2018

Intermediate-term hip survivorship and patient-reported outcomes of periacetabular osteotomy: The Washington University Experience

Joel Wells
University of Texas Southwestern Medical School

Perry Schoenecker
Washington University School of Medicine in St. Louis

Stephen Duncan
Washington University School of Medicine in St. Louis

Charles W. Goss
Washington University School of Medicine in St. Louis

Kayla Thomason
Washington University School of Medicine in St. Louis

See next page for additional authors

Authors
Joel Wells, Perry Schoenecker, Stephen Duncan, Charles W. Goss, Kayla Thomason, and John C. Clohisy

Intermediate-Term Hip Survivorship and Patient-Reported Outcomes of Periacetabular Osteotomy

The Washington University Experience

Joel Wells, MD, MPH, Perry Schoenecker, MD, Stephen Duncan, MD, Charles W. Goss, PhD, Kayla Thomason, BS, and John C. Clohisy, MD

Investigation performed at the Department of Orthopedic Surgery, Washington University School of Medicine, St. Louis, Missouri

Background: The Bernese periacetabular osteotomy (PAO) is an alternative to arthroplasty for treating symptomatic acetabular dysplasia, but there have been few studies on the intermediate-term outcomes of this procedure. In the present study, we assessed intermediate-term hip survival and patient-reported outcomes of PAO used to treat symptomatic acetabular dysplasia.

Methods: From July 1994 to August 2008, 238 hips (206 patients) were treated with PAO. Sixty-two had a diagnosis other than classic acetabular dysplasia, and 22 were lost to follow-up. The remaining 154 hips (129 patients) were evaluated at an average of 10.3 years postoperatively. Kaplan-Meier analysis was used to assess survivorship with an end point of total hip arthroplasty (THA). Hips were evaluated using the University of California at Los Angeles (UCLA) Activity Score, modified Harris hip score (mHHS), and Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) pain subscale score. A WOMAC pain subscale score of ≥10 and/or an mHHS of ≤70 were considered to indicate a clinically symptomatic hip.

Results: Kaplan-Meier analysis revealed a hip survival rate of 92% (95% confidence interval [CI]: 82% to 97%) at 15 years postoperatively. Eight hips (5%) underwent THA at a mean (and standard deviation) of 6.8 ± 5.2 years. Twenty-four additional hips (16%) were considered symptomatic based on a WOMAC pain score of ≥10 and/or an mHHS of ≤70. One hundred and twenty-two hips (79%) did not undergo THA and did not meet the criteria for symptoms, and these hips had a mean mHHS of 92.4 ± 8.4, WOMAC pain subscale score of 1.2 ± 1.9, and UCLA Activity Score of 7.7 ± 2.0 at a mean of 10.1 years. A higher risk of failure was associated with fair or poor preoperative joint congruency (odds ratio [OR]: 8.65; 95% CI: 1.18 to 63.55; p = 0.034) and with a postoperative lateral center-edge angle of >38° (OR: 8.04; 95% CI: 2.01 to 32.22). A concurrent head-neck osteochondroplasty was associated with a decreased risk of failure (OR: 0.27; 95% CI: 0.09 to 0.78; p = 0.016).

Conclusions: This study demonstrates the durability of the Bernese PAO. Fair or poor preoperative joint congruency and excessive postoperative femoral head coverage were found to be predictors of failure, while concurrent head-neck osteochondroplasty in patients with an inadequate range of motion after PAO was associated with a decreased risk of failure.

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

Developmental dysplasia of the hip is a major cause of osteoarthritis in young adults that often results in total hip arthroplasty (THA) at a young age. In affected hips, the predominant deformity is commonly acetabular dysplasia characterized by anterolateral acetabular insufficiency[1-7]. This aberrant anatomy causes changes in hip biomechanics and leads to axial overloading with a decreased contact area, increased contact pressure, and maximum loading at the rim[8-11]. Joint preservation surgery is a desirable option in young adults with symptomatic developmental dysplasia of the hip because

Disclosure: There were no external sources of funding for this study, which did receive funding from the Curing Hip Disease Fund at the authors' institution (J.C.C.). On the **Disclosure of Potential Conflicts of Interest** forms, *which are provided with the online version of the article*, one or more of the authors checked "yes" to indicate that the author had a relevant financial relationship in the biomedical arena outside the submitted work (http://links.lww.com/JBJS/E587).

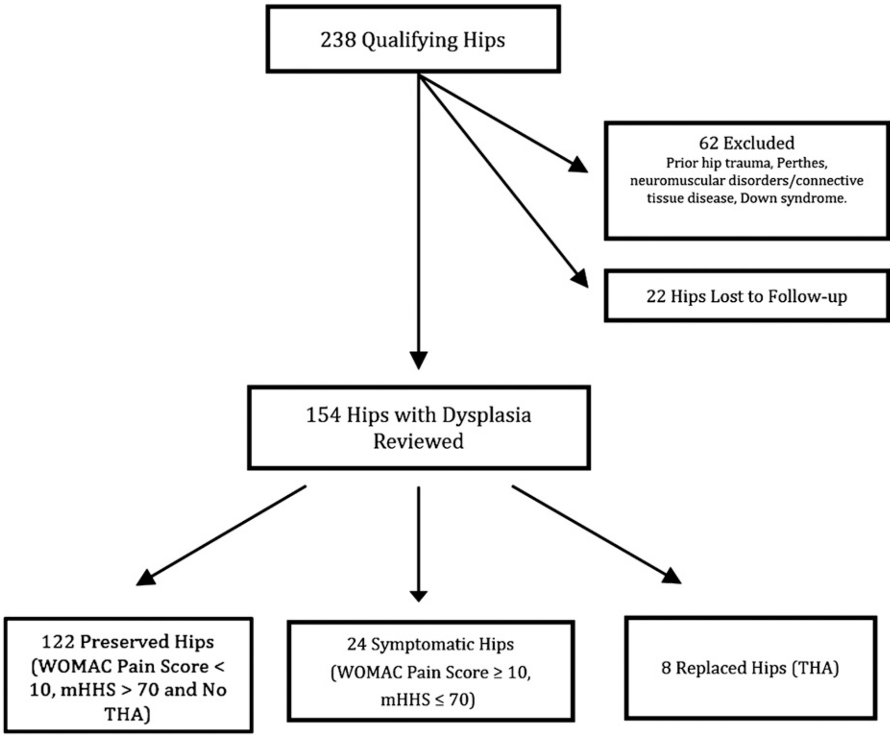

Fig. 1

Flowchart showing the study population, reasons for exclusion, and outcomes.

disease progression is common and THA may be associated with eventual prosthetic failure and activity restrictions[12-17].

Published data on the intermediate-term results of Bernese periacetabular osteotomy (PAO) are limited[18-21]. Determining predictors of hip longevity in an effort to identify patients who are likely to have durable success following PAO remains a challenge. As PAO becomes more widely used[8,18,22-25], a clear understanding of outcomes is needed not only to educate providers and determine which patients will benefit, but also to identify modifiable risk factors to improve outcomes. Failure and poor outcomes have been linked to advanced age, poor joint congruency, preoperative arthrosis, and a nonspherical femoral head without intraoperative offset correction[19-21,25,26]. Therefore, we assessed the intermediate-term hip survivorship and patient-reported outcomes of PAO for treating symptomatic developmental dysplasia of the hip. We hypothesized that PAO would be associated with major symptom relief and excellent hip survivorship (>80%) at an average follow-up of 10 years.

Materials and Methods

This is a retrospective study of 154 hips (129 patients) with developmental dysplasia of the hip identified through a review of the prospective institutional Hip Database of the Department of Orthopaedic Surgery at Washington University, which includes all patients treated with PAO. Institutional review board approval was obtained for the present study. All patients who underwent PAO for symptomatic developmental dysplasia of the hip from July 1994 to August 2008 were eligible for inclusion. The exclusion criteria were a neuromuscular or connective-tissue disorder, prior trauma, and additional diagnoses other than developmental dysplasia of the hip such as Legg-Calvé-Perthes disease, slipped capital femoral epiphysis, and acetabular retroversion.

Patients who presented to the senior authors (J.C.C. and P.S.) with symptomatic developmental dysplasia of the hip[27], radiographic evidence of femoral head uncovering, and a lateral center-edge angle of <25° were offered treatment with PAO. Contraindications to PAO include osteoarthritis without sufficient cartilage to correct into the weight-bearing zone and prior hip trauma. In total, 238 PAOs were performed on 206 patients during the study period. Sixty-two hips were excluded because the patient underwent PAO for indications other than developmental dysplasia of the hip, or for additional diagnoses that did not meet the inclusion criteria, and another 22 hips were considered lost to follow-up because the patient could not be

TABLE I Patient Demographics (N = 154 Hips)

Characteristic	
Age* *(yr)*	26, 10-60
Female *(no. [%] of hips)*	132 (86%)
Height* *(in [cm])*	66 (167.6), 57-74 (144.8-188.0)
Weight* *(lb [kg])*	149 (67.6), 81-245 (36.7-111.1)
Body mass index* *(kg/m²)*	24, 17-34

*The values are given as the mean, range.

reached for follow-up at a minimum of 4 years after the PAO. Patients whose treatment failed and who went on to undergo THA within the 4-year follow-up window were included in the study. A total of 154 hips in 129 patients (86% follow-up rate) met the inclusion criteria (Fig. 1). The average patient age was 26 years (range, 10 to 60 years). There were 113 female patients (132 hips, 86%) and 16 male patients (22 hips, 14%) (Table I).

Conversion to THA or a symptomatic hip was considered a failure of PAO. Hips were classified as symptomatic if the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) pain score was ≥10 and/or the modified Harris hip score (mHHS) was ≤70, in accordance with studies that have correlated these thresholds with substantial symptomatology[21,28,29].

TABLE II Patient and Hip Characteristics by Outcome

Characteristic	No. (%)		P Value†
	Preserved (N = 122*)	Failed (N = 32*)	
Patient characteristics			
Age >25 yr	58 (48%)	11 (34%)	0.165
Female	102 (84%)	30 (94%)	0.076
Body mass index ≥30 kg/m^2	8 (7%)	2 (1%)	0.900
Surgery prior to PAO	17 (14%)	7 (22%)	0.302
Concurrent head-neck osteochondroplasty	59 (48%)	7 (22%)	0.007
Concurrent proximal femoral osteotomy	8 (7%)	0 (0%)	
Concurrent arthroscopy/labral repair/labral debridement	17 (14%)	4 (13%)	0.823
Preoperative radiographic characteristics			
Minimum joint space ≤2 mm	1 (1%)	2 (6%)	0.220
Joint congruency poor or fair	4 (3%)	6 (19%)	0.035
Crossover sign positive	24 (20%)	5 (16%)	0.622
Anteroposterior alpha angle >55°‡	18 (15%)	6 (19%)	0.558
Lateral alpha angle >55°§	11 (12%)	5 (25%)	0.193
Lateral center-edge angle			0.242
<5°	56 (47%)	17 (55%)	
5°-15°	53 (45%)	9 (29%)	
>15°	10 (8%)	5 (16%)	
Tönnis angle >10°	117 (98%)	30 (97%)	0.605
Tönnis grade 2 or 3	5 (4%)	3 (10%)	0.342
Anterior center-edge angle <20°	101 (93%)	28 (90%)	0.750
Postoperative radiographic characteristics			
Minimum joint space ≤2 mm	5 (5%)	8 (26%)	0.013
Joint congruency poor or fair	10 (8%)	11 (34%)	0.006
Crossover sign positive	13 (11%)	3 (9%)	0.659
Anteroposterior alpha angle >55°‡	16 (14%)	9 (28%)	0.090
Lateral alpha angle >55°§	12 (12%)	8 (29%)	0.107
Lateral center-edge angle			0.007
<20°	13 (11%)	4 (13%)	
20°-38°	100 (84%)	17 (53%)	
>38°	6 (5%)	11 (34%)	
Tönnis angle			0.005
<0°	14 (12%)	13 (41%)	
>10°	12 (10%)	5 (16%)	
Tönnis grade 2 or 3	14 (12%)	12 (38%)	0.008
Anterior center-edge angle <20°	15 (13%)	5 (17%)	0.056

*Data on some characteristics were missing for ≥1 hip. The percentages are based on the actual numbers of hips for which data were available. †Based on univariable comparisons between preserved and failed hips. ‡On any anteroposterior radiograph. §On any Dunn, frog-leg, or true lateral radiograph.

TABLE III Radiographic Correction

Characteristic	Mean (SD)		P Value
	Preoperative	Postoperative	
Lateral center-edge angle *(°)*	3 (11)	30 (8)	<0.001
Tönnis angle *(°)*	24 (8)	4 (7)	<0.001
Anterior center-edge angle *(°)*	1 (14)	31 (13)	<0.001
Tönnis grade	0.4 (0.6)	0.8 (0.9)	<0.001
Joint space width *(mm)*	4.4 (1.1)	3.7 (1.2)	<0.001

Twenty-four hips (16%) underwent surgery prior to PAO. The previous procedures included 12 pelvic osteotomies, 7 proximal femoral osteotomies, 9 open reductions performed when the patient was a child, and 2 arthroscopic procedures.

Seventy-eight hips (51%) had concurrent procedures. Sixty-six underwent femoral head-neck osteochondroplasty utilizing a Smith-Petersen approach, 21 underwent hip arthroscopy for labral resection or repair, and 8 underwent a proximal femoral osteotomy (7 varus-producing and 1 valgus-producing). There were no concurrent cartilage repair techniques. Hips that underwent a concurrent surgical procedure were assessed independently.

The PAO procedure has been previously described[30]. After 2002, concurrent femoral head-neck osteochondroplasty was introduced into our practice, with the indications for that procedure being inadequate hip flexion (<90°) and <15° of internal rotation in flexion as judged intraoperatively after the PAO. Two surgeons (J.C.C. and P.S.) performed all PAOs, and all radiographic and clinical data were reviewed independently by 2 other authors (J.W., who reviewed clinical and radiographic data, and S.D., who reviewed clinical data only).

Clinical and Radiographic Analysis

The University of California at Los Angeles (UCLA) Activity Score, mHHS, and WOMAC are validated outcome measures that were used to assess activity, pain, and health-related quality of life[31-34]. The WOMAC pain score addressed pain attributable to the surgically treated hip over 4 weeks with activities including (1) walking on a flat surface, (2) climbing up or down stairs, (3) lying in bed, (4) sitting or lying, and (5) standing upright. The pain was rated as 0 (none), 1 (mild), 2 (moderate), 3 (severe), or 4 (extreme), with the patient completing a separate score for each operatively treated hip. A telephone interview was performed with standardized scripting for patients who could not return for an examination (78 hips).

The lateral center-edge angle of Wiberg[35], acetabular roof angle of Tönnis[36], minimum joint space, joint congruency as described by Yasunaga et al.[37], alpha angle[38], head-neck offset, and Tönnis grade[39,40] were measured on preoperative, early postoperative, and late postoperative standing anteroposterior pelvic radiographs. The anterior center-edge angle described by Lequesne and de Sèze[41] was measured on a false-profile radiograph. The alpha angle and head-neck offset were measured on Dunn, frog-leg, and lateral radiographs[42]. The Tönnis classification was used to grade osteoarthritis as 0 (no changes), 1 (increased sclerosis and minimal osteophytes), 2 (moderate joint space loss and cysts), and 3 (<1 mm of joint space or no joint space)[39,40]. Joint congruency as described by Yasunaga et al. was defined as excellent (radii of curvature of the acetabulum and femoral head identical and joint space maintained), good (curvature of femoral head and acetabulum not identical, but joint space preserved), fair (joint space partially narrowed), and poor (loss of joint space)[37]. One of the authors who was a fellow in hip preservation (J.W.) made all measurements, at 2 different settings 2 weeks apart to determine reliability.

Statistical Analysis

Statistical analysis of radiographic parameters was performed using intraclass correlation coefficients, which were calculated using a 2-way random model for single measurement with absolute testing. All measurements demonstrated excellent agreement. The intraclass correlation coefficients were 0.87 for joint space width, 0.84 for lateral center-edge angle, 0.96 for Tönnis angle, 0.99 for alpha angle measured on the anteroposterior radiograph, 0.99 for anterior center-edge angle, 0.95 for alpha angle measured on the frog-leg radiograph, and 0.97 for alpha angle measured on the Dunn radiograph.

The primary outcome variable was hip failure following PAO, with hip failure defined as conversion of the PAO to a THA or a symptomatic hip (one with a WOMAC pain score of ≥10 or an mHHS of ≤70) at the latest follow-up. The lateral center-edge angle was trichotomized, as previously described in the literature[43]. Data were analyzed using logistic regression and generalized estimating equations to account for correlation between the 2 hips of patients who underwent bilateral PAO. Variables with significant associations ($p < 0.05$) with hip failure in univariable analyses were included in multivariable analysis, and the variables for the final multivariable analysis were selected using a backward elimination approach. Univariable generalized estimating equation models that did not converge were not considered for inclusion in the multivariable model. A logistic regression with generalized estimating equations was also used to analyze patients who had symptoms but not conversion to THA. Kaplan-Meier survival analysis was used to generate a survival plot for the time-to-THA outcome, and 95% confidence intervals (CIs) were estimated using a log-log transformation. Patients who did not undergo a THA were censored at their most recent follow-up date. Preoperative and postoperative characteristics were compared using linear mixed models that included a random effect to account for correlation between the 2 hips of patients with bilateral PAO. All analyses were conducted using SAS version 9.4 (SAS Institute). All statistical analysis was 2-tailed, and p values of <0.05 were considered significant.

Results

Survival analysis of PAO with an end point of THA revealed a 5-year survival rate of 97% (95% CI: 93% to 99%),

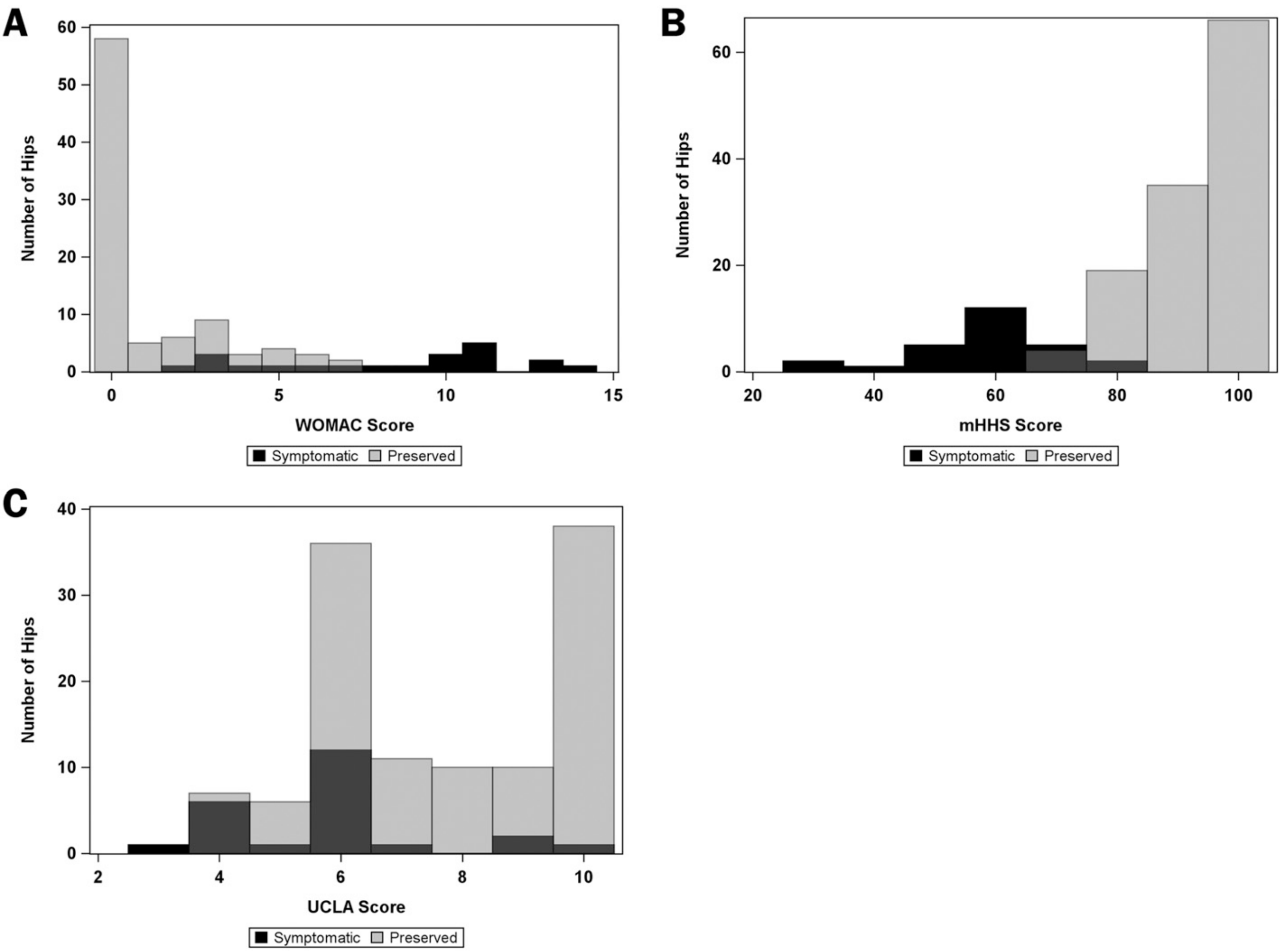

Fig. 2

Histogram showing the distribution of WOMAC scores for hips that did not undergo arthroplasty.

a 10-year survival rate of 95% (95% CI: 89% to 98%), and a 15-year survival rate of 92% (95% CI: 82% to 97%). One hundred and twenty-two hips (79%) were preserved—i.e., were not converted to THA and did not meet the criteria for substantial symptoms at the time of follow-up (mean, 10.3 years; range, 4.1 to 20.5 years). Thirty-two hips were classified as failures: 8 (5%) underwent THA at an average (and standard deviation [SD]) of 6.8 ± 5.2 years after surgery, and 24 (16%) developed symptoms (a WOMAC pain score of ≥10 and/or an mHHS of ≤70) but did not undergo THA (Table II).

Analysis of the differences between the preoperative and postoperative radiographic measurements showed a mean improvement of 27° (from 3° preoperatively to 30° postoperatively; $p < 0.001$) in the lateral center-edge angle, 20° (from 24° to 4°; $p < 0.001$) in the Tönnis angle, and 30° (from 1° to 31°; $p < 0.001$) in the anterior center-edge angle (Table III). At a mean of 10.3 ± 3 years, the patients reported a mean improvement from 66 ± 14 preoperatively to 86 ± 16 at the time of follow-up ($p < 0.001$) in the mHHS, from 7.3 ± 4.5 to 2.5 ± 3.7 ($p < 0.001$) in the WOMAC pain subscale score (Fig. 2), and from 6.5 ± 2.5 to 7.3 ± 2.1 ($p = 0.003$) in the UCLA Activity Score (Table IV). Hips that met no failure criteria had, on average, an mHHS of 92.4 ± 8.4, a WOMAC pain score of 1.2 ± 1.9, and a UCLA Activity Score of 7.7 ± 2.0 after a mean follow-up of 10.1 years (Table V).

Based on the adjusted logistic regression analysis, hips with fair or poor joint congruency preoperatively had 9 times the odds of being classified as a failure (odds ratio [OR]: 8.65; 95% CI: 1.18 to 63.55; $p = 0.034$; Table VI) when compared with hips that had good or excellent joint congruency preoperatively. In addition, hips with a postoperative lateral center-edge angle of >38° had 8 times the odds of failure (OR: 8.04; 95% CI: 2.01 to 32.22). However, hips that underwent concurrent head-neck osteochondroplasty at the time of PAO had a 73% decrease in the odds of failing (OR: 0.27; 95% CI: 0.09 to 0.78; $p = 0.016$) when compared with hips that did not undergo concurrent osteochondroplasty.

Complications were assessed and graded according to the modified Clavien-Dindo classification[44-47] with a focus on identifying "major" (Grade-III or IV) complications. There were 12

TABLE IV Patient-Reported Outcomes for All Hips That Did Not Undergo Arthroplasty

	Mean (SD)		
	Preoperative	Postoperative	P Value
mHHS	66 (14)	86 (16)	<0.001
WOMAC pain	7.3 (4.5)	2.5 (3.7)	<0.001
UCLA	6.5 (2.5)	7.3 (2.1)	0.003

TABLE V Patient-Reported Outcomes at Most Recent Follow-up by Outcome

	Mean (SD)		
	Preserved (N = 122)	Symptomatic (N = 24)	P Value
Time to questionnaire *(yr)*	10.1 (3.1)	12 (3.9)	0.041*
mHHS	92.4 (8.4)	59.9 (11.3)	<0.001
WOMAC pain score	1.2 (1.9)	8.3 (3.8)	<0.001
UCLA Activity Score	7.7 (2.0)	5.8 (1.8)	<0.001

*Although the difference in the time to the questionnaire between the preserved and symptomatic hips was significant, the time to the questionnaire had no effect on the primary outcome.

TABLE VI Adjusted Analysis of Variables Included in the Final Multivariable Model

Variable	OR (95% CI)	P Value
Preoperative fair or poor joint congruency	8.65 (1.18-63.55)	0.034
Postoperative lateral center-edge angle		0.010
<20°*	2.11 (0.43-10.28)	
>38°	8.04 (2.01-32.22)	
Concurrent head-neck osteochondroplasty	0.27 (0.09-0.78)	0.016

*The 95% CI overlapped that of the reference group (20°-38°); therefore, there was no evidence of a significant difference compared with the reference group.

Grade-III complications: 5 nonunions (2 iliac, 1 ischial, 1 posterior column, and 1 pubic) treated with open reduction, 3 cases of hematoma or deep infection treated with irrigation and debridement, 2 cases of heterotopic ossification treated with excision, 1 posterior column fracture treated with acute open reduction and internal fixation, and 1 lateral femoral cutaneous nerve laceration that required repair. There were no vascular injuries or cases of acetabular osteonecrosis.

Discussion

This is one of the largest intermediate-term follow-up studies analyzing outcomes after PAO for symptomatic developmental dysplasia of the hip. There has been limited reporting on the intermediate-term outcomes after PAO. We provide data on these outcomes and also aimed to identify factors associated with failure in a cohort that included only patients with classic symptomatic dysplasia without confounding diagnoses[18-21]. We found that patients who underwent PAO at our center had excellent hip survivorship and improvements in functional scores. Our data suggest that preoperative joint incongruency and excessive acetabular correction are associated with a greater chance of failure. Concurrent head-neck osteochondroplasty was associated with a decreased risk of failure.

This study is limited by its retrospective nature and single-center experience of 2 high-volume surgeons. The senior authors are experienced PAO surgeons, which may limit the generalizability of the results. Retrospective studies are subject to selection, indication, and temporal biases. The absence of a control group also limits reference to an untreated cohort. While we cannot mitigate selection bias, we believe that our stringent inclusion criteria allow for meaningful conclusions regarding a clearly defined group. Indication and temporal biases are limitations of this study as it spanned a period longer than 2 decades. Postoperative hip survivorship and patient-reported outcomes were not available for the 22 hips that were lost to follow-up; therefore, these cases represent the best-case scenario—because any negative outcomes they may have had were not included in the analysis—and introduce transfer bias. Although both hips in patients with bilateral PAO were included for analysis, we used generalized estimating equations to adjust for potential correlation between the 2 hips. Also, mHHS and WOMAC pain data were utilized instead of international Hip Outcome Tool (iHOT) or NAHS (Non-Arthritic Hip Score) data, as the iHOT was not published until 2012 and the NAHS was not published until 2003. Collection of patient-reported outcome measures (PROMs) in this cohort of patients started in 1994, and we have continued with these measures in order to have preoperative and postoperative comparative measures. Lastly, femoral torsion was not evaluated and no preoperative or postoperative cross-sectional imaging was analyzed.

In a study of 68 hips followed for a mean of 20 years after PAO, Steppacher et al.[19] reported that 41 hips (60%) were preserved and 8 (20%) of those 41 were graded as fair or poor according to the Merle d'Aubigné and Postel score. Several variables were identified as increasing the risk of failure, including an age of >30 years, a lower preoperative Merle d'Aubigné and Postel score, a positive preoperative anterior impingement test, a preoperative limp, preoperative arthrosis, and a higher postoperative extrusion index[19]. Some patients had neuromuscular or posttraumatic dysplasia. Wells et al.[21] reported on 121 hips followed for a mean of 18 years after treatment with PAO for symptomatic acetabular dysplasia. Twenty-six hips (21%) underwent THA, and 31 hips (26%) failed as indicated by a WOMAC pain score of ≥10. Variables that were predictive of long-term failure included an age of >25 years, a preoperative joint space width of ≤2 mm, and poor or fair preoperative joint congruency. In the current study, in which 154 hips treated with PAO for developmental dysplasia were followed for a mean of 10.3 years, 8 hips (5%) underwent THA at a mean of 6.8 ± 5.2 years after the surgery and 24 additional hips (16%) were considered symptomatic (a WOMAC pain score of ≥10 and/or an mHHS of ≤70). Our study showed that poor or fair preoperative joint congruency and a postoperative lateral center-edge angle of >38° were predictive of a failed outcome. In addition, concurrent osteochondroplasty was protective.

Albers et al.[20] analyzed the outcomes of 147 non-consecutive patients, from 2 separate chronological series, who were divided into 2 groups according to acetabular reorientation and asphericity of the femoral head. The authors concluded that proper acetabular correction without introducing secondary femoroacetabular impingement improved 10-year hip survivorship. To our knowledge, no other studies have shown a correlation between radiographic evidence of correction, especially that of secondary impingement, and failure. Secondary femoroacetabular impingement is complex and consists not only of acetabular orientation but also of the alpha angle, head-neck offset, and femoral version. The benefit of an optimal reorientation with concomitant osteochondroplasty remains unclear.

In our series, we found a lateral center-edge angle of >38° to be a predictor of failure and concurrent osteochondroplasty to be associated with a decreased risk of failure. Our observations suggest that preventing overcorrection and secondary impingement improves hip survival at 10-year follow-up. Given these data, we currently assess for secondary impingement intraoperatively following PAO. The hip must have at least 90° of flexion and 15° of internal rotation in flexion. If these motion criteria are not met, the femoral head-neck junction is inspected to identify secondary femoroacetabular impingement and, if it is present, osteochondroplasty of the head-neck junction is performed to relieve potential secondary femoroacetabular impingement. Uncommonly, PAO reduction is refined to allow functional, impingement-free hip motion.

Despite favorable outcomes of acetabular reorientation surgery, interest in treating acetabular dysplasia with isolated hip arthroscopy persists. While a few publications have reported favorable short-term outcomes[48-50], longer-term clinical outcomes, reoperation rates, and survivorship data are still unknown. In this study, we have shown that, at a mean of 10.3 years after PAO, the large majority of patients are able to return to a high level of activity with maintenance of an active lifestyle, pain relief, and a high quality of life. We recommend against treating patients with symptomatic acetabular dysplasia with isolated hip arthroscopy as we are not aware of any long-term studies supporting this approach and arthroscopy fails to address the underlying pathomechanics found in developmental dysplasia of the hip. Additionally, the data presented in this study should serve as a useful comparison for alternative treatments of symptomatic dysplasia.

In conclusion, at an average of 10.3 years after PAO, the majority of hips (95%) had not undergone THA, although a small number of additional hips (16%) were classified as symptomatic. Three factors were identified as predictive of a failed outcome (defined as THA, a WOMAC pain score of ≥10, and/or an mHHS of ≤70): (1) poor or fair preoperative joint congruency, (2) a postoperative lateral center-edge angle of >38°, and (3) not undergoing concurrent osteochondroplasty. Although poor preoperative congruency has been shown to be a predictor of worse outcomes, we would consider a PAO for joint stabilization and symptom relief in certain patients with poor preoperative congruency (e.g., one who was very young and had signs and symptoms of instability).

Based on these findings, we believe that avoiding postoperative femoroacetabular impingement may optimize outcomes and hip survivorship after PAO. Studies are under way to better characterize the etiology of symptoms in patients who are symptomatic but have not undergone THA and to identify effective interventions for these patients. ■

Note: The authors thank Geneva Baca, BA, and Gail Pashos, BS, for their assistance with data collection, patient follow-up, and study organization.

Joel Wells, MD, MPH[1]
Perry Schoenecker, MD[2,3]
Stephen Duncan, MD[2,4]
Charles W. Goss, PhD[2]
Kayla Thomason, BS[2]
John C. Clohisy, MD[2]

[1]Department of Orthopaedic Surgery, University of Texas Southwestern Medical School, Dallas, Texas

[2]Departments of Orthopaedic Surgery (P.S., S.D., K.T., and J.C.C.) and Biostatistics (C.W.G.), Washington University School of Medicine, St. Louis, Missouri

[3]Department of Orthopedic Surgery, St. Louis Shriners Hospital for Children, St. Louis, Missouri

[4]Department of Orthopedic Surgery, University of Kentucky, Lexington, Kentucky

E-mail address for J. Wells: jobuwells@gmail.com
E-mail address for J. Clohisy: clohisyj@wudosis.wustl.edu

ORCID iD for J.C. Clohisy: 0000-0001-7040-616X

References

1. Aronson J. Osteoarthritis of the young adult hip: etiology and treatment. Instr Course Lect. 1986;35:119-28.

2. Murphy SB, Ganz R, Müller ME. The prognosis in untreated dysplasia of the hip. A study of radiographic factors that predict the outcome. J Bone Joint Surg Am. 1995 Jul;77(7):985-9.

3. Harris WH. Etiology of osteoarthritis of the hip. Clin Orthop Relat Res. 1986 Dec;213:20-33.

4. Ganz R, Leunig M, Leunig-Ganz K, Harris WH. The etiology of osteoarthritis of the hip: an integrated mechanical concept. Clin Orthop Relat Res. 2008 Feb;466(2):264-72. Epub 2008 Jan 10.

5. Wedge JH, Wasylenko MJ. The natural history of congenital disease of the hip. J Bone Joint Surg Br. 1979 Aug;61-B(3):334-8.

6. Weinstein SL. Natural history of congenital hip dislocation (CDH) and hip dysplasia. Clin Orthop Relat Res. 1987 Dec;225:62-76.

7. Murphy SB, Kijewski PK, Millis MB, Harless A. Acetabular dysplasia in the adolescent and young adult. Clin Orthop Relat Res. 1990 Dec;261:214-23.

8. Leunig M, Ganz R. The evolution and concepts of joint-preserving surgery of the hip. Bone Joint J. 2014 Jan;96-B(1):5-18.

9. Jessel RH, Zurakowski D, Zilkens C, Burstein D, Gray ML, Kim YJ. Radiographic and patient factors associated with pre-radiographic osteoarthritis in hip dysplasia. J Bone Joint Surg Am. 2009 May;91(5):1120-9.

10. Klaue K, Durnin CW, Ganz R. The acetabular rim syndrome. A clinical presentation of dysplasia of the hip. J Bone Joint Surg Br. 1991 May;73(3):423-9.

11. Hipp JA, Sugano N, Millis MB, Murphy SB. Planning acetabular redirection osteotomies based on joint contact pressures. Clin Orthop Relat Res. 1999 Jul;364:134-43.

12. McAuley JP, Szuszczewicz ES, Young A, Engh CAS Sr. Total hip arthroplasty in patients 50 years and younger. Clin Orthop Relat Res. 2004 Jan;418:119-25.

13. Georgiades G, Babis GC, Hartofilakidis G. Charnley low-friction arthroplasty in young patients with osteoarthritis: outcomes at a minimum of twenty-two years. J Bone Joint Surg Am. 2009 Dec;91(12):2846-51.

14. Garellick G, Kärrholm J, Rogmark C, Rolfson O. Swedish Hip Arthroplasty Register: annual report 2012. 2013. https://registercentrum.blob.core.windows.net/shpr/r/Annual-report-2012-HJBqtLpig.pdf. Accessed 2017 Sep 5.

15. Duffy GP, Berry DJ, Rowland C, Cabanela ME. Primary uncemented total hip arthroplasty in patients <40 years old: 10- to 14-year results using first-generation proximally porous-coated implants. J Arthroplasty. 2001 Dec;16(8)(Suppl 1):140-4.

16. Dorr LD, Kane TJ 3rd, Conaty JP. Long-term results of cemented total hip arthroplasty in patients 45 years old or younger. A 16-year follow-up study. J Arthroplasty. 1994 Oct;9(5):453-6.

17. Devitt A, O'Sullivan T, Quinlan W. 16- to 25-year follow-up study of cemented arthroplasty of the hip in patients aged 50 years or younger. J Arthroplasty. 1997 Aug;12(5):479-89.

18. Kralj M, Mavčič B, Antolič V, Iglič A, Kralj-Iglič V. The Bernese periacetabular osteotomy: clinical, radiographic and mechanical 7-15-year follow-up of 26 hips. Acta Orthop. 2005 Dec;76(6):833-40.

19. Steppacher SD, Tannast M, Ganz R, Siebenrock KA. Mean 20-year followup of Bernese periacetabular osteotomy. Clin Orthop Relat Res. 2008 Jul;466(7):1633-44. Epub 2008 May 1.

20. Albers CE, Steppacher SD, Ganz R, Tannast M, Siebenrock KA. Impingement adversely affects 10-year survivorship after periacetabular osteotomy for DDH. Clin Orthop Relat Res. 2013 May;471(5):1602-14. Epub 2013 Jan 25.

21. Wells J, Millis M, Kim YJ, Bulat E, Miller P, Matheney T. Survivorship of the Bernese periacetabular osteotomy: what factors are associated with long-term failure? Clin Orthop Relat Res. 2017 Feb;475(2):396-405. Epub 2016 May 12.

22. Clohisy JC, Schutz AL, St John L, Schoenecker PL, Wright RW. Periacetabular osteotomy: a systematic literature review. Clin Orthop Relat Res. 2009 Aug;467(8):2041-52. Epub 2009 Apr 21.

23. Beaulé PE, Dowding C, Parker G, Ryu JJ. What factors predict improvements in outcomes scores and reoperations after the Bernese periacetabular osteotomy? Clin Orthop Relat Res. 2015 Feb;473(2):615-22.

24. Kim YJ. Nonarthroplasty hip surgery for early osteoarthritis. Rheum Dis Clin North Am. 2008 Aug;34(3):803-14.

25. Troelsen A, Elmengaard B, Søballe K. Medium-term outcome of periacetabular osteotomy and predictors of conversion to total hip replacement. J Bone Joint Surg Am. 2009 Sep;91(9):2169-79.

26. Matheney T, Kim YJ, Zurakowski D, Matero C, Millis M. Intermediate to long-term results following the Bernese periacetabular osteotomy and predictors of clinical outcome. J Bone Joint Surg Am. 2009 Sep;91(9):2113-23.

27. Nunley RM, Prather H, Hunt D, Schoenecker PL, Clohisy JC. Clinical presentation of symptomatic acetabular dysplasia in skeletally mature patients. J Bone Joint Surg Am. 2011 May;93(Suppl 2):17-21.

28. Emerson Kavchak AJ, Cook C, Hegedus EJ, Wright AA. Identification of cut-points in commonly used hip osteoarthritis-related outcome measures that define the patient acceptable symptom state (PASS). Rheumatol Int. 2013 Nov;33(11):2773-82. Epub 2013 Jun 29.

29. Clohisy JC, Nepple JJ, Ross JR, Pashos G, Schoenecker PL. Does surgical hip dislocation and periacetabular osteotomy improve pain in patients with Perthes-like deformities and acetabular dysplasia? Clin Orthop Relat Res. 2015 Apr;473(4):1370-7.

30. Clohisy JC, Barrett SE, Gordon JE, Delgado ED, Schoenecker PL. Periacetabular osteotomy in the treatment of severe acetabular dysplasia. Surgical technique. J Bone Joint Surg Am. 2006 Mar;88(Suppl 1 Pt 1):65-83.

31. Ashby E, Grocott MPW, Haddad FS. Outcome measures for orthopaedic interventions on the hip. J Bone Joint Surg Br. 2008 May;90(5):545-9.

32. Bellamy N, Buchanan WW, Goldsmith CH, Campbell J, Stitt LW. Validation study of WOMAC: a health status instrument for measuring clinically important patient relevant outcomes to antirheumatic drug therapy in patients with osteoarthritis of the hip or knee. J Rheumatol. 1988 Dec;15(12):1833-40.

33. Nilsdotter AK, Lohmander LS, Klässbo M, Roos EM. Hip disability and Osteoarthritis Outcome Score (HOOS)—validity and responsiveness in total hip replacement. BMC Musculoskelet Disord. 2003 May 30;4(1):10. Epub 2003 May 30.

34. Terwee CB, Bouwmeester W, van Elsland SL, de Vet HCW, Dekker J. Instruments to assess physical activity in patients with osteoarthritis of the hip or knee: a systematic review of measurement properties. Osteoarthritis Cartilage. 2011 Jun;19(6):620-33. Epub 2011 Jan 18.

35. Wiberg G. Studies on dysplastic acetabula and congenital subluxation of the hip joint: with special reference to the complication of osteoarthritis. Acta Chir Scand Suppl. 1939;83(Suppl 58).

36. Tönnis D, Behrens K, Tscharani F. A modified technique of the triple pelvic osteotomy: early results. J Pediatr Orthop. 1981;1(3):241-9.

37. Yasunaga Y, Ochi M, Terayama H, Tanaka R, Yamasaki T, Ishii Y. Rotational acetabular osteotomy for advanced osteoarthritis secondary to dysplasia of the hip. J Bone Joint Surg Am. 2006 Sep;88(9):1915-9.

38. Eijer H, Myers SR, Ganz R. Anterior femoroacetabular impingement after femoral neck fractures. J Orthop Trauma. 2001 Sep-Oct;15(7):475-81.

39. Tönnis D. Congenital dysplasia and dislocation of the hip in children and adults. New York: Springer; 1987.

40. Tönnis D, Heinecke A. Acetabular and femoral anteversion: relationship with osteoarthritis of the hip. J Bone Joint Surg Am. 1999 Dec;81(12):1747-70.

41. Lequesne M, de Sèze. [False profile of the pelvis. A new radiographic incidence for the study of the hip. Its use in dysplasias and different coxopathies]. Rev Rhum Mal Osteoartic. 1961 Dec;28:643-52. French.

42. Clohisy JC, Carlisle JC, Beaulé PE, Kim YJ, Trousdale RT, Sierra RJ, Leunig M, Schoenecker PL, Millis MB. A systematic approach to the plain radiographic evaluation of the young adult hip. J Bone Joint Surg Am. 2008 Nov;90(Suppl 4):47-66.

43. Anderson LA, Anderson MB, Erickson JA, Chrastil J, Peters CL. Acetabular wall indices help to distinguish acetabular coverage in asymptomatic adults with varying morphologies. Clin Orthop Relat Res. 2017 Apr;475(4):1027-33. Epub 2016 Sep 6.

44. Dindo D, Demartines N, Clavien PA. Classification of surgical complications: a new proposal with evaluation in a cohort of 6336 patients and results of a survey. Ann Surg. 2004 Aug;240(2):205-13.

45. Sink EL, Leunig M, Zaltz I, Gilbert JC, Clohisy J; Academic Network for Conservational Hip Outcomes Research Group. Reliability of a complication classification system for orthopaedic surgery. Clin Orthop Relat Res. 2012 Aug;470(8):2220-6. Epub 2012 Apr 19.

46. Zaltz I, Baca G, Kim YJ, Schoenecker P, Trousdale R, Sierra R, Sucato D, Sink E, Beaulé P, Millis MB, Podeszwa D, Clohisy JC. Complications associated with the periacetabular osteotomy: a prospective multicenter study. J Bone Joint Surg Am. 2014 Dec 3;96(23):1967-74.

47. Sink EL, Beaulé PE, Sucato D, Kim YJ, Millis MB, Dayton M, Trousdale RT, Sierra RJ, Zaltz I, Schoenecker P, Monreal A, Clohisy J. Multicenter study of complications following surgical dislocation of the hip. J Bone Joint Surg Am. 2011 Jun 15;93(12):1132-6.

48. Domb BG, Stake CE, Lindner D, El-Bitar Y, Jackson TJ. Arthroscopic capsular plication and labral preservation in borderline hip dysplasia: two-year clinical outcomes of a surgical approach to a challenging problem. Am J Sports Med. 2013 Nov;41(11):2591-8. Epub 2013 Aug 16.

49. Nawabi DH, Degen RM, Fields KG, McLawhorn A, Ranawat AS, Sink EL, Kelly BT. Outcomes after arthroscopic treatment of femoroacetabular impingement for patients with borderline hip dysplasia. Am J Sports Med. 2016 Apr;44(4):1017-23. Epub 2016 Feb 1.

50. Byrd JWT, Jones KS. Hip arthroscopy in the presence of dysplasia. Arthroscopy. 2003 Dec;19(10):1055-60.

Update

This article was updated on February 7, 2018, because of a previous error. On page 219, in Figure 1, the text that had read "122 Preserved Hips (WOMAC Pain Score <10, mHHS >70 and THA)" now reads "122 Preserved Hips (WOMAC Pain Score <10, mHHS >70 and No THA)".