Progressive subsidence of a tapered, proximally coated femoral stem in total hip arthroplasty

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Abstract The purpose of this study was to determine if subsidence of a tapered, proximally porous- and hydroxyapatite-coated femoral implant with immediate postoperative weight-bearing differed between men and women. Modified Harris Hip Pain and Function Scores were collected preoperatively, and six weeks and one year postoperatively. Femoral subsidence was determined at six weeks and one year after surgery. Men demonstrated significantly increased Harris Hip Function Scores at six weeks, with slightly inferior Harris Hip Pain Scores at one year. Regardless of sex, subsidence was greater at one year than at six weeks; however, men subsided significantly more at one year than women (1.7 ± 2.0 mm vs 1.0 ± 1.4 mm, $p=0.03$). While it appears that this stem provided excellent early fixation in women, it is unclear if the increased subsidence in men was more related to patient-related factors of age, weight and activity level or with specific implant characteristics.

Résumé Le but de cette étude est de déterminer la migration et l'enfoncement d'une pièce fémorale lors d'une prothèse totale de hanche chez l'homme et chez la femme, après mise en charge immédiate, prothèse porous coated proximale recouverte d'hydroxyapatite. Matériel et méthode: le score de Harris douleur modifiée et le score fonctionnel ont été rapportés en pré-opératoire à 6 semaines et à un an post-opératoire. La migration a été également évaluée à 6 semaines et un an post-opératoire. Résultats: les hommes montrent un score fonctionnel de Harris significativement plus élevé à six semaines avec une diminution du score de

douleur à un an. Si l'on prend en compte le sexe, la migration est plus importante à un an qu'à six semaines, cependant, chez l'homme, cette migration est plus importante à un an si on la compare à celle de la femme ($1,7 \pm 2,0$ mm vs. $1,0 \pm 1,4$ mm, $p=0,03$). En conclusion, il apparaît que cette pièce fémorale donne d'excellents résultats concernant la fixation primaire chez la femme, chez l'homme la migration est un peu plus importante notamment si l'on prend également en compte les facteurs âge, poids, niveau d'activité.

Introduction

Total hip arthroplasty (THA) with cementless fixation of the femoral component has been demonstrated to provide excellent long-term results [6, 8, 10, 13, 14]. In addition, cementless components have demonstrated adequate fixation in the early postoperative period when combined with postoperative rehabilitation protocols involving the use of immediate weight-bearing [2, 3, 11, 17]. Previous investigations have initiated weight-bearing immediately after THA with a straight femoral stem and reported no difference in clinical or radiographic outcomes [3, 17]. Single- and double-tapered femoral designs have demonstrated increased subsidence in the first six weeks after surgery when combined with immediate weight-bearing, but have not resulted in significant progressive migration [2, 11].

The roles of implant design characteristics have been evaluated with regard to subsidence of the femoral stem when used with immediate weight-bearing; however, differences in proximal femoral anatomy between men and women have not been considered. In an attempt to improve outcomes following total knee arthroplasty (TKA), design characteristics of femoral components have been

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modified to address differences in distal femoral anatomy between men and women. While sex differences in distal femoral anatomy have been the focus of recent changes in TKA, potential differences in proximal femoral anatomy have not been closely evaluated with regard to THA. Women have thinner cortices, wider canals and greater age-related changes in bone mineral density and porosity than men [1, 5, 7, 12, 15]. We postulated that these factors may result in greater progressive subsidence in women with cementless femoral components when combined with immediate weight-bearing.

The purpose of this study, therefore, was to determine if progressive subsidence following cementless THA with immediate postoperative weight-bearing using a tapered, proximally porous- and hydroxyapatite-coated, femoral implant differed between men and women.

Materials and methods

Over a two-year period, a single surgeon (CPC) performed 188 consecutive primary THAs on 166 patients using a tapered, wedge-shaped femoral prosthesis with a proximal circumferential porous surface (plasma sprayed) and hydroxyapatite (HA) coating (Accolade® TMZF®, Stryker Orthopaedics, Mahwah, NJ, USA). The Accolade® stem (Fig. 1) was used on all patients that were not wheel-chair bound prior to surgery or on long-term oral prednisone > 5 mg/day during the study period. All patients provided informed consent to participate in this Institutional Review Board-approved protocol. During this time, one male patient died of acute cardiac complications following surgery and was

not included in the investigation. Also, two male patients who were revised within two months of the primary surgery were not included in the study. One patient was revised due to recurrent dislocation, and the other patient was revised for femoral loosening secondary to excessive subsidence. While we recorded the femoral revision due to 23.7-mm subsidence measured at six weeks as a complication, this value was not included in the analyses as only cases with complete radiographic series (immediately after surgery, six weeks and one year postoperatively) were included. The resulting sample included 66 women (75 hips) and 48 men (55 hips). Preoperative diagnoses included osteoarthritis (95 patients), avascular necrosis (9 patients), displaced femoral neck fracture (7 patients), post-traumatic arthritis (1 patient), developmental dysplasia of the hip (1 patient) and femoral neck non-union (1 patient).

Proximal femoral geometry was graded as Dorr type A, B or C by a single evaluator (CPC) from preoperative anteroposterior (AP) and lateral radiographs. Prior to surgery, patients were thoroughly educated as to the procedure, risks and possible complications associated with THA. After adequate premedication, the patient was taken to the operating room, placed on the operating table and anaesthesia was administered. The patient was positioned in the lateral position with bony prominences padded using the peg board. Following standard skin sterilisation and draping, THA was performed using a posterior approach with a minimal skin incision (8–15 cm).

The hip was dislocated and neck osteotomy was performed at a level determined by preoperative templating. A cookie cutter was used, followed by a starter reamer, and broaching up to the size matching that of the femoral

Fig. 1 Accolade® TMZF® femoral prosthesis, which has a tapered, wedge-fit design and proximal hydroxyapatite-coated, plasma sprayed porous surface.

a Anteroposterior view.

b Lateral view

Table 1 Comparisons of age, body mass index and preoperative diagnoses between women and men

	Women	Men	<i>p</i>
Patients	66	48	
Hips	75	55	
Age (years)	66.0±10.9*	60.4±10.4*	0.01*
Body mass index (kg/m ²)	29.7±7.0	30.6±6.0	0.48
Diagnosis			
Osteoarthritis	55	40	> 0.99
Avascular necrosis	2*	7*	0.03*
Femoral neck fracture	7*	0*	0.02*
Femoral neck non-union	1	0	> 0.99
Hip dysplasia	1	0	> 0.99
Post-traumatic arthritis	0	1	0.42

*Statistically significant ($p < 0.05$)

implant. The anteversion of the femoral broach was always approximately 20–25° using the position of the tibia and lesser trochanter as a guide. This routinely required rotating the broach by as much as 20° within the native femur in order to ensure hip stability. Standard and lateralised versions of the Accolade® stem were used, with 132 and 127° neck angles, respectively. The lateralised version was used in 97 hips and the standard version was used in 33 hips. All patients also received cementless acetabular components with HA- and porous-coated shells. In 74 hips, HA Secure-fit® acetabular components (Stryker Orthopaedics, Mahwah, NJ, USA) were used, and 56 hips received Trident PSL® (Stryker Orthopaedics, Mahwah, NJ, USA). Ceramic liners (Trident Alumina®, Stryker Orthopaedics, Mahwah, NJ, USA) were used in 45 hips, 65 hips received liners composed of highly cross-linked polyethylene (Cross-Fire®, Stryker Orthopaedics, Mahwah, NJ, USA) and 20 hips with traditional polyethylene (N₂Vac, Stryker Orthopaedics, Mahwah, NJ, USA).

Following wound closure, each patient was taken to the recovery room where a postoperative AP pelvis radiograph was taken immediately following the procedure. Approximately two to six hours after surgery, patients began immediate weight-bearing as tolerated under the supervision of a physical therapist. During inpatient therapy, patients were encouraged to use a walker for support and balance. Once discharged, patients were instructed to progress from a walker to a cane with the guidance of a physical therapist. Patients were instructed to use a cane until they felt they were walking without a limp.

Repeat radiographs were performed at the six-week and one-year follow-up visits. Subsidence was determined by comparing measurements taken from the immediate postoperative radiographs with those taken six weeks and one year after surgery. A single evaluator (CAJ) measured the distance between the most proximal point on the greater

trochanter and the most prominent point of the superior lateral aspect of the proximal body of the stem. The diameter of the acetabular cup was also measured on each film and was used to correct for differences in magnification. Subsidence greater than 3 mm was considered clinically significant [11], and a 2×2 mixed model analysis of variance (ANOVA) (time × sex) was used to compare six-week and one-year subsidence values between men and women. Two-tailed, independent *t*-tests were used to assess differences in age and body mass index (BMI) between sexes, and Fisher exact tests were used to determine if the sexes differed by preoperative diagnosis or prevalence of Dorr type A, B and C femurs. In addition, modified Harris Hip Scores [9] were recorded for each patient preoperatively, as well as six weeks and one year after surgery, and were compared using Mann-Whitney tests. SPSS version 15.0 (SPSS Inc., Chicago, IL, USA) was used to perform all analyses, and $p \leq 0.05$ was considered significant.

Results

The women evaluated in this study were significantly older than the men (66.0±10.4 vs 60.4±11.4 years, $p = 0.01$); however, BMI did not differ between the sexes. Women had a significantly greater prevalence of femoral neck fractures whereas men had a greater prevalence of avascular necrosis (AVN) (Table 1); however, the sexes did not differ in the prevalence of Dorr type A, B and C femurs ($p > 0.05$). Men had significantly increased Function Scores at six weeks, and, although not statistically significant ($p = 0.07$), men had inferior Pain Scores at one year (Table 2).

Regardless of sex, there was significant progressive subsidence between the six-week (0.7±1.2 mm) and annual follow-ups (1.3±1.7 mm, $p \leq 0.0001$). At six weeks, 3/130 hips (2.3%) demonstrated subsidence > 3 mm, which increased to 13 hips (10%) at 1 year. The sex main effect was not significant ($p = 0.06$), but there was a significant

Table 2 Results of Mann-Whitney tests comparing preoperative, 6-week and 1-year modified Harris Hip (mHHS), Pain and Function Scores between women and men

	Women	Men	<i>p</i>
Preoperative mHHS (/100)	33.9±15.3	35.2±13.4	0.86
Pain (/44)	10.9±9.7	11.5±7.8	0.63
Function (/47)	20.0±7.1	20.6±7.8	0.77
Six-week mHHS (/100)	63.9±12.5	68.0±12.8	0.10
Pain (/44)	37.6±7.9	37.7±8.9	0.78
Function (/47)	20.5±7.4*	24.1±6.0*	0.04*
One-year mHHS (/100)	77.3±11.2	72.7±16.4	0.17
Pain (/44)	42.1±5.5	38.9±10.2	0.07
Function (/47)	28.1±8.3	27.2±7.5	0.27

*Statistically significant ($p < 0.05$)

Table 3 Sex differences in subsidence 6 weeks and 1 year after surgery

	Women	Men	<i>p</i>
Six weeks	0.7±1.3 mm	0.9±1.2 mm	0.32
One year	1.0±1.4 mm*	1.7±2.0 mm*	0.03*

*Statistically significant ($p<0.05$)

time $\times$ sex interaction ($p=0.03$). There was no difference in subsidence between men and women at the six-week follow-up ($p=0.31$); however, men demonstrated significantly increased subsidence at one year (Table 3). To date, two male patients (two hips) have been revised for femoral loosening secondary to excessive subsidence (Fig. 2). The patients were revised eight weeks and three years after the primary procedure, respectively.

Discussion

The purpose of this study was to determine if the amount of progressive subsidence of a tapered, proximally HA- and porous-coated femoral stem differed between men and women in the first postoperative year when used in combination with immediate postoperative weight-bearing. Many factors influence implant migration in the first postoperative year. These factors include postoperative weight-bearing protocols; patient-related factors such as sex, age, weight and activity level; and design characteristics of the femoral stem.

Regardless of sex, the significant progressive subsidence demonstrated in this study does not concur with previous investigations that suggest immediate weight-bearing after cementless THA with either straight or tapered stems does not result in altered fixation of the femoral implant [2, 3, 11, 17]. Our subsidence results were very similar to a previous study of a single-tapered, porous-coated, cementless stem (Taperloc®, Biomet, Warsaw, IN, USA) that began weight-bearing as tolerated on the day after surgery [11]. We report subsidence values of 0.7 mm at six weeks and 1.3 mm at one year, compared to 0.86 mm at six weeks and 1.36 mm at two years reported by Rao et al. [11]. Rao et al. [11] reported greater subsidence at six weeks in patients undergoing simultaneous bilateral THA with immediate weight-bearing compared to patients undergoing unilateral THA who were restricted to 10% weight-bearing for six weeks following surgery (0.86 and 0.39 mm, respectively). Since no differences in subsidence existed between the groups between six weeks and two years postoperatively, Rao et al. [11] concluded that differences in subsidence occurred in the first six weeks. Their conclusion is consistent with many previous investigations that have reported excellent long-term fixation by bony ingrowth with porous-coated tapered stems [6, 8, 10, 13, 14]. However, the statistical analyses performed by Rao et al. [11] did not specifically evaluate whether femoral subsidence significantly increased between the six-week and two-year follow-ups, as their primary purpose was to evaluate differences between patient groups treated with two different weight-bearing protocols. To our knowledge, our study is the first to evaluate and report significant progressive subsidence in the first postoperative year.

Fig. 2 Progressive subsidence of a tapered femoral stem in a male patient between 6 weeks (a) and 3 years (b) after surgery

Furthermore, subsidence in this investigation was significantly greater in men one year after surgery than women—the exact opposite of our original hypothesis. The men in this study were significantly younger than the women. In a study of a double-tapered cementless stem, Bottner et al. [2] reported that patients who demonstrated progressive subsidence over the first two postoperative years were younger and heavier. The authors further stated that younger, heavier patients may be more active, thus placing increased demands on the implant. It should also be noted that men in our investigation demonstrated significantly increased functional scores six weeks after surgery. Considering the results of Bottner et al. [2], it is therefore logical that the younger men with increased early function would demonstrate increased subsidence one year after surgery. Men not only demonstrated significantly increased subsidence at one year, but also demonstrated inferior pain scores at this time point ($p=0.07$). While the causes of delayed pain relief at one year are multifactorial, our results may indicate delayed bony ongrowth by the male femora onto the stem and/or delayed muscle/soft tissue recovery.

While to our knowledge no published studies have directly addressed the issue of sex-related anatomical differences and implant migration, some surgeons have recently suggested that due to the aforementioned differences in bone geometry and quality, women may need a relatively larger femoral component in order to ensure proximal fixation. Our study used a tapered titanium femoral component with proximal porous and HA coatings. The combination of porous and HA coatings has been demonstrated to decrease loss of bone mineral density in the first 2 postoperative years, suggesting improved osseointegration of the femoral component [16]. The composition, geometry and proximal coatings of this implant appear to result in excellent early fixation in women, even when combined with immediate weight-bearing.

On the contrary, men in this study demonstrated significantly increased subsidence at one year, which coincided with inferior pain scores when compared to women. Subsidence and pain may be related to both patient- and implant-related factors. Men in this study were younger with increased early function—both of which have been suggested to increase subsidence [2]. Increased early function may also result in increased pain. Chandler et al. [4] suggested that younger, faster patients may place excessive demands on their hips and may require prolonged use of assistive ambulatory devices in order to protect the hip musculature in the early postoperative period. However, patients in our investigation were allowed immediate weight-bearing as tolerated, which may partially explain both the increased functional scores at six weeks and increased pain at one year in men.

This study did have several limitations. While sex differences were noted in the first postoperative year, longer follow-up is required to determine if these differences are related to implant longevity. Also, despite our attempts to account for differences in magnification, variability in patient positioning, exposure and other factors may introduce error in radiographic measurements of stem subsidence. The accuracy of the manual radiographic measurement technique used certainly does not yield the accuracy of radiostereometric analyses; however, the manual technique used allowed us to evaluate a relatively large sample size compared to more involved measurement techniques. We also caution the reader that these results cannot be generalised to other cementless stem designs, as this investigation used only the Accolade® stem. Future study is warranted to determine if sex differences noted in this study are consistent with other implant designs and, again, to determine if these differences in the early postoperative period are related to long-term fixation of the implant.

In conclusion, significant progressive subsidence of a proximally porous- and HA-coated tapered femoral stem was observed when patients were allowed immediate weight-bearing as tolerated. A group of older women demonstrated improved clinical and radiographic outcomes when compared to men, and 2/48 (4.2%) male patients required revision of a loosened femoral component within the first three years after surgery. While demonstrating improved clinical and radiographic outcomes at the one-year follow-up for women, it is unclear if the increased subsidence demonstrated by men was related more to age or early function of the patients, or to specific implant design characteristics. Surgeons who use immediate postoperative weight-bearing protocols may need to consider patient age, weight, sex and activity level when selecting a cementless femoral component.

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