A commentary by Steven A. Olson, MD, is linked to the online version of this article.

Outcomes of Periacetabular Osteotomy for Borderline Acetabular Dysplasia

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Background: The optimal surgical treatment (hip arthroscopy compared with periacetabular osteotomy [PAO]) for borderline acetabular dysplasia (lateral center-edge angle [LCEA], 18° to 25°) remains a topic of debate. To date, the literature has focused primarily on arthroscopy outcomes, with only a few small reports on PAO outcomes. The purpose of this study was to define PAO outcomes in a large cohort of borderline hips. In a secondary analysis, we assessed the effect of prior failed arthroscopy, concurrent hip arthroscopy, and concurrent femoral osteoplasty on PAO outcomes in this cohort.

Methods: A prospective database was retrospectively reviewed for patients who underwent PAO for symptomatic instability in the setting of borderline dysplasia (LCEA, 18° to 25°). Of the 232 identified hips, 186 (80.2%) were assessed at a mean follow-up of 3.3 ± 2.0 years postoperatively. The mean patient age was 25.2 ± 8.5 years (range, 14 to 45 years), and 88.2% were female. Thirty hips (16.1%) had undergone a failed prior arthroscopy. Arthroscopy was performed concurrently with the PAO in 130 hips (69.9%), and femoral osteoplasty was performed concurrently in 120 hips (64.5%). The modified Harris hip score (mHHS) was assessed relative to the minimal clinically important difference (MCID) of 8 and patient acceptable symptom state (PASS) of 74. Clinical failure was defined as a reoperation for persistent symptoms or a failure to achieve either the mHHS MCID or PASS.

Results: Of the 156 hips undergoing a primary surgical procedure, clinical success was achieved in 148 hips (94.9% [95% confidence interval (CI), 90.2% to 97.4%]). Two hips (1.3% [95% CI, 0.4% to 4.6%]) underwent reoperation (hip arthroscopy) for persistent symptoms and an additional 6 hips (3.8% [95% CI, 1.8% to 8.1%]) failed to achieve the mHHS MCID or PASS, for a clinical failure rate of 5.1% (95% CI, 2.6% to 9.8%); 8.8% reported dissatisfaction with the surgical procedure. Clinical failure was more frequent among the 30 hips (23.3% [95% CI, 11.8% to 40.9%]; p = 0.001) that had undergone a prior failed arthroscopy. There were no outcome differences between hips that had or had not undergone concurrent hip arthroscopy or femoral osteoplasty.

Conclusions: This study demonstrates excellent early outcomes of PAO for borderline acetabular dysplasia, with significant clinical improvement in 94.9% of patients undergoing a primary surgical procedure; 91.2% were satisfied with the surgical procedure.

Level of Evidence: Therapeutic Level IV. See Instructions for Authors for a complete description of levels of evidence.

The optimal surgical treatment for borderline acetabular dysplasia remains a topic of controversy, with proponents of both isolated arthroscopy and periacetabular osteotomy (PAO) (with or without arthroscopy). "Borderline" describes a transitional acetabular coverage pattern between classic acetabular dysplasia[1] and normal[2] coverage. Traditionally, borderline acetabular dysplasia has been defined by a lateral center-edge angle (LCEA) of 20° to 25°[3], although some authors have recently used 18° to 25° as the most appropriate criterion[4-9].

Although success with isolated arthroscopic treatment (labral repair, cam-type femoral deformity correction, capsular repair and plication) has been demonstrated at a short-term follow-up[10-14], as many as 40% of patients may still experience a suboptimal early outcome[15-17]. A recent systematic review observed high variability in reoperation rates (0% to 46.0% [mean, 14.1%]) across 9 studies (425 patients) at a mean follow-up of 2.3 years[18]. However, reoperation rates alone underestimate clinical failure when patients with continued pain do not choose to undergo a reoperation. Cvetanovich et al. reported a reoperation rate of only 3%, but 13% without reoperation failed to reach the modified Harris hip score (mHHS) minimal clinically important difference (MCID) and 33% without reoperation

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failed to reach the mHHS patient acceptable symptom state (PASS)[19]. Domb et al. reported a reoperation rate of 19%, with an additional 14% that failed to reach the mHHS PASS[4]. The variability of outcomes between these studies also likely stems in part from the difficulty in determining the fundamental mechanical diagnosis underlying symptoms in patients with borderline acetabular dysplasia: femoroacetabular impingement (FAI), which may be adequately assessed and treated with isolated arthroscopy, compared with instability, which may require structural correction through PAO, with or without arthroscopy. A comprehensive assessment of the hip, with consideration of both acetabular and femoral morphology and version, is critical to informing an accurate diagnosis. Currently, there remain no clear clinical guidelines to differentiate between fundamental mechanical diagnoses (impingement compared with instability) and definitively guide treatment selection[20]. Concern remains that, in some patients with borderline acetabular dysplasia, failure to address underlying structural deformity may result in high rates of persistent symptoms[21-23]. Conversely, the increased exposure, recovery time, and potential complication risk of PAO may make it a less attractive treatment for patients with primarily FAI-driven symptoms without instability.

Outcome data for PAO in the setting of borderline acetabular dysplasia remain relatively limited and have only recently been reported. In a recent systematic review[24], Murata et al. identified 10 studies (581 patients) that showed outcomes of isolated arthroscopy and only 2 studies (93 patients)[6,25] that showed outcomes of PAO. Across these and 2 other recent reports on PAO outcomes in borderline hips (20 and 44 hips[7,8]), reoperation rates have ranged from 0% to 3.7%. The rates of clinical failure in these studies ranged from 3.7% to 15.0% and generally compared favorably with those reported for isolated arthroscopy. However, across these studies, the definitions for clinical failure varied, and their relatively small sizes prevented the assessment of the effect of factors such as prior surgical procedures and concurrent procedures on PAO outcomes.

The purpose of this study was to define PAO outcomes in a large cohort of patients with borderline hips. In a secondary analysis, we assessed the effect of failed prior hip arthroscopy, concurrent hip arthroscopy, and concurrent femoral osteoplasty on PAO outcomes in this cohort.

Materials and Methods

A prospective database was retrospectively reviewed to identify patients who underwent PAO for symptomatic instability in the setting of borderline acetabular dysplasia (LCEA, 18° to 25°) from 2010 to 2020 by a single surgeon (J.C.C.). Instability was diagnosed by the treating surgeon based on a comprehensive assessment of patient characteristics, physical examination findings, and imaging, rather than on any single parameter. Key factors considered consistent with primarily instability-driven symptoms included acetabular inclination of >10°, an anterior center-edge angle of <20°, internal rotation in flexion of >20°, and a femoral alpha angle of <55°. PAOs were performed as previously described[26,27]. All patients who were treated with PAO had a Tönnis grade of <2, indicating no radiographic evidence of advanced osteoarthritis, and had undergone failed conservative management[28,29]. The goals of the surgical procedure were to stabilize the hip joint, to address intra-articular pathology (by arthroscopy), and to treat any existing or secondary FAI (by osteoplasty), when indicated. Hip arthroscopy was performed in the same surgical setting immediately prior to the PAO in patients with mechanical symptoms consistent with a labral tear and magnetic resonance imaging (MRI) evidence of labral detachment, to assess and treat central compartment pathology. The need for femoral osteoplasty was determined after PAO correction. Hips with <20° of internal rotation in flexion after PAO correction underwent femoral osteoplasty through an open arthrotomy through the PAO incision, with subsequent capsular closure. Postoperatively, all patients followed a similar rehabilitation course involving 4 to 6 weeks of partial weight-bearing and continuous passive motion.

A total of 260 hips were initially identified. Of these, 11 hips were in patients with an age of <14 years (4 hips) or >45 years (7 hips) at the time of the surgical procedure and were excluded. Seventeen additional hips were excluded because of prior open hip surgery (7 hips [osteotomy]) or diagnosis (10 hips: 8 with Legg-Calvé-Perthes disease, 1 with Ehlers-Danlos syndrome, and 1 with Charcot-Marie-Tooth disease). Of the remaining 232 hips, 186 hips (80.2%) in 178 patients had a minimum 1-year follow-up and were the focus of the study (Fig. 1). This cohort was assessed in the 1 to 6-year follow-up interval to standardize follow-up timing relative to the study period.

Preoperative and postoperative radiographs were reviewed independently of the treating surgeon by a reader with excellent reliability[9]. Measurements included the LCEA, acetabular inclination, and Tönnis osteoarthritis grade[30] on a standing anteroposterior pelvic view, and the anterior center-edge angle (ACEA)[31] on a false-profile view.

Complications and reoperations were recorded. Complications were graded with a modified Dindo-Clavien scheme[32]. Elective implant removal, which was performed in 95 hips (51.1%) at a mean follow-up of 1.1 years postoperatively, was not considered a reoperation. Clinical outcomes were assessed through patient-reported outcome scores gathered preoperatively and at the latest follow-up. In patients who underwent reoperation for persistent symptoms, scores reported prior to reoperation were instead assessed. Scores included the mHHS[33], University of California Los Angeles (UCLA) Activity Score[34], Hip disability and Osteoarthritis Outcome Score (HOOS)[35], and 12-Item Short-Form Health Survey (SF-12)[36]. The primary outcome measure, the mHHS, was additionally assessed relative to the MCID of 8[37] and PASS of 74[38]. Clinical failure was defined as reoperation for persistent symptoms or failure to achieve either the mHHS MCID or PASS.

Statistical analysis was performed to assess changes in patient-reported outcomes and proportions of clinical outcome states. A secondary analysis assessed the effect of prior hip arthroscopy, concurrent hip arthroscopy, and concurrent femoral osteoplasty on PAO outcomes. Categorical variables were

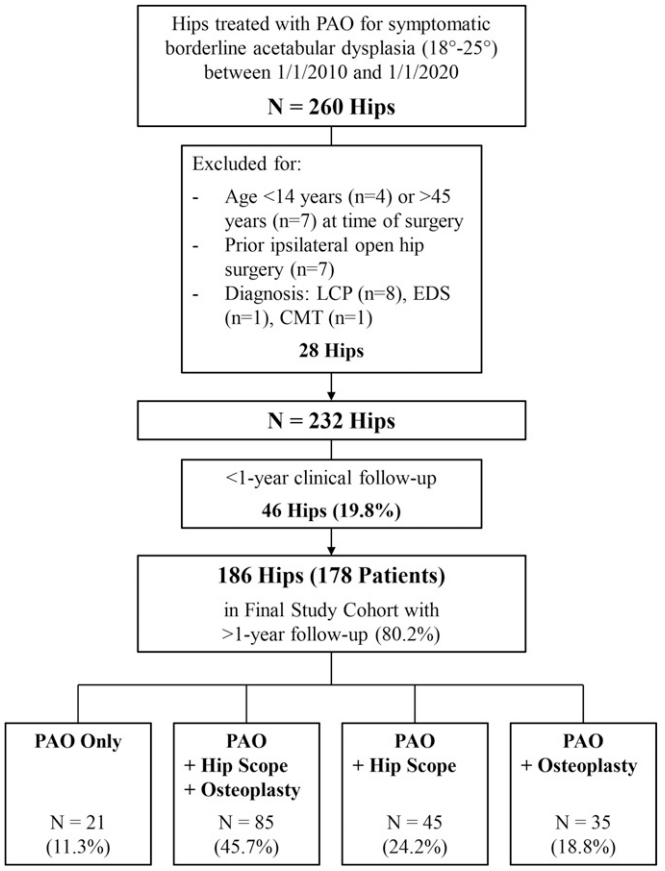

Fig. 1

Hips that were included and excluded in this study and the procedures that were performed. LCP = Legg-Calvé-Perthes, EDS = Ehlers-Danlos syndrome, CMT = Charcot-Marie-Tooth, and hip scope = hip arthroscopy.

compared using chi-square tests, and continuous variables, with 2-tailed Student t tests. Significance was set at $p < 0.05$.

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Results

At the time of the surgical procedure, of the 186 included hips, there was a mean patient age (and standard deviation) of 25.2 ± 8.5 years (range, 14 to 45 years) and patient body mass index of 23.7 ± 3.6 kg/m^2 (18 to 34 kg/m^2), and the patient sex was 88.2% female. The mean LCEA was 20.7° ± 1.9°, with 76 hips (41%) at 18° to 20° and 110 hips [59%]) at >20° to 25°; the mean acetabular inclination was 11.4° ± 3.4°, with 20 hips (11%) at >15°; and the mean ACEA was 21.9° ± 6.3°, with 64 hips (34%) at <20°. The mean internal rotation in flexion was 24° ± 15°, with 63 hips (34%) at <20°. The mean alpha angles were 51.3° ± 18.6° (anteroposterior), 47.6° ± 13.4° (45° Dunn), and 54.5° ± 11.9° (frog-leg lateral). There were 140 hips (75.3%) with Tönnis grade-0 osteoarthritis and 46 hips (24.7%) with Tönnis grade-1 osteoarthritis. Thirty hips (16.1%) had previously undergone arthroscopy, primarily at outside institutions, at a mean time of 2.6 years (range, 0.5 to 8.3 years) prior to the index PAO. Treatments performed at the time of these surgical procedures included labral repair (73.1%), labral debridement (19.2%), psoas release (26.9%), femoral osteoplasty (38.5%), and acetabuloplasty (11.5%). Capsular closure information was not routinely available and likely varied during the period of these initial surgical procedures.

At least 1 additional procedure was performed concurrently with the PAO in 165 (88.7%) of 186 hips (Fig. 1). Concurrent arthroscopy was performed (immediately prior to the PAO) in 130 (69.9%) of 186 hips. Among these 130 hips, 103 (79.2%) underwent ≥1 of the following treatments: labral repair (101 hips [54.3%]), labral debridement (23 hips [12.4%]), acetabular chondroplasty (20 hips [10.8%]), and/or acetabular microfracture (3 hips [1.6%]). Following the PAO, femoral osteoplasty was performed through the PAO incision in 120 hips (64.5%) (Fig. 1).

Following the surgical procedure, the mean LCEA had improved from 20.7° ± 1.9° to 31.3° ± 4.9°, acetabular inclination had improved from 11.4° ± 3.4° to 1.6° ± 4.4°, and ACEA had improved from 21.9° ± 6.3° to 35.2° ± 6.0° (Fig. 2). At the latest follow-up (mean, 3.3 ± 2.0 years), patient-reported outcomes were significantly improved from preoperative baselines across all score domains, including the mHHS (58 to 86), HOOS-Pain (52 to 83), and HOOS-Sport (39 to 76).

There were 5 major complications (2.7%), all requiring reoperation. These included 2 infections requiring irrigation and debridement (Grade III), 1 loss of PAO reduction requiring revision PAO fixation at 1.6 weeks (Grade III), 1 posterior column nonunion requiring open reduction and internal fixation at 5.4 years (Grade III), and 1 instance of psoas tendinitis treated with psoas release and ramus osteoplasty at 0.87 years (Grade III). All 5 of these patients achieved the mHHS MCID or PASS after reoperation for the complication (mean, 3.6 years [range, 1.4 to 7.2 years] after reoperation).

Prior Hip Arthroscopy

Major complications occurred at similar rates among the 156 hips that had not undergone a prior arthroscopy (2.6% [4 hips]) and the 30 hips that had undergone a prior arthroscopy (3.3% [1 hip with infection treated with irrigation and debridement]). However, overall clinical failure rates differed significantly between these 2 groups. Of the 156 hips that had not undergone a prior arthroscopy, 2 (1.3% [95% CI, 0.4% to 4.6%]) underwent reoperation for persistent symptoms (hip arthroscopy at 4.5 and 6.0 years). An additional 6 hips (3.8% [95% CI, 1.8% to 8.1%]) failed to achieve either the mHHS MCID or PASS, for a clinical failure rate of 5.1% (95% CI, 2.6% to 9.8%). Of the 30 hips that had undergone a prior arthroscopy, 1 (3.3% [95% CI, 0.1% to 16.7%]) underwent reoperation for persistent symptoms (hip arthroscopy at 1.8 years). An

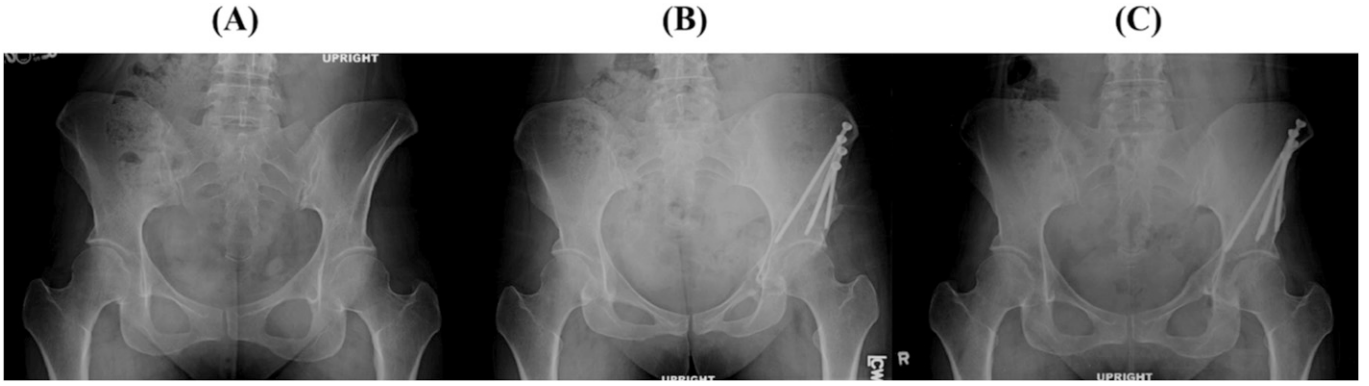

Fig. 2

Preoperative (**Fig. 2-A**), immediate postoperative (**Fig. 2-B**), and follow-up anteroposterior (**Fig. 2-C**) radiographs of a 34-year-old woman with a clinical diagnosis of symptomatic instability in the setting of borderline acetabular dysplasia and a 15-mm anterolateral labral tear in the left hip (preoperative mHHS, 36.3). The patient underwent arthroscopic labral repair and PAO without osteoplasty (hip flexion, 95°; internal rotation in flexion, >20°), with an excellent clinical result at the latest follow-up of 2.9 years (mHHS, 100.1).

additional 6 hips (20.0% [95% CI, 9.5% to 37.3%]) failed to achieve either the mHHS MCID or PASS, for a clinical failure rate of 23.3% (95% CI, 11.8% to 40.9%; p = 0.001) (Table I).

This difference in failure rates between hips that did not or did undergo prior arthroscopy arose despite similarities in follow-up duration (3.3 ± 2.0 compared with 2.9 ± 2.2 years;

TABLE I Patient-Reported Clinical Outcomes for Hips That Had or Had Not Undergone Prior Failed Hip Arthroscopy

	Preoperative			Change			Latest Follow-up*		
Patient-Reported Outcome	No Prior Arthroscopy†	Prior Arthroscopy†	P Value‡	No Prior Arthroscopy†	Prior Arthroscopy†	P Value‡	No Prior Arthroscopy§	Prior Arthroscopy§	P Value‡
mHHS	58 ± 14	57 ± 10	0.800	29 ± 17	25 ± 18	0.367	87 ± 15	82 ± 14	0.173
MCID§ (8)							91.7%	76.7%	**0.015**
PASS§ (74)							78.8%	63.3%	0.067
MCID or PASS#							94.9%	76.7%	**0.001**
UCLA score	6.5 ± 2.7	4.8 ± 1.9	**0.002**	1.0 ± 2.8	2.2 ± 2.1	**0.032**	7.4 ± 1.9	7.0 ± 1.9	0.238
HOOS									
Pain	52 ± 21	48 ± 18	0.299	32 ± 21	29 ± 24	0.547	84 ± 15	78 ± 14	**0.029**
Sport	41 ± 25	30 ± 22	**0.027**	36 ± 25	37 ± 29	0.949	77 ± 20	67 ± 23	**0.012**
Symptom	54 ± 21	44 ± 14	**0.012**	24 ± 22	26 ± 24	0.573	78 ± 17	79 ± 19	**0.028**
Activities of daily living	65 ± 23	60 ± 17	0.263	20 ± 18	21 ± 15	0.591	85 ± 15	82 ± 15	0.314
Quality of life	32 ± 21	19 ± 17	**0.002**	36 ± 25	37 ± 29	0.785	68 ± 22	56 ± 26	**0.016**
SF-12									
Physical	36 ± 10	33 ± 9	0.092	11 ± 11	10 ± 12	0.706	48 ± 9	43 ± 11	**0.028**
Mental	53 ± 10	51 ± 12	0.218	1 ± 11	6 ± 11	0.059	55 ± 9	56 ± 8	0.329
Patient satisfaction									
Satisfied							91.2%	81.5%	0.129
Unsatisfied							8.8%	18.5%	

*There was a minimum 1-year follow-up; the mean follow-up was 3.34 ± 0.9 years (range, 1 to 6 years) for hips that had not undergone a prior hip arthroscopy and 2.91 ± 0.9 years (range, 1 to 6 years) for hips that had undergone prior hip arthroscopy (p = 0.260). †The values are given as the mean and the standard deviation. ‡The significant p values are shown in bold. §The values are given either as the mean and the standard deviation or as the percentage. #For the 3 hips that had undergone reoperation for persistent symptoms, the scores used for all mean score calculations were those collected prior to reoperation, rather than at the latest follow-up (but all 3 were included as MCID or PASS failures).

TABLE II Patient-Reported Clinical Outcomes for Hips with or without Concurrent Osteoplasty or Hip Arthroscopy

Patient-Reported Outcomes	Preoperative			Change			Latest Follow-up*		
	Without†	With†	P Value‡	Without†	With†	P Value‡	Without§	With§	P Value‡
Osteoplasty#									
mHHS	60 ± 12	56 ± 15	0.069	27 ± 18	30 ± 16	0.392	88 ± 14	86 ± 15	0.450
MCID (8)							87.9%	93.9%	0.194
PASS (74)							82.8%	76.5%	0.357
MCID or PASS							91.4%	96.9%	0.128
UCLA	6.2 ± 2.4	6.6 ± 2.8	0.332	1.5 ± 2.9	0.7 ± 2.8	0.133	7.6 ± 2.0	7.3 ± 1.9	0.402
HOOS									
Pain	55 ± 21	50 ± 21	0.168	30 ± 22	34 ± 19	0.314	85 ± 15	84 ± 15	0.578
Sport	46 ± 27	38 ± 24	0.047	35 ± 27	38 ± 24	0.492	81 ± 19	76 ± 21	0.113
Arthroscopy**									
mHHS	62 ± 12	56 ± 15	**0.024**	27 ± 13	30 ± 17	0.333	89 ± 12	86 ± 16	0.301
MCID (8)							95.7%	90.0%	0.244
PASS (74)							82.6%	77.3%	0.447
MCID or PASS							97.8%	93.6%	0.279
UCLA	7.1 ± 2.8	6.2 ± 2.6	**0.043**	0.3 ± 3.2	1.3 ± 2.6	**0.045**	7.4 ± 2.0	7.5 ± 1.9	0.911
HOOS									
Pain	56 ± 20	50 ± 21	0.149	30 ± 19	34 ± 21	0.326	86 ± 14	84 ± 15	0.496
Sport	46 ± 23	39 ± 25	0.093	31 ± 26	39 ± 25	0.098	78 ± 20	78 ± 20	0.996

*The mean follow-up was 3.8 ± 2.1 years (1 to 6 years) for hips that underwent a concurrent osteoplasty and 2.7 ± 1.5 years (range, 1 to 6 years) for hips that did not ($p < 0.001$); the mean follow-up was 3.2 ± 2.1 years (1 to 6 years) for hips that underwent a concurrent arthroscopy and 3.7 ± 1.9 years (range, 1 to 6 years) for hips that did not ($p = 0.120$). †The values are given as the mean and the standard deviation. ‡The significant p values are shown in bold. §The values are given either as the mean and the standard deviation or as the percentage of hips that met the MCID or PASS for each group. For the 3 hips that underwent reoperation for persistent symptoms, the scores used for mean score calculations were those collected prior to the reoperation, rather than at the latest follow-up (all included as MCID or PASS failures). #There were 58 hips that did not undergo osteoplasty and 98 hips that did. **There were 46 hips that did not undergo arthroscopy and 110 hips that did.

$p = 0.260$), patient age (25.3 ± 8.3 compared with 24.7 ± 7.6 years; $p = 0.649$), and patient body mass index (23.5 ± 3.6 compared with 24.8 ± 3.3 kg/m^2; $p = 0.351$). Preoperatively, hips in each group had similar severities of dysplasia as assessed by the LCEA (20.7° ± 1.9° [65 hips (42%) at 18° to 20° and 91 hips (58%) at >20° to 25°] compared with 21.0° ± 1.8° [12 hips (40%) at 18° to 20° and 18 hips (60%) at >20° to 25°]; $p = 0.389$) and ACEA (22.6° ± 6.4° compared with 23.9° ± 7.2°; $p = 0.292$). Hips that had not undergone a prior arthroscopy had slightly higher acetabular inclination (11.7° ± 3.4° compared with 10.0° ± 3.3°; $p = 0.009$). Tönnis grades were similar between groups: 77.6% compared with 63.3% for grade 0 and 22.4% compared with 36.7% for grade 1 ($p = 0.098$). The rates of Outerbridge Grade-3 to 4 acetabular chondromalacia were similar ($p = 0.111$) between hips that had not undergone prior arthroscopy (19.1% [21 of 110]) and those that had undergone prior arthroscopy (35.0% [7 of 20]). No differences between groups were observed in the degree of acetabular correction, and postoperative measurements were similar.

The higher rate of clinical failure in hips that had undergone prior arthroscopy also arose despite comparable preoperative mHHS values between groups (57 compared with 58; $p = 0.800$). Other final patient-reported outcomes that were lower in this group despite preoperative similarities included HOOS-Pain (78 compared with 84; $p = 0.029$) and SF-12 Physical (43 compared with 48; $p = 0.028$). However, patient satisfaction rates were not significantly different between groups at 81.5% compared with 91.2% ($p = 0.129$) (Table I).

Concurrent Procedures

Among the 156 hips that had not undergone a prior arthroscopy, the rates of clinical failure were similar ($p = 0.279$) between those that underwent a concurrent arthroscopy (6.4%) and those that did not (2.2%); the rates were also similar ($p = 0.128$) between those that underwent a concurrent osteoplasty (3.1%) and those that did not (8.6%), as shown in Table II.

Factors Associated with Failure

Among the 156 hips that had not undergone a prior arthroscopy, those with clinical failure had a lower postoperative LCEA (27.7° ± 2.9° compared with 31.7° ± 4.8°; $p = 0.033$) and ACEA (30.6° ± 3.8° compared with 35.5° ± 6.0°; $p = 0.044$) than those without failure. However, preoperatively, groups were similar across all assessed variables (Table III).

TABLE III Factors Associated with Clinical Failure Among the 156 Hips Undergoing Primary Surgery*

Variable	Failure† (N = 8)	Success (N = 148)	P Value†
Patient age§ *(yr)*	26.4 ± 8.8	25.3 ± 8.6	0.729
Patient sex#			0.563
Male	0 (0.0%)	20 (100.0%)	
Female	8 (5.9%)	128 (94.1%)	
Patient body mass index§ *(kg/m²)*	21.3 ± 2.8	23.7 ± 3.6	0.211
Preoperative scores§			
mHHS	60 ± 8	58 ± 14	0.616
UCLA	6.1 ± 2.7	6.5 ± 2.7	0.767
HOOS			
Pain	44 ± 17	53 ± 21	0.273
Sport	35 ± 20	41 ± 25	0.496
Symptom	51 ± 15	54 ± 21	0.754
Activities of daily living	50 ± 25	64 ± 22	0.074
Quality of life	18 ± 15	33 ± 21	0.069
Tönnis grade#			0.538
0	7 (87.5%)	116 (78.4%)	
1	1 (12.5%)	32 (21.6%)	
LCEA			
Preoperative§ *(deg)*	21.2 ± 0.9	20.7 ± 1.9	0.401
Dysplasia severity#			0.334
18° to 20°	2 (3.2%)	62 (96.8%)	
>20° to 25°	6 (6.5%)	86 (93.5%)	
Change§ *(deg)*	6.6 ± 3.3	11.1 ± 5.1	**0.024**
Postoperative§ *(deg)*	27.7 ± 2.9	31.7 ± 4.8	**0.033**
Acetabular inclination§ *(deg)*			
Preoperative	10.4 ± 2.3	11.8 ± 3.4	0.256
Change	−8.0 ± 2.4	−10.6 ± 5.1	0.207
Postoperative	2.4 ± 3.0	1.3 ± 4.5	0.577
ACEA§ *(deg)*			
Preoperative	22.4 ± 7.1	21.9 ± 6.2	0.855
Change	8.3 ± 6.2	13.9 ± 8.1	0.101
Postoperative	30.6 ± 3.8	35.5 ± 6.0	0.044
Concurrent procedure#			
Arthroscopy	6 (75.0%)	104 (70.3%)	0.775
Osteoplasty	5 (62.5%)	85 (57.4%)	0.777

*The mean follow-up was 3.7 ± 1.9 years (range, 1 to 6 years) for hips in the clinical failure group and 3.3 ± 2.0 years (range, 1 to 6 years) for hips in the clinical success group. †Reoperation for persistent symptoms or failure to achieve either the mHHS MCID (8) or PASS (74). ‡The significant p values are shown in bold. §The values are given as the mean and the standard deviation. #The values are given as the number of hips, with the column or row percentage in parentheses.

Discussion

The optimal surgical treatment for borderline acetabular dysplasia remains a controversial topic, with proponents of both isolated arthroscopy and PAO (with or without arthroscopy). To date, the literature has focused primarily on outcomes of isolated arthroscopy[4,11] with only a few small reports (19 to 44 hips) on the outcomes of PAO[6-8,25,39]. To our knowledge, the current series of hips with borderline acetabular dysplasia treated with PAO is the largest reported to date. At the mean follow-up of 3.3 years, significant clinical improvement was observed in 148 hips (94.9%). The major complication rate was low (2.6%), and all of the patients who experienced a major complication had achieved the mHHS MCID or PASS by the final follow-up. Two hips (1.3%) underwent reoperation for persistent symptoms, and an additional 6 hips (3.8%) did not reach either the mHHS MCID or PASS, for an overall clinical failure rate of 5.1% (8.8% were dissatisfied with the surgical procedure).

These results are comparable with those of previous, smaller reports. Among 39 PAO-treated borderline hips (LCEA, 18° to 25°), McClincy et al. noted 1 major complication of pulmonary embolism (2.6%) and no reoperations at a mean follow-up of 2.2 years. Three hips had an mHHS of <70 (7.7% clinical failure)[6]. In a cohort of 44 hips, Møse et al. reported 1 major complication of an obturator nerve injury and adductor paralysis (2.3%) and 1 reoperation (total hip arthroplasty) (2.3%) at a 2-year follow-up. There was significant improvement across all patient-reported outcomes. However, scores were not assessed relative to the MCID or PASS[25]. In a cohort of 27 hips, Ricciardi et al. reported 1 major complication of symptomatic heterotopic ossification (3.7%) and 1 reoperation for heterotopic ossification removal (3.7%) at a mean follow-up of 1.3 years; all achieved the mHHS MCID[7]. At a mean follow-up of 10.1 years, Sierra et al. reported on 19 hips (with LCEA of 18° to 25° and acetabular inclination of 10° to 15°) treated with PAO; 2 hips (10.5%) had undergone reoperation (total hip arthroplasty) and an additional 2 hips had an mHHS of <70 at the latest follow-up (21% clinical failure)[39].

The reports of McClincy et al. and Møse et al. were included in a 2021 systematic review that compared outcomes of PAO (2 studies, 83 patients, mean follow-up of 2 years) and isolated arthroscopy (10 studies, 581 patients, mean follow-up of 3 years) for borderline dysplasia. Although the mean score improvements were similar between the treatment groups, hips treated with isolated arthroscopy had highly varied rates of revision arthroscopic surgery (0% to 25%) and conversion to total hip arthroplasty (0% to 15%)[24]. The persistence of underlying structural disease (dysplasia or FAI) has been reported to be the most common cause of repeat preservation surgery[22] and a leading cause of failed arthroscopic interventions for these pathologies[21,23]. One systematic review of arthroscopic outcomes in dysplastic and borderline dysplastic hips noted an overall 14% rate of revision and a 10% rate of total hip arthroplasty conversion at a mean follow-up of 2.4 years, with similar outcomes in moderate dysplastic and borderline dysplastic hips[40]. Another systematic review examined arthroscopic outcomes specifically in hips with borderline acetabular dysplasia (9 studies, n = 425) and found a mean reoperation rate of 14.1% at the mean follow-up of 2.3 years. However, the rates of persistent symptoms

among patients who did not undergo reoperation were not reported[18].

With contemporary arthroscopic techniques (labral repair, capsular closure, rigorous patient selection), isolated arthroscopic outcomes have been more promising. However, there are subpopulations with poor early outcomes that still need better definition. Cvetanovich et al. reported on 36 hips with borderline dysplasia (LCEA, 18° to 25° [mean, 23.4°]) treated with isolated arthroscopy at a follow-up of 2.6 years. Although there was only 1 reoperation (revision arthroscopy) (2.7%), an additional 13% of hips failed to reach the mHHS MCID and 33% of hips failed to reach the mHHS PASS, suggesting an overall higher rate of persistent symptoms[19]. In a larger cohort (140 hips) by this same surgeon, at the 2-year follow-up, among the hips that did not undergo reoperation, 20% failed to reach the mHHS MCID and 41% failed to reach the mHHS PASS[17]. Domb et al. reported outcomes with isolated arthroscopy in 21 hips with borderline dysplasia (LCEA, 18° to 25°) at the 5-year follow-up and found a reoperation rate of 19%. An additional 14% that did not undergo reoperation failed to reach the mHHS PASS, again suggesting an overall higher rate of persistent symptoms[4].

In comparison, hips in the current study that underwent a primary surgical procedure had a reoperation rate of 1.3% for persistent symptoms. An additional 8.3% of hips failed to reach the mHHS MCID and 21.2% of hips failed to reach the mHHS PASS (with 3.8% reaching neither the MCID nor PASS), for an overall clinical failure rate of 5.1%. For these primary surgical procedures, the only factors associated with clinical failure were postoperative LCEA and ACEA (both lower in those with failure).

A noteworthy finding was the higher failure rate in hips that had undergone prior arthroscopy. This has previously been shown in populations with general hip dysplasia[41,42]. Arthroscopic intervention in an unstable hip may accelerate osteoarthritis progression and decrease the efficacy of subsequent preservation surgery[5,43]. Our results may highlight a similar effect in borderline hips. Hips that had undergone a prior arthroscopy achieved the mHHS MCID or PASS at lower rates than those without prior arthroscopy, despite comparable preoperative mHHS and patient, radiographic, and intraoperative characteristics.

There were several limitations to this study. Its single-surgeon nature (diagnosis and treatment) introduced an increased potential for selection, indication, expertise, and cluster biases, which could have limited generalizability and/or confounded results. Additionally, the small number of hips with failure limited the power of comparisons between failure and success groups and may have prevented identification of additional prognostic factors that may also be important to consider. This limited our analytic approach to an exploratory one with a capacity for hypothesis generation only, particularly with respect to the impact of prior arthroscopy. Finally, hips underwent variable concurrent procedures that could impact clinical outcomes, yet this is representative of contemporary PAO, in which concurrent procedures are indicated on patient-specific bases.

In conclusion, among those undergoing a primary surgical procedure, at a mean follow-up of 3.3 years, the major complication rate was low (2.6%). The rates of reoperation for persistent symptoms (1.3%) were as low as or lower than those reported for isolated arthroscopic interventions at similar intervals. An additional 3.8% of hips that did not undergo reoperation for persistent symptoms failed to reach either the mHHS MCID or PASS, for an overall clinical success rate of 94.9%. Longer-term comparative studies of isolated arthroscopy and PAO (with or without arthroscopy), with thorough characterization of hip morphologies, will be needed to further refine selection for these 2 treatments and to better understand the ideal role of each in the treatment of the hip with borderline acetabular dysplasia. ■

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