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Periacetabular osteotomy for developmental hip dysplasia with labral tears: is arthrotomy or arthroscopy required?

Songkiat Thanacharoenpanich[1], Matthew J. Boyle[2], Robert F. Murphy[3],
Patricia E. Miller[4], Michael B. Millis[4], Young-Jo Kim[4] and Yi-Meng Yen[4]*

[1]Institute of Orthopaedics, Lerdsin General Hospital, Bangkok, Thailand 10500,
[2]Department of Orthopaedics, Starship Children's Hospital, Grafton, Auckland 1023, New Zealand,
[3]Department of Orthopaedics, Medical University of South Carolina, Charleston, SC 29425, USA and
[4]Department of Orthopaedics, Boston Children's Hospital, Boston, MA 02115-5724, USA
*Correspondence to: Y.-M. Yen. E-mail: yi-meng.yen@childrens.harvard.edu
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ABSTRACT

Patients with developmental dysplasia of the hip (DDH) who undergo periacetabular osteotomy (PAO) often have labral tears. The objective of this retrospective study was to compare PAO alone with PAO combined with arthrotomy or arthroscopy in DDH patients who had a full-thickness labral tear on magnetic resonance imaging. In total, 47 hips in the PAO group (PAO) were compared with 60 hips in the PAO with concomitant arthrotomy or arthroscopy (PAO-A) with respect to Hip Disability and Osteoarthritis Outcome Score (HOOS), modified Harris Hip Score (mHHS), Visual Analog Scale (VAS), clinical and radiographic outcomes at a median of 29 months. Reoperation rate and complications were compared between two groups of treatment. The PAO group was younger than the PAO-A group (25.2 ± 9.7 versus 31.3 ± 8.3). The PAO group was more likely to have worse dysplasia: lateral center edge angle ($7.6° \pm 9.63°$ versus $10.8° \pm 6.85°$) and anterior center edge angle ($4° \pm 12.92°$ versus $10.8° \pm 9.92°$). The PAO group had a higher preoperative mHHS (65.2 ± 15.3 versus 57.8 ± 14.8) and HOOS (66.3 ± 17.5 versus 55.8 ± 20.1). There were no significant differences in final functional outcome scores across treatment groups: mHHS (PAO; 86.8 ± 12.4 versus PAO-A, 83.3 ± 17.2), HOOS (86.5 ± 13.3 versus 82.5 ± 16.8) and VAS (2.5 ± 2.8 versus 2.5 ± 3.1). There was no difference in reoperation rate between two groups (6.4% versus 11.6%, $P = 0.51$). The overall complication rate was lower in the PAO group (26% versus 68%), but major complications were comparable. On the basis of our data, we were not able to conclusively demonstrate a clear benefit for the routine treatment of all labral tears; however, arthrotomy or arthroscopy may play a role in some conditions.

BACKGROUND

Developmental dysplasia of the hip (DDH) is one of the more common causes of hip osteoarthritis in young adults. The bony acetabulum in patients with DDH is abnormally shallow, often resulting in labral hypertrophy and forcing the acetabular labrum to play a larger role in weightbearing and joint stability, which may eventually lead to tensile labral failure [1–5]. The weightbearing area of acetabular cartilage is correspondingly reduced resulting in increased cartilage contact forces which can lead to progressive articular cartilage damage. The Bernese periacetabular osteotomy (PAO) is an effective surgical treatment for symptomatic DDH that reorients the dysplastic acetabulum resulting in improved hip stability, femoral head coverage and joint biomechanics [6–9]. Satisfactory outcomes have been reported following PAO, with a hip preservation rate of 76% at 9 years postoperatively [10] and 60% at 20 years postoperatively [11].

Labral pathology is common in patients with DDH, with labral tears reported in 60–100% of patients undergoing

PAO [1, 5]. Labral tears contribute to mechanical symptoms and the generation of hip pain in affected patients. Although PAO has become the mainstay of surgical treatment of symptomatic DDH, the ideal management of associated labral tears is less clear. A PAO biomechanically offloads the damaged labrum, potentially rendering labral pathology obsolete; many studies have reported satisfactory outcomes after isolated PAO despite the high rates of labral pathology in this population [11, 12]. Alternatively, PAO may be combined with hip arthrotomy or arthroscopy to directly assess and treat labral pathology [5, 9, 10, 13–15]; however, the indications and necessity of these additional procedures are unclear. Two reports on arthroscopic treatment of labral pathology after PAO showed modest clinical improvement after arthroscopic surgery [16, 17], suggesting that it may be beneficial to treat labral pathology at the time of PAO. Patients that underwent a concomitant arthroscopy for labral pathology at the time of the PAO had slightly greater improvements in short-term clinical outcomes compared with the PAO alone group in a recent study [14].

There is currently a paucity of information available comparing PAO alone to treatment of labral pathology and PAO in patients with symptomatic DDH and labral tears. The purpose of this study was to compare the clinical, radiographic and functional outcomes after PAO with those after PAO combined with hip arthroscopy or arthrotomy in patients with DDH and full-thickness labral tears on preoperative magnetic resonance imaging (MRI) arthrogram. We hypothesized that PAO combined with hip arthroscopy or arthtomy would demonstrate superior outcomes compared with PAO alone.

MATERIALS AND METHODS

Patient selection
This study is a retrospective review of prospectively collected study data. Following institutional review board approval, a series of 429 patients with DDH who underwent PAO at our institution during April 2009–December 2014 were identified. Study inclusion criteria consisted of skeletally mature DDH patients with a full thickness labral tear on preoperative MR arthrogram (defined as contrast completely traversing the labrum on at least one image) with a minimum of 1 year of follow-up after surgery. Exclusion criteria included any syndromic form of hip dysplasia and those who had incomplete data. After exclusions, a total of 107 hips in 82 patients were enrolled into the final cohort.

Included patients were allocated into two groups; Group 1 (47 hips): patients who underwent PAO alone without joint inspection and without addressing labral pathology (PAO), and Group 2 (60 hips): patients who underwent PAO with concomitant arthrotomy or arthroscopy for evaluation and treatment of intra-articular pathology (PAO-A). In the PAO-A group, 43 hips underwent PAO with arthrotomy whereas 17 hips underwent PAO with arthroscopy. The two groups were compared preoperatively and at final follow-up with respect to clinical assessment, radiographic analysis and functional scores [Harris Hip Score (HHS), Hip Disability and Osteoarthritis Outcome Score (HOOS) subscales and Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC)]. Patients were followed for a mean of 28.11 ± 14.3 months following PAO.

Indications for PAO included a minimum of 3 months of hip and/or groin pain aggravated by activity, despite non-operative management, with radiographic evidence of acetabular dysplasia based on a lateral center-edge angle (LCEA) $<20°$ on an anteroposterior pelvic plain radiograph and/or an anterior center-edge angle (ACEA) $<20°$ on a false profile view. Indications for combined PAO and hip arthroscopy included the prior in addition to a painful, mechanical sensation reported by the patient with hip motion and activity. Indications for combined PAO and hip arthrotomy included the prior in addition to $<10°$ of hip internal rotation with the hip in $90°$ of flexion intra-operatively after repositioning of the acetabular fragment.

Surgical technique
The surgeries were performed by three surgeons; Surgeon A performed PAO in addition to hip arthroscopy or arthrotomy when indicated, Surgeon B performed PAO in addition to hip arthrotomy when indicated, and Surgeon C performed hip arthroscopy only. Hip arthroscopy was performed immediately prior to PAO in selected patients using a two-portal technique and a supine traction table as previously described [18]. Central and peripheral compartments were treated, including labral repair with suture anchors, labral debridement and/or osteochondroplasty of the femoral head neck junction, followed by capsular closure with absorbable suture. PAO was performed according to a previously described technique [19, 20] through an anterior modified Smith Petersen approach. When an arthrotomy was indicated, the direct and reflected heads of rectus femoris were detached and an anterior arthrotomy was performed. The joint was visually inspected, and the central compartment was treated with labral repair using sutures or suture anchors or labral debridement. An osteochondroplasty of the femoral head neck junction was performed to regain internal rotation, followed by capsular closure with absorbable suture and rectus femoris tendon repair with non-absorbable suture.

Postoperatively, all patients were instructed to use crutches with partial weight bearing for the first 6–8 weeks after surgery until radiographic healing was confirmed. Physical therapy was recommended after the 6- or 8-week visit, and gradual increase of functional training was allowed 3 months after surgery. Clinical, radiographic and functional evaluation was then performed at 6 months, 12 months and at 1-year intervals thereafter following surgery.

Clinical data collection
Electronic medical records were used to obtain baseline patient information and symptoms, clinical examination findings, operative details, reoperation or postoperative complication, and duration of follow-up. Postoperative complications were classified according to the modified Dindo–Clavien system [21], which was adapted based on treatment requirement and associated long-term morbidity for hip preservation surgery [22].

Improvement in pain, sports-related activities and hip function was assessed by self-reported questionnaires including the modified HHS (mHHS) (maximum of 100 points) and the HOOS filled before surgery and at a minimum of 1-year follow-up. The HOOS consists of items measuring pain, function in activities of daily living, function in sports and recreation, hip-related quality of life and other symptoms. Each subscale is from 0 to 100, where 0 indicates the worst problem and 100 indicates no problem.

Radiographic evaluation
All radiographs were evaluated by an independent author (S.T.). Preoperative and postoperative anteroposterior radiographs of the pelvis were used to measure the LCEA, Tönnis angle (TA) and Tönnis grading. Preoperative and postoperative false-profile radiographs of the involved hip were used to measure the ACEA. Preoperative and postoperative Dunn lateral radiographs were used to measure the alpha angle of the head–neck junction. Hip joint congruency was evaluated preoperatively and postoperatively with the Yasunaga [23] system by measurement of an anteroposterior radiograph of the pelvis with the hip in maximum tolerable abduction and internal rotation.

Statistical analysis
Baseline information, clinical examination findings, radiographic measurements, operative details and patient-reported outcome measures were summarized for all hips in the study. Categorical characteristics were summarized by frequency and percentage, whereas continuous characteristics were summarized by mean and standard deviation or median and interquartile range (IQR, 25th–75th percentile)

when data deviated from normality. These characteristics were compared across treatment groups using chi-squared tests for categorical and binary variables and Student's *t*-test or the Mann–Whitney *U*-test for continuous variables.

The study's primary outcome was the mHHS. Secondary outcomes included all HOOS domain scores and pain scores. All scores were recorded preoperatively and at most recent follow-up, and mean change in score was assessed along with the 95% confidence interval (CI) for each outcome. Changes in scores were compared across treatment groups using multivariable general linear modeling to control for preoperative characteristics, including patient age, preoperative anterior impingement sign, preoperative mechanical symptoms, preoperative alpha angle, preoperative center-edge angle and chondromalacia. Normality of outcomes was verified using the Shapiro–Wilkes test. All tests were two-sided and *P*-values <0.05 were considered significant.

Overall complication rate was calculated as the proportion of subjects who experienced at least one complication. The most severe complication that a subject experienced was used. The complication rate was estimated for the cohort along with a 95% CI and compared across treatment groups using logistic regression analysis. Complication severity was compared across treatment groups using univariable and multivariable ordinal logistic regression. Odds ratios (OR) with 95% CIs were estimated for significant outcomes across groups.

Subgroup analysis was conducted to compare the change in outcomes across three treatment groups, including PAO only, PAO with arthrotomy and PAO with arthroscopy. The same methods as above were applied across three groups.

An *a priori* power analysis determined that at least 18 subjects were required in order to detect an effect size of 0.5 for the change in mHHS across groups using repeated measures ANOVA at the 5% significance level to achieve 80% power assuming a conservative correlation between measures of 0.10. Although more than 18 subjects would be required to account for the unbalanced nature of the data as well as adjusting for preoperative covariates, we can assume that the 107 subjects obtained for this study were sufficient.

RESULTS

Clinical characteristics
A total of 107 hips in 82 patients were included in the study, with a mean age at surgery of 28 years (range 13.8–48.0 years). Baseline patient information, clinical characteristics and radiological variables for the two patient groups are displayed in Table I. At the time of surgery,

Table I. Baseline characteristics across treatment groups for the entire cohort ($N = 107$)

Variable	PAO (n = 47)		PAO-A (n = 60)		P
	Mean	±SD	Mean	±SD	P
Age (years)	25.2	± 9.65	31.3	± 8.63	0.001
Sex (% male)	6	(13%)	5	(8%)	0.46
BMI	24.8	± 4.37	25	± 4.19	0.77
Side (% right)	23	(49%)	29	(48%)	0.95
Duration of symptoms [months; median (IQR)]	36	(10–56)	36	(18–61)	0.20
Mechanical symptoms (% yes)	28	(60%)	40	(67%)	0.45
Chondromalacia on MRI (% yes)	30	(64%)	43	(72%)	0.39
Anterior impingement sign (% positive)	36	(77%)	56	(93%)	0.02
Posterior impingement sign (% positive)	0	(0%)	3	(5%)	0.99
Trendelenburg gait (% abnormal)	16	(34%)	20	(33%)	0.94
Trendelenburg's sign (% positive)	18	(38%)	31	(52%)	0.17
LCEA	7.6	± 9.63	10.8	± 6.85	0.05
ACEA	4	± 12.92	10.8	± 9.92	0.005
Tonnis angle	23	± 6.47	21.4	± 6.43	0.21
Alpha angle	49.2	± 7.13	60	± 11.23	<0.001
Joint space width (mm)	4.4	± 1.11	4.3	± 0.67	0.50
Joint congruency					
Excellent	23	(49%)	42	(70%)	0.04
Good	1	(2%)	2	(3%)	
Fair	2	(4%)	16	(27%)	
Tonnis grade					
0	24	(51%)	20	(33%)	0.22
1	18	(38%)	38	(63%)	
2	5	(11%)	2	(3%)	
Pain	6.1	± 3.07	6.6	± 2.62	0.41
mHHS	65.2	± 15.32	57.8	± 14.77	0.02
HOOS total score	66.3	± 17.52	55.8	± 20.06	0.008
Symptoms	66.6	± 17.45	53.1	± 21.22	0.002
Pain	62.8	± 20.30	53.4	± 21.11	0.03
Function	75.6	± 18.91	66.6	± 23.13	0.04
Sports	52.4	± 24.47	36.8	± 26.22	0.003
Quality of life	40.2	± 21.32	28.4	± 18.10	0.004

Table II. Change in radiographic measurements from preoperative to postoperative by treatment group

	Preoperative				*Postoperative*				*Change*				
	PAO only		*PAO-A*		*PAO only*		*PAO-A*		*PAO only*		*PAO-A*		
	Mean	*±SD*	*Mean*	*±SD*	*Mean*	*±SD*	*Mean*	*±SD*	*Mean*	*±SD*	*Mean*	*±SD*	*P**
LCEA	7.6	± 9.63	10.8	± 6.85	30.1	± 5.97	28.3	± 4.84	22.5	± 8.25	17.5	± 6.56	0.002
ACEA	4	± 12.92	10.8	± 9.92	28.6	± 7.45	28.8	± 6.03	24.9	± 11.19	18.1	± 8.50	0.002
Tonnis angle	23	± 6.47	21.4	± 6.43	6.3	± 4.08	7	± 3.97	−16.7	± 5.57	−14.4	± 5.72	0.04
AA	49.2	± 7.13	60	± 11.23	47.9	± 5.39	50.3	± 7.34	−1.3	± 4.91	−9.4	± 10.50	<0.001
JSW	4.4	± 1.11	4.3	± 0.67	3.7	± 0.81	3.9	± 0.60	−0.6	± 0.86	−0.3	± 0.68	0.04
	Freq.	(%)	Freq.	(%)	Freq.	(%)	Freq.	(%)	Freq.	(%)	Freq.	(%)	P
Joint congruency													
Excellent	23	(49)	42	(70)	35	(74)	53	(88)	12	(26)	11	(18)	0.75
Good	1	(2)	2	(3)	5	(11)	0	(0)	4	(9)	−2	(−3)	
Fair	2	(4)	16	(27)	6	(13)	7	(12)	4	(9)	−9	(−15)	
Tonnis grade													
0	24	(51)	20	(33)	18	(38)	17	(28)	−6	(−13)	−3	(−5)	0.46
1	18	(38)	38	(63)	23	(49)	38	(63)	5	(11)	0	(0)	
2	5	(11)	2	(3)	6	(13)	5	(8)	1	(2)	3	(5)	

*P-values are result of the comparison of the change in measurement across treatment groups.

the PAO group was significantly younger (mean 25.2 ± 9.65 years versus 31.3 ± 8.63 years, $P = 0.001$) than the PAO-A group, but was otherwise comparable with respect to gender, operative side, body mass index (BMI), and some clinical findings and duration of follow-up (Table I).

Radiographic characteristics

The PAO group displayed a lower preoperative LCEA, ACEA and alpha angle than the PAO-A group; however, there was no significant difference in TA between the two groups (Table I). Overall, the PAO group displayed inferior joint congruency on preoperative von Rosen radiographs compared with the PAO-A group. Radiographic measurements were significantly improved postoperatively in both patient groups (Table II).

Surgical parameters

There was no significant difference in estimated blood loss between the two groups (800 ml (IQR= 420–1200 ml)

versus 850 ml (IQR= 600–1010 ml, $P = 0.27$). Surgical duration was shorter for the PAO group [150 min (IQR= 120–260 min) versus 300 min (IQR= 210–340 min), $P < 0.0001$].

Among the 60 hips in the PAO-A group, 43 of 60 (72%) underwent PAO with arthrotomy and 17 of 60 (28%) underwent PAO with arthroscopy. A total of 25 of 60 hips (42%) had labral tears confirmed on inspection intraoperatively; of the hips that underwent concomitant arthroscopy, 16 of 17 hips (94%) had an identified labral tear, whereas 9 of 43 hips (21%) that underwent arthrotomy had an identified labral tear. Among the PAO-A patients, additional treatment procedures were performed as following; 36 of 60 hips (60%) underwent head–neck osteochondroplasty, 13 of 60 hips (22%) had an acetabular chondroplasty, 13 of 60 hips (22%) underwent labral repair, 6 of 60 hips (10%) underwent labral debridement, 2 of 60 hips (3%) underwent acetabular microfracture, 3 of 60 hips (5%) underwent ligamentum teres debridement, and 3 of 60 hips (5%) underwent recession of the anterior inferior iliac spine.

Table III. Final measurements and outcomes at final follow-up

Variable	PAO (n = 47)		PAO-A (n = 60)		P
	Mean	± SD	Mean	± SD	
Pain	2.5	± 2.81	2.5	± 3.12	0.94
mHHS	86.8	± 12.42	83.3	± 17.23	0.24
HOOS total score	86.5	± 13.28	82.5	± 16.78	0.19
Symptoms	78.2	± 18.55	75.2	± 15.66	0.37
Pain	85.9	± 15.31	83.7	± 18.06	0.51
Function	92.5	± 11.78	89.4	± 15.71	0.27
Sports	77.9	± 21.41	71	± 23.47	0.12
Quality of life	72.6	± 18.50	64.4	± 25.06	0.07
Duration of follow-up [months; median (IQR)]	25	(13–37)	31	(16–54)	0.21

Table IV. Change in outcome scores from preoperative to final follow-up across treatment groups

Outcome	PAO (n = 47)		PAO-A (n = 60)		Unadjusted P-value	Adjusted* P-value
	Mean difference	95% CI	Mean difference	95% CI		
Pain	−3.7	(−4.89, −2.32)	−4.1	(−5.19, −3.06)	0.38	0.32
mHHS	21.6	(15.88, 27.32)	24.8	(19.61, 31.27)	0.64	0.58
HOOS total score	20.2	(13.84, 26.58)	26.7	(20.02, 33.40)	0.22	0.55
Symptoms	11.6	(4.22, 18.97)	22.2	(15.42, 28.91)	0.08	0.20
Pain	23.1	(15.71, 30.46)	30.3	(23.15, 37.35)	0.44	0.98
Function	16.9	(10.43, 23.37)	22.7	(15.59, 29.91)	0.11	0.48
Sports	25.5	(16.11, 34.95)	34.3	(25.27, 43.27)	0.49	0.78
Quality of life	32.4	(24.26, 40.62)	35.9	(28.03, 43.85)	0.52	0.31

*Adjusted P-values are based on multivariable regression models controlling for baseline covariates.

Patient reported outcomes

Preoperatively, the PAO group displayed slightly higher patient-reported scores compared with the PAO-A group (Table I). Both patient groups demonstrated significant postoperative improvements in mHHS, HOOS total score, all of the HOOS domain scores and pain scores (Table III), with no significant difference between the groups (Table IV). Multivariable analysis determined that there was no significant difference between the PAO group and PAO-A group when controlling for preoperative characteristics (Table IV). If minimally important change was defined as multivariable analysis was also undertaken for comparisons among the three specific surgical subgroups (PAO, PAO and arthrotomy, PAO and arthroscopy); there was no significant difference in the postoperative changes when controlling for preoperative factors (Table V). Minimum important change (MIC) was defined as an improvement in mHHS of 8, improvement in HOS Activities of Daily Living subscale (HOS-ADL) 9, improvement in HOS Sport subscale (HOSSport) 6 or absolute score 90 [14]. Utilizing these criteria, 79.8% in the PAO group and 80% in the PAO-A group achieved minimum important change.

Table V. Change in outcome scores from preoperative to final follow-up across three treatment subgroups

Outcome	PAO only (n = 47)		PAO ± arthrotomy (n = 42)		PAO ± arthroscopy (n = 17)		Unadjusted P-value	Adjusted* P-value
	Mean difference	95% CI	Mean difference	95% CI	Mean difference	95% CI		
Pain	−3.7	(−4.92, −2.38)	−4.2	(−5.55, −2.8)	−3.9	(−5.62, −2.26)	0.77	0.66
mHHS	21.5	(15.6, 27.3)	26.8	(19.48, 34.03)	22.8	(13.19, 32.46)	0.46	0.41
HOOS total score	20.4	(13.71, 27.09)	26.9	(18.6, 35.15)	26.2	(15.18, 37.14)	0.06	0.13
Symptoms	12.2	(4.75, 19.63)	20.8	(12.39, 29.27)	24.4	(12.54, 36.28)	0.03	0.08
Pain	23.3	(15.77, 30.8)	30.6	(21.93, 39.26)	29.3	(16.33, 42.2)	0.14	0.31
Function	17.0	(10.09, 23.98)	23.2	(14.19, 32.1)	21.7	(11.39, 32.04)	0.04	0.12
Sports	25.9	(16.33, 35.49)	33.6	(22.73, 44.53)	35.3	(18.35, 52.24)	0.65	0.36
Quality of life	32.6	(24.24, 40.85)	35.9	(26.18, 45.54)	36.0	(21.8, 50.26)	0.20	0.11

*Adjusted P-values are based on multivariable regression models controlling for baseline covariates.

Reoperation and complications

At the median follow-up of 29 months, 10 hips (9.3%) had undergone reoperation. Three of 47 hips (6.4%) in the PAO group had undergone reoperation as follows; 1 total hip arthroplasty, 1 revision PAO in conjunction with intertrochanteric osteotomy and 1 arthroscopic labral repair with concomitant intertrochanteric osteotomy. Seven of 60 hips (11.6%) in the PAO-A group had undergone reoperation as follows: 1 total hip arthroplasty, 4 cases of arthroscopic labral debridement, 2 cases of heterotopic ossification (HO) excision and 1 revision PAO. There was no statistical difference in reoperation rate between the PAO and PAO-A group ($P = 0.51$). Of note, all of the reoperations in the PAO-A group had undergone arthrotomy.

The overall complication rate for the cohort was 49.5%; (95% CI = 39.8–59.3%). Each complication was considered individually; thus, a single hip could have more than one complication (Table VI). Twelve of 47 hips (26%) in PAO group and 41 of 60 (68%) in PAO-A group were associated with at least one complication; this difference was statistically significant ($P = 0.001$). Adjusted analysis determined that the PAO-A group had a five times the odds of a complication compared with the PAO only group (OR = 5.3; 95% CI = 1.89-14.92; $P < 0.001$). Only 6 hips in PAO group and 14 hips in PAO-A groups developed complications classified as Grade 2 or higher, requiring medical or surgical intervention (Table VII). Major complications classified as Grades 3 and 4 occurred in two hips (4%) in the PAO group and two hips (3%) in the

PAO-A group (Table VII). In the PAO group, there was one wound hematoma requiring incision and drainage and one residual femoral head undercoverage requiring revision PAO. In the PAO-A group, there was one HO case requiring excision and one residual femoral head undercoverage requiring revision PAO and intertrochanteric osteotomy. HO occurred after surgery in the PAO group significantly less than in the PAO-A group [7 hips (15%) versus 29 hips (48%), $P = 0.002$].

DISCUSSION

In this retrospective study, we did not find any significant differences in clinical, radiological or functional outcomes between patients that underwent PAO alone and patients that underwent combined PAO and hip arthroscopy or arthrotomy for the treatment of symptomatic DDH in the presence of a labral tear found on MRI.

Previous authors have reported on the satisfactory outcomes following PAO; however, the treatment of any labral pathology varies widely within these reports. Matta *et al.* [24] reported on positive results after PAO alone, and the authors changed from routinely performing an arthrotomy with their PAOs to just the PAO alone as they felt that the arthrotomy and the treatment of the labral tear did not affect their outcomes. In 2009, Matheney *et al.* [10] reported on a series of 135 hips in which 61% of the hips underwent an arthrotomy at the time of the PAO. They did not find that the presence of a labral tear was a predictor of a poor outcome. Similarly, in 2008, Troelsen *et al.* [25] reported on his trans-sartorial technique for

Table VI. Complications by treatment group according to modified Dindo–Clavien system

	PAO = 47, n (%)	PAO-A = 60, n (%)
Grade 1		
HO (Grade 1, or 2)	7 (15)	28 (47)
Spinal headache	0 (0)	1 (2)
Broken and retained Instrument	0 (0)	1 (2)
Grade 2		
LFCN dysesthesia	2 (4)	8 (13)
Peroneal nerve neurapraxia	1 (2)	3 (5)
Delayed union pubic rami (minimal symptom)	1 (2)	0 (0)
Non-union ischial stress fracture (minimal symptom)	0 (0)	1 (2)
Wound complication (central wound breakage, stitch abscess)	0 (0)	2 (3)
Grade 3		
HO (Grade 3 requiring excision)	0 (0)	1 (2)
Wound hematoma (requiring incision and drainage)	1 (2)	0 (0)
Undercoverage (requiring revision PAO)	1 (2)	1 (2)
Grade 4		
None		

Table VII. Complications by treatment groups

Variable	PAO (n = 47)		PAO-A (n = 60)		Unadjusted P-value	**Adjusted*P-value**	Odds ratio	(95% CI)
	Mean	± SD	Mean	± SD				
At least one complication	12	(26%)	41	(68%)	<0.001	0.001	5.3	(1.89–14.92)
Complication grading								
1	6	(50%)	25	(61%)	0.35	0.95		
2	4	(33%)	14	(34%)				
3	2	(17%)	2	(5%)				
4	0	(0%)	0	(0%)				

Odds ratios were estimated from adjusted analysis.
*Adjusted P-values are based on multivariable regression models controlling for baseline covariates.

PAOs in 94 patients and stated that intra-articular assessment was unnecessary. Hartig-Andreasen *et al.* [17] recommended PAO alone for symptomatic DDH, and suggested that patients with continued hip pain after PAO, that is thought to be related to a labral tear, can potentially then be referred for arthroscopic treatment. In contrast, Peters *et al.* [26] reported a change in their surgical procedure to routinely combining an arthrotomy with the PAO due to

concern regarding the potential impact of intra-articular pathology on patient outcomes. Similarly, Kim *et al.* [27] prospectively reported 43 consecutive hips that were treated by combined PAO and arthroscopy, with an average improvement in HHS from 72 to 94 at a mean follow-up of 74 months, and therefore recommended PAO with concomitant hip arthroscopy be considered in all patients. In a recent study, Ricciardi *et al.* [14] also reported a similar improvement in clinical outcomes with patients that had an arthroscopy with a PAO compared with PAO alone. However, compared with our study, Ricciardi *et al.* did not use a preoperative MRI labral tear as an inclusion criteria.

Although PAO alone does result in positive clinical outcomes, it is important to note that there are patients that require additional surgery for associated labral pathology. Previous authors have reported varying rates of success of hip arthroscopy after PAO, which appear to be independent of whether an arthotomy was performed at the time of previous PAO. In 2012, Nassif *et al.* [28] presented a series of 48 cases of PAO alone, with no arthrotomy or arthroscopy, and found a subsequent rate of hip arthroscopy of 8.3% at 2.8 years after PAO. Cvetanovich *et al.* [16] found a rate of 3.1% of hip arthroscopy after PAO, in a series of 556 patients, 56% of whom had undergone combined PAO and arthrotomy. Hartig-Andreasen *et al.* [17] found that 27% of patients underwent a hip arthroscopy within 2 years of a PAO, but those patients that had a PAO alone were functioning better than those had a hip arthroscopy after the PAO. Matheney *et al.* [10] presented a similar series of 157 patients treated with PAO for DDH, 61% of whom had undergone combined PAO and arthrotomy, with a subsequent rate of hip arthroscopy of 11% at a mean of 6.8 years. In our series, none of the patients in the PAO alone group underwent subsequent arthroscopy; however with longer follow-up this remains a possibility. Four patients in the PAO-A group in our study, all of whom had undergone arthrotomy at the time of PAO, subsequently underwent arthroscopic surgery to address labral pathology. Outcomes of hip arthroscopy after PAO are difficult to predict, with a recent study demonstrating no functional improvement after post-PAO hip arthroscopy despite treatment of intra-articular pathology [16]. It may therefore be advantageous to consider concomitant treatment of labral pathology at the time of PAO in selected DDH patients.

In our series, arthroscopy appeared to be superior at identifying a labral tear compared with arthrotomy, which correlates with previous studies [14, 29]. In the PAO-A group in our study, only 42% of the hips had a labral tear identified despite clear evidence of a labral tear with preoperative MRI arthrography. Arthroscopy was able to accurately identify a tear 94% of the time, whereas arthrotomy only identified 21% of hips as having a labral tear. Although it is possible that the labrum may have healed or stabilized between the time of the MRI and surgery, it is more likely that the actual visualization afforded by the arthrotomy technique is inadequate for a complete labral assessment. The four patients in the PAO-A group that required a hip arthroscopy after the original surgery to address labral pathology were all from the arthrotomy subgroup, which supports this hypothesis. In a recent systematic review, Redmond *et al.* presented 151 cases of combined PAO and arthrotomy and 194 cases of combined PAO and arthroscopy. Labral tears were identified in 31 cases (21%) within the arthrotomy group and in 162 cases (84%) within the arthroscopy group. The authors concluded that labral tears were common in this population; however, they were unable to comment on the clinical relevance of these tears, stating that further study was needed to determine whether the treatment of labral injuries can improve outcomes in patients undergoing PAO.

The overall complication rate in our study was significantly greater in the PAO-A group for both minor and major complications. This contrasts with the findings of Ricciardi *et al.* [14] who did not find any difference in complication rates. The addition of an arthroscopy or arthrotomy does add a significant amount of surgical time and potential morbidity; however, most of the complications seen in our study did not require specific treatment. Asymptomatic HO was the most commonly observed complication, with similar rates to a previous multicenter prospective study reported by Zaltz *et al.* [30] HO formation was significantly higher in PAO-A group than in the PAO group in our study, with one patient in the PAO-A group classified as Brooker III that required reoperation for HO excision. The additional soft tissue dissection intrinsic to the patients in the PAO-A group is likely to have contributed to the higher rates of HO formation in this patient group.

Deciding whether to perform an arthroscopy or arthrotomy in combination with PAO can be challenging. As our results demonstrate that the clinical outcome in the short term does not differ with the addition of an arthroscopy or arthrotomy, one might interpret that the addition of another procedure in the setting of a documented labral tear on MRI is unnecessary. However, combining arthroscopy and arthrotomy with the PAO still has advantages in certain situations. Femoroacetabular impingement (FAI) morphology may be present before PAO or be created through acetabular repositioning during PAO; hip arthroscopy or arthrotomy permits proximal femoral osteochondroplasty to be performed at the time of PAO. In our

series, head–neck osteochondroplasty was performed in 60% of PAO-A group. Hip arthroscopy can also be effectively employed in patients scheduled for PAO with preoperative imaging suggesting significant articular cartilage damage that may place them at high risk of clinical failure. If significant chondral damage is identified on arthroscopy in these patients, the PAO can be abandoned with relatively low patient morbidity.

This study has a number of limitations. First, the PAO group was younger than the PAO-A group. Outcomes of PAO have been shown to be superior in younger patients and this age difference between these two groups may have inflated the outcomes of our PAO group. Second, there is a significant risk of selection bias due to the retrospective nature of the study. During the study period, the choice to perform an arthroscopy or arthrotomy was based on patients with more significant mechanical symptoms or with significant additional cam-FAI pathology which is reflected in the slightly lower preoperative patient-reported outcome scores. Additionally, the range of motion data was recorded during each patient visit in medical records by one of the two authors, without reliability testing between the two measurers, which implies a risk of assessment bias and measurement error, respectively. We chose to combine the arthroscopy and arthrotomy groups as there were not enough arthroscopy patients to come to any meaningful analysis. However, arthrotomy of the joint during PAO is a technically different procedure than arthroscopy and could introduce more bias. Finally, although we recommended a standard postoperative rehabilitation protocol, it is possible that differences in compliance with postoperative rehabilitation between the two groups occurred could affect the outcomes.

In conclusion, in patients with symptomatic hip dysplasia and labral tears, there appears to be no difference in clinical outcomes between PAO alone and PAO combined with arthrotomy or arthroscopy at short-term follow-up, with a slightly higher complication rate associated with the addition of arthrotomy or arthroscopy. We therefore cannot recommend routine arthroscopy or arthrotomy in addition to PAO, based upon the presence of a labral tear alone. However, there are likely certain indications that would mandate the consideration of arthrotomy or arthroscopy, in particular, the presence of FAI before or after acetabular repositioning. Arthroscopy would seem to be more advantageous than arthrotomy due to improved intra-articular visualization. Further research, especially prospective randomized studies, needs to be conducted in order to truly ascertain the indications for joint inspection and addressing labral pathology in the presence of dysplasia.

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