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RETROSPECTIVE COMPARATIVE STUDY

Concomitant Hip Arthroscopy and Periacetabular Osteotomy: Is there a Difference in Perioperative Complications compared with Periacetabular Osteotomy Alone?

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ABSTRACT

Purpose: To evaluate the safety of hip arthroscopy combined with a periacetabular osteotomy (PAO) compared with PAO alone in treating concomitant intra-articular pathology in hip dysplasia.

Materials and methods: Forty-one patients (46 hips) with symptomatic hip dysplasia were retrospectively reviewed. Pre- and postoperative radiographic data and intraoperative data consisting of estimated blood loss, intraoperative and postoperative blood transfusions, operative time, and length of hospital stay were recorded. The complications occurring within the first 3 months after surgery including lateral femoral cutaneous and pudendal nerve neuropraxia, wound complications, and reoperations were recorded. Additionally, rates of deep venous thrombosis and other major adverse outcomes (myocardial infarction, pulmonary embolism, stroke, death) were examined.

Results: Twenty-one patients (24 hips) underwent PAO alone. Twenty patients (22 hips) underwent hip arthroscopy followed immediately by PAO. There were no significant differences in the 90-day complication rates between the two groups, comparing the rate of neuropraxia ($p = 0.155$) and wound complications ($p = 0.6$). Operative time for PAO alone was 179 minutes (standard deviation [SD] ± 37) compared with 251 minutes (SD ± 52) for combined hip arthroscopy and PAO ($p < 0.001$). No incidence of deep vein thrombosis or major adverse events was noted in either group. Preoperative lateral center edge angle (LCEA) and acetabular index (AI) were 14° and 20° respectively, in the PAO-alone group and 19° and 16° respectively, in the combined group. Postoperatively, LCEA was 29° in the PAO-alone group and 30° in the combined group. Postoperative AI was 11° in the PAO-alone group and 5° in the combined group.

Conclusion: This study demonstrates that hip arthroscopy in combination with PAO to treat intra-articular pathology shows no difference in 90-day complication rates when compared with PAO alone.

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INTRODUCTION

Developmental dysplasia of the hip (DDH) is one of the most frequent etiologies of osteoarthritis (OA) in young adults.[1-4] The DDH is a relatively common condition[5] and accounts for approximately 20 to 40% of OA in the young adult population.[2,6] The DDH patients have insufficient acetabular coverage that leads to abnormal loading of the articular cartilage and hip instability.[4] This results in early degeneration of articular cartilage and acetabular labral tears[3,7-9] that have been linked with early development of OA.[2,4] In 1984, Reinhold Ganz introduced the Bernese periacetabular osteotomy (PAO) for the treatment of adolescent and adult DDH.[3,7,10,11] The PAO, an extra-articular correction of acetabular coverage of the femoral head, is an effective treatment for hip dysplasia. The PAO corrects instability, improves hip mechanics while preserving the pelvic ring by maintaining the integrity of the posterior column,[2,10,12] and realigning the acetabulum.[2-4,10,13] The goal of PAO is to preserve the joint surface which protects against or delays formation of secondary OA.[3]

Initial descriptions of the PAO did not include routine inspection of the hip joint.[11] This is problematic for two reasons: Intra-articular pathologic conditions (namely labral tears and articular cartilage lesions) are frequently associated with DDH, and reorienting the acetabulum can result in iatrogenic femoroacetabular impingement (FAI).[14-16] Recent literature suggests that despite the bony correction of a PAO, some patients report persistent postoperative symptomatology, such as hip pain and mechanical symptoms.[2,14] This is presumed to

Table 1: Demographic data of the two study cohorts

	Age, years (range)	*BMI*[a]	*Preoperative LCEA*[a]	*Postoperative LCEA*[a]	*Preoperative AI*[a]	*Postoperative AI*[a]
PAO alone N = 24	30.4 (16–48)	25.5 (6.52)	14.0° (6.38)	29.0° (7.40)	20.0° (7.0)	11.0° (5.2)
PAO + hip arthroscopy N = 22	29.4 (17–42)	27.6 (5.21)	19.0° (5.15)	30.0° (4.21)	16.0° (4.8)	5.0° (4.9)
p-value	0.20	0.18	0.005	0.09	>0.05	0.003

[a]mean (SD); BMI: Body mass index

be due to intra-articular pathology present at the time of PAO that was not addressed.[14] It has been shown that approximately 60% of patients with DDH may have concomitant intra-articular pathology including labral tears or cartilage damage.[7,13,14] Additionally, untreated FAI, including the presence of a labral tear, has been reported to negatively influence the outcome of a PAO,[7,17] although the need for hip arthroscopy following PAO has been variably reported in the literature.[18,19] Literature suggests that residual impingement adversely affects 10-year survivorship after PAO for DDH.[7,14] Likewise, patients with an intact labrum after PAO have been shown to have improved long-term outcome scores as well as lower risk of arthrosis progression.[20] Additionally, there is literature to support that labral repair is superior to debridement in the setting of FAI; however, this has not been well studied in the setting of hip dysplasia.[21-23]

In a systematic review of eight studies, Redmond et al[14] reported that at the time of PAO, both labral pathology and chondral injury are easier to identify with concomitant arthroscopy as opposed to concomitant arthrotomy. The increasing utilization of hip arthroscopy to treat hip pathology[24-26] led to the consideration of hip arthroscopy at the time of PAO to diagnose and address intra-articular pathology. Although there have been two uncontrolled studies reporting favorable outcomes of combining a PAO with hip arthroscopy,[27,28] to our knowledge, there have been no reports describing the safety of combining hip arthroscopy and PAO in the same surgical setting *vs* PAO alone. The purpose of this study was to evaluate the safety of hip arthroscopy combined with PAO compared with PAO alone in treating concomitant intra-articular pathology in hip dysplasia. Our hypothesis was that while operative times would be longer with a combined procedure, there would be no significant difference in the 90-day complication rates between the two groups.

MATERIALS AND METHODS

Institutional Review Board approval was obtained for this retrospective chart review. A consecutive series of patients of the principal investigator (PI) who underwent PAO or combined hip arthroscopy and PAO between January 1, 2012, and December 31, 2013, was reviewed. Combined hip arthroscopy and PAO was initiated in December 2012 and all cases that met indications for hip arthroscopy during and after December 2012 underwent hip arthroscopy in combination with PAO. The cohort comprised seven males and 34 females. For cohort demographics, refer Table 1. The PI performed all operations. Five of the patients had bilateral surgery. The remainder of the patients had unilateral surgery. Postoperative examinations were performed by the PI or the PI's physician assistant.

Inclusion criteria for this study were patients greater than 15 years of age, symptomatic hip dysplasia refractory to at least 6 months of conservative treatment (including activity modification, nonsteroidal anti-inflammatory drugs, and intra-articular injections), and evidence of hip dysplasia on preoperative anteroposterior radiographs by a lateral center edge angle (LCEA) less than 20° (Fig. 1). Criteria for a concomitant hip arthroscopy included symptoms of mechanical locking or catching and/or magnetic resonance imaging findings indicative of labral or chondral injury. Exclusion criteria were the same for both groups and included hip OA (Tonnis grade II or greater) or open triradiate cartilage. Forty-one consecutive patients (46 hips) were included in this study. For a list of associated procedures, refer Table 2.

Data previously recorded as part of routine preoperative, perioperative, and postoperative care were collected and reviewed. The main focus of this study was safety, so only postoperative data and complications up to 3 months postoperatively were reviewed. Objective data recorded included intraoperative estimated blood loss (EBL), intraoperative and postoperative blood transfusions, administration of tranexamic acid (TXA), operative time, arthroscopic findings, associated procedures, and hospital length of stay (LOS). Perioperative complications

Table 2: Associated procedures

PAO alone (n = 24)	*PAO + hip arthroscopy (n = 22)*
Open labral repair[13]	Arthroscopic labral repair[19]
Open labral debridement[3]	Arthroscopic labral debridement[1]
Excision paralabral cyst[3]	Arthroscopic excision os acetabulum[1]
Open femoroplasty[6]	Open labral repair[1]
Bone grafting of periacetabular lesion[2]	Arthroscopic debridement ligamentum teres[5]
Repair os acetabulum[1]	Arthroscopic femoroplasty[1]
	Open femoroplasty[13]
	Open psoas tendon lengthening[1]

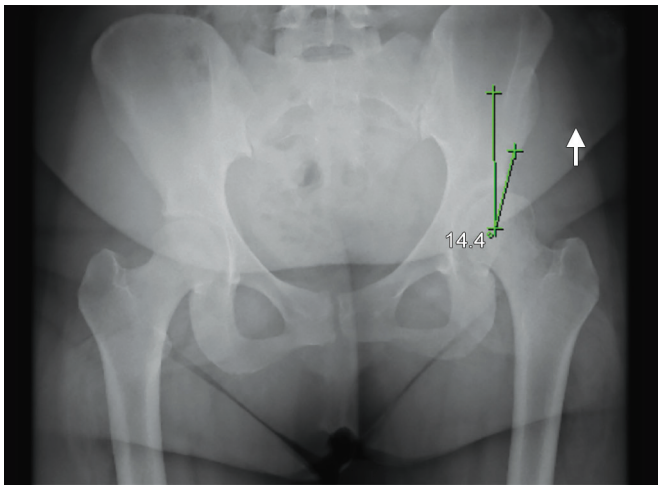

Fig. 1: A preoperative weight-bearing anteroposterior radiograph demonstrating a LCEA measuring 14.4° consistent with moderate to severe acetabular dysplasia

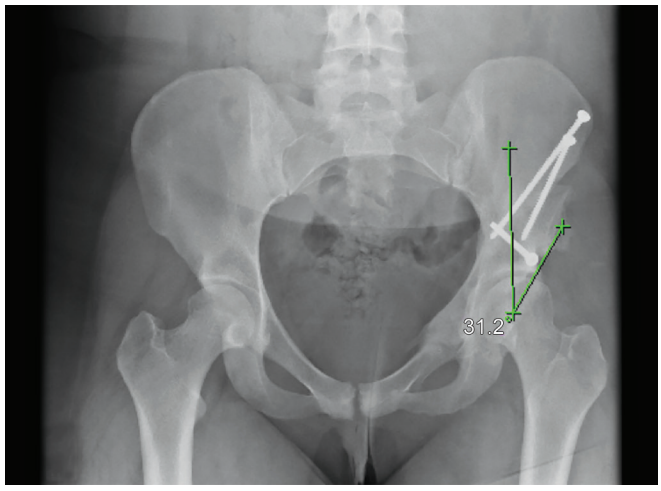

Fig. 2: The postoperative weight bearing anteroposterior radiograph after PAO demonstrates correction of the LCEA to 31.2°

including neuropraxia, wound complications, deep vein thrombosis (DVT), reoperations, and major adverse outcomes (stroke, myocardial infarction, pulmonary embolism, and death) were recorded.

Objective data also included preoperative and postoperative radiographic LCEA and acetabular index (AI). Two independent observers (an orthopaedic resident in the final year of training and the PI) each measured all angles on preoperative and postoperative radiographs, which were then averaged to give single reportable values. Postoperative physical examination findings and anterior–posterior weight-bearing radiographs, Dunn lateral, and Judet views were used to evaluate complications (Fig. 2). Routine descriptive statistics were used to summarize the data. Unidirectional t-tests were used to test for preoperative to postoperative differences for categorical data and a Z-test/chi-square test for proportional data. Statistical significance was set as a p-value of <0.05.

Operative Technique

All patients were placed supine on a PROfx (Mizuho OSI; Union City, CA) or Hana table (Mizuho OSI; Union City, CA). Adhesive drapes were used to form an occlusive seal about the hip and perineum allowing leg motion (mainly hip flexion) during the case.[29] The hip arthroscopy portion was performed first. A well-padded peroneal post specific for hip arthroscopy was utilized. The operative leg was positioned in neutral rotation. The nonoperative leg was in wide abduction and slight external rotation. Fluoroscopy was used to confirm that the traction applied adequately opened up the joint space. Visualization of the hip joint with the 70° arthroscope was achieved using anterolateral and anterior portals combined with an interportal capsulotomy. A thorough examination of the hip joint was performed inspecting the appearance of the labrum, acetabular and femoral head cartilage, and fovea. A torn labrum was repaired using an additional distal anterolateral portal. The area of pathology was prepared using a shaver, a Dyonics 4.0 abrader burr (Smith and Nephew; Andover, MA), and electrocautery device (Arthrocare; Austin, TX). Osteoraptor 2.3 mm (Smith and Nephew; Andover, MA) or CinchLock knotless (Pivot Medical Inc.; Sunnyvale, CA) suture anchors were used to repair the labrum. Inflamed, hypertrophic, or torn fovea tissue was debrided using a shaver and an electrocautery device. Once the intra-articular portion of the case was complete, traction was released and the femoral head was reduced. The hip capsule was not repaired at this time.

The PAO portion of the case immediately followed the hip arthroscopy; the patient remained in the supine position on the operative table (Hana or PROfx). The anesthesia team was alerted to maintain hypotension during this portion to minimize blood loss. The skin incision was made beginning at the gluteal tubercle, extended to a point 2.5 cm lateral to the anterior superior iliac spine and in line distal to the hip flexion crease.[29] The incision for the anterior portal for the hip arthroscopy portion was incorporated using this technique. The remainder of the procedure was performed using a rectus-sparing technique as previously described by Olson.[29]

After dissection, osteotomy, correction, and fixation were achieved, the femoral head/neck was inspected through the prior arthrotomy made from the hip arthroscopy portion of the procedure. A recontouring osteoplasty of the femoral neck was performed using ¼ inch curved osteotome if a bony prominence was visualized during hip flexion. The hip capsule was repaired using No. 2 Ticron suture (Medline Industries, Inc.; Mundelein, Ilinois). The wound was irrigated and closed in a layered manner.

Patients followed a standardized postoperative protocol. The protocol consisted of an epidural plus patient-controlled anesthesia for 36 hours subsequently converted to oral narcotics as tolerated prior to discharge. All patients were placed on low-molecular-weight-heparin and sequential compression devices for DVT prophylaxis postoperatively. Patients remained on low-molecular-weight heparin for 3 weeks postoperatively. Patients were partial weight bearing with 30 pounds for 8 weeks followed by progression to weight bearing as tolerated.

RESULTS

A total of 41 patients (46 hips) with symptomatic hip dysplasia were retrospectively reviewed following a PAO or hip arthroscopy and PAO. Cohort 1 (PAO alone) consisted of 21 patients (24 hips). Cohort 2 consisted of 20 patients (22 hips) who underwent hip arthroscopy immediately followed by PAO. Operative time for the PAO-alone cohort was 179 minutes (SD ± 37) compared with 251 minutes (SD ± 52) for the combined hip arthroscopy and PAO ($p < 0.001$). The addition of the diagnostic hip arthroscopy and treatment of intra-articular pathology increased the operative time by an average of 72 minutes. The LOS in the hospital for cohort 1 was 4.13 days (SD ± 1.18), which was not statistically different from cohort 2 whose LOS was 4.43 days (SD ± 1.14) ($p = 0.28$). The EBL for cohort 1 was 688.54 mL (SD ± 389.81), while EBL for patients who underwent the combined procedure was 441.67 mL (SD ± 298.27) ($p = 0.008$). Of note, only 1/24 (4.2%) in the PAO-alone cohort received TXA compared with 18/22 (81.8%) of the hip arthroscopy plus PAO group. This is because TXA became the standard of care for the PI due to its efficacy in orthopaedic surgery with relatively low complication risk.[30] The PI began to use TXA on all patients beginning in December 2012 unless the patient had a contraindication. Contraindications to the use of TXA included known thrombophilia, renal impairment, cardiac stents, ischemic heart disease, previous DVT, pulmonary embolism, or stroke. For the PAO-alone cohort, intra-operative blood return via Cell Saver (Haemonetics Corporation, Braintree, MA) or blood transfusion via packed red blood cells (PRBCs) was required during surgery in 18 of the 24 hips (75.0%), averaging 363.44 mL (SD ± 255.27) blood returned. For the combined cohort, 4 of the 22 hips (18.2%) received an average of 259.75 mL (SD ± 141.89) blood returned during surgery ($p = 0.45$). For PAO alone, 5 of the 24 hips (20.8%) required a postoperative blood transfusion averaging 1.8 units of PRBCs. No additional blood transfusions were performed postoperatively in cohort 2 ($p = 0.001$). See Table 3 for a summary of the intra- and postoperative data.

Perioperative complications consisted of lateral femoral cutaneous nerve (LFCN) neuropraxia in 6/24 hips (25.0%) for PAO-alone cohort and 2/22 (9.1%) for the PAO and hip arthroscopy cohort ($p = 0.155$). No cases of pudendal nerve palsy were found in either group. In the PAO-alone cohort, there were two wound dehiscences (8.3%) compared with one sterile seroma in the combined group (4.5%) ($p = 0.60$). Both patients with wound dehiscence were treated nonoperatively, while the patient in the PAO and hip arthroscopy cohort with the sterile seroma required irrigation and debridement 5 weeks after surgery. No infections, DVTs, or other major perioperative adverse outcomes occurred in either cohort. These complications have been grouped according to the grading system proposed by Sink et al.[31] The summary of complications can be found in Table 4.

DISCUSSION

There is increasing recognition of intra-articular pathology in patients with DDH, including a hypertrophied or torn

Table 3: Intra- and postoperative data of PAO alone *vs* PAO plus hip arthroscopy

				Blood transfusion			
				Intraoperative		*Postoperative*	
	Operative time (minutes)	*LOS (days)*	*EBL (mL)*[a]	*# hips (%)*	*Amount (mL)*	*# hips (%)*	*Amount (units)*
PAO alone	179 (37)	4.1 (1.2)	688.5 (389.8)	18 (75%)	363.4 (255.3)	5 (21%)	1.8 PRBCs
PAO + hip arthroscopy	251 (52)	4.4 (1.1)	441.7 (298.3)	4 (18%)	259.8 (141.9)	0	NA
p-value	<0.001	0.276	0.008	<0.001	0.45	0.01	

[a]TXA became standard of care and used on all cases in December 2012; NA: Not applicable

Table 4: Summary of complications by operative procedure

	Grade I (requires no deviation from standard treatment)	*Grade III (deviation from normal post-op course: close monitoring or pharmacologic treatment)*	*Grade III (requires surgical, endoscopic, or radiographic intervention)*	*Grade IV (complication that is life threatening)*
PAO alone N = 24		LFCN palsy 6/24 (25%) Non-op wound dehiscence 2/24 (8%)		
PAO + hip arthroscopy N = 22		LFCN palsy 2/22 (9%)	Operative sterile seroma 1/22 (4%)	

Grade V complication: Death

labrum, elongated or torn ligamentum teres, and articular cartilage wear.[2] Ross et al[13] showed that in a study of 73 hips, labral tears and acetabular cartilage pathology were present in 65.8 and 68.5% respectively, of hips that underwent arthroscopy prior to a redirectional osteotomy of the acetabulum. They concluded that in symptomatic acetabular dysplasia, acetabular rim disease is common, and that in 63% of patients these central compartment abnormalities were amenable to arthroscopic treatment.[13] In symptomatic DDH, a concomitant arthroscopy allows more direct visualization of the central compartment, which contains these structures, than does anterior arthrotomy.[2,13,14,32,33] According to Redmond et al,[14] arthroscopy identified 84% of 194 hips to have a labral tear, while arthrotomy identified only 21% of 151 hips. In addition to better visualization, increased accessibility would allow for more optimal treatment and possibly enhance the clinical results of PAO.[14,24,32] This is especially true as Matheney et al[34] reported 15/135 hips required secondary arthroscopic intervention for labral pathology or chondroplasty at an average of 6.8 years following isolated PAO.

There have been previous reports of concomitant hip arthroscopy and PAO. Nakayama et al[32] reported a case of a hip arthroscopy with labral repair and PAO performed in conjunction. The patient experienced good short-term results and was able to return work as a nurse 6 months postoperatively without pain. Kim et al[27] reported on 43 patients treated with arthroscopy and PAO. They found labral lesions in 38 patients and all were treated with labral debridement. They showed improvement in Harris Hip Scores at a mean of 74 months from surgery. However, in their study, the arthroscopy was done without the use of fluid for joint distention or the use of a traction table for joint distraction. The patients in our study were treated in a similar to fashion to those treated by Domb et al.[28] Patients were treated with supine arthroscopy with the use of traction to treat central compartment pathology. In contrast, our patients were maintained on the traction table and the PAO was performed without the need to transfer the patient to a new table. They found intra-articular pathology in 100% of their patients and 14/17 were able to be treated with the labral repair. These patients showed improvement in patient-reported outcome scores at a minimum of 2 years. To our knowledge, our study is the first report on the safety of concomitant PAO and hip arthroscopy.

One of the concerns with combining hip arthroscopy with PAO is the requirement for the surgeon to have a practice with relatively high volumes of both procedures or coordinate between two surgeons who possess the individual technical demanding skills. The Bernese PAO has a challenging learning curve.[10,11,35-39] According to Davey and Santore,[37] the risk of major complication following a PAO decreases significantly in proportion to increasing surgeon experience. Complication rates have been reported between 11 to 45% based on the learning curve,[10,34,37,40] while major complications (grade III or IV) occur in 5.9% of PAOs performed by an experienced surgeon.[35] Arthroscopy is also a technically demanding procedure with a challenging learning curve.[41] Using the complication classification system described by Sink et al,[31] there were no grade IV or V complications in either group. There was one major complication (grade III) in the combined group of a sterile seroma requiring return to the operating room for irrigation and debridement for a rate of 4.5% in this group. There were more minor complications in the PAO-alone group including complaints of altered sensation in the distribution of the LFCN occurring in 6/24 (25.0%) of PAOs *vs* 2/22 (9.1%) in patients receiving the combined procedure. This was an unexpected finding since the LFCN is placed at risk twice during the combined procedure (during hip arthroscopy, specifically with the anterior portal, and again during the PAO). This unexpected finding may be a result of the small sample size. Thawrani et al[38] reported four transient LFCN palsy in a series of 83 patients (4.8%), while Biedermann et al[40] reported LFCN dysesthesia in 33% of patients.

Our results demonstrate patients had a significantly increased mean operative time of 72 minutes following combined hip arthroscopy and PAO. These 72 minutes included an arthroscopic examination of the joint with possible labral repair with or without chondroplasty and/or ligamentum teres debridement. This is similar to the study by Domb et al,[28] which showed the mean time for hip arthroscopy in their series of 17 patients was 59 minutes. The mean operative time for PAO alone in our series was 179 minutes compared with 300 minutes in the study by Domb et al.[28]

LIMITATIONS

There are several limitations of this study. First, this is a retrospective review on a small sample size (46 hips). Based on a power analysis, these groups are large enough to show significant differences in complications between the two groups (>80%). However, to show equivalence between the groups would take sample sizes of approximately 100 patients per group. As a single surgeon series, there is an inherent selection bias, which may limit the ability for the results to translate to other surgeons. Lastly, as this study was performed to assess 90-day complication rates, we did not review patient-reported outcome data or have longer term results that may have revealed other complications or differences between the two procedures.

CONCLUSION

Periacetabular osteotomy combined with hip arthroscopy demonstrates no difference in 90-day complication rates compared with PAO alone and provides an alternative treatment option to a two-staged procedure to treat symptomatic hip dysplasia with intra-articular pathology.

REFERENCES

1. Aronson J. Osteoarthritis of the young adult hip: etiology and treatment. Instr Course Lect 1986;35:119-128.
2. Domb BG, Lareau JM, Baydoun H, Botser I, Millis MB, Yen YM. Is intraarticular pathology common in patients with hip dysplasia undergoing periacetabular osteotomy? Clin Orthop Relat Res 2014 Feb;472(2):674-680.
3. Steppacher SD, Tannast M, Ganz R, Siebenrock KA. Mean 20-year followup of Bernese periacetabular osteotomy. Clin Orthop Relat Res 2008 Jul;466(7):1633-1644.
4. Troelsen A. Assessment of adult hip dysplasia and the outcome of surgical treatment. Dan Med J 2012 Jun;59(6):B4450.
5. Parvizi J, Bican O, Bender B, Mortazavi SM, Purtill JJ, Erickson J, Peters C. Arthroscopy for labral tears in patients with developmental dysplasia of the hip: a cautionary note. J Arthroplasty 2009 Sep;24(6 Suppl):110-113.
6. Cooperman DR, Wallensten R, Stulberg SD. Acetabular dysplasia in the adult. Clin Orthop Relat Res 1983 May;(175):79-85.
7. 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):1602-1614.
8. Byrd JW, Jones KS. Hip arthroscopy in the presence of dysplasia. Arthroscopy 2003 Dec;19(10):1055-1060.
9. Fujii M, Nakashima Y, Noguchi Y, Yamamoto T, Mawatari T, Motomura G, Iwamoto Y. Effect of intra-articular lesions on the outcome of periacetabular osteotomy in patients with symptomatic hip dysplasia. J Bone Joint Surg Br 2011 Nov;93(11):1449-1456.
10. Tibor LM, Sink EL. Periacetabular osteotomy for hip preservation. Orthop Clin North Am 2012 Jul;43(3):343-357.
11. 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 Jul;(232):26-36.
12. Leunig M, Ganz R. The Bernese method of periacetabular osteotomy. Der Orthopade 1998 Nov;27(11):743-750.
13. Ross JR, Zaltz I, Nepple JJ, Schoenecker PL, Clohisy JC. Arthroscopic disease classification and interventions as an adjunct in the treatment of acetabular dysplasia. Am J Sports Med 2011 Jul;39 (Suppl):72S-78S.
14. Redmond JM, Gupta A, Stake CE, Domb BG. The prevalence of hip labral and chondral lesions identified by method of detection during periacetabular osteotomy: arthroscopy versus arthrotomy. Arthroscopy 2014 Mar;30(3):382-388.
15. Ginnetti JG, Erickson J, Peters CL. Periacetabular osteotomy: intra-articular work. Instr Course Lect 2013;62:279-286.
16. 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 Nov 7;94(21):1959-1966.
17. Siebenrock KA, Schöll E, Lottenbach M, Ganz R. Bernese periacetabular osteotomy. Clin Orthop Relat Res 1999 Jun;(363):9-20.
18. Hartig-Andreasen C, Troelsen A, Thillemann TM, Gelineck J, Søballe K. Risk factors for the need of hip arthroscopy following periacetabular osteotomy. J Hip Preserv Surg 2015 Aug 27;2(4):374-384.
19. Cvetanovich GL, Heyworth BE, Murray K, Yen Y-M, Kocher MS, Millis MB. Hip arthroscopy in patients with recurrent pain following Bernese periacetabular osteotomy for acetabular dysplasia: operative findings and clinical outcomes. J Hip Preserv Surg 2015 Jun 13;2(3):295-302.
20. Ohzono K, Sakai T, Haraguchi K, Lee K, Matsui M, Sugano N, Nishii T, Ochi T. The Osaka concept. "Dome osteotomy" with of without labrum resection. Der Orthopade 1998 Nov;27(11):759-764.
21. Philippon MJ, Briggs KK, Yen YM, Kuppersmith DA. Outcomes following hip arthroscopy for femoroacetabular impingement with associated chondrolabral dysfunction: minimum two-year follow-up. J Bone Joint Surg Br 2009 Jan;91(1):16-23.
22. Espinosa N, Rothenfluh DA, Beck M, Ganz R, Leunig M. Treatment of femoro-acetabular impingement: preliminary results of labral refixation. J Bone Joint Surg Am 2006 May;88(5): 925-935.
23. Larson CM, Giveans MR, Stone RM. Arthroscopic debridement versus refixation of the acetabular labrum associated with femoroacetabular impingement: mean 3.5-year follow-up. Am J Sports Med 2012 May;40(5):1015-1021.
24. Lynch TS, Terry MA, Bedi A, Kelly BT. Hip arthroscopic surgery: patient evaluation, current indications, and outcomes. Am J Sports Med 2013 May;41(5):1174-1189.
25. Peters CL, Aoki SK, Erickson JA, Anderson LA, Anderson AE. Early experience with a comprehensive hip preservation service intended to improve clinical care, education, and academic productivity. Clin Orthop Relat Res 2012 Dec;470(12): 3446-3452.
26. Colvin AC, Harrast J, Harner C. Trends in hip arthroscopy. J Bone Joint Surg Am 2012 Feb 15;94(4):e23.
27. Kim KI, Cho YJ, Ramteke AA, Yoo MC. Peri-acetabular rotational osteotomy with concomitant hip arthroscopy for treatment of hip dysplasia. J Bone Joint Surg Br 2011 Jun;93(6): 732-737.
28. Domb BG, LaReau JM, Hammarstedt JE, Gupta A, Stake CE, Redmond JM. Concomitant Hip Arthroscopy and Periacetabular Osteotomy. Arthroscopy 2015 Nov;31(11):2199-2206.
29. Olson SA. The Bernese periactebular osteotomy: a review of surgical technique. Duke Orthop J 2011;1(1):21-26.
30. Ng WC, Jerath A, Wasowicz M. Tranexamic acid: a clinical review. Anaesthesiol Intensive Ther 2015;47(4):339-350.
31. 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): 2220-2226.
32. Nakayama H, Fukunishi S, Fukui T, Yoshiya S. Arthroscopic labral repair concomitantly performed with curved periacetabular osteotomy. Knee Surg Sports Traumatol Arthrosc 2014 Apr;22(4):938-941.
33. Anderson LA, Crofoot CD, Erickson J, Morton DA, Peters CL. Acetabular osteochondroplasty and simultaneous reorientation: background and validation of concept. Orthopedics 2010 May 12;33(5).
34. 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: surgical technique. J Bone Joint Surg Am 2010 Sep;92 (Suppl 1 Pt 2):115-129.

35. Zaltz I, Baca G, Kim YJ, Schoenecker P, Trousdale R, Sierra R, Sucato D, Sink E, Beaulé P, Millis MB, et al. Complications associated with the periacetabular osteotomy: a prospective multicenter study. J Bone Joint Surg Am 2014 Dec 3;96(23): 1967-1974.
36. Peters CL, Erickson JA, Hines JL. Early results of the Bernese periacetabular osteotomy: the learning curve at an academic medical center. J Bone Joint Surg Am 2006 Sep;88(9): 1920-1926.
37. Davey JP, Santore RF. Complications of periacetabular osteotomy. Clin Orthop Relat Res 1999 Jun;(363):33-37.
38. Thawrani D, Sucato DJ, Podeszwa DA, DeLaRocha A. Complications associated with the Bernese periacetabular osteotomy for hip dysplasia in adolescents. J Bone Joint Surg Am 2010 Jul 21;92(8):1707-1714.
39. Hussell JG, Rodriguez JA, Ganz R. Technical complications of the Bernese periacetabular osteotomy. Clin Orthop Relat Res 1999 Jun;(363):81-92.
40. Biedermann R, Donnan L, Gabriel A, Wachter R, Krismer M, Behensky H. Complications and patient satisfaction after periacetabular pelvic osteotomy. Int Orthop 2008 Oct;32(5): 611-617.
41. Hoppe DJ, de Sa D, Simunovic N, Bhandari M, Safran MR, Larson CM, Ayeni OR. The learning curve for hip arthroscopy: a systematic review. Arthroscopy 2014 Mar;30(3):389-397.