Activity Level Maintenance at Midterm Follow-up Among Active Patients Undergoing Periacetabular Osteotomy

Ugochi C. Okoroafor,* MD, Cecilia Pascual-Garrido,* MD, PhD, Maria T. Schwabe,* BS, Jeffrey J. Nepple,* MD, Perry L. Schoenecker,* MD, and John C. Clohisy,*† MD
Investigation performed at the Department of Orthopaedic Surgery, Washington University School of Medicine, Washington University in St Louis, St Louis, Missouri, USA

Background: For active patients undergoing periacetabular osteotomy (PAO), returning to and maintaining a high level of activity postoperatively is a priority.

Purpose: To evaluate the maintenance of activity levels at midterm follow-up in active patients treated with PAO for symptomatic acetabular dysplasia.

Study Design: Case series; Level of evidence, 4.

Methods: Patients who underwent PAO for symptomatic acetabular dysplasia between June 2006 and August 2013 were identified by a retrospective review of our prospective longitudinal institutional Hip Preservation Database. All patients with a preoperative University of California, Los Angeles (UCLA) score of $\geq$7 and a potential minimum 5 years of follow-up were included in the study. Functional outcome measures were the UCLA score, modified Harris Hip Score (mHHS), and Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC). The maintenance of high activity levels was defined as a UCLA score of $\geq$7 at final follow-up. Radiographic parameters were measured. Statistical significance was defined as a P value $<$.05.

Results: A total of 66 hips (58 patients) were included. The mean age was 25.3 years (range, 14-47 years), the mean body mass index was 23.9 kg/m^2 (range, 19-32 kg/m^2), and 72% were female. The mean follow-up was 6.8 years (range, 5-11 years). There were 67% of patients who maintained a UCLA score of $\geq$7. Patient-reported outcomes improved postoperatively from preoperatively for the mHHS (88 $\pm$ 14 vs 67 $\pm$ 17, respectively; $P < .001$) and WOMAC (89 $\pm$ 15 vs 73 $\pm$ 20, respectively; $P < .001$). The lateral center-edge angle, anterior center-edge angle, and acetabular inclination were significantly improved at final follow-up ($P < .001$). Only 4 patients (7%) cited postoperative activity limitations as being caused by hip pain. There were no conversions to total hip arthroplasty.

Conclusion: The majority (67%) of active patients returned to preoperative or higher activity levels after PAO at midterm follow-up.

Keywords: periacetabular osteotomy; hip dysplasia; active patients; hip preservation

Periacetabular osteotomy (PAO) is an established hip preservation technique in skeletally mature patients with symptomatic acetabular dysplasia.[5,8,14,20,22] Acetabular dysplasia is thought to contribute to the progression of osteoarthritis, as undercoverage of the femoral head can result in overloading of the acetabular rim and subsequent chondral damage. In addition to the progression of arthritis, acetabular dysplasia can be symptomatic, with patients experiencing significant pain that limits their daily, recreational, and athletic activities. A previous study found that highly active patients experienced symptomatic hip dysplasia and presented for PAO at a younger age than less active patients, and the combination of high activity levels and severe dysplasia resulted in the youngest age at presentation.[12]

For athletes and physically active patients undergoing PAO, returning to activities postoperatively is of paramount concern. For this reason, it is important to provide active patients with accurate information regarding return to activity after PAO. Studies have shown an improvement in physical activity levels after PAO for symptomatic hip dysplasia at 2-year follow-up.[16,19] Previously, Bogunovic et al[2] reported return to preoperative activity levels or higher in 71% of active patients undergoing PAO at an average of 33 months' follow-up. Heyworth et al[9] reported an 80% rate of return to play in athletic patients after PAO at a mean 3-year follow-up. Recent literature also showed that younger patient age, higher preoperative activity levels, and lower postoperative pain levels were predictive of

The American Journal of Sports Medicine
1–5
DOI: 10.1177/0363546519881421

higher postoperative activity levels.[16] While these studies have provided valuable information, there is a paucity of literature regarding midterm follow-up of activity levels after PAO. The purpose of this study was to evaluate the maintenance of activity levels at midterm follow-up in active patients who underwent PAO for the treatment of symptomatic acetabular dysplasia.

METHODS

Institutional review board approval was obtained for this study. We conducted a retrospective review of prospectively collected data on a cohort of active patients who underwent PAO for symptomatic acetabular dysplasia. All surgical procedures were performed at a single institution between June 2006 and August 2013 by 1 of 2 senior surgeons (P.L.S., J.C.C.) with extensive experience in PAO utilizing the Bernese PAO technique.[6] Patients with symptomatic acetabular dysplasia who did not improve with a minimum 3 months of nonoperative treatment (activity modification, physical therapy, nonsteroidal anti-inflammatory drugs, and intra-articular corticosteroid injections for some patients), radiographic evidence of femoral head uncovering, and a lateral center-edge angle (CEA) <25° were indicated for surgery. Patients were identified by a review of the prospective institutional Hip Preservation Database, which contains all patients who are treated with PAO at our institution. Active patients were defined as those having a University of California, Los Angeles (UCLA), score of ≥7 preoperatively, as previously defined in the literature.[2,11,21] Originally developed for patients with osteoarthritis, the self-reported UCLA score is a validated activity measure that is assessed on a scale of 1 to 10 asking patients to describe their current activity level.[13] It has been previously used to evaluate activity levels in patients undergoing PAO.[2,11] All patients who underwent PAO for acetabular deformity correction and had a UCLA score of ≥7 preoperatively and at least 5 years' follow-up were included in the study. If a patient had bilateral hip procedures, each hip was included as its own data point. Additionally, concomitant procedures were recorded from the operative report in the patient's medical record and were included. Exclusion criteria consisted of patients with a preoperative UCLA score of <7, history of trauma, a neuromuscular or connective tissue disorder, diagnoses other than developmental hip dysplasia, previous surgery, moderate to advanced degenerative joint disease (Tönnis grade >2),[3] or severe deformities such as seen after Perthes disease or slipped capital femoral epiphysis. Patients with missing patient-reported outcomes were lost to follow-up, and the cohort is defined in Figure 1.

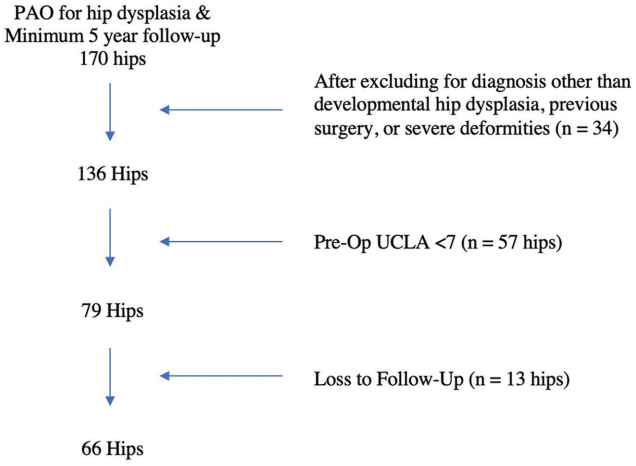

Figure 1. Flowchart showing study population and reasons for exclusion. PAO, periacetabular osteotomy; UCLA, University of California, Los Angeles.

A total of 70 patients (79 hips) met the inclusion criteria, and follow-up was obtained in 58 patients (66 hips) and included in the final analysis, resulting in an 83% follow-up rate (Figure 1). The mean age was 25.3 years (range, 14-47 years), and the mean follow-up was 6.8 years (range, 5-11 years) (Table 1). Moreover, 72% of patients were female, and 28% of patients were male. All hips underwent PAO, with concomitant surgery being performed in 63 of 66 hips (95%) (Table 2). Notably, femoral head/neck osteochondroplasty was performed in 62 hips (94%), concurrent arthroscopic surgery in 33 hips (50%), arthrotomy in 50 hips (76%), and labral repair in 19 hips (29%).

Patient-Reported Outcome and Radiographic Measures

Patient-reported outcomes were collected prospectively. The preoperative activity level was determined using the UCLA score, which was the primary outcome measure.[18] The patients were asked to report their baseline UCLA scores based on their function before they became symptomatic. Secondary patient-reported outcome measures of pain and function included the modified Harris Hip Score (mHHS) and the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC).[1,18] These scores were

†Address correspondence to John C. Clohisy, MD, Department of Orthopaedic Surgery, Washington University School of Medicine, Washington University in St Louis, 660 South Euclid Avenue, Campus Box 8233, St Louis, MO 63110, USA (email: jclohisy@wustl.edu).

*Department of Orthopaedic Surgery, Washington University School of Medicine, Washington University in St Louis, St Louis, Missouri, USA.

One or more of the authors has declared the following potential conflict of interest or source of funding: This work was supported in part by the Curing Hip Disease fund (J.C.C.) and the Jacqueline & W. Randolph Baker fund (J.C.C.). U.C.O. and P.L.S. have received education payments from Elite Orthopaedics. C.P.-G. has received education payments from Elite Orthopaedics and Zimmer Biomet; hospitality payments from Zimmer Biomet, Stryker, and Smith & Nephew; and grants from Sanofi, Arthrex, and Zimmer Biomet. J.J.N. has received consulting fees from Responsive Arthroscopy, Smith & Nephew, and Ceterix Orthopaedics; research support from Smith & Nephew and Zimmer Biomet; and education payments from Elite Orthopaedics and Arthrex. J.C.C. has received grants and consulting fees from Zimmer Biomet, consulting fees and royalties from MicroPort Orthopedics, publication royalties from Wolters Kluwer Health, and consulting fees from Smith & Nephew. AOSSM checks author disclosures against the Open Payments Database (OPD). AOSSM has not conducted an independent investigation on the OPD and disclaims any liability or responsibility relating thereto.

TABLE 1
Patient Characteristics (N = 58 Patients/66 Hips)

	Value
Age, mean (range), y	25.3 (14-47)
Final follow-up, mean (range), y	6.8 (5-11)
Body mass index, mean (range), kg/m^2	23.9 (19-32)
Sex, n (%)	
Male	16 (28)
Female	42 (72)
Laterality, n (%)	
Right	37 (56)
Left	29 (44)

collected preoperatively at the time of the initial patient visit and postoperatively at follow-up visits. The minimal clinically important difference (MCID) was identified for each outcome measure: 7 to 9 for the mHHS and 9 to 12 for the WOMAC.[7,17] Radiographic measurements were performed by trained readers. Radiographic parameters included the lateral CEA, anterior CEA, acetabular inclination, and Tönnis classification. A prior study demonstrated substantial to excellent levels of interobserver reliability for all included radiographic measures of hip dysplasia. Specifically, readers demonstrated excellent interobserver and intraobserver reliability for acetabular inclination (0.80/0.94) and lateral CEA (0.88/0.95), respectively.[15] The maintenance of high levels of activity was defined, as previously reported, as a UCLA score of $\geq$7 at final follow-up.[2,11,21]

Statistical Analysis

Descriptive statistics were used to characterize the study group. A *t* test was used for quantitative variables. Initial univariate analyses were conducted and modeled into multivariate regression analysis to identify potential factors predictive of the maintenance of high activity levels after PAO. The potential predictive factors included sex, age, body mass index, oral contraceptive use, Tönnis classification, lateral CEA, anterior CEA, and acetabular inclination. No techniques were conducted for missing data imputation. Data analysis was performed using SAS 9.4 (SAS Institute). Statistical significance was defined as a P value $<.05$.

RESULTS

Postoperatively, only 4 patients (7%) attributed a lower postoperative activity level to hip pain and/or dysfunction in the operative hip. There were 93% of patients who either maintained a high activity level with a UCLA score of $\geq$7 (39/58 patients; 67%) or had activity limitation unrelated to the surgical hip (15/58 patients; 26%). Other injuries (n = 4) and work, school, or family commitments (n = 4) were the most common reasons for a decrease in activity. All reasons are reported in Table 3.

mHHS and WOMAC (total and all subsets) scores improved significantly ($P < .05$). The mean UCLA score decreased postoperatively by 1 point from 9 to 8 ($P = .002$). Furthermore, 77% of hips achieved the MCID on the mHHS, and 64% of hips achieved the MCID on the WOMAC pain (Table 4). The lateral CEA, anterior CEA, and acetabular inclination were significantly improved at final follow-up ($P < .001$) (Table 5). The Tönnis classification showed a progression from grade 0 to 1 in 3 hips. There was 1 hip that was Tönnis grade 2 preoperatively and did not progress postoperatively. Apart from routine hardware removal, there were no reoperations or conversions to total hip arthroplasty. Univariate and subsequent multivariate regression analyses did not identify any factors predictive of return to high activity levels in this study group. Each variable had >80% complete data in this population.

TABLE 2
PAO and Concomitant Procedures[a]

	n (%)
Isolated PAO	3 (5)
PAO + labral repair	1 (2)
PAO + osteochondroplasty	44 (67)
PAO + osteochondroplasty + labral repair	18 (27)
Other concomitant procedures	
Arthrotomy	50 (76)
Arthroscopic surgery	33 (50)
Adductor release	1 (2)
Microfracture	4 (6)

[a]PAO, periacetabular osteotomy.

TABLE 3
Reasons for Not Maintaining High Levels of Activity[a]

	n (%)
Hip pain	4 (7)
Work, school, or family commitments	4 (7)
Loss of strength, speed, or endurance	1 (2)
Fear of reinjuries	1 (2)
Other injury	4 (7)
Doctor's advice	1 (2)
Other	1 (2)

[a]There were 2 patients (3 hips) lost to follow-up.

DISCUSSION

This study sought to investigate the return to activity at midterm follow-up after PAO for the treatment of acetabular dysplasia in active patients. We found that only 7% of patients had activity restrictions related to their hip. Overall, we observed excellent clinical outcomes, signified by a mean UCLA score of 8 and a mean increase on the mHHS of 21 points. The maintenance of high activity levels was seen in 67% of patients at a mean follow-up of 6.8 years.

Several previous studies have evaluated activity levels after PAO, although these studies primarily had a short-

TABLE 4
Preoperative and Postoperative Outcome Scores[a]

Outcome Measure	Preoperative	Final Follow-up	*P* Value	MCID	Hips Achieving MCID, n
UCLA (n = 66)	9 ± 1	8 ± 2	.002		
mHHS (n = 66)	67 ± 17	88 ± 14	<.001	7-9	51
WOMAC pain (n = 56)	69 ± 20	90 ± 16	<.001	9-12	36
WOMAC stiffness (n = 56)	67 ± 24	81 ± 18	<.001	9-12	31
WOMAC physical function (n = 56)	75 ± 21	91 ± 15	<.001	9-12	33
WOMAC total (n = 56)	73 ± 20	89 ± 15	<.001	9-12	33

[a]Data are shown as mean ± SD unless otherwise indicated. MCID, minimal clinically important difference; mHHS, modified Harris Hip Score; UCLA, University of California, Los Angeles; WOMAC, Western Ontario and McMaster Universities Osteoarthritis Index.

TABLE 5
Preoperative and Postoperative Radiographic Outcomes[a]

Radiographic Measure	Preoperative	Final Follow-up	*P* Value
Lateral CEA (n = 61)	11.6 ± 8.0	28.9 ± 6.9	<.001
Anterior CEA (n = 51)	15.4 ± 8.6	31.1 ± 9.1	<.001
Acetabular inclination (n = 59)	18.9 ± 7.0	4.3 ± 4.1	<.001
Tönnis classification (n = 52), n			
Grade 0	19	16	
Grade 1	32	35	
Grade 2	1	1	

[a]Data are shown as mean ± SD unless otherwise indicated. CEA, center-edge angle.

term follow-up. Clohisy et al[4] evaluated 391 patients (391 hips) of all activity levels with a mean age of 25 years who underwent PAO, with a minimum 2-year follow-up. They found a significant increase in activity levels, evidenced by a mean UCLA score improvement of 0.4 postoperatively.[4] Heyworth et al[9] evaluated rates of return to play at a mean 3-year follow-up in athletic patients undergoing PAO. In that study, 41 patients (46 hips) were evaluated, and the mean patient age was 26 years. They found that UCLA scores were maintained at a high level, with a mean UCLA score of 8 both preoperatively and postoperatively, and 80% of patients returned to play.[9] Bogunovic et al[2] examined activity levels after PAO in 36 patients (39 hips) with a mean patient age of 25 years and mean follow-up of 33 months. They found that 71% of patients maintained high levels of activity after PAO.[2] In that study, a high activity level was defined as a UCLA score of $\geq$7, which was the case in the present study. Our results provide a longer term follow-up in a larger patient cohort and indicate that the maintenance of activity levels is possible over a longer time period. Klit et al[10] conducted a long-term survey of 52 patients (68 hips) with a mean age of 41 years (range, 24-67 years) who underwent PAO. The patients were given a questionnaire consisting of 11 items measured in Likert scales. One item asked patients to rate their ability to participate in sports on a 5-point scale, where 1 indicated that they were always disabled by their hip, and 5 indicated that they were never disabled by their hip. They were asked to answer this question regarding their status preoperatively and at final follow-up. At a mean of 10 years (range, 9-12 years) of follow-up, significant improvements were noted in the ability to participate in sports. While that study did provide a long-term follow-up, it utilized a questionnaire that was developed by the authors specifically for the study rather than validated outcome measures. Last, Ziran et al[23] conducted a long-term study to evaluate survivorship after PAO in 258 patients (302 hips) with a mean age of 33 years and mean 11 years of follow-up. Utilizing the UCLA score as a measure of activity, they found a decrease in UCLA scores in patients with a longer follow-up with a plateau around 10 years postoperatively, although they did not compare this with preoperative values.[23]

Novais et al[16] identified predictors of activity levels after PAO at short-term follow-up. They evaluated 51 patients with a mean age of 27 years who underwent PAO.[16] They found that activity levels improved after PAO, as evidenced by an overall improvement in the mean UCLA score at 2-year follow-up compared with the preoperative assessment.[16] Postoperatively, 31 patients (61%) were in the high activity group (UCLA score $\geq$8) compared with 20 patients in that group preoperatively. Younger patient age, higher preoperative activity levels, and lower postoperative pain levels were predictive of higher postoperative activity levels.

Our study has several limitations. First, we did not have a control group for this study. It would be interesting to discover the percentage of patients maintaining a high activity level after PAO compared with patients without a known hip abnormality, as aging may be a contributing factor to the loss of high activity levels. Second, this was a single-institution study, and patients were treated by 2 experienced PAO surgeons. The results may not be generalizable to surgeons with a low volume of PAO in their practices, as there is a high learning curve for surgeons performing PAO. Additionally, we did not identify the exact sports in which the patients participated preoperatively and postoperatively. For example, marathon running and swimming require different skill sets and levels of physical conditioning, and we did not distinguish between specific activity types. However, the UCLA score is a validated overall measure of physical activity and is a common published activity outcome metric for hips. Last, we did not adjust for missing data for the univariate or multivariate analyses. Future studies with larger cohorts and additional predictive variables may be indicated.

CONCLUSION

In summary, this study evaluated the maintenance of activity levels in active patients at midterm follow-up after PAO. These data indicated excellent overall clinical outcomes (mean UCLA score, 8; mean mHHS score, 88) with a maintenance of high activity levels in 67% of patients. This study provides surgeons and active patients with valuable information and reasonable expectations regarding midterm activity profiles after PAO.

ACKNOWLEDGMENT

This work was supported in part by the Curing Hip Disease Fund (J.C.C.) and the Jacqueline & W. Randolph Baker fund (J.C.C.).

REFERENCES

1. Ashby E, Grocott MP, Haddad FS. Outcome measures for orthopaedic interventions on the hip. *J Bone Joint Surg Br*. 2008;90(5):545-549.
2. Bogunovic L, Hunt D, Prather H, Schoenecker PL, Clohisy JC. Activity tolerance after periacetabular osteotomy. *Am J Sports Med*. 2014;42(8):1791-1795.
3. Busse J, Gasteiger W, Tönnis D. [A new method for roentgenologic evaluation of the hip joint: the hip factor]. *Arch Orthop Unfallchir*. 1972;72(1):1-9.
4. Clohisy JC, Ackerman J, Baca G, et al. Patient-reported outcomes of periacetabular osteotomy from the prospective ANCHOR cohort study. *J Bone Joint Surg Am*. 2017;99(1):33-41.
5. Clohisy JC, Barrett SE, Gordon JE, Delgado ED, Schoenecker PL. Periacetabular osteotomy for the treatment of severe acetabular dysplasia. *J Bone Joint Surg Am*. 2005;87(2):254-259.
6. 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;88(suppl 1, pt 1):65-83.
7. Ehrich EW, Davies GM, Watson DJ, Bolognese JA, Seidenberg BC, Bellamy N. Minimal perceptible clinical improvement with the Western Ontario and McMaster Universities Osteoarthritis Index questionnaire and global assessments in patients with osteoarthritis. *J Rheumatol*. 2000;27(11):2635-2641.
8. Ganz R, Klaue K, Vinh TS, Mast JW. A new periacetabular osteotomy for the treatment of hip dysplasias: technique and preliminary results. *Clin Orthop Relat Res*. 1988;232:26-36.
9. Heyworth BE, Novais EN, Murray K, et al. Return to play after periacetabular osteotomy for treatment of acetabular dysplasia in adolescent and young adult athletes. *Am J Sports Med*. 2016;44(6):1573-1581.
10. Klit J, Hartig-Andreasen C, Jacobsen S, Soballe K, Troelsen A. Periacetabular osteotomy: sporting, social and sexual activity 9-12 years post surgery. *Hip Int*. 2014;24(1):27-31.
11. Lübbeke A, Zimmermann-Sloutskis D, Stern R, et al. Physical activity before and after primary total hip arthroplasty: a registry-based study. *Arthritis Care Res (Hoboken)*. 2014;66(2):277-284.
12. Matheney T, Zaltz I, Kim YJ, et al. Activity level and severity of dysplasia predict age at bernese periacetabular osteotomy for symptomatic hip dysplasia. *J Bone Joint Surg Am*. 2016;98(8):665-671.
13. Naal FD, Impellizzeri FM, von Eisenhart-Rothe R, Mannion AF, Leunig M. Reproducibility, validity, and responsiveness of the hip outcome score in patients with end-stage hip osteoarthritis. *Arthritis Care Res (Hoboken)*. 2012;64(11):1770-1775.
14. Nassif NA, Schoenecker PL, Thorsness R, Clohisy JC. Periacetabular osteotomy and combined femoral head-neck junction osteochondroplasty: a minimum two-year follow-up cohort study. *J Bone Joint Surg Am*. 2012;94(21):1959-1966.
15. Nepple JJ, Martell JM, Kim YJ, et al. Interobserver and intraobserver reliability of the radiographic analysis of femoroacetabular impingement and dysplasia using computer-assisted measurements. *Am J Sports Med*. 2014;42(10):2393-2401.
16. Novais EN, Heyworth B, Murray K, Johnson VM, Kim YJ, Millis MB. Physical activity level improves after periacetabular osteotomy for the treatment of symptomatic hip dysplasia. *Clin Orthop Relat Res*. 2013;471(3):981-988.
17. Smith MV, Klein SE, Clohisy JC, Baca GR, Brophy RH, Wright RW. Lower extremity-specific measures of disability and outcomes in orthopaedic surgery. *J Bone Joint Surg Am*. 2012;94(5):468-477.
18. Terwee CB, Bouwmeester W, van Elsland SL, de Vet HC, 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;19(6):620-633.
19. van Bergayk AB, Garbuz DS. Quality of life and sports-specific outcomes after Bernese periacetabular osteotomy. *J Bone Joint Surg Br*. 2002;84(3):339-343.
20. Wells J, Schoenecker P, Duncan S, Goss CW, Thomason K, Clohisy JC. Intermediate-term hip survivorship and patient-reported outcomes of periacetabular osteotomy: the Washington University experience. *J Bone Joint Surg Am*. 2018;100(3):218-225.
21. Williams DH, Greidanus NV, Masri BA, Duncan CP, Garbuz DS. Predictors of participation in sports after hip and knee arthroplasty. *Clin Orthop Relat Res*. 2012;470(2):555-561.
22. Yasunaga Y, Ochi M, Terayama H, Tanaka R, Yamasaki T, Ishii Y. Rotational acetabular osteotomy for advanced osteoarthritis secondary to dysplasia of the hip: surgical technique. *J Bone Joint Surg Am*. 2007;89(suppl 2, pt 2):246-255.
23. Ziran N, Varcadipane J, Kadri O, et al. Ten- and 20-year survivorship of the hip after periacetabular osteotomy for acetabular dysplasia. *J Am Acad Orthop Surg*. 2019;27(7):247-255.