

# Axial plane coverage and torsion measurements in primary osteoarthritis of the hip with good frontal plane coverage and spherical femoral head

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## Abstract

**Introduction** Mechanical factors play a role in pathogenesis of primary osteoarthritis of the hip. Torsion measures were made to detect whether there is a causal relationship between increase or decrease of femoral anteversion, acetabular anteversion, and osteoarthritis. There are no studies in the literature indicating a relationship between axial plane coverage and osteoarthritis of the hip. Deficient axial plane coverage of femoral head may also play a role in pathogenesis of osteoarthritis.

**Materials and methods** Thirty patients with primary osteoarthritis of the hip and 29 control cases were included in the study. We used the method of Anda et al. (Acta Radiol Diagn 27:443–447, 1986; Comput Assist Tomogr 15:115–120, 1991) to measure axial plane anterior, posterior coverages in patients with primary osteoarthritis of the hip. The computerized tomography sections and pelvic

radiographs indicated good frontal plane coverage and spherical femoral head. In addition to anterior acetabular sector angle, posterior acetabular sector angle, horizontal acetabular sector angles for axial plane coverage detection, femoral anteversion, acetabular anteversion, and McKibbin instability index were also measured.

**Results** Posterior coverage was lower at osteoarthritic hips than the control group's hips ( $96.0 \pm 16.7$ ,  $104.2 \pm 10.6$ ) ( $p < 0.05$ ).

**Conclusion** The results may indicate that in addition to other mechanical factors, axial plane coverage, especially the posterior coverage deficiency, may play a role in the pathogenesis of hip osteoarthritis.

**Keywords** Osteoarthritis · Hip · Axial plane · Coverage · Torsion

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## Introduction

Osteoarthritis is termed 'primary' or idiopathic if no initiating cause can be identified. In primary hip osteoarthritis's pathogenesis, various mechanical factors have been investigated. Understanding the etiology of primary osteoarthritis may direct us to the prevention and treatment [1, 2].

Recently it has been demonstrated that the anterior femoral neck abuts against the anterior acetabulum and intervening labrum in deep hip flexion 'anterior hip impingement' due to acetabular dysplasia by cam impingement or excessive acetabular coverage by pincer impingement leading to hip pain, labral tears, and osteoarthritis. This pathogenic cascade may be a common reason for primary hip osteoarthritis [3–5].

In our investigation of the literature, we could not find any research pointing to a relationship between axial plane

coverage and primary hip osteoarthritis. Most of the studies focused mainly on the etiopathogenetic role of the acetabular, femoral anteversions in hip osteoarthritis. However, in this analysis, the contribution of the coverage dependent on the acetabular and femoral anteversions not considered because it has a different effect in hip biomechanics.

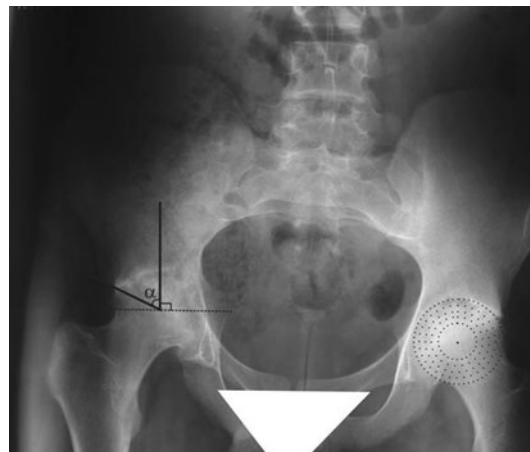
There are two methods described in the literature by Anda et al. [6, 7] and Weiner et al. [8] to measure the coverage of the hip joint in the axial plane by CT evaluation. In order to measure hip coverage correctly by these methods, there are important prerequisites: good frontal plane coverage and femoral head sphericity [6–8].

We think that coverage deficiency in the axial plane may play a role in the pathogenesis of osteoarthritis in the hip joint. Based on this, we mainly aimed to investigate if the hips with primary osteoarthritis have axial plane coverage deficiency by computed tomographic evaluation. We hypothesized that there is an axial plane coverage deficiency in patients having hip osteoarthritis with good frontal plane coverage and spherical femoral head.

## Materials and methods

The patients who had hip osteoarthritis in their pelvic X-rays were examined by computed tomography to make up the patient group (Group P). The study was designed prospectively. We included the patients with primary hip osteoarthritis who agreed to join this study. Hip osteoarthritis was diagnosed as patients having hip pain, joint stiffness with joint space narrowing, osteophytosis, sclerosis, and cyst formation at hip radiographs. Patients suspected of having previous episodes of Legg–Calve–Perthes disease, slipped capital femoral epiphysis, congenital dislocation, infection, rheumatoid or other inflammatory disease, trauma (femoral head, neck or acetabular fractures) in their medical history, physical, and X-ray examinations were excluded. Our inclusion criteria were good frontal plane coverage (Wiberg's CE angle  $\geq 25^\circ$ ) and good femoral head sphericity (less than 2 mm deviation according to evaluation by Mose's [9, 10] concentric circles in frontal, lateral, and axial planes) in their initial pelvic X-rays and computerized tomography sections (Fig. 1). The control group (Group C) was based on the computed tomographic analysis of hip joints that had already been performed on patients who were referred to our radiology department because of abdomino-pelvic diseases and who had healthy hip joints in their scanograms. Our local ethics committee approved this study. Written and informed consents were obtained from both the patients and the control subjects.

According to the criteria described above, 30 patients (Group P) with primary osteoarthritis of hip and 29 control



**Fig. 1** Pelvic radiograph of the patient having bilateral hip osteoarthritis with good frontal plane containment ( $\alpha$  angle; Wiberg's center-edge angle  $\geq 25^\circ$ ) and spherical femoral head ( $< 2$  mm deviation at Mose's concentric circles)

cases (Group C) were included in the study. Demographic information about the groups is given in Table 1.

The CT examinations were performed in supine position with femurs in neutral rotation and the hips and knees in extension. Scanograms were obtained between the anterior superior iliac spine and the level distal to the knee joint in the frontal plane.

Guided by the target scan, continuous 5-mm axial slices through both hip joints, femoral necks, and two 10-mm sections through the femoral condyles with 120 kV, 90 mA, 2 s exposure parameter were obtained using a Hitachi Radix Turbo (Tokyo, Japan) high-resolution scanner with a 512 matrix.

Femoral anteversion (FeAv), acetabular anteversion (AA), McKibbin instability index (Mi), anterior acetabular sector angle (AASA), posterior acetabular sector angle (PASA), and horizontal acetabular sector angles (HASA) were measured. The measurements were obtained from enlarged film copies by two independent observers (H.H.M., S.G.) blinded to the scope of the study. The measurements of senior radiologist (S.G) were used when the measurements of the two observers were different.

Interobserver concordance for acetabular anteversion, femoral anteversion, AASA, and PASA were tested in both hips separately by calculating intraclass correlation coefficients (ICC 3, 1).

**Table 1** Demographic information about the patient and the control groups

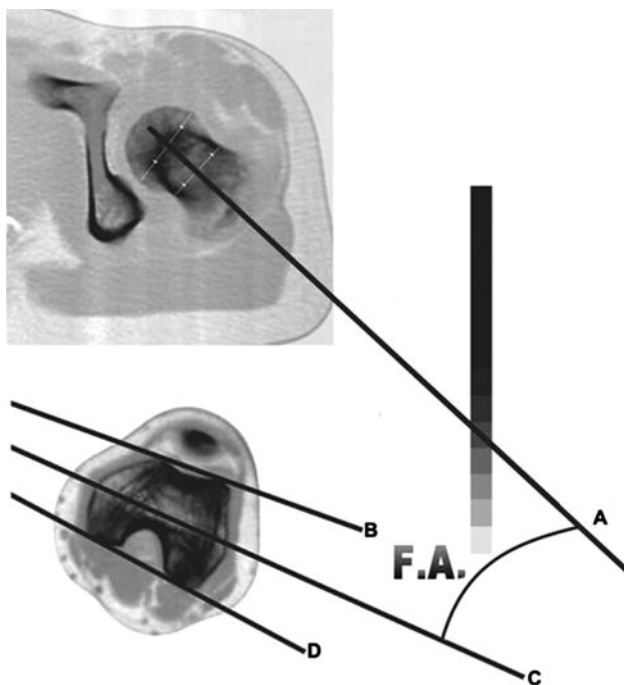
	Patient group	Control group
Sex	22 F, 8 M	13 F, 16 M
Age (mean, range)	64.9 (43–79)	54.1 (19–75)
Affected side	10 left, 14 right, 6 bilateral	–

F female, M male

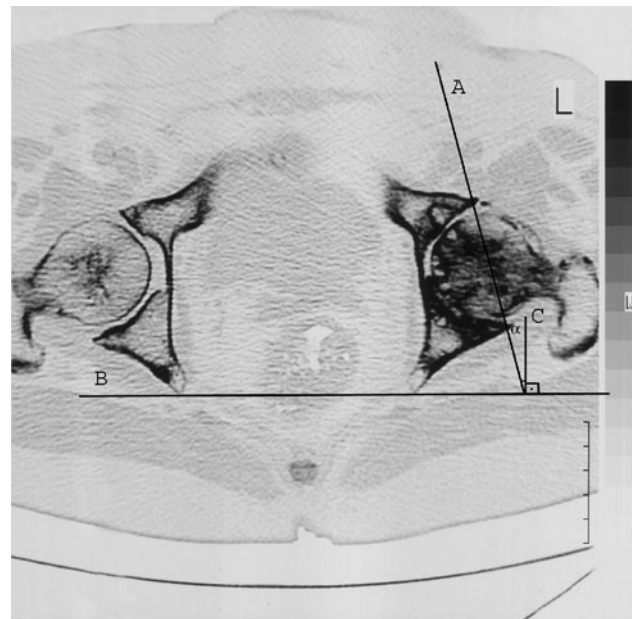
The FeAv was calculated as the angle between the projected head–neck line and the line that intersects the anterior and posterior condylar tangents. The tomogram section with largest head diameter was projected on the other section with largest, best vision of femur neck. The centers of femur head and femur neck were identified. The projected head–neck line was determined by connecting these two centers (Fig. 2).

While measuring acetabular anteversion, obliquity caused by improper positioning of the patient in the CT scanner was controlled by drawing a baseline intersecting the most posterior edges of the ilium. Acetabular anteversion describes the angulation of a line through the anterior lip of the acetabulum and the lip of the posterior acetabulum with the sagittal plane (Fig. 3) [8].

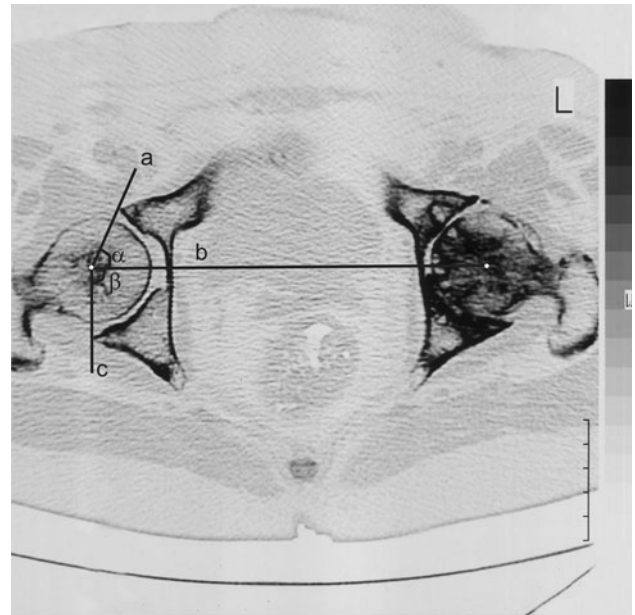
The AASA and PASA were measured in the equatorial plane in the axial plane sections just as Anda et al. [6, 7] used. The equatorial plane was defined as the plane passing axially through the centers of the femoral heads. We used concentric circles for detecting the center of the femoral heads. AASA is defined as the angle between the anterior acetabular margin, the center of femoral head and intercapital center line. PASA was described as the angle between the posterior acetabular margin, the center of the femoral head and intercapital center line (Fig. 4). HASA is defined as the total axial plane coverage angle calculated by the summation of AASA and PASA (AASA + PASA).



**Fig. 2** Femoral anteversion measurement technique. Femoral anteversion (F.A.) is calculated as the angle between the projected head–neck line (A) and the line (C) that intersects the anterior (B) and posterior (D) condylar tangents



**Fig. 3** Acetabular anteversion measurement technique in the axial plane computerized tomographic section of a patient with left hip osteoarthritis. Line B baseline intersecting the most posterior edges of the ilium; line A line intersecting the anterior and posterior lips of the acetabulum; line C line perpendicular to line B;  $\alpha$  (acetabular anteversion angle): angle between the lines A and C



**Fig. 4** Acetabular sector angles measurement technique in the axial plane computerized tomographic section of a patient with left hip osteoarthritis. Line b the equatorial plane is defined as the plane passing axially through the centers of the femoral heads; line a line connecting the center of the femoral head and anterior lip of the acetabulum; line c line connecting the center of the femoral head and posterior lip of the acetabulum;  $\alpha$  (AASA): angle between the lines a and b;  $\beta$  (PASA): angle between the lines b and c

McKibbin instability index (Mi) is calculated by summation of angles of femoral anteversion and acetabular anteversion. Values lower than 20° are regarded as low instability index, while values above 50° constitute high instability index [11].

We grouped the osteoarthritic hips and control subjects into two groups: the first group included the 20–50 values, while the second group included the values above 50 and lower than 20.

#### Statistics

The SPSS for Windows version 10.1 (SPSS Inc., Chicago, IL, USA) was used to place the data. The Pearson correlation analysis test was used to explore the influence of age on groups. Mann–Whitney test was used to investigate sex difference between groups. Kruskal–Wallis test was used to compare the values of hips of the patient groups (all affected, bilateral affected, and unilateral affected hips) with control hips.

#### Results

There was no difference between groups regarding age and sex (all affected patients vs. control group, bilateral affected

patients vs. control group, unilateral affected patients vs. control group) ( $p > 0.05$ ). There was also no correlation of age with FeAv and AA in either group ( $p > 0.05$ ). When FeAv, AA, AASA, PASA, Mi, and HASA values were compared between osteoarthritic hips and control subjects, the Mi and PASA values of osteoarthritic hips were lower than in the control group ( $p = 0.027$ ,  $p = 0.004$ ) (Tables 2, 3). There was no difference between the normal hips of the unilateral cases and the control hips for all parameters ( $p > 0.05$ ). When the osteoarthritic hips and control subjects were examined in terms of their Mi values, the percentages of those with values between 20 and 50 were 52.8 and 74.1%, respectively ( $p = 0.047$ ).

There was interobserver concordance among the independent observers for acetabular anteversion, femoral anteversion, AASA, and PASA ( $p < 0.001$ ). Intraclass correlation coefficient (ICC) analysis results were summarized in Table 4. Correlation analysis revealed negative correlation of AA with AASA and positive correlation of AA with PASA in both patient and control groups ( $p < 0.05$ ) (Table 5).

#### Discussion

Osteoarthritis of the hip is usually classified into two groups. It is termed ‘secondary’ if there is pre-existing abnormality

**Table 2** Measured values in group P (patient group) and group C (control group)

Measured parameters	FeAv (°) (mean ± SD)	AA (°) (mean ± SD)	AASA (°) (mean ± SD)	PASA (°) (mean ± SD)	Mi (°) (mean ± SD)	HASA (°) (mean ± SD)
<b>Group P</b>						
All affected hips ( $n = 36$ )	9.4 ± 11.5	15.6 ± 9.0	65.1 ± 18.6	96.0 ± 16.7	24.9 ± 15.3	161.2 ± 30.4
Bilateral affected hips ( $n = 12$ )	10.6 ± 11.6	11.2 ± 10.4	71.0 ± 18.5	92.1 ± 16.7	21.3 ± 13.7	163.1 ± 24.7
Unilateral affected hips ( $n = 24$ )						
Normal side	13.7 ± 7.0	20.0 ± 8.7	62.8 ± 15.9	104.4 ± 10.4	34.2 ± 12.6	164.4 ± 18.2
Affected side	8.8 ± 11.7	17.8 ± 7.5	62.2 ± 18.3	98.0 ± 16.7	26.7 ± 16.1	160.2 ± 33.3
<b>Group C</b>						
Control group ( $n = 29$ )	13.8 ± 10.6	18.2 ± 7.0	67.0 ± 11.3	104.2 ± 10.6	32.0 ± 12.5	171.3 ± 17.7

FeAv femoral anteversion; AA acetabular anteversion; AASA anterior acetabular sector angle; PASA posterior acetabular sector angle; Mi McKibbin instability index; HASA horizontal acetabular sector angle

**Table 3** Comparisons between groups

	FeAv (°)	AA (°)	AASA (°)	PASA (°)	Mi (°)	HASA (°)
P versus C ( $p$ value)	NS	NS	NS	<0.01	<0.05	NS
EU versus C ( $p$ value)	NS	NS	<0.05	<0.05	NS	NS
B versus C ( $p$ value)	NS	<0.05	<0.05	<0.05	<0.05	NS

P: all affected hips ( $n = 36$ ), C: control hips ( $n = 58$ ), B: bilateral affected hips ( $n = 12$ ), EU: unilateral affected hips ( $n = 24$ )

FeAv femoral anteversion; AA acetabular anteversion; AASA anterior acetabular sector angle; PASA posterior acetabular sector angle; Mi McKibbin instability index; HASA horizontal acetabular sector angle; NS not statistically significant



**Table 4** Intraclass correlation coefficient (ICC) analysis results

	ICC value	95% CI		<i>p</i> value
		Lower bound	Upper bound	
AASA	0.70	0.47	0.82	<0.001
PASA	0.83	0.70	0.90	<0.001
AA	0.81	0.67	0.90	<0.001
FeAv	0.71	0.53	0.83	<0.001

FeAv femoral anteversion; AA acetabular anteversion; AASA anterior acetabular sector angle; PASA posterior acetabular sector angle

**Table 5** Correlations between femoral anteversion (FeAv), acetabular anteversion (AA), anterior acetabular sector angle (AASA), and posterior acetabular sector angle (PASA)

Groups		AASA	PASA
FeAv	Patient	NS	NS
	Control	NS	NS
AA	Patient	$p < 0.05^*$ , $r = -0.37$	$p < 0.01^*$ , $r = 0.49$
	Control	$p < 0.01^*$ , $r = -0.57$	$p < 0.01^*$ , $r = 0.49$

NS not significant

like congenital dislocation, dysplasia, Legg–Calve–Perthes disease, infection, rheumatoid disease, epiphysiolysis of the femoral head, trauma, including medial fracture of femoral neck and acetabular fractures [2].

Primary osteoarthritis of the hip, although referred as idiopathic, may be secondary to mechanical causes. In the literature, there are numerous studies measuring torsion of the bones in lower extremities. Some of them support the hypothesis that a persistent increase in femoral anteversion predisposes to osteoarthritis of the hip [2, 12–14], whereas others do not [1, 15–17]. In other studies, the relationship between osteoarthritis and acetabular retroversion or decreased acetabular anteversion has been reported [18, 19].

Femoral anteversion develops during the second half of pregnancy and reaches 35° at birth. It decreases slowly over time, and the standard deviation of femoral anteversion is very large [13, 15, 20–22]. Acetabular anteversion increases a few degrees during growth and reaches adult values of 15°–20°. Anteversion values are not expected to change after adulthood [11, 13, 21]. Our study results support these reports in that we did not find a relationship between age and the femoral and acetabular anteversion values of the groups.

These changes in acetabulum, femoral anteversion are usually dependent on various intrauterine positions and usually regress spontaneously at birth. However, 15% of them persist into adulthood. This condition can be seen as an isolated congenital disorder or with other conditions such as slipped capital femoral epiphysis, coxa vara, deep

acetabulum, proximal femoral deficiency, or hip dysplasia. Congenital increases or decreases in femoral, acetabular anteversions independently from above conditions may lead to osteoarthritis [21]. However, we did not find any relation between femoral or acetabular anteversions and osteoarthritis in our study.

Reikerras et al. [13] detected that increased femoral anteversion is not compensated by decreased acetabular anteversion in patients with primary osteoarthritis and concluded that this leads to poor adaptation of femur head to acetabulum and later osteoarthritis development.

The McKibbin instability index is dependent on the theory that acetabular anteversion and femoral anteversion may be additive or may offset each other. Tönis et al. stated that a low instability index is a predisposing factor for osteoarthritis. The low number of patients with a high instability index had prevented them from concluding that high index also predisposes to osteoarthritis [11, 21].

We found results similar to those of Tönis et al. The Mi index was lower for osteoarthritic hips. The number of our patients having values above 50 was low for both the osteoarthritis group and the control group. We could not conclude whether a high index predisposes to osteoarthritis. However, for the control subjects, values were more frequently concentrated in the normal range (20°–50°). It can be concluded that increased or decreased femoral anteversion that is compensated with decreased or increased acetabular anteversion may prevent the development of osteoarthritis.

Increased anterior acetabular coverage in bilateral affected patients in our study may be explained by the ‘pincer’ type femoro-acetabular impingement that is seen in some of the patients with primary osteoarthritis of the hip, characterized by abutting the femoral neck against the anterior–superior labrum due to excessive acetabular coverage [3, 4].

In a recent study, it was found that frontal plane dysplasia was found in only 48% of patients with labral tears and concluded that dysplasia may not be quite as dominant a factor as previously thought in the genesis of tears of the acetabular labrum [23]. In previous studies, it was also shown that the highest contact pressures are formed at the posterior superior parts of the acetabulum, and joint reaction forces are directed to these parts [24–26]. We found a posterior coverage deficiency in osteoarthritic hips. However, there was no relation between the total horizontal coverage and osteoarthritis. This might be due to the calculation of horizontal coverage by summation of anterior and posterior coverage.

Acetabular retroversion or decreased anteversion appears as a deficient posterior wall of the acetabulum on pelvic radiographs, and this is reported to be associated with primary osteoarthritis of the hip [18]. We found a

positive correlation with acetabular anteversion and posterior acetabular sector angle in both patient and control groups, which proves that decreased acetabular anteversion with deviation of its value from the normal range is associated with a decrease in axial plane coverage. Based on these, it seems that in the pathogenesis of primary osteoarthritis, axial plane coverage, especially the posterior coverage, plays a role in addition to other mechanical problems. The relation of acetabular anteversion with anterior and posterior sector angles warrants further studies to find out whether axial plane coverage is the result of anteversion or vice versa.

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