Horng JC, Nguyen RT, Burnham MM, Tanji CM, Rimm JB, Crawford SN. Correlations of Alpha Angle on Preoperative Imaging with Intraoperative Fluoroscopy for the Evaluation of Cam Deformity: A Cross-Sectional Study. *Hawaii J Health Soc Welf*. 2026;85(6):142-148. doi:10.62547/IJQG3259

Correlations of Alpha Angle on Preoperative Imaging with Intraoperative Fluoroscopy for the Evaluation of Cam Deformity: A Cross-Sectional Study

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Keywords: femoroacetabular impingement, CAM deformity, imaging, alpha angle

https://doi.org/10.62547/IJQG3259

Abstract

Reliable preoperative imaging of femoroacetabular impingement is important for effective diagnosis and treatment. While numerous imaging techniques exist, their relative accuracy remains unclear. The purpose of this study was to evaluate the accuracy of preoperative standard hip radiographs and magnetic resonance imaging (MRI) axial and radial views compared to the gold standard of intraoperative fluoroscopy for cam-type femoroacetabular impingement. Data were collected from 93 patients who underwent femoroplasty for cam deformity between 2015 and 2020 by a single orthopedic surgeon. One-way analysis of variance with post-hoc pair-wise evaluation, Pearson correlation coefficients, and Bland-Altman plots were used to evaluate differences and agreement between the imaging modalities. The fluoroscopic alpha angle (62.3°±7°) was significantly different than the radiographic (58.5°±7.0°; *P*=.004) and MRI axial angles (52.0°±8.2°; *P*<.001) but was similar to the MRI radial angle (60.7°±7.9°; *P*=.9). MRI radial angles had the highest correlation with fluoroscopy (r=.876, *P*<.001). The analysis revealed a sensitivity of only 27% for radiographic evaluation and a specificity of 41% with MRI axial evaluation. However, MRI radial evaluation displayed a sensitivity of 87% and specificity of 91% for diagnosis of cam deformity in the study population. These findings suggest the alpha angle derived from radial MRI correlated most strongly with intraoperative fluoroscopy. Radial MRI should continue to be the gold standard for preoperative templating and diagnosis of femoroacetabular impingement in symptomatic patients without obvious deformity on radiographs.

Abbreviations

AP = anterior-posterior
BMI = body mass index
CT = computed tomography
FAI = femoroacetabular impingement
LCEA = lateral center-edge angle
MR = magnetic resonance
MRI = magnetic resonance imaging

Introduction

Femoroacetabular impingement (FAI) is a condition affecting the femoral head and acetabular rim due to irregular bone growth at the hip joint.[1] Of the 2 types of FAI, cam-type FAI is characterized by excessive bone growth at the anterolateral head-neck junction with subsequent loss of sphericity at the femoral head.[2] The abnormal contact between the nonspherical femoral head and the acetabular rim can lead to significant discomfort and limited range of motion.[3] If symptoms persist, a femoroplasty is the definitive treatment to correct the cam deformity.

Prior to the surgery, standard radiographs (anteroposterior, Dunn and/or lateral views), magnetic resonance imaging (MRI) axial, and magnetic resonance (MR) radial sequence imaging are common modalities used to characterize the cam deformity.[2] The alpha angle is typically used to quantify the femoral head-neck concavity and acts as a parameter in determining the need for surgical intervention.[2,4,5] A cam deformity is defined as an alpha angle greater than 55°.[5,6]

The asphericity of the femoral head-neck junction is frequently underestimated by conventional preoperative radiographs, computed tomography (CT), and non-radial sequenced MRI in the author's experience. Consequently, cam deformities are often insufficiently resected and lead to failure of treatment.[2,7] At the authors' institution, musculoskeletal radiologists will typically measure the alpha angle from the axial images on plain MR. While not included in the standard imaging sequence for workup of FAI, MR radial sequence imaging techniques along with static and/or dynamic fluoroscopy have been used to reliably assess cam deformities preoperatively and intraoperatively, respectively.[7,8] However, there is a lack of literature comparing the alpha angle accuracy among the various imaging techniques, so MRI radial sequences have not been included as part of the standard preoperative imaging prior to a femoroplasty.[9] Thus, the optimal preoperative imaging sequence to accurately depict a cam deformity remains unclear. An accurate 3-dimensional (3D) awareness and depiction of the concavity of the femoral head-neck junction is crucial for surgeons to evaluate the cam deformity and ensure adequate resection.[2,6] This is critical, as failure to adequately resect the cam lesion is the primary cause of clinical failure after hip arthroscopy.[10] Furthermore, the alpha angle is often used by medical insurance companies to de-

termine the medical necessity of a femoroplasty (Current Procedural Terminology [CPT] code 29914). However, the alpha angle as a sole measurement can be misleading as to the true nature of the deformity, especially when assessed on non-radial sequences or a non-Dunn type lateral radiograph. The gold standard to determine both the presence and accurate resection of the cam deformity is intraoperative fluoroscopy.[2,11] Therefore, the primary objective of this study is to compare the accuracy of standard radiographs, MR axial imaging, and MR radial sequences to intraoperative fluoroscopy for cam-type FAI.

Methods

Institutional review board exemption was obtained for the study protocol. This cross-sectional study included data collected from a consecutive cohort of patients who underwent arthroscopic femoroplasty between 2015 and 2020 to correct a cam deformity. All surgeries were performed by a single fellowship-trained orthopedic surgeon at a multispecialty tertiary community hospital.

Hip images, age, body mass index (BMI), and other patient demographics were obtained through manual review of patient electronic medical records. Only patients over the age of 18 at the time of surgical intervention who had received standard radiographs, MRI views, and intraoperative fluoroscopy of the hip were included in the final analysis. Individuals with preexisting osteoarthritis of the hip or combined cam-pincer impingement were also included.

Patients presenting with suspected femoroacetabular impingement (FAI) were initially assessed using preoperative imaging series including standard radiographs and MRI views. All imaging was performed by radiologic technologists at the study institution. Standard radiographs of the pelvis taken at the initial evaluation included both anterior-posterior (AP) and Dunn (near 90° of flexion and 20° of abduction with the pelvis in neutral rotation) views with the patient supine. MRI included axial and radial sequence views of the affected hip taken using a 3 Tesla (3T) MRI scanner. Immediately prior to the femoroplasty, all patients were required to undergo intraoperative fluoroscopy including standardized 6-view fluoroscopic views of the hip according to the Larson method,[2,11] considered the gold standard to accurately map the cam lesion.

A single blinded reviewer retrospectively evaluated all preoperative and intraoperative images. The alpha angle was measured using the technique described by Nötzli et al in 2002 to characterize concavity at the anterolateral head-neck junction.[12] An initial line was drawn through the center of the femoral head and neck. A circular template was placed over the femoral head, with a line drawn between the beginning of the protuberance on the femoral neck and the center of the femoral head. The alpha angle is the angle formed by the intersection of these lines. An alpha angle >55° as measured on intraoperative fluoroscopy confirmed the presence of a cam deformity. Alpha angle in standard radiographs was calculated using Dunn views only. Lateral center-edge angle (LCEA) was determined on AP radiographs using Ogata et al's modified method, with LCEA >40° indicating a pincer impingement.[13]

Alpha angle data were then compared between the preoperative imaging techniques and fluoroscopy. A one-way analysis of variance with a post-hoc pair-wise evaluation was performed to evaluate differences in measured angles. Additionally, Pearson correlation coefficients and Bland-Altman plots were used to assess the level of agreeance between preoperative and fluoroscopic findings. Sensitivity and specificity of the preoperative alpha angles were calculated using fluoroscopy and the previously described cut-offs to model the prevalence of disease. Diagnostic accuracy calculations could have been influenced by a high disease prevalence, as all selected patients received intraoperative fluoroscopy and FAI surgery. Descriptive statistics were displayed as mean ± standard deviation alongside range. All statistical analyses were performed using SPSS version 25 (IBM Corporation, Armonk, NY) with $P<.05$ considered statistically significant.

Results

Of the 197 identified patients who received femoroplasty for the treatment of cam deformity, 104 were excluded due to missing images, poor image quality, or no fluoroscopy. A total of 93 patients were included in the final analysis, with a mean age of 33.1±10 years and BMI of 26.8 kg/m^2. In all, 78 (84%) patients had an intraoperative fluoroscopic alpha angle ⩾55°. The mean LCEA was 32.6°±5.6°.

Table 1 compares the alpha angles collected using each imaging modality. The MRI radial angle (60.7°±7.9°) was the only modality similar to the fluoroscopic alpha angle (62.3°±7°, $P=.9$). Both the radiographic angle (58.5°±7.0°; $P=.004$) and MRI axial angle (52.0°±8.2°; $P<.001$) were significantly different from fluoroscopy. The Pearson correlation data between imaging modalities are presented in **Table 2** and **Figure 1**, with the MRI radial angle correlating best to fluoroscopy (r=.876, $P<.001$) followed by the radiographic (r=.400, $P<.001$) and MRI axial (r=.381, $P<.001$) angles. Correlation among radiographic and MRI axial angles was relatively poor, with a correlation coefficient below .400.

Agreement between the imaging modalities is also presented as Bland-Altman plots in **Figure 2**. Radiography (r=.551, $P<.001$) and MRI axial evaluation (r=.446, $P<.001$) had poor agreement with fluoroscopy, both displaying a positive correlation. MRI radial evaluation had the greatest agreement with no observed correlation (r=.003, $P=.97$). Furthermore, MRI radial sequence evaluation most accurately predicted the presence of a cam lesion on fluoroscopy, with a sensitivity of 87% and specificity of 91% (**Table 3**).

Discussion

The principal finding of this study is that MRI radial sequence views provided the most accurate preoperative assessment of the alpha angle in patients receiving arthroscopic femoroplasty to correct a cam deformity. MRI radial

Table 1. Demographic and Radiographic Parameters for Individuals Undergoing Femoroplasty for Cam-type Femoroacetabular Impingement from 2015-2020 (N=93).

	Mean (SD)	(Range)
Age	33.1 (10.0)	(19,59)
BMI	26.8 (4.4)	(17.6,39.1)
CEA	32.6 (5.6)	(19,50)
Radial Alpha Angle	60.7 (7.9)	(42,78)
Axial Alpha Angle	52.0 (8.2)	(36,77)
Radiograph Alpha Angle	58.5 (7.0)	(39,75)
Fluoro Alpha Angle	62.3 (7.0)	(45,76)
Radial – Radiograph[a]	2.1 (8.4)	(-18,18)
Radial – Axial[a]	8.7 (9.7)	(-11,34)
Fluoro – Radiograph[b]	3.7 (7.5)	(-13,23)
Fluoro – Radial[b]	1.6 (3.8)	(-5,11)
Fluoro – Axial[b]	10.2 (8.5)	(-7,36)

BMI = body mass index; CEA = center-edge angle; Radial = radial sequence magnetic resonance imaging; Axial = axial sequence magnetic resonance imaging; Fluoro = fluoroscopy

[a]Radial minus radiograph alpha or axial angle

[b]Fluoroscopic alpha angle minus radiograph, radial or axial angle

alpha angles were the most similar to and had the greatest correlation with intraoperative fluoroscopy. Furthermore, MRI radial sequence had the highest sensitivity and specificity in identifying a cam lesion (alpha angle >55°) prior to the operation. These findings suggest MRI radial sequences should be used in the initial characterization, management, and preoperative planning to ensure accurate assessment and resection of cam deformities. This has significant clinical implications for physicians and their patients as insurance companies rely on alpha angle measurements to approve cam resection procedures.

Radial sequence MR imaging is considered the most reliable tool to evaluate cam deformity, especially in patients with a high clinical suspicion but no obvious radiographic signs.[14-17] As a result, MRI findings have often been compared to other preoperative FAI imaging sequences including radiography and CT. However, the best imaging modality to accurately measure the alpha angle in cam lesions has not been identified. To the authors' knowledge, this is the first study comparing the alpha angle as measured on MRI radial sequence to the known alpha angle on intraoperative fluoroscopy.

Previous studies on the role of radial MRI in FAI management have highlighted its high sensitivity, precise circumferential modeling of the femoral head-neck junction, and ability to visualize surrounding soft tissue without use of ionizing radiation.[3,14-16,18] This study confirms an additional benefit of MRI radial views, which is the close approximation of intraoperative fluoroscopic alpha angles used to evaluate adequate resection of cam deformities. The excellent correlation between the 2 modalities could allow surgeons to template a resection with greater precision compared to MRI axial views or standard radiographs.

Multiple articles have explored standard radiographs as a rapid, lower-cost alternative to radial MRI. While some methods (particularly the Dunn and cross-table lateral views) demonstrate a high sensitivity and good alpha angle correlation with radial MRI, there is an associated risk of underdiagnosis.[3,7,18-21] The Dunn view in the current study severely underestimated the incidence of cam deformity, with a sensitivity of 27%. This finding is lower than previously reported values of 52-96% sensitivity of Dunn view alpha angles in studies using MRI to diagnose cam deformity.[18-20] MRI axial views were sensitive (93%) but had a 59% false positive rate, indicating they may overestimate small cam lesions. Furthermore, positive correlations observed on Bland-Altman plots for radiographs and axial MRI suggest possible skewing of alpha angles when attempting to measure especially large or small lesions. These findings suggest standard radiographs and axial MRI are not reliable for the routine diagnosis of cam deformities.

While this study did not evaluate the accuracy of CT, recent studies comparing 3D-MRI and 3D-CT for dynamic simulation of FAI have reported near-equivalent and highly accurate diagnostic outcomes.[15,17,22,23] Due to the radiation exposure introduced by CT, 3D-MRI may be the more practical option for patients who can safely receive MRI.[22,23] Based on these findings, alpha angle accuracy of 3D-CT and 3D-MRI could be a future topic of study.

Limitations

There were multiple limitations in the current study. First, due to the retrospective nature of this study, the data were collected entirely through chart review. Second, this study lacked a control group, as it only included patients selected for arthroscopic FAI surgery. This contributed to an ex-

Table 2. Pearson Correlation between Alpha Angles of Preoperative and Intraoperative Imaging Techniques in Individuals Undergoing Femoroplasty for Cam-type Femoroacetabular Impingement.

	Radiograph r (*P-value*)	Axial r (*P-value*)	Radial r (*P-value*)
Fluoroscopy	.400 (<.001)	.381 (<.001)	.876 (<.001)
Radiograph		.316 (.002)	.379 (<.001)
Axial			.288 (.005)

Radial = radial sequence magnetic resonance imaging; Axial = axial sequence magnetic resonance imaging

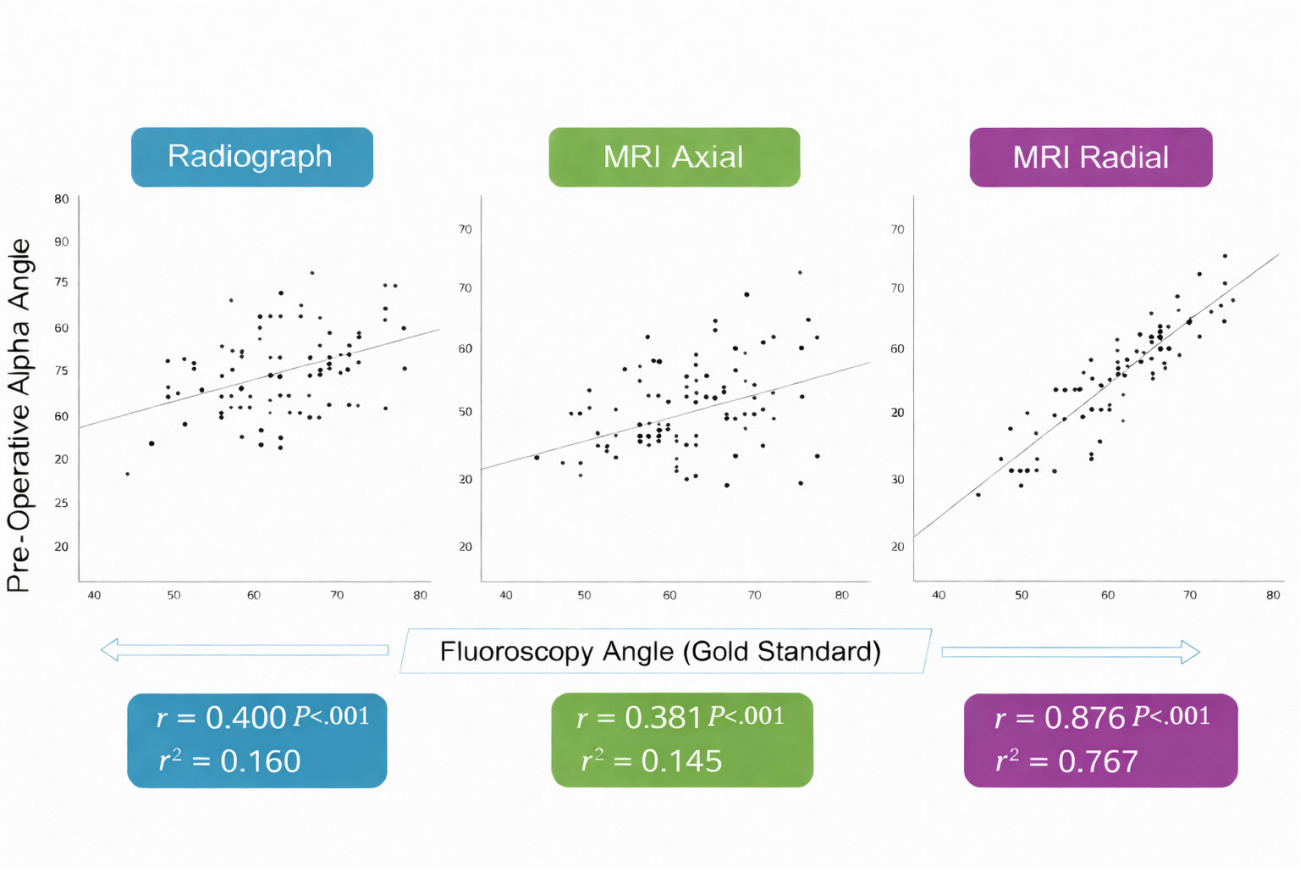

Figure 1. Alpha Angle Assessment Accuracy Comparison of Radiographic, Axial, and Radial Magnetic Resonance Imaging (MRI) to Fluoroscopy Angle

Scatterplot of alpha angles calculated using preoperative imaging modalities (y-axis) and intraoperative fluoroscopic alpha angles (x-axis). Pearson's correlation coefficient (r) for each comparison is included.

tremely high prevalence of disease, which could lead to overestimated sensitivity of the tested imaging modalities. Third, alpha angle as a diagnostic criterion for cam deformity is controversial with shifting recommendations. While a commonly reported cutoff of >55° was selected in this study, recommendations range significantly and are not perfectly diagnostic for cam lesions. Fourth, all radiographic measurements are subject to a degree of error. Fifth, unintentional variation in the positioning of patients for imaging procedures could have had a slight impact on derived measurements. Finally, all procedures were done by a single surgeon at a single institution, which may limit generalizability based on patient selection, demographics, and management protocols.

Conclusion

This study suggests preoperative MRI radial sequence provides a more accurate alpha angle measurement compared to standard radiographs and axial MRI imaging by most closely correlating to the alpha angle derived from intraoperative fluoroscopy. As a result, MRI radial sequencing may be effective in diagnosis and preoperative templating of cam-type FAI deformity.

Conflict of Interest and Disclosures

Dr. Scott N. Crawford reports serving as the founder and president of the Hawai'i Orthopedic Performance Education organization. No other authors identify any conflict of interest or financial disclosures.

Submitted: September 09, 2025 PDT. Accepted: October 05, 2025 PDT. Published: June 01, 2026 PDT.

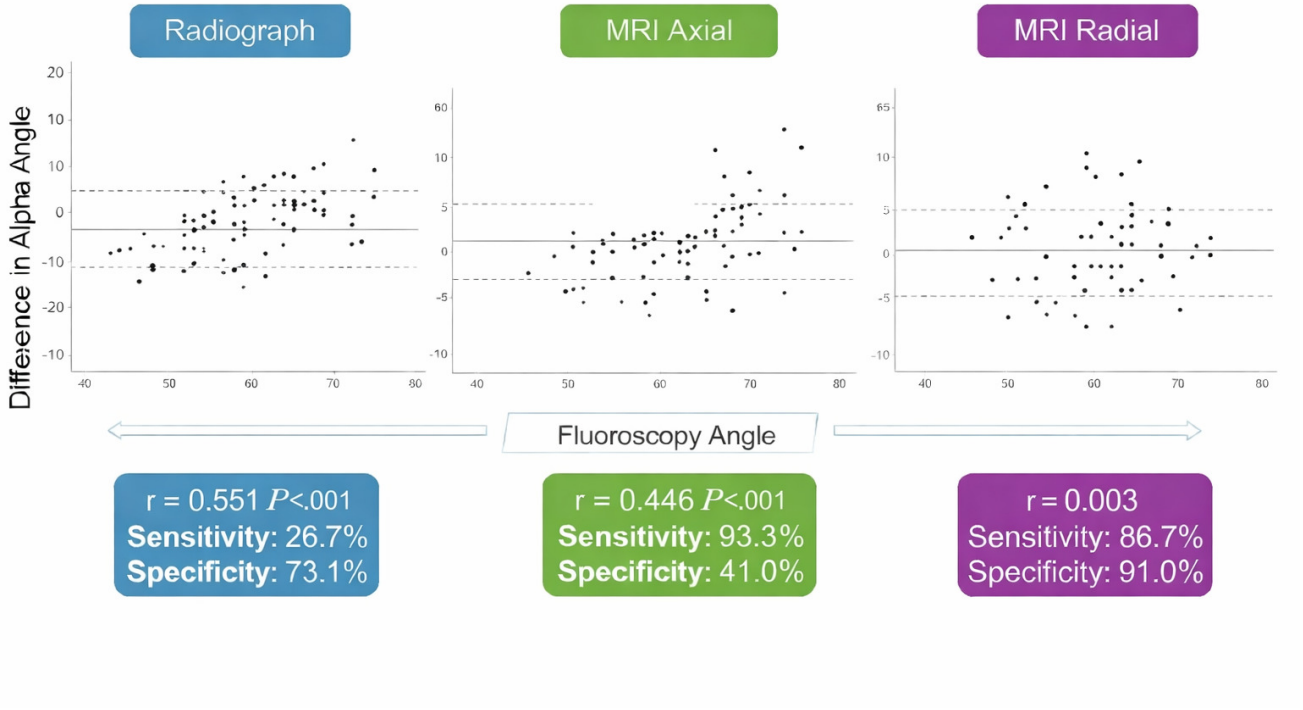

Figure 2. Diagnostic Accuracy of Alpha Angle Measurements

Bland-Altman plots and r-values comparing level of agreement between preoperative imaging modalities and intraoperative fluoroscopy. Sensitivity and specificity for cam deformity is also shown for each preoperative imaging modality. Radial sequence MRI displayed the highest level of agreement with a near-zero correlation. MRI = magnetic resonance imaging.

Table 3. Bland Altman Correlation and Accuracy of Radiographic, Axial, and Radial MRI Measurement Techniques

Bland-Altman correlation				
	Fluoroscopy r (*P-value*)		Sensitivity	Specificity
Radiograph	.551 (<.001)	Radiograph	26.7%	73.1%
Axial	.446 (<.001)	Axial	93.3%	41.0%
Radial	.003 (.974)	Radial	86.7%	91.0%

Radial = radial sequence magnetic resonance imaging; Axial = axial sequence magnetic resonance imaging

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