Arthroplasty Today 5 (2019) 510–515

Contents lists available at ScienceDirect

Arthroplasty Today

journal homepage: http://www.arthroplastytoday.org/

Original research

Total hip arthroplasty utilizing an uncemented, flat, tapered stem with a reduced distal profile

Rachelle Morgenstern, MPH *, Thomas Alastair Denova, BS, Imraan Khan, MPH, Kaitlin M. Carroll, BS, Edwin P. Su, MD

Adult Reconstruction & Joint Replacement Division, Department of Orthopedic Surgery, Hospital for Special Surgery, New York, NY, USA

ARTICLE INFO

Article history:
Received 10 January 2019
Received in revised form
13 August 2019
Accepted 14 August 2019
Available online 19 September 2019

Keywords:
Total hip arthroplasty
Uncemented stem
Reduced distal profile
Bone integration
Biological fixation

ABSTRACT

Background: The aim of this study was to report the midterm results of an uncemented, flat, and tapered femoral stem with a reduced distal profile.
Methods: 219 total hip arthroplasties were performed using this stem between March 2007 and October 2012. Survival, radiographs, and modified Harris Hip Scores were analyzed.
Results: Twenty-two (11.1%) patients died from comorbidities but retained their hips; 18 (9.1%) patients were lost to follow-up. Of the remaining 179 hips, all stems remained in situ at a median follow-up of 8.4 (7.0-9.3) years. There was 97.5% (95% CI: 95.1-99.9) survival for all-cause revision with 4 hips revised for instability. Early stem subsidence was identified in 2 patients within 3 months postoperative measured at 4 mm in patient 1 and 3 mm in patient 2. Long-term radiographic follow-up showed 2 hips with incomplete radiolucencies but no evidence of stress shielding, osteolysis, or subsidence among examined hips (n = 93). Spot welding and cortical hypertrophy were present in 58 (62.4%) and 50 (53.8%) hips, respectively. Femoral component position did not change from early postoperative imaging relative to long-term follow-up at ≥5 years (P = .097). Median modified Harris Hip Scores improved from 58.3 (49.5-64.9) points preoperative to 95.7 (88.0-100) points at follow-up (P < .0001).
Conclusions: The reduced distal profile stem studied showed no stem revisions at long-term follow-up with an all-cause survivorship of 97.5% at a median follow-up of 8.4 (7.0-9.3) years. The stem showed good bone integration and stability at midterm follow-up in most patients reviewed.

Introduction

Primary total hip arthroplasty (THA) with uncemented, tapered, porous-coated femoral components are designed to achieve maximum biological fixation through bone ingrowth. Studies using uncemented femoral components, particularly with long and/or cylindrical stems, have shown mixed results [1-4]. In contrast, mid to short length femoral stems conserve more bone, potentially preventing pain associated with diaphyseal loading and stress shielding on the proximal femur. Long-term results reported from studies using uncemented, tapered femoral components have demonstrated a high prevalence of osteointegration and a low prevalence of loosening. Overall, studies have shown high survivorship from tapered, cementless femoral components [5-15].

A rare but potentially serious complication of proximally coated tapered stems is a failure to achieve osteointegration due to distal fixation. In a study of patients implanted with a proximally coated tapered stem, there was a minority of patients in which there was an increased distal width of the stem relative to the proximal portion. As a consequence there was distal rather than proximal wedging and fixation, which ultimately led to a failure to osteointegrate [16]. A reduced distal width, in relation to the proximal width, potentially allows for further conservation of endosteal bone, maximum metaphyseal fit, and avoids diaphyseal fixation. Theoretically, stems with reduced distal widths allow for a better fit within bones of different geometries, such as Dorr A type femora [17]. Accordingly, a better fit within the femoral canal can potentially more closely replicate a patient's femoral neck geometry and length.

One or more of the authors of this paper have disclosed potential or pertinent conflicts of interest, which may include receipt of payment, either direct or indirect, institutional support, or association with an entity in the biomedical field which may be perceived to have potential conflict of interest with this work. For full disclosure statements refer to https://doi.org/10.1016/j.artd.2019.08.009.

* Corresponding author. Hospital for Special Surgery, 535 East 70th Street, New York, NY 10021, USA. Tel.: +1 212 606 1128.
E-mail address: morgensternr@hss.edu

https://doi.org/10.1016/j.artd.2019.08.009
2352-3441/

Furthermore, neck angles with optimal circulotrapezoidal neck geometry have shorter neck lengths, and allow for easier conservative neck resections and the restoration of leg length as well as offset.

The objective of this study is to determine femoral stem component survival in patients who underwent primary THA using an uncemented, tapered stem with a reduced distal width (Fig. 1), as well as radiographically evaluate stem stability and positioning, and assess patients' physical function and hip pain [1].

Material and methods

A retrospective analysis of 219 THAs performed in 199 patients by a single surgeon between March 2007 and October 2012 was conducted. The protocol was approved by our Institutional Review Board and per the study design a waiver of consent was approved according to 45 CFR 46.117(c) and a waiver of the Health Insurance Portability and Accountability Act authorization in accordance with 45 CFR 164.512(i). Patients were followed until death, femoral component revision, or a minimum of 5 years postoperatively. The ANTHOLOGY (Smith & Nephew, London, UK) femoral component was used in all hips. The acetabular component comprises a titanium cup with a cobalt chromium or oxinium femoral head on a highly cross-linked polyethylene liner. The femoral component was designed as an uncemented, tapered stem with a reduced distal width as well as circulotrapezoidal neck geometry with 131° neck shaft angle [1]. The hip system uses Roughcoat porous coating technology with an hydroxyapatite coating application [18-22]. Radiographic evaluation was performed on postoperative radiographs obtained 4-6 weeks post-THA. Anteroposterior (AP) radiographs of the hip and pelvis and a true lateral view of the hip were assessed for femoral component position and degree of angulation as described by Khalily and Lester [23]. Radiographs available at ≥5 years postoperative were evaluated for subsidence, stress shielding, as well as osteolysis and radiolucencies, in the Gruen zones. Signs of stem stability were evaluated by assessing cortical hypertrophy and spot welding in the Gruen zones [24,25]. Heterotopic ossification was assessed using the Booker classification system. Femoral component position and degree of angle at postoperative and follow-up were calculated and compared. As a subanalysis, radiographs available at ≥1 year and <5 years postoperative were assessed. Modified Harris Hip Scores (mHHSs) were used to assess functional level and evaluate hip pain. Preoperative and mHHS at ≥5 years postoperative were compared.

Figure 1. The femoral component is characterized by a flat taper design and reduced distal profile, both of which ensure less endosteal bone removal.

Normality testing was performed, and mean with range as well as 95% confidence interval, or median with interquartile range, were presented accordingly. In all patients who underwent THA revisions and in all living patients with ≥5 years postoperative survival data, Kaplan-Meier survival analysis was used to generate survivorship curves for freedom from all-cause revision and freedom from femoral component revision. In all nonrevised, living patients with ≥5 years postoperative follow-up data, Wilcoxon signed-rank tests were used to compare preoperative and follow-up mHHS. Wilcoxon signed-rank tests, McNemar-Bowker tests, chi-squared tests, *Z* test for equality of proportions, and Freeman-Halton extension of the Fisher's exact probability test were used to compare postoperative and follow-up radiographs in living patients with stems in situ at follow-up. Statistical analysis was conducted using SAS software version 9.4 (SAS Institute Inc., Carey, NC), with a 5% significance level.

Results

Over the course of the study, a total of 22 patients (11.1%) died from comorbidities, all with their femoral components in place. Of the remaining 197 hips, 18 (9.1%) were lost to follow-up before 5 years postoperative. At the time of surgery, the median age of the 107 women and 54 men was 67.2 (60.6-71.5) years and the predominant indication for primary THA was osteoarthritis. A detailed description of the cohort is shown in Table 1. Intraoperative complications included 1 calcar crack that was cabled and caused no long-term damage. Immediate postoperative complications included 6 (3.4%) cases of superficial infection/cellulitis, 4 (2.2%)

Table 1
Demographic and clinical characteristics at the time of surgery in living patients with a minimum of 5 years of postoperative survival data.

No. of hips	179
No. of patients	161
Age (median, y)	67.2 (60.6-71.5)
Gender, male:female	54:105
Weight (median, kg)	77.7 (66-86.3)
Height (median, cm)	167.6 (160-172.7)
Body mass index (median, kg/m^2)	27.4 (24.4-30.7)
Primary diagnosis, n (%) hips	
Osteoarthritis	163 (91.1)
Avascular necrosis	8 (4.5)
Post-traumatic arthritis	5 (2.8)
Rheumatoid arthritis	2 (1.1)
Fracture	1 (0.6)

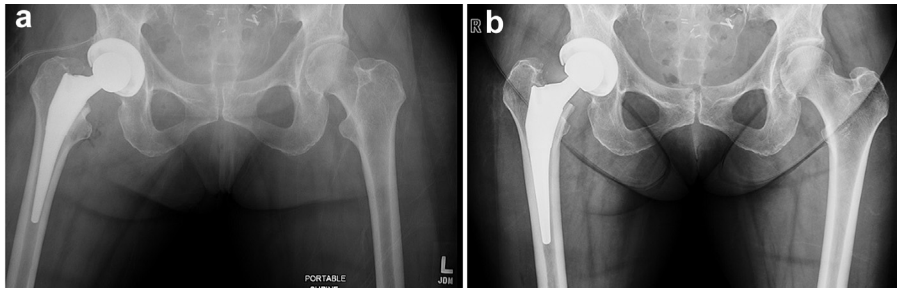

Figure 2. A representative anteroposterior (AP) radiograph from 1 of the 2 hips in which the femoral stem, presented in its original placement on a portable radiograph (a), subsided 4 mm as demonstrated on a radiograph taken at the first postoperative visit (b).

cases of suture abscesses, 3 (1.7%) dislocations, and 2 (1.1%) deep vein thrombosis/pulmonary embolism, none of which caused long-term damage to the patient or the implant. There was immediate postoperative subsidence of 2 (1.1%) femoral stems in which 1 stem subsided 4 mm and the second one subsided 3 mm. Both stems stabilized within approximately 3 months, and at a follow-up of ≥8 years all stems remained in situ (Fig. 2). Of note, none of the patients who experienced subsidence underwent revision of the acetabular component.

Survivorship

In all examined hips there were no femoral component revisions but 4 acetabular component revisions in 4 patients, all for instability. At the time of revision, femoral components were inspected and found to be stable, without change in position, and therefore retained. As such only acetabular components were revised. At a median follow-up of 8.4 (7.0-9.3) years, Kaplan-Meier analysis demonstrated a survival rate of 100% for femoral component revision and 97.5% (95% confidence interval 95.1-99.9) for all-cause revision (Figs. 3 and 4).

Clinical outcome

At ≥5 years postoperative, mHHSs were available for 157 (87.7%) hips from living patients who had not undergone femoral component revision. The median mHHS increased from 58.3 (49.5-64.9) points preoperatively to 95.7 (90.2-100) points at follow-up ($P < .0001$). The clinical outcome of 122 hips was graded as excellent; 27 hips as good; 4 as fair; and 4 as poor.

Radiographic analysis

Of living patients who had not undergone femoral component revision, radiographs at ≥5 years postoperative were available for 93 (52%) hips; 56 (31.3%) were unable to be contacted; 20 (11.2%) refused further imaging, and 10 (5.6%) had active comorbidities preventing them from obtaining further imaging, and all had no concerns with their hip. At ≥5 years of follow-up, radiographs of all examined hips demonstrated no evidence of stress shielding, osteolysis, or subsidence. At ≥9 years of follow-up, a single incomplete radiolucent line was found in 2 hips, both in the

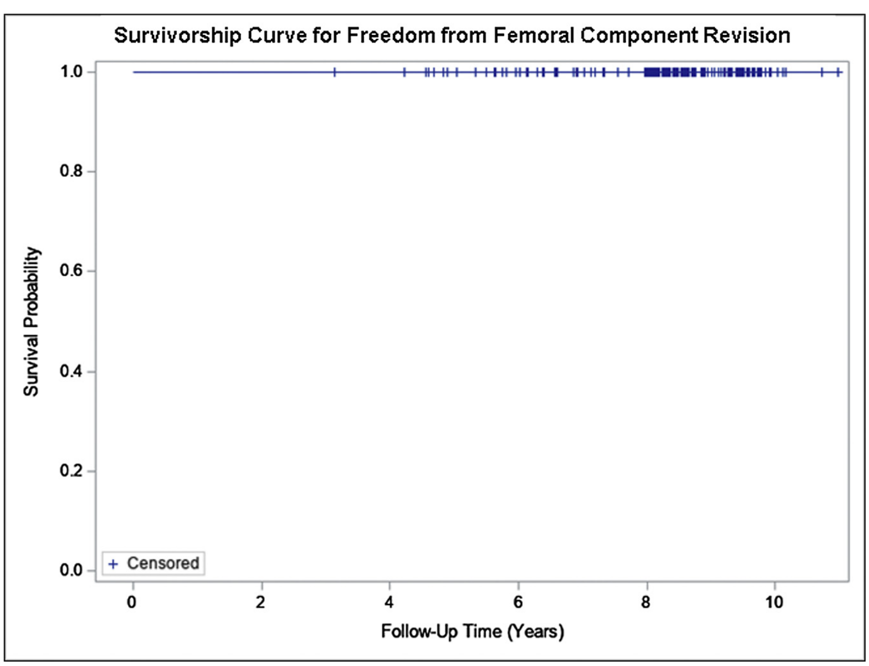

Figure 3. Kaplan-Meier survivorship curve for freedom from femoral component revision in patients who underwent THA with the stem is 100% at a median follow-up of 8.4 (7.0-9.3) years up until the most recent follow-up of 11 years. Other than patients with femoral component revisions, only living patients with a minimum follow-up of 5 years were included.

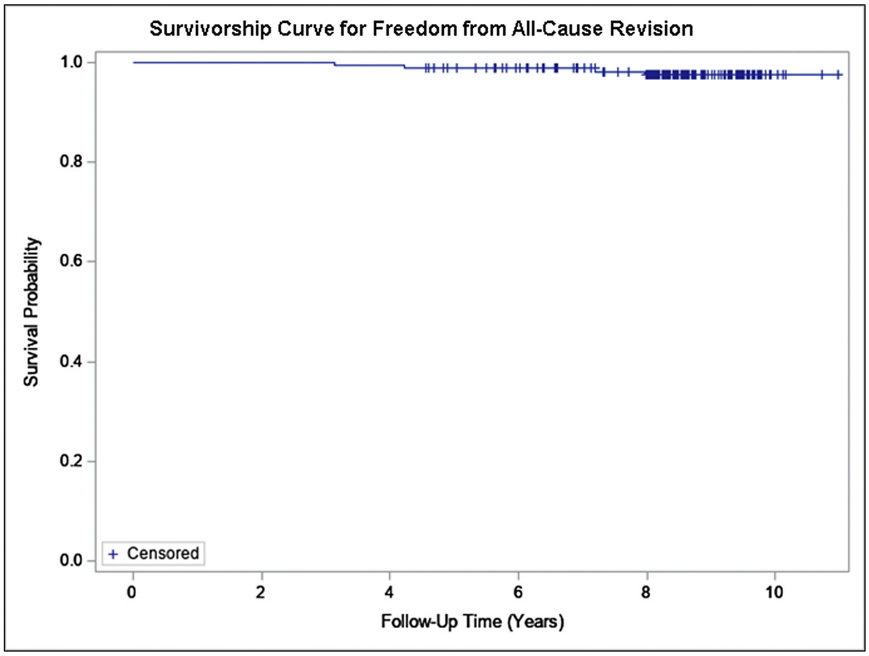

Figure 4. Kaplan-Meier survivorship curve for freedom from all-cause revision in patients who underwent THA with the stem is 97.5% (95% confidence interval 95.1-99.9) at a median follow-up of 8.4 (7.0-9.3) years up until the most recent follow-up of 11 years. Other than revised patients, only living patients with a minimum follow-up of 5 years were included.

nonporous-coated region of the femoral component. The radiolucent lines were <50% of Gruen zone 3 and 5, respectively (Fig. 5).

New bone formation identified as spot welding was rated as present in at least 1 Gruen zone in 58 (62.4%) hips. Cortical hypertrophy, defined as fusiform enlargements of the conical bone in the bone-prosthesis region, was rated as present in at least 1 Gruen zone in 50 (53.8%) hips. The distribution of radiolucencies, spot welding, and cortical hypertrophy according to Gruen zones are presented in Table 2. Heterotopic ossification was noted in 9 (9.7%) hips on follow-up radiographs; 5 were Brooker Grade I, 3 were Brooker Grade II, and 1 was Brooker Grade III. There were no cases of Brooker Grade IV heterotopic bone.

Radiographically, femoral component position and alignment on AP pelvis and AP lateral was neutral in 56 (60.9%) hips at $1.3° \pm 0.9°$ and $2.7° \pm 1.8°$ respectively; valgus in 8 (8.7%) hips at $1.6° \pm 0.7°$ and $3.6° \pm 1.1°$, respectively; varus in 28 (30.4%) hips at $2.7° \pm 1.1°$ and $2.1° \pm 0.8°$, respectively. Comparing immediate postoperative and all radiographs available at $\geq$5 years postoperative, there was no significant difference between femoral component position ($P = .80$) or alignment (AP pelvis, $P = .17$; AP lateral, $P = .14$; Fig. 6).

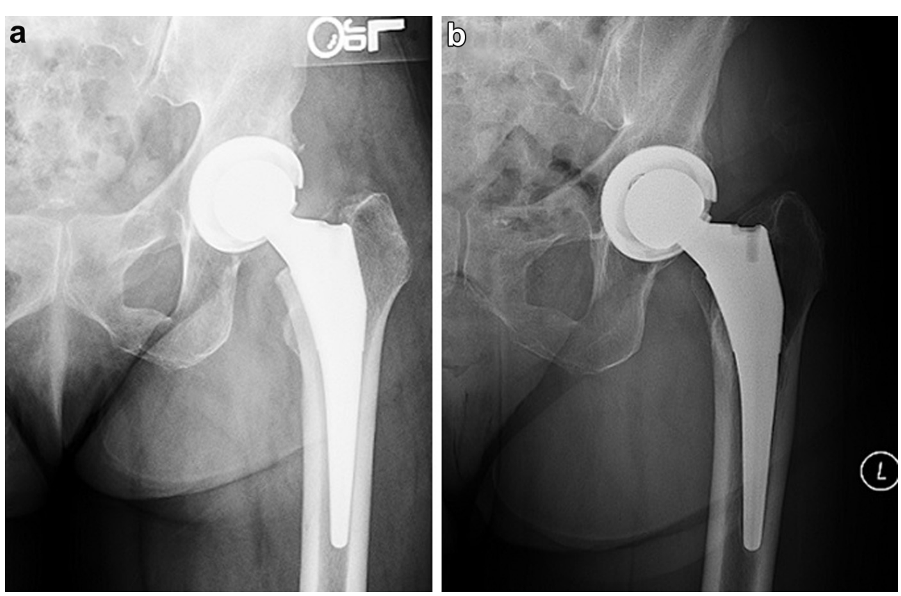

Figure 5. A representative AP hip radiograph from 1 of the 2 hips in which there was no evidence of radiolucency at immediate postoperative (a), but at most recent follow-up a single incomplete, radiolucent line which represented <50% of Gruen zone 5 was present (b).

Table 2
Distribution of radiographic findings by Gruen zone in 93 living hips with primary femoral components in situ and radiographs at a minimum of 5 years postoperatively.

Gruen zone	n (%)		
	Radiolucent line	Cortical hypertrophy	Spot welding
1	0 (0)	1 (1.1)	4 (4.3)
2	0 (0)	30 (32.3)	25 (26.9)
3	0 (0)	25 (26.9)	16 (17.2)
4	0 (0)	0 (0)	0 (0)
5	2 (2.2)	30 (32.3)	11 (11.8)
6	0 (0)	34 (36.6)	31 (33.3)
7	0 (0)	2 (2.2)	4 (4.3)
Total with changes in any zone	2 (2.2)	50 (53.8)	58 (62.4)

There was 65 hips available for a subanalysis of living patients who had not undergone femoral component revision and had radiographic follow-up at ≥1 year and <5 years postoperative. At follow-up, radiographs demonstrated no evidence of stress shielding, osteolysis, subsidence, radiolucent lines, or heterotopic ossification in any of the hips. Spot welding and cortical hypertrophy were rated as present in at least 1 Gruen zone in 35 (53.85%) and 31 (47.69%) hips, respectively. Comparing the 2 cohorts of hips, those with follow-up radiographs at ≥1 year and <5 years vs ≥5 years, there were no significant differences in the proportion of patients with spot welding and cortical hypertrophy ($P = .284$ and $P = .453$, respectively).

In hips with follow-up radiographs at ≥1 year and <5 years vs ≥5 years, there was no significant difference in the proportion of femoral components positioned neutral, valgus, or varus ($P = .377$). Overall alignment on AP pelvis was not significantly different between those with follow-up radiographs at ≥1 year and <5 years vs ≥5 years at 1.41° ± 1.04° and 1.79° ± 1.16°, respectively ($P = .117$); alignment on the AP lateral view was also not significantly different at 2.13° ± 1.72° and 2.46° ± 1.65°, respectively ($P = .317$). Femoral component positioning was unchanged on follow-up in radiographs available at ≥1 year and <5 years compared to immediate postoperative radiographs ($P = 1.0$); alignment was also not significantly different on AP pelvis and AP lateral ($P = .402$ and $P = .388$, respectively). The sample size was too small to conduct an analysis of position and alignment together.

Discussion

In this study, high implant survival was found in a cohort of patients who underwent THA using an uncemented femoral component with a tapered stem and reduced distal profile. In patients with a follow-up of ≥5 years, at a maximum of 11 years there were no femoral component revisions and survivorship from all-cause revision was 97.5%. In contrast to cementless femoral components which are not tapered, the overall clinical performance of uncemented, tapered stems has been positive [1-4]. Findings from this study are consistent with previous reports on implant survivorship using uncemented, tapered femoral components. In clinical studies, survivorship ranged from 99.1% at 11 years to 90% at 29 years in 1 implant, and in another implant was found to be 95% at 10 years [5-13].

The femoral component utilized has a flat taper design that allows for less endosteal bone removal which can help maintain blood flow and facilitate bone ingrowth. Radiographically, at ≥5 years postoperatively, there was stable fixation of the femoral components by bone ingrowth. Periprosthetic diaphyseal endosteal bone formation was present in the majority of hips at follow-up, with no significant changes in femoral component position or alignment. There was an increase in bone density in the majority of patients, likely due to increased loading of the surgical hip and a normal proliferative response in uncemented femoral components. Of note, good bone ingrowth was evident in patients with ≥1 year and <5 years of follow-up radiographs, which is suggestive of good long-term results since late loosening of uncemented, well ingrown femoral components is unlikely to be a common problem. Additionally, imaging data were not significantly different between hips with follow-up radiographs at ≥1 year and <5 years vs ≥5 years.

This study is limited by the retrospective nature of its design; however, standard-of-care prospectively obtained clinical and radiographic data were used to update results. Additionally, this study is a single-center, single surgeon study which is also a limitation. A minimum of 5 years of postoperative data were not available from the entire cohort, although their clinical and radiographic materials were reviewed in detail and all patients were found to have well-functioning femoral components at their most recent evaluation. Finally, this study evaluated a product from a company which the senior author of the paper acts as a consultant. However, these limitations are not specific to our study and do not detract from the significance of its findings and the validity of its conclusions.

Conclusions

There were no stem revisions in this series, and at follow-up the femoral stem utilized, significant for its reduced distal profile, was stable and showed good bone integration in the majority of patients. This study is the first to report on the survival of the aforementioned femoral stem and results support the continued use of it in patients undergoing THA.

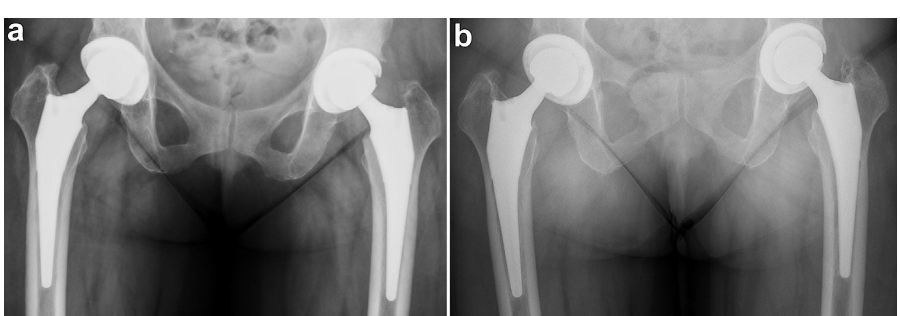

Figure 6. A representative radiograph of a stable femoral component in which there is no significant change in alignment on an AP pelvis radiograph at 1 month postoperative (a) compared to a radiograph at 10 years of follow-up (b).

Acknowledgments

We would like to acknowledge our patients who continue to participate in clinical trials and enable us to further our understanding of and treatments for musculoskeletal diseases. The principle investigator has been paid for consultancy work with the implant manufacturer of the studied implant but has not consulted in relation to this implant and does not receive royalties related to the implant. The principle investigator received no grant in relation to this study but the study was funded through a specific grant to the institution where the research took place.

References

[1] de Nies F, Fidler MW. The Harris-Galante cementless femoral component: poor results in 57 hips followed for 3 years. Acta Orthop Scand 1996;67:122.
[2] Maloney WJ, Woolson ST. Increasing incidence of femoral osteolysis in association with uncemented Harris-Galante total hip arthroplasty: a follow-up report. J Arthroplasty 1996;1:130.
[3] Engh CA, Massin P. Cementless total hip arthroplasty using the anatomic medullary locking stem. Results using a survivorship analysis. Clin Orthop Relat Res 1989;249:141.
[4] Haddad RJ, Cook SD, Brinker MR. A comparison of three varieties of noncemented porous-coated hip replacement. J Bone Joint Surg Br 1990;72:2.
[5] Parvizi J, Keisu KS, Hozack WJ, Sharkey PF, Rothman RH. Primary total hip arthroplasty with an uncemented femoral component: a long-term study of the Taperloc stem. J Arthroplasty 2004;19:151.
[6] McLaughlin JR, Lee KR. Total hip arthroplasty with an uncemented tapered femoral component in patients younger than 50 years. J Arthroplasty 2011;26:9.
[7] McLaughlin JR, Lee KR. Total hip arthroplasty with an uncemented tapered femoral component in patients younger than 50 years of age: a minimum 20-year follow-up study. J Arthroplasty 2016;3:1275.
[8] Hozack W, Gardiner R, Hearn S, Eng K, Rothman R. Taperloc femoral component: a 2–6-year study of the first 100 consecutive cases. J Arthroplasty 1994;9:489.
[9] Purtill JJ, Rothman RH, Hozack WJ, Sharkey PF. Total hip arthroplasty using two different cementless tapered stems. Clin Orthop Relat Res 2001;393:121.
[10] Burt CF, Garvin KL, Otterberg ET, Jardon OM. A femoral component inserted without cement in total hip arthroplasty. A study of the Tri-Lock component with an average ten-year duration of follow-up. J Bone Joint Surg Br 1998;80:952.
[11] Teloken MA, Bissett G, Hozack WJ, Sharkey PF, Rothman RH. Ten to fifteen-year follow-up after total hip arthroplasty with a tapered cobalt-chromium femoral component (tri-lock) inserted without cement. J Bone Joint Surg Br 2002;84:2140.
[12] Carlson SW, Goetz DD, Liu SS, Greiner JJ, Callaghan JJ. Minimum 10-year follow-up of cementless total hip arthroplasty using a contemporary triple-tapered titanium stem. J Arthroplasty 2016;31:2231.
[13] García-Cimbrelo E, Bru-Pomer A, García-Benítez B, Hernández-Blanco M, Vaquero J. Multicentric and prospective study of the Summit cementless stem. Hip Int 2010;20:63.
[14] Healy WL, Tilzey JF, Iorio R, Specht LM, Sharma S. Prospective, randomized comparison of cobalt-chrome and titanium trilock femoral stems. J Arthroplasty 2009;24:831.
[15] Callaghan JJ. Not all cementless stems are created equal: a selection algorithm. J Bone Joint Surg Br 2016;98:10.
[16] Cooper HJ, Jacob AP, Rodriguez JA. Distal fixation of proximally coated tapered stems may predispose to a failure of osteointegration. J Arthroplasty 2011;26:78.
[17] Dorr LD, Faugere MC, Mackel AM, Gruen TA, Bognar B, Malluche HH. Structural and cellular assessment of bone quality of proximal femur. Bone 1993;14:231.
[18] Smith & Nephew Data. Bead pull-off testing of Ti-6AI-4V. In-house Test Data Summary. 1993.
[19] Lemons JE, editor. Quantitative characterization and performance of porous implants for hard tissue applications: a symposium; 1987. ASTM International.
[20] Robinson T, Bearcroft J. Smith & Nephew advanced technology report. 1993.
[21] Bobyn JD, Pilliar RM, Cameron HU, Weatherly GC, Kent GM. The effect of porous surface configuration on the tensile strength of fixation of implants by bone ingrowth. Clin Orthop Relat Res 1980;149:291.
[22] Jaffe WL, Scott DF. Total hip arthroplasty with hydroxyapatite-coated prostheses. In: Joint Arthroplasty. Tokyo: Springer; 1999. p. 159.
[23] Khalily C, Lester DK. Results of a tapered cementless femoral stem implanted in varus. J Arthroplasty 2002;17:463.
[24] Engh CA, Bobyn JD, Glassman AH. Porous-coated hip replacement. The factors governing bone ingrowth, stress shielding, and clinical results. J Bone Joint Surg Br 1987;69:45.
[25] Gruen TA, McNeice GM, Amstutz HC. "Modes of failure" of cemented stem-type femoral components: a radiographic analysis of loosening. Clin Orthop Relat Res 1979;141:17.