Developmental dysplasia of the hip: Is acetabular retroversion a crucial factor?

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KEYWORDS
Congenital hip dysplasia; Retroversion; Periacetabular osteotomy-hip coverage

Summary
Objective: The objective of this study was to investigate a possible relation between congenital hip dysplasia and acetabular retroversion and to explore the eventual influence of the latter in the surgical decision for periacetabular osteotomy.

Materials and methods: We assessed the classical morphological characteristics of both hips, with an additional newly described retroversion index. The study was conducted in 174 patients with uni- or bilateral congenital hip dysplasia having undergone unilateral (153 patients) or bilateral (21 patients) periacetabular osteotomy when respectively one or both dysplastic hips remained symptomatic.

Results: In the group of operated hips (195 hips in total), 53% of the acetabuli were anteverted, 42% retroverted, and 5% neutral orientations. The group of nonoperated hips (153 hips) included 24% normal hips, 22% hips with normal coverage but retroverted, 35% dysplastic hips with anteverted or neutral orientation, and 19% dysplastic retroverted hips. Comparing the two hips in the subgroup of patients in whom the operated and nonoperated sides were both dysplastic failed to demonstrate statistically significant difference in the mean retroversion index. However, all the other variables measured were significantly different; with the operated side more dysplastic. Comparing the two hips in the other subgroups showed that acetabular retroversion was nearly always bilateral and symmetrical, even in presence of unilateral congenital dysplasia.

Discussion: Our data suggest that the presence of acetabular retroversion is probably independent of the congenital hip dysplasia and that this abnormality seems at best a secondary factor in the appearance of dysplastic hip symptoms.

Level of evidence: Level IV, retrospective diagnostic study.

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Introduction

Acetabular dysplasia is responsible for mechanical abnormalities of the hip resulting in excess load and the appearance of premature osteoarthritis [1—4]. Realignment osteotomies have been proposed to reposition the dysplastic acetabulum optimally above the femoral head and to slow down or stop the progression of osteoarthritis [5—8]. The orientation of the dysplastic acetabulum is a very important parameter to consider during this type of surgery because it directly influences both the correction and the result.

Historically, the orthopaedic community has thought that congenital hip dysplasia was always associated with excessive acetabulum anteversion. This is defined by several radiological parameters: the Tönnis angle greater than 13° [9], the vertical center edge (CE) or lateral coverage angle less than 20° [10], and the anterior coverage angle less than 20° [11]. Yet, certain studies have shown that a relatively high number of dysplastic hips—one out of three [12] to one out of six [13]—were retroverted. Reynolds et al. [14] were the first to describe acetabular retroversion as an isolated abnormality and reported that this condition was generally bilateral and symmetrical. This same acetabular retroversion is associated with premature osteoarthritis in absence of dysplasia [15].

To our knowledge, no recent study using plain radiographs has quantified the severity of acetabular retroversion, whether or not associated with hip dysplasia. Moreover, all the previous studies that reported the incidence of acetabular retroversion associated with dysplasia [12,13] did not report on the contralateral hips when they were asymptomatic or nondysplastic. Consequently, the objective of the present study was to determine the incidence and severity of acetabular retroversion on both hips in patients with unilateral or bilateral hip dysplasia requiring corrective osteotomy and to explore the possible influence of this associated retroversion in the organization of the surgical decision.

Material and methods

Patients

This study was approved by the ethics committee in our institution. Between January 1995 and December 2003, 227 patients were treated with periacetabular osteotomy for symptomatic congenital hip dysplasia by one of the authors (RT): 204 patients were treated with unilateral periacetabular osteotomy and 23 patients were operated on for bilateral periacetabular osteotomy in two stages. All these patients experienced pain related to their congenital hip dysplasia; only the symptomatic hips were operated on, even in patients presenting radiological signs of bilateral congenital dysplasia.

The preoperative radiographs of the pelvis were reviewed and included in the study based on the following criteria [16]:

1. the exposure was sufficiently clear to emphasize the contours of the anterior and posterior walls, the bearing surface (sourcil), and the external edge of the acetabulum;
2. the AP radiograph of the pelvis was properly centered, based on the symmetry of the iliac wings and the obturator foramen;
3. the coccyx was properly centered on a point located between 0 and 2 cm above the pubic symphysis;
4. the hips were in neutral abstraction on the AP X-ray so that the percentage of femoral head coverage could be appropriately measured;
5. a Lequesne false profile was available.

Patients were excluded from the study if they presented neuromuscular dysplasia or dysplasia related to Legg-Perthes-Calvé disease, or if the X-rays were of poor quality or not available. Consequently, only 174 patients (384 hips) were retained. The mean age was 30 years (range, 15—56 years; SD = 10.5). There were 137 females (79%) and 37 males (21%). Seventy-four patients (43%) were treated with left periacetabular osteotomy, 79 (45%) were treated with right periacetabular osteotomy, and 21 (12%) were treated with bilateral periacetabular osteotomy.

Radiographic measurements

All the X-rays were analyzed by the lead author. To determine the intraobserver variability, 50 of the 348 hips examined were randomly chosen and studied a second time three weeks later. All the hips (dysplastic and nondysplastic) were included in the study. The following measurements were taken on each of the 348 hips examined:

1. the Wiberg lateral coverage angle [10] (Fig. 1) was obtained on the AP pelvis X-ray. Wiberg reported that the angles greater than 25° were normal, the values between 20° and 25° were borderline, and the values less than 20° indicated hip dysplasia;
2. the acetabular bearing surface index, the Tönnis angle [9] (Fig. 2), was the angle formed between a line parallel to the bearing surface of the acetabulum and a horizontal line. Values greater than 13° were found in patients with acetabular dysplasia;
3. the anterior coverage angle (Fig. 3) was measured on the false hip profile. Lequesne and DeSeze [11] reported that values less than 20° were encountered in acetabular dysplasia;
4. the femoral head extrusion index (Fig. 4) [17] is the percentage of femoral head not covered by the acetabulum. Normally, the femoral head can be uncovered up to 25%, whereas more than 25% extrusion is encountered in acetabular dysplasia;
5. the acetabular depth/height index (Fig. 5) [16] quantifies the depth of the acetabulum. Values less than 43% are encountered in cases of acetabular dysplasia [16];
6. the femur head to ilioischial distance (Figs. 6 and 7) is the distance (D) between the medial edge of the femoral head at its equator and the ilioischial line that remains intact after periacetabular osteotomy. This measurement provides information on the femoral head extrusion; this distance is greater than 12 mm in cases of hip dysplasia [18];
7. acetabular ante- or retroversion designates the orientation of the acetabular opening on the sagittal plane. This...
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Anteversion is present when the entire acetabulum is oriented toward the front, with the posterior wall projecting more laterally than the anterior wall on the AP radiograph and no contact at the sourcil (Fig. 6). If the two walls project equally and are superimposed, the acetabulum is classified as neutral. If the two projections cross such that the anterior wall projects more laterally than the posterior wall in the proximal part of the crossover sign [14], then the acetabulum is classified as retroverted (Fig. 7). Giori and Trousdale [15] showed that this aspect on the AP X-ray can be reproduced by a deficiency in the posterior wall of the acetabulum;

(8) the acetabular retroversion index: the crossover sign indicates the place where the acetabulum changes orientation and becomes retroverted in relation to its height. We calculated an acetabular retroversion index by dividing the distance between the superolateral edge of the acetabulum and the crossover sign (X) by the total height of the acetabulum (Y) measured between the superolateral edge of the acetabulum and the point where the posterior wall meets the ischium distally. The retroversion index thus provides an estimation of the proportion of the retroverted acetabulum expressed as a percentage (Fig. 7). The retroversion index’s reliability was verified using a bone pelvis on which we outlined the contours of the anterior and posterior walls of the two acetabuli using metallic wires. This pelvis was positioned on a horizontal table with the plane of the anterosuperior iliac spines and the pubis pulled back 5° to imitate the pelvis’s normal anatomical position in the sitting or standing position [19], with full knowledge that there could be extreme variations in certain cases [20]. In this position, an AP radiograph was taken respecting the criteria delineated by Siebenrock et al. [16] (Fig. 8). This X-ray showed a crossover sign (Fig. 8A) at the left acetabulum, indicating unilateral retroversion with a 37% retroversion index. The pelvis was then turned left 10° (Fig. 8B) then 20° (Fig. 8C) around its longitudinal axis to simulate an increase in torsion of the left acetabulum, and X-rays were taken in the two new positions. This was designed to increase the radiographic appearance of the retroversion by pushing down the point where the anterior and posterior walls meet. The retroversion index calculated in these two new positions increased from 37% (neutral position) to 50% (10° rotation) and 78% (20° rotation), respectively. This confirms that the retroversion index was a good indicator of the proportion of retroverted acetabulum.

Radiological comparison of operated versus nonoperated hips

In this study, a hip was considered dysplastic when the lateral coverage CE angle was less than 20° and/or the Tönnis angle or acetabular index of the bearing surface was greater than 13°. First we calculated the incidence of acetabular retroversion in the group of operated hips and the group of nonoperated hips. Then we were able to compare dysplasia severity and ante- or retroversion between the operated and nonoperated hips in the subgroups of patients whose nonoperated hip was also dysplastic. Finally, given that some of the nonoperated hips were simply retroverted with no associated dysplasia, we studied whether the contralateral operated dysplastic hips were also retroverted and to what extent using the retroversion index.

Statistical analysis

Statistical analysis was performed using the SAS Statistics software (SAS Institute, Cary, NC, USA, Version V8 for Windows). The tests used to compare the means and the ANOVA test were used for the descriptive statistics, the Student
\( t \)-test was used for the continuous variables, and the chi-square or the Fisher exact test was used for the categorical variables.

**Results**

The mean intraobserver variability for all the measurements was 0.91.

**Incidence of acetabular retroversion**

For the operated hips, Table 1 shows the morphological characteristics of the 195 hips (153 patients treated with unilateral osteotomy and 21 with bilateral osteotomy) treated with periacetabular osteotomy. All these hips showed radiological signs of dysplasia (CE angle < 20° and/or Tönnis angle > 13°). Preoperative acetabular ante- or retroversion of these operated hips was neutral in 11 cases (5%), anteverted in 103 cases (53%), and retroverted in 81 cases (42%).

For the nonoperated hips, Table 2 shows the morphological characteristics of the 153 nonoperated hips (153 patients treated with unilateral osteotomy) also obtained by analysis of variance. Seventy of these hips were not dysplastic (CE angle > 20° and/or Tönnis angle < 13°), 37 (24%) of which were normal and 33 (22%) retroverted without dysplasia.

The 83 remaining hips were dysplastic (CE angle < 20° and/or Tönnis angle > 13°) but nonoperated because the dysplasia was slight or nonsymptomatic. Twenty-nine (19%) of them were retroverted and 54 (35%) anteverted or neutral,
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Figure 7 Retroverted left acetabulum showing a crossover sign. The retroversion index is obtained by dividing the distance between the lateral edge of the acetabular sourcil and the crossover sign (X) by the total length of the acetabulum (Y).

with more than one in three nonoperated dysplastic hips retroverted.

The mean value of the retroversion index in the operated hips was 33% (10—64; SD = 12.32) and 31% (9—69; SD = 12.58) in the nonoperated hips for either anteversion or retroversion with no significant difference between the two groups.

Comparison of operated and nonoperated sides when both hips were dysplastic

In this subgroup of 83 patients (Table 3), 60% of the hips on the operated side were anteverted, 34% retroverted, and 6% neutral. On the nonoperated side, 35% of the hips were retroverted, 60% anteverted, and 5% neutral. A cross tabulation (chi-square) is presented in Table 4. The results indicated high agreement between the operated and nonoperated sides. If the operated hip was anteverted or retroverted, the nonoperated hip was also anteverted or retroverted in 70 and 78% of the cases, respectively (chi square = 24.29; p < 0.0001). In addition, when we used the Student t-test (Table 3) to test the difference between the operated and nonoperated sides, there was no difference in the retroversion index (33% versus 31%, respectively; p = 0.5631), but the operated hips had a tendency (non-significant in this subgroup) to have less coverage in the front than the nonoperated hips (CA angle = −4° versus +4°, respectively; p = 0.05). All the other variables measured were significantly different between the two groups with the operated side more dysplastic than the nonoperated side.

Comparison of the operated and nonoperated sides when the nonoperated side was retroverted with no dysplasia (CE > 20° and Tönnis < 13°)

Thirty-three (21%) of the nonoperated hips were retroverted with no sign of dysplasia, even though the contralateral hip was sufficiently dysplastic and symptomatic to require periacetabular osteotomy. The acetabulum was retroverted in 26 (79%) of these contralateral operated hips, but anteverted in seven (21%). We used the Student t-test to compare

Figure 8 A. AP radiograph of the pelvic bone where the contours of the anterior and posterior walls of the two acetabuli have been outlined with metallic wires. Note that the left acetabulum shows a crossover sign with the retroversion index calculated to be 37%. B. AP radiograph of the same pelvic bone with left 10° rotation. Note that the location of the crossover sign is more distal and the retroversion index has increased to 50%. C. AP radiograph of the same pelvic bone with a 20° left rotation. Note that the location of the crossover sign is even more distal and the retroversion index has increased to 78%.
Table 1  Analysis of variance showing the morphological characteristics of the hips operated with periacetabular osteotomy.

<table>
<thead>
<tr>
<th>Description acetabulum (operated side)</th>
<th>CE angle (degrees)</th>
<th>CA angle (degrees)</th>
<th>Tönnis angle (degrees)</th>
<th>FHEI (%)</th>
<th>ADHI (%)</th>
<th>Retroversion index (%)</th>
<th>Femur head to ilioschial line distance (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neutral (n = 11)</td>
<td>Mean 11</td>
<td>8.1</td>
<td>21.3</td>
<td>38.2</td>
<td>39.0</td>
<td>12.2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>SD 7.1</td>
<td>10.9</td>
<td>3.4</td>
<td>6.1</td>
<td>7.1</td>
<td>4.4</td>
<td></td>
</tr>
<tr>
<td>Anteverted (n = 103)</td>
<td>Mean 5.6</td>
<td>−0.6</td>
<td>24.6</td>
<td>44.5</td>
<td>36.7</td>
<td>14.8</td>
<td></td>
</tr>
<tr>
<td></td>
<td>SD 10.3</td>
<td>14.6</td>
<td>6.7</td>
<td>8.7</td>
<td>6.0</td>
<td>4.4</td>
<td></td>
</tr>
<tr>
<td>Retroverted (n = 81)</td>
<td>Mean 4.8</td>
<td>0.05</td>
<td>23.7</td>
<td>42.3</td>
<td>33.9</td>
<td>32.9</td>
<td>17.8</td>
</tr>
<tr>
<td></td>
<td>SD 12.7</td>
<td>19.6</td>
<td>8.2</td>
<td>10.8</td>
<td>7.0</td>
<td>12.3</td>
<td>5.0</td>
</tr>
<tr>
<td></td>
<td>F 2.2</td>
<td>1.9</td>
<td>2.2</td>
<td>3.8</td>
<td>4.8</td>
<td>11.4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>df FHEI</td>
<td>2.0</td>
<td>2.0</td>
<td>2.0</td>
<td>2.0</td>
<td>0</td>
<td>2.0</td>
</tr>
<tr>
<td></td>
<td>P 0.12</td>
<td>0.17</td>
<td>0.08</td>
<td>0.03</td>
<td>0.01</td>
<td>0.0005</td>
<td></td>
</tr>
</tbody>
</table>

All the hips in this group had a lateral coverage CE angle < 20° and a Tönnis angle > 13°.

CE angle: Wiberg lateral coverage angle; Tönnis angle: acetabular bearing surface index; CA angle: Lequesne anterior coverage angle; FHEI: femoral head extrusion index; ADHI: acetabular depth/height index; F: F test; df: degrees of freedom.

Table 2  Analysis of variance showing the morphological characteristics of the nonoperated hips.

<table>
<thead>
<tr>
<th>Description acetabulum (nonoperated side)</th>
<th>CE angle (degrees)</th>
<th>CA angle (degrees)</th>
<th>Tönnis angle (degrees)</th>
<th>FHEI (%)</th>
<th>ADHI (%)</th>
<th>Retroversion index (%)</th>
<th>Femur head to ilioschial line distance (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Classic dysplasia (anteverted + neutral hips) (n = 54)</td>
<td>Mean 14.8</td>
<td>1.0</td>
<td>17.8</td>
<td>37.3</td>
<td>40.0</td>
<td>13.5</td>
<td>4.2</td>
</tr>
<tr>
<td></td>
<td>SD 8.1</td>
<td>16.8</td>
<td>5.1</td>
<td>8.5</td>
<td>5.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Classic dysplasia (retroverted hips) (n = 29)</td>
<td>Mean 15.1</td>
<td>13</td>
<td>19.2</td>
<td>35.5</td>
<td>38.8</td>
<td>31.1</td>
<td>14.9</td>
</tr>
<tr>
<td></td>
<td>SD 8.2</td>
<td>13.2</td>
<td>6.3</td>
<td>9.5</td>
<td>6.8</td>
<td>9.5</td>
<td>4.1</td>
</tr>
<tr>
<td>Hips only retroverted (n = 33)</td>
<td>Mean 31.6</td>
<td>33.3</td>
<td>5.3</td>
<td>21.5</td>
<td>43.9</td>
<td>35.7</td>
<td>11.2</td>
</tr>
<tr>
<td></td>
<td>SD 7.6</td>
<td>8.1</td>
<td>4.7</td>
<td>6.7</td>
<td>7.2</td>
<td>14.5</td>
<td>2.6</td>
</tr>
<tr>
<td>Normal hips (n = 37)</td>
<td>Mean 31.7</td>
<td>23.1</td>
<td>6.1</td>
<td>23.8</td>
<td>46.9</td>
<td>9.4</td>
<td>3.6</td>
</tr>
<tr>
<td></td>
<td>SD 6.4</td>
<td>10.7</td>
<td>4.5</td>
<td>9.5</td>
<td>6.4</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Here the groups vary with dysplastic hips (CE angle < 20° and Tönnis angle > 13°) and hips with normal coverage (CE angle > 20°, Tönnis angle < 13°) for either ante- or retroversion.

CE angle: Wiberg lateral coverage angle; Tönnis angle: acetabular bearing surface index; CA angle: Lequesne anterior coverage angle; FHEI: femoral head extrusion index; ADHI: acetabular depth/height index.

Table 3  Comparison of the morphological characteristics of the operated and nonoperated groups when the nonoperated hips were dysplastic only (CE angle < 20° and Tönnis angle > 13°).

<table>
<thead>
<tr>
<th>Student t-test</th>
<th>CE angle (degrees)</th>
<th>CA angle (degrees)</th>
<th>Tönnis angle (degrees)</th>
<th>FHEI (%)</th>
<th>ADHI (%)</th>
<th>Retroversion index (%)</th>
<th>Femur head to ilioschial line distance (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operated side (n = 83)</td>
<td>Mean 4.8</td>
<td>−4.0</td>
<td>24.6</td>
<td>44.68</td>
<td>35.4</td>
<td>32.6</td>
<td>16.9</td>
</tr>
<tr>
<td></td>
<td>SD 11.7</td>
<td>16.8</td>
<td>6.8</td>
<td>9.0</td>
<td>6.4</td>
<td>10.8</td>
<td>4.9</td>
</tr>
<tr>
<td>Nonoperated side (n = 83)</td>
<td>Mean 14.9</td>
<td>4.4</td>
<td>18.3</td>
<td>36.6</td>
<td>39.6</td>
<td>31.1</td>
<td>13.9</td>
</tr>
<tr>
<td></td>
<td>SD 8.1</td>
<td>18.3</td>
<td>5.6</td>
<td>8.8</td>
<td>6.0</td>
<td>9.5</td>
<td>4.2</td>
</tr>
<tr>
<td></td>
<td>t −6.9</td>
<td>−2.0</td>
<td>7.1</td>
<td>6.2</td>
<td>−4.8</td>
<td>0.58</td>
<td>5.9</td>
</tr>
<tr>
<td></td>
<td>df 74</td>
<td>24</td>
<td>74</td>
<td>73</td>
<td>74</td>
<td>20</td>
<td>73</td>
</tr>
<tr>
<td></td>
<td>P &lt; 0.0001</td>
<td>0.05</td>
<td>&lt; 0.0001</td>
<td>&lt; 0.0001</td>
<td>&lt; 0.0001</td>
<td>0.5</td>
<td>&lt; 0.0001</td>
</tr>
</tbody>
</table>

CE angle: Wiberg lateral coverage angle; Tönnis angle: acetabular bearing surface index; CA angle: Lequesne anterior coverage angle; FHEI: femoral head extrusion index; ADHI: acetabular depth/height index; t: t-test; df: degrees of freedom.
the morphological characteristics of the operated and non-operated sides in the 26 patients in this subgroup, in whom the operated side was also retroverted (Table 5). The mean retroversion index was 36% on the nonoperated side and 38% on the operated side with no significant difference between the two. However, the difference in the Lequesne anterior coverage angle (CA) was significant (p < 0.05): the operated retroverted hips showed much less coverage in front (mean CA = 18°) than the nonoperated retroverted hips (mean CA = 36°). All the other variables measured were much less deviated toward dysplasia in the operated group.

Discussion

This study underscores that acetabular retroversion associated with hip dysplasia is much more frequent than once believed. Our study is in agreement with other references investigating this association where the frequency of retroversion in dysplastic hips is one out of three to one out of six [12,13]. Since dysplasia of the hip has been historically considered to cause an anterior coverage deficit, requiring a retroversion maneuver during periacetabular osteotomy, it is very important for the hip surgeon to realize that a subgroup of patients exists who may require a reverse maneuver to normalize their acetabular ante- or retroversion. The earlier investigations that studied the association of hip dysplasia and acetabular retroversion in a context of congenital hip dysplasia is independent of this condition and probably does not contribute to the appearance of the symptoms of dysplasia in the hip. In patients with bilateral dysplasia (Table 4), it seems to be

Table 4 Proportion of dysplastic hips that were bilaterally concordant versus acetabular ante- or retroversion.

<table>
<thead>
<tr>
<th>Dysplastic hips</th>
<th>Nonoperated side</th>
<th>Operated side</th>
</tr>
</thead>
<tbody>
<tr>
<td>Retroverted</td>
<td>77.7</td>
<td>22.2</td>
</tr>
<tr>
<td>Anteverted</td>
<td>22.2</td>
<td>69.7</td>
</tr>
<tr>
<td>Neutral</td>
<td>0.0</td>
<td>6.98</td>
</tr>
</tbody>
</table>

Chi square = 24.29; P < 0.0001.

Table 5 Comparison of the morphological characteristics of the operated and nonoperated groups when the nonoperated hips were retroverted with no dysplasia, with operated retroverted dysplastic hips (26 patients).

<table>
<thead>
<tr>
<th>Student t-test</th>
<th>CE angle (degrees)</th>
<th>CA angle (degrees)</th>
<th>Tönnis angle (degrees)</th>
<th>FHEI (%)</th>
<th>ADHI (%)</th>
<th>Retroversion index(%)</th>
<th>Femur head to iliioschial line distance (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operated side</td>
<td>Mean 3.5</td>
<td>18.7</td>
<td>22.5</td>
<td>40.6</td>
<td>34.7</td>
<td>38.3</td>
<td>17.1</td>
</tr>
<tr>
<td></td>
<td>SD 15.3</td>
<td>21.5</td>
<td>9.6</td>
<td>11.6</td>
<td>8.3</td>
<td>13.8</td>
<td>4.8</td>
</tr>
<tr>
<td>Nonoperated side</td>
<td>Mean 31.7</td>
<td>35.5</td>
<td>5.6</td>
<td>21.6</td>
<td>43.8</td>
<td>35.7</td>
<td>11.3</td>
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<td>SD 8.3</td>
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<td>7.5</td>
<td>−5.7</td>
<td>1.0</td>
<td>5.2</td>
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<td>df</td>
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<td>25</td>
<td>25</td>
<td>25</td>
<td>25</td>
<td>25</td>
</tr>
<tr>
<td>P</td>
<td>&lt; 0.0001</td>
<td>&lt; 0.05</td>
<td>&lt; 0.0001</td>
<td>&lt; 0.0001</td>
<td>&lt; 0.001</td>
<td>0.3264</td>
<td>&lt; 0.0001</td>
</tr>
</tbody>
</table>

CE angle: Wiberg lateral coverage angle; Tönnis angle: acetabular bearing surface index; CA angle: Lequesne anterior coverage angle; FHEI: femoral head extrusion index; ADHI: acetabular depth/height index; t: t-test; df: degrees of freedom.
the degree of dysplasia that influences the indication and need for corrective osteotomy, much more than the proportion of retroverted acetabulum. In this subgroup of patients, the proportion of retroverted acetabulum was similar in the two hips, but the operated hips were more dysplastic.

The presence of retroversion on the operated and non-operated sides seems to be concordant even when the operated side is dysplastic and the nonoperated side retroverted with no dysplasia (Table 5). We also suspect that acetabular retroversion, whether or not it is associated with hip dysplasia, is an independent phenomenon, its symmetry relating it to the embryological constitution of the pelvis [26]. We believe that a dysplastic retroverted acetabulum stems from the dysplasia related to a defect of a concentric femoral head in the acetabulum during growth [27,28] combined with acetabular retroversion. Our data (Table 5) significant 36\(\text{°}\) decrease in the CA angle on the operated and dysplastic nonoperated side (also retroverted but dysplastic) \(p<0.05\) with an identical mean retroversion index on both sides \(p=0.32\).

It is therefore possible that the determinants of the orientation of the acetabular opening are independent of those that determine the coverage of the femoral head and the inclination of the roof. Even though the determinants of the acetabular orientation remain unknown, they seem to be related to the development of the pelvic ring [26], whereas the coverage of the head and inclination of the roof are more related to the concentric reduction of the femoral head in the acetabulum during development [27,30]. In cases of pelvic ring deficiency such as in exostrophy of the bladder, the diastasis of the pubic bones results in bilateral acetabular retroversion [26]. However, the initial treatment of congenital hip dysplasia imposes a concentric reduction of the femoral head to provide for normal acetabular development [28,29]. On the other hand, incomplete dislocation of the femoral head does not stimulate the acetabulum adequately so that it can remodel itself and cover the femoral head normally [29,30].

We can therefore conclude that acetabular morphology abnormalities seem to follow a continuum of deformities even if they originate differently. These abnormalities can affect lateral and/or anterior coverage or acetabular ante- or retroversion. Most of these deformities can be treated with acetabular reorientation osteotomy with minor technical differences that should be respected in the reorientation of the osteotomized acetabular segment. Therefore, it is very important to recognize and take into account the acetabular orientation in this type of surgery. Finally, retroversion and its severity are important factors in the reorientation procedure to prevent any postoperative anterior impingement, but at best it appears to be a secondary factor in the appearance of acetabular dysplasia symptoms.

Conflicts of interest

None.

References

Developmental dysplasia of the hip: Is acetabular retroversion a crucial factor?


