Journal of Hip Preservation Surgery, 2022, **9**, 44–50
DOI: https://doi.org/10.1093/jhps/hnac004
Advance access publication date: 21 January 2022
Research article

The relationship between pre-operative pain characteristics and periacetabular osteotomy outcomes in patients with acetabular dysplasia

Brandon P. Everett[1], Paul A. Nakonezny[2], Edward P. Mulligan[3], Avneesh Chhabra[4] and Joel Wells[5*]

[1]Medical School, UT Southwestern Medical Center, 5323 Harry Hines Boulevard, Dallas, TX 75390, USA, [2]Department of Population and Data Sciences, UT Southwestern Medical Center, 5323 Harry Hines Boulevard, Dallas, TX 75390, USA, [3]School of Health Professions, UT Southwestern Medical Center, 5323 Harry Hines Boulevard, Dallas, TX 75390, USA, [4]Department of Radiology, UT Southwestern Medical Center, 5323 Harry Hines Boulevard, Dallas, TX 75390, USA and [5]Department of Orthopaedic Surgery, UT Southwestern Medical Center, 5323 Harry Hines Boulevard, Dallas, TX 75390, USA

*Correspondence to: J. Wells. E-mail: Joel.Wells@UTSouthwestern.edu

ABSTRACT

The aims of this study were to determine if pre-operative pain characteristics (location of maximum severity of pain, presence of non-groin pain, maximum severity of pain and number of pain locations) affect patient-reported outcome measures in patients undergoing periacetabular osteotomy (PAO) for acetabular dysplasia. We reviewed 52 hips (48 patients) treated with PAO for acetabular dysplasia from February 2017 to July 2020 using modified Harris Hip Score (mHHS), Hip Outcome Score (HOS) and international Hip Outcome Tool (iHOT-12) score, radiographic analysis and pain location/severity questionnaires. Descriptive statistics, analysis of covariance and Spearman partial correlation coefficients were implemented. Twenty-six hips experienced the most severe pre-operative pain in the groin, and 26 hips experienced equal or greater pain in a non-groin location. Outcome scores between these groups were not significantly different (mHHS $P = 0.59$, HOS $P = 0.48$, iHOT-12 $P = 0.99$). Additionally, the presence of pre-operative pain in any non-groin location had no significant relationship with PROM (all P-values ≥ 0.14). Furthermore, the maximum severity of pre-operative pain and number of pain locations showed no significant relationship with PROM (maximum severity: mHHS $P = 0.82$, HOS $P = 0.99$, iHOT-12 $P = 0.36$; number of pain locations: mHHS $P = 0.56$, HOS $P = 0.10$, iHOT-12 $P = 0.62$). Varying pre-operative pain characteristics do not appear to have any significant impact on outcomes. Therefore, a wide array of patients with acetabular dysplasia might expect similar, favourable outcomes from PAO regardless of pre-operative pain characteristics.

INTRODUCTION

Acetabular dysplasia in young adults plays a large role in the pathogenesis of early osteoarthritis leading to total hip arthroplasty (THA) [1–3]. Therefore, hip preservation with the Bernese Periacetabular Osteotomy (PAO) is the preferred procedure for acetabular dysplasia since PAO is well-tolerated and has favourable outcomes that allow for an active lifestyle [4–7].

Patients undergoing PAO for acetabular dysplasia report different presentations of pain. Acetabular dysplasia has been attributed as a major cause of hip pain in adolescents because it can result in hip instability [5]. Pain can arise due to inflammation or capsulitis of the hip joint itself. However, other locations of pain can arise as the instability of the hip places increased load on other stabilizers, such as the iliopsoas [8]. In a study of 65 hips, Nunley *et al.* found that patients with acetabular dysplasia most commonly have pain in the groin (72%), lateral hip (66%) anterior thigh (29%) and the buttock (18%) [9]. Based on where the hip instability places the most stress, and the intensity of that stress, it can lead patients with acetabular dysplasia to have varying pre-operative pain characteristics.

Although pain characteristics, outcomes and potential complications for patients who undergo PAO are understood, to our knowledge, no study has evaluated the relationship between pre-operative pain characteristics and post-operative patient-reported outcome measures (PROM). Moreover, the relationship between pain severity and the number of pain locations with post-operative PROM is unknown. As PAO is becoming more widely used [10–14], there is a need to study the relationship between pain characteristics and patient outcomes to better educate providers and determine, which patients will most benefit from PAO.

We therefore sought to answer the following questions in patients who underwent PAO for acetabular dysplasia: (i) Does maximum severity of pain in a location other than the groin that

Submitted 5 September 2021; Revised 29 November 2021; revised version accepted 5 January 2022

is greater or equal to that of the groin affect PROM? (ii) Does the presence of non-groin pain affect PROM? (iii) Does the severity of pain affect PROM? (iv) Does the number of pain locations affect PROM?

MATERIALS AND METHODS

Participants

This is a prospective case series of 52 hips (48 patients) that underwent PAO by a single, fellowship-trained orthopaedic surgeon in hip preservation. We obtained institutional review board approval for the study. Inclusion criteria were all patients who underwent PAO for symptomatic acetabular dysplasia from February 2017 to July 2020. Exclusion criteria were patients with neuromuscular disorders, prior trauma or diagnosis other than acetabular dysplasia. Patients who presented to the treating orthopaedic surgeon with acetabular dysplasia [9], radiographic evidence of femoral head uncovering and a lateral centre-edge angle of $< 25^{\circ}$ were offered treatment with PAO. In total, 52 PAOs were performed on 48 patients during the study period with no patients meeting the exclusion criteria or being lost to follow-up.

Surgical technique

The PAO surgical technique reported by Matheney *et al.* [15] was performed according to Ganz *et al.* [16] with the abductor-sparing approach described by Murphy and Millis [17]. PAO was performed on 30 right hips (58%) and 22 left hips (42%). Forty-six hips (88%) had concurrent procedures. Forty-three hips underwent hip arthroscopy for the treatment of labral resection or repair, and 15 hips underwent femoral head-neck osteochondroplasty using an arthrotomy via a Smith-Petersen approach for the treatment of abnormal femoral head-neck offset resulting in hip impingement. Twelve of the 43 hips that underwent concurrent labral resection or repair also had concurrent osteochondroplasty.

Clinical and radiographical outcomes

Location of maximum pain severity, number of pain locations, maximum severity of pain, modified Harris Hip Score (mHHS), Hip Outcome Score (HOS) and international Hip Outcome Tool (iHOT-12) were assessed by patient self-reported hip questionnaires completed at pre-operative and post-operative visits [18–21]. Post-operative measures were taken at the most current follow-up appointment. The mHHS, HOS and iHOT-12 range on a scale of 0–100, with 100 being the highest possible score for each outcome measure. The minimal clinical important difference (MCID) values used in this study for mHHS, HOS and iHOT-12 are 8, 6 (Kemp *et al.* reported individual MCIDs for HOS-ADL and HOS-SS subscales. When these are combined, taking into account the weight of the individual sub-scores, the HOS MCID is 5.3. We rounded this up to 6 to be more rigorous.) and 13.0, respectively [22, 23].

Patients marked their locations of pain on the questionnaires. Pain could be located in the groin, anterior thigh, knee, lower back, buttock, posterior thigh, trochanter and/or lateral thigh. In addition, patients noted the severity of pain at each location based on the following, previously reported scale [24–27]: 0 = No Pain, 1 = Pain with extreme activity only, 2 = Pain with moderate activity or specific movements only, 3 = Pain with daily activities, 4 = Pain at rest during the day and 5 = Pain at night that wakes you up or pain all the time (Fig. 1, p. 14).

Pre-operative and post-operative radiographical measurements were made by the treating orthopaedic surgeon. These included Tonnis Grade, anterior centre-edge angle (ACEA), lateral centre-edge angle (LCEA), Tonnis Angle, Alpha angle measured in the Frog-leg view and Alpha angle measured in the Dunn view. Intra-reader reliability values (κ) for these measurements are $\kappa(\text{Tonnis Grade}) = 0.57$, $\kappa(\text{ACEA}) = 0.88$, $\kappa(\text{LCEA}) = 0.88$, $\kappa(\text{Tonnis Angle}) = 0.83$, $\kappa(\text{Alpha Frog}) = 0.76$ and $\kappa(\text{Alpha Dunn}) = 0.98$ [28, 29]. Age, sex, race, previous hip surgery, weight, height and body mass index (BMI) data were collected from medical records.

Statistical analysis

Demographic and clinical characteristics for the sample of patients who underwent PAO for symptomatic acetabular dysplasia were described using the sample mean and standard deviation for continuous variables and the frequency and percentage for categorical variables. A separate fixed-effects general linear model analysis of covariance (ANCOVA), with robust standard errors (HC3 sandwich first order residual empirical estimator), was used to examine the main effect of pain location on each post-operative PROM, while controlling for pre-operative patient-reported measures, age, BMI and follow-up time. Least squares means (LSM, adjusted means) of the PROM were estimated as part of the ANCOVA model and were then compared between various pain locations. Cohen's d was calculated and interpreted as the effect size estimator for the between-subjects group effect. Next, the mean of mHHS, HOS and i-HOT12 at pre- and post-treatment stratified by pain level was compared using the dependent samples t-test. Finally, a correlation analysis, using the Spearman partial correlation coefficient (r_s), was conducted to evaluate the relationship between pre-operative maximum severity of pain and number of pain locations with post-operative PROM while controlling for pre-operative patient-reported measures, age, BMI and follow-up time. Statistical analyses were carried out using SAS software, version 9.4 (SAS Institute, Inc., Cary, NC). The level of significance was set at $\alpha = 0.05$ (two-tailed).

RESULTS

Participant characteristics

The sample of 48 patients was 90.38% female, with a mean age of 25.57 ± 6.89 years (range = 14–41 years). Mean BMI was 27.00 ± 5.15 kg/m^2. The mean follow-up time 463.32 ± 320.78 days (range = 75–1270 days). Patient demographic and pre-operative clinical characteristics are presented in Table I (p. 15). Additionally, 50 hips had pre-operative groin pain (96%), 42 hips had trochanteric pain (81%), 23 hips had lower back pain (44%), 19 hips had buttock pain (37%), 16 hips had anterior thigh pain (31%), 16 hips had knee pain (31%), 12 hips had lateral thigh pain (23%) and 7 hips had posterior thigh pain (13%).

Pain Drawing and Scales

Patient Name:_____

ALL QUESTIONS RELATE TO THE OPERATIVE SIDE – LEFT

1.) Please identify any area(s) where you are experiencing pain by placing a number in the box next to the area(s) on the diagram below. Use the scale below to identify your level of pain.

0 = No Pain

1 = Pain with extreme activity only (running, excessive walking, etc.)

2 = Pain with moderate activity or specific movements only (getting in/out of a chair or car; going up/down stairs)

3 = Pain with daily activities (bathing, getting dressed, going to bathroom, etc.)

4 = Pain at rest during the day

5 = Pain at night that wakes you up, or pain all the time

2.) For any areas on the diagram where you indicated having pain, please check one small box that best represents the frequency of this pain. (Daily, Weekly, or Monthly)

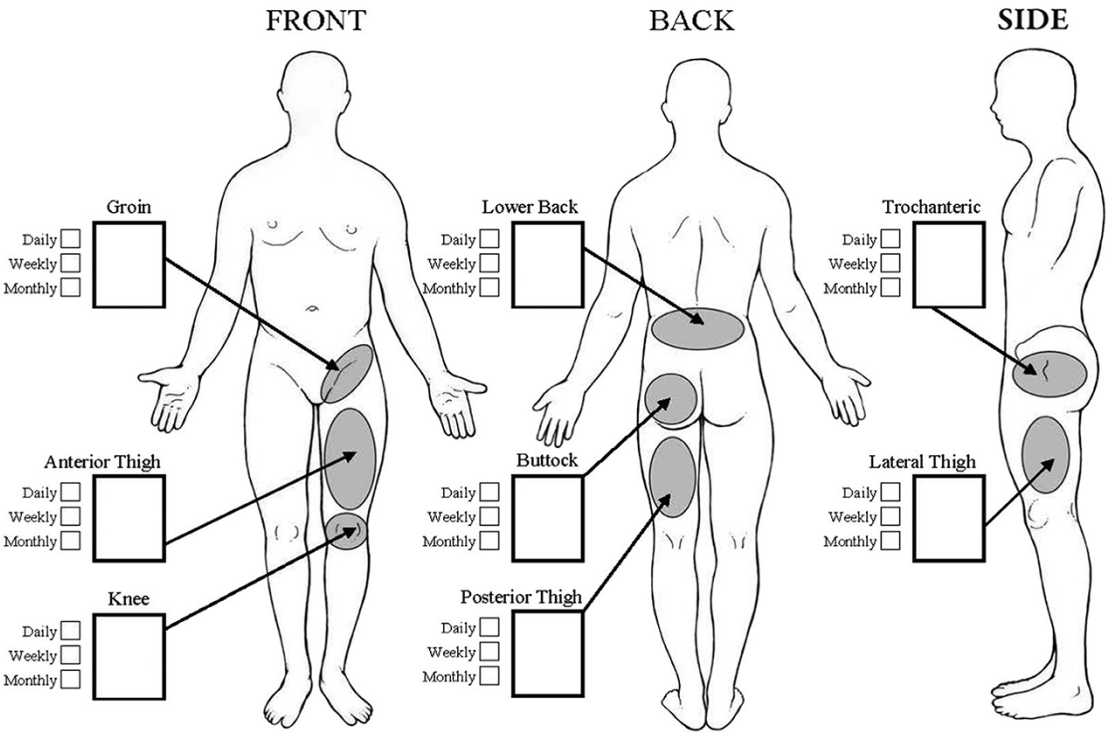

Fig. 1. Pain severity and locations drawing included on the hip questionnaire, which was sent to potential study participants.

Location of maximum severity of pre-operative pain

Patients were grouped by the location of maximum pre-operative pain severity based on whether their worst pain was in the groin (26 hips) or if they had greater or equal pain to that felt in the groin at another location (26 hips) on the diagram in Fig. 1 (p. 16). The ANCOVA results revealed none of the post-operative PROM between these two locations were significantly different (mHHS $P = 0.59$, HOS $P = 0.48$, iHOT-12 $P = 0.99$) (Table II, p. 17).

Presence of non-groin pain

The ANCOVA also examined the relationship between each of the pre-operative pain locations specified above, except for groin as 96% of hips experienced groin pain, and each of the post-operative hip outcome scores, while controlling for pre-operative patient-reported measures, age, BMI and follow-up time. The ANCOVA results revealed that there was no significant relationship between non-groin pain location and any post-operative PROM (*P*-value range for outcome scores at each pain location: Trochanter $P = 0.14$–0.53, lower back $P = 0.40$–0.99, buttock $P = 0.20$–0.48, anterior thigh $P = 0.63$–0.99, knee $P = 0.39$–0.96, lateral thigh $P = 0.29$–0.57, posterior thigh $P = 0.30$–0.80) (Table III, p. 18).

Maximum severity of pain

No hips had a maximum pain severity of 0 or 1. For maximum severity of 2–5, every group saw an improvement in all outcome

Table I. Demographic and clinical characteristics of the overall sample

Pre-operative characteristics	*Overall sample (N = 52)*
Patient demographics	
Age, years, *M* (SD, Range)	25.57 (6.89, 14–41)
Female gender, % (*n*)	90.38% (47)
Patient factors	
BMI, kg/m^2, *M* (SD, Range)	27.00 (5.15, 17–39)
Time pre- to post-treatment, days, *M* (SD, Range)	463.32 (320.78, 75–1270)
Pain Severity Score, *M* (SD, Range)	4.09 (0.97, 2–5)
Number of pain locations, *M* (SD, Range)	3.55 (2.03, 1–8)
HHS, *M* (SD, Range)	52.88 (11.43, 7–77)
HOS, *M* (SD, Range)	53.84 (15.09, 14–88)
iHOT12, *M* (SD, Range)	30.34 (14.28, 5–73)
LCEA, *M* (SD, Range)	13.05 (5.62, –1-19)
ACEA, *M* (SD, Range)	14.67 (10.46, –15-40)
Alpha Dunn, *M* (SD, Range)	65.90 (15.62, 38–102)
Alpha frog, *M* (SD, Range)	62.48 (12.56, 41–94)
Tonnis angle, *M* (SD, Range)	14.09 (6.15, 2–27)
Tonnis Grade 0, % (*n*)	78.85% (41)
Tonnis Grade 1, % (*n*)	21.15% (11)
Previous hip arthroscopy, % (*n*)	19.23% (10)

M = Sample Mean; SD = standard deviation. Pain severity scale ranges from 1 to 5 (higher score = greater severity of pain).

Table II. Patient-reported outcomes by location of maximum pain severity

Post-operative outcome measure	*Location of maximum severity*	*Adjusted LSM of outcome measure (SE)*	*P-value (d)*
mHHS	Groin	82.09 (3.27)	0.59 (0.15)
	Other	84.59 (3.05)	
HOS	Groin	80.95 (2.95)	0.48 (0.20)
	Other	83.83 (2.47)	
iHOT-12	Groin	71.03 (5.12)	0.99 (0.003)
	Other	70.95 (4.36)	

SE = Standard Error; *P*-value = ANCOVA was used to test for the difference of the LSM estimate between groin and other locations on each post-operative outcome. *d* = Cohen's *d*. Sample size was 26 per group for the 'groin' and 'other' locations. 'Other' includes patients with maximum severity of pain in a non-groin location that is equal or greater than the severity of pain in groin.

measurements from pre-operative to post-operative (Table IV, p. 20). Three hips had a maximum severity of 2 (6%), 13 hips had a maximum severity of 3 (25%), 12 hips had a maximum severity of 4 (23%) and 24 hips had a maximum severity of 5 (46%). Post-operative PROM was similar across every severity group. Spearman partial correlation coefficients (r_s) showed that there was no significant relationship between pre-operative maximum severity of pain and post-operative PROM while controlling for pre-operative patient-reported measures, age, BMI and follow-up time (mHHS: $r_s = -0.033$ $P = 0.82$, HOS: $r_s = -0.001$ $P = 0.99$, iHOT-12: $r_s = -0.133$ $P = 0.36$).

Number of pain locations

There were 12 hips with two pain locations (23%), 11 hips with three pain locations (21%), 8 hips with four pain locations (15%), 7 hips with one pain location (13%), 5 hips with five pain locations (10%), 4 hips with eight pain locations (8%), 3 hips with six pain locations (6%) and 2 hips with seven pain locations (4%). Hips in every pain location group scored similarly on all post-operative outcome measurements. Spearman partial correlation analysis found no significant relationship between number of pain locations (1–8) and post-operative outcome measures (mHHS: $r_s = 0.086$ $P = 0.56$, HOS: $r_s = 0.239$ $P = 0.10$, iHOT-12 $r_s = 0.072$ $P = 0.62$). Additionally, patients were grouped into 'pain locations >3' (22 hips, 42%) or 'pain locations ≤3' (30 hips, 58%) since the distribution of the number of pain locations was skewed towards two and three locations. The ANCOVA results revealed there was no significant difference between these two groups (>3 vs. ≤3) on any post-operative PROM (Table V, p. 21). Finally, Spearman point-biserial partial correlation analysis found no significant relationship between the number of pain locations when grouped (>3 vs. ≤3) and post-operative outcome measures (mHHS: $r_s = 0.064$ $P = 0.66$, HOS: $r_s = 0.280$ $P = 0.053$, iHOT-12 $r_s = 0.159$ $P = 0.28$).

DISCUSSION

As PAO is increasingly performed for patients with acetabular dysplasia, it is important to understand the relationship between pain presentation and outcomes. To our knowledge, this study is the first study to examine the relationship between pre-operative pain characteristics and post-operative PROM. Our goal was to report how different pain locations, maximum pain severity and number of pain locations affect PROM, as patient presentations may vary.

A large majority of patients saw improvements in their mHHS, HOS and iHOT-12 scores from their pre- to post-operative visit. Table IV (p. 22) shows that, on average, patients, regardless of pain severity level, exceeded the MCID for each outcome score. Individually, 47 (90.4%) met the mHHS MCID, 45 hips (86.5%) met the HOS MCID and 43 (82.7%) met the iHOT-12 MCID. These findings are consistent with other studies that found most patients have favourable short- and long-term outcomes after PAO [4–7, 30].

The most common pain locations in our study were the groin (96%) and lateral hip (trochanter) (81%). In a study of 65 hips, Nunley *et al.* also found that the most common pain locations were in the groin (72%) and trochanter (66%) [9]. Another study characterizing pain in 443 hips with osteoarthritis secondary to acetabular dysplasia found that pain was located in the groin of 393 hips (89%), in the buttock of 170 hips (38%), in the anterior thigh of 130 hips (29%), at the greater trochanter of 118 hips (27%), in the low back of 76 hips (17%) and in the lower leg of 34 hips (8%) [31].

We found that having the most severe pain in the groin or another location does not appear to affect post-operative outcomes. Although it is generally believed that intra-articular joint pathologies most often present with most severe pain in the groin [32, 33], the results of our study show that patients may experience similar post-operative outcomes whether the location of maximum pain severity is in the groin or not. Additionally, the

Table III. Post-operative patient-reported outcomes by presence or absence of pain in non-groin locations

	mHHS		*HOS*		*iHOT-12*	
Pain location	*Adjusted LSM (SE)*	*P-value (d)*	*Adjusted LSM (SE)*	*P-value (d)*	*Adjusted LSM (SE)*	*P-value (d)*
Trochanter						
Yes ($n = 42$)	84.15 (2.37)	0.53 (0.18)	83.71 (2.07)	0.21 (0.36)	74.10 (3.50)	0.14 (0.43)
No ($n = 10$)	79.76 (6.22)		76.86(4.66)		57.94 (9.86)	
Lower back						
Yes ($n = 23$)	82.32 (2.72)	0.67 (0.12)	84.24 (2.10)	0.40 (0.24)	70.97 (4.41)	0.99 (0.003)
No ($n = 29$)	84.09 (3.07)		80.93 (2.99)		71.01 (5.04)	
Buttock						
Yes ($n = 19$)	85.22 (3.15)	0.48 (0.20)	85.70 (2.75)	0.20 (0.38)	76.02 (5.05)	0.31 (0.29)
No ($n = 33$)	82.21 (2.77)		80.49 (2.52)		68.10 (4.97)	
Anterior thigh						
Yes ($n = 16$)	84.27 (3.50)	0.75 (0.09)	82.38 (3.35)	0.99 (0.003)	68.56 (4.81)	0.63 (0.14)
No ($n = 36$)	82.88 (2.61)		82.41 (2.12)		72.07 (4.72)	
Knee						
Yes ($n = 16$)	80.37 (4.46)	0.39 (0.25)	82.54 (3.42)	0.96 (0.01)	70.52 (5.39)	0.92 (0.03)
No ($n = 36$)	84.61 (2.21)		82.33 (2.16)		71.20 (4.21)	
Lateral thigh						
Yes ($n = 12$)	87.27 (4.17)	0.29 (0.31)	84.24 (3.75)	0.57 (0.16)	74.51 (6.12)	0.54 (0.17)
No ($n = 40$)	82.12 (2.37)		81.84 (2.04)		69.93 (4.02)	
Posterior thigh						
Yes ($n = 7$)	80.13 (5.27)	0.52 (0.19)	80.98 (6.15)	0.80 (0.07)	63.40 (7.48)	0.30 (0.30)
No ($n = 45$)	83.80 (2.18)		82.62 (1.88)		72.17 (3.67)	

SE = standard error, *P*-value = ANCOVA was used to test for the difference of the LSM estimate between non-groin pain location and each post-operative outcome. *d* = Cohen's *d*.

Table IV. Patient-reported outcomes by pre-operative maximum severity of pain

Outcome measure	*Maximum severity of Pain*	*n*	*Mean ± SD (Pre-OP)*	*Mean ± SD (Post-OP)*	*P-value*
mHHS	2	03	51.66 ± 11.71	72.00 ± 11.79	0.0019
	3	13	57.00 ± 7.81	89.00 ± 10.39	<0.0001
	4	12	58.50 ± 7.19	84.41 ± 10.27	<0.0001
	5	24	48.00 ± 13.04	81.08 ± 16.27	<0.0001
HOS	2	03	56.25 ± 13.21	76.24 ± 14.94	0.0210
	3	13	54.54 ± 10.37	81.98 ± 12.70	<0.0001
	4	12	59.31 ± 15.99	86.40 ± 9.77	<0.0001
	5	24	50.42 ± 16.80	81.36 ± 12.88	<0.0001
i-HOT12	2	03	33.33 ± 2.31	65.33 ± 22.36	0.1413
	3	13	31.53 ± 10.39	71.92 ± 22.34	0.0004
	4	12	32.75 ± 17.66	78.12 ± 15.76	<0.0001
	5	24	28.12 ± 15.36	67.62 ± 24.28	<0.0001

SD = standard deviation. *P*-value (two-tailed) = Dependent samples t-test was used to test for differences in sample means from pre- to post-OP. Change was operationally defined as post- minus pre-OP score. FDR values were 0.0023 (for $P = 0.0019$), 0.0002 (for $P < 0.0001$), 0.0229 (for $P = 0.0210$), 0.0005 (for $P = 0.0004$) and 0.1413 (for $P = 0.1413$).

presence of pre-operative pain at any non-groin location is not significantly related to any PROM when compared to hips without pain in that location. For some pain locations (buttocks, trochanter and lateral thigh), the presence of pre-operative pain yielded slightly better outcomes in each of the three measures, while in one location (posterior thigh), the absence of pain yielded slightly better outcomes. Some pain locations had mixed results (anterior thigh, knee and lower back); the presence of pre-operative pain resulted in better outcomes for some measures, while the absence of pain resulted in better outcomes for the other measures. Thus, even if a patient with acetabular dysplasia does not present with the typical most-severe pain in the groin, PAO could still be indicated and produce a favourable outcome if the patient meets the criteria for surgery.

This study also found that there was no significant relationship between either maximum severity of pain or number of pain locations and post-operative PROM. However, there was a modest inverse correlation between pre-operative maximum pain severity and PROM, suggesting that more severe pain could be related with slightly lower post-operative outcome scores. This could be due to pain catastrophizing, as certain patients with more severe pain could be exaggerating pain, and potentially these patients may report worse post-operative outcomes [34–36]. The relationship between pain severity and pain catastrophizing

Table V. Post-operative patient-reported outcomes by number of pre-operative pain locations

Outcome measure	*Grouped number of pain locations*	*Adjusted LSM of outcome measure (SE)*	*P-value (d)*
mHHS	>3	84.26 (3.20)	0.72 (0.10)
	≤3	82.61 (2.92)	
HOS	>3	86.08 (2.50)	0.09 (0.49)
	≤3	79.70 (2.55)	
iHOT-12	>3	76.46 (4.49)	0.21 (0.37)
	≤3	66.97 (5.23)	

Sample sizes for pain location groups >3 and ≤3 were 22 and 30, respectively. SE = standard error, *P*-value = ANCOVA was used to test for the difference of the LSM estimate between the grouped number of pain locations and each post-operative outcome. *d* = Cohen's *d*.

is not well understood. Bierke *et al.* established that patients with higher pain catastrophizing scores can experience worse outcomes; however, their study evaluated total knee replacement, whereas this study evaluated PAO. Another potential explanation for this slight inverse correlation is that more severe pre-operative pain could be associated with more advanced disease, ultimately resulting in worse post-operative outcomes. However, in osteoarthritic joints, the extent of joint damage has little relation to the severity of joint pain [37]. Further studies looking at the relationship between pre-operative pain severity and radiographic and visual evidence of damage in patients with acetabular dysplasia are warranted.

Additionally, we observed a positive relationship between number of pain locations and PROM, but the correlation coefficients were small and not significant. Furthermore, when hips were grouped by less than or equal to three pain locations and greater than three pain locations, there was no significant difference in the mean post-operative outcome scores, although hips with greater than three pain locations had slightly higher PROM. This might indicate that hips with more pain locations have better outcomes. This would contradict the hypothesis that patients who have more pain locations, and thus may be catastrophizing, have worse post-operative outcomes. However, the observed correlations for both pain severity and pain locations were not statistically significant.

This study has limitations. First, these surgeries were performed by one surgeon. Therefore, the results may not be representative of other surgeons or centres. However, clear and consistent PAO indications were used, and previously validated PROM were used. Additionally, some of the categories used for statistical analysis had small sample sizes due to the overall smaller number of hips included in the study. The observed effect sizes in this study were very small; thus, the small sample size could have, in part, contributed to a Type II error affecting the findings of this study. Finally, a large percentage of patients received concurrent procedures during PAO, which could have introduced some selection bias.

In summary, this study is a comprehensive analysis on the relationship between pre-operative pain characteristics and post-operative PROM in patients with symptomatic acetabular dysplasia undergoing PAO. The study evaluated whether the maximum pain being in or outside of the groin, the presence of non-groin pain, the maximum severity of pain and the number of locations of pain had an impact on post-operative PROM. The study found that there was no significant relationship between maximum severity of pain in or outside of the groin and PROM. Further, we found no significant relationship between the presence of non-groin pain and PROM. We also found that there was no significant relationship between maximum severity of pain experienced by the patient pre-operatively and PROM, although there was a modest inverse correlation. Finally, we found that there was no significant relationship between the number of pain locations and PROM, although there was a slight positive correlation. To our knowledge, this is the first study that has assessed these questions. Further efforts should ask patients to clearly indicate where they are experiencing the worst pain and include more patients. To conclude, a wide array of patients with acetabular dysplasia might expect similar, favourable outcomes from PAO regardless of the location, severity and number of locations of pre-operative pain and pre-operative pain characteristics.

DATA AVAILABILITY

Data available upon request.

ACKNOWLEDGEMENT

None declared.

FUNDING

This work was supported by The Hoglund Foundation.

CONFLICT OF INTEREST STATEMENT

None declared.

REFERENCES

1. Ganz R, Leunig M, Leunig-Ganz K *et al.* The etiology of osteoarthritis of the hip: an integrated mechanical concept. *Clin Orthop Relat Res* 2008; **466**: 264–72.
2. Harris WH. Etiology of osteoarthritis of the hip. *Clin Orthop Relat Res* 1986; **213**: 20–33.
3. Rogers BA, Garbedian S, Kuchinad RA *et al.* Total hip arthroplasty for adult hip dysplasia. *J Bone Joint Surg Am* 2012; **94**: 1809–21.
4. Clohisy JC, Schutz AL, St John L *et al.* Periacetabular osteotomy: a systematic literature review. *Clin Orthop Relat Res* 2009; **467**: 2041–52.
5. Swarup I, Zaltz I, Robustelli S *et al.* Outcomes of periacetabular osteotomy for borderline hip dysplasia in adolescent patients. *J Hip Preserv Surg* 2020; **7**: 249–55.
6. Wells J, Millis M, Kim YJ *et al.* Survivorship of the Bernese periacetabular osteotomy: what factors are associated with long-term failure? *Clin Orthop Relat Res* 2017; **475**: 396–405.
7. Wells J, Schoenecker P, Duncan S *et al.* Intermediate-term hip survivorship and patient-reported outcomes of periacetabular osteotomy: the Washington University experience. *J Bone Joint Surg Am* 2018; **100**: 218–25.
8. Kraeutler MJ, Garabekyan T, Pascual-Garrido C *et al.* Hip instability: a review of hip dysplasia and other contributing factors. *Muscles Ligaments Tendons J* 2016; **6**: 343–53.
9. Nunley RM, Prather H, Hunt D *et al.* Clinical presentation of symptomatic acetabular dysplasia in skeletally mature patients. *J Bone Joint Surg Am* 2011; **93**: 17–21.
10. Beaule PE, Dowding C, Parker G *et al.* What factors predict improvements in outcomes scores and reoperations after the Bernese periacetabular osteotomy? *Clin Orthop Relat Res* 2015; **473**: 615–22.

11. Kim YJ. Nonarthroplasty hip surgery for early osteoarthritis. *Rheum Dis Clin North Am* 2008; **34**: 803–14.
12. Kralj M, Mavcic B, Antolic V *et al.* The Bernese periacetabular osteotomy: clinical, radiographic and mechanical 7-15-year follow-up of 26 hips. *Acta Orthop* 2005; **76**: 833–40.
13. Leunig M, Ganz R. The evolution and concepts of joint-preserving surgery of the hip. *Bone Joint J* 2014; **96-B**: 5–18.
14. Troelsen A, Elmengaard B, Soballe K. Medium-term outcome of periacetabular osteotomy and predictors of conversion to total hip replacement. *J Bone Joint Surg Am* 2009; **91**: 2169–79.
15. Matheney T, Kim YJ, Zurakowski D *et al.* Intermediate to long-term results following the Bernese periacetabular osteotomy and predictors of clinical outcome. *J Bone Joint Surg Am* 2009; **91**: 2113–23.
16. Ganz R, Klaue K, Vinh TS *et al.* A new periacetabular osteotomy for the treatment of hip dysplasias: technique and preliminary results. *Clin Orthop Relat Res* 1988; **2004**; 3–8.
17. Murphy SB, Millis MB. Periacetabular osteotomy without abductor dissection using direct anterior exposure. *Clin Orthop Relat Res* 1999; **364**: 92–8.
18. Ramisetty N, Kwon Y, Mohtadi N. Patient-reported outcome measures for hip preservation surgery-a systematic review of the literature. *J Hip Preserv Surg* 2015; **2**: 15–27.
19. Griffin DR, Parsons N, Mohtadi NG *et al.* Multicenter arthroscopy of the hip outcomes research N. A short version of the International Hip Outcome Tool (iHOT-12) for use in routine clinical practice. *Arthroscopy* 2012; **28**: 611–6. quiz 16-8.
20. Jacobs CA, Peabody MR, Duncan ST *et al.* Development of the HOOSglobal to assess patient-reported outcomes in patients undergoing hip preservation procedures. *Am J Sports Med* 2018; **46**: 940–6.
21. Wasko MK, Yanik EL, Pascual-Garrido C *et al.* Psychometric properties of patient-reported outcome measures for periacetabular osteotomy. *J Bone Joint Surg Am* 2019; **101**: e21.
22. Kemp JL, Collins NJ, Roos EM *et al.* Psychometric properties of patient-reported outcome measures for hip arthroscopic surgery. *Am J Sports Med* 2013; **41**: 2065–73.
23. Nwachukwu BU, Chang B, Beck EC *et al.* How should we define clinically significant outcome improvement on the iHOT-12? *HSS J* 2019; **15**: 103–8.
24. Nam D, Nunley RM, Clohisy JC *et al.* Does patient-reported perception of pain differ based on surgical approach in total hip arthroplasty? *Bone Joint J* 2019; **101-B**: 31–6.
25. Nam D, Nunley RM, Sauber TJ *et al.* Incidence and location of pain in young, active patients following hip arthroplasty. *J Arthroplasty* 2015; **30**: 1971–5.
26. Nam D, Meyer Z, Rames RD *et al.* Is the direct superior, iliotibial band-sparing approach associated with decreased pain after total hip arthroplasty? *J Arthroplasty* 2017; **32**: 453–7.
27. Barrack RL, Paprosky W, Butler RA *et al.* Patients' perception of pain after total hip arthroplasty. *J Arthroplasty* 2000; **15**: 590–6.
28. Carlisle JC, Zebala LP, Shia DS *et al.* Reliability of various observers in determining common radiographic parameters of adult hip structural anatomy. *Iowa Orthop J* 2011; **31**: 52–8.
29. Barton C, Salineros MJ, Rakhra KS *et al.* Validity of the alpha angle measurement on plain radiographs in the evaluation of cam-type femoroacetabular impingement. *Clin Orthop Relat Res* 2011; **469**: 464–9.
30. Ricciardi BF, Fields KG, Wentzel C *et al.* Complications and short-term patient outcomes of periacetabular osteotomy for symptomatic mild hip dysplasia. *Hip Int* 2017; **27**: 42–8.
31. Nakamura J, Oinuma K, Ohtori S *et al.* Distribution of hip pain in osteoarthritis patients secondary to developmental dysplasia of the hip. *Mod Rheumatol* 2013; **23**: 119–24.
32. Byrd JW. Evaluation of the hip: history and physical examination. *N Am J Sports Phys Ther* 2007; **2**: 231–40.
33. Suarez JC, Ely EE, Mutnal AB *et al.* Comprehensive approach to the evaluation of groin pain. *J Am Acad Orthop Surg* 2013; **21**: 558–70.
34. Bierke S, Petersen W. Influence of anxiety and pain catastrophizing on the course of pain within the first year after uncomplicated total knee replacement: a prospective study. *Arch Orthop Trauma Surg* 2017; **137**: 1735–42.
35. Hampton SN, Nakonezny PA, Richard HM *et al.* Pain catastrophizing, anxiety, and depression in hip pathology. *Bone Joint J* 2019; **101-B**: 800–7.
36. Quartana PJ, Campbell CM, Edwards RR. Pain catastrophizing: a critical review. *Expert Rev Neurother* 2009; **9**: 745–58.
37. Dieppe PA, Lohmander LS. Pathogenesis and management of pain in osteoarthritis. *Lancet* 2005; **365**: 965–73.