Intraoperative positioning of the acetabular and femoral components influences periprosthetic dislocation rates and material wear characteristics following total hip arthroplasty (THA). Implanting the acetabular and femoral components in the optimal position and at the optimal angle is thus crucial to avoiding dislocation after THA. Compared with patients in the United States and Europe, most cases of osteoarthritis of the hip in Japanese patients are secondary to developmental dysplasia (DDH). Femurs with DDH show a smaller, more anteverted canal than normal femurs. Furthermore, most Japanese patients with hip disorders are female and of smaller stature than patients in the United States and Europe. Navigation systems are very useful for precise implantation of the acetabular component in THA. Generally, the hip surgeon inserts the femoral stem using anteversion of the femoral neck as an index. However, we sometimes encounter problems with stems implanted in a greater degree of anteversion than planned preoperatively, particularly among patients with severe hip deformity.

After the 1990s, the importance of the calcar femorale in patients with osteoarthritis of the hip secondary to developmental dysplasia (DDH) has been recognized. The calcar femorale is a cortical septum in the region of the lesser trochanter of the femur, which is important for the stability of the femoral component during THA.

**Background:** We investigated whether the calcar femorale correlates with results of femoral stem implantation in patients with osteoarthritis of the hip secondary to developmental dysplasia using computed tomography.

**Methods:** This retrospective study included 277 hips (41 males and 236 females; age, 37 to 92 years) of patients who had presented to Okayama Medical Center with hip pain. Of these, a total of 219 hips (31 males and 188 females) had previously undergone total hip arthroplasty. According to the Crowe classification, 147 hips were classified as Crowe grade I, 72 hips as Crowe grade II–IV, and 58 hips as normal.

**Results:** The calcar femorale was identified in 267 hips (96.4%). The calcar femorale was significantly shorter and more anteverted in Crowe grade II–IV hips than in Crowe grade I or normal hips. Significant differences in the shape of the calcar femorale were found according to the severity of hip deformity. Three stem designs were analyzed: single-wedge (59 hips), double-wedge metaphyseal filling (147 hips), and modular (13 hips). Single-wedge stems were inserted more parallel to the calcar femorale rather than femoral neck anteversion, while other types of stems scraped the calcar femorale.

**Conclusions:** The angle of the calcar femorale differs according to the severity of hip deformity, and the calcar femorale might thus serve as a more useful reference for stem insertion than femoral neck anteversion in total hip arthroplasty using a single-wedge stem.

**Keywords:** Femoral neck, Hip dislocation, Total hip replacement
Tetsunaga et al. Calcar Femorale in Patients with Osteoarthritis of the Hip
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Calcar femorale to the initial stability and alignment of the femoral stem of THA was reported. First described in 1874 by Merkel, a German anatomist, the calcar femorale is a spur that projects from the endosteum of the medio-dorsal femoral neck into the medullary space. This structure runs from the femoral neck to the lesser trochanter, and divides the femoral canal in half. The modern nomenclature was coined by Harty in 1957. Several studies of the calcar femorale were performed using computed tomography (CT) in the 1980s. Hansson et al. analyzed the position of the femoral head in relation to the calcar femorale, reporting that this feature was useful in determining the degree of femoral head slip in both adolescents and adults. In a series of CT-based virtual stem implantation, the degree of contact achieved between the calcar femorale and cementless stems with an anatomic or straight design was evaluated in patients with primary osteoarthritis. Patients with severe DDH are known to require different femoral components compared to patients with normal hips, but few reports have analyzed the relationship between the calcar femorale and stems in cases of secondary osteoarthritis of the hip. The present study therefore analyzed the anatomical structure of the calcar femorale in patients with DDH and investigated whether this structure could be used as an indicator in femoral stem implantation.

METHODS

This retrospective study was approved by the Institutional Review Board at Okayama Medical Center (IRB No. K1606-511-001) and all protocols were performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki. Written informed consents were obtained. This study investigated 277 consecutive hips (41 males and 236 females) managed at our hospital from December 2011 to January 2015 for the chief complaint of hip pain. When patients presented with bilateral pain, both hips were included in this study. All patients were retrospectively identified from the author’s (TT) database. Mean patient age on presentation was 68.9 years (range, 37 to 92 years); mean height was 153 cm (range, 138 to 175 cm); and mean body mass index was 24.1 kg/m² (range, 14.5 to 36.1 kg/m²). Harris Hip Score was determined at the time of enrollment for all patients, as a score previously validated for patients with osteoarthritis of the hip. All patients underwent CT examinations of the pelvis and entire femur at the initial visit in the supine position using a multislice CT with routine parameters (slice thickness, 1.0 mm; 120 kV; 300 mA). Retrospective radiographic evaluation was performed by an orthopedic surgeon (TT) to confirm the osteoarthritic grade. According to the Crowe classification, the severity of hip deformity in hips with osteoarthritis was defined as grade I in 147 hips, grade II in 38 hips, grade III in 21 hips, and grade IV in 13 hips. Patients without deformity (58 hips) were classified as normal. We divided patients into three groups: Crowe grade I (147 hips), Crowe grade II–IV (72 hips), and normal (58 hips) (Table 1). No significant differences in patient characteristics were evident among the groups.

| Variable               | Normal (n = 58) | Crowe I (n = 147) | Crowe II–IV (n = 72) | p-value |
|------------------------|-----------------|-------------------|----------------------|---------|
| Age (yr)               | 67 ± 13         | 70.5 ± 10.6       | 69 ± 10.3            | 0.6     |
| Sex (male:female)      | 10:48           | 25:122            | 6:66                 | 0.2     |
| BMI (kg/m²)            | 23 ± 3.3        | 24 ± 3.9          | 23.8 ± 4.3           | 1.0     |
| HHS (point)            | 50 ± 15         | 49 ± 14           | 46 ± 14              | 0.7     |

Values are presented as mean ± standard deviation. BMI: body mass index, HHS: Harris Hip Score.
Crowe classification I–IV underwent THA. We analyzed the relationship between the stem and calcar femorale in 219 consecutive hips (31 males and 188 females) for which THA was performed. Mean age at the time of surgery was 70 years (range, 37 to 92 years). All patients in this study had been operated on by one of three experienced hip surgeons (TT, TS, and NS). The direct-lateral (Hardinge) approach was used in all patients. We used three different types of stems: single-wedge stem using TRI-LOCK implant (DePuy, Warsaw, IN, USA; group T: 59 hips, January 2014 to January 2015); double-wedge metaphyseal filling stem using Summit implant (DePuy; group S: 147 hips, December 2011 to December 2013); and modular stem using SROMA implant (DePuy; group A: 13 hips). According to Crowe classification, group T included Crowe grade I in 40 hips, grade II in 15 hips, and grade III in 4 hips; and group S included Crowe grade I in 107 hips, grade II in 24 hips, and grade III in 16 hips. No significant differences in the severity of dysplasia were seen between groups T and S ($p = 0.09$). We used modular-type stems in cases of severe dislocation of the hip in Crowe grade IV patients that required subtrochanteric shortening osteotomy (group A, 13 hips). We compared the contact point between the stem and calcar femorale using axial CT...
sections at the level of maximum calcar femorale length determined after surgery (Fig. 2). The angle of the calcar femorale, stem anteversion, and femoral neck anteversion were also compared among groups using axial CT sections taken before surgery (Fig. 1D-G). Stem anteversion was measured by a line tangent to the most dorsal points of the posterior condyles.

**Statistical Analysis**

All data were normally distributed and are expressed as means with standard deviations. Differences between groups were compared using one-way analysis of variance with the Bonferroni post-hoc test. We used unpaired t-tests for continuous data and the chi-square test for categorical data to assess linear trends in proportions across categories. For groups of fewer than five subjects, Fisher exact test was used. Values of $p < 0.05$ were considered statistically significant.

**RESULTS**

**Analysis of the Calcar Femorale**

The calcar femorale was identified in 267 hips (96.4%), but was not identified in 10 hips (3.6%). Two of the 10 hips in which the calcar femorale was not visible were Crowe grade I and had secondary osteoarthritis of the hip because of femoral neck fracture. Five of the other hips were severely dislocated (Crowe grade IV). Significant differences in the shape of the calcar femorale were evident between groups ($p < 0.001$) (Fig. 3). Normal hips displayed a greater percentage of spur-type calcar femorale (43.1%). In contrast, Crowe grade II–IV patients

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**Fig. 3.** Different types of calcar femorale. A calcar femorale was observed in all normal hips. In Crowe II–IV, the most common type of calcar femorale was ridge type. Values are presented as number of hips (%).

**Fig. 4.** Length of the calcar femorale (A) and difference between calcar femorale angle and femoral neck anteversion (B) measured on computed tomography scans. *$p < 0.05$.**
displayed a significantly greater percentage of ridge-type calcar femorale (43.1%), while only 13.9% of Crowe II–IV patients showed septum-type calcar femorale.

We analyzed the length and angle of the calcar femorale to identify differences between different types of hip joint deformities. The calcar femorale of patients with Crowe grade II–IV deformities was significantly shorter and more anteverted than that in normal hips ($p = 0.012$ and $p < 0.001$, respectively) or in Crowe grade I hips ($p = 0.017$ and $p < 0.001$, respectively) (Fig. 4). Femoral neck anteversion was significantly greater in patients with Crowe grade II–IV deformities than in normal hips ($p = 0.002$) or in patients with Crowe grade I deformities ($p = 0.035$) (Fig. 4B). We analyzed whether any differences existed between femoral neck anteversion and the angle of the calcar femorale. In Crowe grade II–IV patients, the angle of the calcar femorale was significantly larger than the angle of femoral neck anteversion ($p = 0.018$) (Fig. 4B).

**DISCUSSION**

Femoral neck anteversion in DDH is well known to be larger than that in the normal hip. This study focused on the calcar femorale in DDH as one of the factors contributing to the stability of THA during stem insertion. The results of this study indicate that the calcar femorale could be identified in almost all patients with DDH and that the shape of the calcar femorale differs in accordance with the severity of hip deformity. The results of our analysis in patients for which THA was performed showed that single-wedge stems were inserted more parallel to the calcar femorale rather than femoral neck anteversion.

Adam et al. reported that the calcar femorale was found in all cadaveric specimens without osteoarthritis of the hip on high-resolution CT, regardless of sex or age. In the present study, the calcar femorale was detected in all

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**Table 2. Differences of the Angle between Stem Anteversion and Calcar Femorale/Femoral Neck Anteversion**

| Variable          | Calcar femorale – stem anteversion (°) | Femoral neck – stem anteversion (°) | $p$-value |
|-------------------|--------------------------------------|-------------------------------------|-----------|
| Group T ($n=59$)  | 6.6 ± 5.3                            | 9.4 ± 7.2                           | 0.0       |
| Group S ($n=147$) | 8.1 ± 7.7                            | 9.8 ± 8.2                           | 0.348     |
| Group A ($n=13$)  | 13.4 ± 12.7                          | 14.3 ± 11.2                         | 0.665     |

Values are presented as mean ± standard deviation.

Group T: single-wedge stem, Group S: double-wedge metaphyseal filling stem, Group A: modular stem.
normal hips. In addition, almost all patients with secondary osteoarthritis of the hip had a calcar femorale, with the exception of those with osteoarthritis secondary to a femoral neck fracture or severe osteoporosis. These results indicate that bone density influences the presence or absence of the calcar femorale, not the presence or absence of osteoarthritis of the hip. The calcar femorale can take various shapes, lengths, and thicknesses. Le Corroller et al.\(^\text{24}\) classified the shape of the calcar femorale into three types among normal hips without osteoarthritis. A ridge type was present in 17.0% of hips, a spur type in 66.5%, and a septum type in 16.5%. In this study, the spur type was less common (43.1%) and both septum-type (25.9%) and ridge-type (31.0%) were more common than previously described. The large number of thin (septum-type) or short (ridge-type) calcar femorale detected in patients with normal hips in our study may be attributable to postmenopausal osteoporosis because patients in this study were predominantly postmenopausal women, while more than half of the patients in the analysis by Le Corroller et al. were male. Resorption of the thigh spur during osteoporosis would contribute to a higher incidence of proximal femur fractures in older adults.\(^\text{25}\)

The calcar femorale is thickest medially, where it joins the compression buttress of the neck, and gradually thins as it extends laterally.\(^\text{21,22}\) The length of the calcar femorale was significantly shorter in Crowe grade II–IV hips than in Crowe grade I or normal hips. Differences were also seen in the types of calcar femorale of patients with secondary osteoarthritis and that of normal hips. Various factors may contribute to these differences. First, patients with severe osteoarthritis of the hip cannot walk or adequately bear weight because of hip pain. Second, differences in calcar femorale may suggest a relationship between this structure, the position of the femur in the hip joint, and the load carried by the femur.\(^\text{26}\) The internal cortical structure of the spur is important for stress distribution through the medial cortex and is part of the compressive trabecular system.\(^\text{27}\) For this reason, different load vectors created by increased femoral neck anteversion in patients with secondary osteoarthritis of the hip may have an influence on the calcar femorale type.

Wroblewski et al.\(^\text{28}\) reported on the role of the calcar femorale in cemented THA. Without clearing of the calcar femorale, a stem abutting on the calcar femorale will have little to no space for cement. To offer space for a cement layer that will support the stem proximally and posteriorly, clearing of the calcar femorale is recommended. That report supports our finding that single-wedge stems were inserted relatively parallel to the calcar femorale. Antever-

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.
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