Extent of Cam Resection Relative to Epiphyseal Line and Its Association With Clinical Outcomes After Arthroscopic Treatment for Femoroacetabular Syndrome

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Background: Inadequate resection of cam lesions can cause inferior outcomes after hip arthroscopy and result in revision surgery for femoroacetabular impingement syndrome (FAIS).

Purpose: To evaluate the association between postoperative cam lesions measured using the proximal boundaries of resection area (PBRE) relative to the epiphyseal line and 2-year outcomes after hip arthroscopy.

Study Design: Cohort study; Level of evidence, 3.

Methods: Included were patients with FAIS who had undergone primary hip arthroscopy between 2016 and 2018. The PBRE was calculated by measuring the linear distance from the PBRE to the epiphyseal line, dividing it by the diameter of the femoral head, and multiplying by 100; PBRE measurements were made at the 12-, 1-, and 2-o'clock positions on postoperative hip computed tomography. Within each clockface position, patients were divided into subgroups depending on whether their postoperative PBRE was greater than a half standard deviation above the mean (adequate resection) or less than or equal to a half standard deviation above the mean (inadequate resection). Patient-reported outcomes (PROs; Hip Outcome Score–Activities of Daily Living [HOS-ADL], International Hip Outcome Tool–Short Form [iHOT-12], modified Harris Hip Score [mHHS], and pain visual analog scale [VAS]) and rates of achieving the minimal clinically important difference (MCID) and patient-acceptable symptomatic state (PASS) were compared among the subgroups.

Results: Included were 80 pairs of hips at 12 o'clock, 81 pairs of hips at 1 o'clock, and 80 pairs of hips at 2 o'clock. All subgroups demonstrated significant improvements in PRO scores at a minimum 2-year follow-up compared with preoperatively. At the 12-o'clock position, the subgroup with adequate resection had significantly superior HOS-ADL ($P = .004$), iHOT-12 ($P < .001$), and mHHS ($P < .001$) scores and were more likely to achieve the MCID for the iHOT-12 score ($P = .035$) and the PASS for the HOS-ADL ($P = .003$), iHOT-12 ($P = .007$), and mHHS ($P < .001$) scores compared with the matched subgroup. There were no significant differences in PRO scores or rates of MCID and PASS for the 1- or 2-o'clock groups.

Conclusion: The epiphyseal line may be a useful and reproducible landmark measurement for cam-type deformity. Patients considered to have inadequate resection at 12 o'clock had lower outcome scores at a minimum 2-year follow-up.

Keywords: femoroacetabular impingement syndrome; cam deformity; epiphyseal line; hip arthroscopy; patient-reported outcomes

Femoroacetabular impingement syndrome (FAIS) is a common cause of hip pain and reduced range of motion in the young and active population.[5,8] Surgical intervention may be recommended for patients who fail to respond to nonoperative management.[15] The use of hip arthroscopy to treat FAIS has grown exponentially and is associated with high success and low complication rates.[20,23] Despite most patients showing good to excellent patient-reported outcome (PRO) scores after hip arthroscopy, a proportion of patients do not have satisfactory postoperative results.[15,34] One of the most common causes for inferior outcomes after hip arthroscopy and revision surgery is inadequate resection of cam lesions.[10,25]

The cam-type deformity is an osseous bump at the femoral head-neck junction that results in abnormal contact between the acetabulum and femoral head.[29] It is reported that cam-type deformities are acquired during adolescence and are due to physical activity.[1,2,32] Furthermore, Agricola et al[3]

reported that cam-type deformities can present before complete closure of the growth plate in soccer players. After a minimum 2-year follow-up, they observed that a cam-type deformity only developed when the growth plate was open. In addition, a cam-type deformity is associated with greater extension of the growth plate into the femoral neck.[3,31]

The findings from the aforementioned studies[3,31] have sparked speculation on whether the epiphyseal line could be a landmark for measuring the extent of resection of cam deformities. Developing a simplified method for determining the extent of resection that is adequate for cam-type deformities could help improve hip arthroscopic outcomes in FAIS and potentially reduce the need for revision surgery due to underresection. Measuring the proximal boundaries of resection area (PBRE) may be useful for evaluating the extent of resection.

The purpose of this study was to evaluate the association between postoperative cam lesions measured using the PBRE relative to the epiphyseal line and 2-year PROs after hip arthroscopy. We hypothesized that patients with larger postoperative PBREs would have superior postoperative functional outcomes.

METHODS

Patient Selection and Imaging

Approval for the study protocol was obtained from the ethics committee at our institution. We used retrospective data for hip arthroscopic procedures performed at our institution from August 1, 2016, to December 1, 2018. All arthroscopic procedures were performed by 3 senior authors (Y.X., X.Z., J.-Q.W.). Study inclusion criteria included primary hip arthroscopy for FAIS, cam- or mixed-type deformity treated with femoroplasty, patient age between 16 and 55 years, and a minimum 2-year follow-up. Exclusion criteria included isolated pincer lesion, revision hip surgery, hip dysplasia (preoperative lateral center-edge angle [LCEA], <25°), moderate to advanced osteoarthritis (Tönnis grade, ≥2), sacroiliac joint disease, congenital hip disorders (Legg-Calves-Perthes disease, avascular necrosis), and incomplete radiographs and medical records.

During the study period, 434 patients underwent arthroscopic hip procedures at our hospital. Two hips were excluded due to advanced osteoarthritis, 15 hips for previous ipsilateral hip operation, 37 hips for contralateral or revision hip arthroscopy, 23 hips for evidence of dysplasia, and 88 hips for inaccessible postoperative hip computed
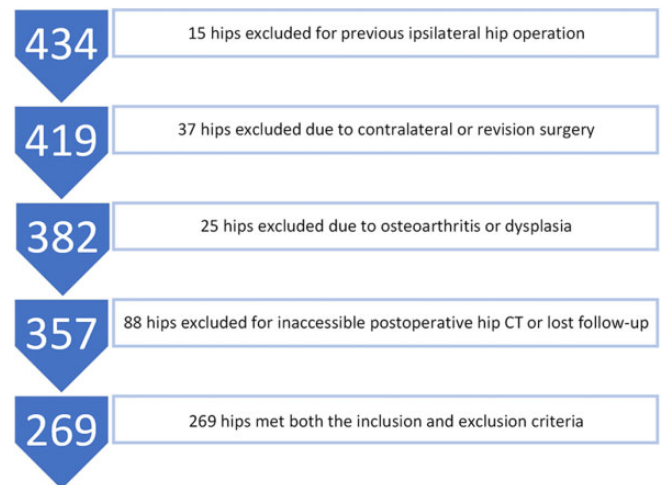
Figure 1. CONSORT (Consolidated Standards of Reporting Trials) diagram indicating patient exclusion and inclusion in the study. CT, computed tomography.

tomography (CT) imaging. Therefore, 269 patients met the inclusion and exclusion criteria and had a minimum 2-year follow-up (Figure 1).

All study patients had undergone preoperative anteroposterior (AP) pelvis and 45° Dunn lateral radiography as well as unilateral hip CT and magnetic resonance imaging (MRI). Radiographic measurements were performed using a picture archiving and communication system (GE Healthcare). The LCEA and joint space were measured on AP pelvis radiographs. An LCEA >40° indicated pincer impingement. The alpha angle was measured on 45° Dunn lateral radiographs, with an angle >55° indicating cam impingement. MRI was used to evaluate the status of labral and articular cartilage. Three dimensional CT was used for preoperative and postoperative Cam deformity evaluation.

Surgical Procedure and Postoperative Rehabilitation

Indications for surgery were persistent pain and failed non-operative treatment after at least 3 months (physical therapy, oral anti-inflammatory drugs, and/or intra-articular injection). The patient was placed in the modified supine position in standard hip traction (Smith & Nephew). The perineum was protected, and the limb undergoing surgery was tractioned with an 8- to 10-mm distractor for hip joint

Figure 2. The radial cuts rotate clockwise in 30° intervals around the femoral head-neck axis. PBRE measurements were performed throughout the cranial hemisphere from 12 o'clock to 2 o'clock.

space. The procedure began with fluoroscopic localization of the anterolateral (AL) portal, midanterior portal (MAP), and proximal midanterior portal (PMAP), using a 70° arthroscope. An interportal capsulotomy was performed among the 3 portals to improve visualization and access with instruments.[26] Most pathology in the central compartment, including pincer deformity, labral injury, and chondrolabral injury, was treated through labral debridement, repair, or reconstruction depending on the labral condition. Labral tears were repaired with suture anchor fixation when possible, while irreparable labral tears were treated with labral reconstruction with autograft gracilis. Chondroplasty was performed for partial-thickness cartilage lesions and chondral flaps. After addressing pathology in the central compartment, the arthroscope was introduced into the peripheral compartment for decompression of the cam deformity using a high-speed bur. Satisfactory resection was confirmed through dynamic examination with an impingement test and intraoperative fluoroscopy of the AP and 45° Dunn lateral views, with the alpha angle and LCEA restored to normal. The capsule was routinely repaired at the end of the procedure.

All patients followed a standardized prescribed rehabilitation protocol under the direct supervision of our physical therapy team, as previously described.[36] Rehabilitation took an average of 4 to 5 months and was divided into 4 phases. Briefly, the first phase comprised isometric contractions and passive range of motion exercises; the second phase focused on maintaining a regular gait and restoring full range of motion; the third phase was about regaining lower extremity strength as well as normal functional activities; and the final phase focused on resuming preinjury higher-level activities.
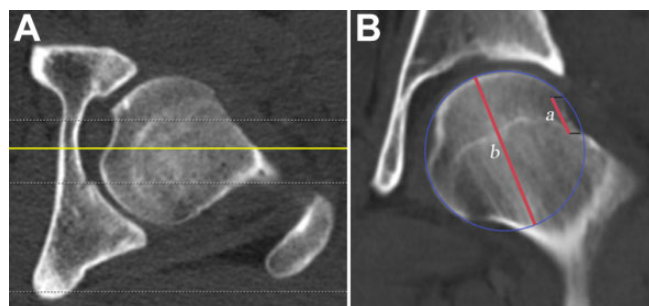
Figure 3. Measurement of the PBRE on postoperative CT scans of a left hip at 12 o'clock. (A) Axial plane showing the level at which coronal plane measurements were taken (yellow line). (B) Measurements on the coronal plane. The PBRE was calculated as $a/b \times 100$, where line a is the resection area and line b is the diameter of the femoral head. CT, computed tomography; proximal boundaries of resection area.

PBRE Measurement

The PBRE was measured on postoperative CT scans at 12, 1, and 2 o'clock on the clockface of the anterosuperior head segment (Figure 2), as these are the common locations for cam lesions.[20,32,35] The PBRE was determined by measuring the linear distance from the PBRE to the epiphyseal line, dividing it by the diameter of the femoral head, and multiplying the quotient by 100. Stereo-correlation localization was used to determine the accurate section on the axial views, and then PBRE was measured on coronal views in the same plane as the axial view (Figure 3). All CT scans were evaluated by an independent musculoskeletal

TABLE 1
Comparison of Patient Characteristics Between Subgroups for Each Clockface Position[a]

	12 o'clock			1 o'clock			2 o'clock		
Variable	PBRE, >13.3 (n = 80)	PBRE, ≤13.3 (n = 80)	P	PBRE, >12.9 (n = 81)	PBRE, ≤12.9 (n = 81)	P	PBRE, >12.2 (n = 80)	PBRE, ≤12.2 (n = 80)	P
Age, y	36.5 ± 10.3	36.4 ± 9.4	.981	35.6 ± 10.2	37.7 ± 9.8	.178	37.6 ± 9.9	37.1 ± 9.3	.700
BMI, kg/m^2	22.8 ± 3.0	22.7 ± 3.1	.796	22.5 ± 3.1	22.9 ± 3.1	.397	23.1 ± 3.3	22.9 ± 3.1	.713
Sex			>.999			.746			.871
Female	49 (61.3)	49 (61.3)		49 (60.5)	51 (63.0)		49 (61.3)	50 (62.5)	
Male	31 (38.7)	31 (38.7)		32 (39.5)	30 (37.0)		31 (38.7)	30 (37.5)	
Tönnis grade			.742			.132			.519
0	52 (65.0)	50 (62.5)		59 (72.8)	50 (61.7)		50 (62.5)	46 (57.5)	
1	28 (35.0)	30 (37.5)		22 (27.2)	31 (38.3)		30 (37.5)	34 (42.5)	
Follow-up, mo	38.4 ± 8.2	38.7 ± 7.7	.812	37.5 ± 7.8	38.5 ± 7.1	0.391	38.6 ± 8.1	38.2 ± 7.2	.751

[a]Data are reported as mean ± SD or n (%). BMI, body mass index; PBRE, proximal boundaries of resection area.

radiologist and 1 of the authors (H.J.H.). Both observers were blinded to all clinical data of patients. Measurements were taken twice within a 3-week interval to ensure the production of reliable and clinically meaningful results.

Study Groups

Patients were divided into 3 groups based on the 3 clockface positions (12-, 1-, and 2-o'clock groups). As PBRE is a continuous variable, to facilitate comparison within each clockface group, 2 subgroups were created. The first subgroup consisted of patients for whom the PBRE was greater than a half standard deviation above the mean (about 33% of the patients based on a normal distribution curve), who were considered as having adequate resection, and the second subgroup consisted of patients for whom the PBRE was less than or equal to a half standard deviation above the mean (about 66% of the patients based on a normal distribution curve),[11] who were considered to have inadequate resection. The PBRE values that were a half standard deviation above the mean were 13.3, 12.9, and 12.2 for the 12-, 1-, and 2-o'clock positions, respectively.

A 1:1 propensity score match based on age, sex, body mass index (BMI), Tönnis grade, symptom duration before surgery, and follow-up time was performed to control for potential confounding variables within each subgroup pair.

Functional Outcomes

PRO measures included the Hip Outcome Score–Activities of Daily Living (HOS-ADL), International Hip Outcome Tool–Short Form (iHOT-12), and modified Harris Hip Score (mHHS). Visual analog scale (VAS) was also provided for pain assessment and was evaluated on a scale of 0 (no pain) to 10 (extreme pain). The Hip Outcome Score–Sports-Specific Subscale (HOS-SSS) was not included in this study because nearly half of the patients were not involved in regular exercise routines. Differences between preoperative and postoperative scores were calculated. The minimal clinically important difference (MCID) and patient-acceptable symptomatic state (PASS) from previous studies

were also used to determine meaningful improvement in outcomes. PASS thresholds were 87 for HOS-ADL, 72.2 for iHOT-12, and 83.3 for mHHS,[4,24] and the MCID thresholds were 10.14 points for HOS-ADL, 13.73 points for iHOT-12, and 8.76 points for mHHS.[18,24]

Statistical Analysis

An a priori power analysis using G*Power (Version 3.1) was performed to determine sample size. The means (55 and 74) and standard deviations (19) from a study evaluating the association between the preoperative and postoperative mean mHHS values and postoperative cam lesions were used for sample size calculation.[17] The sample size was determined to be 20 patients per subgroup using an alpha of 0.05 and beta of 0.2 (80% power).

The Shapiro-Wilk test was used to ensure that all parametric statistical assumptions were satisfied. We used a 2-tailed unpaired Student t test to compare continuous demographic data between each subgroup pairing, and a 2-tailed paired Student t test to compare pre- and postoperative PROs. The chi-square test or Fisher exact test was used to compare categorical variables between each subgroup pairing.

The intraobserver and interobserver reliability of the PBRE measurements were calculated using the intraclass correlation coefficient (ICC; <0.40, poor; 0.40-0.59, fair; 0.60-0.74, good; and >0.75, excellent). SPSS (Version 26; IBM) was used for all statistical analyses. $P < .05$ was considered the threshold for statistical significance.

RESULTS

Patient Characteristics

Propensity score matching (based on age, sex, BMI, Tönnis grade, and follow-up time) yielded 80 matched pairs for the 12-o'clock group, 81 matched pairs for the 1-o'clock group, and 80 matched pairs for the 2-o'clock group. The demographic data of all patients are presented in Table 1.

TABLE 2
Comparison of Procedures Performed Between Subgroups for Each Clockface Position[a]

	12 o'clock			1 o'clock			2 o'clock		
	PBRE, >13.3	PBRE, ≤13.3	P	PBRE, >12.9	PBRE, ≤12.9	P	PBRE, >12.2	PBRE, ≤12.2	P
Labral									
None	3 (3.8)	1 (1.3)	.613	4 (4.9)	2 (2.5)	.677	2 (2.5)	3 (3.8)	>.999
Debridement	7 (8.8)	5 (6.3)	.548	6 (7.4)	9 (11.1)	.416	9 (11.3)	8 (10.0)	.798
Repair	68 (85.0)	71 (88.8)	.482	70 (86.4)	68 (84.0)	.658	66 (82.5)	68 (85.0)	.668
Reconstruction	2 (2.5)	3 (3.8)	>.999	1 (1.2)	2 (2.5)	>.999	3 (3.8)	1 (1.3)	.613
Acetabuloplasty	55 (68.8)	61 (76.3)	.288	59 (72.8)	62 (76.5)	.588	53 (66.3)	58 (72.5)	.391
Iliopsoas release	4 (5.0)	5 (6.3)	>.999	5 (6.2)	4 (4.9)	.732	6 (7.5)	4 (5.0)	.514
LT treatment	5 (6.3)	4 (5.0)	>.999	4 (4.9)	6 (7.4)	.514	5 (6.3)	6 (7.5)	.755
SSI	2 (2.5)	2 (2.5)	>.999	5 (6.2)	3 (3.7)	.717	1 (1.3)	2 (2.5)	>.999
Synovectomy	30 (37.5)	27 (33.8)	.620	29 (35.8)	26 (32.1)	.619	27 (33.8)	24 (30)	.611

[a]Data are reported as n (%). LT, ligamentum teres; PBRE, proximal boundaries of resection area; SSI, subspine decompression.

The ICC values of the PBRE measurements were >0.80 for each parameter, indicating excellent intraobserver and interobserver reliability.

Intraoperative Findings and Procedures Performed

The intraoperative findings and procedures performed during arthroscopic surgery are summarized in Table 2. Overall, the majority of the study participants underwent labral repair, femoral osteoplasty, and acetabular rim trimming. There were no significant differences in intraoperative findings and the procedures performed among the subgroups.

Patient-Reported Outcomes

There was no significant difference in the baseline PROs between any of the subgroup pairings. All groups demonstrated a net improvement in PROs at the final follow-up compared with preoperative levels ($P < .001$ for all). At the 2-year follow-up in the 12-o'clock group, patients with adequate resection (PBRE, >13.3) had significantly higher HOS-ADL ($P = .004$), iHOT-12 ($P < .001$), and mHHS ($P < .001$) scores as compared with the matched patients with inadequate resection (PBRE, ≤13.3) (Figure 4, Table 3). No difference was observed in the postoperative VAS pain score ($P = .053$) (Table 3). At the 2-year follow-up in the 1- and 2-o'clock groups, patients with adequate resection (PBRE, >12.9 and >12.2, respectively) had significantly higher iHOT-12 scores ($P = .004$ and .019, respectively) as compared with the matched subgroups with inadequate resection. There was no other significant difference in PROs at 1 and 2 o'clock.

Patients in the 12-o'clock group with adequate resection were more likely to achieve the MCID for the iHOT-12 score ($P = .035$) and PASS for the HOS-ADL ($P = .003$), iHOT-12 ($P = .007$), and mHHS ($P < .001$) score compared with the matched subgroup (Figure 5). There were no other differences in the PASS and MCID among the subgroups (Table 4).
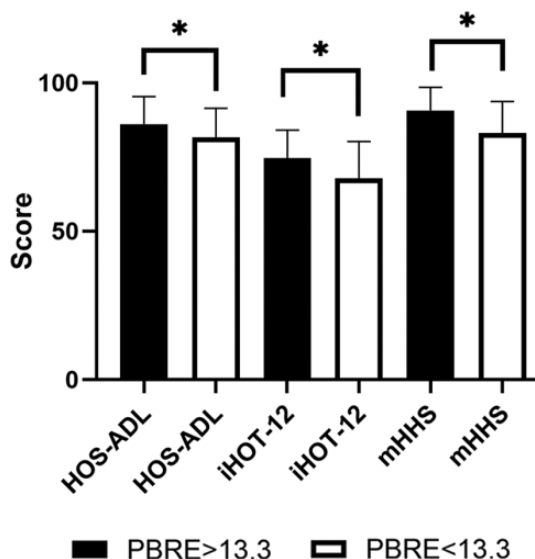

Figure 4. Box plot showing the results of patient-reported outcomes between the subgroups for the 12-o'clock position. Error bars indicate standard deviations. *Statistically significant difference between groups compared ($P < .05$). HOS-ADL, Hip Outcome Score–Activities of Daily Living; iHOT-12, International Hip Outcome Tool–Short Form; mHHS, modified Harris Hip Score; PBRE, proximal boundaries of resection area.

Complications and Secondary Surgery

The overall complication rates at 12, 1, and 2 o'clock were 7.5%, 9.9%, and 10.0%, respectively, with no significant differences between the subgroups with respect to complications or revision surgery. Complications included heterotopic ossification, transient musculocutaneous nerve palsy, and lower limb venous thrombosis. In the 12-o'clock group, a total of 6 hips (3.8%) underwent revision hip arthroscopy due to residual cam deformity and gradual onset of symptoms, including 4 patients in the study group and 2 patients in the control group ($P > .999$). The rate of revision surgery between the

TABLE 3
Comparison of Patient-Reported Outcomes Between Subgroups for Each Clockface Position[a]

	12 o'clock			1 o'clock			2 o'clock		
	PBRE, >13.3	PBRE, ≤13.3	P	PBRE, >12.9	PBRE, ≤12.9	P	PBRE, >12.2	PBRE, ≤12.2	P
HOS-ADL									
Pre	63.6 ± 8.4	64.7 ± 7.9	.428	64.2 ± 9.3	64.6 ± 8.3	.794	63. 9 ± 8.3	64.7 ± 8.7	.511
Post	86.1 ± 9.3	81.7 ± 9.7	**.004**	85.5 ± 9.1	82.9 ± 9.9	.087	84.5 ± 8.9	82.2 ± 10.7	.133
iHOT-12									
Pre	41.7 ± 7.8	41.0 ± 6.7	.548	41.6 ± 8.6	41.3 ± 6.5	.818	41.6 ± 8.6	41.1 ± 5.6	.689
Post	74.6 ± 9.5	67.8 ± 12.4	**<.001**	74.1 ± 10.6	68.9 ± 12.0	**.004**	72.6 ± 9.3	68.5 ± 12.7	**.019**
mHHS									
Pre	63.5 ± 8.1	61.8 ± 6.9	.154	62.5 ± 8.6	62.4 ± 6.9	.921	61.6 ± 8.3	62.0 ± 6.4	.734
Post	90.7 ± 7.8	83.1 ± 10.6	**<.001**	88.2 ± 9.7	85.4 ± 10.2	.071	87.5 ± 9.8	85.0 ± 11.0	.126
VAS pain									
Pre	6.2 ± 1.7	5.9 ± 1.2	.186	6.2 ± 1.5	5.9 ± 1.2	.144	6.3 ± 1.4	6.0 ± 1.2	.130
Post	1.6 ± 1.4	2.0 ± 1.7	.053	1.6 ± 1.4	2.0 ± 1.6	.098	1.7 ± 1.5	2.1 ± 1.7	.124

[a]Data are reported as mean ± SD. Boldface *P* values indicate a statistically significant difference between groups compared (*P* < .05). HOS-ADL, Hip Outcome Score–Activities of Daily Living; iHOT-12, International Hip Outcome Tool–Short Form; mHHS, modified H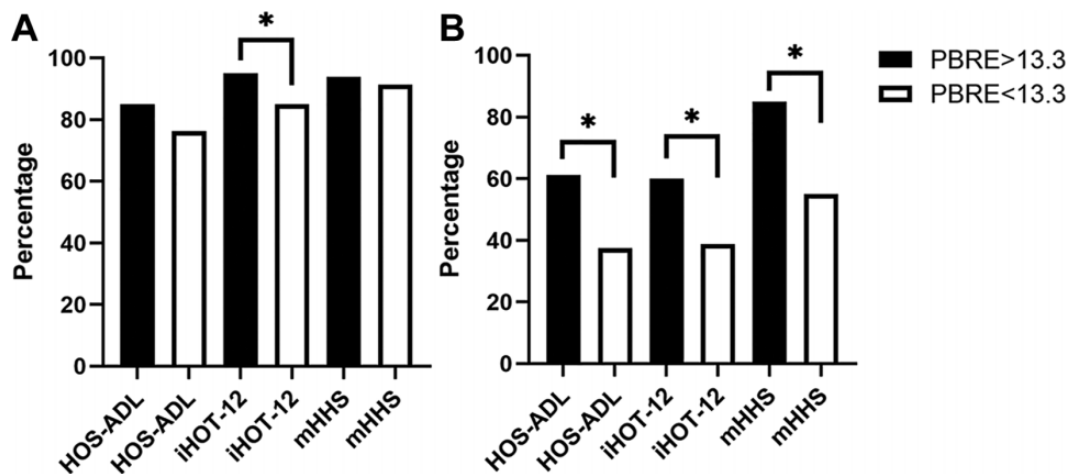arris Hip Score; PBRE, proximal boundaries of resection area; Pre, preoperative; Post, postoperative; VAS, visual analog scale.

Figure 5. Rates of (A) minimal clinically important difference and (B) patient-acceptable symptomatic state for the subgroups in the 12-o'clock position. Error bars indicate standard deviations. *Statistically significant difference between groups compared (*P* < .05). HOS-ADL, Hip Outcome Score–Activities of Daily Living; iHOT-12, International Hip Outcome Tool–Short Form; mHHS, modified Harris Hip Score; PBRE, proximal boundaries of resection area.

matched subgroups in the 1- and 2-o'clock groups was not significantly different (*P* > .999). No patient required conversion to total hip arthroplasty in any of the groups.

DISCUSSION

The most important finding from the present study is that the epiphyseal line may be a useful and reproducible landmark for measuring cam-type deformity. At the 12-o'clock position, patients with inadequate resection (PBRE, ≤13.3) had significantly lower HOS-ADL, iHOT-12, and mHHS functional outcome scores at the 2-year follow-up. The matched subgroup of patients with adequate resection (PBRE, >13.3) was more likely to achieve the MCID for the

iHOT-12 score and PASS for all the PROs. For the 1- and 2-o'clock positions, although the PBRE >12.9 and >12.2 subgroups had significantly higher iHOT-12 scores compared with their matched patients with inadequate resection (*P* = .004 and .019, respectively), the results did not imply clinical relevance as indicated by the MCID and PASS.

The cam-type deformity, which is generally diagnosed in young and active adults, is thought to be caused by excessive femoral loading due to a high level of physical activity during skeletal development.[13,22] Chronic mechanical stress has a great impact on the structure and tissue properties of bone during skeletal development, as immature tissue is more elastic. Roels et al[28] used finite element models to study the impact of mechanical stress on cam-type deformities and found that the development of a cam-type

TABLE 4
Comparison of MCID and PASS Rates Between Subgroups for Each Clockface Position[a]

	12 o'clock			1 o'clock			2 o'clock		
	PBRE, >13.3	PBRE, ≤13.3	P	PBRE, >12.9	PBRE, ≤12.9	P	PBRE, >12.2	PBRE, ≤12.2	P
MCID									
HOS-ADL	85.0	76.3	.161	81.5	79.0	.693	81.3	75.0	.339
iHOT-12	95.0	85.0	**.035**	97.5	91.4	.086	95	86.3	.058
mHHS	93.8	91.3	.548	91.4	87.7	.442	96.3	91.3	.191
PASS									
HOS-ADL	61.3	37.5	**.003**	54.3	46.9	.346	50.0	45.0	.527
iHOT-12	60.0	38.8	**.007**	59.3	45.7	.084	50.0	43.8	.428
mHHS	85.0	55.0	**<.001**	70.4	64.2	.402	71.3	63.8	.311

[a]Data are shown as percentages. Boldface *P* values indicate a statistically significant difference between groups compared (*P* < .05). HOS-ADL, Hip Outcome Score–Activities of Daily Living; iHOT-12, International Hip Outcome Tool–Short Form; MCID, minimal clinically important difference; mHHS, modified Harris Hip Score; PASS, patient-acceptable symptomatic state; PBRE, proximal boundaries of resection area.

deformity is directly related to the physical activities undertaken by the individual before growth plate closure. Moreover, a large epiphyseal extension increases the risk of formation of a cam-type deformity.[3,28] These findings indicated that cam-type deformities are part of developmental deformities and may derive from the epiphyseal line. This is the basis for the use of the epiphyseal line in measuring the extent of resection of a cam deformity.

Cam resection is central to surgical management of FAIS, with residual cam deformity being the most common reason for revision hip arthroscopic surgery.[6,27,30] In these studies, measurements were done on plain radiographs (frog-leg lateral view or Dunn view), which mainly capture the cam lesion between the 1- and 2-o'clock positions.[33] However, when judging FAIS pathology on a single view, one may underestimate or overestimate the cam-type deformity since impingement occurs in multiple planes.[14] Kaplan et al[11] used the femoroacetabular impingement resection arch (FAIR) on the 45° Dunn view to measure cam deformity and found that patients with a lower postoperative cam maximal radial distance relative to the FAIR arc (indicating larger femoroplasty at 1:30-2 o'clock) demonstrated significantly improved outcomes. However, the extent of femoroplasty was not associated with postoperative PROs at 1 and 2 o'clock in the present study. Instead, larger extents of cam resection at 12 o'clock were associated with higher PROs. Interestingly, it has been shown that the most common location for a cam lesion is between 1:30 and 2 o'clock on the clockface.[33,35] The disparity in these results could be because although the PBRE values were considered to be inadequate at 1 and 2 o'clock (≤12.9 and ≤12.2, respectively), the resection was enough for asymptomatic status. Previous literature has reported that asymptomatic populations have a high prevalence of radiographic cam deformity, especially in elite athletes (40%-69.4%).[7,9,12,16] Furthermore, asymptomatic cam deformity does not show functional impairments.[5] Although malformation between 1 and 2 o'clock is most common and pronounced, it may not be a leading cause of hip or groin pain in some patients. Cam deformity at 12 o'clock may play a more important role in hip or groin

pain, which may have contributed to the differences in results between our study and previous studies.

Mofidi et al[21] used intraoperative 3-dimensional (3D) CT, performed before and after osteoplasty, to assess the adequacy of cam and pincer resection. However, the postoperative alpha angle was only measured in the oblique view and not in multiple planes. Cam-type morphology is a 3D deformity, and single 2D measurements should be interpreted with caution, as they may not provide a true estimate of the magnitude of the deformity.[19] Taken together, preoperative 3D assessment of cam deformity, especially at 12 o'clock, should be given more attention and femoroplasty should be sufficient during operation. However, only the proximal extent of the cam resection was measured by PBRE, and not the depth. Kaplan et al,[11] using FAIR to measure cam resection depth, reported that improved functional outcome scores were associated with greater reduction in cam height. It may be that the depth of femoroplasty is more important for clinical outcome at the 1- and 2-o'clock positions in this study.

The results of this study indicate that functional outcomes after arthroscopic surgery for FAIS are related to the extent of cam resection relative to the epiphyseal line. The cam resection range should be confirmed with C-arm fluoroscopy, compared with the preoperative location view; an adequate resection should at least exceed the epiphyseal line on the AP view. However, excessive resection should be avoided, as very aggressive resection of the proximal boundary may compromise the sealing effect of the labrum.

Limitations

This study has some limitations. First, since the study group only included patients with cam- or mixed-type FAIS who had undergone femoroplasty, the results may not be applicable to an average FAIS patient. Second, only the extent of resection of cam deformity was studied, yet the depth of femoroplasty also plays a role in PROs and can influence the results. Finally, because this was a retrospective study, there was an inherent bias. Despite the use of

propensity score matching to control for potential confounding variables, additional confounding variables could have influenced our results.

CONCLUSION

Patients considered to have inadequate resection at the 12-o'clock position had lower outcome scores at a minimum 2-year follow-up versus matched patients with adequate resection. The epiphyseal line may be a useful and reproducible landmark measurement for cam-type deformity.

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