**Original Article** Clinics in Orthopedic Surgery 2017;9:413-419 • https://doi.org/10.4055/cios.2017.9.4.413

# Calcar Femorale in Patients with Osteoarthritis of the Hip Secondary to Developmental Dysplasia

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**Background:** We investigated whether the calcar femorale, a cortical septum in the region of the lesser trochanter of the femur, 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*

Intraoperative positioning of the acetabular and femoral components influences periprosthetic dislocation rates and material wear characteristics following total hip arthroplasty (THA).[1] 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).[2] Femurs with DDH show a smaller, more anteverted canal than normal femurs.[3,4] 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.[5] 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 femo-

Received June 20, 2017; Accepted September 18, 2017
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rale to the initial stability and alignment of the femoral stem of THA was reported.[6-8] First described in 1874 by Merkel,[9] 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.[10] The modern nomenclature was coined by Harty[11] in 1957. Several studies of the calcar femorale were performed using computed tomography (CT) in the 1980s.[10,12,13] Hansson et al.[14] 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.[8] Patients with severe DDH are known to require different femoral components compared to patients with normal hips,[15] 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/m$^2$ (range, 14.5 to 36.1 kg/m$^2$). 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.[16] 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,[15] 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. We compared the shape, length, and angle of the calcar femorale among the groups using axial CT sections (Fig. 1). The maximum length of the calcar femorale in the mediolateral direction was measured on the axial CT section (Fig. 1D). The angle of the calcar femorale was defined as the angle between the calcar femorale and the posterior condylar axis on this section (Fig. 1D and G). Femoral neck anteversion was defined as the angle between the neck axis and the posterior condylar axis using the method described by Sugano et al.[17] (Fig. 1E and G). We classified the shape of the calcar femorale according to a modification of the classification described by Le Corroller et al.,[18] defining ridge type as short and thick (< 9 mm), septum type as thin and long (≥ 13 mm), and spur type as intermediate between the two (Fig. 1A-C).

Of the patients described above, patients with

**Table 1.** Patient Characteristics

| 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/m$^2$) | 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.

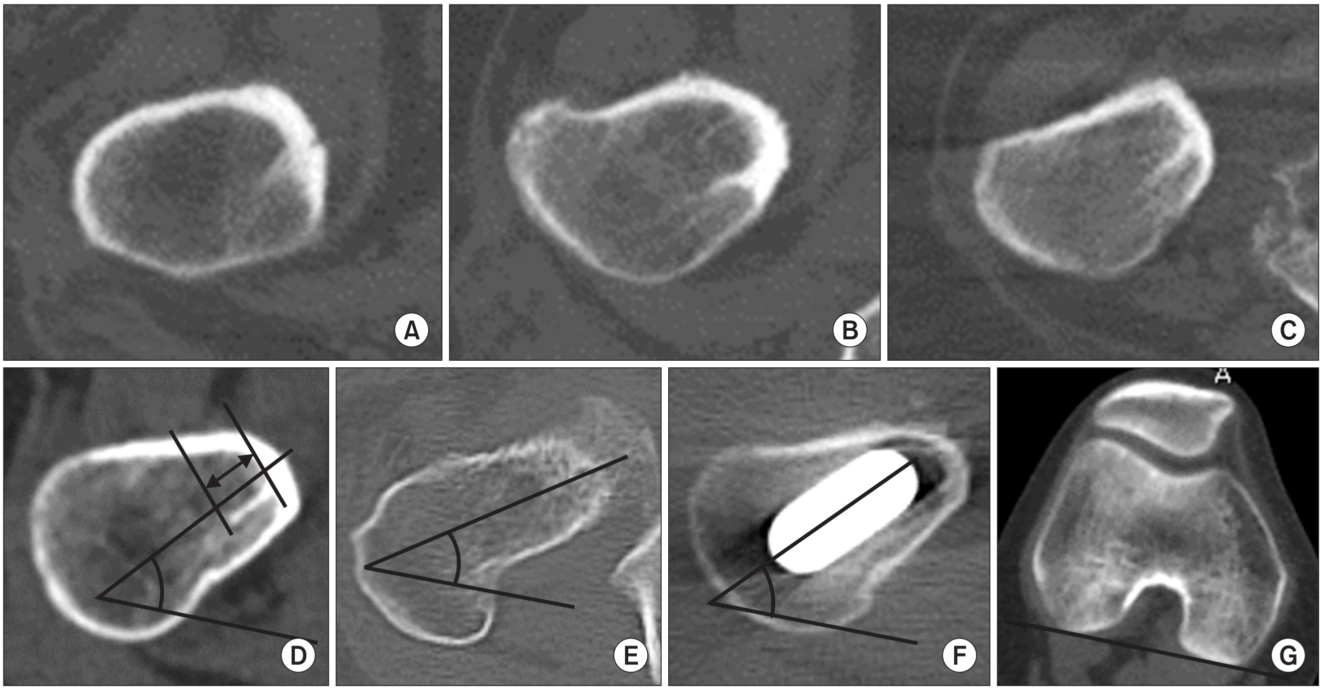



**Fig. 1.** Different types of calcar femorale in three different individuals: ridge type (A), spur type (B), and septum type (C). (D) Length of the calcar femorale was measured from the axial computed tomography section, and the calcar femorale angle was measured with reference to the posterior condylar axis (G). (E) Anteversion of the femoral neck was defined as the angle between the neck axis at the level just below the head and the posterior condylar axis (G). (F) Stem anteversion was defined as the angle between the stem axis and the posterior condylar axis (G).

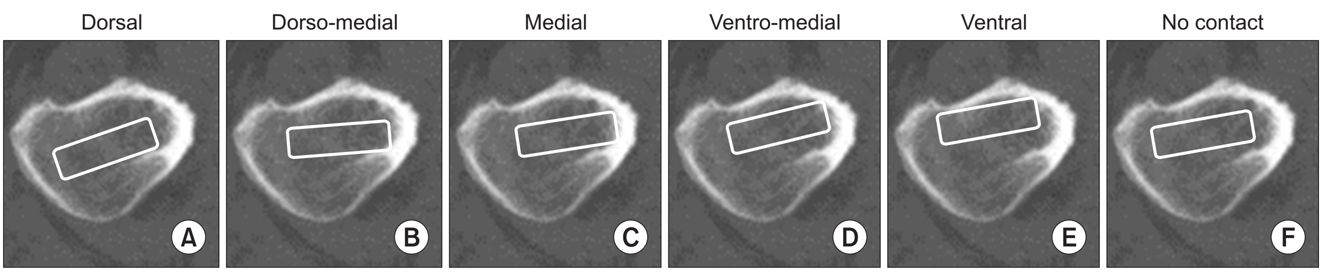



**Fig. 2.** Contact location between the calcar femorale and the stem. Contact locations were divided into six types using axial computed tomography cuts at the level of maximum length of the calcar femorale: dorsal (A), dorso-medial (B), medial (C), ventro-medial (D), ventral (E), and no contact (F).

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).[19] 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).[8] 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.[20]

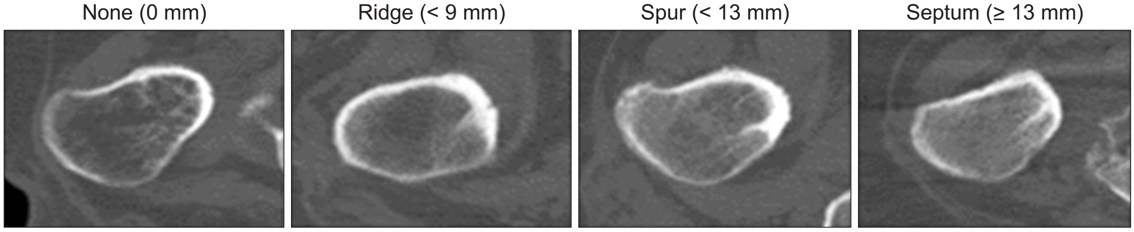
### Statistical Analysis

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



| | None (0 mm) | Ridge (< 9 mm) | Spur (< 13 mm) | Septum (≥ 13 mm) |
|---|---|---|---|---|
| Normal (n = 58) | 0 | 18 (31.0) | 25 (43.1) | 15 (25.9) |
| Crowe I (n = 147) | 2 (1.4) | 52 (35.4) | 45 (30.6) | 48 (32.7) |
| Crowe II–IV (n = 72) | 8 (11.1) | 31 (43.1) | 23 (31.9) | 10 (13.9) |
| Osteoarthritis (n = 219) | 10 (4.6) | 83 (37.9) | 68 (31.1) | 58 (26.5) |

**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 (%).

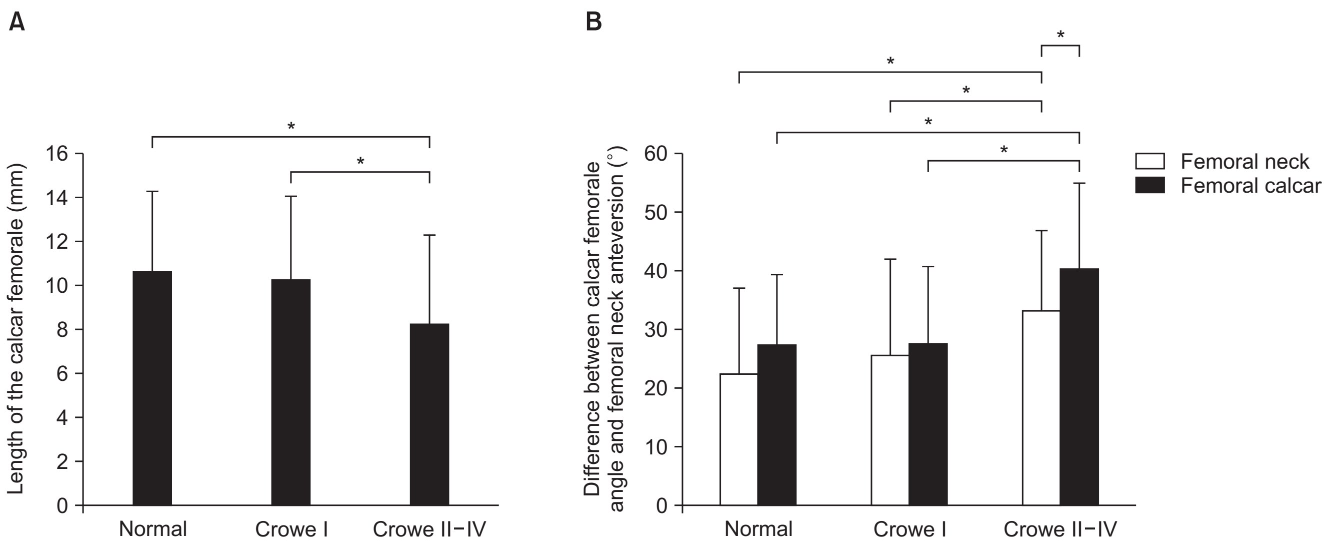
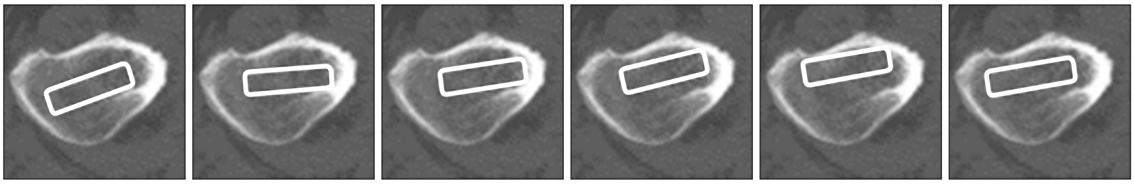



**Fig. 4.** Length of the calcar femorale (A) and difference between calcar femorale angle and femoral neck anteversion (B) measured on computed tomography scans. *$p < 0.05$.



| | Dorsal | Dorso-medial | Medial | Ventro-medial | Ventral | No contact |
|---|---|---|---|---|---|---|
| Group T (n = 59) | 43 (72.9) | 4 (6.8) | 10 (16.9) | 0 | 2 (3.4) | 0 |
| Group S (n = 147) | 55 (37.4) | 55 (37.4) | 26 (17.7) | 9 (6.1) | 0 | 2 (1.4) |
| Group A (n = 13) | 1 (7.7) | 5 (38.5) | 7 (53.8) | 0 | 0 | 0 |

**Fig. 5.** Contact between the calcar femorale and the three types of stems assessed on axial computed tomography sections. In most cases, a single-wedge stem was inserted in contact with the calcar femorale, while other types of stems scraped the calcar femorale. Values are presented as number of hips (%). Group T: single-wedge stem, Group S: double-wedge metaphyseal filling stem, Group A: modular stem.

**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.

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).

### Relationship between Calcar Femorale and Implantation Parameters

Contact points between the calcar femorale and implant were assessed (Fig. 5). The number of stems inserted in contact with the calcar femorale (dorsal contact) was 43 (72.9%) in group T and 55 (37.4%) in group S, and the number of stems inserted that scraped the calcar femorale (dorsomedial and medial contact) was 14 (23.7%) in group T and 81 (55.1%) in group S. Significant differences in the locations of contact points were evident between group T and group S ($p < 0.001$).

In group T, the angle of the calcar femorale minus stem anteversion was 6.6° ± 5.3° (Table 2). The angle of the femoral neck anteversion minus stem anteversion in group T was 9.4° ± 7.2°. The stem in group T was inserted more parallel to the calcar femorale rather than femoral neck anteversion ($p$ = 0.016). No significant differences were observed between calcar femorale angle minus stem anteversion and femoral neck anteversion minus stem anteversion in group S and group A ($p$ = 0.348 and $p$ = 0.665, respectively).

## 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.[7] 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 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.[18] 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.[7]

The calcar femorale is thickest medially, where it joins the compression buttress of the neck, and gradually thins as it extends laterally.[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.[23] The internal cortical structure of the spur is important for stress distribution through the medial cortex and is part of the compressive trabecular system.[24] 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.[25] 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. Anteversion of the femoral neck is widely recognized as an important index during stem insertion. However, the hip surgeon sometimes notes that stem anteversion inadvertently differs from femoral neck anteversion. Garden[26] reported the calcar femorale, "the true neck of the femur," as the uninterrupted continuation of the posteromedial cortex upon which the lesser trochanter is based. In patients with secondary osteoarthritis of the hip due to DDH, a large calcar femorale angle would create excessive anteversion of a single-wedge stem. Clearing the calcar femorale might be necessary to reduce anteversion of a single-wedge stem, or another type of stem may be desirable in such cases.

Some limitations must be considered when interpreting the findings of our study. First, this analysis was performed using CT scans of all patients who presented with hip pain. However, performing CT on all patients who require THA is not feasible. Second, we used a direct-lateral approach in all cases. Investigations using another approach, such as an anterolateral, direct anterior, or posterior approach, might obtain different results. Third, the original classification of calcar femorale by Le Corroller et al.[18] does not offer sufficient reproducibility or reliability due to the lack of objectivity of the classification. We therefore classified the shape of the calcar femorale using a modification of the classification described by Le Corroller et al.[18] into "ridge type" for a short and thick structure ($< 9$ mm), "septum type" for a thin and long structure ($\geq 13$ mm), and "spur type" for an intermediate structure, for better objectivity. In order to further improve reliability, calcar femorale should be classified after correcting for patient height, not simply by considering its length. Finally, measurement of the angle of the calcar femorale is not difficult in the septum and spur types because of adequate length of the calcar femorale in such cases, while this measurement may be difficult in some ridge type cases where the length of the calcar femorale is too short.

In conclusion, the calcar femorale can be identified in almost all patients, and the shape and angle of this structure differ in accordance with the severity of hip deformity. The calcar femorale may offer a useful barometer for single-wedge stem insertion in patients with DDH.

## CONFLICT OF INTEREST

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

## REFERENCES

1. Widmer KH, Zurfluh B. Compliant positioning of total hip components for optimal range of motion. J Orthop Res. 2004;22(4):815-21.
2. Hoaglund FT, Shiba R, Newberg AH, Leung KY. Diseases of the hip: a comparative study of Japanese oriental and American white patients. J Bone Joint Surg Am. 1985;67(9):1376-83.
3. Sugano N, Noble PC, Kamaric E, Salama JK, Ochi T, Tullos HS. The morphology of the femur in developmental dysplasia of the hip. J Bone Joint Surg Br. 1998;80(4):711-9.
4. Nishii T, Sugano N, Miki H, Takao M, Koyama T, Yoshikawa H. Five-year results of metal-on-metal resurfacing arthroplasty in Asian patients. J Arthroplasty. 2007;22(2):176-83.
5. Iwana D, Nakamura N, Miki H, Kitada M, Hananouchi T, Sugano N. Accuracy of angle and position of the cup using computed tomography-based navigation systems in total hip arthroplasty. Comput Aided Surg. 2013;18(5-6):187-94.
6. Laine HJ, Lehto MU, Moilanen T. Diversity of proximal femoral medullary canal. J Arthroplasty. 2000;15(1):86-92.
7. Adam F, Hammer DS, Pape D, Kohn D. The internal calcar septum (femoral thigh spur) in computed tomography and conventional radiography. Skeletal Radiol. 2001;30(2):77-83.
8. Decking J, Decking R, Schoellner C, Drees P, Eckardt A. The internal calcar septum and its contact with the virtual stem in THR: a computer tomographic evaluation. Acta Orthop Scand. 2003;74(5):542-6.
9. Merkel F. Betrachtungen uber das Os femoris. Arch Pathol Anat Physiol Klin Med. 1874;59(2):237-56. https://doi.org/10.1007/BF01963543.
10. Dai KR, An KN, Hein T, Nakahjima I, Chao E. Geometric and biomechanical analysis of the human femur. Trans Orthop Res Soc. 1985;10:99-102.
11. Harty M. The calcar femorale and the femoral neck. J Bone Joint Surg Am. 1957;39(3):625-30.
12. Brown TD, Ferguson AB Jr. Mechanical property distributions in the cancellous bone of the human proximal femur. Acta Orthop Scand. 1980;51(3):429-37.
13. Walker PS, Robertson DD. Design and fabrication of cementless hip stems. Clin Orthop Relat Res. 1988;(235):25-34.
14. Hansson LI, Hagglund G, Ordeberg G, Sandstrom S. The calcar femorale as a landmark in hip physiolysis. Acta Orthop Scand. 1988;59(2):134-8.
15. Crowe JF, Mani VJ, Ranawat CS. Total hip replacement in congenital dislocation and dysplasia of the hip. J Bone Joint Surg Am. 1979;61(1):15-23.
16. Hoeksma HL, Van Den Ende CH, Ronday HK, Heering A, Breedveld FC. Comparison of the responsiveness of the Harris Hip Score with generic measures for hip function in osteoarthritis of the hip. Ann Rheum Dis. 2003;62(10):935-8.
17. Sugano N, Noble PC, Kamaric E. A comparison of alternative methods of measuring femoral anteversion. J Comput Assist Tomogr. 1998;22(4):610-4.
18. Le Corroller T, Dediu M, Pauly V, Pirro N, Chabrand P, Champsaur P. The femoral calcar: a computed tomography anatomical study. Clin Anat. 2011;24(7):886-92.
19. Khanuja HS, Vakil JJ, Goddard MS, Mont MA. Cementless femoral fixation in total hip arthroplasty. J Bone Joint Surg Am. 2011;93(5):500-9.
20. Waidelich HA, Strecker W, Schneider E. Computed tomographic torsion-angle and length measurement of the lower extremity: the methods, normal values and radiation load. Rofo. 1992;157(3):245-51.
21. Griffin JB. The calcar femorale redefined. Clin Orthop Relat Res. 1982;(164):211-4.
22. Stiehl JB, Jacobson D, Carrera G. Morphological analysis of the proximal femur using quantitative computed tomography. Int Orthop. 2007;31(3):287-92.
23. Glinkowski W, Ciszek B. The topographic and comparative study of the calcar femorale. Folia Morphol (Warsz). 1989;48(1-4):183-91.
24. Zhang Q, Chen W, Liu HJ, et al. The role of the calcar femorale in stress distribution in the proximal femur. Orthop Surg. 2009;1(4):311-6.
25. Wroblewski BM, Siney PD, Fleming PA, Bobak P. The calcar femorale in cemented stem fixation in total hip arthroplasty. J Bone Joint Surg Br. 2000;82(6):842-5.
26. Garden RS. The structure and function of the proximal end of the femur. J Bone Joint Surg Br. 1961;43(3):576-89.