Comparison of Specific Femoral Short Stems and Conventional-Length Stems in Primary Cementless Total Hip Arthroplasty

YOUNG-SOO SHIN, MD; DONG-HUN SUH, MD; JONG-HOON PARK, MD; JEONG-LAE KIM, MD; SEUNG-BEOM HAN, MD

abstract

There are several reported disadvantages with conventional-length femoral stems in cementless total hip arthroplasty (THA). Therefore, various efforts have been made to develop a specific femoral short stem to improve physiologic bone remodeling at the femoral aspect of a cementless THA. However, there are potential disadvantages with specific femoral short stems, such as malalignment, inadvertent subsidence, and potential proximal femoral fracture. Therefore, the authors quantitatively compared radiographic and clinical outcomes as well as component-specific complications between 2 groups of patients following primary cementless THA. A matched comparison was made between specific femoral short stems (n=50) and conventional-length femoral stems (n=50) in cementless THA procedures performed between January 2008 and January 2012. Patients were matched for age, sex, body mass index, height, surgical approach, and surgeon. No significant differences were found between the 2 groups in mean postoperative radiographic outcomes, functional outcomes, or complications. Both groups showed satisfactory performance at 5-year follow-up. Specific femoral short stems resulted in a higher incidence of malalignment and subsidence and a lower incidence of thigh pain and proximal bone resorption compared with conventional-length femoral stems. Although longer follow-up is required, specific femoral short stems may have clinical and radiographic advantages with equivalent perioperative complications relative to conventional-length femoral stems. However, this technique requires proper patient selection in combination with careful preoperative planning and meticulous surgical technique. [Orthopedics. 2016; 39(2):e311-e317.]

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ver the past several decades, conventional femoral fixation with tapered stems has been used in cementless total hip arthroplasty (THA) in an effort to provide reliable long-term fixation in patients with functional improvement. Recent studies showed overall survivorship of greater than 94% for general conventional-length tapered femoral components at 20-year follow-up.¹³ However, conventional-length femoral stems in cementless THA have several reported disadvantages, including challenges with proximal-distal femoral mismatch, preservation of the osseous femoral neck, and optimal proximal load transfer.⁴⁻⁵ There has been a recent surge of interest in the use of shorter stems for younger, more active patients undergoing cementless THA. Pain relief, improved function, and the radiographic stability of short stems of various designs were shown with follow-up of 2 to 8 years.⁶⁻⁷ Various efforts have been made to develop a femoral neck-preserving short stem to improve physiologic bone remodeling at the femoral aspect of a cementless THA. In addition, femoral neck-preserving short stems have several proposed advantages, including their in-

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clinical outcomes as well as component-specific complications in 2 groups of patients after primary cementless THA. It was hypothesized that the results with the specific femoral short stems would be at least equivalent to those with the currently available conventional-length femoral stems.

**MATERIALS AND METHODS**

**Patient Selection and Study Design**

Starting in January 2008, THA with BiCONTACT (Aesculap, Tuttingen, Germany) was performed predominantly at the study institution, along with METHA (Aesculap). During the study period, the stem type was selected by the surgeon in a nonsystematic manner, with the typical process of trial and implementation. The 2 stems were compared in patients who had 5 years of follow-up. The authors were aware that the BiCONTACT stem had good long-term results compared with other contemporary femoral stems. A total of 237 THA procedures were performed at the study institution between January 2008 and January 2012. The current study included patients with indications for primary THA. The use of specific femoral short stems was begun at the institution in June 2008. Exclusion criteria for METHA treatment were radiographically noticeable osteoporosis with T-score of less than 2.5 and dysplastic hips with abnormal deviation of the femoral neck or metaphyseal deformity secondary to fracture that would exclude insertion of the specific model of short stem that was used. Simple radiographs, dual-energy x-ray absorptiometry, and intraoperative bone stock findings were used to assess bone quality because inadequate bone structure may lead to poor fixation, even in patients with good bone quality. The authors evaluated 54 consecutive THA procedures performed with specific femoral short stems between June 2008 and January 2012. Four patients declined to participate in follow-up for reasons unrelated to the THA. After these patients were excluded, 50 patients who had specific femoral short stems were included in the current study, with a minimum 5-year follow-up. These patients underwent THA with specific femoral short stems (METHA) with a modular acetabular component consisting of a hemispherical titanium cup (PLASMACUP SC; Aesculap) with an outer coating of plasma-sprayed pure titanium (Plasmapore; Aesculap) and a 36-mm delta ceramic femoral head and liner. This stem was composed of monoblock with 120°, 130°, and 135° head-neck-shaft angles and had a proximal rough titanium, plasma-sprayed, microporous coating with a thin 20-μm layer of pure calcium phosphate (Figure 1). Digital templating is considered an essential step before METHA implantation and is commonly used to determine the head-neck-shaft angle preoperatively and to ensure the femoral resection level and the anatomy of the femoral neck intraoperatively. Patients receiving the short stem THA were classified as group A and were reviewed in a case-matched analysis with 133 consecutive THA procedures performed with conventional-length femoral stems (BiCONTACT; Aesculap). In these patients, THA was performed with conventional-length femoral stems (BiCONTACT) with a modular acetabular component consisting of a hemispheric titanium cup (PLASMACUP SC) with an outer coating of plasma-sprayed pure titanium (Plasmapore) and a 36-mm delta ceramic femoral head and liner. This is a straight, collarless stem made of titanium alloy with plasma spray (pore size, 50-200 μm). Patients who underwent THA with the conventional-length stem were classified as group B. For every patient who was treated with a specific femoral short stem, a matched patient who was treated with a conventional-length stem was identified from the database by age (±5 years), sex, body mass index (±2 kg/m²), height (±5 cm), surgical approach, and surgeon in a 1:1 ratio. Matching in a 1:2 ratio was not possible because of the limited sample size. All procedures were performed by a single surgeon (S.-B.H.) using a postero-
lateral surgical approach. All patients were administered prophylactic antibiotics perioperatively to prevent postoperative infection. This study was approved by the ethics committee at the study institution, and informed consent was obtained from all patients.

Clinical Evaluation
A simple questionnaire was completed, and clinical outcomes were determined using the Harris Hip Score (HHS) and the Western Ontario and McMaster Universities Arthritis Index (WOMAC) score at each visit. Data were recorded preoperatively and at 6 weeks, 6 months, 1 year, and annually thereafter. Preoperative demographic and clinical data for the 2 groups were evaluated (Table 1). Preoperative HHS and WOMAC score were not significantly different between the 2 groups.

Radiographic Evaluation
Each patient had regular evaluation preoperatively and at 6 weeks, 6 months, 1 year, and annually thereafter by analyzing radiographic outcomes for implant alignment and stability as assessed by 2 independent radiographic reviewers. The patients were placed in the supine position, with the affected leg in 20° internal rotation. The foot was fixed by an assistant to inhibit measurement errors. Stem position was defined as angulation along the stem relative to the femoral shaft. Varus or valgus positioning (>5° from neutral) was measured. Subsidence was analyzed by measuring the change in distance from the superior tip of the greater trochanter to the distal tip of the implant and was defined as greater than 2 mm. Radiographic findings in the femur were evaluated in the conventional 7 zones for bony ingrowth or resorption, including proximal bone resorption, defined as loss of trabecular bone density or loss of definition between the cortical and cancellous bone, blending into a uniform density; endosteal spot welds, defined as local deposition of new bone trabeculae bridging the cortex and the implant surface; and cortical hypertrophy, defined as new bone of cortical density that resulted in an increase in cortical thickness. Additionally, heterotopic ossification was observed and classified according to the Brooker grading system. Component-specific complications, such as subsidence, fracture, and malalignment, were evaluated.

Statistical Analysis
Statistical analysis was performed with SPSS statistical software, version 20 (IBM Corp, Armonk, New York). P<.05 was considered statistically significant. The HHS, WOMAC score, and radiographic data in the 2 groups at final follow-up were compared with independent samples t test for continuous variables. Chi-square (Fisher’s exact) test was used for categorical variables to determine whether the incidence of complications and sex were different in the 2 groups.

RESULTS

Clinical Outcomes
In group A, mean preoperative HHS and WOMAC score of 55.0 and 53.0, respectively, improved to mean postoperative values of 98.6 and 3.3, respectively, at an average follow-up of 37.2 months. Therefore, HHS and WOMAC score improved by 43.6 and 49.7 points, respectively, in group A. In group B, mean preoperative HHS and WOMAC score of 53.0 and 49.5, respectively, improved to mean postoperative values of 97.8 and 4.4, respectively, at an average follow-up of 35.3 months. Therefore, in group B, HHS

<table>
<thead>
<tr>
<th>Variable</th>
<th>Group A (n=50)</th>
<th>Group B (n=50)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex, M/F, No.</td>
<td>35/15</td>
<td>32/18</td>
<td>.211</td>
</tr>
<tr>
<td>Age, mean (range), y</td>
<td>48.45 (30-68)</td>
<td>49.91 (40-67)</td>
<td>.472</td>
</tr>
<tr>
<td>Body mass index, mean (range), kg/m²</td>
<td>23.4 (19.5-34.2)</td>
<td>23.8 (18.4-38.1)</td>
<td>.337</td>
</tr>
<tr>
<td>Height, mean (range), m</td>
<td>1.73 (1.53-1.82)</td>
<td>1.71 (1.50-1.79)</td>
<td>.281</td>
</tr>
<tr>
<td>Follow-up, mean (range), mo</td>
<td>56.5 (36-77)</td>
<td>59.5 (36-83)</td>
<td>.255</td>
</tr>
<tr>
<td>Bone mineral density, mean (range), g/cm²</td>
<td>Neck 0.785 (0.542-0.935)</td>
<td>0.711 (0.527-0.910)</td>
<td>.207</td>
</tr>
<tr>
<td></td>
<td>Trochanter 0.732 (0.530-0.851)</td>
<td>0.776 (0.541-0.816)</td>
<td>.809</td>
</tr>
<tr>
<td></td>
<td>Intertrochanter 1.210 (0.883-1.336)</td>
<td>1.058 (0.776-1.280)</td>
<td>.439</td>
</tr>
<tr>
<td></td>
<td>Ward’s triangle 0.635 (0.437-0.912)</td>
<td>0.666 (0.432-0.953)</td>
<td>.664</td>
</tr>
<tr>
<td></td>
<td>Total 0.999 (0.607-1.108)</td>
<td>0.974 (0.684-1.211)</td>
<td>.373</td>
</tr>
<tr>
<td>Diagnosis, No. (%)</td>
<td>Osteoarthritis 5 (10)</td>
<td>8 (16)</td>
<td>&gt;.999</td>
</tr>
<tr>
<td></td>
<td>Avascular necrosis 39 (77)</td>
<td>36 (71)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Septic hip sequelae 6 (13)</td>
<td>6 (13)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Harris Hip Score, mean±SD (range) 55.0±10.4 (29-76)</td>
<td>53.0±8.4 (25-75)</td>
<td>.316</td>
</tr>
<tr>
<td></td>
<td>Western Ontario and McMaster Universities Arthritis Index, mean±SD (range) 53.0±14.6 (40-64)</td>
<td>49.5±12.3 (32-78)</td>
<td>.359</td>
</tr>
</tbody>
</table>

Abbreviations: F, female; M, male.
Table 2

Valgus Position of Implants (Group A)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Patients in Valgus Position (n=2)</th>
<th>Patients in Neutral Position (n=48)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preoperative Harris Hip Score</td>
<td>41.5±13.4 (32-51)</td>
<td>55.9±9.7 (29-74)</td>
<td>.056</td>
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<tr>
<td>Preoperative Western Ontario and McMaster Universities Arthritis Index</td>
<td>51.9±1.4 (50-52)</td>
<td>52.7±15.1 (24-79)</td>
<td>.875</td>
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<tr>
<td>Postoperative Harris Hip Score</td>
<td>98.5±2.1 (97-100)</td>
<td>98.6±2.0 (93-100)</td>
<td>.935</td>
</tr>
<tr>
<td>Postoperative Western Ontario and McMaster Universities Arthritis Index</td>
<td>5.0±4.2 (2-8)</td>
<td>3.2±2.8 (0-8)</td>
<td>.404</td>
</tr>
</tbody>
</table>

*Independent samples t test.

Table 3

Incidence of Complications

<table>
<thead>
<tr>
<th>Complication</th>
<th>Group A (n=50)</th>
<th>Group B (n=50)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subsidence</td>
<td>1 (2)</td>
<td>0 (0)</td>
<td>.313</td>
</tr>
<tr>
<td>Periprosthetic fracture</td>
<td>1 (2)</td>
<td>1 (2)</td>
<td>1.000</td>
</tr>
<tr>
<td>Malalignment</td>
<td>2 (4)</td>
<td>1 (2)</td>
<td>.554</td>
</tr>
<tr>
<td>Leg length discrepancy</td>
<td>1 (2)</td>
<td>0 (0)</td>
<td>.313</td>
</tr>
<tr>
<td>Thigh pain</td>
<td>0 (0)</td>
<td>2 (4)</td>
<td>.151</td>
</tr>
<tr>
<td>Heterotopic ossification</td>
<td>1 (2)</td>
<td>2 (4)</td>
<td>.554</td>
</tr>
<tr>
<td>Infection</td>
<td>0 (0)</td>
<td>1 (2)</td>
<td>.313</td>
</tr>
<tr>
<td>Dislocation</td>
<td>1 (2)</td>
<td>1 (2)</td>
<td>1.000</td>
</tr>
</tbody>
</table>

*Fisher’s exact test.

and WOMAC score improved by 44.8 and 45.1 points, respectively. In addition, no significant differences in mean postoperative HHS (P=.168) or WOMAC score (P=.158) were observed in the 2 groups, according to an independent samples t test. Table 2 shows 2 stems (4%) located in valgus position (>5° from neutral). Mean preoperative and postoperative HHS and WOMAC score were similar to those for stems located neutrally in group A.

Radiographic Findings

All stems in group A showed bone bridging and endosteal spot welds distributed in Gruen zones 2 and 6 as evidence of bony ingrowth with no radiolucencies (Figure 2). Two patients in group B had a slight decrease in bone density, mostly in Gruen zones 1 and 7. No radiographic evidence of osteolytic lesions, cortical hypertrophy, or acetabular fractures was detected in either group, and no patient required revision surgery for aseptic loosening.

Complications

Chi-square (Fisher’s exact) test showed no significant difference in patient complications in the 2 groups (Table 3). One patient in group A with a head-neck-shaft angle of 135° had subsidence (>2 mm, P=.313) that showed bony ingrowth, with no further progression of subsidence at final follow-up. Two patients (1 in group A and 1 in group B) had intraoperative minor femur neck fracture (P=1.00). These patients were treated with cerclage wires without further incident. Three patients (2 in group A, valgus and head-neck-shaft angle of 135°; 1 in group B, varus) had malalignment (P=.554) that was not associated with loosening. One patient in group A with a head-neck-shaft angle of 135° had leg length discrepancy of greater than 1 cm (shortening, P=.313). Two patients in group B had thigh pain (P=.151) that disappeared after a few months. Three patients (1 in group A and 2 in group B) had heterotopic ossifications (P=.554) that were categorized as Brooker class I in 2 patients and class II in 1 patient and did not limit their activities. One patient in group B had a superficial wound infection that was treated with local debridement and antibiotics. Early dislocation occurred.
in 2 patients (1 in group A and 1 in group B). Two patients reported postoperative falls at the bedside, and both were treated with closed reduction without further procedures. No hips had deep venous thrombosis or pulmonary embolism.

**Discussion**

The most important finding of the current study was that no significant differences in clinical or radiographic outcomes or component-specific complications were observed between the 2 groups. Additionally, valgus alignment after insertion of METHA stems did not negatively affect clinical outcomes at short- to midterm follow-up. Although no significant differences were observed in thigh pain or proximal bone resorption in the 2 groups, patients in group B had a higher incidence of thigh pain (4%) and proximal bone resorption (4%) than patients in group A. Additionally, although no significant difference in malalignment or subsidence was found between the 2 groups, patients in group A who had a head-neck-shaft angle of 135° had a higher incidence of malalignment (4%) and subsidence (2%) than those in group B.

One of the most common complications of conventional-length stems in cementless THA is the potential risk of proximal stress shielding.19 Therefore, many studies investigated patients who underwent treatment with a femoral neck-preserving short stem to allow more proximal load transfer and reduction of the stress shielding effect. However, there have been no direct in vivo simultaneous comparisons of specific femoral short stems (METHA) and conventional-length femoral stems (BiCONTACT) after primary cementless THA. Only 1 biomechanical study of strain patterns with 2 synthetic femora showed that both stems apparently decreased strain in the greater trochanter and subtrochanteric regions; furthermore, the BiCONTACT stem dramatically decreased strain around the calcar with a combination of metaphyseal and diaphyseal load transfer.20 These earlier results indicated that both stems similarly decreased fundamental strain and the risk of stress shielding in the proximal femur; however, the anchorage location of the femur may be different. In contrast, a study of clinical and radiographic outcomes in 177 patients who underwent THA with a BiCONTACT stem reported that proximal bone resorption was 6% at long-term follow-up.20 This discrepancy was likely due to the use of synthetic bone, which may have affected the measurement of proximal bone resorption as a result of altered stress in the proximal femur. In the current study, patients in group B had a higher incidence (4%) of proximal bone resorption than those in group A, even with a short follow-up period. This proximal bone resorption may have occurred because there was no primary goal to achieve press-fit and maximal canal filling, including less reproducible insertion with a surgical technique because of an initial learning curve. In addition, all patients who had proximal bone resorption had thigh pain. In general, thigh pain is related to a stem design that occupies the diaphysis, although BiCONTACT stems are designed to achieve proximal load transfer.5,21 This may explain the current finding that the METHA stem minimized stress shielding as a result of proximal bone resorption and thigh pain and provided more successful bone remodeling, according to Wolff's law.22

With the METHA stem, it is necessary to avoid any valgus position that could lead to subsidence without proximal-lateral support, whereas other short stems may be prone to the varus position when encountering osteoporotic bone with a widened intramedullary canal.23,24 One study showed that the level of neck resection with a short metaphyseal stem affects the stem position, the head-neck-shaft angle, femoral offset, and leg length, indicating that a lower neck resection causes a more vertical stem position, which decreases offset and leg length and increases the head-neck-shaft angle.25 This was similar to previous findings that showed that the final position of the METHA stem and the head-neck-shaft angle were significantly higher with lower neck resection and that the offset was in a lower position compared with more proximal resections.26 The current study showed that 1 of 2 patients in group A who had a valgus stem position with a head-neck-shaft angle of 135° simultaneously had subsidence and leg length discrepancy. This finding suggested that an unintentionally lower neck resection could change stem position and offset, leading to subsidence. Interestingly, the current findings showed no difference in HHS and WOMAC score in the valgus position of implants compared with the neutral position of implants in group A. Discrepancies between clinical and radiographic outcomes may be the result of the lack of standardized scoring systems based on a relatively arbitrary patient report. Other differences may be the result of unexpectedly complicated biomechanics of the hip between various tissues and bony structures. Together, clinically, these studies suggest that preservation of a 5- to 10-mm cortical ring around the femoral neck and osteotomy at an angle of 50° to the femoral shaft axis may have advantages during METHA stem implantation, including more accurate neck resection and better control of the stem position (Figure 3).

Many studies have investigated the factors that predispose patients to periprosthetic fractures of the femur and found that they may include stem design and individual parameters, such as body mass index and bone mineral density.27,28 However, the current study showed no significant differences in periprosthetic fractures between the 2 groups in body mass index, bone mineral density, age, sex, preoperative diagnosis, or stem design, although the very specific tapered nature of the stemless implant caused significant hoop stress, increasing the likelihood of femoral neck fracture. It is possible that most of the periprosthetic fractures were seen
Conclusions and implications could be drawn because the specific femoral short stem was not just a shorter design of the conventional-length stem. Furthermore, the design of this particular stemless implant allows subsidence in the short term, and unlike most cementless stems, subsidence of greater than 2 mm is consistent with ingrowth because of the tapered stem design. However, no consensus has been reached on specific criteria for comparison of 2 implants. Finally, the median follow-up of 5 years was relatively short to allow a conclusion regarding implant safety. However, the current study provides baseline comparison data, especially in terms of functional scores and complication rates. Despite these limitations, to the authors’ knowledge, this in vivo study is the first to simultaneously compare specific femoral short stems with conventional-length femoral stems in patients undergoing primary cementless THA.

**References**


