Prevalence of High-Grade Cartilage Defects in Patients With Borderline Dysplasia With Femoroacetabular Impingement: A Comparative Cohort Study

Ioanna K. Bolia, M.D., M.S., Ph.D., Karen K. Briggs, M.P.H., Renato Locks, M.D., Jorge Chahla, M.D., Hajime Utsunomiya, M.D., Ph.D., and Marc J. Philippon, M.D.

Purpose: To compare the prevalence, size, and location of Outerbridge grade III and IV cartilage defects on the femoral head and acetabulum between patients with borderline acetabular dysplasia and patients with non-borderline dysplasia who underwent hip arthroscopy for femoroacetabular impingement (FAI). **Methods:** Patients aged 18 years or older who underwent primary hip arthroscopy for correction of FAI and labral repair from November 2005 to April 2016 were included. We excluded patients with previous hip surgery, a radiographic hip joint space of 2 mm or less, and/or a lateral center-edge angle (LCEA) of less than 20° or greater than 40°. The study patients were divided into 2 groups based on the LCEA on the anteroposterior pelvic radiograph: Patients with an LCEA between 20° and 25° were included in the borderline group, and patients with an LCEA between 25° and 40° were included in the non-borderline group. The prevalence, size, and location of Outerbridge grade III and IV chondral lesions on the femoral head and acetabulum were recorded intraoperatively. Comparisons between groups were performed with the Mann-Whitney *U* test for nonparametric testing and the *t* test for data that were normally distributed. Data were analyzed to calculate odds ratios associated with the various factors. **Results:** In total, 2,429 patients (1,114 women and 1,315 men) met the inclusion criteria. The borderline group consisted of 305 patients (150 men and 155 women), whereas the non-borderline dysplasia group comprised 2,124 patients (1,165 men and 959 women). Outerbridge grade III and IV chondral lesions were found on the femoral head in 118 patients with borderline dysplasia (39%) and 127 patients with non-borderline dysplasia (6%) and on the acetabulum in 132 patients with borderline dysplasia (43%) and 874 patients with non-borderline dysplasia (41%). Patients with borderline dysplasia were 10 times more likely (95% confidence interval, 7.3-13.4; $P < .001$) to have a grade III or IV cartilage defect on the weight-bearing surface of the femoral head ($P < .001$) than patients with non-borderline dysplasia. On the acetabular side, no difference in the prevalence of severe cartilage damage was detected between the 2 groups ($P = .588$). The size of chondral damage was significantly greater in patients with borderline dysplasia on the acetabulum ($P = .039$) compared with the non-borderline dysplasia group. **Conclusions:** Patients with FAI and borderline dysplasia are at higher risk of having Outerbridge grade III and IV chondral damage on the femoral head than patients with non-borderline dysplastic hips. Borderline dysplastic hips also presented with significantly larger chondral defects on the acetabular surface. **Level of Evidence:** Level III, retrospective comparative study.

Hip arthroscopy over the past 10 years has been indicated for the treatment of femoroacetabular impingement (FAI) such as cam and pincer deformities.[1] Through the years, this procedure has advanced to successfully treat a variety of intra- and extra-articular hip diseases including complex chondrolabral pathology and

From the Steadman Philippon Research Institute (I.K.B., K.K.B., R.L., J.C., H.U., M.J.P.) and The Steadman Clinic (R.L., M.J.P.), Vail, Colorado, U.S.A.

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Address correspondence to Karen Kay Briggs, M.P.H., Steadman Philippon Research Institute, 181 W Meadow Dr, Ste 1000, Vail, CO 81657, U.S.A. E-mail: karen.briggs@sprivail.org

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joint instability or microinstability.[2] Acetabular dysplasia is sometimes present during examinations of patients with hip impingement or joint instability.[3]

Different radiographic measurements are used to assess acetabular dysplasia such as the anterior center-edge angle, lateral center-edge angle (LCEA), and Tönnis angle.[4,5] An LCEA of less than 20° measured on the standard anteroposterior (AP) pelvic radiograph is commonly used as a criterion to determine the presence of true acetabular dysplasia. Borderline dysplasia is commonly reported in the literature as an LCEA of 20° to 25°.[6] Wyatt et al.[7] recently introduced the femoro-epiphyseal acetabular roof index, which aids in the identification of the cause of hip pain (FAI or instability) in patients with an LCEA of less than 25°.

Acetabular dysplasia has been associated with various biomechanical consequences such as labral hypertrophy and/or inversion that can lead to a tear and generation of pain.[8] Hip dysplasia also contributes to the pathogenesis of hip osteoarthritis, which is thought to be the result of chronic joint instability and subsequent pathologic biomechanical stress, which leads to chondral surface overload.[9] Russell et al.[10] reported elevated cartilage contact pressures in patients with developmental dysplasia of the hip during the gait cycle. The interaction between structurally abnormal femoral and acetabular bones predisposes the hip to the development of osteoarthritis.[10] Dwyer et al.[11] found that cartilage damage was a strong predictor of conversion to total hip arthroplasty in patients with hip dysplasia. In addition, Wells et al.[12] showed that osteoarthritis develops rapidly in patients with FAI and dysplasia.

To better characterize the patients with hip dysplasia and other bony abnormalities, geographic zone methods have been implemented to predict different patterns of articular cartilage damage based on the hip morphologic changes. Kaya et al.[13] showed that hip morphology influences the pattern of cartilage damage. In a study by Bhatia et al.,[14] factors identified to be associated with Outerbridge grade IV chondral defects included decreased joint space (<2 mm) on the preoperative AP pelvic radiograph, increased time from symptom onset to arthroscopy, and male sex. However, it is unclear whether patients with FAI and borderline dysplasia are more likely to have cartilage damage in the early stages compared with patients with just FAI, which may contribute to the development of osteoarthritis.

The purpose of this study was to compare the prevalence, size, and location of Outerbridge grade III and IV cartilage defects on the femoral head and acetabulum between patients with borderline acetabular dysplasia and patients with non-borderline dysplasia who underwent hip arthroscopy for FAI. We hypothesized that patients with borderline acetabular dysplasia would have a higher prevalence of chondral defects and unique presentation, such as size and location.

Methods

Study Design

This study was approved by the institutional review board. Prospectively collected data were retrospectively analyzed on all hips with FAI syndrome that underwent labral repair by a single surgeon (M.J.P.) between November 2005 and April 2016. The inclusion criteria were age of 18 years or older, primary hip arthroscopy, diagnosis of FAI syndrome,[15] and LCEA between 20° and 40°. Patients were excluded if they had prior surgery on the same hip, a radiographic hip joint space of 2 mm or less, joint pathology other than FAI, and/or an LCEA of less than 20° or greater than 40°. We also excluded patients who underwent labral debridement or labral reconstruction. The study patients were divided into 2 groups: Patients with borderline dysplasia, with an LCEA between 20° and 25°, made up group 1, and patients with non-borderline dysplasia, with an LCEA between 25° and 40°, made up group 2.

Patient Evaluation

Patients who presented to our clinic with hip pain and/or limitation of function underwent preoperative evaluation according to our standardized protocol. Physical examination included special hip tests such as impingement tests (anterior and posterior), the flexion—abduction—external rotation (FABER) distance test, and the hip dial test. Provocation of pain during the anterior or posterior impingement test indicated FAI (cam, pincer, or mixed) and/or labral pathology. The FABER distance test was positive if a difference of more than 4 cm in the FABER distance between the left and right legs existed. Increased FABER distance was associated with reactive soft-tissue tightness, such as muscle contraction, due to intra-articular or peri-articular hip pathology. Hip pain generation during the FABER distance test was indicative of FAI syndrome or sacroiliac joint pathology depending on the location.

The supine AP hip radiograph was used to evaluate the joint space, Sharp angle, Tönnis angle, and LCEA. Pincer FAI was assessed using the crossover sign or the posterior wall sign on the AP pelvis radiograph. Alpha angle measurements were made on the cross-table lateral view before 2014 or on the 45° Dunn lateral view from 2014 to 2016 to assess for cam FAI. Diagnosis of cam FAI was made based on an alpha angle greater than 55°, and diagnosis of pincer FAI was made using the crossover sign or posterior wall sign.[16] The diagnosis was confirmed on dynamic examination at the time of hip arthroscopy.

Table 1. Demographic Characteristics of Patients With Borderline Versus Non-borderline Dysplasia

	Borderline Dysplasia	Non-borderline Dysplasia	*P* Value
No. of patients	305	2,124	
Sex, n	150 M and 155 F	1,165 M and 959 F	.063
Age, yr	33 ± 16 (31.4-35.2)	33 ± 16 (32.3-33.7)	.97
Average LCEA, °	23.3 ± 1.5 (23.3-23.7)	34.5 ± 5 (34.3-34.7)	<.001
Alpha angle. °	73 ± 13.5 (71.5-74.5)	70.6 ± 12.9 (70-71)	.001
WBS angle, °	10.3 ± 4.7 (9.8-10.8)	6.4 ± 6.5 (6.1-6.7)	<.001
Sharp angle, °	42 ± 6.5 (41.2-42.7)	38.8 ± 5.3 (38.57-39.0)	<.001
Lateral joint space, mm	3.9 ± 0.9 (3.8-4.0)	4.0 ± 0.9 (3.96-4.0)	.03
Medial joint space, mm	3.7 ± 0.8 (3.6-3.8)	3.7 ± 0.8 (3.67-3.73)	.74
Fovea joint space, mm	3.8 ± 1.0 (3.7-3.9)	3.9 ± 1.5 (3.8-3.96)	.54
Combined cam and pincer impingement, n	213 (70%)	1,571 (74%)	.13

NOTE. Data are presented as mean ± standard deviation (95% confidence interval) unless otherwise indicated.
F, female; LCEA, lateral center-edge angle; M, male; WBS, weight-bearing surface.

Surgical Technique

The patient was positioned in a modified supine position on a fracture table. Traction was applied to facilitate access to the hip joint. The anterolateral and midanterior portals were established first. After inter-portal capsulotomy, diagnostic hip arthroscopic evaluation was performed with a 70° arthroscope. The presence of cartilage injury was evaluated at both the femoral and acetabular surfaces. Cartilage defects were graded intraoperatively by the senior author (M.J.P.) using the Outerbridge classification. For grade III and IV defects, the size was measured in millimeters with the aid of a 4-mm (tip length) arthroscopic probe. The locations of defects on the acetabulum were recorded as anterior-superior (12- to 3-o'clock position), posterior-superior (9- to 12-o'clock position), anterior-posterior (9- to 3-o'clock position), or other (3- to 5-o'clock and 7- to 9-o'clock positions). On the femoral head, the central and peripheral compartments are divided by the labrum. In the central compartment, perifoveal lesions are in the non—weight-bearing area around the fovea. Weight-bearing lesions are beyond the fovea in the weight-bearing zone.

Statistical Methods

Statistical analysis was performed with SPSS software (version 11.0; SPSS, Chicago, IL). Statistical significance was set at $P < .05$. Comparisons between groups 1 and 2 were performed with the Mann-Whitney U test for nonparametric testing and the t test for data that were normally distributed. Data were analyzed to calculate odds ratios associated with the various factors.

Results

In total, 2,429 patients (1,114 women and 1,315 men) underwent primary hip arthroscopy and met the inclusion criteria. Patient demographic characteristics and preoperative radiographic measurements for both groups are presented in Table 1. Statistically significant differences between the patients with borderline dysplasia and those with non-borderline dysplasia were detected for the Tönnis angle, Sharp angle, LCEA ($P < .001$), and alpha angle ($P = .001$). The prevalence of combined impingement (cam and pincer) was not significantly different between the groups ($P = .13$).

The prevalence and size of cartilage defects on the femoral head and the acetabulum are shown in Table 2. Group 1 patients (borderline dysplasia) were 10 times more likely (95% confidence interval, 7.3-13.4; $P < .001$) to have a grade III or IV cartilage defect on the weight-bearing surface of the femoral head ($P < .001$) than group 2 patients (non-borderline dysplasia). There was no difference between the 2 groups regarding the prevalence of Outerbridge grade III and IV chondral defects on the acetabular surface ($P = .255$). The size of the chondral defects (Outerbridge grade III and IV) on the acetabular surface was significantly larger in patients with borderline dysplasia than in patients with non-borderline dysplasia ($P = .004$).

Table 2. Prevalence and Size of Outerbridge Grade III and IV Cartilage Defects on Femoral Head and Acetabular Side

	Borderline Dysplasia	Non-borderline Dysplasia	*P* Value
Acetabulum grade III or IV defects			
n	132 (43%)	874 (41%)	.42
Size, mean ± SD (95% CI), mm^2	143 ± 155 (117-169)	95 ± 90 (89-101)	.004
Femoral head grade III or IV defects			
n	118 (39%)	127 (6%)	<.001
Size, mean ± SD (95% CI), mm^2	142 ± 125 (119-165)	126 ± 92 (110-142)	.288

CI, confidence interval; SD, standard deviation.

Table 3. Distribution of Chondral Damage Location on Acetabular Surface

Defect Location on Acetabulum	Borderline Dysplasia	Non-borderline Dysplasia	*P* Value
Anterosuperior (12- to 3-o'clock position), n	92 (70%)	625 (72%)	.688
Posterosuperior (9- to 12-o'clock position), n	11 (8%)	130 (15%)	.04
Anterior and posterior (9- to 3-o'clock position), n	24 (18%)	91 (10%)	.012
Other (3- to 5-o'clock and 7- to 9-o'clock positions), n	5 (3.8%)	28 (3%)	.792

The locations of chondral defects on the acetabular and femoral sides are presented in Tables 3 and 4, respectively. Severe chondral damage was most commonly located in the central compartment both in patients with borderline dysplasia (weight bearing, 50%; perifoveal, 14%) and in patients with non-borderline dysplasia (weight bearing, 81%; perifoveal, 15%).

Discussion

This study showed that patients with borderline dysplasia who underwent hip arthroscopy to address FAI were 10 times more likely to have Outerbridge grade III or IV chondral defects on the femoral head than patients with non-borderline dysplasia. No difference in the prevalence of severe cartilage defects on the acetabulum was detected between the groups. The size of the acetabular lesions was significantly larger in patients with dysplasia than in patients with non-borderline dysplasia. In addition, patients with borderline dysplasia showed a tendency for development of severe cartilage damage in the peripheral hip joint compartment, whereas in patients with non-borderline dysplasia, the lesions were mostly located in the perifoveal area (central compartment).

Current literature on hip chondral defects in patients with borderline acetabular dysplasia is limited. Kaya et al.[13] investigated the pattern of cartilage damage on the femoral head and acetabular surfaces of patients with various indications for hip arthroscopy (FAI, joint laxity, and acetabular dysplasia defined by LCEA measurement). The depth of the chondral defects was measured based on the International Cartilage Repair Society grading system.[17] The anatomic localization of the lesions was based on geographic zones as previously described by Ilizaliturri et al.[18] According to Kaya et al., hip morphology is crucial for the pattern of hip cartilage damage. In addition, patients with borderline dysplasia mostly presented with full-thickness cartilage defects (International Cartilage Repair Society grade 3 or 4).[13] Fukui et al.[19] reported 44% and 37% prevalence rates of chondral defects on the femoral head and the acetabulum, respectively, in patients with borderline dysplasia. The grades of the lesions were not reported. Byrd and Jones[20] reported a preoperative diagnosis of chondral damage in 60% of patients who underwent hip arthroscopy and had an LCEA of less than 25°. Domb et al.[21] reported the presence of cartilage defects during surgery in 19 of 22 patients (86.3%) who underwent hip arthroscopy for borderline dysplasia (defined as LCEA $\geq$18° and $\leq$25°) but only 3 of them (13.6%) had grade 3 lesions evaluated by use of the acetabular labrum articular disruption grading system. Nawabi et al.[22] performed osteochondroplasty in 72% of patients who underwent hip arthroscopy to address FAI syndrome and had borderline dysplasia, but whether the cartilage defect was on the femoral head or acetabulum was not reported.

Our study found a relatively high prevalence of Outerbridge grade III or IV cartilage defects in patients with borderline dysplasia who underwent arthroscopic FAI surgery (femoral side, 48.1%; acetabulum, 46.2%). In a previous study of 71 patients including patients with borderline and true dysplasia who underwent arthroscopy for mechanical symptoms before a redirectional osteotomy of the acetabulum, acetabular chondral defects were found in 67.1%.[23] The authors also reported the average surface area of the defect, which was 171.7 mm^2 (range, 1-1,250 mm^2). In addition, the cartilage lesions were evaluated using the Beck classification. In our study the incidence of severe chondral damage on the acetabular side was 46.2% (150 of 324 hips) in patients with borderline dysplasia using the Outerbridge classification.

Similar to the findings of Ross et al.,[23] the size of the acetabular chondral defects in our study was 143 mm^2

Table 4. Distribution of Chondral Damage Location on Femoral Head Surface

Defect Location on Femoral Head	Borderline Dysplasia	Non-borderline Dysplasia	*P* Value
Central compartment, n			
Weight bearing	59 (50%*)	103 (81%*)	<.001
Perifoveal	16 (14%)	19 (15%)	.856
Peripheral compartment, n			
Anterior/medial	40 (34%)	4 (3%)	<.001
Posterior/lateral	3 (2.5%)	1 (0.1%)	.354

*Percentage of patients with severe chondral damage in this location.

on average (standard deviation, 155 mm^2). Shibata et al.[24] showed that hips with instability without inherent bony dysplasia presented a straight-anterior or lateral location of acetabular cartilage damage. There is no consensus in the literature regarding the assessment tool used to evaluate cartilage damage in patients with borderline dysplasia. In addition, the depth and location of chondral defects are not consistently reported. Because of significant study variability on this subject, conclusions regarding the prevalence of chondral defects in patients with borderline dysplasia cannot be made.

As we discussed earlier, the location of the cartilage damage in patients with borderline dysplasia was previously investigated. Kaya et al.[13] found that for the acetabular surface, the chondral lesions most commonly occurred in the anterosuperior region, as well as around the acetabular fossa. Our findings agree with these results. We also found the most common location of severe cartilage damage was anterosuperior (68%). Regarding the site of the lesion on the femoral head in our study group, the most common location (60%) of severe cartilage damage in patients with borderline dysplasia was the weight-bearing surface (anterior, superior, and posterior).[25] Kaya et al. also identified the superior and lateral femoral head surface as the most common location of cartilage defects in patients with borderline dysplasia.

Studies have shown that patients with dysplasia are at higher risk of early-onset osteoarthritis and worse hip arthroscopy outcomes than the non-borderline dysplastic population.[12,26,27] Our study showed that patients with borderline dysplasia are at increased risk of grade III or IV cartilage defects on the femoral head. This may be explained by the abnormal contact between the pericotyloid fossa and apex of the femoral head. Bone morphologic changes characteristic of the dysplastic population might act as focal stress concentrators that may be the forerunner in cartilage degeneration.[13] Chondral damage frequently occurs in the pericotyloid fossa area of the acetabulum and the apex of the femoral head in correspondence to the acetabular lesions. This mechanism of cartilage overloading has also been reported in an older biomechanical study.[25] It is unclear whether this chondral damage hastens the need for bony correction of the dysplasia. These findings may help educate patients and lead to the development of programs to manage the risk. In addition, further research is needed to determine what other factors may increase or decrease the risk of cartilage lesions, including early arthroscopic treatments.

The clinical outcomes of patients with borderline acetabular dysplasia and FAI compared with patients with non-dysplastic FAI have been satisfactory. Significantly improved outcomes, comparable with patients without dysplasia, have been reported in patients undergoing hip arthroscopy in the presence of borderline dysplasia at 2 years' follow-up.[21] Philippon and colleagues[19] reported the clinical outcomes in 100 patients with borderline dysplasia (LCEA of 20°-25°) who underwent primary hip arthroscopy with labral repair, correction of FAI, and capsular closure with 2 years' follow-up. They observed statistically significant ($P < .001$) improvements after surgery compared with preoperative values for the modified Harris Hip Score (from 63.5 points to 84.9 points on average), Western Ontario and McMaster Universities Osteoarthritis Index score (from 25.3 to 9.7 on average), and Short Form 12 physical component score (from 42.5 to 50.9 on average). Hip arthroscopy can be useful in patients with FAI and borderline dysplasia as a diagnostic and therapeutic intervention. The patient selection process is crucial, given that a hip joint space of 2 mm or less on AP radiographs has been associated with poor clinical outcomes.[28]

Limitations

We recognize some limitations of this study. A major limitation is that the borderline dysplastic hips were only diagnosed by 1-dimensional measures. Patients were divided into the 2 groups based on the LCEA. Several other measures, including the anterior center-edge angle, Tönnis angle, and femoral head extrusion index, have been used to diagnose dysplasia. In addition, computed tomography surface area and/or volumetric coverage and acetabular and/or femoral version can provide additional information on the diagnosis of dysplasia. This group of patients was seeking treatment for FAI symptoms. The standard measurement for dysplasia in these patients in our practice is the LCEA. We also used the Outerbridge classification for cartilage defects. Although other classifications have been described, the Outerbridge classification is the most commonly reported, and this allows for comparison of our article with other articles. In addition, multiple observers were involved in data collection. This may limit the reliability of the data; however, studies have shown acceptable inter-rater reliability for many of the measurements used in our study.[29] Additional limitations include the lack of magnetic resonance imaging as a modality for predicting chondral injuries before arthroscopy. No outcome data were included in this study. This study was meant to look only at the odds of severe chondral defects in the 2 patient groups. There was no matching of treatments so that the outcomes could be compared. For example, not all patients underwent microfracture of the chondral defect. It would be difficult to compare the 2 groups' outcomes because they may have undergone different treatments. Finally, we used the crossover sign for the diagnosis of pincer FAI on radiographs; however, its specificity is limited. The crossover sign has also been reported to be a sign of global acetabular retroversion. The final decision on the treatment of pincer lesions was made intraoperatively.

Conclusions

This study showed that in patients with FAI, when borderline dysplasia is present, the odds of having Outerbridge grade III and IV chondral damage on the femoral head are higher compared with non-borderline dysplastic hips. Borderline dysplastic hips also presented with significantly larger chondral defects on the acetabular surface. On the acetabulum, no difference in the prevalence of severe cartilage damage was detected between the 2 groups.

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