The prevalence of acetabular anomalies associated with pistol-grip-deformity in osteoarthritic hips

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Accepted: 4 June 2012

Summary

Background: Acetabular retroversion, excessive acetabular coverage and abnormal head-neck-junction with a so-called "pistol-grip-deformity" were added to the classical description of hip dysplasia to describe pathological hip morphology. The aim of the current study was the detection of pathological acetabular geometry in patients with an abnormal head-neck-junction.

Hypothesis: Femoroacetabular impingement and hip dysplasia features are frequent in patients with end-stage osteoarthritis before 60 years of age.

Materials and methods: We analysed our data bank retrospectively for all patients who received a Total Hip Arthroplasty (THA) due to end-stage osteoarthritis before the age of 60 years. The pelvic-views and the Dunn-view of these patients were screened for an abnormal head-neck-junction by measuring the head-ratio and the alpha-angle. An orthopaedic surgeon and a radiologist did this independently. These radiographies were measured for signs of acetabular dysplasia, excessive acetabular coverage and crossing sign.

Results: A consecutive series of 135 total hip arthroplasties were performed in patients aged less or equal to 60 years because of end-stage osteoarthritis. From these, 81 patients were classified as having an abnormal head-neck-junction. The mean head-ratio in these 81 patients was $1.52 \pm 0.35$, the mean alpha-angle was $62.5 \pm 9.3^\circ$. The mean CE-angle of these 81 patients was $35.8 \pm 10.4^\circ$, the mean CA-angle was $36.7 \pm 5.7^\circ$, the mean depth-width ratio was $49.1 \pm 10$, the mean extrusion index was $19.1 \pm 9.2$ and the mean CCD-angle was $131.7 \pm 7.3^\circ$.

Of these 81 hips, 14 had isolated pistol-grip-deformity, while 11 hips had associated dysplasia, 38 had excessive acetabular coverage, and 14 had crossing sign. In addition, a crossing sign was identified in four of the 11 dysplastic hips and 19 of the 38 of the hips having excessive acetabular coverage. There was no statistically significant difference in regard to the age between the four groups ($P = 0.087$). In contrast, the hips that had excessive acetabular
coverage had increased CE-angle (44.6° ± 7.2°) and decreased extrusion index (12.6 ± 6.5) (P < 0.001), while dysplastic hips had increased roof obliquity (17.5° ± 4.5°) and increased extrusion index (29.6 ± 9.1), as well as decreased CE-angle (20.7° ± 3.0°) (P < 0.001).

Conclusion: There is a high coincidence of radiographic findings associated with an abnormal head-neck-junction consisting in excessive acetabular coverage and retroversion as well as hip dysplasia. These results advocate for restoring of the normal anatomy at the early stage to prevent end-stage osteoarthritis.

Level of evidence: Level IV retrospective historical study.

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Introduction

The reasons for the development of end-stage osteoarthritis of the hip are manifold. Biochemical, genetic and acquired abnormalities seem to be involved [1—4].

Terms like acetabular retroversion, excessive acetabular coverage and abnormal head-neck-junction with the "pistol-grip-deformity" [5—8] were added to the classical description of hip deformity with an increased CE- and CA-angles as well as acetabular index angle [9]. These changes in the acetabular geometry and the head-neck-junction lead to the femoroacetabular impingement (FAI), which has been identified as a main cause for hip pain and progressive degenerative changes leading to early osteoarthritis of the hip [7,10—12].

Acetabular retroversion and an excessive acetabular coverage with a pathological contact between the acetabular rim and the femoral neck leads to the pincer-impingement. The "cam-impingement" is caused by an abnormal head-neck-junction, which leads to repetitive damage to the cartilage in the area of the antero-superior rim [5—12]. The diagnosis of these two kinds of femoroacetabular impingement should be based on detailed physical examination and appropriate imaging studies.

Recent studies already described lateral radiographs like cross-table or Dunn-view as best for the detection of cam-impingement [13—16]. For the three-dimensional structural change, two radiographic plans are needed to detect this kind of deformity and to describe the severity [17,18].

Many radiographic criteria on pelvic-views have also been established to detect classical dysplasia, excessive acetabular coverage or acetabular retroversion [19—24]. The head-ratio and the alpha-angle have previously been described as reliable for the detection of an abnormal head-neck-junction such as "pistol-grip-deformity" [10,12,16,18]. Former studies have focused on the influence of a pathological head-neck-junction and the development of osteoarthritis of the hip, but no previous study assessed the coincidence of femoral-acetabular and pathological hip morphology in patients with "pistol-grip-deformity" on plain radiographs.

The aim of the current study was the detection of pathological acetabular geometry in patients with "pistol-grip-deformity". We tested the hypothesis that femoroacetabular and pathological hip morphology are frequent in patients with end-stage osteoarthritis before 60 years of age.

Material and methods

Patients

We analysed our data bank retrospectively for all patients who received a Total Hip Arthroplasty (THA) due to end-stage osteoarthritis before the age of 60 years in the period between 1st January 2006 and 31st December 2010.

All patients had a digital pelvic-view and Dunn-view of the affected hip joint as part of the routine preoperative preparations. These x-rays were taken using a standardized technique with the beam focused on the symphysis. All pelvic radiographs included in this study were supine without any pelvic rotation as the distance between the tip of the coccyx and the middle of the symphysis was 32 mm for men and 47 mm for women [5] and the teardrop sign appeared symmetrical. The Dunn-view was taken with the hip in 90° of flexion, 20—45° of abduction and neutral rotation [25].

Methods

The pelvic-views and the corresponding Dunn-view of these patients were screened for "pistol-grip-deformity" by measuring head-ratio on pelvic-views (Fig. 1) and the alpha-angle on Dunn-views (Fig. 2). An alpha-angle greater than 51° and/or a head-ratio greater than 1.16 were considered as pathological [16,18,19]. This was done independently by an orthopaedic surgeon experienced in hip surgery and a radiologist at the end of his fellowship.

In a second step, the radiographic pictures were measured for signs of acetabular dysplasia, excessive acetabular coverage (Figs. 3 and 4) and acetabular retroversion by screening for a crossing sign and classified if at least one radiographic sign was pathological.

Statistical analysis

The statistical software package R version 2.13.1 (R Foundation for Statistical Computing, Vienna, Austria) and SPSS version 19 were used for the statistical analysis. Data are presented as mean ± standard deviation (minimum—maximum) or as absolute and relative frequencies. To test for gender-related differences the two-sample t test or the Mann-Whitney U test were used. Pearson correlation coefficients were calculated to evaluate an association between different radiographic findings. The
Acetabular anomalies and pistol-grip-deformity in osteoarthritic hips

Two hundred and twenty-eight total hip arthroplasties in patients aged less or equal to 60 years were performed during the observation period. One hundred and thirty-five of these patients received a THA because of clinical and radiographic signs of end-stage osteoarthritis of the hip.

Eighty-one (36%) of these patients were classified as having a "pistol-grip-deformity" because of a pathological alpha-angle and/or head-ratio. Fifty-three were male and 18 were female. The demographic data of the different groups is detailed in Table 1. No statistical significant gender-related difference was seen in age (P = 0.982), CE-angle (P = 0.173), CA-angle (P = 0.720), depth-to-with ratio (P = 0.146) and extrusion index (P = 0.96) between male and female patients. A statistical significant difference was seen between male and female, these last having larger roof obliquity (P = 0.032) and CCD-angle (P = 0.019), and smaller head-ratio (P = 0.007) and alpha-angle (P = 0.001) (Table 1). The statistical correlations of the different radiographic findings are shown in Table 2.

Of these 81 patients with pistol-grip-deformity, 18 (22.2%) patients demonstrated no other pathological radiographic finding than a pathological head-ratio and/or alpha-angle (entitled the "pistol-grip deformity" group), 11 (13.6%) patients presented with at least one radiographic finding for hip dysplasia (entitled the "pistol-grip deformity and dysplasia" group), 38 (46.9%) patients presented at least one radiographic finding for excessive acetabular coverage (entitled the "pistol-grip deformity and excessive acetabular coverage" group), 14 patients (17.3%) presented no other acetabular anomaly than a crossing sign as note for acetabular retroversion (entitled "pistol-grip-deformity and crossing sign" group). The demographic data of these four groups are presented in Table 3. In addition, a crossing sign was identified in four of the 11 dysplastic hips and 19 of the 38 of the hips having excessive acetabular coverage (in summary, 37 hips had a crossing sign when considering the 23 hips and the 14 hips from the "pistol-grip-deformity and crossing sign" group).
There was no statistically significant difference in regard to the age between the four groups ($P = 0.087$). Pairwise comparisons showed the largest difference between the "pistol-grip-deformity/dysplasia-group" and "pistol-grip-deformity/crossing sign" group ($53.5 ± 4.1$ vs. $48.2 ± 5.1$). The values of the "pistol-grip-deformity" and "pistol-grip-deformity/overcaverage" group lay in between ($50.0 ± 6.8$ and $49.8 ± 5.8$) (Fig. 5). In contrast, the hips that had excessive acetabular coverage had increased CE-angle ($44.6 ± 7.2 ^\circ$) and decreased extrusion index ($12.6 ± 6.5$ ($P < 0.001$), while dysplastic hips had increased roof obliquity ($17.5 ± 4.5 ^\circ$) ($P < 0.001$).

The Bland-Altman plot for testing inter-observer reliability of the different measurements is shown in Fig. 6. These plots demonstrated a very good reliability for all radiographic measurements as there was only a small spread around the bias.

### Discussion

Two different kinds of FAI have been detected as a main reason for the development of OA in young adults. The reasons for the so-called pincer-impingement could be found in the acetabular geometry with excessive acetabular coverage or acetabular retroversion. The so-called cam-impingement is caused by an abnormal head-neck-junction with a repetitive pathological contact in the region of the superior acetabular rim, which leads to continuous damage to the labrum [5–12]. The current study suggests that a mixed-type FAI with radiographic signs of femoroacetabular and hip dysplasia features are frequent in patients with end-stage osteoarthritis before 60 years of age.

The current study has several limitations. Firstly we measured the x-rays of patients with end-stage osteoarthritis therefore the results could be influenced by degenerative changes such as osteophytes. The evaluation of the x-rays before the development of end-stage osteoarthritis might have demonstrated other results. On the other hand, previous study already demonstrated that pathological hip morphology predates osteoarthritis and is not secondary to the osteoarthritic process [25,34–36]. Secondly we did not perform CT-scans to measure the deformity more accurately. The use of other radiographic parameters for detection of FAI or a CT-scan might have given different results.

Several authors have shown that a pathological head-neck-junction is not associated with risk factors or secondary to degenerative changes. They suggested that a mild, unrecognized slipped epiphysis during growth leads to that kind of deformity. The resulting "posterior head tilt" has been well established as pre-arthritic deformation and the critical point of the head-ratio of 1.35 was defined at which a "pistol-grip-deformity" should be suspected [12,26,37]. In addition, former studies have established standard values for alpha-angle and head-ratio to distinguish normal from pathological shapes [16,18]. Ipach et al. [18] suggested the critical ratio to be at a value of 1.16 and Barton et al. [16] tuned the pathological values for the alpha-angle at 51°. Our pathological value may drive the current study to underestimate "pistol-grip-deformities" that would be better recognized using a higher alpha-angle or head-neck ratio.

Stulberg et al. [26] described an abnormal head-neck-junction and labelled this deformity "pistol-grip-deformity" according to the radiographic picture it presents on pelvic-views. This kind of abnormal head-neck-junction
Table 2  Correlation between the different radiographic findings for "pistol-grip-deformity", dysplasia and excessive coverage.

<table>
<thead>
<tr>
<th>CEA</th>
<th>CA-angle</th>
<th>Depth-to-width</th>
<th>Extrusion</th>
<th>Roof obliquity</th>
<th>CCD</th>
<th>Head-ratio</th>
<th>Alpha-angle</th>
</tr>
</thead>
<tbody>
<tr>
<td>CE-angle</td>
<td>Correlation according to Pearson significance (2-sided)</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CA-angle</td>
<td>Correlation according to Pearson significance (2-sided)</td>
<td>−.363&lt;sup&gt;c&lt;/sup&gt;</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Depth-to width</td>
<td>Correlation according to Pearson significance (2-sided)</td>
<td>.365&lt;sup&gt;c&lt;/sup&gt;</td>
<td>−.189</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Extrusion</td>
<td>Correlation according to Pearson significance (2-sided)</td>
<td>−.718&lt;sup&gt;a&lt;/sup&gt;</td>
<td>.399&lt;sup&gt;c&lt;/sup&gt;</td>
<td>−.475&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Roof obliquity</td>
<td>Correlation according to Pearson significance (2-sided)</td>
<td>−.609&lt;sup&gt;b&lt;/sup&gt;</td>
<td>.235&lt;sup&gt;c&lt;/sup&gt;</td>
<td>−.238&lt;sup&gt;c&lt;/sup&gt;</td>
<td>.554&lt;sup&gt;b&lt;/sup&gt;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CCD</td>
<td>Correlation according to Pearson significance (2-sided)</td>
<td>−.029</td>
<td>−.005</td>
<td>−.093</td>
<td>−.028</td>
<td>.020</td>
<td>1</td>
</tr>
<tr>
<td>Head-ratio</td>
<td>Correlation according to Pearson significance (2-sided)</td>
<td>.028</td>
<td>−.130</td>
<td>.046</td>
<td>.063</td>
<td>−.159</td>
<td>.085</td>
</tr>
<tr>
<td>Alpha-angle</td>
<td>Correlation according to Pearson significance (2-sided)</td>
<td>.093</td>
<td>−.039</td>
<td>−.112</td>
<td>.098</td>
<td>−.051</td>
<td>−.283&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

CCD: caput-collum-diaphyseal angle.

<sup>a</sup> High correlation.
<sup>b</sup> Moderate correlation.
<sup>c</sup> Weak correlation.
Table 3 Demographic data of the different groups (Mean ± standard deviation [Minimum–Maximum]) from the 81 that demonstrated pistol-grip-deformity.

<table>
<thead>
<tr>
<th></th>
<th>''Pistol-grip-deformity'' and ''Dysplasia'' (n = 11)</th>
<th>''Pistol-grip-deformity'' and excessive acetabular coverage (n = 38)</th>
<th>''Pistol-grip-deformity'' and crossing sign (n = 14)</th>
<th>''Pistol-grip-deformity'' (n = 18)</th>
<th>Significant difference between the groups (P)</th>
<th>Normal value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>53.5 ± 4.1 (46–58)</td>
<td>50.0 ± 6.8 (24–59)</td>
<td>48.2 ± 5.1 (41–56)</td>
<td>49.8 ± 5.8 (39–59)</td>
<td>0.087</td>
<td></td>
</tr>
<tr>
<td>Sex</td>
<td>f: 7, m: 4</td>
<td>f: 10, m: 28</td>
<td>f: 4, m: 10</td>
<td>f: 7, m: 11</td>
<td>0.1</td>
<td></td>
</tr>
<tr>
<td>Side</td>
<td>l: 6 r: 5</td>
<td>l: 23 r: 15</td>
<td>l: 7 r: 7</td>
<td>l: 8 r: 10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CE-angle</td>
<td>20.7 ± 3.0° (14–24°)</td>
<td>44.6 ± 7.2° (36–66°)</td>
<td>32.1 ± 2.6° (25–35°)</td>
<td>29.4 ± 3.1° (25–35°)</td>
<td>&lt; 0.001</td>
<td>25–35°</td>
</tr>
<tr>
<td>Depth-to-width ratio</td>
<td>44.4 ± 8.3° (26–55.6)</td>
<td>52.4 ± 11.1° (35–80)</td>
<td>45.5 ± 7.6° (37–65)</td>
<td>47.7 ± 7.8° (34–61)</td>
<td>0.048</td>
<td>&gt; 40</td>
</tr>
<tr>
<td>Extrusion index</td>
<td>29.6 ± 9.1° (12.5–40°)</td>
<td>12.6 ± 6.5° (0–23)</td>
<td>22.6 ± 4.3° (17–33)</td>
<td>23.7 ± 6.9° (10–35)</td>
<td>&lt; 0.001</td>
<td>10–25</td>
</tr>
<tr>
<td>Roof obliquity</td>
<td>17.5 ± 4.5° (12°–26°)</td>
<td>5.7 ± 2.3° (2–11)</td>
<td>7.5 ± 3.5° (3–17)</td>
<td>10.3 ± 4.4° (2–22°)</td>
<td>&lt; 0.001</td>
<td>0°–10°</td>
</tr>
<tr>
<td>CCD-angle</td>
<td>134° ± 13° (116°–158°)</td>
<td>132° ± 7° (119°–145°)</td>
<td>131° ± 5° (122°–139°)</td>
<td>131° ± 6° (121°–145°)</td>
<td>0.947</td>
<td>120°–140°</td>
</tr>
<tr>
<td>Positive crossing-sign</td>
<td>4</td>
<td>19</td>
<td>14</td>
<td>0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Patients have been included in ''overcoverage'' group or ''dysplasia'' group if at least one radiographic finding was pathological.
A statistical significant difference between the three groups was seen for CE-angle, depth-to-width ratio, extrusion index and roof obliquity.
CCD: caput-collum-diaphyseal angle; f: female; m: male; l: left side; r: right side.
Figure 3  

- **a**: CE-angle: the lateral centre-edge-angle is formed by a line joining the centre of the femoral head with most lateral edge of the acetabulum and a vertical line through the centre of the femoral head. Values less than 25° were considered to be dysplastic, values greater than 35° as signs for FAI with over-coverage [18,26,27];
- **b**: roof obliquity: this angle is formed by a line drawn parallel to the weight bearing surface and a second, horizontal line. An acetabular index angle greater than 10° was considered as dysplastic and an angle less than 0° as a sign for FAI [18,26,27];
- **c**: extrusion index: this index describes the ratio of the non-covered femoral head/diameter of the whole femoral head. Three vertical lines are drawn through the medial/lateral edge of the femoral head and through the most lateral edge of the acetabulum. The ratio of the distance between these lines (X/Y) is multiplied by 100. A value greater than 25 was considered as dysplastic, a value less than 10 as sign of overcoverage [28–30];
- **d**: depth-to-width ratio: The ratio of the depth-to-width is multiplied with 100, at which the width is measured by a line joining the most lateral edge of the acetabulum with the most caudal edge of the acetabulum and another line perpendicular to this line at the point of greatest acetabular depth. A value of less than 40 was considered as dysplastic [28–30].

Figure 4  

- **a**: the CCD-angle is formed between the longitudinal axes of the femoral neck and the longitudinal axes of the femoral shaft. An angle greater than 140° was considered as Coxa valga, a value less than 120° as Coxa vara [31];
- **b**: the AC-angle is formed by a line joining the most lateral edge of the acetabulum and the pelvic teardrop and a second horizontal line through the teardrop. A measurement greater than 43° was considered to be dysplastic [18,26,27].

Figure 5  

Boxplot-diagram showing the age distribution between the three different groups of acetabular geometry facing the pistol-grip-deformity. There was no statistically significant difference in regard to the age between the four groups (P = 0.087).
The current study underlined 46.9% of all patients with a "pistol-grip-deformity" had radiographic findings of overcoverage. Radiographic signs for dysplasia in patients with "pistol-grip-deformity" were seen in 13.7% of all cases. Thirty-eight (47%) patients presented radiographic signs of excessive acetabular coverage and 14 patients (17.3%) presented an additional crossing sign as a result for acetabular retroversion. Eighteen (22.2%) patients demonstrated no other pathological radiographic finding than a pathological head-ratio and/or alpha-angle radiographic findings. This supposes that patients with cam-impingement have a high coincidence with additional overcoverage or acetabular retroversion that is consistent with the results published by Ganz et al. [25].

No statistical significant difference in age was detected in patients with radiographic findings for both kinds of FAI and in patients with cam-impingement only. This implies that the dominant deformation for the development of OA in young adults might be the "pistol-grip-deformity" and a reconstruction of a normal head-neck-junction is much more important than the correction of the acetabular geometry. These findings support the results of previous studies, where the pistol-grip-deformity was strongly associated with labral tears and idiopathic arthritis and suggested an early correction of this deformity to prevent end-stage arthritis [34–37,40–43]. Nichols et al. [36] demonstrated that patients with an increased alpha-angle and radiographic parameters for acetabular dysplasia (decreased CE-angle and increased extrusion index) showed a higher risk for the development of OA. They also demonstrated that the alpha-angle and the CE-angle predict the risk for THA independently which is also consistent with our findings.

In contrast to these findings, Audenaert et al. [44] suggested that not only a cam lesion is involved in the development of FAI, but the overall hip anatomy should be analysed. They suggested that more bone resection is necessary than a simple resection of a bump.

**Conclusion**

There is a high coincidence of radiographic findings of an abnormal head-neck-junction with acetabular anomalies such as overcoverage or acetabular retroversion. A restoring of the normal anatomy should be performed at the early stage to avoid end-stage osteoarthritis.

**Disclosure of interest**

The authors declare that they have no conflicts of interest concerning this article.

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