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Comparison of Different Materials and Proximal Coatings Used for Femoral Components in One-Stage Bilateral Total Hip Arthroplasty

Kazumasa Miyatake, MD, PhD, Tetsuya Jinno, MD, PhD, Daisuke Koga, MD, PhD, Yuki Yamauchi, MD, PhD, Takeshi Muneta, MD, PhD, Atsushi Okawa, MD, PhD

Department of Orthopaedic Surgery, Medical Hospital, Tokyo Medical and Dental University, Tokyo, Japan

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ABSTRACT

To evaluate the mid-term effects of different materials and coatings used for femoral components, we prospectively performed 21 one-stage bilateral total hip arthroplasties using 2 anatomical stems which have identical geometries, randomized to side. One stem was made of Ti6Al4V alloy and had a hydroxyapatite coating on grit-blasted surface proximally, and the other was made of TMZF™ alloy and had a proximal coating of hydroxyapatite in addition to an arc-deposited titanium surface coating. Although we found extensions of radiopaque lines to the surface of coatings of seven grit-blasted stems whereas we found none in the case of the arc-deposited titanium stems, all hips showed excellent clinical and radiological outcomes as shown by radiographs and bone mineral density at the final follow-up, average 5.5 years postoperatively.

Total hip arthroplasty (THA) is widely recognized as a successful and effective treatment of degenerative joint disease, and it has been projected that there will be drastic increase in the number of THAs to be performed [1,2]. Although many excellent clinical and radiographical outcomes of cementless THA have been reported, periprosthetic bone loss such as wear-related osteolysis and late periprosthetic bone resorption due to stress shielding still remains an issue of concern and may lead to revision surgery or make revision surgery difficult [3–6]. Moreover, as THA has recently been indicated in relatively young patients who have a higher rate of revision surgeries than elderly patients, such postoperative bone-related problems are an issue [7]. Therefore, selecting an optimal implant is one of the most important steps in total hip arthroplasty to obtain better survival of THA and more proximal fixation.

Wear-related osteolysis seems to have been greatly reduced with the introduction of highly cross-linked polyethylene liners [8]. Nevertheless, late periprosthetic bone resorption of the femoral side due to stress shielding remains unsolved [6,9,10]. Therefore, stems with surface modifications such as proximal hydroxyapatite (HA) and porous coatings are commonly used for primary cementless THA to accelerate proximal osseointegration and maintain proximal load transfer [3]. Postoperative thigh pain is suggested to be related to stress shielding, as well as bone–prosthesis micromotion, excessive stress transfer to the femur, periosteal irritation, or a mismatch in Young's modulus of elasticity [11,12]. To examine the effects of differences in stem geometry as well as proximal coatings on periprosthetic bone remodeling, different stems have been compared in previous studies [13–16]. However, these studies had limitations in that they could not completely eliminate the effects of age [5] or of individual patient differences. Comparison using one-stage bilateral THA is an option to minimize the effects of such confounding factors [17,18].

The morphological features of developmental dysplasia of the hip are reported to be quite different from those of normal hips. Noble et al and Sugano et al reported that more than 90 % of osteoarthritic hip joints of Japanese patients are due to dysplastic hip and have similar abnormalities of femora even in mild cases compared to normal controls, and they recommended the use of modular or specially-designed components to accommodate the shape of the dysplastic canal [19,20]. Harada et al reported that although THA for dysplastic hip patients achieved acceptable clinical results using anatomical stem designs based on normal femurs, radiographical fit of the stems was not optimal and therefore an anatomically designed stem based on dysplastic femurs was necessary to obtain a better proximal fit [21].

The CentPillar stem (Stryker Orthopaedics, Mahwah, NJ, USA) is a cementless femoral component design based on the anatomical geometry of Japanese dysplastic femurs to obtain a better proximal fit for patients with dysplastic hip [20,22,23]. The stem has two kinds of options of material and coating. The aims of this study were to evaluate the stability of CentPillar stems, and to investigate the optimal material and coating. A prospective, randomized study was performed using

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Reprint requests: Tetsuya Jinno, MD, PhD, Department of Orthopaedic Surgery, Medical Hospital, Tokyo Medical and Dental University, 1-5-45 Yushima, Bunkyo-ku, Tokyo 113-8519, Japan.

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one-stage bilateral THA to minimize the effects of confounding factors [17,18]. We report the mid-term results of the study comparing the stems with the same geometric configurations and different materials and coatings.

Materials and Methods

Subjects

Twenty-one consenting patients (all female; 42 hips; mean age at surgery, 51.1 years; range, 17–61 years) who underwent one-stage bilateral THA between 2007 and 2010 were included in the study. They received one of the 2 options of CentPillar stems in one hip and the other option in the other hip, randomized to side. Eighteen had osteoarthritis, and the remaining 3 patients had osteonecrosis. No patients dropped out of the study. This prospective, randomized study (evidence level I) was approved by the Institutional Research Ethics Committee and was performed in compliance with the Helsinki Declaration. On the basis of a preliminary study evaluating the appearance of radiographic reactive lines, a power analysis, with a power of 80% and an α of .05, demonstrated that a sample size of 15 patients was needed (G*power 3.1; Heinrich Heine University Düsseldorf, Düsseldorf, Germany), and 21 patients were enrolled in the study assuming a 25% exclusion.

Implants and Surgical Procedure

The CentPillar stem is a cementless femoral component design based on the anatomy of dysplastic hips to achieve proximal fixation and minimize stress shielding [20,22–24]. With the better proximal metaphyseal fit, the stem is tapered and slotted distally, and the length of the stem is relatively short (101–137 mm). There are 2 options of material and proximal coating (Fig. 1). The CentPillar GB HA stem (GB) is made of titanium alloy (Ti6Al4V) with a proximal circumferential coating of hydroxyapatite (HA) on grit-blasted surface. The CentPillar TMZF HA stem (TMZF) is made of TMZF™ alloy which is a beta titanium alloy consisting of titanium, molybdenum, zirconium, and iron (Ti12Mo6Zr2Fe), and is supposed to achieve a superior combination of flexibility, strength, notch resistance, and better biocompatibility when compared to other alloys including Ti6Al4V [25]. A proximal circumferential HA coating on an arc-deposited commercially pure titanium coating is applied. Thus, although the geometry of the 2 stems is identical, the material and types of proximal coating are different.

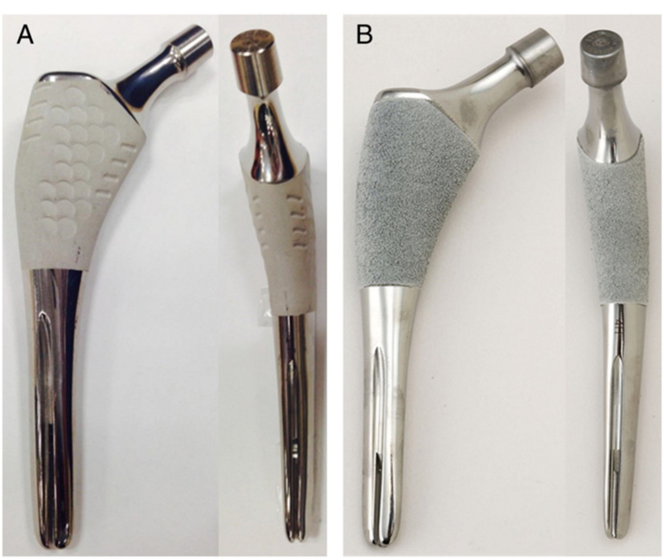

Fig. 1. CentPillar stems: (A) GB HA stem (GB) and (B) TMZF HA stem (TMZF) (Stems for the right hip, in these figures). The CentPillar stems have identical geometry with different materials and types of proximal coating. (A) GB stem is made of titanium alloy (Ti6Al4V) with a proximal circumferential coating of hydroxyapatite (HA) on grit-blasted surface. (B) TMZF stem is made of TMZF™ alloy with a proximal circumferential HA coating on an arc-deposited commercially pure titanium coating.

The CentPillar stems were press-fit after hand reaming of the medullary canal with taper reamers followed by rasping. All surgeries were performed using the same approach for both sides by, or under the supervision of the senior author (TJ). Patients received a GB stem in one hip and a TMZF stem in the other hip, randomized to side. Selection of the approach (posterolateral, anterolateral, or direct anterior) for each patient was made by the surgeon considering factors such as the deformity of the joint and the risk of postoperative dislocation, but the same approach was used for both sides. The acetabular components and bearings were also the same for both sides. The most common type of acetabular component and head was a ceramic-on-ceramic (CoC) bearings using the Trident® Acetabular System (Stryker Orthopaedics, Mahwah, NJ, USA), in 19 patients. The other type was a metal-on-metal bearing in 2 patients (ADEPT; Finsbury Orthopaedics, London, United Kingdom). The acetabular components were press-fit, and supplemental fixation screws were used for CoC acetabular components depending on the stability. A standardized postoperative protocol was used, and all patients were encouraged to ambulate and bear weight to a tolerable extent starting on the second postoperative day after removal of a suction drain.

Methods

Hip function was assessed clinically using the Japanese Orthopaedic Association (JOA) hip score [17,18,26] at the final follow-up (mean of 5.5 years after surgery; range 4.0–7.0 years) and was compared with the preoperative JOA score. The JOA scoring system comprises 4 categories, namely: pain (0–40 points), range of motion (ROM: flexion/extension and abduction/adduction, 0–20 points), walking ability (0–20 points), and activities of daily living (0–20 points). Thigh pain, defined as any postoperative pain in the anterior thigh [11,27], and squeaking phenomenon, particularly arising from CoC bearings [28,29], were also recorded. Complications such as infections, dislocations, and periprosthetic fractures were recorded during the follow-up period.

Radiographically, postoperative alignment of components was evaluated in the immediate postoperative radiographs. Briefly, postoperative malalignment of the acetabular cup was determined as either perforation through the ilioischial line or an inclination of more than 50° or less than 30° according to Lewinnek et al [30]. Malalignment of the stem was defined as more than 2° of varus or valgus alignment according to Zwartele et al [31]. Migration of the component was detected in comparisons between consecutive radiographs. Fixation of the stem was graded as bone-ingrown stable, fibrous stable, and unstable according to the classification given by Engh et al [32] using anteroposterior and lateral radiographs. The prevalence of cancellous condensation, radiopaque lines, cortical hypertrophy, and atrophy of the femur attributed to stress shielding in each zone was assessed according to Gruen's zone [33] and used to grade the fixation of the stem [32,34]. Radiopaque lines at Gruen's zone 1 were further evaluated using 2 subclassifications of zone 1 as non-coated area (NC) and coated area (CO) according to the area of circumferential coating. Stress shielding was evaluated also using the grading system by Engh et al [35]. Cortical hypertrophy was defined as the occurrence of more than a 2-mm increase in the outside diameter of the cortex as seen on the final follow-up radiograph compared with the appearance on the radiograph made immediately postoperatively [34]. Osteolysis was also evaluated by comparing consecutive radiographs. In addition, two patients who had metal-on-metal bearings underwent CT scans and MRI evaluations to detect adverse reactions to metal debris (ARMD) as Bosker et al recommended in their cohort study [36]. Three independent, experienced hip surgeons (TJ, DK, and KM) examined all the radiographs. The qualitative parameters that resulted in inconsistent assessments were re-evaluated by