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Basic Science

Difference in Postoperative Periprosthetic Bone Mineral Density Changes Between 3 Major Designs of Uncemented Stems: A 3-Year Follow-Up Study

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ABSTRACT

Background: Although few studies have examined the direct effect of stress shielding on clinical outcomes, periprosthetic bone loss due to stress shielding is still an issue of concern, especially when physicians perform uncemented total hip arthroplasty (THA) in younger patients. Differences in femoral stem design may affect the degree of postoperative stress shielding. Therefore, the characteristics of the behavior for stress shielding of each type of femoral stem should be determined. This study compares differences in bone mineral density (BMD) change in the femur after primary THA between 3 major types of uncemented stems.

Methods: Among a total of 89 hips, 26 hips received THA with a fit-and-fill type stem (VerSys Fiber Metal MidCoat; Zimmer, Inc, Warsaw, IN), 32 hips received a tapered rectangular Zweymüller-type stem (SL-Plus; Smith & Nephew Inc, Memphis, TN), and 31 received a tapered wedge-type stem (Accolade TMZF; Stryker Orthopaedics, Mahwah, NJ). BMD measurements were performed with a HOLOGIC Discovery device (Hologic Inc, Waltham, MA).

Results: BMD in the medial-proximal femur was maintained for 3 years after THA in the group with the tapered wedge-type stem. BMD in the lateral-proximal femur was maintained for 3 years after THA in the group with the Zweymüller-type stem. There were no significant differences in the Harris Hip Score among the 3 stem groups preoperatively and 1, 2, and 3 years after surgery.

Conclusion: There are clear differences in postoperative BMD loss of the proximal femur among these 3 commonly used uncemented stems.

In total hip arthroplasty (THA), the use of cemented or uncemented implants remains controversial; however, the use of uncemented implants is increasing in most national registries [1]. Various types of uncemented implants are commercially available at present. Khanuja et al [2] classified uncemented femoral stem designs into 6 types according to the geometry and fixation mode. They described that a number of uncemented femoral stems are associated with excellent long-term survivorship and that loosening and thigh pain are less prevalent with modern stem designs. However, stress shielding is present in most cases, even with newer stem designs.

Resorptive bone remodeling, secondary to stress shielding, is a concern associated with uncemented THA. Previous studies suggest that aseptic loosening of the implant due to bone destruction as a result of stress shielding is the leading cause of implant failure [3-5]. Although few studies have examined the direct effect of stress shielding on the clinical outcome, periprosthetic bone loss due to stress shielding is still an issue of concern especially when physicians perform THA in younger patients.

Stress shielding is especially one of the major concerns in the use of fully coated porous stems. Even with a tapered stem, a high frequency of severe stress shielding was reported in one type of femoral stem [6]. Differences in femoral stem design may affect the degree of postoperative stress shielding. Therefore, the characteristics of the behavior for stress shielding of each type of femoral stem should be determined.

In the present study, we aimed to compare postoperative changes in the bone mineral density (BMD) of the femur around the stem and radiological findings related to stress shielding and stem

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fixation among 3 different types of uncemented femoral stems. The uncemented femoral stems used in this study had different initial fixation concepts (types 1, 2, and 3C according to Khanuja et al's classification [2]), and the 3 stem designs are commonly used in many countries. We investigated the characteristics and differences in postoperative BMD change among these 3 major stem designs.

Materials and Methods

This retrospective study was approved by our institutional review board and all subjects provided informed consent. We reviewed the electronic medical records of 281 patients who underwent primary uncemented THA for osteoarthritis of the hip in our institution between November 1, 2006 and March 31, 2011. We had changed the type of uncemented stem used in our institution twice during the study period, so 3 types of stem were examined in the present study. The VerSys Fiber Metal MidCoat (VerSys FMM) stem (Zimmer, Inc, Warsaw, IN; November 2006-October 2008) has a circumferential titanium fiber-mesh surface in its trapezoidal proximal part, which improves proximal fill and rotational stability. The distal part of this stem is tapered and polished to avoid distal fixation [7]. The SL-Plus stem (Smith & Nephew Inc, Memphis, TN; October 2008-September 2010) is a so-called "third-generation Zweymüller stem," which has a tapered rectangular-shape and grit-blasted titanium surface on its entire length. The SL-Plus is designed to be fixed at the metaphyseal-diaphyseal junction of the proximal femoral canal [8]. The Accolade TMZF stem (Stryker Orthopaedics, Mahwah, NJ; May 2009-March 2011) is a tapered wedge designed stem which has a thin, flat body to preserve bone stock of the proximal femur and circumferential porous coating on its proximal side to enhance biological fixation between the bone and the stem [9] (Fig. 1).

From a total of 281 cases, we excluded subjects who had taken any bone-modulating drug (ie, vitamin D, bisphosphonates, or recombinant parathyroid hormone and its analogues) before surgery or within 3 years after the index surgery. Six cases with intraoperative femoral calcar crack were also excluded because the cerclage wire used for those cases would compromise the results of the dual-energy X-ray absorptiometry (DEXA) scans. This left 89 hips from 89 subjects (89 of 281: 31.6%), which were included in our study. Of those 89 hips, 26 hips received the VerSys FMM stem, 32 hips received the SL-Plus stem, and 31 the Accolade TMZF stem.

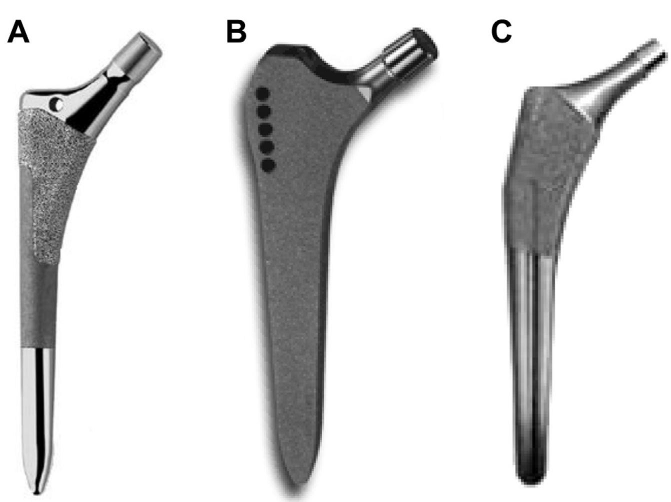

Fig. 1. Three stems used for comparison in the present study. (A) VerSys Fiber Metal MidCoat (Zimmer, Inc., Warsaw, IN), (B) SL-Plus (Smith & Nephew Inc., Memphis, TN), and (C) Accolade TMZF (Stryker Orthopaedics, Mahwah, NJ).

Standardized anteroposterior (AP) and lateral radiographs taken at the first postoperative week and third postoperative year were used for radiologic assessment. The AP projection was centered on the symphysis pubis and was taken at a standard distance of 1 m. The width of the proximal femoral canal on the operated side was measured from preoperative AP radiographs of the hip, with Noble et al's canal flare index (CFI) calculated for each patient [10]. Applying the original methods of CFI calculation, measurements of metaphyseal width were taken 2 cm proximal to the superior surface of the lesser trochanter, with measurements of the diaphyseal width taken 10 cm distal to the same reference point. Based on Noble et al's classification, femurs were divided into 3 groups of femoral canal shapes: champagne flute (CFI: $\geq$4.7), intermediate (CFI: 3-4.7), and stovepipe (CFI: $<$3). We evaluated the degree of postoperative stress shielding and stem subsidence using the AP radiograph of the operated hip taken at the third postoperative year. Postoperative stress shielding was assessed according to Engh et al [11]. They categorized the degree of stress shielding into 4 levels: a slight round-off in the medial edge of the femoral neck being first degree; significant rounding off of the medial edge of the neck combined with resorption of the calcar femorale corresponding to second-degree stress shielding; resorption of the medial cortex below the lesser trochanter was classified as third-degree stress shielding; and cortical resorption extending to the diaphysis was defined as fourth-degree stress shielding. Amount of stem subsidence was measured by comparing AP radiographs taken at the first postoperative week and 3 years after surgery. The distance between the most proximal point of the greater trochanter and the lateral shoulder of the stem was measured to assess the sinking distance of the stem [12].

BMD measurements were performed using a HOLOGIC Discovery device (Hologic Inc, Waltham, MA). Preoperative scans of the lumbar spine (L2-L4) were acquired to assess the systemic skeletal status of the subjects. The lumbar BMD values were evaluated using the T-score, which represents the number of standard deviations from the mean BMD of the young adult population of the same sex. We also obtained postoperative DEXA scans in the AP projection on the operated proximal femoral region at the first postoperative week as a reference, then at 6, 12, 24, and 36 months after THA. We set the femur at the first postoperative week as a reference to avoid the effect of the removal of bone during the index surgery. We used Gruen's zones [13] to assess the BMD change in the femur around the stem. The scans of the postoperative femur were analyzed using the manufacturer-provided software to exclude the metal region from the scan area and calculate the apparent BMD (g/cm^3) in each Gruen's zone. The BMD measured at each follow-up period was converted to a percentage ratio relative to the baseline reference at 1 week postoperatively. We compared the average percentage change in the BMD at each Gruen's zone among the 3 types of stem. We assessed clinical outcomes using the Harris Hip Score (HHS) [14] measured preoperatively and 1, 2, and 3 years after surgery.

Numerical data were expressed as mean and standard deviation. One-way analysis of variance test and Fisher's exact test were used to compare the data among the 3 groups. *P* values in multiple pairwise comparisons following one-way analysis of variance test were adjusted using Tukey's method. All statistical analyses were performed using R software, version 3.0.1 (R Foundation for Statistical Computing, Vienna, Australia). A significance level of $P < .05$ was used.

Results

Table 1 shows the demographic data of the subjects by implanted stem type. The mean age of the subjects was 62.7 ± 10.1