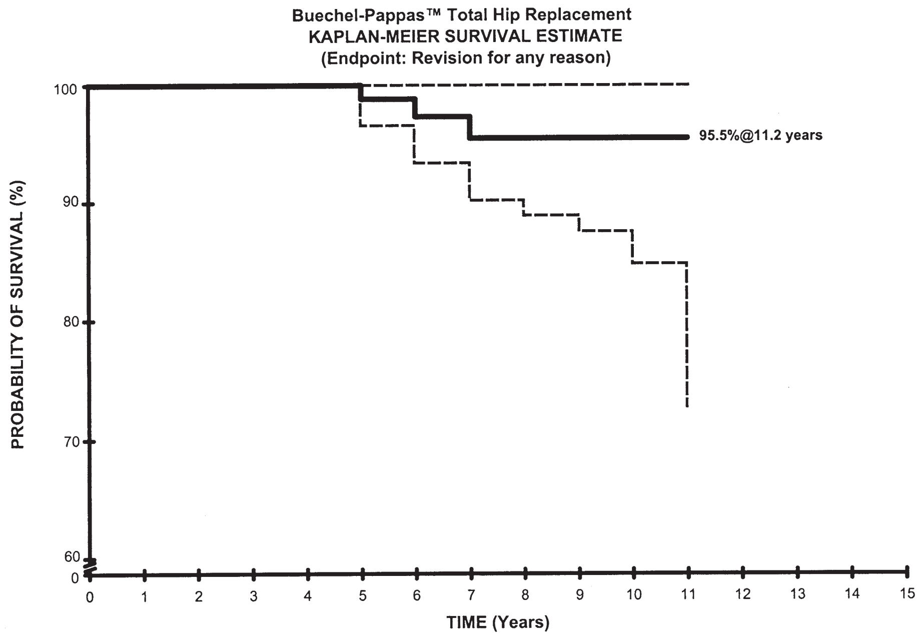


Fig. 4. Kaplan-Myer survivorship of Buechel-Pappas Total Hip Replacements with an endpoint of revision for any reason.

would be most helpful and should be considered as a future research direction.

Osteolysis around acetabular or femoral components was not seen. Radiolucent zones were nonprogressive and <2 mm in Gruen zones 1 through 14. Femoral stem subsidence was encountered in 1 patient (0.8%) but was asymptomatic. No acetabular cup migration was encountered, although 1 (0.8%) acetabular component was revised elsewhere for reported loosening.

The clinical results of this study compare favorably to the long-term results of the cemented [40–44] and extensively coated cementless hip arthroplasties [45–51]. They are superior to the reported results of other cementless, proximally porous ingrowth devices [52–56]. Temporary thigh pain was noted in 7 patients overall. In 6 patients (4.6%), thigh pain was mild and did not interfere with activities of daily living. This pain resolved at an average of 2.1 years (range, 2–6 years) after sur-

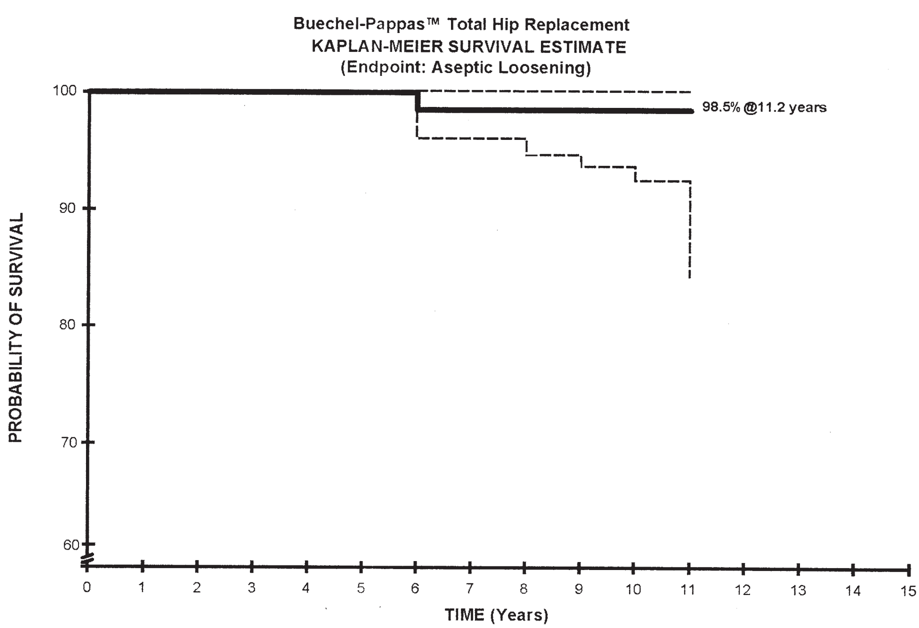


Fig. 5. Kaplan-Myer survivorship of Buechel-Pappas Total Hip Replacements with an endpoint of aseptic loosening of any component.

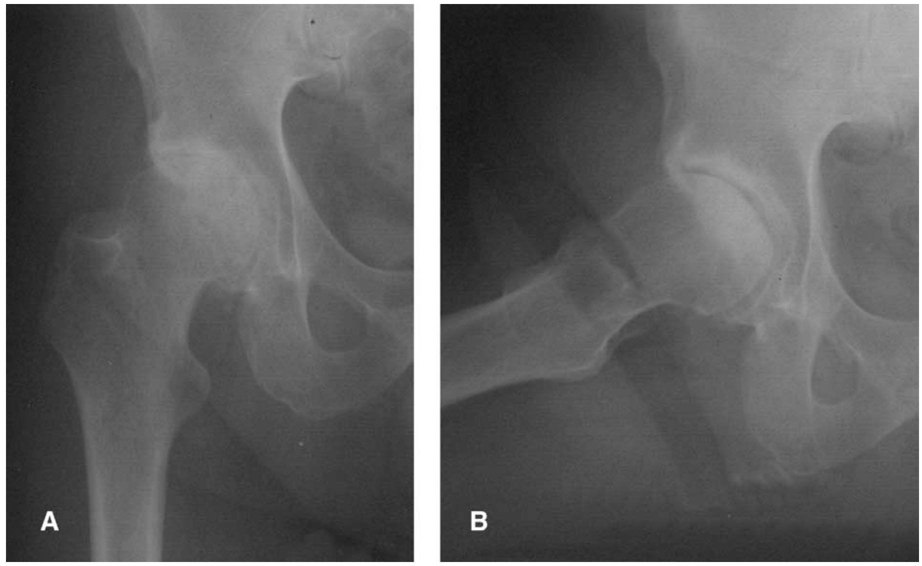


Fig. 6. Preoperative (A) AP and (B) lateral radiographs of an active 67-year-old man demonstrating severe osteoarthritis of the right hip.

gery. In 1 patient (0.8%) thigh pain was moderate and associated with chronic trochanteric bursitis following a fracture of the greater trochanter. This patient's pain resolved after 3.2 years. This was a significant improvement over other cementless devices [56,57].

Kaplan-Meier survivorship analysis using an endpoint of revision of any component for any reason was 95.5% at 11.2 years, which compares favorably with the cemented Charnley (90.1% at 9 years) and the cementless AML prostheses (90.8% at 10 years) [50] at similar time intervals. Fixation survivorship of 100% of the femoral stem and 98.5% of the acetabular cup at the 12-year interval also compares favorably to the AML stem (97%) and cup (92%) at 12 years [50]. The current prosthesis also improves on the survivorship of the Mallory Head [56] (94% at 8 years), the Muller Stem [43] (94% at 10 years), the Harris-Galante [48] (acetabular survivorship of 79.7% at 13 years and femoral stem survivorship of 76.3% at 13 years), and the PCA stem [55] (44% at 9 years).

Early clinical and survivorship results that document equivalence or superiority to standard devices

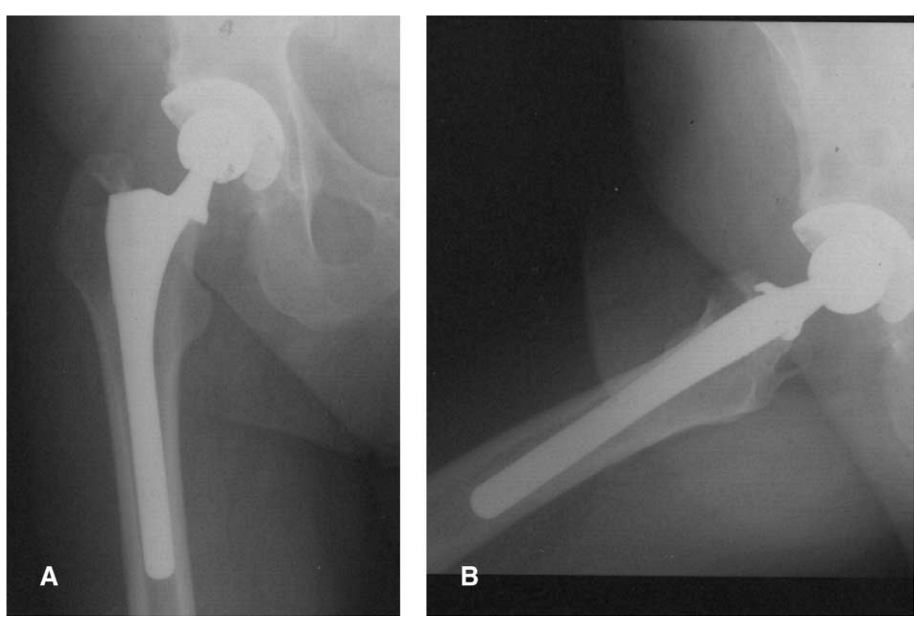


Fig. 7. Postoperative (A) AP and (B) lateral radiographs of the same patient at 1 year postoperatively demonstrating good alignment; ingrowth fixation; and a stable, well-loaded calcar without resorption.

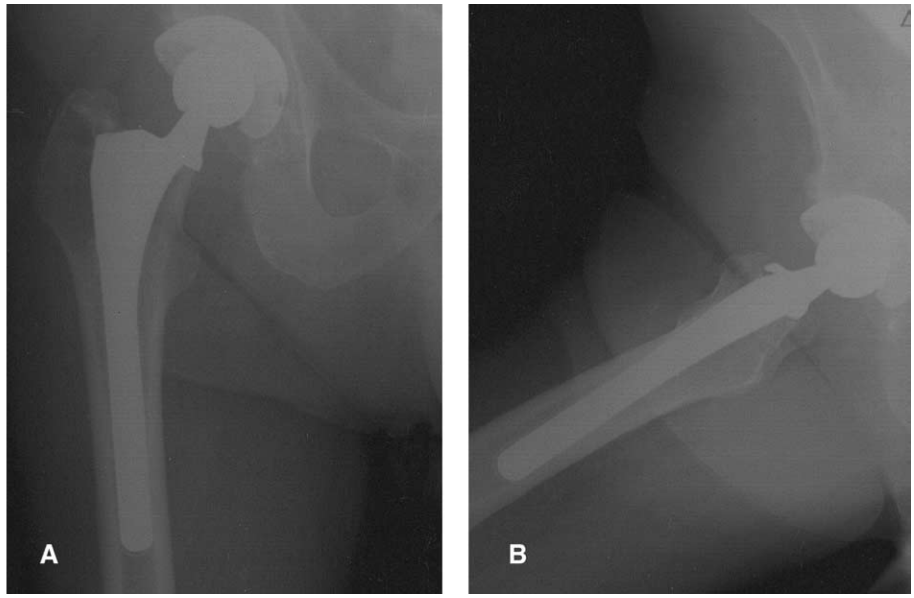


Fig. 8. Postoperative (A) AP and (B) lateral radiographs of the same patient at 9 years' postoperatively demonstrating no change from the 1-year radiograph.

while providing an improved feature, such as calcar retention, have been proposed as a method for improving joint arthroplasty technology without sacrificing safety and efficacy [58]. The current study follows these guidelines for improving the state-of-the-art. Based on current radiographic and clinical and survivorship data, this proximally porous-coated hip arthroplasty offers some design improvements over other standard devices, and its continued use is recommended.

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