

Ultrasound is as reliable as plain radiographs in the diagnosis of cam-type femoroacetabular impingement

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Abstract

Introduction In the diagnosis of femoroacetabular impingement (FAI), plain radiographs are accepted as the initial imaging method. However, there is no consensus regarding the optimal lateral view, and radiographs can underestimate the asphericity of the head–neck junction. Our research question was if ultrasound has at least the same reliability as X-ray and can be used as an alternative or additional method in the initial imaging of FAI.

Materials and methods Forty patients with a median age of 39 years were consecutively included after diagnosis of cam-type FAI on magnetic resonance imaging (MRI). All patients underwent radiography involving a plain antero-posterior-view, frog-leg lateral view, and ultrasound of the hip joint in the ventral longitudinal section at 20° internal rotation. Parameters measured by MRI, radiographs, and ultrasound were the alpha angle, anterior offset, offset ratio, and anterior femoral distance.

Results No significant difference between the alpha angle on MRI (64.8°), the frog-leg view (66.3°), or ultrasound (65.6°) could be detected. Comparable correlation was found between the alpha angle on MRI and the frog-leg lateral view ($r = 0.73$; $p < 0.0001$) and between the alpha angle on MRI and sonograms ($r = 0.77$; $p < 0.0001$). The intra-class correlation coefficient for measurements using ultrasound was 0.81–0.98, and using radiographs was

0.83–0.99, with the exception of measurements involving the anterior offset on the frog-leg lateral view (0.61 and 0.64).

Conclusions Ultrasound is as reliable as plain radiographs in the diagnosis of cam-type FAI and can serve as an alternative or additional method in initial imaging.

Keywords Ultrasound · Hip · Alpha angle · MRI · Frog leg · Femoroacetabular impingement

Introduction

Early diagnosis of a femoroacetabular impingement (FAI) prior to cartilage damage is of major importance, because FAI is postulated to play a major role in the development of early osteoarthritis of the hip [1–3]. Insufficient anterior head–neck offset leads first to labral tears and then to acetabular hyaline cartilage damage in the case of cam-type FAI. In the initial imaging undertaken to detect abnormalities at the head–neck junction, plain radiographs in an anteroposterior (ap) and lateral view are the generally accepted method. Previous studies have shown a predominance of the Dunn (45° and 90°) and frog lateral view as compared with the cross-table view [4–8]. However, there is no clear consensus regarding the best lateral view on plain radiographs in literature. Prior studies have reported an intra- and inter-class correlation ranging from 0.83 to 0.98 for alpha angle measurement on the Dunn and frog-lateral view [4, 5, 7, 9, 10]. Analyses of reliability regarding other parameters measured on plain radiographs are rare and a control to magnetic resonance imaging (MRI) measurement is missing. In the literature, correlations between alpha angle on plain radiographs and on MRI or computed tomography (CT) of ≤ 0.77 were found [6, 8].

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However, three studies have demonstrated the limits of reliability of FAI diagnosis using X-rays [10–12]. In addition, knowledge of the correct technique to produce high-quality radiographs is essential [13, 14]. In cases involving a normal head–neck junction on plain radiographs, but with symptomatic groin pain, further examination using MRI or CT is still demanded. The question arises as to why plain radiographs are accepted as the initial imaging modality for cam-type FAI despite the published restrictions. There is no alternative imaging modality that is as readily available as X-rays. Although MRI gives the most detailed information, the time required for examination and the costs involved are high; construction and analysis of the tilted scans are restricted to radiologists and surgeons who specialize in the field of hip joint MRI. In our study group, we take efforts to find out if ultrasound might help with the issue of groin pain. We already reported a strong correlation between MRI and ultrasound measurements regarding cam-type FAI [15]. The anterolateral region of the femoral head–neck junction can be assessed with ultrasound in the ventral longitudinal section during 20° internal rotation of the hip joint [15]. Relative to radiographs, ultrasound is a quick, inexpensive, and widely available imaging modality without the requirement for radiation exposure. With this study, we now want to bring light to a new aspect concerning the reliability of ultrasound in the diagnoses of cam-type FAI compared to the reliability of radiographs in those patients. The question is if ultrasound fulfills at least the same characteristics as X-ray and can consequently serve as an alternative or additional method in the initial imaging of patients with groin pain.

Materials and methods

From June 2010 to January 2012, a consecutive series of 40 patients (15 female and 25 male) with a median age of 39 years were included in a prospective study after presenting with indications for hip arthroscopy. Approval was granted from our local ethics committee. Inclusion criteria were as follows: (1) the existence of a preoperative MRI with axial oblique sequences and the diagnosis of a cam-type FAI; (2) preoperative radiographs with a plain ap-view in neutral rotation of the femur and a plain frog-leg lateral view in 45° hip flexion and 45° abduction [16]; and (3) a preoperative ultrasound of the hip joint in the ventral longitudinal section at 20° internal rotation. Exclusion criteria were osteoarthritis or pincer impingement.

Only MRIs carried out at our institution were included to ensure a consistent MRI protocol. The use of a contrast material was not necessary, because we focused on a bony structure, which could be visualized irrespective of the

presence of contrast medium. The examinations were carried out using a 1.5-T scanner (Symphony Quantum; Siemens, Erlangen, Germany) with a flexible surface coil. The protocol included a three-dimensional isotropic, T1-weighted spoiled gradient echo (MPRAGE/Turbo-FLASH) sequence with water excitation (25-cm field of view; 1-mm slice thickness; 256 × 256 matrix; TR/TE/flip angle = 1970 ms/7 ms/158°; 1 average). Multi-planar reformation was carried out to generate 2-mm-thick oblique axial plane images, parallel to the long axis of the femoral neck.

Standardized sonographic examination [15] was conducted in the ventral longitudinal section at 20° internal rotation. In this standard section, the ultrasonic transducer was positioned along the course of the long axis of the femoral neck. The acetabular edge, capsule, femoral head, and femoral neck should be visible as references. The following muscles were also present in this section: the sartorius muscle, rectus femoris muscle, tensor fasciae latae muscle, iliopsoas muscle, and gluteus medius muscle (Fig. 1). Examinations were performed by one experienced orthopedic surgeon who specialized in hip joint diseases using the same US device (Nemio XG; Toshiba Medical Systems GmbH, Neuss, Germany) with a 5-MHz linear transducer.

Imaging measurements were undertaken as follows using a JiveX DICOM Viewer (Version 4.5; ©VISUS Technology Transfer GmbH, Bochum, Germany): on the angled axial magnetic resonance image through the mid-femoral neck alpha angle using the method of Nötzli et al.

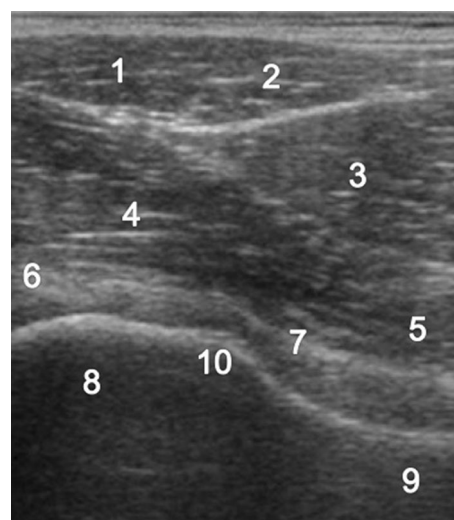


Fig. 1 The ventral longitudinal section at 20° internal rotation with the ultrasonic transducer positioned along the course of the long axis of the femoral neck (1 sartorius muscle, 2 rectus femoris muscle, 3 tensor fasciae latae muscle, 4 iliopsoas muscle, 5 gluteus medius muscle, 6 acetabular edge and labrum, 7 capsule, 8 femoral head, 9 femoral neck, 10 epiphyseal overgrowth at the head–neck junction)

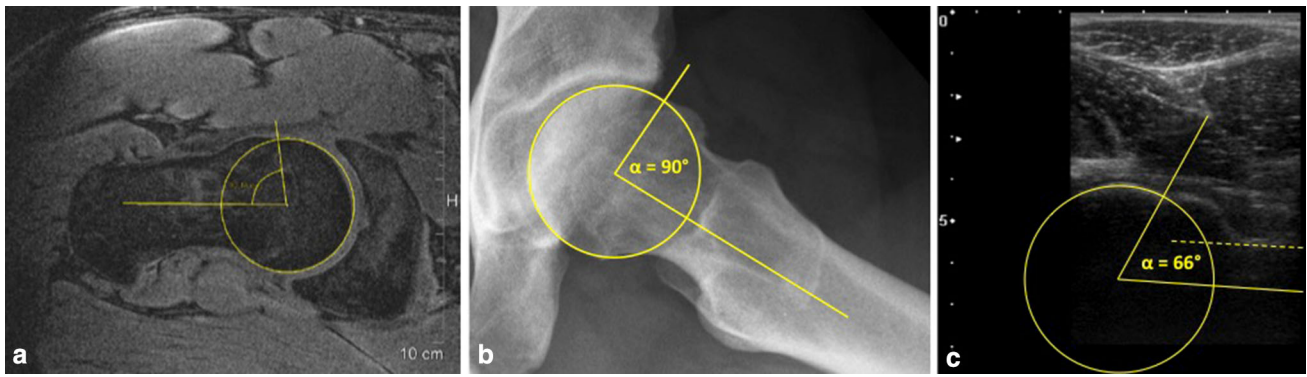


Fig. 2 Alpha angle measured on oblique axial MRI (a) and a frog-leg lateral radiograph (b) as described by Nötzli et al. [17] and the alpha angle measured using ultrasound (c) in the ventral longitudinal section at 20° internal rotation as adjusted by Lerch et al. [15]

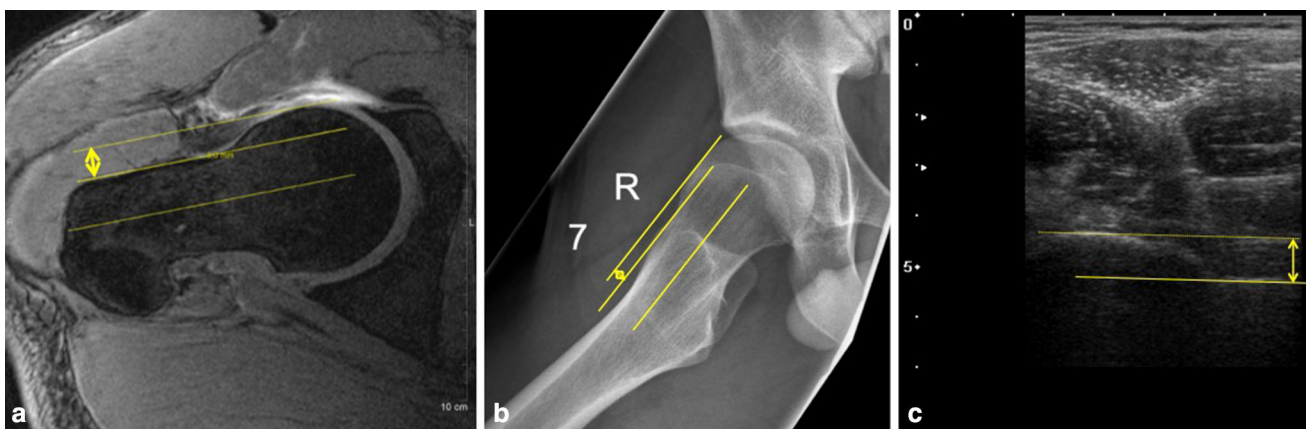


Fig. 3 Anterior head–neck offset measured on oblique axial MRI (a) and a frog-leg lateral radiograph (b) as described by Eijer et al. [18] and anterior head–neck offset measured on ultrasound (c) in the ventral longitudinal section at 20° internal rotation as adjusted by Lerch et al. [15]

[17] (Fig. 2a); the anterior head–neck offset using the method of Eijer et al. [18] (Fig. 3a); and the anterior femoral distance (AFD) described by Lohan et al. [19] and the diameter of the head were measured. The offset ratio, defined as the quotient of the head–neck offset to the head diameter, was assessed. On radiographs in both views, measurements were conducted in the same manner (Figs. 2b, 3b). On sonograms, the same adjusted parameters for femoroacetabular cam impingement were measured as described by our study group [15]: three points on the visible sector of the femoral head were selected to construct a circle. The diameter of this circle corresponded to the diameter of the femoral head. The first arm of the alpha angle was parallel to the visible surface of the femoral neck through the center of this circle. The second arm of the angle was drawn from the center of the circle to the point where the head extended beyond the margin of this circle (Fig. 2c). For the anterior head–neck offset, a tangent to the visible surface of the femoral neck was drawn. Another line was drawn parallel to the first one along the anterior outer part of the head. The distance between the two lines was

determined as the offset (Fig. 3c). For the AFD, we measured the distance between the same first and second lines, which were drawn parallel to the first line along the greatest perpendicular depth of epiphyseal overgrowth at the anterior femoral head–neck junction.

All images (MRI, radiographs, and sonographs) were anonymized and analyzed independently at different time points by an experienced orthopedic surgeon who specialized in hip joint diseases. Measurements on radiographs and ultrasound were repeated by the same orthopedic surgeon and by a second surgeon with 8 years of experience in hip joint imaging to determine the intra- and inter-observer reliability.

Statistics were performed using SPSS® software (Version 17.0: SPSS Inc., Chicago, IL, USA). The *T* test was used to evaluate differences between parameters on MRI, radiographs, and ultrasound. To determine the degree of agreement between measurements obtained from ultrasound and MRI as compared with parameters from radiographs and MRI, Pearson correlation coefficients were used. Bland and Altman plots were further conducted to

provide a visual assessment of parameter agreement between ultrasound and MRI sections on the one hand and radiographs and MRI on the other hand. These plots included horizontal lines depicting the level of bias and the limits of agreement [20]. To assess the intra- and inter-observer reliability, the intra-class correlation coefficient was used.

Results

No significant difference was found between the alpha angle on MRI (64.8°), on the ap-view (69.5°), on the frog-leg lateral view (66.3°), and on ultrasound at 20° internal rotation (65.6°). However, the alpha angle on the ap-view ($r = 0.39$; $p = 0.025$) showed a poorer significant correlation with the alpha angle on MRI than the alpha angle on the frog-leg lateral view ($r = 0.73$; $p < 0.0001$). This correlation was comparable to those between the alpha angle on sonograms at 20° internal rotation and on MRIs ($r = 0.77$; $p < 0.0001$). The Bland–Altman plots showed a high level of agreement between alpha angle values on MRI and ultrasound and, accordingly, between alpha angle values on MRI and on the frog-leg lateral view (Fig. 4). The average values of the alpha angle on MRI and ultrasound/frog-leg lateral view (x -axis) were plotted against

the differences between them (y -axis). The lines in the middle represent the mean values of the differences, and the upper and lower lines represent the mean values \pm two standard deviations of the differences. For MRI and ultrasound, 95 % of the marked values lay within these lines as compared with 92.5 % for MRI and the frog-leg lateral view.

There were no correlations between the AFD and the anterior offset on the ap-view, on the frog-leg lateral view or on MRI. In addition, the average values differed significantly, with the exception of the AFD on the ap-view and MRI (5.4 and 4.8 mm, respectively). In contrast, there was a significant correlation between the AFD on ultrasound at 20° internal rotation and on MRI ($r = 0.49$; $p < 0.002$). There were significant correlations regarding the offset ratio between MRI and the frog-leg lateral view ($r = 0.56$; $p = 0.012$) as well as between MRIs and sonographs at 20° internal rotation ($r = 0.43$; $p = 0.008$), but no correlation was found between MRI and the ap-view.

Measurements of the head diameter differed significantly between the ap-view (57.6 mm) and the frog-leg lateral view using X-ray radiographs (55.9 mm) and MRI (45.9 mm), whereas no significant difference between the head diameter on MRI (45.9 mm) and ultrasound at 20° internal rotation (45.1 mm) was found.

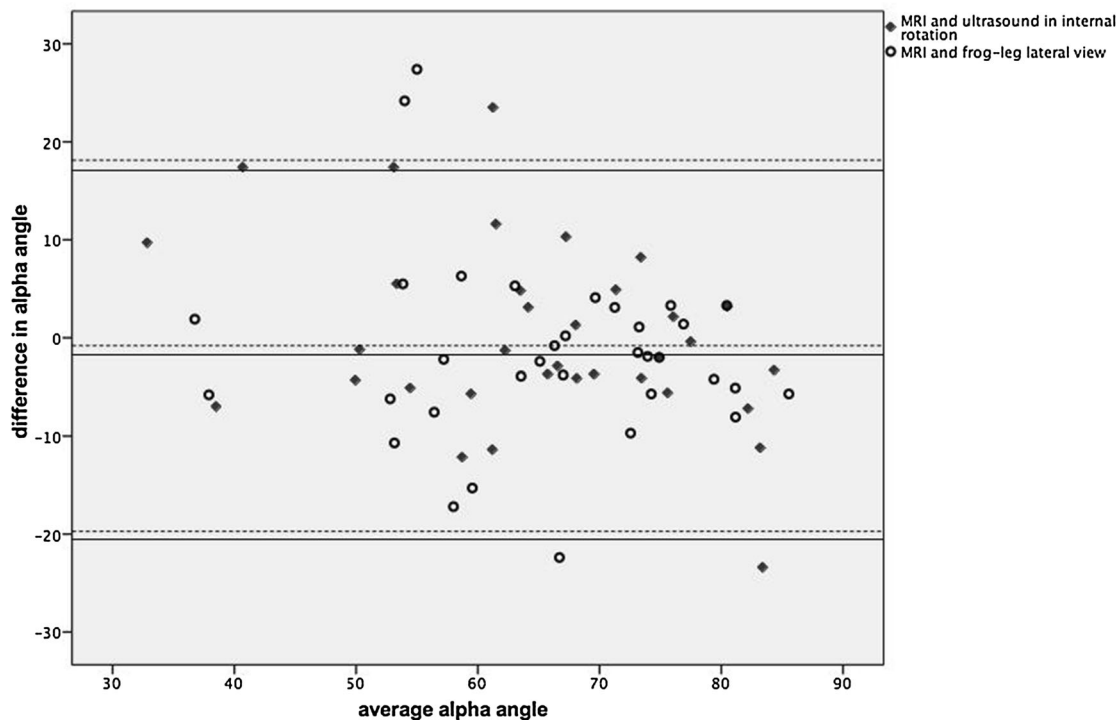


Fig. 4 Bland–Altman plots of agreement between the alpha angle measured on MRI and ultrasound at 20° internal rotation (rhombus and solid lines) and accordingly on MRI and the frog-leg lateral view

(circle and dotted lines). On the x -axis, the mean angle of both values (MRI and ultrasound/frog-leg lateral view) is plotted against the difference between them on the y -axis

Table 1 The intra- and inter-observer intra-class correlation coefficients (ICCs) for measurements of alpha angle, anterior femoral distance (AFD), anterior offset, offset ratio, and head diameter on plain radiographs and ultrasound

	Alpha angle	AFD	Anterior offset	Offset ratio	Head diameter
Intra-observer ICC					
Ap view	0.99	0.97	0.91	0.94	0.99
Frog-leg	0.91	0.84	0.61	0.85	0.99
Ultrasound	0.98	0.95	0.95	0.94	0.81
Inter-observer ICC					
Ap view	0.94	0.97	0.88	0.92	0.99
Frog-leg	0.91	0.83	0.64	0.83	0.99
Ultrasound	0.95	0.88	0.87	0.87	0.86

The intra-class reliability for measurements using ultrasound ranged from 0.81 to 0.98. The inter-observer reliability for ultrasound measurements between the two surgeons ranged from 0.86 to 0.95. Similar intra-rater (0.84–0.99) and inter-rater (0.83–0.99) correlations were found for measurements on radiographs, with the exception of measurements involving the anterior offset on the frog-leg lateral view. An intra-class reliability of 0.61 and an inter-observer reliability of 0.64 were found (Table 1).

Discussion

Over the last two decades, the problem of FAI has become increasingly recognized by orthopedic surgeons and radiologists. Because of enormous scientific efforts, there is now a better understanding of FAI and its biomechanical complexity. However, there are still young patients presenting with a long history of hip pain. The reasons for this treatment deficit are that knowledge concerning the pathology of FAI has been restricted to specialized surgeons and is not generally known, and that the generally accepted, initial imaging examination using plain radiographs can underestimate the asphericity of the head–neck junction [10–12]. In the literature, there is no clear consensus regarding the best lateral view on plain radiographs. Some authors favor the Dunn view in 45° of hip flexion [6–8], others favor the Dunn view in 90° of hip flexion [4], and others again prefer the frog lateral view [5, 8, 21]. The only agreement is that the frog lateral or Dunn view is more reliable for alpha angle measurement than the cross-table view and the ap-view when compared with each other. However, one study has shown that the frog lateral view is not reliable for measuring the alpha angle [10], and another study has shown a kappa value of only 0.46–0.56 for the reproducibility of the diagnosis of FAI [11]. In summary, there is no reliable initial imaging modality to detect or exclude a cam-type FAI at present. However, early diagnosis of a cam-type FAI at the commencement of pain symptoms is of major importance in preventing secondary derangements [1, 22]. Buck et al. [23] first

postulated that a cam-type FAI can be evaluated by ultrasound with a curved array transducer based on qualitative criteria. Our study group was able to show a high correlation between MRI and ultrasound measurements for the diagnosis of cam-FAI using a linear transducer [15]. Our research question thus was if ultrasound as a quick, inexpensive, and immediately available method has at least the same reliability as X-ray. If so, ultrasound could help making a timely diagnosis of cam-type FAI.

In this study, some limitations need to be noted. The frog-leg view was used exclusively as a lateral radiograph, and no other lateral views were compared with each other concerning correlations with MRI measurements or reliability. However, as described above, there is agreement in the literature that the frog-leg and Dunn views are the best lateral radiographs for FAI diagnosis [4–8, 21]. In an experimental study, Cavaignac et al. postulated that the frog-leg lateral view was a better screening method for femoral head abnormalities relative to the Dunn 45° and Dunn 90° views [5]. Furthermore, we used oblique axial MRI images, although it has been proposed that higher alpha angle values can be measured on radial MRI images than on oblique axial images [24]. Our MRI protocol was developed in accordance with the original publication of Nötzli et al. [17]. However, no relevant underestimated or missed contour abnormality of the head–neck junction was assumed in the present study, because one of the inclusion criteria was the diagnosis of a cam-type FAI on preoperative axial oblique MRI.

We found a high level of agreement between alpha angle measurements on MRI, plain radiographs, and ultrasound. The comparable and appropriate high correlations for alpha angle measurements between MRI and the frog-leg lateral view, and between MRI and ultrasound, are also comparable to those reported in the literature. Studies where the accuracy between the alpha angle on plain radiographs and on MRI or CT has been evaluated have found correlations of ≤ 0.77 [6, 8]. In addition, the intra- and inter-class correlations we found in this study are comparable to those reported in the literature with values of 0.83–0.98 for the alpha angle measurement on the Dunn

and frog-lateral views [4, 5, 7, 9, 10]. On ultrasound, Buck et al. [23] showed a lower intraclass correlation coefficient of only 0.51 and 0.52 for alpha angle measurements. This could be due to the curved array transducer used in their study. In contrast to the linear transducer used in the study at hand, the curved one gives a distorted image of the osseous contour. As a consequence, the femoral neck axis serving as a reference for alpha angle measurement cannot be utilized. In addition, a possible tilting due to the curved shape of the transducer makes reproducibility of ultrasound images difficult. However, in the literature, only the alpha angle has been well reviewed regarding reliability. There has been only one study that has measured the anterior offset on a standard lateral X-ray view (frog lateral, cross-table) [21], but the measurement control on MRI is missing. In addition, other parameters regarding FAI measurement or the head diameter are missing. Espié et al. also measured the anterior offset, but in a modified manner and on a new and specific radiographic lateral view [25]. The considerably poorer reliability regarding the measurement of the anterior offset on the frog-leg lateral view was noticeable in our study. Comparably low intra- and inter-class correlations were found in the above study by Clohisy et al. with an intra-observer agreement level of 0.74 and an inter-observer agreement level of 0.52 on the frog lateral view [21]. In a subsequent study, Clohisy et al. [11] described the head–neck junction as symmetrical, with a decreased offset or with a prominence on the ap-, frog lateral, and cross-table views. Their detected kappa value was also low and ranged from only 0.19 to 0.55. The anterior offset that we measured was first presented by Eijer et al. [18] and was described regarding the cross-table lateral radiographs of 12 patients with symptomatic hips and 10 patients with asymptomatic hips. In their study, an analysis of reliability is missing. In contrast, the AFD first described by Lohan et al. [19] on axial oblique MRI slices showed a much better reliability regarding measurement on X-ray radiographs. However, no correlations for both parameters (anterior offset and AFD) between plain radiographs and MRI were found. Correlations for the offset ratio between MRI and the frog-leg lateral view should be interpreted as purely statistical results without clinical relevance, because of the significant differences in head diameter values between measurements on plain radiographs and MRI. In comparison to these findings, significant correlations of the AFD and offset ratio between MRI and sonograph at 20° internal rotation could be found. The alpha angle is a well-investigated and accepted parameter for the diagnosis of cam-type FAI on plain radiographs [4–10, 12, 19]. There has been a lack of detailed investigations concerning other parameters for FAI measurements on X-ray radiographs. The results that have been presented lead to the assumption that other

parameters, such as anterior offset, AFD, and offset ratio, are not reliable in the diagnosis of cam-type FAI on plain radiographs. None of the analyses conducted regarding correlation or reliability have shown poorer results for ultrasound at 20° internal rotation relative to plain radiographs. Rather, there are indications that other parameters concerning FAI measurements, such as AFD and the offset ratio, can be dependable using sonographs.

We conclude that ultrasound as a quick, inexpensive, and widespread imaging modality, without a requirement for radiation exposure, is as reliable as plain radiographs in the diagnosis of cam-type FAI. Ultrasound of the hip joint can serve as an alternative or additional method in the initial imaging of groin pain with the goal of increasing the probability of early diagnosis of cam-type FAI before secondary derangements occur.

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