Reliability of a new hip lateral view to quantify alpha angle in femoroacetabular impingement

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1. Introduction

Femoroacetabular impingement (FAI) associates hip pain, labral lesions and early osteoarthritis of the hip [1,2]. Three types of FAI have been described [1,3]. Cam-type FAI is due to a bony prominence, mainly in the anterosuperior quadrant of the femoral head, leading to early contact with the acetabular rim in flexion-adduction-internal rotation. Pincer-type FAI is due to excessive acetabular coverage of the femoral head [4]. A mixed-type FAI has also been described [3,5] combining both of the above abnormalities.

For cam-type FAI, the bony prominence at the femoral head-neck junction is quantified on MRI imaging by the alpha angle (AA) described by Nötzli et al. [6]. CT-arthrography can also accurately measure the AA and visualize labral tears and cartilage damage [7]. More recently, several studies focused on standard radiographic views to quantify the AA, as it is the routine basic imaging technique in orthopaedic departments, easily obtainable in consultation [2,8–12]. Several studies have found that the Dunn (45° or 90°) views were efficient to quantify the femoral head-neck contour [11,13]. Clohisy et al. [8] found the frog-leg lateral view most efficient to quantify the AA when compared to AP view and cross table lateral view, but Konan et al. found that it was not reliable when compared to CT-scan measures [10]. Neppe et al. [14] found that a combination of 3 plain radiographs (AP pelvis, Dunn 45° and frog-leg lateral views) was needed to accurately

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ABSTRACT

Background: Radiographic measurement of the alpha angle (AA) in femoroacetabular impingement (FAI) is not well codified and invasive techniques such as MR- or CT-arthrography remain the gold standard. Excessive acetabular coverage described in pincer-type FAI can be seen on plain radiographs but has never been quantified and anterior center edge (ACE) angle, described on the false-profile view (FP) to measure anterior acetabular coverage has never been evaluated in FAI.

Hypothesis: In this study we wanted to determine if a plain radiograph could efficiently measure AA compared to CT-arthrography and if ACE could quantify the acetabular coverage in FAI.

Materials and methods: We developed a hip view combining a lateral view and a FP, called profile view in impingement position (PIP). Twenty-six patients operated for FAI had CT-arthrography, PIP and FP. Nineteen control subjects had the PIP, AA were measured twice by three raters and ACE once. We compared AA measured on patients between CT and PIP, on PIP between patients and controls, ACE measured on patients between PIP and FP, and did a reproducibility analysis. Means were compared by paired or unpaired t-tests; reproducibility was measured by intraclass correlation coefficient (ICC).

Results: Mean AA was 65.8° (range, 48–85°) on CT-arthrography and 63.9° (range, 50–87°) on PIP (P > 0.05). ICC for PIP measures were 0.8–0.9 for intra-rater and 0.6–0.9 for inter-rater reliability. Mean AA on PIP in patients was 63.3° (range, 52–87°) and 44.9° (range, 34–67°) in controls (P < 0.001). Mean ACE was 26.8° (range, 14–41°) on PIP and 32.8° (range, 18–56°) on the FP (P < 0.015).

Discussion: The PIP is a reliable view to measure the AA in FAI as measures on PIP and CT-arthrography were not significantly different with a good reproducibility. All of the painful hips and 2 controls had an AA > 50°. PIP was not efficient to measure ACE.

Level of evidence: Level III, case-control study.

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characterize the deformation. Thus, there is no conclusion in the ideal position to determine AA by standard radiographs in FAI.

In pincer-type FAI, abnormalities of the acetabulum leading to excessive cover of the head such as retroversion [15] or deep acetabulum have been described [16]. However, no quantifying method has been investigated on standard radiographs in pincer-type FAI to quantify an excess of acetabular coverage. Lequesne and de Sèze reported anterior coverage of the hip could be measured by the anterior centre edge angle (ACE) on the false-profile view (FP) [17]. This view has been reported to be reliable for geometric evaluation of anterior coverage in normal and dysplastic hips [18]. This view could be useful for quantifying excessive anterior coverage in FAI.

In this study, we developed a new lateral hip radiographic view which associates a lateral view of the femoral neck with a FP of the acetabulum, which we called profile view in impingement position (PIP). The objectives were to compare AA measures between CT-scan and PIP in patients, AA measures on PIP between patients and control, determine the reproducibility of the two techniques and to compare the measures of ACE angles in patients between PIP and FP.

2. Materials and methods

2.1. Patients

CT-arthrography and radiographs of 26 consecutive patients operated in the orthopaedic department from 2002 to 2004 by a single surgeon were retrospectively analyzed. There were no exclusion criteria. All patients had anterior hip pain and a positive impingement test. CT-arthrography found labral tears for all the patients, cartilage damage for 16 of them. The mean age was $39 \pm 10.7\, \text{years}$ (range, 17–58) and included 10 women for 16 men (Table 1). On the 26 patients, 8 had the PIP of one hip and 18 of the 2 hips according to the symptoms (44 PIP in total), 17 had an interpretable CT-arthrography done in our institution (9 had a CT-scan done elsewhere which could not be used). We thus had 17 hips where we could compare AA measured on CT-arthrography and on the PIP, 17 CT-arthrography and 44 PIP for reproducibility analysis. Fifteen patients also had the FP, which enabled us to compare ACE on the FP and on the PIP.

A control group of 19 patients was recruited in the orthopaedic consultation. They had no history of hip pain, and gave their consent to have the PIP of one hip. Mean age was $39 \pm 11.7\, \text{years}$ (range, 16–56) and included 7 women for 12 men (Table 1).

2.2. Methods of measurements

The PIP view was realised the patient standing up, the studied hip flexed 90°, the foot standing on an adjustable stool to maintain this position, the thigh being horizontal (Fig. 1A and B). The axis of the thigh made a 50° angle with the film cassette, thus the femoral neck was parallel to the film. The beam was horizontal, perpendicular to the film. The pelvic bone made a $65^\circ$ angle with the film, like in FP. Thus, the angle between the femur and the pelvic bone was $65^\circ$, which is in adduction and flexion (Fig. 2). The standard FP was realized as described initially [17]. All radiographs were checked to match the following quality criteria: the 2 femoral heads had to be separated by a distance equal to the size of a femoral head.

Radiographs were numerized with a vertical scanner (Vidar Sierra Plus) in order to obtain a numeric treatment and avoid parallax errors. The different measures were realized using the Declic software (32 bits, 5.22.1.0 version, http://emmanuel.ostenne.free.fr/declic).

CT-arthrography was performed after injection in the articulation (Hexabrix® 320, Guerbet), on a Siemens Sensation 16 (Siemens, Erlangen, Germany). Two-dimensional multiplanar reformations of 10 mm thickness at 10 mm intervals were performed on a Wizard graphic workstation according to three planes: para-axial (horizontal plane passing through the centre of the femoral head and the femoral neck axis), para-sagittal and para-coronal. The selected view for the measure of the AA was the medial para-axial slice passing through the center of the femoral head and its most anterior point, as described by Nötzli et al. for MRI [6].

The AA was measured according to the method described by Nötzli et al. [6] on PIP and CT and the ACE angle was measured according to Lequesne and de Sèze [17] on the FP and PIP.

Three different raters analyzed the radiographs to assess intra- and inter-rater reliability. Two were orthopaedic surgeons: a resident (GAO), a senior surgeon (FG), and one radiologist (HR). GAO did two measures of the AA at two months intervals on CT-arthrography and PIP, and one measure of the ACE angle on the PIP and on the FP. HR did one measure of AA on CT-arthrography and two measures on PIP. FG made two measures of AA on radiographs. All measures were blinded.

2.3. Statistical analysis

All the data was tabulated in SPSS for windows (Version 16.0, Chicago, SPSS Inc). A $P$-value $\leq 0.05$ was considered significant. All variables had a normal distribution (Kolmogorov-Smirnov test). An a priori power analysis was performed using the data from Nötzli et al. [6] to calculate sample size. In that study, standard deviation was 5.4°, we decided that a difference $< 4°$ was not clinically significant, and for a power of 80%, we found that 17 patients were needed. To compare AA measures on CT-arthrography and on the PIP view, a two-tailed paired $t$-test to compare means and

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<th>Table 1</th>
<th>Characteristics of patients and controls.</th>
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<td>Patients</td>
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<td>$n$</td>
<td>26</td>
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<tr>
<td>Mean age $\pm$ SD [range]</td>
<td>$39 \pm 10.7$ [17–58]</td>
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<td>Gender (F/M)</td>
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a Pearson's correlation analysis were performed. A two-tail t-test for two variables was realized to compare means between AA in patients and in controls with post-hoc power analysis, and for ACE angles measures between PIP and FP. Bias between measures and between raters were examined by a two-tail paired t-test for CT-arthrography measures and by a two-way ANOVA for repeated measures with a Student-Newman-Keuls multiple comparisons post-hoc test for radiographic measures. Intra and inter-rater agreements were determined by the intraclass correlation coefficient (ICC, single measure, absolute agreement, two-way random effect analysis of variance model: ICC2). To illustrate the difference in the measurements between two measures of the same rater, a Bland and Altman plot was realized.

3. Results

3.1. Comparison of AA measured on CT-arthrography and on PIP

Mean AA on CT-arthrography was 66.1 ± 11.6° (range, 48–85°) for GAO and 65.6 ± 11.8° (range, 49–84°) for HR (P > 0.05) (Table 2). Mean AA on the PIP was 63.6 ± 8.9° (range, 50–87°) for GAO and 64.3 ± 9.2° (range, 50–87°) for HR (P > 0.05). A two-way paired t-test to compare means between CT-arthrography and radiographic measures found no significant difference for both raters and a good Pearson’s correlation coefficient r = 0.73 (P = 0.0004) for GAO and r = 0.8 (P = 0.001) for HR.

3.2. Reproducibility of the AA measure on CT-arthrography

ICC for inter-rater reliability on CT-arthrography measures was 0.86 (range, 0.64–0.95) (P < 0.0001) (Table 2). Intra-rater reliability on CT-arthrography measures was high with an ICC = 0.91 (range, 0.82–0.94) (P < 0.0001), and no bias was found on the paired t-test.

3.3. Reproducibility of the AA measure on PIP

A two-way ANOVA for repeated measures on AA measured on the PIP, found no bias between observations and between raters. Intra-rater reliability was 0.88 (range, 0.81–0.92) for GAO, 0.82 (range, 0.71–0.89) for HR, 0.9 (range, 0.84–0.94) for FG (P < 0.001 for the 3 ICC). A Bland and Altman plot has been realized to visualize the difference between the two measures (Fig. 3). On the PIP, global inter-rater reliability was 0.78 (range, 0.71–0.84) (P < 0.0001). Inter-rater reliability for each pair of measures found ICC ranging from 0.6 to 0.9.

3.4. Comparison of AA measures on PIP in patients and in the control group

Mean AA on the PIP of the painful hips of FAI patients was 63.3 ± 8.2° (range, 52–87°) and 44.9 ± 8.1° (range, 34–67°) for the control group (P < 0.0001 with power analysis above 0.99 for the three raters). If a 50° cut-off was taken, none of the 44 painful hips had an AA < 50°, and 2 (10.5%) of the 19 control hips had an AA > 50°. Odd ratio was 623 (P < 0.0001).

3.5. ACE angle measures

Mean ACE angle on the PIP was 26.8 ± 8.8° (range, 14–41°) and 32.8 ± 6.9° (range, 18–56°) on the FP, the difference was statistically significant (P = 0.015). Pearson’s correlation coefficient found a moderate correlation r = 0.58 (P < 0.05).

4. Discussion

In cam-type FAI, the bony prominence in the anterosuperior quadrant of the femoral head is best quantified by the AA described on MR-arthrography [6] but several studies found that AA measurements on plain radiographs were reliable [8,13]. In pincer and mix-type FAI, excessive acetabular coverage can be seen on plain radiographs but no quantification technique has been described. In this study, we made the hypothesis that AA could be measured on plain radiographs and that an excessive acetabular coverage could be quantified by ACE angle measurement. We developed a new lateral hip view that combines a lateral view of the head-neck junction with a posterior view of the acetabulum, aimed at a precise quantification.
Fig. 3. Bland and Altman plot of the intra-rater variability in the measurement of alpha angle on the profile view in impingement position. We see that there is no correlation between the alpha angle and the variability in the measurement.

in impingement position and a FP, which we called profile view in impingement position (PIP). In our study, we:

- compared AA measured on PIP and on CT-arthrography, in patients and control using the same technique used by Nötzli et al. on MR-arthrography;
- did a reproducibility analysis;
- compared ACE angle measured on PIP and FP in patients.

There are several limitations in our study. First, only 26 patients were enrolled in the study and had the PIP view, of which 17 had the CT-arthrography and 15 the FP. We decided not to redo CT-arthrography done elsewhere to limit the radiation exposure as statistical analysis reached significance. Second, a reproducibility analysis of the PIP view technique has not been performed. However, the PIP was performed according to a standardized protocol in a single center, which limits the bias. Finally we have not performed a comparison analysis with other plain radiographs used in FAL as our aims were to determine if this view was efficient compared to CT-arthrography and if it could efficiently measure ACE angle.

In this study, AA measured on the PIP was reliable compared to CT-arthrography measures with correlation coefficients of 0.73 to 0.8. Two recent studies have also found that AA measured on the Dunn lateral view had a good correlation coefficient of 0.702 to 0.772 [13,19] compared to MRI measures. Several studies have reported that although the diminished offset is measured anteriorly, it is most pronounced anterosuperiorly and potentially at any location within the anterosuperior quadrant [9,16,20]. However, no correlation of AA on the conventional oblique axial plane and the other planes was performed, as AA in the oblique axial view could be representative of the importance of the bump in the anterosuperior quadrant. Thus a single radiographic view would be sufficient. A recent study found that a combination of three radiographic view (AP pelvis, 45° Dunn, and frog lateral) could effectively characterize femoral head-neck junction malformations as these views screened the entire anterosuperior quadrant [14].

For AA measured on the PIP, intra-rater reliability was very good (> 0.8) for all observers and inter-rater reliability was good (0.78). Several studies had previously showed a high intra-observer and inter-observer reliability of AA measurement on radiographs [13]. We also found that the PIP was effective to distinguish patients from control subjects and a cut-off could be determined at 50°. None of the FAL patients had an AA < 50°, which means that sensitivity was 100%. Thus the PIP could be a good screening test, excluding FAI if AA < 50° in painful hips.

We found a moderate correlation between ACE angles on PIP and FP, and a significant difference when comparing means, ACE on the PIP was always lower than on the FP. It has been shown that ACE angle is dependent on pelvic tilt [18] and FAI patients could have a retroverted pelvis during thigh flexion due to the anterior impingement. This could lead to a diminished anterior coverage of the femoral head during flexion, increasing the stress on the anterior labrum. We found that the mean ACE angle on FP view was 32.8°, and this is consistent with the average ACE angle found in control groups in the literature [21].

In conclusion, we found that the PIP view is a good radiographic view to assess the anterior head-neck femoral junction compared to CT-arthrography. None of the painful FAI patients had an AA < 50°. Therefore this view can be efficiently used to exclude cam-type FAI in painful hips when AA is below 50°.

Disclosure of interest

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

References


