The Importance of Comprehensive Cam Correction

Radiographic Parameters Are Predictive of Patient-Reported Outcome Measures at 2 Years After Hip Arthroscopy

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Background: The specific influence of preoperative and postoperative radiographic measurements on patient-reported outcome measures after hip arthroscopy for femoroacetabular impingement (FAI) remains unclear.

Purpose: To investigate the relationship between radiographic measurements and 2-year outcomes after hip arthroscopy for the treatment of FAI.

Study Design: Case series; Level of evidence, 4.

Methods: A clinical registry of patients undergoing primary hip arthroscopy for FAI between January 1, 2012, and December 31, 2014, was queried. Outcome measures included the Hip Outcome Score (HOS) Activities of Daily Living (ADL), HOS Sport-Specific Subscale (SSS), modified Harris Hip Score (mHHS), and visual analog scale (VAS) for pain and satisfaction. Preoperative and postoperative radiographic measurements were recorded. Univariate analysis was conducted to identify relationships between all radiographic and demographic variables and outcome scores. A multivariate regression analysis, controlling for demographic factors, was used to identify independent associations between radiographic measurements on plain radiographs and patient-reported outcomes.

Results: The authors identified 707 patients who underwent primary hip arthroscopic management for FAI who were included for analysis. Two-year outcome surveys were completed for 78% to 84% of patients. The mean age of the patients was 33.2 ± 12.3 years, and 64.4% of the patients (n = 456) were female. The mean anteroposterior (AP) alpha angle decreased by 34.3° ($P < .0001$), false profile alpha angle by 25.2° ($P < .0001$), Dunn lateral alpha angle by 28.9° ($P < .0001$), lateral center edge angle by 2.6° ($P < .0001$), and anterior center edge angle by 3.4° ($P < .0001$). The HOS-ADL score increased from 65.7 ± 18.7 preoperatively to 85.9 ± 16.7 postoperatively ($P < .0001$), HOS-SSS increased from 43.4 ± 23.1 to 72.6 ± 27.2 ($P < .0001$), and mHHS increased from 57.7 ± 14.0 to 79.1 ± 17.2 ($P < .0001$). With multivariate analysis, independent predictors of the postoperative HOS-ADL score included the preoperative false profile alpha angle (beta = −0.16, P = .028). Independent predictors of HOS-SSS score were preoperative AP alpha angle (beta = −0.33, P = .032) and preoperative false profile alpha angle (beta = –0.28, P = .041). For the postoperative mHHS score, independent predictors included preoperative AP alpha angle (beta = −0.18, P = .046), preoperative false profile alpha angle (beta = −0.20, P = .014), and postoperative false profile alpha angle (beta = –0.48, P = .035). The preoperative AP alpha angle (beta = 0.28, P = .024) was a significant predictor for the postoperative VAS pain score. The preoperative false profile alpha angle (beta = −0.34, P = .040) was a significant predictor for the postoperative VAS satisfaction score.

Conclusion: The authors observed that radiographic measurements, specifically the preoperative false profile alpha angle, AP alpha angle, and postoperative false profile alpha angle, are independent predictors of 2-year clinical outcomes. The femoral-side measurements were the strongest independent predictors of outcomes, especially measurements of the anterior and lateral-based CAM lesion.

Keywords: hip; arthroscopic surgery; radiographic measurements; femoroacetabular impingement

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In recent years, femoroacetabular impingement (FAI) has become recognized as a major cause of hip pain and limited range of motion, particularly in young adult populations.[6,25] The prevalence of FAI in both symptomatic and asymptomatic patients is striking. Diesel and colleagues[5] determined the prevalence of FAI to be 53% in a cross-sectional study of 185 asymptomatic participants, while studies involving symptomatic patients have described a prevalence as high as 79% in patients presenting with hip or groin pain.[1] Despite improvements in our understanding of the complex origin of FAI, preoperative diagnostic assessments remain of the utmost importance given their implications for surgical planning and patient prognosis.

One such diagnostic tool is the use of plain radiographs, as these imaging modalities provide objective measurements that confirm the presence of FAI in symptomatic patients, in conjunction with the physical examination.[11,15] The alpha angles measured on anteroposterior (AP), false profile, and Dunn lateral plain radiographic views are highly implicated in the diagnosis of FAI, with angles greater than 50° specifically diagnostic of cam-type deformity of the femoral head.[15] As such, these objective measurements provide valuable insight for surgeons when developing patient-specific operative plans for an individual with evidence of FAI on radiographs.

Arthroscopic management of FAI is an emerging operative treatment modality for resolving FAI, given the minimally invasive nature of this management, its favorable and reproducible clinical outcomes, and low rate of complications.[4] Indeed, hip arthroscopy for FAI has been shown to improve hip function, decrease pain, and improve various patient-reported outcome scores including the modified Harris Hip Score (mHHS) and performance of activities of daily living (ADL).[6,10,17,20] Despite continuing developments in the surgical techniques used to reduce the morphological deformities found in cam, pincer, and mixed-type FAI, residual impingement may contribute to premature osteoarthritis in young adults and subsequently decreased survivorship.[17,25] Larson and colleagues[17] conducted a matched-cohort study comparing outcomes between patients undergoing arthroscopic hip revision for residual FAI versus patients undergoing primary arthroscopic FAI surgery. Patients in the revision group had inferior outcomes relative to patients undergoing primary arthroscopic intervention.[17] As such, it is important that cam deformities are addressed intraoperatively and fully resected in order to avoid incidences of future revision and to improve patient outcomes. Despite this knowledge, the degree to which outcomes in patients with preoperative cam deformity and postoperative residual cam deformities can be predicted with radiographic measurements used to initially diagnosis FAI is poorly understood.

Although plain radiographs are widely used to confirm the diagnosis of FAI, the ability to use measurements taken on pre- and postoperative plain radiographs to provide prognostic information is relatively unknown. As such, it is plausible that the use of radiographs may provide insight into the propensity for patients to undergo successful arthroscopic intervention as well as to postoperatively counsel patients on their recovery. The purpose of this study was to investigate the relationship between radiographic measurements and 2-year outcomes after hip arthroscopy for the treatment of FAI. Our group hypothesized that both pre- and postoperative alpha angles would be inversely correlated with patient-reported measures of satisfaction and function at short-term follow-up.

METHODS

Patient Selection

This study received institutional review board approval to track outcomes of consenting patients after hip arthroscopy for FAI performed by a single fellowship-trained surgeon. All clinical data were obtained prospectively in a secured repository. The repository was queried for all patients who underwent hip arthroscopy for primary FAI from January 1, 2012, to December 31, 2014. Inclusion criteria were all patients within this time frame with history, physical examination, and imaging findings consistent with symptomatic FAI who underwent hip arthroscopy (n = 749) with a minimum 2-year follow-up. Exclusion criteria included acetabular dysplasia, moderate osteoarthritis (Tönnis grade > 2), history of substantial ipsilateral hip or knee injury, revision surgical procedure, and labral reconstruction. Patient data were collected, including age, sex, body mass index (BMI), a history of smoking, preinjury activity level, self-reported mental illness, workers' compensation claim, and symptom duration (<4 months, 4-12 months, 12-24 months, or >24 months). Complications were recorded, including infection, neuropathy, deep vein thrombosis (DVT), conversion to total hip arthroplasty, revision hip arthroscopy, and heterotopic ossification.

Surgical Technique

All hip arthroscopic procedures were performed at a tertiary referral center dedicated to hip arthroscopic surgery and preservation. The patient was placed under general anesthesia in the supine position on a standard traction table. The senior author's (S.J.N.) surgical technique has been described previously.[9,10,13,20] With the patient in the supine position, a minimum of 2 portals (anterolateral under fluoroscopic guidance and midanterior under direct

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visualization) were created under traction to access the central compartment. For all cases, an interportal T-capsulotomy was used for visualization of the peripheral compartment, and diagnostic arthroscopy was performed. The indications for primary arthroscopic surgery were predominately symptomatic labral tears and impingement syndrome with failure of nonoperative treatment including intra-articular injections, nonsteroidal anti-inflammatory medications, and physical therapy. Procedures were performed as needed and included acetabuloplasty (rim trimming) with a 5.5-mm bur for pincer deformities, labral debridement, and femoral osteochondroplasty for cam deformities. Cartilage quality was graded intraoperatively as normal, mild, moderate, or severe, and the presence of cartilage delamination was recorded. Labral tears were repaired (n = 674) when there was a gross detachment of the labrum from the acetabular rim, but debridement was selectively performed (n = 27) until a stable labrum was achieved for patients with sufficient labral tissue with little or no detachment. Microfracture (n = 19) of the femoral head was performed with an awl for discrete chondral lesions after chondroplasty and debridement to a stable rim. A dynamic examination confirmed that there was no longer evidence of impingement. At the conclusion of the procedure, a capsular plication was performed to ensure proper soft tissue tension. Three high-strength sutures were passed through the vertical limb of the T-capsulotomy to plicate the iliofemoral ligament, followed by 2 or 3 sutures to close the interportal capsulotomy.

Postoperative Rehabilitation

All patients were given a fitted hip brace postoperatively to limit flexion, abduction, and extension and were instructed to restrict flatfoot weightbearing on the operative limb to 20 pounds for 3 weeks postoperatively. Night splints were used postoperatively for the first 4 weeks to limit foot rotation and facilitate labral and capsular healing. Patients were also instructed to avoid sitting for longer than 30 minutes at a time during the 3-week postoperative period. Circumduction of the hip was permitted.

Physical therapy began on the first postoperative day with a specific protocol determined based on the procedure performed, which usually included focus on motion initiation. Thereafter, physical therapy focused on soft tissue mobilization, isometrics, and stretching, with an ideal goal of symmetric hip range motion by 6 to 8 weeks postoperatively. After 3 weeks postoperatively, patients were permitted to discontinue the use of crutches and begin full weightbearing as tolerated. Progressively, more functional exercises were introduced as ambulation increased.

Functional Outcome Evaluation

Patients completed hip-specific outcome instruments preoperatively and at a minimum of 2 years postoperatively that included the Hip Outcome Score (HOS) ADL, HOS Sport-Specific Subscale (SSS), mHSS, visual analog scale (VAS) for pain, and VAS for satisfaction. Reoperations and conversion to total hip arthroplasty (THA) were recorded. The following information was recorded for each patient: BMI, age, sex, smoking history, workers' compensation status, a history of mental disorders, and level of activity participation.

Radiographic Analysis

All patients were assessed with preoperative and postoperative AP pelvic views, Dunn lateral views[7] with the hip flexed to 90°, and false profile views. The lateral center edge angle of Wiberg[27] was obtained on preoperative and postoperative AP radiographs to assess acetabular undercoverage or overcoverage, and the anterior center edge angle[18] was measured on preoperative and postoperative false profile radiographs. Tönnis angle (acetabular inclination) was measured on preoperative AP radiographs using the method described by Jessel et al.[16] The alpha angle was measured on preoperative and postoperative AP, false profile, and Dunn lateral radiographs according to the method previously defined by Nötzli et al.[22] Cartilage quality was assessed by measuring hip joint space width at the superolateral, apical, and superomedial positions.[3,23] All measurements were made digitally by a single trained observer using a picture archiving and communication system. Cartilage quality was assessed by measuring hip joint space width at the superolateral, apical, and superomedial positions.[3,23] Measurements were made twice for 20 patients, with measurements separated by at least 2 months. Individual intraclass correlation coefficients ranged from 0.83 to 0.99.

Statistical Analysis

Statistical analysis was performed by use of Stata version 14 (StataCorp). The relationships between all radiographic and demographic variables and clinical outcome scores were evaluated first with univariate analysis. For comparison of mean outcome scores between categorical variables, unpaired 2-tailed t tests were used. For analysis of the relationship between mean outcome scores and continuous variables, Spearman rank correlations were calculated. Next, multivariate regression analysis was performed for each clinical outcome score. Any variable with at least a statistical trend toward significance in univariate analysis ($P < .10$) was included in the multivariate linear regression modeling. The unstandardized coefficients from the multivariate linear regression models are reported as beta coefficients and reflect the amount of change in the independent variable needed to increase or decrease the dependent variable by 1 unit. Statistical significance was defined as $P < .05$.

RESULTS

We identified 707 patients (94.3%) who underwent primary hip arthroscopic management for FAI who were included for analysis out of a total cohort of 750 patients (43 patients lost to follow-up). The mean age of the patients was 33.2 ± 12.3 years, and 64.4% of the patients (n = 456)

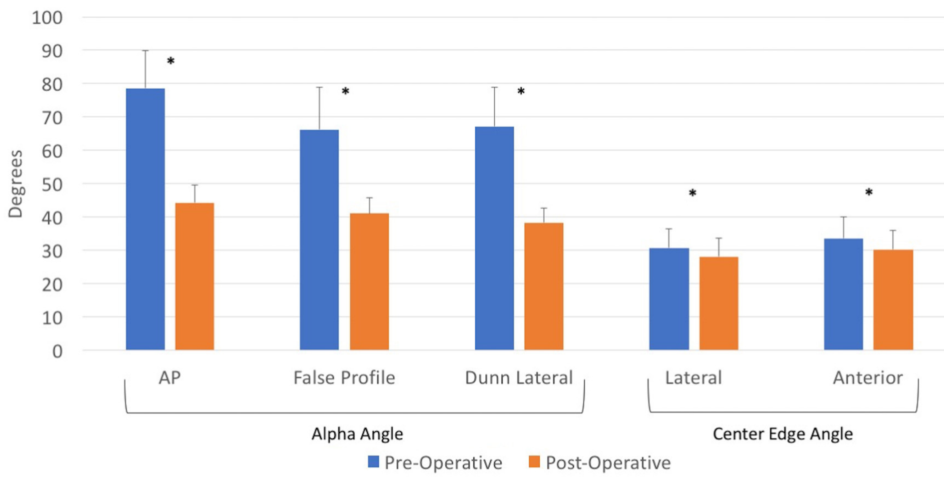

Figure 1. Preoperative and postoperative radiographic measurements for patients undergoing hip arthroscopy for femoroacetabular impingement. All radiographic measurements decreased significantly after surgery (*$P < .0001$). AP, anteroposterior.

were female. Two-year postoperative outcome scores were completed by 84.0% (n = 630) for HOS-ADL, 78.0% (n = 585) for HOS-SSS, 82.5% (n = 619) for mHHS, 80.1% for VAS pain score, and 82.0% (n = 615) for VAS satisfaction score. The mean AP alpha angle decreased by 34.3° ($P < .0001$), false profile alpha angle by 25.2° ($P < .0001$), Dunn lateral alpha angle by 28.9° ($P < .0001$), lateral center edge angle by 2.6° ($P < .0001$), and anterior center edge angle by 3.4° ($P < .0001$) (Figure 1). The HOS-ADL score increased from 65.7 ± 18.7 preoperatively to 85.9 ± 16.7 postoperatively ($P < .0001$), HOS-SSS increased from 43.4 ± 23.1 to 72.6 ± 27.2 ($P < .0001$), and mHHS increased from 57.7 ± 14.0 to 79.1 ± 17.2 ($P < .0001$). An alpha angle greater than 50° on the postoperative radiograph was seen on the AP radiograph for 176 patients (n = 24.9%), Dunn lateral for 133 patients (18.8%), and false profile for 145 patients (20.5%). The total complication rate was 4.4% (n = 33; infection = 6, neuropathy = 12, DVT = 1, total hip arthroplasty = 7, revision hip arthroscopy = 6, heterotopic ossification = 1).

Through univariate analysis (Table 1), the HOS-ADL was significantly correlated with the preoperative AP alpha angle, preoperative Dunn lateral alpha angle, and postoperative false profile alpha angle. For the HOS-SSS score, significant correlations with radiographic measures were noted with the preoperative AP alpha angle, preoperative false profile alpha angle, preoperative Dunn lateral alpha angle, preoperative anterior center edge angle, postoperative false profile alpha angle, and postoperative anterior center edge angle. The postoperative mHHS was significantly correlated with postoperative lateral joint space width, preoperative AP alpha angle, preoperative false profile alpha angle, preoperative Dunn lateral alpha angle, postoperative false profile alpha angle, postoperative Dunn lateral alpha angle, and postoperative anterior center edge angle. The postoperative VAS pain score was significantly correlated with preoperative AP alpha angle, preoperative false profile alpha angle, and postoperative false profile alpha angle. The postoperative VAS satisfaction score was significantly correlated with postoperative lateral joint space width, preoperative AP alpha angle, preoperative false profile alpha angle, preoperative Dunn lateral alpha angle, and postoperative false profile alpha angle.

Multivariate analysis (Table 2) identified multiple significant independent predictors for the postoperative patient-reported outcome scores. A radiographic measurement that was an independent predictor of the post-operative HOS-ADL score was the preoperative AP alpha angle (beta = –0.16, P = .028). For the postoperative HOS-SSS score, independent predictors of the outcome measure included pre-operative AP alpha angle (beta = –0.33, P = .0032) and preoperative false profile alpha angle (beta = –0.28, P = .041). For the postoperative mHHS score, independent predictors included preoperative AP alpha angle (beta = –0.18, P = .046), preoperative false profile alpha angle (beta = –0.20, P = .014), and postoperative false profile alpha angle (beta = –0.48, P = .035). The preoperative AP alpha angle (beta = 0.28, P = .024) was a significant predictor for the postoperative VAS pain score. The preoperative false profile alpha angle (beta = –0.34, P = .04) was a significant independent predictor for the postoperative VAS Satisfaction score. Non-radiographic variables which were significant negative predictors in these models included workman's compensation status (HOS-ADL [P = .009] and HOS-SS [P = .023]), positive smoking history (VAS pain score [$P < .001$]), self-reported mental illness (HOS-ADL [P = .009], HOS-SS [$P < .001$], mHHS [P = .002], VAS pain score [P = .007], and VAS satisfaction [P = .029]), and severe cartilage damage (HOS-ADL [P = .024]).

DISCUSSION

The bony abnormalities of FAI, including the femoral-based deformity seen in cam impingement and acetabular-based abnormalities seen in pincer-type, can lead to chondral

TABLE 1
Univariate Correlations Between Patient-Reported Outcome Measures and Radiographic Measurements Before and After Hip Arthroscopy

Variable	Rho	*P* Value
Hip Outcome Score Activities of Daily Living		
Preoperative AP alpha angle	–0.19	<.0001
Preoperative Dunn lateral alpha angle	–0.11	.018
Postoperative false profile alpha angle	–0.10	.025
Hip Outcome Score Sport-Specific Subscale		
Preoperative AP alpha angle	–0.24	<.0001
Preoperative false profile alpha angle	–0.22	<.0001
Preoperative Dunn lateral alpha angle	–0.14	.003
Preoperative anterior center edge angle	0.10	.065
Postoperative false profile alpha angle	–0.10	.023
Postoperative anterior center edge angle	0.092	.045
Modified Harris Hip Score		
Postoperative lateral joint space width	0.083	.047
Preoperative AP alpha angle	–0.18	<.0001
Preoperative false profile alpha angle	–0.22	<.0001
Preoperative Dunn lateral alpha angle	–0.09	.048
Postoperative false profile alpha angle	–0.14	.002
Postoperative Dunn lateral alpha angle	–0.12	.008
Postoperative anterior center edge angle	0.085	.057
Postoperative visual analog scale pain score		
Preoperative AP alpha angle	0.21	<.0001
Preoperative false profile alpha angle	0.21	.0001
Postoperative false profile alpha angle	0.10	.024
Postoperative visual analog scale satisfaction score		
Postoperative lateral joint space width	0.087	.039
Preoperative AP alpha angle	–0.19	<.0001
Preoperative false profile alpha angle	–0.22	<.0001
Preoperative Dunn lateral alpha angle	–0.12	.008
Postoperative false profile alpha angle	–0.093	.039

and labral injuries. Hip arthroscopy allows for the successful treatment of both the bony impingement and resultant soft tissue injury. The purpose of this study was to evaluate the relationship between preoperative and postoperative radiographic measurements of FAI with patient-reported postoperative outcome measurements. We observed that multiple radiographic findings were independent predictors of clinical outcome measures, especially the preoperative false profile alpha angle (higher values predictive of inferior postoperative HOS-SSS, mHHS, and VAS satisfaction scores), preoperative AP alpha angle (higher values predictive of inferior postoperative HOS-ADL, HOS-SSS, mHHS, and VAS pain scores), and postoperative false profile alpha angle (higher values predictive of inferior postoperative mHHS scores). The results of this study highlight the effect of the magnitude of the preoperative cam deformity and importance of a comprehensive cam correction, both the anterior and lateral aspects of the cam deformity, on 2-year clinical outcomes.

The current study indicates that severity and chronicity of FAI, particularly on the femoral side, can have important repercussions on patient-based outcomes. This may be attributable to the extent of secondary structural abnormality, which is classically generated through repetitive edge loading of an aspherical cam deformity in a position of flexion, adduction, and/or internal rotation. With time, the abnormal abutment of the anterolateral femoral head-neck junction with the anterosuperior acetabular labral complex can contribute to labral hypertrophy, intrasubstance degeneration, symptomatic tear formation with adjacent propagation, and worsening chondrolabral delamination.[2] Radiographically, an increasing alpha angle (normal $\leq 50°$) reflects progressive cam deformity and potentially a broader chondrolabral zone of injury. Specifically, alpha angle measurements on AP and false profile radiographic views allow for scrutiny of a pathologic laterally based and anterior cam lesion, respectively, both for preoperative planning and postoperative assessment for residual deformity.[14] In the current series, these variables served as significant independent predictors for patient-reported outcomes at 2-year follow-up, with increasing preoperative alpha angle measurements corresponding to lower endpoints on selected patient-reported outcome measures. This supports the underlying hypothesis that increased burden of disease, especially cam deformity, contributes to worse outcomes, even after controlling for joint space narrowing, symptom duration, and intraoperative cartilage grading. Additionally, the influence of the false profile and AP alpha angle measurements on 2-year outcomes highlights the importance of addressing both the anterior and lateral components of the bony impingement deformity.

TABLE 2
Multivariate Regression Independent Predictors of Patient-Reported Outcome Measures

Radiographic Measurement	Beta Coefficient	*P* Value
Postoperative Hip Outcome Score Activities of Daily Living		
Preoperative AP alpha angle	–0.16	.028
Postoperative Hip Outcome Score Sport-Specific Subscale		
Preoperative AP alpha angle	–0.33	.032
Preoperative false profile alpha angle	–0.28	.041
Postoperative modified Harris Hip Score		
Preoperative AP alpha angle	–0.18	.046
Preoperative false profile alpha angle	–0.20	.014
Postoperative false profile alpha angle	–0.48	.035
Postoperative visual analog scale pain score		
Preoperative AP alpha angle	0.28	.024
Postoperative visual analog scale satisfaction score		
Preoperative false profile alpha angle	–0.34	.04

While inadequate rehabilitation, inappropriate indications, and other technical errors may contribute to suboptimal outcomes after FAI-related hip arthroscopy, incomplete resection remains the most common cause for revision hip arthroscopy.[12,24] Accordingly, preoperative planning with 3-dimensional imaging, hypothetical modeling, and/or intraoperative assessment with a dynamic fluoroscopic examination during arthroscopy should be considered to avoid inadequate cam decompression.[21] In this investigation, for approximately every 1° increase in alpha angle on the postoperative false profile view (beta = –0.48), there is a 0.5-point decrease in total mHHS. However, this also stands in stark contrast to other research that questions the relative value of femoral-side treatment. In their series of 106 hips with isolated acetabular rim trim and labral repair for combined-type FAI, Tjong and colleagues[26] noted no differences in the International Hip Outcome Tool, mHHS, HOS, and patient satisfaction scale according to preoperative alpha angle, and no cases of revision hip surgery were required at greater than 3-year follow-up. The authors subsequently concluded that alpha angle had limited effect on postoperative outcomes or secondary revision rates, although this study did not report range of motion postoperatively or feature a comparative group with adjunctive femoroplasty. Our preference is to perform femoral osteochondroplasty with a goal of alpha angle less than 50° in all planes, while taking care to not place the patient at risk of iatrogenic femoral neck fracture with overresection.

As with any large data registry, certain limitations must be acknowledged. While these data were prospectively gathered, they were retrospectively reviewed and featured no corresponding control group (ie, untreated osseous deformity) for comparison. Additionally, we did not control for all other potentially confounding variables, such as compensatory lumbopelvic or gait abnormalities. Our measurements were made on 2-dimensional radiographs so we were not able to include assessments of femoral and acetabular version, although these are also important anatomic factors.[8,19] Multivariate linear regression modeling, as used here, fits a data set based on linear relationships, although more complex relationships between the variables may be present. There may also be ceiling or floor effects with both the radiographic measurements and the outcome variables. We performed multiple statistical comparisons here. We attempted to limit our error rate with the a priori criteria from univariate analysis used to include variables for multivariate linear analysis. Last, this analysis is subject to performance bias, as the senior author performed a meticulous fluoroscopically guided arthroscopic evaluation after cam decompression to confirm adequate degree of resection. As such, this may underestimate the relative effect of increased postoperative alpha angle on persistent symptoms or patient-reported outcomes.

In conclusion, the findings from this study highlight the importance of both preoperative and postoperative radiographic measurements of bony impingement in subjective outcomes 2 years after arthroscopic management of FAI. The femoral-sided measurements were the strongest independent predictors of outcome, especially measurements of the anterior and lateral-based cam lesion. Surgeons should ensure both adequate preoperative planning and intraoperative dynamic evaluation of femoral-side lesions to ensure complete resection to optimize postoperative outcomes.

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