Tapered cementless femoral components have been used in total hip arthroplasty constructs for more than 20 years. In the past 5 to 10 years, these stems have gained popularity in the United States. The purpose of this study was to evaluate the results of the authors’ initial experience using a contemporary tapered, proximally porous-coated, titanium femoral component at 4 to 6 years of follow-up. Eighty-eight patients underwent 100 total hip arthroplasties using the Summit stem (DePuy, Warsaw, Indiana) and a cementless acetabular component. Average age at the time of surgery was 61.6 years. Patients were prospectively followed for 4 to 6 years or until death. Patients were evaluated clinically using Harris Hip Scores and the need for revision. Radiographs were evaluated for femoral loosening and osteolysis. At final follow-up, no hips had been revised for femoral or acetabular loosening. Two hips required revision for dislocation and 1 for early femoral fracture. Bony ingrowth was seen in all but 2 femoral components. There was 1 instance of proximal femoral osteolysis and none distally on radiographs (cross-linked polyethylene was used in 73% of cases). There were 2 cases of severe stress shielding. One percent of cases had an early fracture (too tight) and 1% subsided without ingrowth (too loose). One patient reported significant thigh pain that did not limit activity. At final follow-up, the Summit femoral component demonstrated durable results at 4 to 6 years. Stability of the implant without femoral fracture is paramount.
Cementless stems have been successfully used in total hip arthroplasty (THA) for more than 20 years.\textsuperscript{1-3} In particular, tapered stem designs have shown excellent durability at 15- to 20-year follow-up.\textsuperscript{3,6} Tapered stems also have the purported advantage, over other cementless stem designs, of causing less thigh pain and less proximal femoral remodeling.\textsuperscript{7,8} During the 15 to 20 years cementless tapered stems have been in use, there have been numerous design iterations as well as a shift in surgical indications toward the inclusion of older, more sedentary adults. However, it has only been in the past 5 to 10 years that these stems have gained popularity in the United States.

The purpose of this study was to evaluate the results of the authors’ initial experience in cementless THA using a contemporary double-tapered, proximally porous-coated femoral implant at 4- to 6-year follow-up. Because this was a newer double-tapered stem and broach design, the authors aimed to verify durability similar to or better than previous designs.

\textbf{MATERIALS AND METHODS}

The authors prospectively followed and retrospectively reviewed the first 88 patients (100 hips) who had the Summit Porocoat femoral component (DePuy, Warsaw, Indiana) implanted between April 2002 and October 2003. The Summit Porocoat is a double-tapered, proximally porous-coated titanium stem (porous-coated over the proximal third and chromium blasted distally) with a 28-, 32-, or 36-mm modular Articul/eze femoral head. The femoral component was mated with the Pinnacle Sector 2 acetabular component (DePuy) in all hips. For all cases, the acetabulum was reamed to 1 mm less than the diameter of the component used. Two or three 5.1-mm titanium alloy dome screws were used to augment fixation. The liners used were moderately cross-linked polyethylene (Marathon; DePuy) in 60 hips, gamma vacuum foil (GVF) polyethylene in 13 hips, and cobalt-chromium-molybdenum (CoCrMo) metal liners in 27 hips (Ultamat; DePuy). For all cases, the canal was initially reamed and broaches were introduced to the appropriate size. Hence, it was a ream-and-broach preparation. At 4 to 6 years after index THA, 78 patients (89 hips) were living, 9 patients (10 hips) were deceased, and 1 patient (1 hip) was lost to follow-up (Table 1). After locating living patients, consent for study participation was obtained as per the protocol previously approved by the institutional review board. Average clinical follow-up was 5.1 years (range, 4.0-6.6 years) for living patients and 4.9 years (range, 0.4-6.6 years) for the entire cohort. Preoperative diagnosis was primary osteoarthritis (OA) in 88% of hips in the original cohort (Table 2).

All surgeries were performed by a single surgeon (D.D.G.). An anterolateral approach was used in all cases. Patients were partially weight bearing for 6 weeks and then progressed to full weight bearing as tolerated.

Final follow-up evaluation was conducted 4 to 6 years after index THA. Patients returned to the clinic for follow-up or, if they were unable to return, sent current radiographs for evaluation. Early postoperative and interval follow-up radiographs included anteroposterior projections of the pelvis that included the tip of the femoral prosthesis and lateral projections of the femur that included the hip. Follow-up clinical evaluation\textsuperscript{7} of the patients included Harris Hip Score (HHS)\textsuperscript{10} and the need for revision surgery.

Radiographic observations and measurements were based on the anteroposterior radiographs from the early postoperative period and those at final follow-up. Among the 78 living patients (89 hips), 73 (82%) hips had a minimum 4-year follow-up radiograph. Two authors not involved in the surgery reviewed all radiographs (A.R., J.J.C.), with interpretation reported by consensus. Correction for magnification was completed by standardizing all measurements against the known size of the femoral head.

Femoral component fixation was evaluated for bone ingrowth, stable fibrous fixation, or unstable fibrous fixation according to the criteria of Engh et al.\textsuperscript{11} Femoral component subsidence was determined using the relationship of the top of the lesser trochanter to the medial aspect of the stem collar, defined as a decrease of at least 5 mm between the initial postoperative radiograph and those from final follow-up.\textsuperscript{12} Osteolysis was defined as any nonlinear radiolucency at the

<table>
<thead>
<tr>
<th>Variable</th>
<th>Value</th>
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<tbody>
<tr>
<td>Total no. of patients (hips)</td>
<td>88 (100)</td>
</tr>
<tr>
<td>Average age at index surgery, y</td>
<td>61.6 (range, 25.4-90.2)</td>
</tr>
<tr>
<td>Sex, No. of patients (hips)</td>
<td>37 (40) Male, 51 (60) Female</td>
</tr>
<tr>
<td>Average body mass index, kg/m(^2)</td>
<td>30.1 (range, 17.7-59.9)</td>
</tr>
<tr>
<td>Dorr classification, No. of hips</td>
<td>A: 50, B: 39, C: 11</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Diagnosis</th>
<th>No. of Patients (Hips)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Osteoarthritis</td>
<td>79 (88)</td>
</tr>
<tr>
<td>Avascular necrosis</td>
<td>5 (8)</td>
</tr>
<tr>
<td>Rheumatoid arthritis</td>
<td>2 (2)</td>
</tr>
<tr>
<td>Protrusio</td>
<td>1 (1)</td>
</tr>
<tr>
<td>Nonunion/malunion</td>
<td>1 (1)</td>
</tr>
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\textbf{Table 1: Patient Demographics}

\textbf{Table 2: Preoperative Diagnoses}
bone-prosthesis interface that was at least 5 mm² according to the 7 femoral zones defined by Gruen et al. Radiolucenties were also recorded according to the 7 femoral zones of Gruen et al. Femoral component stress shielding was defined using a modification of the criteria defined by Engh and Bobyn. Mild stress shielding was limited to the upper third of the implant, moderate stress shielding extended to the middle third, and severe stress shielding extended below the middle third. Acetabular components were evaluated for bone-prosthesis radiolucencies and acetabular component migration according to the criteria of Massin et al. The definition of acetabular osteolysis was the same as that for femoral osteolysis.

Kaplan-Meier survivorship analysis was performed for the endpoints of revision for any reason and radiographic evidence of femoral component loosening. Radiographic evidence of loosening was defined as definite or probable loosening, including cases revised for femoral loosening or unstable fibrous fixation on radiograph for the femoral component. A $t$ test was used to analyze statistical difference between pre- and postoperative HHS. A $P$ value less than .05 was considered significant.

**RESULTS**

Mean duration of clinical follow-up was 5.1 years (range, 4.0-6.4 years) among living patients. At last follow-up, average HHS was 89.5 (range, 46-100), which was significantly higher than the average preoperative score of 33.2 ($P \leq .0001$). There were no significant differences between postoperative HHS for patients with metal-on-metal THA (average, 91.6) compared with nonmetal-on-metal THA (average, 88.3; $P = .31$). In addition, only 1 patient reported significant nonactivity-limiting thigh pain. This patient did not have a metal-on-metal THA.

Radiographic evaluation of the 73 hips in living patients with minimum 4-year radiographic follow-up (average, 5.1 years) demonstrated femoral bone ingrowth in 71 (97.3%) hips. For the 2 hips that did not have bone ingrowth, 1 hip demonstrated stable fibrous ingrowth radiographically at 6.3-year follow-up and the other was radiographically classified as unstable fibrous ingrowth at 6-year follow-up (Figure 1). The hip that demonstrated unstable fibrous ingrowth was considered radiographically loose on Kaplan-Meier survivorship analysis (subsided 5 mm in first 2 years but stabilized). Proximal radiolucencies (zones I and/or VII) occurred in 4% (3 hips), and distal tip radiolucencies (zone IV) occurred in 3% (2 hips). Proximal femoral osteolysis (less than 1×1 cm²) occurred in 1% (1 hip) (Figure 2), and no cases of distal femoral osteolysis occurred. Femoral stress shielding was mild in 58% (42 hips), moderate in 11% (8 hips), and severe in 3% (2 hips). Radiographic evaluation of the acetabular construct demonstrated 17 hips with bone-prostheses radiolucencies (2 in metal-on-metal hips and 15 in nonmetal-on-metal hips), none of which were completely circumferential to include the screws, and no components migrated. One case of osteolysis occurred around the acetabular component (zone I), which was minimal (0.5×0.5 cm²) and nonprogressive (nonmetal-on-metal hip).

Of the original 100 hips, no hips were revised for aseptic loosening or infection. Three (3%) hips were revised at 4- to 6-year follow-up. One revision occurred on postoperative day 4 following a peri-prosthetic fracture that required femoral component revision. This patient died approximately 1 year after revision surgery. The 2 other hips underwent revision for recurrent dislocations, and both cases required revision of the original acetabular shell. The native femoral component was retained in both patients. Average time to revision was 14 months (range, 0.2-35.9 months). Survivorship analysis demonstrated a survival rate of 96.9% (95% confidence interval [CI], 91%-99%; 7 hips at risk) at 6 years for revision for any reason (Figure 3).

Of the 9 patients (10 hips) who died before the minimum 4- to 6-year follow-up, all stems were fully bone ingrown at last follow-up. Among this group was the patient who underwent femoral revision on postoperative day 4 following a peri-prosthetic fracture. No other deceased patient had undergone revision surgery.

Kaplan-Meier survivorship analysis with an endpoint of radiographic loosening of the femoral component demonstrated a survival rate of 80% (95% CI, 20%-97%) at 6 years. At this follow-up interval, only a small amount of the entire cohort (7 hips) had achieved a minimum 6-year radiographic follow-up. Thus, given the small number of patients at risk in this survivorship analysis and the fact that
loosening of this hip occurred at 6 years, the lower-than-expected survival rate for radiographic loosening of the femoral component can be explained. The authors expect that as more hips within this cohort reach the 6-year radiographic follow-up cutoff for this endpoint, the survival rate will increase to a more expected rate.

**DISCUSSION**

Cementless THA has been successfully used for more than 20 years. In the past 5 to 10 years, the popularity of cementless stems has increased following the publication of studies documenting the long-term durability of these constructs over time. First-generation tapered cementless stems have also demonstrated excellent durability in long-term follow-up evaluation. The purpose of the current study was to examine the results of the authors’ initial experience using a contemporary double-tapered, proximally porous-coated, titanium femoral component at 4- to 6-year follow-up.

The Summit Porocoat femoral prosthesis demonstrated excellent durability in this cohort of 88 patients (100 hips) at an average follow-up of 5.1 years. Radiographic evaluation demonstrated bone ingrowth in 97% of cases, with only 1 instance of a radiographically loose femoral component (initially subsided by 6 mm but stabilized within the first year, and the patient was asymptomatic at follow-up) (Figure 1). There was 1 case of proximal femoral osteolysis, which was small and nonprogressive, and no cases of distal femoral osteolysis. This low incidence of osteolysis could be the result of minimal wear associated with moderately cross-linked polyethylene, which was used in the majority (73%) of cases. There was only 1 case of femoral component revision, which occurred on postoperative day 4 following a peri-prosthetic fracture, and all other femoral components were retained at this length of follow-up. Survivorship in this series was 96.9% at 6 years for revision of the hip for any reason. Clinical outcomes were also excellent in this cohort, with only 1 patient reporting significant thigh pain. Average HHS improved significantly following the procedure.

The strengths of this study include the follow-up of a consecutive, nonselected series of patients and the independent clinical and radiographic evaluation by observers who were not involved in the surgeries. This study has many of the same limitations as other radiographic studies of THA, including inter- and intraobserver variability of radiographic measurement. However, all radiographic findings were agreed on by 2 observers. In addition, the determination of stress shielding can be problematic due to the variability in radiographic quality and observer interpretations. In an effort to minimize this variability, the authors used a simple, established grading system (minimal, moderate, or severe) for bone remodeling. Another limitation is the fact that both metal-on-metal and polyethylene-on-metal bearing surfaces were used, as were varying femoral head sizes. However, there were no failures at the bearing surface at this interval of follow-up. Lastly, as with all research of this type, there are limitations to retrospective study designs.

The current study’s results compare favorably with other reports of the Summit stem at 5-year follow-up (Table 3). These authors report bone ingrowth rates of 100% in their respective cohorts and no cases of revision of the femoral component for aseptic loosening. In the reports by Hwang et al and Garcia-Cimbrelo et al, the surgeons used ceramic-on-ceramic bearings in all patients, unlike the moderately cross-linked polyethylene-on-metal (73%) and metal-on-metal (27%) bearing-surface materials used in the current cohort. In addition, the current 3.0% rate of revision for any reason at 4- to 6-year follow-up is supported by a similar rate of revision published in the Australian Orthopaedic Association National Joint Replacement Registry Annual Report, where a 2.0% revision rate was found 5 years after index THA with a Summit femoral component and a Pinnacle acetabular component. The Summit stem used in the current cohort performed equally compared with other cementless stem designs in terms of bone ingrowth rate, need for revision, and clinical outcome measures such as the HHS. Because this is a ream-and-broach system, comparison with broach-only systems will be important in the long term.

**CONCLUSION**

This study’s results demonstrate excellent durability of this contemporary double-tapered, proximally porous-coated, ti-
tanium femoral component at 4- to 6-year follow-up, especially considering that this was the surgeon’s initial experience with a double-tapered stem. Such studies in surveillance are warranted when new designs are introduced. These results encourage the authors to continue to use this stem design in their THA constructs.

**References**


23. Lombardi AV, Berend KR, Mallory TH.
