Radiographic Subsidence in Asymptomatic Patients After THR Using the Furlong Active HAP Stem

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Received: 29 April 2012/Accepted: 12 May 2013 / Published online: 21 June 2013
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Abstract *Background:* The short, tapered, collarless Furlong Active stem has been recently associated in the published literature with significant subsidence using Roentgen stereophotogrammetric analysis. *Questions/Purposes:* The purpose of this study was to analyze the short-term radiographic subsidence in Furlong Active HAP stems and correlate the results with the age, gender, bone morphology, and bone quality of the proximal femur, stem diameter, and medullary canal filling. *Methods:* Sixty-five consecutive patients (70 hips) receiving the Furlong Active HAP stems were enrolled in this prospective series. The average follow-up was 2.99 ± 1.38 years. All patients were evaluated clinically using the Harris Hip Score (HHS) and radiographically for femoral stem subsidence. In addition, proximal femoral osteopenia, proximal femur morphology, and medullary canal filling were also evaluated. *Results:* The average subsidence was 2.4 mm (from 0 to 13 mm) at the end of the follow-up period. The average HHS score at the end of follow-up was 90 (range, 81–98). There was one

intraoperative fracture. *Conclusions:* Of the Furlong Active stems 61% subsided with initial weight bearing. Subsidence is higher in males, but no correlation has been found with age, stem diameter, morphology, osteopenia, or canal filling.

Keywords subsidence · cementless · stem · Furlong Active

Introduction

Subsidence is frequently reported in cementless stems. The published reports on subsidence in cementless hip stems reflect a great variability ranging from an average of 0.45 to 2.23 mm [11, 14, 16, 19, 20, 24, 27] as well as in the proportion of stems with subsidence, from 0.5% to 10% [2, 7, 13, 17, 27]. Some authors describe this finding early in the postoperative period up to 3 months [25, 26], 1 year [8], or 2 years [4]. Factors related with the subsidence of some stems included male patients [12], osteoporotic bone [18], Dorr type C proximal femur [27], undersized stem [1], or a large stem diameter [27].

Furlong stems (JRI, London, UK) have demonstrated good clinical and radiographic survivorship (99% after 13 years) [21]. The fully coated hydroxyapatite Furlong Active stem was introduced in 2006 and differs from the “classical” Furlong stem as it does not have a collar, has a longer and thicker metaphyseal segment, a shorter diaphyseal stem, and a more “tapered” design (Fig. 1). By 2010, the published literature reported an average subsidence measured with Roentgen stereophotogrammetric analysis (RSA) of 0.99 mm (0.38–1.6) with this new stem after 6 months (three times greater than that of the “classical” stem) [22, 23].

The present study aims at answering several questions: first, to determine the actual subsidence of the Furlong Active HAP stem; secondly, to identify possible risk factors associated with radiographic instability and subsidence including gender, age, proximal femoral morphology, and bone quality; and, finally, to determine

Level of Evidence: Therapeutic Study, Level IV (Case Series, No Control Group)

Electronic supplementary material The online version of this article (doi:10.1007/s11420-013-9342-z) contains supplementary material, which is available to authorized users.

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Fig. 1. Furlong vs. Furlong Active.

whether or not stem diameter or medullary filling (factors that are not patient-related) played a significant role in femoral stem subsidence.

Patients and Methods

Our institutional Ethical Review Committee approved this prospective, non-randomized study. Seventy consecutive primary total hip arthroplasties using the Furlong Active HAP stem were performed by the author (JCA) in 65 patients from June 2006 to July 2011. The average age was 64 years (range, 27–80 years). There were 26 female patients and 39 male patients. No patient was lost to follow-up. All 65 patients (70 total hip arthroplasties) were available for review at the end of follow-up period and continued to be reviewed periodically in external office.

The operative indications for a Furlong Active total hip arthroplasty were chronic severe pain and functional limitation (accounting for a total Harris Hip Score (HHS) score under 50) because of a chronic hip disease (excluding acute hip fractures), an advanced radiographic hip disease with a disappearing joint line, age under 81 years, and absence of local radiotherapy/chemotherapy/local cancer. The inclusion criterion was all patients operated with a Furlong Active HAP stem. The exclusion criterion was any sign of infection along follow-up.

Table 1 Number of cases according to osteopenia degree, femoral morphology, and stem diameter

Osteopenia (Singh)	1	2	3	4	5	6
No. of cases	1	10	22	24	10	2
Femur morphology (Dorr)	A	B	C			
No. of cases	38	24	8			
Stem diameter	9	10	11	12		
No. of cases	19	15	22	14		

One asymptomatic patient along 2 years after surgery suffered a fall from a stairs and then presented progressive pain and radiological loosening; considered a mechanical loosening, the stem was exchanged by a revision Furlong long stem. Multiple intraoperative cultures were positive for *Staphylococcus epidermidis*; the patient was diagnosed of a Tsukayama type IV infection and treated with oral combined antibiotics for 6 months. Clinical and radiological results are good 3 years after surgical revision. This case is not considered for statistical analysis.

The Furlong Active HAP prosthesis was inserted via a posterolateral approach to the hip joint. The stem diameters are presented in Table 1. After femoral neck osteotomy and acetabular preparation, the medullary canal of the femur was accessed with a Moore quadrangular chisel and a long spoon and finally prepared line to line with standard diaphyseal and metaphyseal reamers. Hip stability and limb length were repeatedly checked with the trial components and with the final implants.

All patients were indicated bed rest the day after surgery, when the postoperative X-ray was taken. On the second postoperative day, the drainage was removed and patients were allowed to sit. On the third day after surgery, they began partial weight bearing with the help of two crutches. Patients were sent home according to their ability to walk with two crutches from the 6th to the 14th postoperative days.

Patients were followed clinically and radiographically at 1, 3, 6, 12, 36, and 60 months after surgery. No patient was lost to follow-up. The average follow-up of the total series is 2.99 ± 1.38 years, with a minimum of 1 year and a maximum of 5 years.

Clinical evaluation was performed using the HHS. Additionally, we asked specifically for thigh pain from all patients at each of the visits. Standard anteroposterior radiographs of the pelvis and “frog-lateral” radiographs of the hip were obtained immediately after the operation and at each follow-up visit following the same X-ray protocol. The patient was positioned supine with his/her feet together. The X-ray tube was positioned over the symphysis pubis 1 m from and perpendicular to the table. To reduce inter-observer error, measurements were made by a single author (PP) who had not been involved in surgery. Intra-observer variability was not measured. All measures were obtained with the digital X-ray software of the hospital (Centricity Enterprise Web 3.0, General Electric Medical Systems). Magnification error was addressed using the known diameter of the prosthetic femoral head as an internal reference. Each distance/value was measured three times in each of the films and the average calculated. Subsidence was measured as the perpendicular distance from the tip of trochanter to the “shoulder” of the stem (Fig. 2).

Fig. 2. Subsidence measurement.

Preoperative proximal femoral osteopenia was graded in six stages according to Singh et al. [23] (Table 1). Proximal femoral morphology was classified according to Dorr et al. [5] as “A” (“champagne glass”), “B” (“intermediate morphology”), or “C” (“fluted” or “cylindrical”; Table 1).

Femoral medullary canal filling was calculated as the ratio of the width of the stem to the width of the medullary canal.

Femoral component fixation was graded as radiographic bone ingrowth, fibrous stable, or unstable according to the criteria for porous prostheses as described by Engh et al. [6]. Heterotopic ossification was classified using the Brooker classification. A zonal analysis was performed in the zones described by Gruen et al. [10] along follow-up radiographs looking for focal osteolysis [9] and radiolucent lines.

Statistical Analysis

Arithmetic mean, standard deviation, and range have been calculated for quantitative variables. Qualitative variables have been expressed as counts and percentages. A p value of <0.05 was considered to be significant for all statistical tests. The influence of gender was analyzed with Student’s t test. Correlation of Dorr type was evaluated using ANOVA and Student’s t test. The influence of age, Singh, stem size, and canal filling was analyzed with Pearson’s correlation test.

Results

Sixty-one percent of stems (42/69, after excluding the infected one, as explained before) suffered some degree of radiological subsidence as measured from the immediate postoperative to the 1-month X-ray control (along this period, patients began partial weight bearing with two crutches).

This subsidence averaged 2.4 ± 2.96 mm (from 0 to 13 mm). After 1 month, no additional subsidence has been measured.

HHS averaged 90.3 (range, 81–98) at the end of follow-up after excluding the infected case. The clinical results may be considered excellent (HHS from 91 to 100) in 78% of patients and good (HHS from 81 to 90) in 22% of patients. The average score for pain was 43/44 and for function was 42/47. The main complaints from patients were related to difficulties with climbing stairs and putting on shoes. Up to now, and with the present follow-up, no clinical consequences have been observed. Those patients with stems at the high end of the subsidence values fared clinically as well as those without subsidence, even those with subsidence over 10 mm.

According to postoperative X-ray, 48 (68.6%) stems were implanted in the neutral position ($\pm 2^\circ$ from the longitudinal axis of the femur), 19/70 (27.1%) in varus, and 3 (4.3%) in valgus; no changes in this initial position were observed along the follow-up. Radiolucent lines narrower than 1 mm and of partial length (not extending along all Gruen zones) were identified around nine stems (12.9%) in zones 1, 3, 6, and/or 7. Excluding the infected patient (with a radiologically unstable stem), all 69 stems presented radiological signs of bone ingrowth along the follow-up according to Engh’s criteria; not one case was diagnosed as fibrous-stable or unstable.

Radiological subsidence correlated statistically with gender, being higher in men (2.87 ± 3.4 mm) than in women (1.47 ± 1.7 mm, $p=0.029$), but did not correlate with age ($r=0.00002$). The measured radiological subsidence is neither statistically correlated with proximal femoral morphology (Dorr types A, B, or C; $p=0.136$) nor is correlated with proximal femur osteopenia (Singh degrees 1–6; $r=0.020$).

Femoral medullary canal filling, calculated as the ratio of the width of the stem to the width of the medullary canal, measured 0.62 ± 0.16 at level A (proximal part of the cylindrical diaphyseal stem) and 0.75 ± 0.18 at level B (distal part of the cylindrical diaphyseal stem) [3]. The measured radiological subsidence is neither statistically correlated with medullary canal filling in the proximal ($r=-0.008$) or distal regions ($r=0.037$) nor with stem diameter ($r=0.293$).

One patient suffered an intraoperative crack in the calcar, treated by non-weight bearing for 3 months; HHS scored 87 at the end of the follow-up and total subsidence was 6 mm. Two patients presented a recurrent dislocation; after the third episode, they were surgically revised with exchange of the cup (one too anteverted and the other too horizontal). The stem was found to be solidly fixed intraoperatively in both cases at the time of the acetabular revision. One patient presented Brooker III heterotopic ossifications with HHS=85. Fortunately, this patient presented a clear tip

of the greater trochanter in spite of the ossifications, so this reproducible landmark was successfully used.

Discussion

Subsidence is frequently reported in cementless stems [2, 7, 11, 13, 14, 16, 17, 19, 20, 24, 26, 27]. The factors related include male patients [12], osteoporotic bone [18], Dorr type C proximal femur [27], undersized stem [1], or a large stem diameter [27]. Furlong Active stems (JRI), introduced in 2006, present some differences with the “classical” one: absence of collar, longer and thicker metaphyseal segment, shorter diaphyseal stem, and a more “tapered” design. A recent paper has communicated a subsidence up to three times higher than that of the “classical” stem when analyzed by RSA [22, 23]. It has been our purpose to analyze short-term radiological subsidence in Furlong Active HAP stems as well as correlations with age, gender, osteopenia, and morphology of the proximal femur, stem diameter, and medullary canal filling.

The main limitation of this study is the lack of intra-observer reliability measure. Nevertheless, each measure was repeated three times and the average calculated, minimizing this intra-observer variability.

A minor limitation is the short follow-up for total hip, 2.99 ± 1.38 years (range, 1–5 years). We have not observed clinical (pain, thigh pain) or radiographic (loosening, progressive radiolucent lines) consequences of the analyzed subsidence up to now. Nevertheless, the measured subsidence is a limited phenomenon which develops when patients begin weight bearing in some femoral stems (pure metaphyseal or suprametaphyseal loading stems have shown negligible subsidence), so, after this initial settlement, a definitive stationary situation without further migration could be expected. According to the literature, most of the subsidence in cementless stems occur within the first 2 years [4, 8, 25, 26].

Another minor limitation is the size of the series, limited to 69 stems. It could be speculated that a larger series would be able to reach statistical significance, but statistical correlations are so low (the highest was 0.293), which clearly do not point to any tendency. A larger series probably would not be significant either.

Subsidence is greater and more frequent in our series than in those published previously, being radiographically measurable in 61% of our Furlong Active stems. The literature offers great variability in the proportion of stems with sinking, from 0.5% to 36% [2, 7, 8, 13, 17, 26, 27]; these figures vary according to the threshold established by each author [27], but our percentages are much higher than the published ones. Moreover, we measured an average subsidence of 2.4 ± 2.96 mm (from 0 to 13 mm), clearly higher than the 0.99 mm reported by Simpson et al. [22] with the same stem. Most papers about other stems report great variability in average sinking, from 0.005 to 2.23 mm [2, 4, 11, 12, 14–16, 19, 20, 24, 25, 27]; nevertheless, all these figures are smaller than ours. We have detected subsidence only along the first month after surgery, from immediate postoperative to 1 month control; some authors have also described the finding

as appearing only along the initial phases of the arthroplasty, from the postoperative period to 3 months [25, 26], 6 months [4], 1 year [8], or 2 years [25, 26].

Subsidence in our Furlong Active stems is correlated with gender, being greater in men (2.87 ± 3.4 mm) than in women (1.47 ± 1.7 mm, $p=0.029$). This finding is similar to that reported by Jacobs and Christensen [12], who also described more subsidence in male patients. On the contrary, subsidence is not correlated at all with age ($r=0.00002$).

Subsidence in our Furlong Active stems is not statistically correlated with proximal femoral morphology ($t=0.136$), as is the case for other series [27]. On the contrary, one paper [27] does establish a significant increase of the phenomenon in those patients with a Dorr C proximal femur. Similarly, subsidence in our series is not statistically correlated with Singh degrees ($r=0.020$), as is also published by other authors [27], but an experimental study in vitro relates osteoporotic bone with sinking and fractures [18].

Subsidence is not statistically correlated with stem diameter implanted in our patients ($r=0.293$), but this is not the case in a published series of Accolade stems in which the finding is associated with larger stem diameters [27]. Correspondingly, subsidence in our Furlong Active is not correlated with medullary canal filling in the proximal ($r=-0.008$) or distal regions ($r=0.037$), as also published for other designs [27], although a paper describes an association of undersized stems, late progressive subsidence (after 10 years), and aseptic loosening [1].

According to the literature, cementless stems show early radiological sinking quite frequently, but Furlong Active stems subside more and more frequently than usually reported. In this series, subsidence was greater in male patients, but was not related to age, femoral geometry, osteopenia, stem diameter, or canal filling. Up to now, this finding has had neither clinical nor radiographic consequences, but periodic and long-term follow-up is compulsory.

Disclosures

Conflict of Interest: José Cordero-Ampuero, MD, PhD received travel support for meetings from MBA for the study; is a paid consultant for Pfizer, receives payment for presentation from MSD and Pfizer and travel support from MBA, Sanofi and Stryker, outside the work. Pablo Peñalver, MD, received travel support for meetings for the study from MBA; receives travel support from Sanofi, Rovi, Pfizer, and MBA, outside the work. Rodrigo Antón, MD received travel support for the study from MBA, Sanofi, and Rovi; received travel support from Sanofi and Rovi, outside the work. María Galán, MD, received travel support for meetings for the study from MBA; received travel support from MSD, Pfizer, Sanofi, and Rovi, outside the work. Enrique Cordero declared that he has no conflict of interest.

Human/Animal Rights: All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2008 (5).

Informed Consent: Informed consent was obtained from all patients included in the study.

Required Author Forms Disclosure forms provided by the authors are available with the online version of this article.

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