The Etiology of Cam-type Femoroacetabular Impingement: A Cadaveric Study

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Background: There is a dearth of literature examining the causes of cam-type femoroacetabular impingement (FAI) and when such morphology appears. The purpose of the current study was to analyze how the ossific portion of the proximal femur develops over time with respect to standard cam-type FAI parameters.

Methods: A collection of 193 femurs from cadavers aged 4 to 21 years were evaluated. The age, sex, ethnicity, and status of the proximal femoral physes (open or closed) of each were recorded. Each specimen was digitally photographed in standardized anteroposterior and modified axial positions. From these photographs, the anterior offset, anterior offset ratio (AOR), and α-angle were determined. A cam lesion was defined as an α-angle >55 degrees on the lateral view.

Results: The mean age of the specimens was 17.5 ± 4.2 years. The majority were male (69%) and African American (79%) with closed physes (78%). There were significant differences among discrete age groups with respect to α-angle ($P = 0.01$), anterior offset ($P < 0.01$), and AOR ($P < 0.01$). In addition, younger femurs with open physes had a significantly higher mean α-angle ($P < 0.01$), lower mean anterior offset ($P < 0.01$), and higher mean AOR ($P < 0.01$) compared with older ones with closed physes. Specimens defined as having a cam deformity had a statistically higher α-angle ($P < 0.01$) and lower anterior offset ($P < 0.01$), but there was no difference in AOR values compared with specimens without a cam lesion ($P = 0.1$).

Conclusions: The apparent decline in α-angles as age increases indicates that the traditional α-angle in younger patients measures a different anatomic parameter (ossified femur excluding the cartilaginous portion) than in older patients (completely ossified femur). This suggests that the bony α-angle is inappropriate in the evaluation of cam lesions in the immature physis. The AOR, rather than the anterior offset, may be more accurate in the evaluation of the growing proximal femur.

Clinical Relevance: This study provides novel insight into, and enhances the understanding of, the development of cam-type FAI.

Key Words: femoroacetabular impingement, cam, etiology, cadaver

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Cam-type morphology associated with femoroacetabular impingement (FAI) is an increasingly recognized anatomic variant of the proximal femur found in 10% to 74% of the general population.[1] Despite the relatively high prevalence of cam-type FAI, its etiology is not clearly defined. As early as 1971, Murray and Duncan[2] were credited with identifying a structural variant of the proximal femur that was termed a "pistol-grip deformity." Several theories have been proposed to account for its development. Genetic predisposition may place individuals at risk for cam morphology and early development of osteoarthritis.[3] Reactive bone formation at the femoral head-neck junction may occur secondary to repetitive impaction.[4–7] Furthermore, a correlation has been proposed between slipped capital femoral epiphyses and cam formation.[8–13] Legg-Calve-Perthes disease, trauma to the proximal femur, and tumors have also been linked to cam-type FAI.[6,8–13]

Recently, several studies have analyzed the relationship between cam morphology and physeal closure during proximal femoral development. Carsen et al[14] evaluated magnetic resonance imaging (MRI)s of adolescents prephyseal and postphyseal closure. None of the 23 patients studied had evidence of cam morphology before physeal closure. However, 3 of 21 (14%) patients showed evidence of cam lesions following closure of the physis. The authors concluded that cam-type FAI develops during the period of physeal closure. Carter et al[13] reviewed the MRI findings of adolescent patients treated for cam-type FAI. The authors noted that cam deformity was found further from the physis in patients with closed growth plates than those with open ones. They suggested a causal relationship between physeal injury and the development of cam morphology in adolescents with FAI.

The purpose of our study was to analyze the ossific proximal femoral anatomy of cadaveric specimens aged

21 years and under to determine how it develops over time with respect to standard cam-type FAI parameters.

METHODS

Researchers evaluated cadaveric femoral specimens of all skeletons aged 21 years and younger at the Hamann-Todd Osteological Collection at the Cleveland Museum of Natural History. These specimens were comprised of unclaimed human remains from 1912 to 1938 at the Cleveland city morgue. The specimens were visually analyzed in a technique similar to that performed by Toogood and colleagues.[15–17]

Skeletons were excluded if their age was not recorded or if they were over the age of 21 years, if the femora were not intact or had gross visual deformity, or if there was visual evidence or a recorded patient history of osteomyelitis, fracture, metabolic disease, or nutritional deficiency known to affect skeletal development.[15–17]

Each femur was digitally photographed in standardized anteroposterior and modified axial positions using the technique described by Toogood et al[15] to avoid any distortion or inconsistency while making measurements. A specimen was noted to have open physes if the femoral head was separate from the shaft. If the head/neck were attached, the physis was considered closed. In specimens with open physes, the femoral head was reattached using a thin layer (< 1 mm) of evenly distributed adhesive putty (Fig. 1). Typically, mating borders of the femoral head and shaft were congruently irregular and pieced together in a similar manner to 2 pieces of a jigsaw puzzle. If there was a discrepancy when replicating the physis, the specimen was excluded.

For each specimen, the age, sex, state of the proximal femoral physis (open or closed), and ethnicity were recorded. Utilizing ImageJ software (version 1.48, National Institutes of Health Bethesda, MD), several standard FAI measurements were obtained from the images of each specimen (Fig. 2): α-angle, anterior offset, femoral head diameter, and the anterior offset ratio (AOR). Length and distance measurements were initially collected in pixels, but were converted to millimeters with the aid of a calibration ruler placed in each image. All measurements were performed by the same investigator using established techniques.[15,16,18–20]

The α-angle was determined by the method described by Toogood et al.[15] The α-angle was defined on the modified axial view as the angle formed between the axis of the femoral neck and a line extending from the center of a best-fit circle inscribed around the femoral head to the point where the anterior cortex of the femoral head/neck junction first exited the circle. Although there is no single universal objective radiographic standard for diagnosing a cam deformity, the α-angle is the most commonly used.[20] Although the threshold for identifying an abnormal α-angle is controversial, several studies have advocated for a cut-off of 55 degrees.[21–23] Consequently, a cam deformity in the present study was defined by an α-angle > 55 degrees. In addition, the anterior offset was calculated as the distance between a line drawn along the anterolateral edge of the femoral neck and another parallel line at the anterolateral aspect of the femoral head.[20] Moreover, the femoral head diameter was described as the diameter of a best-fit circle around the femoral head by which the head did not extend beyond 1 mm outside of the circle on the anteroposterior view.[16,18,19] Finally, the AOR was calculated as the anterior offset divided by the femoral head diameter.[20] Of note, data for the femoral head diameter are not presented in this manuscript as it was not a primary measurement of interest, but rather a means to determining the AOR.

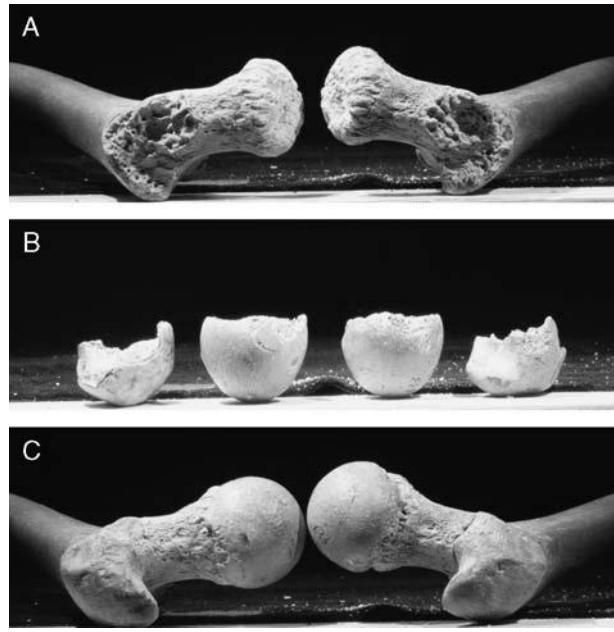

FIGURE 1. Demonstration of reattachment of femoral components in specimen with open physes. A, Proximal femurs with missing femoral heads and greater trochanters. B, Femoral head and trochanteric pieces. C, Reapproximated specimens.

Calculations were made for the entire population as well as for subpopulations based upon cadaveric sex, status of the proximal femoral physis, age, and presence or absence of a cam deformity. Statistical analysis was performed with SPSS software (version 16.0.1, Chicago, IL). Independent t and Mann-Whitney U tests were employed when data were and were not normally distributed, respectively. Analysis of variance and Kruskal-Wallis testing were used when comparing > 2 groups when the data were and were not normally distributed, respectively. χ^2 tests evaluated binary data. P-values are 2-tailed with $P < 0.05$ indicating significance.

RESULTS

A total of 193 femurs were obtained from the collection and photographed. The specimen demographics are presented in Table 1. Specimens ranged in age from 4 to 21 years. The majority of the specimens were male,

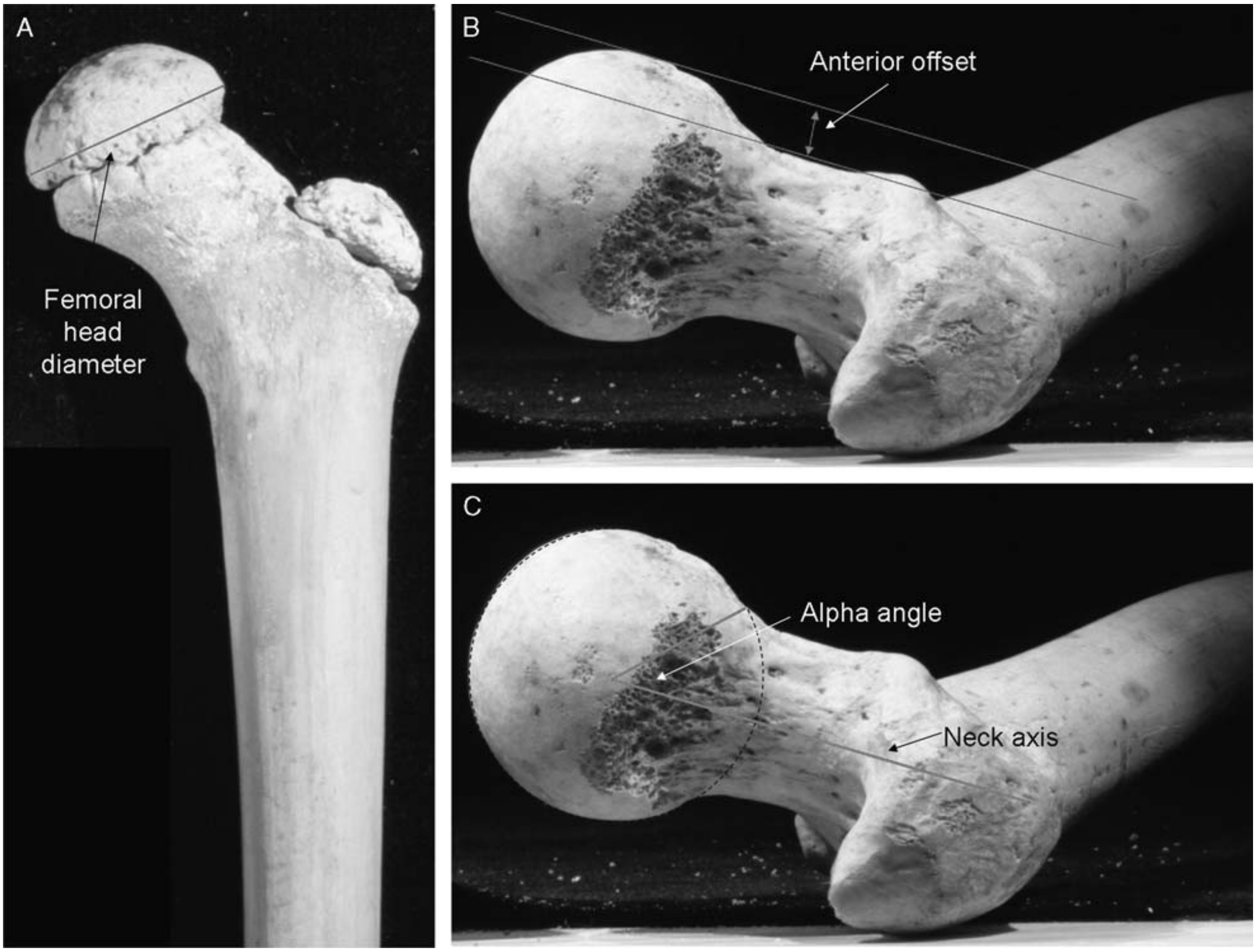

FIGURE 2. Clinical measurements obtained from each specimen. A, Femoral head diameter, (B) anterior offset, and (C) α-angle (with dotted circle representing best-fit circle around femoral head).

from African American cadavers, and had closed proximal femoral physes.

α-angle measurements were stratified by sex, status of the proximal femoral physis, and age (Fig. 3). Males had a mean α-angle of 47.1 degrees (SD = 7.2 degrees), whereas females maintained a mean of 43.7 degrees (SD = 5.9 degrees). This difference was statistically significant ($P < 0.01$). In addition, femurs with open physes had a significantly higher mean α-angle (49.5 degrees; SD = 7.6 degrees) compared with those with closed physes (45.1 degrees; SD = 6.5 degrees) ($P < 0.01$). With regard to specimen age, there was a significant difference among discrete age groups ($P = 0.01$).

Anterior offset values were also stratified (Fig. 4). Males had a mean anterior offset of 7.5 mm (SD = 1.6

TABLE 1. Demographics of Femoral Specimens

Characteristics	N (%)	Mean Age (SD) (y)	Age Range (y)
Entire population	193 (100)	17.5 (4.2)	4-21
Sex			
Male	133 (69)	18.5 (3.5)	6-21
Female	60 (31)	15.3 (4.7)	4-21
Ethnicity			
White	40 (21)	18.7 (2.6)	12-21
African American	153 (79)	17.2 (4.5)	4-21
Physes			
Open	43 (22)	10.8 (3.7)	4-17
Closed	150 (78)	19.5 (1.5)	14-21

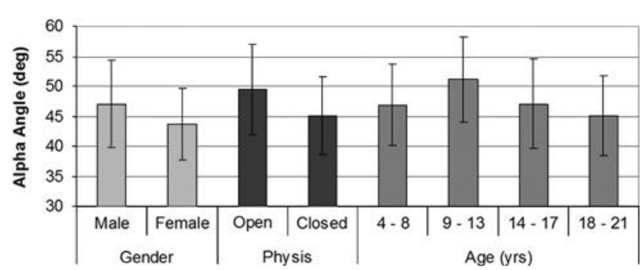

FIGURE 3. α-angle measurements stratified by sex, status of physis, and age. Mean values and SD bars are provided.

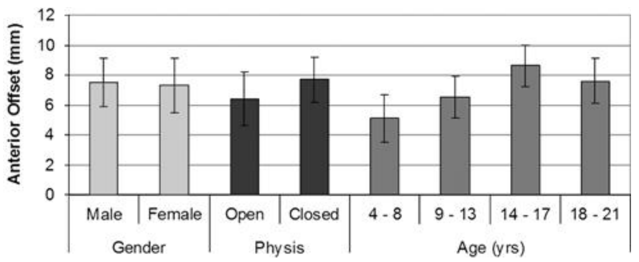

FIGURE 4. Anterior offset measurements stratified by sex, status of physis, and age. Mean values and SD bars are provided.

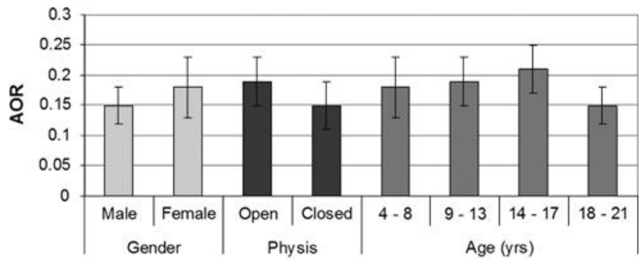

FIGURE 5. Anterior offset ratio measurements stratified by sex, status of physis, and age. Mean values and SD bars are provided. AOR indicates anterior offset ratio.

mm), whereas females maintained a mean of 7.3 mm (SD = 1.8 mm). However, this difference was not significant ($P = 0.40$). Moreover, femurs with open physes had a significantly lower mean anterior offset (6.4 mm; SD = 1.8 mm) compared with those with closed physes (7.7 mm; SD = 1.5 mm) ($P < 0.01$). In addition, there was a significant difference among various discrete age groups ($P < 0.01$).

Figure 5 illustrates the AOR values. Overall, female specimens had a significantly higher AOR than males ($P < 0.01$), those with open physes had a significantly higher AOR than those with closed physes ($P < 0.01$), and there was a significant difference among age groups ($P < 0.01$). Specifically, males had a mean AOR of 0.15 (SD = 0.03), whereas females maintained a mean of 0.18 (SD = 0.05). Also, femurs with open physes had a mean AOR of 0.19 (SD = 0.04) compared with 0.15 (SD = 0.04) for those with closed physes. Specimens between 14 and 17 years had the highest AOR at 0.21 (SD = 0.04), whereas those between 18 and 21 years had the lowest at 0.15 (SD = 0.03).

Of the 193 femurs, 19 (10%) were defined as having a cam deformity (Table 2). There were no significant differences in the rate of cam deformities among different sexes ($P = 0.13$) or ethnicities ($P = 0.08$). Consistent with the bony α-angles, a greater percentage of specimens with open physes fulfilled criteria for cam deformities compared with those with closed physes ($P < 0.01$). The youngest specimens to have an apparent cam deformity were 10 years old (n = 5). Once cam deformities were identified, the aforementioned measurements were subsequently stratified according to the presence or absence of a cam deformity (Table 3). Femurs with a cam deformity had a statistically higher α-angle, significantly lower anterior offset, and lower AOR values that trended toward, but did not achieve, statistical significance compared with those without cam deformities.

DISCUSSION

Cam-type FAI has been linked to pain, cartilage/labral damage, and eventual degenerative arthritis of the hip.[1,2,24–26] Because cam impingement is often found in asymptomatic patients, it is unclear as to what stage of development the femoral morphologic variant arises. It is also unclear as to what the etiology of cam-type anatomy truly is.[24] Siebenrock et al[5] have proposed that cam-type deformities may occur as an alteration of the growth plate in adolescent athletes secondary to increased sporting activity. The authors performed a case-control study of elite male basketball athletes versus an age-matched cohort. They reported an 8.3% prevalence of cam morphology in the closed physeal group but no cam lesions in the open or transitional physeal group. Similarly, in a pediatric MRI study, Carsen et al[14] reported that cam morphology was found only in patients with closed physes. Each study concluded that cam-type morphology likely occurs during the period of physeal closure.

By describing how the ossific portion of the proximal femur develops over time with respect to standard cam-type FAI parameters, our study assists in further understanding its natural history. This will help to further stratify patients for risk of impingement and aid in treatment decision making. A total of 193 femurs were examined, making this the largest study of pediatric/adolescent proximal femora to date. This study also analyzed the largest range of pediatric ages (4 to 21 y of age) available in the literature for cam/physeal analysis. Seventy-eight percent of specimens had closed proximal femoral physes. However, 43 specimens with open physes were available. Ten percent of specimens were found to have cam morphology (defined as an α-angle > 55 degrees). This is consistent with previously reported prevalence rates.[21,24]

Specimens with open versus closed physes were initially compared. Interestingly, femora with open proximal physes had significantly higher mean α-angles than those with closed physes. This contradicts the findings of Siebenrock and colleagues and Carsen and colleagues in which no patients with open physes demonstrated cam lesions.[5,6,14] In our study, specimens as young as 10 years of age had α-angles > 55 degrees. This, again, contradicts previous studies.[5,6,14] The discrepancy likely resulted because the ability to judge FAI in a skeletally immature femur is limited in the present study as the cartilage is missing from the analysis. This limits our ability to claim that a true cam lesion was observed in younger patients. If anything, one would expect the rate of cam lesions to be higher in patients with closed physes, as there is no evidence to suggest that cams remodel on their own. Consequently,

TABLE 2. Characteristics of Specimens With Alpha Angle >55 Degrees Deformities

Characteristics	N (%)	Mean Age (SD) (y)	Age Range (y)	P
Entire population	19 (10)	15.5 (4.5)	10-21	—
Sex				0.13
Male	16 (12)	16.4 (4.3)	10-21	
Female	3 (5)	11.3 (2.3)	10-14	
Ethnicity				0.08
White	1 (3)	20 (0)	—	
African American	18 (12)	15.3 (4.5)	10-21	
Physes				< 0.01
Open	10 (23)	12 (2.9)	10-17	
Closed	9 (6)	19.6 (1.2)	18-21	
Age (y)				< 0.01
4-8	0 (0)	—	—	—
9-13	7 (39)	10.3 (0.5)	10-11	0.01
14-17	3 (12)	16 (1.7)	14-17	0.04
18-21	9 (7)	19.6 (1.2)	18-21	0.35

"N" refers to the number (and "%" denotes the percentage) of specimens with each characteristic that have a alpha angle > 55 degrees lesion.

the higher prevalence of cam deformities found in patients with open physes likely indicates that the observed cam lesion is apparent rather than true (due to the lack of ossification of the cartilage in the younger group). The observation that α-angles varied by age across the entire specimen population supports the fact that the α-angle in the younger child measures a different anatomic parameter (the ossified femur excluding the cartilaginous portion) than in the older child (completely ossified femur).

Anterior offset values have also been proposed as an indicator of cam impingement.[27] Typically, a smaller anterior offset value is indicative of cam morphology. Specimens with open physes had a significantly lower anterior offset than those with closed physes. When divided into discrete age groups, specimens 13 years and under had significantly lower anterior offset values than those 14 to 21 years of age. Theoretically, however, a younger patient may be incorrectly diagnosed with a cam lesion based upon anterior offset values alone because an anatomically smaller femoral head would be expected to have a proportionally smaller anterior offset value.[28] The AOR corrects for this error by standardizing for femoral head size. A smaller AOR correlates with an increased likelihood of cam impingement.[29] Specimens with open physes had a significantly higher AOR (0.19) compared with those with closed physes (0.15). When grouped by age, no clear pattern was determined when using AOR calculations. These data may discount some of the previous anterior offset values in which patients with an open physis were found to be at a greater risk for cam impingement. Therefore, the higher AOR values likely represent fewer cam lesions in younger patients, which further argues that the α-angles overestimated the prevalence of cam lesions in this population.

Based upon previous studies, males display a significantly higher prevalence of cam-type morphology than females (9.6% to 24% vs. 5%).[14,21,30] In our study, males possessed an average α-angle of 47.1 degrees. This was significantly greater than the 43.7-degree mean value of the females. Despite this, there was no significant difference in the rate of cam lesions between sexes (based upon α-angles). However, our study did find that male specimens had a significantly lower AOR (0.15) compared with 0.18 in females. This may suggest that males are actually at increased risk for cam impingement.

Several studies have attempted to analyze the prevalence of cam impingement among different ethnicities, most commonly comparing white populations to Asian populations.[31–33] To date, no studies have compared the prevalence rates of cam morphology between whites and African Americans. Our study found no significant difference in the rate of cam morphology in the African American group compared with the white subset, although the lack of a difference is tempered by the small proportion of whites in the study.

There are several limitations to this study. First, this is a cadaveric study. However, the methods of anatomic measurements were based on previously validated stud-

TABLE 3. Measurements Stratified by Alpha Angle >55 Degrees Versus <55 Degrees

	Alpha Angle > 55 Degrees		Alpha Angle < 55 Degrees		
Measurements	Mean (SD)	Range	Mean (SD)	Range	P
α-angle (deg.)	59.3 (2.9)	56.3-65.9	43.9 (7.2)	29.5-54.4	< 0.01
Anterior offset (mm)	6.2 (1.1)	4.3-7.9	7.6 (1.6)	4.2-12.9	< 0.01
AOR	0.14 (0.03)	0.1-0.2	0.16 (0.04)	0.1-0.3	0.1

AOR indicates anterior offset ratio.

ies.[15,16] This study contained the largest pediatric femoral sample size to date. Secondly, the authors had to recreate the proximal femoral anatomy of specimens with open physes. This was performed in a meticulous manner. The cadaveric anatomy provided a reproducible anatomic template based upon the congruency of each adjacent segment. In addition, as previously mentioned, the inability to account for the cartilaginous portion of the femur in the younger patients limits our ability to determine the presence of true cam lesions.

Based upon data analyzed from cadaveric proximal femoral anatomy, the apparent decline in α-angles with age indicates that the traditional bony α-angle in younger patients measures a different anatomic parameter (ossified femur excluding the cartilaginous portion) than in older patients (completely ossified femur). This suggests that use of the bony α-angle is inappropriate in the evaluation of cam lesions in the immature physis. Furthermore, the AOR, rather than the anterior offset or α-angle, may be more accurate in the evaluation of the growing proximal femur.

REFERENCES

1. Ganz R, Parvizi J, Beck M, et al. Femoroacetabular impingement: a cause for osteoarthritis of the hip. *Clin Orthop Relat Res*. 2003;417:112–120.
2. Murray RO, Duncan C. Athletic activity in adolescence as an etiological factor in degenerative hip disease. *J Bone Joint Surg Br*. 1971;53:406–419.
3. Pollard TC, Villar RN, Norton MR, et al. Genetic influences in the aetiology of femoroacetabular impingement: a sibling study. *J Bone Joint Surg Br*. 2010;92:209–216.
4. Siebenrock KA, Behning A, Mamisch TC, et al. Growth plate alteration precedes cam-type deformity in elite basketball players. *Clin Orthop Relat Res*. 2013;471:1084–1091.
5. Siebenrock KA, Ferner F, Noble PC, et al. The cam-type deformity of the proximal femur arises in childhood in response to vigorous sporting activity. *Clin Orthop Relat Res*. 2011;469:3229–3240.
6. Siebenrock KA, Schwab JM. The cam-type deformity—what is it: SCFE, osteophyte, or a new disease? *J Pediatr Orthop*. 2013;33(suppl 1):S121–S125.
7. Nepple JJ, Riggs CN, Ross JR, et al. Clinical presentation and disease characteristics of femoroacetabular impingement are sex-dependent. *J Bone Joint Surg Am*. 2014;96:1683–1689.
8. Albers CE, Steppacher SD, Haefeli PC, et al. Twelve percent of hips with a primary cam deformity exhibit a slip-like morphology resembling sequelae of slipped capital femoral epiphysis. *Clin Orthop Relat Res*. 2015;473:1212–1223.
9. Akiyama M, Nakashima Y, Kitano T, et al. Remodelling of femoral head-neck junction in slipped capital femoral epiphysis: a multicentre study. *Int Orthop*. 2013;37:2331–2336.
10. Chen A, Youderian A, Watkins S, et al. Arthroscopic femoral neck osteoplasty in slipped capital femoral epiphysis. *Arthroscopy*. 2014;30:1229–1234.
11. Leunig M, Juni P, Werlen S, et al. Prevalence of cam and pincer-type deformities on hip MRI in an asymptomatic young Swiss female population: a cross-sectional study. *Osteoarthritis Cartilage*. 2013;21:544–550.
12. Siebenrock KA, Wahab KH, Werlen S, et al. Abnormal extension of the femoral head epiphysis as a cause of cam impingement. *Clin Orthop Relat Res*. 2004;418:54–60.
13. Carter CW, Bixby S, Yen YM, et al. The relationship between cam lesion and physis in skeletally immature patients. *J Pediatr Orthop*. 2014;34:579–584.
14. Carsen S, Moroz PJ, Rakhra K, et al. The Otto Aufranc Award. On the etiology of the cam deformity: a cross-sectional pediatric MRI study. *Clin Orthop Relat Res*. 2014;472:430–436.
15. Toogood PA, Skalak A, Cooperman DR. Proximal femoral anatomy in the normal human population. *Clin Orthop Relat Res*. 2009;467:876–885.
16. Unnanuntana A, Toogood P, Hart D, et al. Evaluation of proximal femoral geometry using digital photographs. *J Orthop Res*. 2010;28:1399–1404.
17. Goodman DA, Feighan JE, Smith AD, et al. Subclinical slipped capital femoral epiphysis. Relationship to osteoarthrosis of the hip. *J Bone Joint Surg Am*. 1997;79:1489–1497.
18. Young EY, Gebhart J, Cooperman D, et al. Are the left and right proximal femurs symmetric? *Clin Orthop Relat Res*. 2013;471:1593–1601.
19. Young EY, Gebhart JJ, Bajwa N, et al. Femoral head asymmetry and coxa magna: anatomic study. *J Pediatr Orthop*. 2014;34: 415–420.
20. Nepple JJ, Prather H, Trousdale RT, et al. Diagnostic imaging of femoroacetabular impingement. *J Am Acad Orthop Surg*. 2013;21(suppl 1):S20–S26.
21. Hack K, Di Primio G, Rakhra K, et al. Prevalence of cam-type femoroacetabular impingement morphology in asymptomatic volunteers. *J Bone Joint Surg Am*. 2010;92:2436–2444.
22. Sankar WN, Nevitt M, Parvizi J, et al. Femoroacetabular impingement: defining the condition and its role in the pathophysiology of osteoarthritis. *J Am Acad Orthop Surg*. 2013;21(suppl 1):S7–S15.
23. Kang AC, Gooding AJ, Coates MH, et al. Computed tomography assessment of hip joints in asymptomatic individuals in relation to femoroacetabular impingement. *Am J Sports Med*. 2010;38: 1160–1165.
24. Collins JA, Ward JP, Youm T. Is prophylactic surgery for femoroacetabular impingement indicated? A systematic review. *Am J Sports Med*. 2014;42:3009–3015.
25. Ranawat AS, Schulz B, Baumbach SF, et al. Radiographic predictors of hip pain in femoroacetabular impingement. *HSS J*. 2011;7:115–119.
26. Beck M, Kalhor M, Leunig M, et al. Hip morphology influences the pattern of damage to the acetabular cartilage: femoroacetabular impingement as a cause of early osteoarthritis of the hip. *J Bone Joint Surg Br*. 2005;87:1012–1018.
27. Ehrmann C, Rosskopf AB, Pfirrmann CW, et al. Beyond the alpha angle: alternative measurements for quantifying cam-type deformities in femoroacetabular impingement. *J Magn Reson Imaging*. 2015. [Epub ahead of print].
28. Eijer H, Leunig M, Mahomed MN. Cross-table lateral radiographs for screening of anterior femoral head-neck offset in patients with femoro-acetabular impingement. *Hip Int*. 2001;11:37–41.
29. Tannast M, Siebenrock KA, Anderson SE. Femoroacetabular impingement: radiographic diagnosis—what the radiologist should know. *AJR Am J Roentgenol*. 2007;188:1540–1552.
30. Gosvig KK, Jacobsen S, Sonne-Holm S, et al. The prevalence of cam-type deformity of the hip joint: a survey of 4151 subjects of the Copenhagen Osteoarthritis Study. *Acta Radiol*. 2008;49:436–441.
31. Fukushima K, Uchiyama K, Takahira N, et al. Prevalence of radiographic findings of femoroacetabular impingement in the Japanese population. *J Surg Res*. 2014;9:25–30.
32. Dudda M, Kim YJ, Zhang Y, et al. Morphologic differences between the hips of Chinese women and white women: could they account for the ethnic difference in the prevalence of hip osteoarthritis? *Arthritis Rheum*. 2011;63:2992–2999.
33. Mori R, Yasunaga Y, Yamasaki T, et al. Are cam and pincer deformities as common as dysplasia in Japanese patients with hip pain? *Bone Joint J*. 2014;96-B:172–176.