

Ultrashort versus Conventional Anatomic Cementless Femoral Stems in the Same Patients Younger Than 55 Years

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Abstract

Background Because the clinical and radiographic performance of an ultrashort anatomic cementless stem has been investigated in only two randomized controlled studies, well-designed trials should aim for a thorough comparison of the outcomes of ultrashort anatomic cementless and conventional anatomic cementless stems.

Questions/purposes The purposes of this study were to compare (1) the clinical results, including Harris hip score, thigh pain, and WOMAC index score, (2) radiographic results, (3) bone mineral density; and (4) proportions of patients undergoing revision of a THA using an ultrashort

anatomic cementless stem versus a conventional anatomic cementless stem in the same patients who underwent bilateral sequential THAs under the same anesthetic.

Methods Two hundred patients (mean age, 53 years; range, 26–54 years) who underwent bilateral sequential THAs received an ultrashort anatomic cementless stem in one hip and a conventional anatomic cementless stem in the contralateral hip. From January 2004 to December 2005, we performed 524 same-day bilateral short and conventional anatomic cementless THAs in 262 patients, of whom 212 (81%) participated in this study. Five patients were lost to followup before 2 years, five were lost between 2 to 10 years, and two were lost between 10 to 13 years, leaving 200 patients. Patients who had end-stage bilateral hip disease and were younger than 55 years were selected for inclusion. The predominant diagnoses were osteonecrosis (118 patients, 59%) and osteoarthritis (44 patients, 22%). One hundred thirty-eight were men and 62 were women. At the time of each followup, the patients were assessed clinically and radiographically. In addition, each patient completed the WOMAC and the University of California Los Angeles (UCLA) activity scores. The minimum followup was 10 years (mean, 11.8 years; range, 10–13 years). Followups were done in person, with all images and followup clinic notes. Based on the power analysis, we estimated a sample size of 178 hips was needed in each group to detect a 3-point difference in the Harris hip score with 80% power.

Results At the latest followup, there were no differences between the two groups regarding the mean Harris hip scores (94 versus 94 points; $p = 0.189$), mean WOMAC scores (17 versus 16 points; $p = 0.191$), or mean UCLA activity scores (9 versus 9 points; $p = 0.381$). Two patients in the ultrashort stem group and one patient in the conventional stem group had severe (9 points) thigh pain, and

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Each author certifies that his or her institution approved the human protocol for this investigation, that all investigations were conducted in conformity with ethical principles of research, and that informed consent for participation in the study was obtained.

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30 patients (15%) in the conventional stem group had mild thigh pain (2 or 3 points) after vigorous exercise. Bone mineral density in the ultrashort and conventional stem groups, respectively, was greater in the ultrashort stem group than in the conventional stem group. Bone mineral density in Zone 1 at 12 years was 3.29 versus 1.88 g/cm² ($p = 0.021$), and 2.97 versus 0.91 g/m² in Zone 7 ($p = 0.001$). With the numbers available, there were no differences between the stem designs in terms of the proportion undergoing revision (one hip, 0.5%, in the short-stem group versus one hip, 0.5%, in the conventional group; $p = 1.881$).

Conclusions At followup into the second decade, ultrashort stems showed no differences from conventional cementless stems in terms of validated outcomes scores or fixation, although less stress shielding was observed. Reduction of stress shielding may reduce the long-term risk of periprosthetic fracture, but this was not shown in our study.

Level of Evidence Level I, therapeutic study.

Introduction

Conventional cementless femoral stems are known to provide a high rate of satisfactory clinical and radiographic performance at long-term followups [1, 7, 12, 14, 15, 18, 33]. However, they may have potential clinical consequences related to stress shielding, thigh pain, periprosthetic fractures, proximodistal dimensional mismatch, and removal during revision [9, 11, 16, 17, 19, 21–23, 35, 38]. In an effort to reduce the risk of stress shielding, thigh pain, periprosthetic fracture, and proximodistal dimensional mismatch and to facilitate removal of a well-fixed stem, an ultrashort anatomic (left or right) metaphyseal-fitting cementless femoral stem was developed. The absence of the diaphyseal anchorage sought to achieve more-proximal load transfer to reduce stress shielding, thigh pain, and proximodistal dimensional mismatch; it also sought to preserve more diaphyseal bone for future revisions [4, 16, 17, 19, 21–23, 35, 41]. Biomechanical studies showed that ultrashort cementless stems exhibited good fixation and sustained high loads to failure with axial loading [35, 40]. However, there are concerns about lower loads to failure regarding torsional loads in the proximal femur [36]. Thus, the distal fixation achieved with a conventional cementless stem may provide greater resistance to torsional loads [29]. Questions regarding whether an ultrashort stem will be sufficiently biomechanically stable to achieve durable bone ingrowth and longer-term clinical performance have been raised [17, 21, 22, 34].

Because clinical and radiographic performance of this ultrashort anatomic cementless stem have been investigated in only a few studies and at short-term followup [16, 17, 19, 21–23, 34], it remains to be determined whether an ultrashort anatomic cementless stem shows similar clinical and radiographic results, bone mineral density (BMD), and revision rate as a conventional cementless stem at long-term followup.

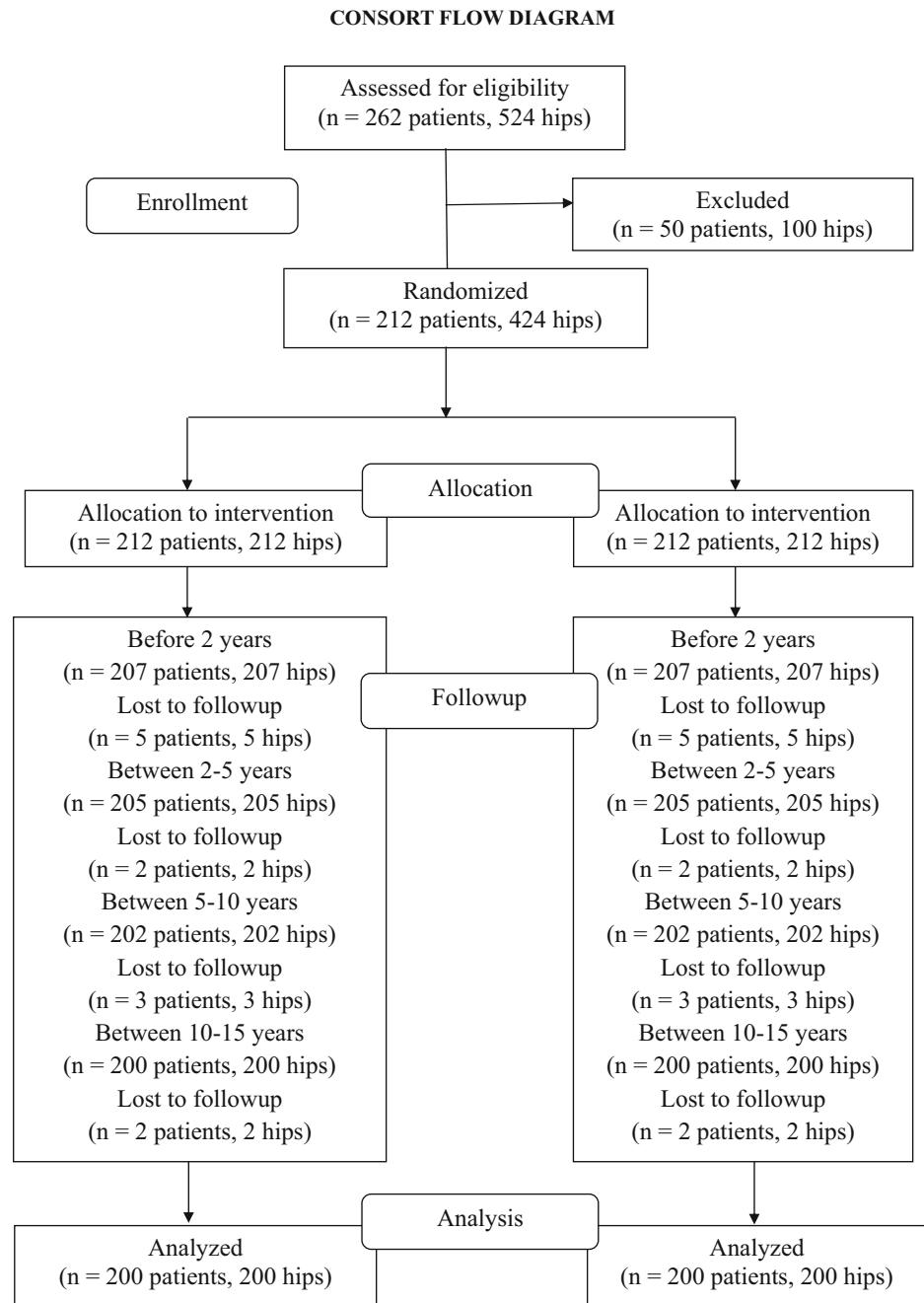
The purposes of this prospective randomized study were to compare (1) the clinical results, including Harris hip score [13], thigh pain, and WOMAC index score; (2) radiographic results, including stress shielding, and implant aseptic loosening; (3) BMD; and (4) proportions of patients undergoing revision of cementless THA using an ultrashort anatomic metaphyseal-fitting cementless stem versus a conventional anatomic proximal porous-coated cementless stem in the same patients who underwent bilateral sequential THAs under one anesthetic.

Patients and Methods

From January 2004 to December 2005, a total of 262 patients (524 hips) underwent bilateral sequential THAs under the same anesthetic and were considered for inclusion in this within-patient randomized trial. Of these, 212 patients (424 hips) met the inclusion criteria and agreed to participate in the study. Patients were excluded if they were older than 55 years (the age limit was chosen arbitrarily considering activity level), they had inflammatory arthritis, or they had a foot or ankle disorder that limited walking. Contraindications for an ultrashort stem were patients with a high-riding dislocation of the femoral head, severe osteoporosis, or intertrochanteric fracture. The study protocol, including the consent forms, was approved by the institutional review board at our institution. All patients provided informed consent. Twelve patients were lost to followup, but no patient died during the interim, leaving 200 patients (400 hips) available for study with a minimum duration of followup of 10 years (mean, 11.8 years; range, 10–13 years) (Fig. 1).

There were 138 men and 62 women with a mean age of 52.5 years (range, 26–54 years) at the time of surgery. The mean height of the patients was 168.2 cm (range, 158–183 cm) and mean body weight was 83 kg (range, 69–118 kg). The mean BMI was 29.6 kg/m² (range, 27.6–35.8 kg/m²). The diagnosis was osteonecrosis of the femoral head in 118 patients (59%), osteoarthritis in 44 (22%), osteoarthritis secondary to childhood septic arthritis in 18 (9%), ankylosing spondylitis in 10 (5%), and multiple epiphyseal dysplasia in 10 (5%). There were no differences between the two groups in terms of preoperative conditions,

Fig. 1 The Consort diagram for our study is shown.



including the extent of disease, pain, functional disability, deformity, ROM, bone loss, and/or prior surgical treatments (Table 1).

Randomization to treatment with an ultrashort anatomic cementless stem or a conventional anatomic cementless stem was accomplished using study numbers in sealed envelopes, which were opened in the operating room before the skin incision was made. All patients were equally assigned, using a computer program, to receive one type of component in one hip and another type in the contralateral hip. This study was done by intent-to-treat.

The first hip received the prosthesis indicated in the envelope and the contralateral hip received the other prosthesis. No patients had the second procedure aborted because of intraoperative problems such as hypotension or heart problems.

All operations were performed by the senior author (YHK) using a posterolateral approach. The ultrashort anatomic cementless (Proxima™, DePuy, Leeds, UK) stem is made of titanium alloy and is entirely porous coated with sintered titanium beads, having a mean pore size of 250 μm , to which a 30- μm thick hydroxyapatite coating is

Table 1. Preoperative conditions of patients

| Parameter | Ultrashort stem | Conventional stem | Mean difference (95% CI) p value (Wilcoxon test) |
|---|--|--|--|
| Extent of disease | End stage hip disease (osteonecrosis or arthritis) | End stage hip disease (osteonecrosis or arthritis) | - |
| Pain (Harris hip scoring system) | Mean, 19 points (9–23 points) | Mean, 20 points (10–24 points) | 1 (–1.15 to 2.98) p = 0.191 |
| Functional disability (Harris hip scoring system) | Mean, 28 points (15–39 points) | Mean, 29 points (16–41 points) | 1 (–1.48 to 3.31) p = 0.189 |
| Deformity (Harris hip scoring system) | Mean, 3 points (0–4 points) | Mean, 3 points (0–4 points) | 0 (–0.6 to 0.9) p = 0.113 |
| ROM (degrees) | | | |
| Permanent flexion | Mean, 15 (10–51) | Mean, 14 (5–48) | 1 (–1.81 to 3.22) p = 0.211 |
| Flexion | Mean, 105 (85–115) | Mean, 101 (75–118) | 4 (–3.1 to 7.9) p = 0.381 |
| Abduction | Mean, 17 (0–35) | Mean, 18 (5–30) | 1 (–1.69 to 3.31) p = 0.419 |
| Adduction | Mean, 25 (15–35) | Mean, 21 (10–30) | 4 (–2.9 to 8.1) p = 0.391 |
| External rotation in extension | Mean, 38 (30–45) | Mean, 35 (20–50) | 3 (–3.9 to 7.8) p = 0.771 |
| Internal rotation in extension | Mean, –27 (–45 to 10) | Mean, –30 (–41 to 15) | 3 (–3.6 to 8.2) p = 0.478 |
| Prior surgical treatment | | | |
| Core decompression of femoral head | 28 hips (14%) | 31 hips (16%) | Odds ratio (CI) 2.2 (0.17–9.7) p = 0.751 |
| Intertrochanteric derotation osteotomy | 4 hips (2%) | 5 hips (3%) | 1.3 (0.35–3.9) p = 0.672 |
| Arthrotomy of hip to drain pus | 8 hips (4%) | 6 hips (3%) | 1.3 (0.31–4.1) p = 0.579 |

applied, except at the distal tip (Fig. 2). The femoral neck was cut horizontally at the head-neck juncture. The proximal femur was prepared by the “round the corner” technique [17, 23, 34]. The size of the femoral component selected matched the size of the largest broach used. Stability of the femoral component was determined by the torsional stability of the stem as dictated by bone quality rather than by canal fit and fill. A 28-mm diameter BIOLOX[®] forte ceramic femoral head (CeramTec AG, Polchingen, Germany) was used in all hips. A cementless DURALOC[®] cup (DePuy, Warsaw, IN, USA) with a 28-mm internal-diameter BIOLOX[®] forte ceramic liner (CeramTec) was used in all hips.

The conventional anatomic cementless stem (Profile[®]; DePuy) is made of titanium alloy and is an anatomic metaphyseal and diaphyseal fit and fill, not a tapered stem. The proximal 1/3 of the stem is porous-coated with titanium sintered beads. This stem also has a smooth diaphyseal stem below the metaphyseal porous coating (Fig. 2). The pore size was 250 µm. A 28-mm diameter BIOLOX[®] forte ceramic femoral head was used in all hips. A cementless DURALOC[®] cup and a 28-mm internal diameter BIOLOX[®] forte ceramic liner were used in all hips. The conventional anatomic cementless femoral component was inserted with a press-fit as determined by the preoperative use of templates. At the time of the operation, an attempt was made to fill the femoral canal with the broach, leaving

little cancellous bone remaining. The mean duration of the THA for each hip was 55 minutes (range, 48–101 minutes).

Patients were mobilized on the second postoperative day and progressed to full weightbearing with a walker or crutches as comfort permitted; they were advised to use a walking aid for 6 weeks [23, 24]. The patients were reviewed at 3 months, 1 year, and yearly thereafter, by one of the authors (JWP), who was not directly involved in the treatment of the patients. The Harris hip score [13] and WOMAC score [2] were recorded at each visit. Thigh pain was scored on a 10-point VAS [6], where 0 represents no pain and 10 equals severe pain. Activity level was assessed at the most recent followup using the UCLA activity score [42]. All the data were collected and analyzed by a research associate (DRK) who was not part of the surgical team. Any clicking or squeaking sound from the ceramic-on-ceramic bearing was recorded. At each followup, all patients were asked specifically, by an examiner (YHK), whether they heard a clicking or squeaking sound.

Radiologic evaluation was done at 3 months and 1 year postoperatively and yearly thereafter. A supine AP radiograph of the pelvis with both hips in extension with 15° internal rotation and a crosstable lateral radiograph of each hip were obtained 7 days postoperatively and at each subsequent visit. The morphologic features of the femur were determined preoperatively using Dorr’s classification system [8]. Femoral component position in the coronal and

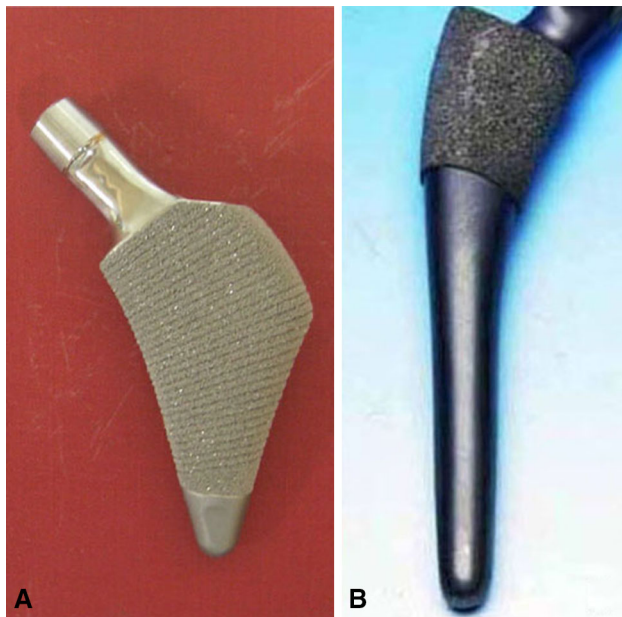


Fig. 2A–B The photographs show (A) the Proxima™ ultrashort cementless anatomic stem and (B) a Profile® conventional cementless anatomic stem.

sagittal planes, center of rotation in the horizontal and vertical planes, femoral offset, abductor moment arm, femoral neck length, and limb-length discrepancy also were analyzed. Anteversion and inclination of the acetabular component were measured, using the method of Engh et al. [10], by a research associate (DRK) who was not directly involved in the treatment of patients.

Definite loosening of the femoral component was defined when there was progressive axial subsidence greater than 3 mm or a varus or valgus shift greater than 3° [19]. The degree of stress shielding was assessed by Engh and Bobyn's criteria [9]. Osteolytic lesions were assessed for their location and size using the method of Zicat et al. [43]. Radiographic data were analyzed by a research associate (DRK) with no knowledge of the patient's name. The intraobserver error in all the radiographic measurements ranged from 0.95 to 1.00 by the chance-corrected kappa coefficient [25], indicating excellent reproducibility. BMD was determined using dual-energy X-ray absorptiometry (DEXA) as reported by Kim et al. [16, 17, 19–22]. DEXA scans were taken at 1 week, 1 year, 10 years, and at the final followup after surgery (mean, 11.8 years). BMD data was analyzed, by one observer (DRK), from the lower border of the lesser trochanter to the tip of the greater trochanter in Zone 1 and from the lower border of the lesser trochanter to the femoral neck-cut level in Zone 7. The intraobserver error for BMD analysis was 0.95 (range, 0.91–0.97) by the chance-corrected kappa coefficient [25], indicating excellent reproducibility.

To detect an effect size of 0.5, corresponding to an anticipated difference of 3 points in the Harris hip score and a

SD of 6 points, we calculated that 178 patients were required in each group. In anticipation of a 10% dropout rate, we aimed to include 200 patients in each group. The two-tailed Student's t-test was used to evaluate the changes in Harris hip score. To analyze complication rates and the radiologic data, the chi-square test with Yate's correction was used. BMD was compared using a two-tailed Student's t-test [21].

A probability level of 0.05 was used for all tests. Statistical analyses were performed using SPSS Statistics for Windows (version 14.0, SPSS Inc, Chicago, IL, USA).

Results

Comparison of mean preoperative and postoperative Harris hip scores, WOMAC scores, and UCLA activity scores revealed no differences between the two groups. The mean preoperative Harris hip score was 48 points for the ultrashort stem group and 45 points for the conventional stem group (mean difference, 3 points; 95% CI, -3.6 to 8.0; $p = 0.189$). The mean postoperative Harris hip score was 93.5 points for the ultrashort stem group and 94 points for the conventional stem group (mean difference, 0.5 points; 95% CI, -1.41 to 2.83; $p = 0.189$). The mean preoperative WOMAC score was 62 points for the ultrashort stem group and 59 points for the conventional stem group (mean difference, 3 points; 95% CI, -2.9 to 7.5; $p = 0.114$). The mean postoperative WOMAC score was 17 points for the ultrashort stem group and 16 points for the conventional stem group (mean difference, 1 point; 95% CI, -1.62 to 3.11; $p = 0.191$). The mean preoperative UCLA activity score was 2 points for both groups (mean difference, 0 points; 95% CI, -0.7 to 0.81; $p = 0.151$). The mean postoperative UCLA activity score was 8.7 points for both groups (mean difference, 0 points; 95% CI, -0.7 to 0.9; $p = 0.381$). Thigh pain was more common with the conventional anatomic stem. Two patients (1%) had severe (9 points) thigh pain in the ultrashort anatomic cementless stem group, and the remaining 198 patients in this group had no thigh pain. Twenty-six patients (13%) had mild (2 or 3 points) thigh pain, four (2%) had moderate (5 or 6 points) thigh pain, and one (0.5%) had severe (9 points) thigh pain in the conventional stem group. There was a greater odds of thigh pain with the conventional stem compared with the ultrashort stem (odds ratio, 15; 95% CI, 11.9–21.8; $p = 0.045$).

The morphologic features of the proximal femur [8], position of the femoral component, center of rotation, femoral offset, abductor moment arm, femoral neck length, leg length discrepancy, and inclination and anteversion of the acetabular component did not differ between the two groups (Table 2). All but two hips in the ultrashort stem group and all but one in the conventional stem group had solid fixation by bone ingrowth (Fig. 3). Two ultrashort stems were unstable. All hips in the ultrashort anatomic

Table 2. Radiographic results

| Parameter | Ultrashort stem | Conventional stem | p value (Student's t-test) |
|--|-------------------|-------------------|---|
| Dorr bone type [8] (number, %) | | | |
| Type A | 102 (51%) | 100 (50%) | 0.131 |
| Type B | 62 (31%) | 64 (32%) | 0.171 |
| Type C | 36 (18%) | 36 (18%) | 0.183 |
| Femoral component position coronal plane (number, %) | | | |
| Neutral | 190 (95%) | 192 (96%) | 0.169 |
| Varus | 8 (4%) | 6 (3%) | – |
| Valgus | 2 (1%) | 4 (1%) | – |
| Sagittal plane (number, %) | | | |
| Anatomic | 200 (100%) | 200 (100%) | – |
| Mean center of rotation (mm) (range) | | | Mean difference (95% CI) |
| Horizontal | 40 (36–49) | 39 (35–47) | 1 (–1.56 to 3.84) p = 0.471 |
| Vertical | 17 (13–24) | 16 (12–26) | 1 (–1.63 to 2.98) p = 0.579 |
| Mean femoral offset (mm) (range) | 43 (37–54) | 40 (33–52) | 3 (–2.1 to 7.9) p = 0.512 |
| Mean abductor moment arm (mm) (range) | 44 (37–81) | 44 (35–79) | 0 (–0.6 to 0.9) p = 0.671 |
| Mean femoral neck length (mm) (range) | 35 (33–81) | 34 (31–40) | 1 (–1.58 to 2.99) p = 0.776 |
| Mean limb-length discrepancy (mm) (range) | 0.4 (–1.4 to 0.9) | 0.5 (–1.1 to 0.8) | 0.1 (–0.7 to 1.0) p = 0.789 |
| Migration of femoral component < 2 mm (number, %) (stabilized) | 2 hips (1%) | 6 hips (3%) | Odds ratio (CI) 3 (0.24–12.1) p = 0.31 |
| Stress shielding | | | |
| Grade 1 | 200 hips (100%) | 22 hips (11%) | Odds ratio (CI) 9.1 (2.7–14.8) |
| Grade 2 | 0 | 26 hips (13%) | p = < 0.001 |
| Grade 3 | 0 | 92 hips (46%) | |
| Grade 4 | 0 | 60 hips (30%) | |
| Acetabular component position | | | Mean difference (CI) |
| Inclination (degrees) | 43 (35–48) | 40 (36–45) | 3 (–2.3 to 8.1) p = 0.135 |
| Anteversion (degrees) | 26 (20–31) | 26 (21–29) | 1 (–1.61 to 3.12) p = 0.812 |

cementless stem group showed Grade 1 stress shielding in the calcar region. In the conventional anatomic cementless stem group, 22 hips (11%) showed Grade 1 stress shielding, 26 (13%) showed Grade 2 stress shielding, 92 (46%) showed Grade 3 stress shielding, and the remaining 60 (30%) showed Grade 4 stress shielding (Table 2).

BMD was greater in the ultrashort stem group than in the conventional stem group. In the ultrashort stem group, the BMD increased in Zone 1 at each followup but slightly decreased in Zone 7. In the conventional stem group, BMD in Zones 1 and 7 was decreased at each followup. BMD in the Zone 1 at 12 years followup was $3.29 \pm 0.28 \text{ g/cm}^2$ in

the ultrashort stem group and $1.88 \pm 0.18 \text{ g/cm}^2$ in the conventional stem group ($p = 0.021$), BMD in the Zone 7 at 11.8 years followup was $2.97 \pm 0.25 \text{ g/cm}^2$ in the ultrashort stem group and $0.91 \pm 0.09 \text{ g/cm}^2$ in the conventional stem group ($p = 0.001$) (Table 3).

One patient in each group underwent revision surgery. One patient in the ultrashort stem group underwent revision surgery for an unstable stem after a fall. The patient had implantation of an Anatomical Medullary Locking (AML[®]) cementless stem (DePuy) (Fig. 4), however another patient refused revision surgery (Fig. 5). One patient in the conventional stem group had an



Fig. 3 An AP radiograph of both hips of a 45-year-old male patient with bilateral osteonecrosis of the femoral head shows the ultrashort cementless stem (right hip) and conventional cementless stem (left hip) are firmly embedded in a satisfactory position with no radiolucent line and no osteolysis around the component in either hip at 13 years postoperatively.

unstable stem and underwent revision surgery with implantation of a larger Profile® stem. With the numbers available, we detected no difference between the study groups in terms of the proportion of hips that underwent revision (one hip [0.5%] in each group; same hazard by a mean factor of 1.19; 95% CI, 0.81–2.81).

Discussion

There are few short-term studies of the ultrashort stem [17, 19, 21, 22, 34], and to our knowledge well-designed randomized controlled long-term studies regarding the performance of ultrashort and conventional stems in the same patients have not been published. We therefore sought to compare ultrashort and conventional anatomic cementless stems in the same patients to document the long-term performance of both stems. We found no differences in patient-reported outcome scores, slight benefits favoring the short stem in terms of thigh pain which was more common in the conventional stem group, but it generally was mild. Harris hip scores and BMD were not different between the groups. There were no differences between the stems in terms of fixation or the likelihood of revision surgery at a minimum followup of 10 years.

This study has some limitations. First, because of the ceiling effects of the scores used, our ability was limited to differentiate the outcomes between the two groups. However, we obtained similar excellent results in both groups. Second, the high incidence of the primary diagnosis of osteonecrosis combined with the low BMI (29.6 kg/m²) may limit the populations to which this study applies. However, the active and younger patients in our study group were good candidates for studying both stems. Third, we did not evaluate interobserver variability to ensure consistency in interpreting hip scores and radiographic and BMD findings. However, the chance-corrected kappa

coefficient for intraobserver agreement ranged from 0.95 to 1.00, indicating excellent reproducibility of the measurements. Fourth, the outcomes of 12 patients who were lost to followup are unknown. Finally, evaluating longitudinal changes in BMD during the DEXA examination of the different prosthetic designs can be problematic. Minor changes in femoral rotation or patient position can lead to a 5% precision error by altering the area of the medial femoral cortex [28]. Therefore, there may be a potential bias in interpretation of the DEXA results.

We found favorable clinical results in both groups, including the Harris hip score and the WOMAC score, and these results are comparable to those of previous studies [10, 17–19, 35]. Studies support the idea that the ultrashort stem relieves pain and restores function comparable to conventional stems at short- and long-term followup [10, 17, 19, 35]. Thigh pain is believed to be related to stem design and implant stiffness [3, 5, 6, 9, 24, 30, 37]. The normal modulus of elasticity of cortical bone is less than 20 GPa [5], whereas most conventional metal implants occupying the diaphysis have a modulus of elasticity between 80 and 200 GPa [30, 37]; therefore, an ultrashort or tapered, polished intramedullary stem is one way to preserve femoral elasticity and avoid thigh pain. The absence of thigh pain in all but two patients in the ultrashort stem group may be attributed to rigid axial and torsional stability in the proximal femur and maintaining a normal modulus of elasticity in the diaphysis by absence of the distal stem. The two patients with severe (9 points) thigh pain in the ultrashort stem group had an unstable stem. In the conventional stem group, thigh pain might be attributed to the increase of the modulus of elasticity in the diaphysis by the presence of the distal stem.

A potential concern is whether an ultrashort stem will be sufficiently biomechanically stable to achieve durable bone ingrowth and whether longer-term clinical performance is maintained [17, 21, 22, 34]. Walker et al. [39], based on biomechanical testing, suggested that an ultrashort stem is sufficient if the stem has lateral flare. Santori and Santori [34] reported solid fixation of their custom-made ultrashort stem at a mean 8 years followup. Between 3½ and 7½ years followup, Kim et al. [16, 17, 19, 21, 22] reported firm fixation of the Proxima™ ultrashort stem. On the basis of their findings, torsional stability of the ultrashort stem can be provided without diaphyseal fixation by preservation of the femoral neck and lateral flare of the femoral component. In the current study, we observed that the performance of the ultrashort stem in our younger patients was comparable to that of the conventional cementless stems.

The Profile® conventional anatomic femoral stem used in the current study is designed for metaphyseal and diaphyseal fixation. To establish proximal load transfer, the

Table 3. Bone mineral density around ultrashort and conventional stems

| Zone | Ultrashort stem (mean/SD) | Conventional stem (mean/SD) | Difference | p value (Student's t-test) |
|----------------------------------|---------------------------|-------------------------------|------------------------|----------------------------|
| Zone 1 (g/cm²) | | | | |
| 1 week (n = 100) | 3.18 (0.28) | 3.16 (0.27) | 0.02 | 0.021 |
| 1 year (n = 95) | 3.14 (0.29) | 2.31 (0.21) | 0.83 | |
| 10 years (n = 89) | 3.25 (0.37) | 2.21 (0.21) | 1.04 | |
| 11.8 years (n = 68) | 3.29 (0.28) | 1.88 (0.18) | 1.41 | |
| Zone 7 (g/cm²) | | | | |
| 1 week (n = 100) | 3.38 (0.46) | 3.33 (0.22) | 0.05 | < 0.001 |
| 1 year (n = 95) | 3.15 (0.33) | 2.22 (0.22) | 0.93 | |
| 10 years (n = 89) | 3.10 (0.35) | 1.12 g/cm ² (0.12) | 1.98 g/cm ² | |
| 11.8 years (n = 68) | 2.97 (0.25) | 0.91 (0.09) | 2.06 | |

n = number of patients at each followup.

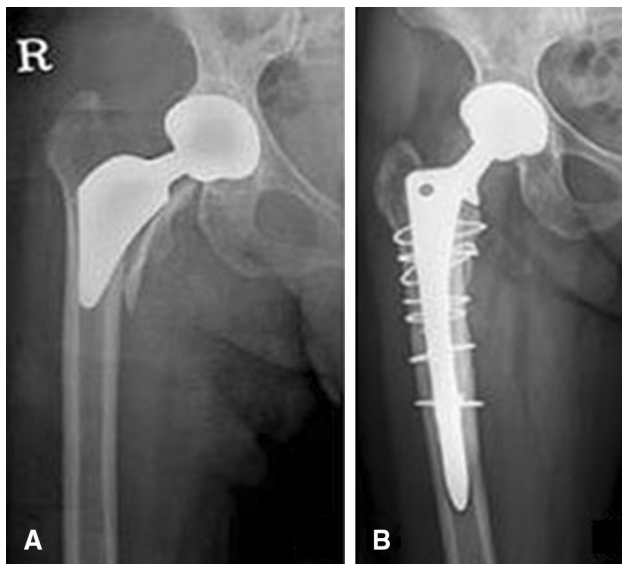


Fig. 4A–B (A) A 53-year-old woman with osteoarthritis underwent implantation of an ultrashort stem. An AP radiograph of the patient's right hip taken 2 weeks after surgery shows the stem is unstable after she experienced a fall. (B) The patient underwent revision surgery with implantation of an AML[®] cementless stem.

proximal 1/3 of the stem was porous coated and the distal stem had a matte surface. Although Kim et al. [20] reported stable fixation radiographically after a minimum 8 years followup, cortical thinning and atrophy of the proximal femur was observed in all hips, indicating distal load transfer (Fig. 6). Our results are consistent with those of the previous study by Kim et al. [20]. Results of the DEXA examination showed that BMD increased in Zone 1, but slightly decreased in Zone 7 in the ultrashort stem group and decreased in Zones 1 and 7 in the conventional stem group. These findings are consistent with those of a previous study [20]. In that study, BMD in the ultrashort stem group was reported to have increased in Zone 1 at 3 years after the surgery, but slightly decreased in Zone 7. In the

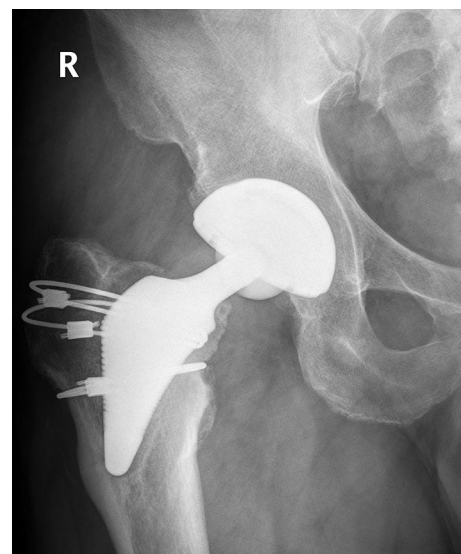


Fig. 5 An AP radiograph of the right hip of 49-year-old man with osteoarthrosis secondary to childhood pyogenic arthritis taken 1 year after implantation of an ultrashort stem shows varus tilting and subsidence of the stem.

conventional stem group, BMD decreased in Zones 1 and 7. Findings of the BMD signify that the ultrashort stem had a predominantly proximal load transfer and that the conventional stem had a predominantly distal load transfer. This phenomenon may lead to further proximal femoral bone loss in the conventional stem group with longer-term followup.

We found no difference in the proportion of stems in each group that underwent revision, and the overall percentage of hips that were revised in both groups compared favorably with percentages reported by others [28, 29, 34–36]. Although results of previous reports of short stems [16, 17, 21, 22, 26, 27, 31, 32] were good, the followup periods in those series were short. Results of our current study showed that the survival rate of the ultrashort

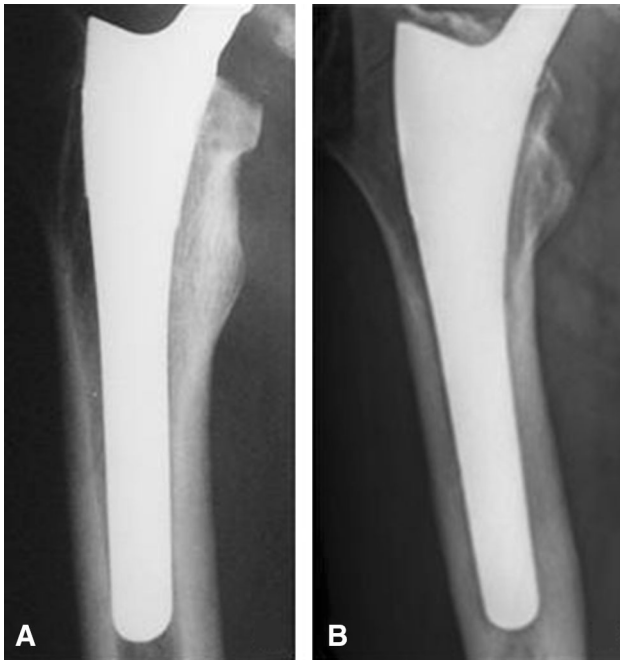


Fig. 6A–B AP radiographs of the right hip of a 48-year-old man with osteoarthritis taken (A) 1 week and (B) 13 years after surgery using a Profile® stem show stress shielding-related bone atrophy of the proximal femur.

stem had equivalent survival rates to the conventional stem at mean followup of 12 years.

When choosing a femoral stem, the surgeon should aim for optimal distribution of stress in the proximal femur, for maximal preservation of bone without compromising stability and for long-lasting fixation. At followup into the second decade, ultrashort stems showed no differences from conventional cementless stems in terms of validated outcomes scores or fixation, while showing slightly less stress shielding and less thigh pain, although this difference may not have been clinically important; in the conventional group, thigh pain was mostly mild, and there were no differences in hip scores. Reduction of stress shielding may reduce the long-term risk of periprosthetic fracture, but this was not shown here. Future studies might document the reduction of the long-term risk of periprosthetic fracture by reduction of stress shielding.

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