The Utility of False-Profile Radiographs for the Detection of Osteoarthritis Progression in Acetabular Dysplasia

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Background: Both the lateral center-edge angle and acetabular roof obliquity on anteroposterior radiographs are well-known prognostic predictors of osteoarthritis progression in patients with acetabular dysplasia. However, few studies have evaluated osteoarthritis progression on false-profile radiographs. In the present study, osteoarthritis progression was evaluated on anteroposterior and false-profile radiographs.

Methods: We retrospectively evaluated 76 patients with acetabular dysplasia with Tönnis grade-0 or 1 osteoarthritis, from a group of 179 patients (209 hips), who had undergone unilateral periacetabular osteotomy from 1995 to 2005. We evaluated the hip joint of the contralateral, untreated side. All patients were followed for ≥10 years. Of the 76 patients, 52 patients with Tönnis grade-0 or 1 osteoarthritis at the latest follow-up were categorized into the non-progression group and the remaining 24 patients with Tönnis grade-2 or 3 osteoarthritis were categorized into the progression group. We evaluated patient characteristics as well as radiographic parameters, including the preoperative lateral center-edge angle, acetabular roof obliquity, and anterior center-edge angle.

Results: The mean duration of follow-up was 12.6 years (range, 10 to 19 years). On univariate analysis, body weight, body mass index, and all radiographic parameters indicating the severity of acetabular dysplasia significantly differed between the 2 groups. On multivariate analysis, both the anterior center-edge angle and acetabular roof obliquity were considered to be significant predictive factors for osteoarthritis progression. On receiver operating characteristic curve analysis, the cutoff values for the lateral center-edge angle, acetabular roof obliquity, and anterior center-edge angle were 15.5°, 15.5°, and 12.5°, respectively.

Conclusions: In addition to the lateral center-edge angle and acetabular roof obliquity, we showed that the anterior center-edge angle is a possible prognostic predictor of osteoarthritis progression. These findings indicate that radiographic parameters based on the false-profile view are relevant. Additionally, patients with an anterior center-edge angle of ≤12.5° and a lateral center-edge angle of ≤15.5° seem to be at higher risk of osteoarthritis progression over a 10-year period.

Level of Evidence: Prognostic Level IV. See Instructions for Authors for a complete description of levels of evidence.

Acetabular dysplasia is one of the main causes of hip pain and secondary osteoarthritis1,2. It is characterized by morphological abnormalities, including a shallow acetabulum and reduced acetabular coverage of the femoral head, which result in chronic mechanical overload of the acetabular rim and structural instability3,4. The identification of the prognostic predictors of disease progression is clinically beneficial. Several studies have investigated the relationship between acetabular dysplasia and osteoarthritis1,5-9. Both the lateral center-edge angle and acetabular roof obliquity are well-known prognostic predictors of osteoarthritis progression in patients with acetabular dysplasia. The anterior center-edge angle quantifies the amount of anterior coverage of the femoral head by the acetabular roof. To our knowledge, no long-term analyses of the anterior center-edge angle have been performed.

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Moreover, although many researchers have assessed osteoarthritis progression on anteroposterior radiographs, few reports have described the evaluation of osteoarthritis progression on false-profile radiographs.

In the present retrospective study, we evaluated the progression of osteoarthritis in the hip joints of patients with untreated acetabular dysplasia with use of false-profile radiographs. Our primary aim was to determine the utility of false-profile radiographs for the detection of osteoarthritis progression in hips with acetabular dysplasia. Our secondary aim was to identify sensitive prognostic predictors of hip osteoarthritis.

**Materials and Methods**

We performed a retrospective review of 209 consecutive hips in 179 patients who had undergone periacetabular osteotomy for the treatment of symptomatic acetabular dysplasia from 1995 to 2005. The contralateral, untreated hips of patients who had undergone periacetabular osteotomy were reviewed. We excluded 30 patients who had undergone bilateral periacetabular osteotomy, 11 hips in 11 patients who had undergone other surgical treatments before or after periacetabular osteotomy, 19 hips in 19 patients with acetabular dysplasia with Tönnis grade-2 or 3 osteoarthritis in the contralateral hip at the time of periacetabular osteotomy; 11 hips in 11 patients with Legg-Calvé-Perthes-like deformity of the femoral head in the contralateral hip, and 2 hips in 2 patients with psychological depression. Of the remaining 106 contralateral hips with Tönnis grade-0 or 1 osteoarthritis, 30 hips were excluded because the patients were followed for <10 years. Finally, 76 hips in 76 patients (6 male and 70 female) were included in this study; of these, 52 hips had Tönnis grade-0 osteoarthritis and 24 hips had Tönnis grade-1 osteoarthritis. The follow-up rate was 72%.

In our department, the indications for periacetabular osteotomy included pain and limitation of daily activities for >5 months, a lateral center-edge angle of <25° on anteroposterior radiographs with improvement in the congruency of the hip in abduction, an age of <65 years at the time of surgery, and an intention to undergo surgery. We routinely made false-profile radiographs of the contralateral hips if these untreated hips showed acetabular dysplasia (a lateral center-edge angle of <25°) on anteroposterior radiographs.

The patients were classified into non-progression and progression groups on the basis of the presence or absence of osteoarthritis progression, respectively. At the time of the latest follow-up, 52 patients with acetabular dysplasia (3 male and 49 female) with Tönnis grade-0 or 1 osteoarthritis constituted the non-progression group, and 24 patients (3 male and 21 female) with Tönnis grade-2 or 3 osteoarthritis constituted the progression group. The mean duration of follow-up was 12.6 years (range, 10 to 19 years). We evaluated clinical data for each patient (including sex, age at the time of surgery, duration of follow-up, and postoperative Harris hip score on the operatively treated side) in relation to hip osteoarthritis. Additionally, for each patient, we evaluated patient demographic information and clinical characteristics, including height, weight, body mass index (BMI), smoking status, and daily alcohol consumption.

**Radiographic Evaluations**

We evaluated the radiographic parameters of the hip joint on the contralateral, untreated side. The severity of acetabular dysplasia was assessed on standardized radiographs of the pelvis and hip, including anteroposterior and false-profile views. Radiographic evaluations included preoperative acetabular measurements of the lateral center-edge angle, acetabular roof obliquity, acetabular head index, peak-to-edge distance, lateral subluxation, superior (vertical) subluxation, and minimum hip joint space on anteroposterior pelvic radiographs. The crossover sign was recorded as an index of acetabular retroversion. The anterior center-edge angle as described by Lequesne and de Seze, which quantifies the amount of anterior coverage of the femoral head by the acetabular roof, also was assessed on false-profile radiographs. False-profile radiographs were made with the patient in the standing position and with an angle of 65° between the pelvis and the film as described by Lequesne and de Seze. The ipsilateral second metatarsal axis was parallel to the surface of the film, and the tube was at a right angle to the film. The tube-film distance was 100 cm, with the femoral head positioned at the center (Fig. 1).

The severity of osteoarthritis was classified both preoperatively and postoperatively according to the Tönnis system as grade 0 (no signs of osteoarthritis), grade 1 (slight narrowing of the joint space, slight lipping at the joint margin, and slight sclerosis of the femoral head or acetabulum), grade 2 (small cysts in the femoral head or acetabulum, increased narrowing of the joint space, and moderate loss of sphericity of the articular cartilage), grade 3 (advanced osteoarthritis, absence of the articular cartilage, and severe deformity of the articular surface of the femoral head and acetabulum), and grade 4 (severe osteoarthritis with clinical symptoms and a hip replacement).
femoral head), or grade 3 (large cysts, severe narrowing or obliteration of the joint space, severe deformity of the femoral head, and osteonecrosis).

The measurements were performed by 2 authors (S.A. and A.M.) who were blinded to the clinical results. The same observers reviewed the radiographs 3 times on different days, and the mean values were calculated. The measurements were analyzed for intraobserver and interobserver reliability. The intraclass correlation coefficients for these measurements were 0.89 to 0.96 (intraobserver variance) and 0.81 to 0.91 (interobserver variance).

**Statistical Analysis**

The Student t test and the chi-square test were used to compare patient data and radiographic parameters between the 2 groups. Multiple logistic regression analysis was applied to determine independent predictors of osteoarthritis progression in patients with acetabular dysplasia. We confirmed multicollinearity with use of the variance inflation factor (VIF). As a result, the weight was excluded. All other parameters had a VIF of <5. The cutoff values of the lateral center-edge angle, acetabular roof obliquity, and anterior center-edge angle that optimized sensitivity and specificity were identified with use of a receiver operating characteristic curve. The Pearson correlation coefficient (r) was used to evaluate correlations between the lateral center-edge angle and the anterior center-edge angle. The level of significance was defined as p < 0.05. Statistical analyses were performed with use of SPSS software (version 23.0, IBM).

**Results**

The clinical data for the 2 groups are shown in Table I. There were no significant differences in terms of age at the time of surgery, sex, duration of follow-up, or Harris hip score on the operatively treated side.
The patient characteristics and radiographic findings are shown in Table II. Body weight (p = 0.017), BMI (p = 0.021), and all radiographic parameters other than the crossover sign (p = 0.131) were significantly different between the 2 groups. There were no significant differences in height, smoking status, or daily alcohol consumption between the 2 groups.

On multivariate analysis, both the anterior center-edge angle and acetabular roof obliquity were identified as significant predictive factors (Table III). The risk of osteoarthritis progression significantly increased as the anterior center-edge angle decreased (odds ratio [OR], 0.74; 95% confidence interval [CI], 0.57 to 0.95) or as the acetabular roof obliquity increased (OR, 1.50; 95% CI, 1.03 to 2.19). The anterior center-edge angle was found to have a significant correlation with the lateral center-edge angle (r = 0.700; p < 0.001).

Receptor operating characteristic curve analysis showed that the anterior center-edge angle was a fair predictor of osteoarthritis progression in patients with acetabular dysplasia (Table IV). An anterior center-edge angle cutoff value of 12.5° offered the maximum specificity and sensitivity (91% and 91%, respectively). Twenty-three patients (30%) had an anterior center-edge angle of ≤12.5°. Of these, 20 patients (87%) developed progression of osteoarthritis within 10 years. This anterior center-edge angle cutoff value was associated with a significant increase in the risk of osteoarthritis progression (OR, 77; 95% CI, 15.8 to 376).

The cutoff values of the acetabular roof obliquity and lateral center-edge angle were 15.5° and 15.5°, respectively. The acetabular roof obliquity cutoff value had a specificity and sensitivity of 96% and 88%, respectively, and the lateral center-edge angle cutoff value had a specificity and sensitivity of 90% and 92%, respectively. This lateral center-edge angle cutoff value, which is generically used as an index of acetabular dysplasia, was also associated with a significant increase in the risk of osteoarthritis progression (OR, 103; 95% CI, 18.6 to 575). Among the patient demographic characteristics, BMI was the most sensitive indicator. The cutoff value for BMI was 27 kg/m² (specificity, 92%; sensitivity, 29%), and that for weight was 66 kg (specificity, 94%; sensitivity, 33%). Eleven patients (14%) had a BMI of >27 kg/m²; of those, 7 patients (64%) were in the progression group (OR, 4.9; 95% CI, 1.3 to 19).

The anterior center-edge angle was found to have a significant correlation with the lateral center-edge angle (r = 0.700; p < 0.001).

### Discussion

Few studies have investigated the detection of osteoarthritis progression on the basis of 3-dimensional analysis. In the present study, we evaluated osteoarthritis progression with use of both anteroposterior and false-profile radiographic views. We also evaluated patient characteristics and radiographic parameters to identify potential prognostic predictors of osteoarthritis progression in hips affected by acetabular dysplasia.

We found that the anterior center-edge angle and acetabular roof obliquity were independent predictors of osteoarthritis progression. The anterior center-edge angle cutoff value of 12.5° was found to predict osteoarthritis progression with the greatest sensitivity and specificity (Table IV). Furthermore, this anterior center-edge angle cutoff value and a BMI of 27 kg/m² were additive risk factors for osteoarthritis progression. When neither of these factors was present, the risk for osteoarthritis progression was low (4%; 2 of 50); if both were present, however, the risk increased to 100% (6 of 6).

Murphy et al. evaluated osteoarthritis progression with use of anteroposterior radiographs and reported that none of their patients with well-functioning hips at the age of 65 years had a lateral center-edge angle of <16° or an acetabular roof obliquity of >15°. Omeroglu et al. evaluated the need for secondary surgery in hips with acetabular dysplasia among patients 5 to 7 years of age and concluded that acetabular roof obliquity was the best of 15 examined radiographic parameters on the basis of decisions made by experienced surgeons. Thus, our findings support their conclusion that acetabular roof obliquity may be a useful radiographic parameter during follow-up of patients with acetabular dysplasia.

Jacobsen et al. investigated a large cohort of subjects from Denmark (n = 3,859). Although that study was cross-sectional, the lateral center-edge angle and acetabular head index were identified as useful predictive factors of osteoarthritis progression. In concordance with our findings, these parameters were related to the severity of acetabular dysplasia and osteoarthritis progression.

Our study demonstrated a correlation between the lateral center-edge angle and the anterior center-edge angle (r = 0.700; p < 0.001). However, on multivariate analysis, both the anterior center-edge angle and acetabular roof obliquity were identified as significant predictive factors (Table III), indicating that the anterior center-edge angle is a useful parameter in terms of the prediction of osteoarthritis progression. In addition, acetabular dysplasia has been known to have morphological varieties. For

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**TABLE III Multivariate Regression Analysis**

| Parameter                  | Odds Ratio | 95% CI       | P Value |
|----------------------------|------------|--------------|---------|
| Anterior center-edge angle | 0.74       | 0.57 to 0.95 | 0.019   |
| Acetabular roof obliquity  | 1.50       | 1.03 to 2.19 | 0.034   |

**TABLE IV Receiver Operating Characteristic Curve Analysis**

| Parameter                  | Cutoff | Specificity | Sensitivity |
|----------------------------|--------|-------------|-------------|
| Anterior center-edge angle | 12.5°  | 91%         | 91%         |
| Acetabular roof obliquity  | 15.5°  | 96%         | 88%         |
| Weight                     | 66 kg  | 96%         | 32%         |
| BMI                        | 27 kg/m² | 96%       | 32%         |
example, some patients with acetabular dysplasia showing a
normal lateral center-edge angle, despite having clinical
symptoms, have an abnormal anterior center-edge angle.30,31
Furthermore, Ganz and Leunig29 reported that making surgical
decisions or prognostic predictions on the basis of isolated
radiographically recorded parameters is questionable because
of the multitude of pathomorphological variations of acetab-
ular dysplasia. Thus, we believe that false-profile radiographs
may allow for a more detailed evaluation of acetabular dysplasia
that cannot be confirmed only on the basis of anteroposterior
radiographs.

Systematic reviews analyzing clinical data and patient
characteristics have established an evidence base for several
well-recognized risk factors for hip osteoarthritis, such as
previous hip injury, occupations involving heavy lifting, and
obesity.27-29 In the present study, weight and BMI significantly
differed between the 2 groups, and obesity was identified as a
risk factor for osteoarthritis progression. In our data on Japa-
nese patients with osteoarthritis, the risk of osteoarthritis
progression was significantly higher among those with a body
weight of ≥66 kg (OR, 8.2) or a BMI of ≥27 kg/m² (OR, 4.9).

The present study had some limitations. First, the false-
profile view has some issues related to the method of mea-
surement. The method of measurement can be influenced by
the pelvic rotation angle and the position of the foot, which
may introduce calculation errors. In addition, the correlation
of the anterior center-edge angle with anterior acetabular
coverage in the sagittal plane was low; thus, the anterior center-
edge angle cannot be transposed onto the sagittal plane. The
clinical importance of the anterior center-edge angle therefore
must be interpreted with consideration of the natural corre-
lation with osteoarthritis progression.30,31 These factors could
have led to miscalculations in the present study. Second, we
could only evaluate a small number of cases, and we did not
achieve an 80% follow-up rate. Loss to follow-up increases bias,
and this factor may have affected the study results. Third, we
only followed up the contralateral, untreated side. Although
there were no significant differences between the 2 groups in
terms of the Harris hip score on the operatively treated side, we
believe that our results were affected by the operatively treated
to some extent. Fourth, BMI was significantly different
between the 2 groups, which strongly affected the postoperative
radiographic findings. Therefore, bias was present in this
comparison. Fifth, although a recent study showed that a high
activity level and severe dysplasia may lead to the development
of symptoms of osteoarthritis,29 we could not collect data on
the activity levels of our patients and thus we did not evaluate
this potential factor. Finally, although the Tönnis grade is a
traditional classification parameter for osteoarthritis, it is a
qualitative rather than a quantitative parameter. Image analysis
using magnetic resonance imaging techniques, such as delayed
gadolinium-enhanced magnetic resonance imaging of carti-
lage and various other mapping images, is being developed
for the quantitative evaluation of the articular cartilage in pa-
ients with osteoarthritis.

In conclusion, we showed that the anterior center-edge
angle is a possible prognostic predictor of osteoarthritis
progression. Our findings indicate that radiographic parameters
based on the false-profile view are relevant. In addition, pa-
tients with an anterior center-edge angle of ±12.5° and a lateral
center-edge angle of ≤15.5° seem to be at higher risk of oste-
arthrosis progression over a period of 10 years.

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