Development of the acetabulum in patients with slipped capital femoral epiphysis. A three-dimensional analysis based on CT.

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Summary

Orientation and shape of the acetabulum was determined by the use of three-dimensional reconstruction of CT data sets in 22 patients with a total of 30
slipped capital femoral epiphyses. We developed an interactive three-dimensional software program to measure the anteversion and inclination of the acetabulum without projectional and pelvis tilting errors. Furthermore, we determined the height, width, depth, volume, and surface of the acetabulum as parameters describing the acetabular shape. Comparison of the affected side to the contralateral unaffected hip showed no significant differences for acetabular orientation and shape. The relationship between the degree of the slip and the acetabular orientation was calculated. No correlation was found. Based on the results of this study we conclude that the slipping of the femoral capital epiphysis has no influence on acetabular development.

**Keywords**
slipped capital femoral epiphysis - acetabulum - development - anteversion - inclination - shape

**Introduction**
Slipped capital femoral epiphysis (SCFE) is the most common cause of adolescent hip disease (4-5/100,000) and involves the change in the spatial relationship between the femoral epiphysis and the femoral neck. The incidence of bilaterality ranges from 20 % - 80 %. Several factors, for instance endocrin disorders [12, 19], genetic factors [8, 10], have been discussed as etiologic agents. Obesity, coupled with a decreased femoral anteversion and bone immaturity, appears to play a major role in the etiology of SCFE [2, 18, 22]. Evaluation and treatment of SCFE have traditionally focused on the geometry of the proximal femur. Although a few articles described the
acetabular anteversion based on 2D CT data sets there is, to our knowledge, no three-dimensional radiological measurement of the acetabular orientation (anteversion and inclination) and shape. The use of three-dimensional computed tomographic reconstructions to determine the acetabular orientation provides exact angles without inaccuracies caused by projection or pelvis tilting failures. The accurate acetabular orientation is essential for preoperative planning of reorientation osteotomies of the proximal femur. Furthermore, the orientation and shape of the acetabulum provides information regarding whether a SCFE leads to disturbance of the development of the acetabulum. A malorientated and malformed acetabulum could be associated with the development of a secondary degenerative joint disease.

Methods

Three-dimensional models based on CT and radiograms of 22 patients, 8 females and 14 males with slipped capital femoral epiphysis were reviewed. The mean age of the patients was 13.4 years (9.3-16.8). The right hip was affected in ten and the left hip in twenty cases. The patients were examined supine with 2-5 mm contiguous, axial slices through the hip joint. Three-dimensional models were reconstructed based on "The Visualization Toolkit" (kitware, Inc.; Clifton Park; NY 12065; USA). Further standard anteroposterior and frog-leg radiograms (45° of flexion and 45° of abduction) of the hip joint were analyzed. The measurements of the acetabular anteversion and inclination were performed by using three-dimensional models. We developed a new interactive measurement software to determine the acetabular orientation. The software program enables measurement of projected angles between two planes. The 3D
model and measure tool can be freely shifted and rotated in all planes. To validate the software program we performed a phantom scan. The measurements of the 3D digital model are compared with the measurements on the real phantom. The average difference (± one standard deviation) for the anteroposterior angle is -0.02° ± 0.84° and +0.06° ± 1.16° for the torsion measurement.

To determine the orientation of the acetabulum, the acetabular plane was positioned parallel to the three bony eminencies at the ventral, dorsal and superior parts of the acetabular margin (fig. 1).

**Figure 1.** Definition of the acetabular plane. A: Ventral view. B: Dorsal view. C: Caudal view.

The anteversion (α) and the inclination (ß) of the acetabulum were measured as illustrated in figures 2+3.

**Figure 2.** Acetabular anteversion. A: Cranial view. B: Dorsolateral view. C: Acetabular anteversion (α).
Furthermore, the shape of the acetabulum described by the height, width, depth, acetabular volume, and surface was determined. 3D reconstruction of the acetabulum, possible only in 16 cases, was used to determine the acetabular volume and surface (fig. 4).

The determination of the mentioned parameters and the reconstruction of the acetabulum was performed three times. Calculations were carried out using the mean value. The mean standard deviation was 2.1.

The amount of slippage was determined by calculating the femoral head-shaft angles as proposed by Southwick [26]. The varus angulation on the anteroposterior roentgenograms (α) and the posterior tilting (β) on the frog-leg roentgenograms were assessed. The difference of the degree of the head-shaft angle (α, β) between the affected side and the contralateral uninvolved hip
provided the amount of the slipping in both planes. In bilateral cases we subtracted 10 degrees of the head-shaft angle $\beta$. Thus, a slip was classified as “mild” when the amount of slippage was $< 30^\circ$, as “moderate” when it ranged between $30^\circ$ and $50^\circ$, and as “severe” when it was $> 50^\circ$. The measurements were performed by two independent observers. The mean standard deviation was 4.3 degrees.

The plain radiographic degree of slip was rated mild, moderate, or severe according to the method described by Wilson et al [31]. A mild slip was classified as displacement of less than one-third of the diameter of the femoral neck. Displacement of more than one-third and less than one-half of the diameter of the neck was considered moderate. A severe slip was defined as a displacement of more than one-half of the neck diameter.

Statistical analysis was carried out by using the Mann-Whitney U-Test, Kruskal-Wallis H-Test, and Spearmann rank correlation.

**Results:**

The mean value of the inferior slip was 19.5 degrees (range: 5.0º-51.0º) and 39.4 degrees (range: 2.0º-78.0º) for the posterior tilt. According to Wilson, five of the patients had a grade 1, nine a grade 2 and sixteen a grade 3 slip. The amount of slippage determined with the method of Southwick [26] was less than 30 in ten, in between 30 and 50 in seven and more than 50 in 13 cases.

Results of measurements of all patients and affected versus unaffected are demonstrated in table 1+2.

**Table 1. Orientation and size of the acetabulum in patients with SCFE. Affected and unaffected.**
Table 2. Orientation and size of the acetabulum in patients with SCFE. Affected versus unaffected.

<table>
<thead>
<tr>
<th></th>
<th>affected No.</th>
<th>Mean</th>
<th>Range</th>
<th>unaffected No.</th>
<th>Mean</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anteversion</td>
<td>30</td>
<td>12.3°</td>
<td>4.6 – 23.4</td>
<td>14</td>
<td>11.4°</td>
<td>3.4 – 17.9</td>
</tr>
<tr>
<td>Inclination</td>
<td>30</td>
<td>54.4°</td>
<td>47.6 – 64.9</td>
<td>14</td>
<td>54.0°</td>
<td>46.3 – 62.6</td>
</tr>
<tr>
<td>Height</td>
<td>30</td>
<td>56.9 mm</td>
<td>47.4 – 64.8</td>
<td>14</td>
<td>56.4 mm</td>
<td>49.1 – 62.7</td>
</tr>
<tr>
<td>Width</td>
<td>30</td>
<td>53.3 mm</td>
<td>44.6 – 64.6</td>
<td>14</td>
<td>52.5 mm</td>
<td>44.6 – 64.6</td>
</tr>
<tr>
<td>Depth</td>
<td>30</td>
<td>23.2 mm</td>
<td>16.4 – 31.4</td>
<td>14</td>
<td>22.6 mm</td>
<td>15.3 – 28.0</td>
</tr>
<tr>
<td>Acetabular Volume</td>
<td>23</td>
<td>25.9 mm³</td>
<td>16.0 – 41.3</td>
<td>9</td>
<td>27.3 mm³</td>
<td>17.5 – 45.4</td>
</tr>
<tr>
<td>Acetabular Surface</td>
<td>23</td>
<td>6266 mm²</td>
<td>4238 - 9251</td>
<td>9</td>
<td>6534 mm²</td>
<td>4917 - 8196</td>
</tr>
</tbody>
</table>

A significant difference between the involved and the uninvolved side was not given for acetabular anteversion (p: 0.85) and inclination of the hip cup (p: 0.83). Furthermore there was no significance between the affected and unaffected side for parameters of the acetabular shape: height (p: 0.82), width (p: 0.71), depth (p: 0.81), volume (p: 0.82), surface (p: 0.48). In addition, we found no significant differences for the acetabular orientation and shape depending on grade (according to Wilson), sex, side and the arrangement of groups (>30°; 30°-50°; >50°) of the slip. We found no significant correlation whether for degree of inferior slipping and acetabular inclination (p: 0.78), nor posterior tilting and anteversion (p: 0.17).

Discussion
The presence of a well centered femoral head is essential for a normal development of the acetabulum. Growth of the proximal femur and the development of the acetabulum are interrelated. In patients with SCFE the capital femoral epiphysis usually slips posteroinferiorly [5]. Thus, normal acetabular development might be disturbed. Furthermore, it is conceivable that the acetabulum orientation might change, comparable to the remodeling of the femoral neck, as a process of adaptation to the changed anatomy [16, 32]. However, Hoiseth et al found no correlation between the femoral anteversion and the acetabulum version in 13 patients with an increased mean femoral anteversion of 25 degrees [13]. In a previous study Reikeras et al pointed out that an increased anteversion of the femoral neck was not compensated for by a corresponding reduction of the ventral orientation of the acetabulum [23].

The goal of the presented study was to observe wether the development of the acetabulum is influenced by a slipped capital femoral epiphysis. Reikeras et al reported acetabular anteversion of 14° ± 4° in 40 patients with immature pelvis [23]. Weiner et al in a study of 170 adolescents with normal immature hip joints reported a mean acetabular anteversion of 13° (range: 7° to 16°) [29]. The ventral orientation of the hip cup of our groups was comparable to their results. Stanitski et al reported a two-dimensional acetabular anteversion averaged 11.9° in 52 cases of stable SCFE and 15.9° in 8 cases of unstable SCFE [27]. They observed no significant differences between the affected and unaffected hips. The results of the present study demonstrated likewise no significant differences between the affected and unaffected hips neither for the acetabular orientation (anteversion and inclination) nor for the shape. It is conceivable, that the development of the acetabulum is not affected by the
slipped capital femoral epiphysis because the average age of our test group was 13.4 years, whereas the majority of acetabular development is determined by age 8 years [11]. Weiner et al reported likewise no further change of the acetabular anteversion after closure of the triradiate cartilage, which occurs between the ages of 11 and 12 years [29].

Patients with slipped capital femoral epiphysis generally do well if the slip is mild because good congruity between the femoral head and the acetabulum remains. Moderate or severe slips may cause some incongruity and eventually lead to degenerative joint disease [6]. The opinion about therapy of mild slips with in-situ-pinning is uniform. However, concepts of therapy in cases of more severe slips are highly divergent [1, 3, 6, 20, 25, 9, 24]. Several authors recommend different techniques of reorientation osteotomies [4, 7, 14, 17, 26, 28, 30]. Furthermore, the timing of performing the osteotomy discussed is controversial. Some authors prefer to perform a late realignment osteotomy on the supposition that a remodeling of the femoral neck will improve the femoral orientation. Wong-Chung et al recommended an initial pin fixation and a wait of at least 2 years before performing realignment osteotomies [32]. He found evidence of femoral remodeling in one hundred percent of 11 severe slips. According to our findings (in normal development of the acetabulum) and the fact that remodeling of the femoral neck may lead to an improvement of the proximal femoral orientation in slipped epiphysis, we recommend delaying possible reorientation osteotomy of the proximal femur after initial pin fixation unless there is clear impingement of the anterior neck on the anterior acetabular rim in positions of function.

**Conclusion**
In case of slipped capital femoral epiphysis the development of the acetabulum is not affected.

Acknowledgment

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References


Figure 1. Definition of the acetabular plane. A: ventral view. B: dorsal view. C: caudal view.

Figure 2. Acetabular anteversion. A: Cranial view. B: Dorsolateral view. C: Acetabular anteversion (α).

Figure 3. Acetabular inclination. A: Ventral View. B: Lateral View. C: Acetabular inclination (β).

Figure 4. Acetabular reconstruction (left). Height, width, and depth of the acetabulum (right).