



Measuring the osteochondral connection of the femoral head and neck in patients with impingement femoroacetabular by determining the angle of 2α in lateral and anteroposterior hip radiographic images

Merenje osteohondralnog spoja glave i vrata femura kod bolesnika sa femoroacetabularnim *impingement*-om određivanjem ugla 2α na lateralnim i anteroposteriornim radiografskim snimcima kuka

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Abstract

Background/Aim. Femoroacetabular impingement, a pathophysiological mechanism of small morphological changes of the hip leads to early arthritic changes. The aim of this study was to present a simple method for the quantification of femoral head and neck junction in patients with cam form of femoroacetabular impingement, in standardized anteroposterior and profile DUNN 90 radiograms of the hips. **Methods.** In standardized anteroposterior and profile DUNN 90 images of the hips we determined the angle of 2α , defined by our own original method. We tested 141 hips in 81 patients without clinical signs of femoroacetabular impingement, and 153 hips in 76 patients with clinically clear signs of femoroacetabular impingement. **Results.** The value of the angle 2α in anteroposterior hip radiograms was on average 113.7° for the patients with clinical symptoms of impingement, and 84.2° for the control group of patients ($p \leq 0.0001$), and in DUNN 90 profile radiography of the hip, the value of 2α angle in the patients group was 97.2° , and 74.6° in the control group ($p \leq 0.0001$). The proposed method of determining the angle 2α showed a high level sensitivity (97.8%) and specificity (98.7) and positive predictive value (98.6%). It was false positive in only 1.3%, and false negative in 2.12% of patients. **Conclusion.** Using standardized anteroposterior and profile radiographs of the hips, and without determination of femoral neck axis in patients with femoroacetabular impingement with the cam effect at the junction of the femoral head and neck, we proposed the method of measuring joint abnormalities of femoral head and neck junction, very capable to predict the disease development in an asymptomatic risk group of patients and high sensitive in the diagnosis of the disease in the group of patients.

Key words:

hip; osteoarthritis; diagnosis; methods; radiography.

Apstrakt

Uvod/Cilj. Femoroacetabularni *impingement* predstavlja patofiziološki mehanizam koji na terenu malih morfoloških promena u predelu kuka vodi do nastanka rane artroze kuka. Cilj rada bio je da se prikaže jednostavna metoda za kvantifikaciju morfoloških abnormalnosti na spoju femoralne glave i vrata kod bolesnika sa cam formom femoroacetabularnog *impingement*-a, na standardizovanim anteroposteriornim i profilnim DUNN 90 radiografskim snimcima kukova. **Metode.** Na standardizovanim anteroposteriornim i profilnim DUNN 90 snimcima kukova, određivali smo ugao 2α . Testirali smo 153 kuka kod 81 bolesnika bez kliničkih znakova *impingement*-a, i 141 kuk kod 76 bolesnika sa jasnim kliničkim znacima femoroacetabularnog *impingement*-a. **Rezultati.** Vrednosti ugla 2α na anteroposteriornim radiografskim snimcima kukova je iznosila u proseku $113,7^\circ$ za bolesnike sa kliničkim znacima *impingement*-a i $84,2^\circ$ za kontrolnu grupu bolesnika ($p \leq 0,0001$), a na DUNN 90 profilnim radiografskim snimcima kukova, vrednost ugla 2α u grupi bolesnika bila je $97,2^\circ$ i u kontrolnoj grupi $74,6^\circ$ ($p \leq 0,0001$). Predloženi metod određivanja ugla 2α pokazao je visok nivo senzitivnosti (97,8%), specifičnosti (98,7%), te pozitivnu prediktivnu vrednost od 98,6%; lažno je bio pozitivan kod svega 1,3%, a lažno negativan kod 2,12% bolesnika. **Zaključak.** Korišćenjem standardizovanih anteroposteriornih i profilnih radiografskih snimaka kukova, bez prethodnog određivanja osovine vrata butne kosti kod bolesnika koji imaju femoroacetabularni *impingement* sa cam osteohondralnom abnormalnošću na spoju femoralne glave i vrata, prikazali smo metodu merenja abnormalnosti spoja femoralne glave i vrata, sa visokom sposobnošću predviđanja razvoja bolesti u asimptomatskoj, rizičnoj grupi bolesnika, kao i sa visokim stepenom senzitivnosti u dijagnostici bolesti u grupi bolesnika.

Cljučne reči:

kuk; osteoarthritis; dijagnoza; metode; radiografija.

Introduction

Femoroacetabular impingement (FAI) is a pathophysiological mechanism, manifested as a nonphysiological contact of the anterosuperior connection of the femoral head and neck on the anterior or anterosuperior edge of the acetabulum, as a consequence of the small, often hardly noticeable morphological changes at the proximal femur, acetabulum or in combination on the proximal femur and acetabulum at the same time. Given the primary localization of morphological changes, there are three basic forms of FAI¹. First, Pincer, is the mechanism of FAI with primary morphological changes in the acetabulum in the form of localized overcoverage of the femoral head, known as acetabulum retroversion or *coxa profunda* and *protrusio acetabuli*. Second, cam, is mechanism of FAI with morphological changes in proximal femur in the form of osteochondral abnormalities on the femoral head and neck connection (Figure 1), which reduces the space between the anterosuperior edge of the acetabulum and the anterolateral femoral head and neck connection. During movement or flexion, internal rotation and adduction of the thigh in the hip, this osteochondral prominence goes under the initially intact labrum, putting pressure on it, and then, lifts the labrum adjacent articular cartilage, from the subchondral bone¹⁻⁵. The true reason for this osteochondral prominence occurring is unknown, but it is thought that it occurs in: silent forms of femoral head epiphysiolysis in adolescence (SLIP), in Leg Calve Perthes disease, in poorly healed fractures of the femoral neck, in avascular necrosis of the femoral head and others^{4,6-8}. Third, a mixed mechanism of FAI is a combination of the two previous morphotypes with changes in the acetabulum and in the femoral head and neck connection, and it appears most frequently in daily clinical work.



Fig. 1 – Osteochondral deformity at the anterosuperior side of the femoral head and neck junction

Cam FAI is more common among young people, often very active persons and it is manifested clinically as a feeling of jumping, snapping or groin pain¹, which can be reproduced by the so-called impingement test with the leg in internal rotation, hip in flexion ranged of 30°–90° and different values of thigh adduction. The appearance of the FAI and the consequent damage to the hip joint are already documented in the form of silent and subacute cases of femoral head epi-

physiolysis in adolescents⁴. On the other hand, a number of studies suggest that mild, barely visible, anatomical changes in the hip joint, could be a significant cause of arthrosis in the hip in the latter ages of life^{3,9}. Stulberg at al.⁹ describe the so-called “pistol grip” deformity, of the proximal femur, which is present in 40% of the patients who develop hip arthrosis.

In the literature and daily clinical practice descriptive the used terms that only describe the deformity at the femoral head and neck junction are “pistolgrip”, “post-slip”, “head tilt” which are easily observed on the standard hips anteroposterior (AP) radiographic records^{6,9-11} but cannot be used to quantify the severity of hip deformity. Goodman et al.¹² state that the basic deformity is a subclinical form of the femoral head epiphysiolysis in the adolescents (SLIP) in the sagittal plane, therefore on the anterior side of the femoral neck, and, if so, it is not necessary to be visible in AP hip images.

Radiological methods and criteria for quantification of morphological changes on the proximal femur and the acetabulum in patients with anterior impingement are described by several authors¹³⁻¹⁷. Nötzli et al.¹³ in 2002 promoted the method of determining the angle α , which measures the osteochondral prominence at the junction of the head and neck of the femur in the nuclear magnetic resonance (NMR) cones. The imperative of this method is that the NMR images must precisely plot the femoral neck axis as the one of the arms of the angle α . The problem and disadvantage of the method is an insufficient precision in determining the angle α , given that there is no “gold standard” in determination of the femoral neck axis in the NMR images, as well as in standardized AP and lateral (cross table leg, Dunn 90, Dunn 45, frog-leg) radiographic hip records. It turned out that the method by which the femoral neck axis always passes through the center of rotation of femoral head is not reliable when it comes to hip morphology that is similar to cam FAI morphotype^{6,15,16}. This suggests that neither the angle α values measured by this method in patients with FAI form of cam are not reliable enough^{6,9,12}.

Therefore, we defined the double angle α (2α), as the sum of two angles, the angle α defined in the literature, and the angle which sits on the angle α just opposite to the femoral neck axis and which is equal to the angle α , since the marked axes symmetrically divides the femoral neck into two equal halves in the healthy population. Then, we assumed that it is possible to numerically measure, without prior determination of the femoral neck axis, using this angle of 2α , morphological changes on the anterolateral connection of the head and neck of the femur, on standardized radiographic AP and lateral recordings.

The aim of this paper was to show that in patients with clinical symptoms and signs of FAI and with morphological changes at the junction of the head and neck of the femur, an osteochondral abnormality at this junction can be measured using the classic, standardized AP and lateral radiographic records^{16,17} by determining the angle of 2α , without prior determination of the femoral neck axis, and also that the angle 2α values, obtained in a group of clinically symptomatic patients significantly differ from that of the control group of people with healthy hips. Also, we assumed that, due to

anatomical differences in the thickness of the femoral neck occur in AP and lateral radiographic records of the hip, and the difference in the values of the angle α in these two recordings occurs either, we suggested two upper limits for the normal values of the angle 2α in AP and lateral radiographic records of the hips. To compare our method of determining the angle 2α , with the method of measuring the angle α we determined in our material, at the same time, the angle α in AP and in lateral DUNN 90 radiographic hip records.

Methods

For this study we chose two groups of examinees. One group consisted of patients with positive clinical symptoms and radiological changes in the hips, which corresponded to the cam form of the FAI and the control group of healthy subjects. Criteria of inclusion patients with positive clinical findings were: groin pain, which lasted at least 3–18 months before setting suspicion to FAI, a positive impingement test¹⁸, internal rotation of the symptomatic hip was less than 20° at the hip flexion on 90° , present radiographic signs of cam morphotype FAI and absent signs of radiographic changes in the morphology of the acetabulum. Within these radiographic criteria a normal acetabulum is meant the absence of *coxa profunda*, *protrusio acetabuli*, retroversion of the acetabuli and the value of center edge (CE) angle of 25° – 35° on standardised AP radiographic recordings of the hips^{16,19}. Criteria for exclusion from the study were: previous history and/or surgery of the hip, posttraumatic conditions, the CE angle less than 25° or greater than 35° , clear signs of femoral head avascular necrosis, septic or rheumatoid arthritis and advanced osteoarthritis (Tönnis degree ≥ 2). The group of subjects with cam FAI form (patient group), consisted of 81 patients (49 men and 32 women), aged 30.3 years \pm 8.3 years (range 19–55 years), where for the purposes of this study we examined 153 radiographic records of the hips of which there were 70 right hips and 83 left hips, and 9 hips were excluded from the study. The second group of subjects (control group) consisted of 76 subjects with

asymptomatic, healthy hips with 40 men and 36 women, average age, 34 ± 5.8 years (range 21–54 years), in who we analyzed 141 hips, 68 right and 73 left. The study included subjects with saddle pain, lower back and ischialgic region pain with radiographic images made from differential diagnostic reasons. The criteria for inclusion in the control group were: asymptomatic, painless hip, internal rotation greater than 20° at 90° flexion of the leg in the hip, and negative impingement test. Eleven hips are excluded from the study because internal rotation of the hip was lower than 20° , and in four of the subjects groin pain during forced adduction of the thigh in the hip was present, with radiographic suspicion to Pincer FAI form. Internal rotation of the thigh in the hip in both tested groups was on average $32 \pm 9^\circ$ (range 20° to 40°) for the control group, and $9.4^\circ \pm 6.7^\circ$ (range 0° – 15°) for the group of patients.

For all the subjects of both groups radiographic hip images were made: one standardized AP radiographic image of the hip¹⁵, with the patient lying on his back with feet in internal rotation of 15° , the distance between the focus of the X-ray apparatus and X-ray film was 120 cm, with central ray directed at the center line of the body on the half way between the bispinal line and pubic symphysis. In order to assess effects of pelvic rotation and tilt on the values of the angle 2α on each recorded AP radiographic image of the hips, the distance from the top of the upper edge of the pubic symphysis to the middle of the sacrococcygeal joint was measured, where the normal value of 3–5 cm in men and 2–3 cm in women²⁰ was taken, and the central axis of the body was going through the pubic symphysis. The second radiographic image that we used for this study was the lateral Dunn Ripstein Müller 90° (DUNN 90) radiographic record of the hip⁷, which was made with a patient lying on his back, hips and knees flexed at 90° , and upper thigh abducted on 20° , with the feet in neutral rotation. The distance focus of the X-ray apparatus X-ray cassette was 120 cm, and central X-rays was aimed at the middle of the pubic symphysis.

The method of determining the angle 2α (Figure 2) was as follows: After making AP and lateral hip radiographs

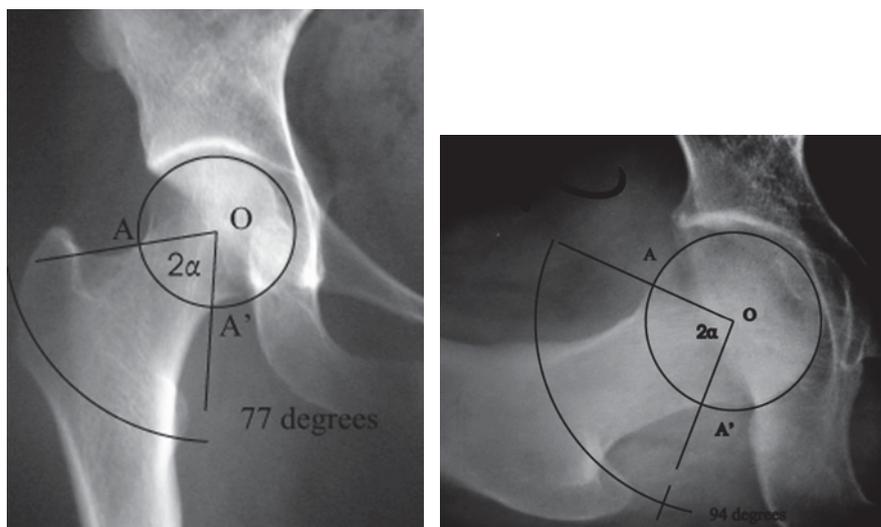


Fig. 2 – Measuring of the angle 2α in the anteroposterior (left) and DUNN 90 (right) radiographic images of the hips in the control group of the subjects (explanation of the method is given in the text)

(DUNN 90 in the control group, the angle 2α was determined using Mosse concentric circles, the center of rotation of the femoral head (point O) was determined, using a compass, circular line was plotted on the edge of the femoral head, and the intersections of these lines with the edges of the femoral neck were plotted and marked as points A and A'. A ruler was used to draw lines connecting the center of rotation of the femoral head with points A and A', and then with protractors of the angle AOA' or angle 2α was measured. The angle 2α was determined in the same way in DUNN 90 or lateral radiographs of the hips. To determine this angle it was not necessary to determine the femoral neck axis. The method of determining the angle 2α was the same in the group with clinically suspected to positive form of cam FAI (Figure 3), but the point A is marked in the place of cir-

without touching the edge of the acetabulum with its osteochondral prominence present at the junction of the femoral head and neck.

The angle α (Figure 4) was determined using the same method described by Nötzli et al. in 2002¹³: after determining the femoral head rotation center O and the circular line marking the edge of the X-ray projection of the femoral head, the central point between two points in the narrowest part of the femoral neck was determined and marked as point B. The resulting middle point of the neck was connected with the center of rotation of the femoral head and thus the femoral neck axis was obtained and marked as OB. From the center of rotation of the femoral head a line was drawn passing through the point A. The angle between the line AO and the line of femoral neck axis OB is the angle α .

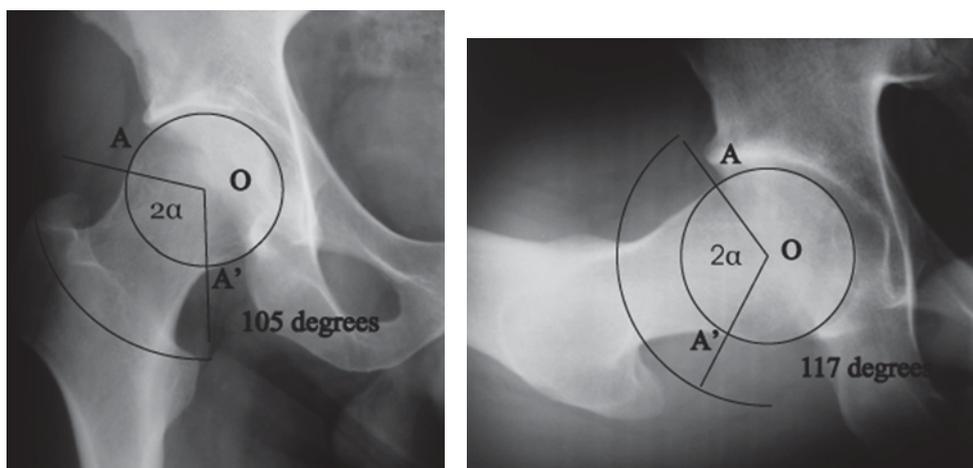


Fig. 3 – Measuring of the angle 2α in the anteroposterior (left) and DUNN 90 (right) radiographic images of the hips in patients with Cam form of impingement femoroacetabular (explanation of the method is given in the text)

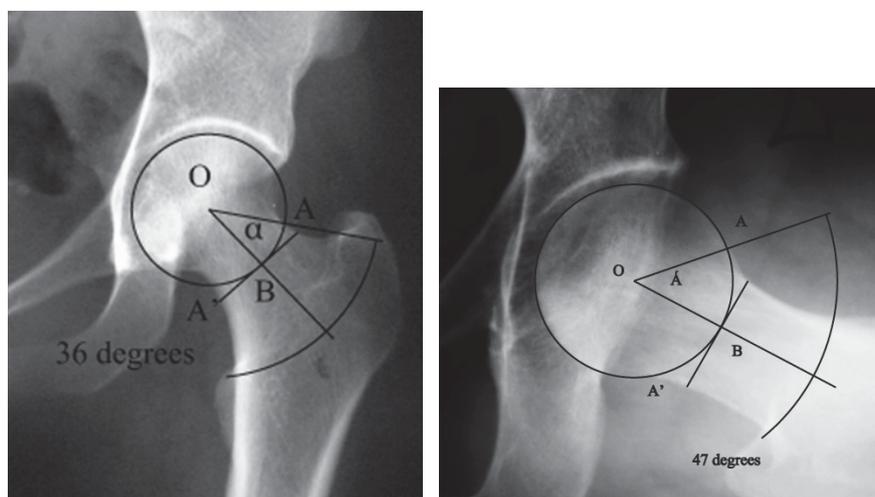


Fig. 4 – Measuring of the angle α by Nötzli method on the anteroposterior (left) and DUNN 90 (right) radiographic images of the hip in the control group of subjects (explanation of the method is given in the text)

cular line of the femoral head intersecting osteochondral prominence at the junction of the head and neck of the femur^{13, 21, 22}. These points represent pathoanatomical end point of femoral head sphericity, ie. point up to which the femoral head slips below the labrum in the acetabulum,

For statistical processing of the obtained data, we used several statistical parameters. Normality of distribution of the obtained data was checked using the Kolmogorov-Smirnov test. Student's *t*-test was used to test the hypotheses and to test intra- and interobserver agreement. To determine

the intraobserver and interobserver agreement in the study, we included two independent orthopedic surgeons who, at a 3-week intervals, performed two measurements of the angle 2α on standardized AP and lateral DUNN 90 radiographic images of the hip. To measure the validity of the test, ie. to determine the sensitivity, specificity and other parameters, we formed a contingency table. To correlate values of the angle 2α , the angles α and α' the Pearson's correlation coefficient was used.

A confidence interval of 95% ($p < 0.05$) was taken. The statistical power of the test was greater than, or equal to 80%. Processing of graphics image was done in the video image processing Corell Draw 11 and all the data were processed in the computer statistical program SPSS 8.0 for Windows.

Results

Using the Kolmogorov Smirnov test we obtained a normal distribution of all measured values of the angle 2α , the angle α , as in the standardized AP radiographic images of the hip, and in lateral DUUN 90 radiographic images of the hip in the control group and in the group of patients.

Before the study began, we had conducted a pilot study whith the aim to confirm the assumption that the an-

DUNN 90 radiographic recordings were similar to, $\bar{x} = 39.23^\circ \pm 4.69^\circ$, $SE = 0.396^\circ$, and the angle α' , $\bar{x} = 38.29^\circ \pm 3.57^\circ$, $SE = 0.302^\circ$, and there was no significant difference, either, in the values of the two angles in DUNN 90 lateral radiographic images of hip ($p = 0.755$), suggesting that the angles α and α' are approximately equal angles, thus the summ of these two angles is the angle 2α , which was the aim of this study.

The average value of the angle 2α , in AP radiographic hip images of the control group of subjects (Table 1) was for the right hip $\bar{x} = 83.5^\circ \pm 5.7^\circ$ (range 70° – 95°), for the left hip for $\bar{x} = 84.3^\circ \pm 5.5^\circ$ (range 72° – 95°) while the difference was not found in the values of angle 2α for the left and right hip ($p = 0.34$), and the average value for the left angle 2α and right, cumulatively, in all 141 hips was $\bar{x} = 84.2^\circ \pm 5.6^\circ$ (range 70° – 95°), with $SE = 0.471^\circ$. In the cam FAI group of subjects in standardized AP radiographic images of the hip angle 2α values are (Table 1), collectively, for the left and right hip observed $\bar{x} = 113.7^\circ \pm 14.3^\circ$ (range 85° – 146°), with $SE = 1.156^\circ$, where the values for the right hip were $\bar{x} = 114.5^\circ \pm 13.3^\circ$, and for the the left hip $\bar{x} = 113^\circ \pm 15.3^\circ$, with no significant differences in the values of the angle 2α between the left and right sides ($p = 0.30$).

For lateral DUNN 90 X-ray shot of the hips, in the control group of patients (Table 1), the obtained values of the

Table 1
The values of the angle α in the anteroposterior (AP) or DUNN 90 radiographic images in the control subjects and patients with clinical signs of Cam FAI

Angles	Radiographic images		Control group		Cam FAI group	
			Right side (n = 68)	Left side (n = 73)	Right side (n = 70)	Left side (n = 83)
2α	AP	Range	70–95	72–95	93–142	
		$\bar{x} \pm SD$	83.5 (± 5.7)	84.3 (± 5.5)	114.5 (± 13.3)	113.1 (± 15.3)
		SE	0.47			
α	AP	Range	30–50	35–53	50–98	47–106
		$\bar{x} \pm SD$	42.3 (± 3.34)	42.3 (± 3.2)	71 (± 13.4)	70.6 (± 14.6)
		SE	0.291			
2α	DUNN 90	Range	60–90	64–90	76–126	64–125
		$\bar{x} \pm SD$	74.5 (± 6.3)	75.8 (± 5.8)	97.8 (± 11.11)	96.6 (± 12.6)
		SE	0.581			
α	DUNN 90	Range	30–49	31–51	48–89	34–90
		$\bar{x} \pm SD$	38.8 (± 2.2)	39.6 (± 2.0)	60.9 (± 10.5)	62.1 (± 10.4)
		SE	0.176			

DUNN 90 – Dunn Rippsetin Mueller radiographic image; Cam FAI – cam form of femoroacetabular impingement; \bar{x} – mean; SD – standard deviation; SE – standard error of the mean

gle 2α in fact is a sum roughly equal to two angles that lie at the opposite sides of the femoral neck axis and goes from the center of rotation of the femoral head. We measured the angles α and its opposite angle α' in AP and DUNN 90 radiographic images of the hips in the control group of patients. We used 50 right and 50 left hips with AP and lateral DUNN 90 radiographic images. Statistical analysis showed that the mean value (\bar{x}) of the angle α in the AP recordings was $42.5^\circ \pm 3.42^\circ$ with a standard error of the mean (SE) of 0.284° and of the angle α' , $\bar{x} = 41.7^\circ \pm 3.29^\circ$, $SE = 0,0273^\circ$ and no significant difference in values between these angles was found ($p = 0.694$). The values of the angle α in the

angle 2α , for the right hip were $\bar{x} = 74.5^\circ \pm 6.3^\circ$, for the left hip $\bar{x} = 75.8^\circ \pm 5.8^\circ$; there was no difference in the value of angle 2α between the left and right sides ($p = 0.13$), and the measured values of the angle 2α for the left and right sides, cumulatively, were $\bar{x} = 75.3^\circ \pm 6.9^\circ$ with $SE = 0.581^\circ$. We found a significant difference ($p < 0.0001$) for values of the angle 2α measured in AP and DUNN 90 radiographic recordings of the hip in the control groups. In the group with cam FAI in lateral DUNN 90 radiographs of the hips the average value of angle 2α for the left and right hip, cumulatively, was $\bar{x} = 97.2^\circ \pm 11.8^\circ$ (range 64° to 126°), with $SE = 0.954$, the values of the same angle for the right hip were $\bar{x} =$

$97.8^\circ \pm 11.11^\circ$, and for the left hip $\bar{x} = 96.6^\circ \pm 12.6^\circ$. A significant difference was found in the values of angle 2α ($p < 0.00001$) measured in standardized AP radiographs of hips in the control group and cam FAI group of patients, as well as values obtained by the same angle in lateral DUNN 90 hip radiographs ($p < 0.0001$) of the control group and the group of patients.

The values of angle α , assessed by Nötzly method, in our recordings for the AP hip radiographic images in the control group of subjects (Table 1), were for both, left and right hip, $\bar{x} = 42.4^\circ \pm 3.28^\circ$ with $SE = 0.291^\circ$, which are almost identical values received by Nötzly et al.¹³ ($42.2^\circ \pm 2.2^\circ$), and the value of the same angle on the DUNN 90 radiographic images were for the control group, for both hips $\bar{x} = 39^\circ \pm 2^\circ$ with $SE = 0.176^\circ$. The average value of the angle α in the cam FAI group of patients was in average, for AP, $\bar{x} = 70.8^\circ \pm 14^\circ$ with $SE = 1.132^\circ$, and for DUNN 90 hip radiographs $\bar{x} = 61.54^\circ \pm 10.9^\circ$ with $SE = 0.88^\circ$, and with a significant difference compared to the control group of subjects ($p < 0.001$). Using comparative analysis of the value of angle α and 2α using the Pearson's correlation coefficient, we obtained very high level of agreement in the values of these angles within the control and patient groups for the AP ($r = 0.926$, $p < 0.01$) and DUNN 90 (0.956 , $p < 0.01$). radiographic recordings of hips.

To obtain the maximum and minimum limit value of the angle 2α in our material, at the confidence interval of 95%, we enlarged the average value of angle 2α in the control group of healthy subjects, for 2 standard deviations. So, we got the maximum value of the angle 2α in AP radiographs of the hips of 94.6° and the minimum value of angle 2α of 73° . The value of 95° was taken as maximum upper, marginal, normal, possible value of the angle 2α in the group of healthy hips for standardized AP radiographic images of the hips. Limits for the angle 2α on DUNN 90 radiographic images of the hips were determined in the same way, and amounted to $75.3^\circ \pm 13.8^\circ$ (two standard deviations) with the minimum possible value of this angle of 61.5° , a maximum value up to 89.1° , so we have taken 90 degrees as the upper limit, normal value of angle 2α , for the lateral DUNN 90 hip radiographic images of the control group of subjects.

These limit values of the angle 2α were used to form a contingency table 2×2 and to determine the validity parameters of a diagnostic test measuring angle 2α . A high ability of the resulting test to predict the disease in the group of patients (sensitivity test) was obtained 97.8% for AP and 97.4% for DUNN 90 radiographic images of the hips, as well as high capacity of the test to diagnose healthy persons in the control group of subjects (specificity test), 98.6% for the AP and 87.4% for DUNN 90 hip radiographs. The ability of the test to predict the disease was 98.6%, for AP radiographs of the hips and 96.5% for DUNN 90 radiographs of the hips, and the test was false positive in 1.3% for AP and 3.6% for DUNN 90 radiographs of the hips, and a false negative for AP 2.12% and 2.63% for DUNN 90 radiographic images of hips.

Intraobserver agreement of the received values showed no statistically significant differences in the measurement of the angle 2α in the control group and the group of patients,

within the same examiner, between the first and second measurements, with a delay of three weeks between the measurements (for the first examiner $p = 0.2$, for other examiners $p = 0.14$). Interobserver measurements showed no significant differences in the values obtained in the measurement of the angle 2α between the examiners ($p = 0.18$ for the first measurement and $p = 0.33$ for the second measurement).

Discussion

A critical point beyond which the rest of the femoral head in the patients with cam FAI form cannot slip without resistance in the acetabulum during movements or flexion, adduction and internal rotation, and in doing this in which, the process of mechanical damage of the labrum and cartilage of acetabulum began, is a marked point A in the enclosed radiographic images of the angle 2α measurements. In the patients cam type, there is osteochondral prominence at the junction of head and the neck of the femur as a consequence of morphological changes such as: wide neck, formation of osteophytes or posterior dislocation of the femoral head, which are the primary reasons for the angle 2α to take on pathological values. On the other hand, some other FAI reasons such as acetabulum retroversion, *coxa profunda*, *protrusio acetabuli*, osteophytes of the acetabulum, will not influence the value of the angle 2α , but can explain the existence of clinical signs of FAI such as groin pain, positive impingement test and the reduction of internal rotation of the hip in normal limits of the angle 2α which is characteristic of Pincer FAI form.

Stulberg et al.⁹ introduced the term "pistol-grip deformity" to describe the radiographic image abnormalities in the junction of the femoral head and neck in the standardized AP radiographic hip images. Although they found that the predominant deformity is present in young active men and in many patients with a so-called "idiopathic" arthrosis of the hip, they did not try to elucidate the pathological mechanism underlying this deformity. There were anatomical differences in the femoral neck diameter in the frontal and horizontal planes²³.

Structural abnormalities at the junction of the head and neck of the femur in mature skeletal individuals are associated with arthrosis of the hip^{1, 2, 5, 9, 11, 24, 25}, therefore, further exploration of the disorder etiology is imperative to determine the occurrence of abnormalities, the time of its origin, method of well-timed diagnosis, but not just to describe but also to quantify.

Nötzli et al.¹³ described the angle α , and the index of offset as an excellent method for measuring abnormal femoral head and neck junction in radial MRI hip cuts, and obtained the average value of angle α $42.2^\circ \pm 2.2^\circ$ (range $33^\circ - 48^\circ$) which is almost identical to the value obtained in this study in the AP radiographic images of the hips in the control group measuring of the angle α . If the mean value of the angle α in the paper of Nötzli et al.¹³ is multiplied by 2 the value of Nötzli is received angle α two times multiply, which is $84.4^\circ \pm 4.4^\circ$. On the other hand, in our material, the mean 2α angle value was $84.3^\circ \pm 5.5^\circ$ (range 70°

to 98°). After Nötzli et al.¹³ paper was published, many authors began to use this method of measuring osteochondral prominence at the junction of femoral head and neck, not only on NMR and CT images of the hips, but on the AP radiographic hip and lateral images of the hips^{22, 26–29}. The measuring the angle α in these papers is not standardized, and thus the lack of precise determination of the femoral neck exists. All authors are setting up the axis through the center of rotation of femoral head and the midpoint of the femoral neck at its narrowest part. Unfortunately, this way of measuring the femoral neck axis is not accurate when it comes, at least, in a number of patients with cam FAI form, backward and/or downward sliding of the femoral head epiphysis, over the period of adolescence, which is one of the reasons for the femoral head center to relocate outside of the axis of the femoral neck and which also happens in patients with poorly healed femoral neck fractures^{12, 23, 29, 30}. Murray⁶ has determined in AP radiographic images the axis of the femoral neck using the midpoint between the top of the greater and lesser trochanter, on the one hand, and the midpoint of the narrowest part of the femoral neck, on the other, and then he determined the femoral head “ratio” to show that the femoral neck axis does not go always through the center of rotation of femoral head in a number of patients with already formed hip arthrosis^{6, 10}. Using skeletal preparations Goodman et al.¹² showed epiphysiolysis, the deformity of femoral head and neck junction to be predominantly anteriorly positioned and 3-dimensional, and as the femoral head slides back and forth, than the center of rotation of femoral head is positioned further from the femoral neck axis. Therefore, they recommend the use of lateral radiographic image to describe the hip deformity in the axial plain in front of the femoral head and neck junction which indicates “anterior” edge mechanism known in the literature as FAI¹².

Measurements carried out and presented in this paper were aimed to propose a modified method of measuring the value of osteochondral prominence at the junction of the head to the neck of the femur, which is not a prerequisite for determining the femoral neck axis and the possible consequent inaccuracy. The results presented in this paper show a significant difference in the values of the angle 2α on AP and DUNN 90 lateral hip radiographic images within the control group of subjects which is a consequence of anatomical differences in the thickness of the femoral neck, and not a consequence of structural abnormalities²³. Also, we can concluded that there is a significant difference in the values of angle 2α between the cam group of patients with FAI hip morphology and groups of asymptomatic individuals in AP and DUNN 90 radiographic images of the hips, as a consequence of structural and morphological osteochondral prominence at the junction of femoral head and neck as the only pathoanatomical sub-

strate that was detected in this region. High degree correlation of the presented method, with the already accepted method of determining angle α , indicates the applicability of the presented method in clinical practice.

In the absence of the gold standard, and analysing the value of angle 2α in the control group of patients measured in AP and DUNN 90 radiographic hip images, we obtained the top, normal value of this angle for AP hips radiographs to be 95°, and for DUNN 90 hips images was 90° and that each measured value of the angle 2α over proposed can be considered as pathological. This means that in the case of symptomatic patients with clinical signs of groin pain and positive impingement test, the values over the specified for the angle 2α are considered as abnormal with high degree of sensitivity for the cam FAI form. If, however, there is an asymptomatic hip, in which, as noted incidental radiographic finding of the existence of values above the recommended angle 2α , then the probability that a person will develop clinical form of FAI is 98.6% for AP, and 96.5% for the DUNN 90 radiographic images of the hips, with 1.3% probability for AP, and 3.6% for DUNN 90 radiographs of the hips, that the measured value gave a false positive result.

If a significant number of authors suggest the abnormality of the junction of femoral head and neck as a factor in the development of hip arthrosis, it is necessary to make efforts toward earlier detection and recognition of deformity, as to its earlier treatment and, if possible, which is most importantly, to its prevention^{1, 4, 10, 11, 25, 31–34}. Unfortunately, so far, a generally accepted method for identification the risk group of hips has not been developed, and there are not yet defined radiographic criteria (lack of “gold standards”) of the limit values for osteochondral prominence at the junction of the head and neck of the femur. The method of determining the angle 2α ³⁵ numerically quantifies the relationship between the lateral and anterior femoral head and neck using it for AP and DUNN 90 radiographs of the hips, and the technique of measuring angle 2α is simple, which is confirmed by a high degree of intra- and interobserver agreement requiring no determination of the femoral neck axis as it is the case for the measurement of the angle α .

Conclusion

In this paper we proposed a relatively simple method and the limit values for measuring osteochondral prominence at the junction of the head and neck of the femur, which can be defined in the radiographic images and be used in everyday clinical practice.

This method has a high ability to predict disease development in an asymptomatic risk group of patients and a high sensitivity in the diagnosis of the disease in the group of patients.

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