Acetabular Morphologic Characteristics Predict Early Conversion to Arthroplasty After Isolated Hip Arthroscopy for Femoroacetabular Impingement

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Background: Hip arthroscopy in the setting of dysplasia and borderline dysplasia is controversial. Dysplasia severity is most often defined by the lateral center edge angle (LCEA) but can also be evaluated radiographically by the acetabular inclination (AI).

Purpose/Hypothesis: The purpose was to determine the effect of AI on outcomes after isolated hip arthroscopy for femoroacetabular impingement (FAI). We hypothesized that patients with dysplasia would have higher rates of arthroplasty as well as inferior clinical and functional outcomes compared with patients who did not have dysplasia.

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

Methods: A hip arthroscopy registry was reviewed for participants undergoing arthroscopic correction of FAI from February 28, 2008, to June 10, 2013. Participants required a clinical diagnosis and isolated arthroscopic correction of FAI with preoperative imaging and intraoperative cartilage status recorded. AI dysplasia was defined as an AI greater than 10°, LCEA dysplasia as LCEA less than 18°, and borderline LCEA dysplasia as LCEA 18° to 25°. Patients without an acetabular deformity (LCEA 25°-40°; AI $<10°$) served as a control population. Postoperative variables included patient-reported outcome surveys with conversion to arthroplasty as the primary endpoint. Minimum 5-year outcome scores were obtained for 337 of 419 patients (80.4%) with an average follow-up of 75.2 $\pm$ 12.7 months.

Results: This study included 419 patients: 9 (2%) with LCEA dysplasia, 42 (10%) with AI dysplasia, and 51 (12%) with borderline dysplasia. The AI but not LCEA was significantly correlated with lower outcome scores on the modified Harris Hip Score ($r = 0.13$; $P = .01$), Non-Arthritic Hip Score ($r = 0.10$; $P = .04$), and Hip Outcome Score–Sports Subscale ($r = 0.11$; $P = .04$). A total of 58 patients (14%) underwent arthroplasty at 31 $\pm$ 20 months postoperatively. Patients with LCEA dysplasia had an arthroplasty rate of 56% (odds ratio, 8.4), whereas patients with AI dysplasia had an arthroplasty rate of 31% (odds ratio, 3.3), which was significantly greater than the rate for the nondysplastic cohort (13.5%; $P < .0001$). Patients with borderline LCEA dysplasia did not have increased rates of arthroplasty. A multivariate analysis found increasing age, increasing AI, Tönnis grade higher than 1, and femoral Outerbridge grade higher than 2 to be most predictive of conversion to arthroplasty.

Conclusion: We found that an elevated AI, along with increasing age, Tönnis grade, and femoral Outerbridge grade significantly predict early conversion to arthroplasty after isolated hip arthroscopy. We recommend using the AI, in addition to the LCEA, in evaluating hip dysplasia before hip arthroscopy.

Keywords: hip arthroscopy; femoroacetabular impingement; hip; imaging

Hip joint stability represents a complex marriage of dynamic and static anatomic stabilizers that act in concert to promote postural balance, mobility, and dynamic joint motion.[5,6,36] Alterations in soft tissue physiological or osseous morphological characteristics in the setting of hip dysplasia impair the inherent stability of the hip joint.[30,32,35] This may consequently pose a risk for arthroscopy as a tool to address symptomatic intra-articular joint abnormality in the setting of femoroacetabular impingement (FAI). Reports on the use of arthroscopic techniques for dysplastic hips range from cautionary to favorable, with predictors of failure including age, severity of dysplasia, and cartilage status at the time of surgery.[9-11,23,27,33,40,45] In contrast, arthroscopic techniques used to address conditions such as FAI labral-chondral abnormalities or synovial abnormalities have a high rate of good to excellent results, durable therapeutic gain, and a high rate of return to sport.[13,24,34]

Although arthroscopy is well-suited to address intra- and/or extra-articular abnormalities that frequently accompany hip dysplasia, specific concerns have been raised by reports of rapidly progressive joint deterioration

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after arthroscopy on dysplastic hips.[10,11,40] Acetabular coverage in the hip preservation literature is predominantly evaluated through the lateral center edge angle (LCEA) in addition to secondary markers such as the acetabular inclination (AI) and anterior center edge angle (ACEA). A recent study by Vahedi et al[46] found a 24.7% rate of conversion to total hip arthroplasty (THA) at an average of 4 years after hip arthroscopy in a cohort with dysplasia (LCEA <20°) compared with a 2.5% rate in the nondysplastic cohort. Although isolated hip arthroscopy on patients with LCEA dysplasia is generally contraindicated due to high risks of short-term conversion to THA and concerns regarding iatrogenic microinstability, the results after arthroscopy on patients with undercoverage based on other markers of dysplasia are less clear.[10,46,49] Hatakeyama et al[15] recently reported that decreased ACEA and an AI greater than 15° were predictive of reoperation (conversion to THA, revision arthroscopy, or shelf acetabuloplasty) in a cohort of 11 of 45 patients with borderline dysplasia.[15] Further, in a systematic review of patients with LCEA dysplasia and borderline dysplasia, Shah et al[42] found a larger AI, broken Shenton line, and preoperative arthritis (<2-mm joint space) predictive of failure of isolated arthroscopy.[42] Although these studies found that elevated AI in the setting of LCEA dysplasia was associated with premature reoperation, to our knowledge no study has identified AI as an independent risk factor for failure of primary arthroscopy.

The purpose of this study was to determine the effect of AI on outcomes after isolated hip arthroscopy for FAI. Our primary objective was to determine the rate of joint failure, as defined by a conversion to total hip arthroplasty or hip resurfacing, in patients with AI dysplasia (AI >10°) compared with a nondysplastic cohort. A secondary objective was to evaluate the effect of AI dysplasia on postoperative patient-reported outcome (PRO) measures. We hypothesized that patients with AI dysplasia would have higher arthroplasty rates as well as inferior clinical and functional outcomes compared with nondysplastic patients.

METHODS

Patient Selection

An institutional review board (IRB No. 00001341) approved review of prospectively collected data in a hip arthroscopy registry was conducted for patients undergoing surgery for FAI and associated chondrolabral abnormality between February 28, 2008, and June 10, 2013, by the senior author (B.G.D.). A complete data set was requisite to inclusion, and patients between the ages of 14 and 60 years with a minimum 2-year follow-up were deemed eligible for the study. Patients who were treated for extra-articular impingement, underwent open or hybrid open arthroscopic hip surgery, or underwent labral reconstruction were excluded. Likewise, patients who had incomplete documentation of demographic variables, incomplete radiographic data, or age outside the included range were excluded from the study population. Demographic information including sex, age, and body mass index (BMI) was also collected from the registry.

Radiologic Analysis

All patients in this study underwent a thorough preoperative radiographic evaluation. The anteroposterior (AP) pelvic radiographs obtained for the initial clinic visit were used for this study. The AP pelvic radiographs were taken in the supine position and used to measure the LCEA of Wiberg, the AI, and preexisting arthritis according to the Tönnis classification. The LCEA was determined by the angle between a line through the center of the femoral head perpendicular to the transverse axis of the pelvis and a second line drawn from the femoral head center through the most superolateral margin of the weightbearing zone of the acetabulum (Figure 1A).[8,38,44] All measurements were obtained by the senior author during the initial clinic visit. The AI was determined as the angle between a line parallel to the acetabular teardrops beginning at the most inferior point of the sclerotic acetabular sourcil and a line extending from this point to the lateral margin of the sourcil (Figure 1B).[8] Patients with an LCEA of less than 18° or AI greater than 10° were considered to have LCEA or AI dysplasia, respectively, whereas patients with an LCEA between 18° and 25° were considered to have borderline dysplasia. Patients without an acetabular deformity (LCEA 25°-40°; AI <10°) served as the control population. All radiographic measurements were evaluated through use of GE Healthcare's Picture Archiving and Communications System.

Surgical Technique and Rehabilitation

The surgical technique has been published previously.[7,19] In brief, patients with symptomatic FAI with a failure of

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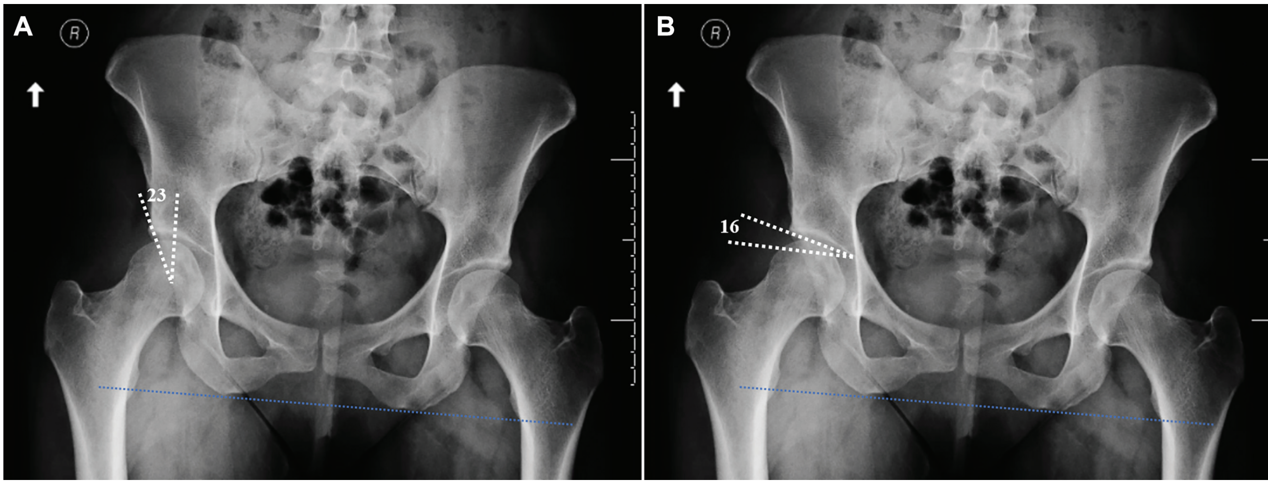

Figure 1. Determination of (A) lateral center edge angle (LCEA) and (B) acetabular inclination (AI) in a patient with borderline LCEA dysplasia and AI dysplasia.

nonoperative management were considered surgical candidates. Hip arthroscopy was performed through anterolateral, modified anterior, and distal anterolateral portals with the patient in the supine position. An interportal capsulotomy was created followed by a diagnostic arthroscopy. Central compartment work included labral repair and rim resection as well as management of other intra-articular abnormalities as indicated. Acetabular rim resection was minimized for patients who had dysplasia and borderline dysplasia. Peripheral compartment work included femoroplasty for cam deformities. After this, the capsule was repaired or left open, closed, or plicated at the surgeon's discretion. Capsular release was defined as a hip capsule that was not repaired intraoperatively. At the time of surgery, acetabular and femoral head cartilage status was graded by the Outerbridge classification.[39] Postoperatively, patients were instructed to maintain toe-touch weightbearing in a brace with deep vein thrombosis prophylaxis consisting of 325 mg aspirin twice daily for 2 weeks. They began physical therapy on postoperative day 1 and transitioned to weightbearing as tolerated beginning in week 3 as part of the 5-phase return-to-sport physical therapy protocol. Patients were evaluated clinically at 2 weeks, 6 weeks, and 3 months postoperatively.

Outcome Assessment

Validated outcome scores including the Hip Outcome Score (HOS),[26] modified Harris Hip Score (mHHS),[26] and Non-Arthritic Hip Score (NAHS)[25] were administered preoperatively and 2 years postoperatively. After the 2-year mark, questionnaires were administered annually. Pain and satisfaction with surgery were collected on a 1- to 10-point visual analog scale. Additionally, patients were followed to assess for endpoint status, including revision surgery and conversion to THA or hip resurfacing. The patients requiring THA or hip resurfacing were combined into an arthroplasty cohort. Of the 419 patients included in the study, 337 (80.4%) completed 5-year outcome scores with a mean postoperative follow-up time of 75.2 ± 12.7 months.

Statistical Analysis

Data were analyzed through use of the JMP statistics platform (version 13.0). PRO scores, as well as age, BMI, LCEA, and AI, were evaluated as continuous variables, whereas capsular management (release vs repair/plication) and endpoint progression were evaluated as categorical variables. One-way analysis of variance was used to compare continuous and categorical variables (ie, outcome scores vs capsular management), the Fisher exact test and the Pearson χ^2 test were used to compare categorical variables (capsular management vs endpoint status), and bivariate regression was used to compare continuous variables (LCEA vs outcome scores). For multiple comparisons (ie, Tönnis grade vs acetabular dysplasia), the Tukey honestly significant difference test was used. A multivariate nominal logistic model was constructed to assess the effects of age, sex, BMI, LCEA, and preoperative joint status (Tönnis grade, acetabular and femoral head Outerbridge grades) on conversion to arthroplasty. This model was repeated to include AI in place of LCEA. Preoperative to postoperative PRO scores were assessed with a matched pair analysis, and the lack of fit test was used to determine the adequacy of nominal logistic models. An a priori power calculation was not performed because this was an analysis of patients enrolled in a prospective registry.[12] An alpha P value of less than .05 was considered statistically significant.

RESULTS

Baseline Demographics and Preoperative Joint Status

The study group had 210 female participants (50%), the mean ± SD study age was 37.7 ± 12.5 years, and the

TABLE 1
Patient Demographic, Radiographic, and Intraoperative Data[a]

	Mean ± SD or n (%)
Demographic parameters	
Patients, n	419
Age, y	37.67 ± 12.54
Female sex	210 (50)
BMI	25.9 ± 5.4
Radiographic indices	
LCEA, deg	31.0 ± 6.5
LCEA dysplasia (LCEA <18°)	9 (2)
Borderline dysplasia (LCEA 18°-25°)	51 (12)
No deformity (LCEA 25°-40°; AI <10°)	336 (80)
Pincer (LCEA >40°)	23 (6)
AI, deg	4.54 ± 4.66
AI dysplasia (AI >10°)	42 (10)
Tönnis grade 0	311 (74)
Tönnis grade 1	98 (24)
Tönnis grade 2	10 (2.5)
Intraoperative cartilage status	
Acetabular Outerbridge grade 0	28 (7)
Acetabular Outerbridge grade 1	106 (25)
Acetabular Outerbridge grade 2	129 (31)
Acetabular Outerbridge grade 3	83 (20)
Acetabular Outerbridge grade 4	73 (17)
Femoral Outerbridge grade 0	319 (76)
Femoral Outerbridge grade 1	8 (2)
Femoral Outerbridge grade 2	32 (8)
Femoral Outerbridge grade 3	35 (8)
Femoral Outerbridge grade 4	25 (6)

[a]AI, acetabular inclination; BMI, body mass index; LCEA, lateral center edge angle.

BMI was 25.9 ± 5.4. Mean follow-up time for the study was 75.2 ± 12.7 months. A total of 257 patients (61%) underwent a capsular release, whereas 162 (39%) patients had joint capsule repair. The mean ± SD LCEA was 30.9° ± 6.5° and AI was 4.5° ± 4.7° (Table 1). A total of 311 (74%) patients had Tönnis grade 0, whereas 98 (24%) and 10 (2.4%) had grades 1 and 2, respectively. We found that 9 (2.1%) patients had dysplasia (determined as LCEA <18°) and 51 patients (12.2%) had borderline dysplasia (LCEA 18°-25°). Further, 42 patients had dysplasia based on the AI; 8 of 42 patients (20%) had both AI and LCEA dysplasia, 17 of 42 (40%) had AI dysplasia and borderline LCEA dysplasia, and 17 of 42 (40%) had a normal LCEA (25°-40°). We found that 23 patients had a pincer deformity (5.5%; LCEA >40°), whereas 336 patients (80%) did not have any acetabular deformity as defined by the LCEA or AI (LCEA 25°-40°, AI <10°). Patients with AI dysplasia had significantly greater age (43.6 ± 14.4 vs 37.0 ± 12.2 years; P = .001), higher BMI (28.5 ± 5.8 vs 25.6 ± 5.3; P = .009), and lower LCEA (22.8° ± 5.5° vs 31.9° ± 5.9°; $P < .0001$) compared with patients without AI dysplasia. No differences were found in sex (48% vs 50% female; P = .73) or Tönnis grade 0 (68% vs 74%; P = .39) between the AI dysplastic and nondysplastic cohorts, respectively.

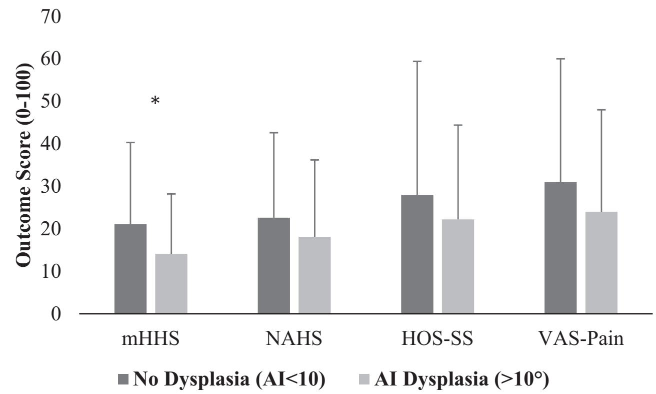

Figure 2. Patient-reported outcome improvements for patients with acetabular inclination (AI) dysplasia versus those without AI dysplasia. Patients with AI dysplasia had significantly lower HHS outcomes compared with patients without dysplasia. HOS-SS, Hip Outcome Score–Sports Subscale; mHHS, modified Harris Hip Score; NAHS, Non-Arthritic Hip Score; VAS-Pain, Visual Analog Scale for pain (1-10). *$P < .05$.

Patient-Reported Outcomes

Significant postoperative improvement was seen in all PROs for both dysplastic and nondysplastic cohorts ($P < .0001$). Increased age was associated with lower improvement on mHHS (r = 0.13; P = .008), HOS–Sports Subscale (HOS-SS) (r = 0.11; P = .03), and pain level (r = 0.15; P = .01). Increasing AI, when evaluated as a continuous variable, was associated with lower improvement in mHHS (r = 0.13; P = .01), NAHS (r = 0.10; P = .04), HOS-SS (r = 0.11; P = .04), and pain scores (r = 0.13; P = .01). Patients with femoral Outerbridge grade 2 changes had significantly lower improvement on the HOS-SS compared with Outerbridge grade 0 patients (11.2 ± 33.1 vs 29.2 ± 29.0; P = .03); however, no other significant differences were seen in scores between other acetabular or femoral Outerbridge grades. Patients with AI dysplasia (AI >10°) had lower improvement on HHS scores (Figure 2) (14.1 ± 20.2 vs 21.1 ± 19.2; P = .03) compared with nondysplastic patients but no significant differences for the NAHS, HOS-SS, or pain scores. No differences were seen in outcome scores for BMI, LCEA dysplasia, borderline LCEA dysplasia, or LCEA when evaluated as a continuous variable.

Reoperation Rates

We noted that 40 (9.5%) patients required a revision arthroscopy at 21 ± 19 months postoperatively, with the majority of patients undergoing surgery secondary to continued pain. No differences were seen in revision rates between the AI or LCEA dysplastic and nondysplastic cohorts (AI dysplasia, 2/42 [4.8%]; LCEA dysplasia, 1/9 [11.0%]; borderline LCEA dysplasia, 5/51 [9.8%]; no dysplasia, 30/336 [8.9%]; $P > .05$). Of these 40 revision cases, 6 patients (15%) eventually required conversion to THA.

TABLE 2
Demographic, Radiographic, and Intraoperative Differences in Groups Requiring Total Hip Arthroplasty After Hip Arthroscopy[a]

	No Arthroplasty	Arthroplasty	*P* Value
Participants	361 (86)	58 (14)	
Age, y	36.1 ± 12.5	47.5 ± 6.6	**<.001**
BMI	25.5 ± 5.4	28.2 ± 4.4	**<.001**
LCEA, deg	31.1 ± 6	30.0 ± 8.7	.14
AI, deg	4.1 ± 4.4	7.0 ± 5.5	**<.001**
Tönnis grade			
0	285 (79)	26 (45)	**<.001**
1	73 (20)	25 (43)	**<.001**
2	3 (1)	7 (12)	**<.001**
Acetabular Outerbridge grade			
0	27 (7.5)	1 (2)	.1
1	100 (28)	6 (10)	**.004**
2	113 (31)	16 (27)	.57
3	73 (20)	10 (17)	.60
4	48 (13)	25 (43)	**<.001**
Femoral Outerbridge grade			
0	290 (80)	29 (50)	**<.001**
1	7 (2)	1 (2)	.94
2	26 (7)	6 (10)	.36
3	20 (6)	15 (26)	**<.001**
4	18 (5)	7 (12)	**.03**

[a]Values are expressed as n (%) of patients or as mean ± SD for the given parameters. The arthroplasty cohort had significantly greater proportions of Tönnis grade 1 and Tönnis grade 2 changes as well as acetabular Outerbridge grade 4 and femoral Outerbridge grades 3 and 4. Boldface indicates statistical significance. AI, acetabular inclination; BMI, body mass index; LCEA, lateral center edge angle.

A total of 58 patients (14%) underwent arthroplasty at 31 ± 20 months postoperatively; 5 patients underwent resurfacing whereas 53 patients required THA. Patients who underwent resurfacing were younger (42.5 ± 4.8 vs 48.0 ± 6.6 years; *P* = .08), had lower BMI (25.6 ± 1.9 vs 28.4 ± 4.5; *P* = .18), and entailed a higher proportion of male patients (80% vs 57%; *P* = .31). Patients requiring arthroplasty (either THA or resurfacing) were older (47.5 vs 36.1 years; *P* < .001), had a higher BMI (28.2 vs 25.5; *P* < .001), and had a higher AI (7.0° vs 4.1°; *P* < .001) (Table 2). Tönnis grades 1 or 2, acetabular Outerbridge grade 4, and femoral Outerbridge grades 3 and 4 entailed significantly higher conversion rates to THA than did grade 0 changes.

Dysplastic Joint Status and Conversion to Arthroplasty

Patients with AI dysplasia, compared with patients who had no deformity, had significantly greater Tönnis grade 2 changes (7% vs 2%, respectively; *P* = .03), acetabular Outerbridge grade 4 changes (33% vs 16%, respectively; *P* = .004), and femoral Outerbridge grade 2 changes (19% vs 7%, respectively; *P* = .003) (Table 3). Patients with borderline LCEA dysplasia, compared with patients with no deformity, had significantly greater acetabular Outerbridge grade 4 changes (31% vs 16%%, respectively; *P* = .007) but no differences in Tönnis grade or femoral Outerbridge scores (Table 3). For the AI dysplastic cohort, 38% (16/42) of participants had grade 2 changes or greater in femoral head Outerbridge grade, compared with 21% (68/336) of patients without deformity (*P* = .007).

We found that 5 of 9 (56%) patients with LCEA dysplasia required arthroplasty at 23 ± 11 months postoperatively compared with 45 of 336 (13%) patients without deformity at 31 ± 18 months postoperatively (Table 4) (*P* < .001). Further, 13 of 42 (31%) of patients with AI dysplasia required conversion to arthroplasty at 34 ± 23 months postoperatively compared with 45 of 336 (13%; *P* = .0007) of the nondysplastic patients. As well, 5 of 8 patients (63%) with both LCEA and AI dysplasia required arthroplasty at 23 ± 11 months postoperatively. Patients with borderline LCEA dysplasia had no increased rates of conversion to arthroplasty after hip arthroscopy compared with patients who had no deformity (12% vs 13%; odds ratio, 0.95; *P* = .93).

Multivariate Analysis

Based on the results from the univariate analysis, a nominal logistic regression analysis was constructed incorporating the effects of age, sex, BMI, LCEA, AI, Tönnis grade, capsular management strategy, and femoral and acetabular Outerbridge grades on conversion to arthroplasty (Table 5). Age (*P* = .0003) and preoperative Tönnis grade 2 (*P* = .002) changes were the most significant predictors of conversion to arthroplasty in our model, followed by increasing AI (*P* = .003), femoral Outerbridge grades 3 and 4 (*P* = .02 and .01), and Tönnis grade 1 (*P* = .02) (Table 5). Acetabular Outerbridge grade, LCEA, sex, and BMI did not significantly affect conversion rates. According to the odds ratio, for every increasing degree of AI, the arthroplasty risk increased by 15%. Similarly, for every increasing year, the arthroplasty risk increased by 7%.

DISCUSSION

In a study of 419 patients undergoing hip arthroscopy for FAI, our hypothesis that AI dysplasia would negatively affect patient outcomes was confirmed. We found that patients with AI dysplasia had higher rates of arthroplasty as well as preoperative Tönnis grade 2 radiographic changes, and intracoperative acetabular grade 4 and femoral grades 2-4 outerbridge changes compared to the nondysplastic cohort. Using a multivariate analysis, we found that age, AI, Tönnis grade higher than 1, and femoral Outerbridge grade higher than 2 were most predictive of conversion to total hip arthroplasty within 5 years of index surgery. We also found that increasing AI was correlated with decreased improvement in multiple PRO scores (HHS, NAHS, HOS-SS, VAS-Pain).

Clinical outcomes for patients with dysplasia and borderline dysplasia after isolated arthroscopic surgery for FAI have been varied in the literature. In a recent

TABLE 3
Preoperative Cartilage Status of Patients With AI Dysplasia, LCEA Dysplasia, and Borderline Dysplasia Compared With Patients Without Acetabular Deformity[a]

	No Deformity	AI Dysplasia	*P* Value	LCEA Dysplasia	*P* Value	Borderline Dysplasia	*P* Value
All participants	336 (80)	42 (10)		9 (2)		51 (12)	
Tönnis grade							
0	248 (74)	29 (71)	.4	6 (67)	.62	39 (7)	.7
1	80 (24)	10 (24)	.92	3 (33)	.5	11 (22)	.75
2	8 (2)	3 (7)	**.03**	0 (0)	.63	1 (2)	.83
Acetabular Outerbridge grade							
0	23 (7)	1 (2)	.24	0 (0)	.42	4 (8)	.76
1	87 (26)	11 (26)	.89	1 (11)	.32	12 (24)	.96
2	102 (30)	9 (21)	.17	2 (22)	.57	13 (25)	.33
3	72 (21)	7 (16)	.6	3 (33)	.3	6 (12)	.11
4	52 (16)	14 (33)	**.004**	3 (33)	.2	16 (31)	**.007**
Femoral Outerbridge grade							
0	261 (77)	26 (63)	.02	6 (67)	.38	35 (68)	.25
1	7 (2)	0 (0)	.36	0 (0)	.69	0 (0)	.31
2	23 (7)	8 (19)	**.003**	2 (22)	.07	4 (8)	.97
3	26 (8)	6 (14)	.14	1 (11)	.66	8 (16)	.07
4	19 (6)	2 (5)	.73	0 (0)	.47	4 (8)	.61

[a]Values are expressed as n (%) of patients. AI dysplasia was defined as AI >10°, LCEA dysplasia as LCEA <18°, borderline dysplasia as LCEA 18°-25°, and no deformity as LCEA 25°-40° and AI <10°. Patients with AI dysplasia had significantly increased Tönnis grade 2, as well as acetabular Outerbridge grade 4 and femoral Outerbridge grade 2 changes, compared with patients with no deformity. Patients with borderline LCEA dysplasia had significantly higher acetabular grade 4 changes. Boldface indicates statistical significance. AI, acetabular inclination; LCEA, lateral center edge angle.

TABLE 4
Arthroplasty Conversion Rates in the Participants With Dysplasia and Borderline Dysplasia[a]

	Arthroplasty Rate, n/N (%)	*P* Value	OR	95% CI
AI dysplasia	13/42 (31)	**.001**	3.3	1.6-6.8
LCEA dysplasia	5/9 (56)	**.0004**	8.4	2.2-32.3
Borderline LCEA dysplasia	6/51 (12)	.75	0.95	0.33-2.0

[a]Conversion rates are compared with the rate of nondysplastic arthroplasty (45/336; 13%). Patients with AI dysplasia had AI >10°; patients with LCEA dysplasia had LCEA <18°; patients with borderline LCEA dysplasia had LCEA of 18°-25°. Boldface indicates statistical significance. AI, acetabular inclination; LCEA, lateral center edge angle; OR, odds ratio.

systematic review, Yeung and colleagues[49] highlighted this discrepancy and postulated that although most studies use the LCEA, the variability in the criteria used to define dysplasia and borderline dysplasia may explain seemingly contradictory results.[49] The indications for hip arthroscopy in the setting of dysplasia have evolved over the course of the past decade, with current guidelines suggesting that isolated hip arthroscopy in the setting of frank dysplasia (LCEA <18°) is contraindicated, and arthroscopy for borderline dysplasia (LCEA 18°-25°) should be approached with caution.[1,16,20,40] This is consistent with the low percentage of patients with LCEA dysplasia who received arthroscopy in our cohort (9/419; 2%); this cohort received surgery before the guidelines were well-established. For the arthroplasty cohort in our study, the LCEA was not significantly different from the nonarthroplasty group (30.0° vs 31.1°); however, the AI was significantly higher (7.0° vs 4.1°; $P < .01$). This change in AI reflects a 45% increased risk in requiring early arthroplasty when using the risk ratio identified in the multivariate analysis. Similarly, a patient with an AI of 10° is at a 150% increased risk of requiring arthroplasty compared with a patient with an AI of 0°. The LCEA dysplastic group (LCEA <18°) had significantly higher rates of conversion to arthroplasty (5/9; 56%); however, the low number of patients with dysplasia (n = 9) receiving surgery precluded meaningful analysis of PROs or preoperative cartilage status. Despite this, the significantly greater proportion of patients requiring early arthroplasty for dysplasia (59%) compared with the borderline dysplasia cohort (12%) is consistent with the recommendations against isolated arthroscopy for the dysplastic population.

Compared with the low number of patients with LCEA dysplasia in our cohort, a substantially greater number of patients had AI dysplasia (42/419; 10%). In a study evaluating patients who required a periacetabular osteotomy (PAO) after failed hip arthroscopy, Ross et al[40] documented an elevated AI (>10°) in 93% of their cohort. The AI has

TABLE 5
Nominal Logistic Multivariate Analysis for Conversion to Arthroplasty After Primary Hip Arthroscopy for Femoroacetabular Impingement[a]

Determinant	*P* Value	OR	95% CI
Age[b]	**.0003**	**1.07**	**–0.12 to –0.04**
Female sex	.75	0.88	–0.44 to 0.32
BMI[b]	.61	1.01	–0.08 to 0.05
LCEA[b]	.22	1.04	–0.11 to 0.03
AI[b]	**.003**	**1.15**	**–0.23 to –0.04**
Tönnis grade 1	**.02**	**2.37**	**–1.6 to –0.1**
Tönnis grade 2	**.002**	**17.8**	**–3.9 to –0.3**
Acetabular Outerbridge			
Grade 1	.42	2.61	–4.0 to 1.1
Grade 2	.17	4.77	–1.8 to 0.4
Grade 3	.24	3.96	–0.8 to 1.2
Grade 4	.22	4.1	–1.1 to 1.05
Femoral Outerbridge			
Grade 1	.82	1.3	–2.3 to 2.8
Grade 2	.28	0.3	–2.2 to 3.4
Grade 3	**.02**	**3.1**	**–3.4 to –0.47**
Grade 4	**.01**	**4.1**	**–1.6 to –0.10**
Capsular release	.96	0.98	–0.45 to 0.47

[a]AI, acetabular inclination; BMI, body mass index; LCEA, lateral center edge angle; OR, odds ratio. Boldface indicates statistical significance.

[b]These are continuous variables where the OR represents cumulative increased risk for every integer increase in the variable (ie, for every 1-year increase in age, there is an 7% increase in conversion to arthroplasty).

also previously been evaluated as a prognostic factor for arthroplasty, with Uchida et al[45] demonstrating elevated AI in their cohort experiencing failure (15° vs 11°), although this did not reach significance (P = .44). In a more recent matched case-control study by Davies et al,[9] the AI and LCEA as well as cartilage wear were directly evaluated as prognostic markers for future conversion to hip arthroplasty. In a group of 44 participants requiring arthroplasty, the investigators reported an average LCEA of 19° and AI of 10.2°, which were both significantly higher than values in the control population that did not require arthroplasty. We found that increasing AI (P = .003) was the third most significant determinant of conversion to arthroplasty, behind increasing age (P < .001) and preoperative Tönnis grade 2 (P = .002) changes, and that patients with AI dysplasia were 3.3 times more likely to require early arthroplasty after isolated hip arthroscopy.

It is well-known that acetabular morphologic features are important determinants of hip joint stability as well as predictors for the future development of osteoarthritis (OA).[21,23,31] In a study of 286 patients after unilateral THA, Murphy et al[31] found that dysplastic characteristics were strong predictors of progression to severe OA in the contralateral hip. In the arthroscopic setting, cartilage damage is a common finding in both FAI and dysplasia; however, the mechanism, severity, and zone of injury are often distinct.[2-4,11,15,22,41] In an arthroscopic evaluation of dysplastic patients before PAO, Ross et al[40] reported high rates of acetabular cartilage wear that proportionally increased with dysplasia severity. Conversely, in a more recent report by Bolia et al,[4] the population with borderline dysplasia (LCEA 20°-25°) was found to have a significantly greater proportion of high-grade femoral head changes (Outerbridge grades 3 and 4) compared with a nondysplastic cohort. Similarly, we found increased rates of Outerbridge grade 3 and 4 changes in our borderline dysplastic cohort, although this did not reach significance, likely due to a smaller sample size. We also found a significant increase in high-grade (grades 2-4) femoral head changes in the patients with AI dysplasia compared with patients without an acetabular deformity. This finding suggests that the femoral head changes in AI dysplastic hips may more closely reflect the borderline LCEA group compared with the truly dysplastic LCEA group.

When considering hip preservation surgery, good outcomes are dependent on identifying the correct diagnosis and pursuing the appropriate treatment plan. Although acetabular dysplasia in the hip preservation literature has primarily referenced the LCEA, this references only lateral coverage of the femoral head by the sourcil.[10,39,41] A thorough evaluation of acetabular coverage parameters will assist the clinician and can include the AI, ACEA, anterior and posterior wall indices, the head extrusion index, crossover and posterior wall signs, and the femoral epiphyseal acetabular roof (FEAR) index.[17,43,48] Given radiographic limitations, advanced imaging can also be used to evaluate the 3-dimensional architecture of the acetabulum to aid in characterizing dysplasia. In a study evaluating preoperative computed tomography (CT) imaging on dysplastic patients undergoing PAO, Nepple et al[37] described 3 common variants of dysplasia in the young adult population: 30% of their cohort had anterosuperior deficiency, 36% had global deficiency, and 34% had posterosuperior deficiency. The variability of acetabular morphologic features, particularly in the setting of undercoverage, limits strictly radiographic interpretation; advanced imaging, typically with CT or magnetic resonance imaging, is generally indicated. In the present study, we identified 34 patients (8%) who had AI dysplasia but no evidence of frank LCEA dysplasia, which supports the practice of obtaining CT imaging before hip preservation surgery to evaluate the 3-dimensional morphologic features of the acetabulum.

Surgical decision making is further complicated in patients with both borderline dysplasia and FAI, as they may have elements of both impingement and instability.[4,15] In a recent study of patients with borderline dysplasia (LCEA 18°-25°) receiving either PAO or hip arthroscopy, McClincy et al[29] reported a significantly increased AI (12.6° vs 4.0°; P < .001) and FEAR index with significantly decreased ACEA and anterior wall index measurements.[29] Further, the investigators identified multiple dysplastic features in the borderline dysplastic population and recommended a comprehensive approach as opposed to an isolated evaluation of the LCEA when assessing acetabular coverage.[29,47] In addition to osseous morphologic characteristics, soft tissue constraints affect the dynamic stability of the hip, and preoperative factors such as fatigue overload, myotendinous atrophy or tendinosis, poor tone, and altered neuromuscular balance may render a joint much less stable and subsequently affect outcomes.[14,18,32,35] The hip preservation surgeon can also distinguish clinical differences between instability (pain with upright activities, abductor fatigue, and a positive apprehension test) and impingement (pain with flexion and internal rotation, negative apprehension test).[28] The complex interactions between presenting symptoms, dynamic (soft tissue) constraints, and global acetabular coverage in the borderline dysplastic population underscore the importance of a thorough examination as well as a complete radiographic and advanced imaging workup before implementing a treatment plan. When evaluating borderline and dysplastic patients, we recommend obtaining low-dose radiation CT scans to evaluate the 3-dimensional morphologic features of the acetabulum.[37]

Limitations

This study has multiple limitations. Despite a large initial cohort size, the numbers of patients with dysplasia were modest for both LCEA (n = 9) and AI (n = 42). This is consistent with other studies and the prevailing theory that dysplasia is a relative contraindication for arthroscopic correction of FAI. Compared with the low number of patients with LCEA dysplasia, a significantly larger number of patients with AI dysplasia were included, and they comprised 10% of the patient population in our study. Additional limitations to this study include the retrospective design and the lack of a control population of patients with dysplasia who did not receive surgery. Future long-term prospective studies will be required to best evaluate how isolated hip arthroscopy, PAO, or hip arthroscopy combined with PAO affect the natural history of OA in adults with dysplasia and borderline dysplasia.

CONCLUSION

We found that hip dysplasia, as defined by either the LCEA ($<18^\circ$) or the AI ($>10^\circ$), predicted early conversion to arthroplasty after isolated hip arthroscopy; and that age, preoperative Tönnis grade, and increasing AI were the 3 most significant factors in early conversion to arthroplasty. Additionally, we found patients with AI dysplasia to have greater preoperative femoral head and acetabular wear compared with patients without an acetabular deformity. We recommend the AI as an important radiographic adjunct to the LCEA when clinicians evaluate hip dysplasia before considering isolated hip arthroscopy.

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