CT assessment of asymptomatic hip joints for the background of femoroacetabular impingement morphology

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PURPOSE
The purposes of this study were to assess the presence of cam and pincer morphology in asymptomatic individuals with a negative femoroacetabular impingement test, and to determine and compare the ranges of alpha angle using two measurement methods.

MATERIALS AND METHODS
In total, 68 consecutive patients who underwent abdominopelvic computed tomography (CT) for reasons other than hip problems were the patient population. Patients who had a positive femoroacetabular impingement test were excluded. Alpha angle measurements from axial oblique (AN) and radial reformatted-based images (AR) from the anterior through the superior portion of the femoral head-neck junction, as well as femoral head-neck offset, center-edge angle, acetabular version angle measurements, and acetabular crossover sign assessment, were made.

RESULTS
Overall prevalences of cam (increased alpha angle, decreased femoral head-neck offset) and pincer morphology (increased center-edge angle, decreased acetabular version) were 20.0%, 26.8%, 25.8%, and 10.2% of the hips, respectively. The mean AR ranged from 41.64°±4.23° to 48.13°±4.63°, whereas AN was 41.10°±4.44°. The values of AR were higher than AN, and the difference was statistically significant (P < 0.001). The highest AR values were measured on images from the anterosuperior section of the femoral head-neck junction.

CONCLUSION
In asymptomatic subjects, higher alpha angle values were obtained from radial reformatted images, specifically from the anterosuperior portion of the femoral head-neck junction compared with the axial oblique CT images. Other measurements used for the assessment of cam and pincer morphology can also be beyond the ranges that are considered normal in the general population.

Femoroacetabular impingement (FAI) is a recognized risk factor for the development of osteoarthritis (1, 2). Morphological abnormalities of the proximal femur and/or acetabulum result in abnormal contact between the femur and acetabulum during hip motion, especially during flexion and internal rotation. The resulting abnormal stress on the acetabular labrum and articular cartilage can cause degeneration and tearing of the labrum, damage the adjacent acetabular cartilage, and eventually lead to osteoarthritis (1).

Morphological variations and measurements demonstrating such alterations in the proximal femoral head and acetabulum that might be responsible for the development of FAI have become a research focus (2–7). The alpha angle (AA) is a parameter that demonstrates the degree of focal femoral epiphyseal overgrowth and reflects insufficiency of the anterolateral femoral head-neck offset and asphericity of the femoral head (5, 7). Since the concept of FAI was proposed, the AA measurement has become a widely used method to quantify osseous deformity at the femoral head-neck junction (5). However, there has been some controversy regarding its validity in clinical use, because of the substantial overlap in AA measurements between volunteers and symptomatic patients with cam-type deformity (8, 9).

Our purposes in this prospective study were to determine the range of AA values in radial reformatted computed tomography (CT) images, to assess the prevalence of cam and pincer morphology in asymptomatic patients with a negative hip impingement test, and to compare the AA values using two measurement methods.

Materials and methods
Patient population
The local ethics committee approved our study, and we obtained written consent from all subjects prior to radiological examinations. In total, 68 consecutive patients aged 18–46 years (mean age, 32.9 years) who underwent abdominopelvic CT over a five-month period for reasons other than hip problems and who agreed to participate in this study constituted the patient population. Patients who claimed to have had hip and/or vertebral disorders, including pain and previous surgery, and who had a positive FAI test were excluded. Eventually, 131 hips were available for assessment.

CT examination and image reconstruction
All CT examinations were performed using three different multidetector CT units with 4, 16, or 64 channels (Somatom Volume Zoom, n=2; Somatom Sensation, n=0; and Somatom Definition, n=16; respec-
교통 관계 목록 | Siemens Healthcare Solutions, Erlangen, Germany). Starting from the superior iliac wing, axial 2 mm reconstructions were obtained through the femoral neck from source images, 5 mm in thickness. These images were then transferred to workstations. One radiologist (S.V.) (other than the eventual readers) reformatted the images for two different approaches to AA measurements: a) axial oblique AA ($A_{nn}$), as described originally by Nötzli et al. (5) (Fig. 1), and b) radial AA ($A_{r}$), from the anterior to superior section of the femoral head-neck junction (Fig. 2) ($A_{1}$ through $A_{7}$; $A_{1}$, anterior-most and $A_{7}$, superior-most section). Additionally, the femoral head-neck offset (FHNO), center-edge angle (CEA), and acetabular version angle (AV) measurements, and acetabular crossover sign assessments were performed.

For $A_{nn}$, an axial oblique image through the mid-femoral neck was used. For $A_{r}$ measurements, multiplanar reformatting (MPR) was conducted to generate 2 mm thick axial oblique images perpendicular to the long axis of the femoral neck, using the center of the femoral neck as the axis of rotation (Fig. 2a, 2b); seven radial images were generated at 15° intervals. As such, all radial MPR images were oriented perpendicular to the femoral head-neck junction at the anterior, anterosuperior, and superior segments (Fig. 2c; $A_{1}$–$A_{7}$, $A_{1}$ being the anterior-most and $A_{7}$ the superior-most sections of the femoral head-neck junction). The reason for choosing the anterior through the superior portion of the femoral head-neck junction for radial reformatted sections was that previous studies involving radial magnetic resonance imaging (MRI) of the hip have found that the greatest degree of contour deformity, and thus the highest AA value, occurs anterosuperiorly rather than at other locations (6, 10). All reformatted images were transferred to a picture archiving and communication system (PACS) workstation (Centricity PACS-IW 3.7.3, GE Healthcare, Milwaukee, Wisconsin, USA) and all measurements were made in this system. Prereformatted images were used for AA measurements, to enable two readers to make AA measurements on the same set of images.

**Image evaluation**

**Alpha angle measurements**

All AA measurements were performed by two experienced radiologists (F.B.E., E.$\ddagger$). To assess the intra- and interobserver observer variability of AA measurements, 10 randomly selected patients (20 hips) were re-examined after a two-week period by the same two readers. Before performing AA measurements, the two radiologists worked together on five other patients not included in the study, using previously described AA measurement methods (5). On every image, the AA was measured at the center of the femoral head between the axis through the femoral neck and the center of the femoral head and the point where the distance from the center of the femoral head to the peripheral contour of the femoral head exceeded the radius of the femoral head (5). The center of the femoral head was identified by placing a PACS-generated circle over the contours of the femoral head. The axis of the femoral neck was defined as a line that passes through the center of the femoral head and the center of the femoral neck at its narrowest point (Fig. 3).

**Other measurements**

Other measurements/observations including FHNO, CEA, AV, and the crossover sign were made on each hip joint by a single radiologist (F.B.E.). The FHNO was measured on the image that was used for the $A_{nn}$ measurement. Decreased femoral head-neck offset was defined as <8 mm (11) (Fig. 4). The CEA was measured in the transparent three-dimensional pelvis model (Fig. 5). Coxa profunda was defined as CEA being >40° (11). The AV was measured on the orthogonal axial reformatted image at the level where the acetabular fossa was the deepest; this plane was determined by cross-refere-
The ability of AN and AR measurements, and for intra- and interobserver variability of AN and AR, were used for comparisons of mean AN and AR, respectively. For the assessment of gender difference for AA, FHNO, CEA, and AV, independent sample t tests were used. The Statistical Package for the Social Sciences (SPSS) software (version 17.0 for Windows, SPSS Inc., Chicago, Illinois, USA) was used for all calculations.

**Data analysis**

The paired sample t test and Pearson’s correlation coefficient were used for comparisons of mean AN and AR, and for intra- and interobserver variability of AN and AR measurements, respectively. For the assessment of gender difference for AA, FHNO, CEA, and AV, independent sample t tests were used. The Statistical Package for the Social Sciences (SPSS) software (version 17.0 for Windows, SPSS Inc., Chicago, Illinois, USA) was used for all calculations.

**Results**

The mean age of the 68 patients (38 males, 30 females) was 32.9±7.70 years (range, 19–46 years). Five joints in five patients were excluded because the impingement test was positive on that side. In total, 131 hips were evaluated; none showed evidence of established degenerative changes, such as joint space narrowing, osteophytes, subchondral cysts, and/or sclerosis.

**Alpha-angle measurements**

The mean of AN (A1–A7) ranged between 41.64±4.23° and 48.13±4.63° whereas AN was 41.10±4.44°. There was a statistically significant difference between AN (A2–A7) and AN (P<0.001), and AN values were higher than AN. The maximal AN values were measured from the A4–A6 locations (corresponding to the anterosuperior segment of the femoral head-neck junction) (Table 1; Fig. 8). The mean values of A5 and A6 were 48.78±5.0° and 49.22±4.7° for males, and 46.69±4.0° and 46.95±4.0° for females, respectively; the difference was statistically significant at both locations (P<0.01). For other locations, no statistically significant gender difference was found.

In 21 subjects (31 hips), AN values were equal to or higher than 55° in 46 locations (Table 2). Of these 21 patients, 14 (66%) were males and 7 (34%) were females. AN values in these patients were ≥55° in two or more locations in 12 subjects, and in only one location in nine patients. In one patient, while AN was 55°, AN was increased in more than one location.

For AN and AR measurements, the intraobserver correlation was moderate to very strong (r=0.65–0.92) and the interobserver correlation was moderate to high (r=0.53–0.87); both were statistically significant (P<0.001).

**Other measurements**

The mean FHNO was 9.01±1.77 mm (range, 5–13 mm). No statistically significant gender difference was detectable.
ed for FHNO (P > 0.05). In 37 subjects (26.8%, 37 hips), FHNO was <8 mm.

The mean CEA was 37.28°±6.12° (range, 25°–56°). No statistically significant gender difference was detected for CEA (P > 0.05). In 33 patients (25.8%, 33 hips), CEA was >40°. The mean AV angle was 21.52°±4.98° (range, 12°–39°). There was a statistically significant gender difference in terms of AV; higher values were observed in females. In 13 patients (10.2%, 13 hips), the AV angle was <15°. In 15 patients (15 hips, 11.7%), there was an acetabular crossover sign.

Overall prevalences of cam morphology (increased radial AA, decreased FHNO) and pincer morphology (increased CEA, decreased AV, and presence of acetabular crossover sign) were 20.0%, 26.8%, 25.8%, 10.2%, and 11.7% of the hips, respectively.

Discussion

In this prospective study performed in an asymptomatic patient population with negative impingement tests, we found that the prevalence of increased AA value (≥55°) was 20%; for AA measurements, maximum values were in the anterosuperior (A4–A6) portions of the femoral head-neck junction and for those locations, increased values were predominantly seen in males versus females. The prevalences of cam and pincer morphology varied between 20% and 26.8% and 10.2% and 25.8%, respectively (ranges are due to the use of various parameters, as mentioned above).

Table 1.

<table>
<thead>
<tr>
<th>Segments</th>
<th>( A_A (°) )</th>
<th>( A_N (°) )</th>
<th>( P )</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>41.64±4.23 (33–54)</td>
<td></td>
<td>0.005</td>
</tr>
<tr>
<td>A2</td>
<td>41.92±4.42 (33–57)</td>
<td></td>
<td>0.001</td>
</tr>
<tr>
<td>A3</td>
<td>44.25±4.74 (36–58)</td>
<td></td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>A4</td>
<td>46.18±5.00 (37–62)</td>
<td>41.10±4.44 (32–55)</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>A5</td>
<td>47.97±4.52 (39–66)</td>
<td></td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>A6</td>
<td>48.13±4.63 (38–62)</td>
<td></td>
<td>0.001</td>
</tr>
<tr>
<td>A7</td>
<td>46.51±4.09 (37–59)</td>
<td></td>
<td>&lt; 0.001</td>
</tr>
</tbody>
</table>

\( A_A \) is a measurement that is made from anterior portion of femoral head-neck junction, so there is only one measurement for \( A_A \) for all segments.

\( A_N \) is a measurement that is made from anterior portion of femoral head-neck junction, so there is only one measurement for \( A_N \) for all segments.

\( P < 0.001 \) was considered statistically significant difference. Statistically significant difference was detected between \( A_A \) and \( A_N \) measurements in all segments except A1.

The AA measurements were used initially to quantify cam-type deformities only at the anterior aspect of the femoral head and neck (5). Later, radial plane images were introduced to assess the AA around the whole femoral circumference (6, 10). In prior studies, a variety of threshold values were used for distinguishing normal and abnormal AAs. More recently, however, the use of AA for assessing cam-type deformities has become controversial. Sutter et al. (8) demonstrated that increasing the AA threshold value from 55° to 60° reduced false-positive results in a study that was performed to develop threshold values of AA in volunteers and patients with FAI. They also found that 38%–62% of volunteers had an AA value greater than 55°. In our study, 20% of the asymptomatic subjects had AAs greater than 55° in at least one radial plane. Our finding that the maximum AA values were obtained at the A4–A6 locations (i.e., the anterior-superior segment of the femoral head-neck junction) is consistent with the findings of Sutter et al. (8) and Reichenbach et al. (13).

In this study, we found a statistically significant difference in terms of AV; higher values were observed in females. In 13 patients (10.2%, 13 hips), the AV angle was <15°. In 15 patients (15 hips, 11.7%), there was an acetabular crossover sign.

Overall prevalences of cam morphology (increased radial AA, decreased FHNO) and pincer morphology (increased CEA, decreased AV, and presence of acetabular crossover sign) were 20.0%, 26.8%, 25.8%, 10.2%, and 11.7% of the hips, respectively.

In our patient population, most (14/21) of the patients with AA greater than 55° were males; this is also in accordance with previous reports. We found a statistically significant difference between males and females in terms of AA values at the A5 and A6 locations. In the literature, AA values were higher in the anterosuperior portion of the femoral neck not only in patients with suspected cam-type impingement but also in asymptomatic individuals (3, 8, 9, 14). In a study of 50 patients, some degree of cam-type deformity was found in 74% of asymptomatic patients in at least one plane of the reconstructed CT data set with

Table 2.

<table>
<thead>
<tr>
<th>A1</th>
<th>A2</th>
<th>A3</th>
<th>A4</th>
<th>A5</th>
<th>A6</th>
<th>A7</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>2</td>
<td>5</td>
<td>10</td>
<td>12</td>
<td>12</td>
<td>5</td>
<td>46</td>
</tr>
</tbody>
</table>

\( A_A \) was ≥55° at 46 segments in 31 hips of 21 subjects.

Figure 8. a–c. An asymptomatic 45-year-old male with negative impingement test. Alpha angles from A6 (anterosuperior segment of the femoral head-neck junction) (a), A2 (anterior segment of femoral head-neck junction) (b), and AN (c). Note that AA at A6 is higher than that at A2 and AN.
a nonquantitative assessment (3). Reichenbach et al. (9) in a population of 244 young asymptomatic male individuals who underwent magnetic resonance imaging (MRI) with radial reconstructions, definite cam-type deformities were detected in 24%. They also demonstrated that a mild decrease of the femoral head-neck offset was seen in 74% of the population, mostly at the anterosuperior position.

For intra- and interobserver variability/agreement in AA measurement, various results have been published. While Nötzli et al. (5) reported low intraobserver variability (2% intraobserver difference), Lohan et al. (4) found up to 30% intraobserver difference for AA measurements. In a study by Nouh et al. (15) for the validation of AA measurements, moderate reproducibility was found after repeated assessments by the same reader (15). In some studies, interobserver agreement and reproducibility for AA measurements were reported to be moderate-to-good with intraclass coefficient constant values ranging from 0.50 to 0.79 (8, 9, 14). In our study, however, we found moderate-to-high (r=0.53–0.87) correlation levels in our study.

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First, our patient population was limited and larger studies are required to further validate the findings. Second, we did not perform radial AA measurements through the entire circumference of the femoral head and neck, limiting our measurements instead to the anterior, anterosuperior, and superior segments. Considering that the majority of cam deformities are found in these segments, this limitation would not seem to have much clinical impact. Third, we did not look for the more recently described “noncam, nonpincer” FAI morphology of the so-called “subspine” impingement and femoral antetorsion variations (16, 17).

In conclusion, higher AA values in the anterosuperior portion of the femoral head-neck junction on radial reformatted CT images—compared with the axial oblique—is a not infrequent finding in an asymptomatic population, especially in males. Radiologists should also be aware that, not infrequently, the other measurements (FHNO, CEA, AV, acetabular crossover sign) used for the assessment of cam and pincer morphology can also be beyond the range considered normal in the general population.

Conflict of interest disclosure
The authors declared no conflicts of interest.

References