Systematic Review

Open and Arthroscopic Treatment of Adult Hip Dysplasia: A Systematic Review

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Purpose: To compare patient-reported outcome (PRO) and rates of conversion to total hip arthroplasty (THA) after hip arthroscopy, Bernese periacetabular osteotomy (PAO), and a combined approach for the management of patients with different grades of hip dysplasia. **Methods:** We searched MEDLINE and PubMed databases for articles published since 2000 using the following terms: ((((“hip dysplasia”) or “dysplastic”) and “arthroscopy”)) or ((((“hip dysplasia”) or “dysplastic”) and “osteotomy”). Two authors independently reviewed the literature. Inclusion criteria were English language, relevance to hip dysplasia, surgical outcomes, and sample size of 10 patients or more. We excluded articles that were reviews or techniques; articles that included overlapping populations, patients with a mean age less than 18 years, patients with other hip conditions, patients with genetic or neuromuscular causes of hip dysplasia, and patients with Tonnis grade 2 or greater arthritis; articles on femoral osteotomy, and articles on previous surgical intervention, except hip arthroscopy. Articles were analyzed for PRO scores and rates of conversion to THA. **Results:** Ten of 759 articles reviewed met the inclusion and exclusion criteria. Of 834 hips treated for dysplasia with a mean age of 31 years, 114 were treated with arthroscopy alone, 703 were treated with PAO alone, and 17 were treated with both procedures. Mean follow-up was 3.2 years, 6.5 years, and 5.6 years, respectively. Conversion rates to THA were 4.8%, 12.0%, and 17.7%, respectively. In studies reporting pre- and postoperative PRO scores, all but one reported improvement. **Conclusions:** The management of hip dysplasia may entail hip arthroscopy, PAO, or a combined approach. Arthroscopy has resulted in improved outcomes in borderline dysplastic cases (lateral center edge angle between 18° and 25°). PAO has primarily been used in true dysplasia with continued success. There were too few combined procedures of arthroscopy with PAO to reach a reliable conclusion in this subgroup. **Level of Evidence:** Systematic review of Level III and Level IV studies.

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Pathologic morphology of the hip exists on a spectrum from undercoverage or dysplasia to overcoverage or femoroacetabular impingement (FAI), both of which have been implicated as a cause of osteoarthritis (OA) in the hip.[1-3] Dysplasia of the acetabulum, or insufficient coverage of the femoral head, has been defined as a lateral center edge angle (LCEA) of less than 25°.[4] The reduced area of the acetabular cartilage surface, hypertrophy of the acetabular labrum, and elongation of the ligamentum teres accompanying lateral subluxation of the femoral head are among the factors that can lead to tears of the labrum and ligamentum teres and articular cartilage injury. These pathologic conditions may ultimately contribute to degeneration of the hip in the setting of dysplasia.[5]

Hip preservation surgery aims at correcting the pathologic anatomy to relieve pain, improve function, and prevent progression to OA.[6] Various procedures have been developed over the past century to correct the acetabular and femoral morphologic conditions encountered in hip dysplasia.[7,8] The Bernese periacetabular osteotomy (PAO) has been a very useful tool in hip preservation in this setting by allowing one to obtain an extensive reorientation of the acetabulum using a single incision, without disruption of the

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Table 1. Inclusion and Exclusion Criteria Used to Identify Articles for This Systematic Review

Inclusion Criteria	Exclusion Criteria
English language	Review articles
Commented on parameters or diagnostic testing that may be evidence of developmental hip dysplasia	Technique articles
	Mean age < 18 yr
Contained outcome data on patients undergoing the surgical procedure	Patients with other hip deformities like Legg-Calve-Perthes, slipped capital femoral epiphysis, postinfectious deformity
N ≥ 10 patients	Patients with genetic or neuromuscular causes of hip dysplasia
Published since 2000	Patients with Tonnis grade 2 or higher arthritic changes in the hip
	Patients with revision surgical intervention, except after hip arthroscopy
	Patients with femoral osteotomy

posterior column and with minimal internal fixation, allowing early mobilization.[9] In so doing, PAO has been shown to mitigate the effects of altered joint biomechanics and to provide reduced peak joint contact pressure.[10,11] However, it has various technical complexities, requires a steep learning curve, and may have complication rates as high as 41%.[12,13] There is also a propensity to cause overcoverage of the femoral head and thereby create iatrogenic FAI (caused by impingement of a previously present cam lesion that was not engaging with the acetabulum preoperatively).[1,14]

Hip arthroscopy, in contrast, has emerged as a minimally invasive procedure to address intra-articular and periarticular hip pathologic conditions in the 21st century. Although it has shown excellent outcomes in the setting of FAI,[15-17] hip arthroscopy has met with skepticism in its isolated use for the management of dysplasia.[18,19] However, recent literature has suggested a role for hip arthroscopy in addressing intra-articular pathologic conditions concurrently with PAO. In addition, hip arthroscopy alone has been successfully used for a subset of patients with borderline dysplasia, which has been defined as an LCEA between 20° and 25°.[1,5,14,20]

Patient selection in any operative procedure is important to obtain optimal results. Hip preservation surgery in the setting of dysplasia deals with the advantages and disadvantages of PAO and hip arthroscopy. The purpose of this systematic review was to compare the patient-reported outcomes (PROs) and rates of conversion to total hip replacement after hip arthroscopy, PAO, and a combined approach, for the management of patients with different grades of hip dysplasia. We hypothesized that all 3 surgical treatments would have improved outcomes in patients with hip dysplasia.

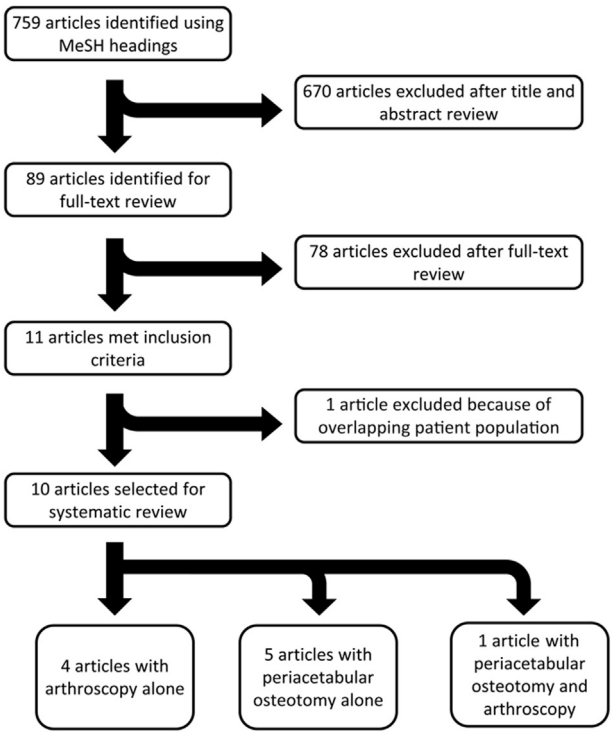

Fig 1. Flowchart of search strategy.

Methods

In February 2015, we searched the MEDLINE and PubMed databases for articles published since 2000 pertaining to hip arthroscopy and PAO in the setting of developmental hip dysplasia. Articles were identified using the following Medical Subject Heading terms: ((((“hip dysplasia”) or “dysplastic”) and “arthroscopy”)) or (((“hip dysplasia”) or “dysplastic”) and “osteotomy”). Two reviewers (P.L., S.C.) independently reviewed the titles and abstracts to select relevant articles for full-text review. Articles without abstracts were chosen for full-text review by default. Both reviewers then examined the full-text articles for eligibility. Articles were included based on the following criteria: (1) were in the English language, (2) commented on parameters or diagnostic testing that may be evidence of developmental hip dysplasia, (3) contained outcome data on patients undergoing the surgical procedure, (4) had a sample size of at least 10 patients, and (5) were published since 2000. We excluded review articles, technique articles, articles with overlapping patient populations, articles including patients with a mean age less than 18 years, patients with other hip conditions (like Legg-Calve-Perthes, slipped capital femoral

Table 2. Findings from Articles Using Hip Arthroscopy Alone to Treat Dysplasia

Study	Year	Level of Evidence	Patients, n (% female)	Mean Age, yr (range)	Follow-up, yr (range)	CE Angle (range)	Preoperative PRO Scores	Postoperative PRO Scores	Results	Total Conversions to THA	Mean Time to Conversion to THA, yr
Byrd and Jones[22]	2003	IV	48 (58)	34 (14-64)	2.25 (1-5)	20°-25°, 32 patients (borderline) < 20°, 16 patients (dysplastic)	mHHS in borderline cases = 57 mHHS in dysplastic cases = 50	mHHS in borderline cases = 83 mHHS in dysplastic cases = 77	79% showed at least 10-point improvement Ligamentum teres and loose bodies did best Arthritic hips did poorest	2	1.5
Yamamoto et al.[21]	2005	IV	10 (100)	33.7 (14-62)	8.2 (2-14)	12.4° (0°-20°)	HHS = 64.5	HHS = 92.5	60% were bucket-handle deformities Rapid progress of OA not observed after limbectomy	Not reported	NA
Parvizi et al.[18]	2009	IV	34 (65)	34 (19-51)	3.5 (1-7)	30 hips, CE < 20°	SF-36 and SUSHI	Declined to 76 points at 2 yr	Labral debridement in all cases 24 patients had continued symptoms; 3 required revision hip arthroscopy, which also failed 14 patients had progression of OA	3	Not reported
Domb et al.[20]	2013	IV	22 (82)	20 (14-39)	2.3 (1.4-3.25)	22.2° (18°-25°)	mHHS = 69 HOS-ADL = 72.9 HOS-SSS = 49 NAHS = 68.6 VAS = 5.8	mHHS = 86.2 HOS-ADL = 89.6 HOS-SSS = 77 NAHS = 85.9 VAS = 2.9 Satisfaction = 8.4	All patients received capsular plication theorized to decrease abnormal translational motion of the femoral head and protect the labrum and acetabular cartilage from further injury 21 labral repairs, 1 selective debridement 13 ligamentum teres debridements 15 iliopsoas releases 9 osteoplasties and chondroplasties	0	NA

CE, center edge; HHS, Harris Hip Score; HOS-ADL, Hip Outcome Score—Activities of Daily Living; HOS-SSS, Hip Outcome Score—Sports Specific Subscale; mHHS, modified Harris Hip Score; NA, not available; NAHS, Nonarthritic Hip Score; OA, osteoarthritis; PRO, patient-reported outcome; SF-36, 36-item short form; SUSHI, Super Simple Hip; THA, total hip arthroplasty; VAS, visual analog scale.

Table 3. Findings from Articles Using Periacetabular Osteotomy Alone to Treat Dysplasia

Study	Year	Level of Evidence	Patients, n (% female)	Mean Age, yr (range)	Follow-up, yr (range)	CE Angle Before Procedure (range)	CE Angle After Procedure (range)	Preoperative PRO Scores	Postoperative PRO Scores	Results	Total Conversions to THA	Mean Time to Conversion to THA, yr
Biederman et al.[12]	2008	IV	50 (72) 60 hips	27.3 (12-44)	7.4	8.7°	31.5°	NA	SF-36 = 76.4 WOMAC = 25.1	41% minor complications 37% major complications	0	NA
Armiger et al.[10]	2009	IV	12 (100)	35* (20-50)	9.5 (9-10)	9.8° (−6° to 21°)	30.9° (23°-47°)	q-score = 69 HHS = NA	q-score = 94 (10 yr) HHS = 95 (2 yr)	2 patients deteriorated from 2 to 10 yr postoperatively	1	3
Nunley et al.[24]	2011	IV	57 (72)	24 (13.4-44.3)	2.4	−1.2° (−30° to 19°)	27.4° (10°-47°)	HHS = 66.4	HHS = 91.7	95% of patients improved in function 1 hip progressed to Tonnis 2 changes	1	Not reported
Beaulé et al.[6]	2015	IV	67 (69) 72 hips	32 (14-54)	5* (1-8.3)	16.5°* (−24° to 28°)	31.0°* (10.7°-49.0°)	WOMAC = 53.9 UCLA = 5.3 SF-12, mental = 45.3 physical = 37.2	WOMAC = 74.4 UCLA = 6.6 SF-12, mental = 48.0 physical = 44.9	Preoperative higher alpha angle associated with lower WOMAC scores Additional reoperations = 3 hip arthroscopies and 1 THA 94.1% survival at 5 yr	1	7.2
Birch et al.[23]	2015	IV	468 eligible or converted to THA 228 had follow-up (83) All data refer to this cohort	33.4 (13-61)	7.1 (1.9-13.6)	14° (29°-50°)	31° (0°-49°)	Not reported	SF-36 female, mental = 55.7 physical = 49.2 SF-36 male mental = 57.4 physical = 52.2	Physical SF-36 scores in the study population lower than the reference Danish population No association between radiographic angles and QoL Limitation: only patients with preserved joints asked to answer QoL not different between hypermobile and nonhypermobile patients	80	Not reported

CE, center edge; HHS, Harris Hip Score; NA, not applicable; PRO, patient-reported outcome; QOL, quality of life; q-score, self-administered questionnaire; SF-12, 12-item short form; SF-36, 36-item short form; THA, total hip arthroplasty; UCLA, University of California, Los Angeles; WOMAC, Western Ontario and McMaster Osteoarthritis Index.
*Median.

Table 4. Findings from Articles Using Hip Arthroscopy and Periacetabular Osteotomy to Treat Dysplasia

Study	Year	Level of Evidence	Patients, n (% female)	Mean Age, yr (range)	Follow-up, yr (range)	CE Angle Before Procedure (range)	CE Angle After Procedure (range)	Preoperative PRO Scores	Postoperative PRO Scores	Results	Total Conversions to THA	Mean Time to conversion to THA, yr
Kain et al.[25]	2011	III	17 in arthroscopy + PAO group; 34 in PAO-only group; 51 (100) in total	31 (14-49) in arthroscopy + PAO group; 31 (16-48) in PAO-only group	NA	10° in arthroscopy + PAO group; 5.1° in PAO-only group	28.2° in arthroscopy + PAO group; 25.2° in PAO-only group	WOMAC for arthroscopy + PAO group: Pain = 10.9, Stiffness = 4.1, Function = 29; WOMAC for PAO-only group: Pain = 10.1, Stiffness = 2.6, Function = 22	WOMAC for arthroscopy + PAO group: Pain = 5.8, Stiffness = 2.6, Function = 17.7; WOMAC for PAO-only group: Pain = 4.2, Stiffness = 1.9, Function = 10.9	Previous arthroscopic labral treatment may not have a negative effect on functional outcome. When arthroscopy fails to improve symptoms in dysplastic patients, PAO can achieve good functional results	3 (17.6%) of arthroscopy + PAO group; 1 (2.9%) of PAO-only group	4.7 for arthroscopy + PAO group; 2.6 for PAO-only group

CE, center edge; NA, not available; PAO, periacetabular osteotomy; PRO, patient-reported outcome; THA, total hip arthroplasty; WOMAC, Western Ontario and McMaster Universities Osteoarthritis Index.

epiphysis, or postinfectious hip deformities), patients with genetic or neuromuscular causes of hip dysplasia, patients with Tonnis grade 2 or higher arthritic changes in the hips, articles covering femoral osteotomy, and articles on previous surgical intervention, except hip arthroscopy (Table 1). Additionally, the references of identified articles were searched for relevant articles for full-text review.

We performed a full-text review of the chosen articles to determine the demographics of the patients included, mean follow-up period, LCEA, PRO scores, and the number of patients who converted to total hip arthroplasty (THA) after hip arthroscopy or PAO, or both, as well as the mean times to these conversions. We defined patients with an LCEA from 18° to 25° as having borderline dysplasia and those with an LCEA less than 18° as having true dysplasia. A power analysis was performed to determine the number of patients required to compare groups in such a way that sufficiently ruled out type II error, assuming that the conversion rate of THA in each group was the same as that found in the current review. A power of 0.8 or greater was considered sufficient.

Results

In February 2015, our literature search identified 759 articles from the MEDLINE and PubMed databases. After abstract and title review, we selected 89 articles for full-text review. Of these, 11 met the inclusion criteria. We excluded one of these articles because it reported on the same patient population as another article by the same authors in the recent literature. Four articles[18,20-22] reported on the outcomes of arthroscopic treatment alone, 5 articles[6,10,12,23,24] reported on the outcomes of PAO alone, and one article[25] reported on the outcomes of PAO both alone and combined with arthroscopy (Fig 1). The characteristics and findings of these 10 articles that were selected for this systematic review are presented in Tables 2-5.

Of the 10 articles included in this review, there was one article[25] with Level III evidence and 9 articles with Level IV evidence. These studies reported on 834 hips treated for dysplasia. Of these, 114 were treated with arthroscopy alone (60 with true dysplasia and 54 with borderline dysplasia), 703 were treated with PAO alone (all with true dysplasia), and 17 were treated with PAO combined with arthroscopy (all with true dysplasia). The mean age of patients was 31 years for all treatment modalities. Mean follow-up time was 3.2 years for patients treated with arthroscopy alone, 6.5 years for patients treated with PAO alone, and 5.6 years overall. The follow-up time for patients undergoing PAO and arthroscopy was not reported.[25] Mean values of preoperative LCEA were consistently reported in the 5 articles that reported the outcomes of PAO (mean, 10.5°; range, −24° to 50°) but not in the articles that

Table 5. Demographics of Patient Population in Selected Articles

Demographic	Arthroscopy	PAO	Arthroscopy and PAO	Total
No. of hips	114	703	17	834
Mean age, yr	31.3	31.1*	31	31.1*
Mean follow-up, yr	3.2	6.5*	Not reported	5.6
Preoperative LCEA, range, °	0-25	−24 to 50 (mean: 10.5*)	Not reported	−24 to 50
Conversion to THA, %	4.8†	12.0†	17.7	11.3†
Mean time to conversion to THA, yr	1.5†	4.3†	4.7	3.7†

LCEA, lateral center edge angle; PAO, periacetabular osteotomy; THA, total hip arthroplasty.
*Excluded studies that did not report mean values.
†Excluded studies that did not report conversion to THA or did not report mean time to conversion.

reported the outcomes of arthroscopy (range, 0° to 25°). Two articles[20,22] reporting outcomes of arthroscopy divided the patient groups into those with borderline dysplasia (LCEA from 18° or 20° to 25°) and those with true dysplasia (LCEA < 18° or 20°).

Rates of conversion to THA were 4.8% for patients treated with arthroscopy alone, 12.0% for patients treated with PAO alone, and 17.7% for patients treated with PAO combined with arthroscopy, whereas mean times to conversion were 1.5 years, 4.3 years, and 4.7 years, respectively (Table 3, Fig 2). There was insufficient power to rule out type II error for meaningful comparisons between the treatment modalities. Assuming that the ratios of patients who received each treatment remained constant, sufficient power of 0.8 would require 313 patients between the arthroscopy alone and PAO combined with arthroscopy groups (121 included in this review) and 12,308 patients between the PAO alone and PAO combined with arthroscopy groups (720 included in this review).

Although all studies included in this review assessed PRO scores, the scores used were not consistent. Three scores were assessed by more than one article; the 36-Item Short Form (SF-36)[12,18,23] and the Harris Hip Score (HHS)[10,21,24] were assessed in 3 studies each, whereas the modified Harris Hip Score (mHHS) was assessed in 2 studies[20,22] (Table 2). Of the studies that reported both pre- and postoperative PRO scores, nearly all reported improvement. One study in the arthroscopy-alone group showed a decline in PRO scores postoperatively.[18] This study assessed the SF-36 and the Super Simple Hip score (SUSHI) results in 34 patients with LCEA less than 20° and showed a decline in functional scores of 76 points at 2 years postoperatively.

Discussion

Hip dysplasia in the young adult has been predominantly managed with open surgical techniques aimed at reorienting the acetabulum, with occasional realignment of the proximal femur.[26] Hip arthroscopy has gained popularity in the management of FAI[15-17]; however, it has met skepticism when implemented in isolation for dysplasia.[18,19] The purpose of this study was to evaluate the outcomes of hip arthroscopy and

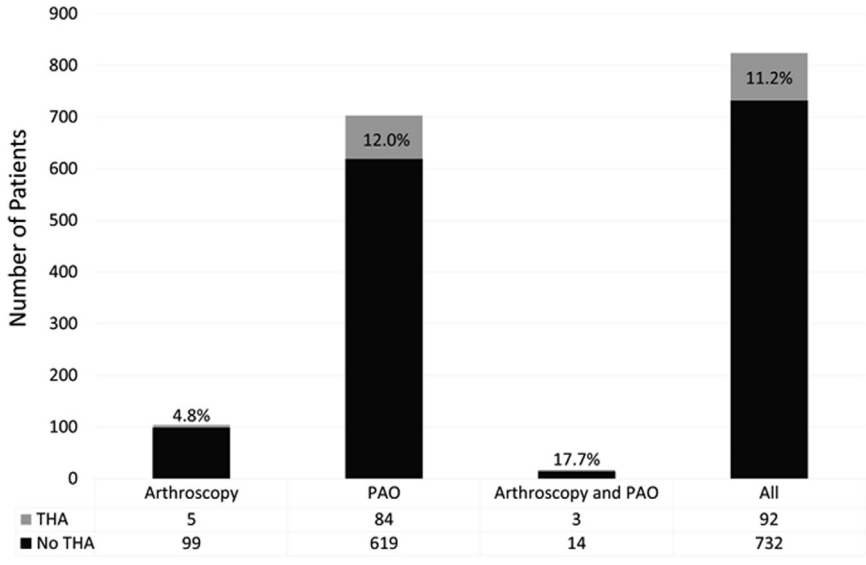

Fig 2. Conversion rates to total hip arthroplasty in the treatment groups for hip dysplasia. (PAO, periacetabular osteotomy; THA, total hip arthroplasty.)

PAO, in isolation and in combination, for the management of patients with hip dysplasia in the 21st century. We reviewed 10 articles that reported outcomes of patients undergoing hip arthroscopy, PAO, or a combination thereof, for the treatment of hip dysplasia. The rates of conversion to THA were 4.8%, 12.0%, and 17.7%, respectively. Both arthroscopy and osteotomy have shown favorable outcomes according to PRO scores in appropriately selected patients.

In the study by Byrd and Jones,[22] 48 patients with evidence of dysplasia underwent hip arthroscopy with a mean follow-up of 27 months. The study group was divided into 16 patients with LCEA less than 20° and 32 patients with LCEA between 20° and 25°. Labral pathologic conditions, chondral damage, and ligamentum teres disruption were the 3 most common diagnoses encountered. The mHHS scores for the dysplastic group improved from 57 preoperatively to 83 postoperatively and scores for the borderline dysplastic group improved from 50 preoperatively to 77 postoperatively. There was no statistical difference between the 2 groups. Two patients required conversion to THA. Factors correlating to improved outcomes included younger age, traumatic onset of pain, debridement of a ruptured ligamentum teres, and removal of loose bodies. Interestingly, labral and chondral lesions showed average results despite being the most commonly encountered arthroscopic pathologic conditions. This may have been related to selective debridement of the deteriorated portion of the labrum instead of attempts to preserve it.

Domb et al.[20] assessed 22 patients who underwent hip arthroscopy with a mean LCEA of 22.2° (range, 18° to 25°), which the authors categorized as borderline dysplasia, (similar to the definition alluded to by Byrd and Jones[2]). This article assessed mHHS, Nonarthritic Hip Score (NAHS), Hip Outcome Score—Sports Specific Subscale (HOS-SSS), Hip Outcome Score—Activities of Daily Living (HOS-ADL), and visual analog scale (VAS). At a mean 27.5 months of follow-up, the authors found improvements in all PRO scores, with postoperative scores of 86.2, 85.9, 77, 89.6, and 2.9 for mHHS, NAHS, HOS-SSS, HOS-ADL, and VAS, respectively. Additionally, satisfaction was rated at 8.4 on a scale of 1 to 10, with 1 being completely unsatisfied and 10 being completely satisfied. Most common arthroscopic findings were similar to those reported by Byrd and Jones.[22] They included labral tears (in all patients), cartilage damage at the chondrolabral junction (19 patients), and ligamentum teres tears (13 patients). However, there was an emphasis on labral preservation, with 21 of the 22 labral tears being repaired, leaving only one that was selectively debrided. The effort toward labral preservation was thought to restore the suction seal of the hip joint using previous studies on the function of the labrum.[27-29] In addition, this article introduced the use of capsular plication, whereby the inferior capsule was shifted proximally in this patient population with borderline dysplasia. The authors theorized that doing so would aid in decreasing abnormal translational motion or microinstability of the hip and protect the articular cartilage and labrum from further injury.

Although the aforementioned articles supported hip arthroscopy in hip dysplasia, Parvizi et al.[18] cautioned against its use. In their article, 36 hips with an LCEA less than 20° underwent arthroscopy and were followed for a mean of 3.5 years. Of these hips, 24 (67%) had a decline in functional scores at 2 years, and 14 (39%) and 13 (36%) hips had accelerated arthritis and migration of the femoral head, respectively, at a mean of 34 months postoperatively. Sixteen of 34 patients (47%) underwent further surgical intervention, with 3 hips (8%) requiring conversion to THA. This high failure rate in their patient cohort led the authors to suggest a more judicious use of hip arthroscopy in the setting of hip dysplasia.

Since the introduction of the Bernese PAO in 1984, there have been myriad articles on the topic. We chose to investigate the ones reported in the 21st century to parallel strides in research made in hip arthroscopy, which has predominantly been studied during the same period. Most recently, Beaulé et al.[6] published their results on 67 patients (72 hips) undergoing PAO for hip dysplasia with a minimum 1-year follow-up. Of the 41 patients who had completed 5 postoperative years, 39 (95%) were available for follow-up. Overall, the Western Ontario and McMaster Osteoarthritis Index (WOMAC) improved from 54 to 74, the 12-item Short Form (SF-12) physical component score improved from 37 to 45, with no change in the mental component, and the University of California, Los Angeles (UCLA) activity score improved from 5 to 7. All these improvements were statistically significant. The median LCEA and Tonnis angle improved from 16.5° to 31.0° and 15.3° to 8.0°, respectively. There was one conversion to THA (1.4%) at 86 months postoperatively. The authors also performed osteochondroplasty of the head and neck junction using an arthrotomy in 68% of patients, improving the alpha angle from a median 52.8° to 45°. Interestingly, a higher preoperative alpha angle was the only factor associated with lower postoperative WOMAC scores. The authors alluded to the presence of increased cartilage damage in the presence of the cam lesion as a potential cause of poorer outcomes, and they suggested addressing it along with intra-articular pathologic features as a topic of further research.

Birch et al.[23] recently investigated the correlation between radiological parameters and PRO scores in patients with hip dysplasia after PAO. Of the potential 529 patients who underwent PAO, they excluded 141 patients—80 (15%) because of conversion to THA, 40 because of other syndromes causing hip dysplasia, and

21 because of an inability to establish contact. They achieved 58% (228 of 388 eligible patients) follow-up at a mean of 7.1 years. The LCEA increased a mean of 18° postoperatively and the acetabular index decreased a mean of 14° postoperatively. The physical component of the SF-36 score was significantly lower in the study group compared with the Danish population, which was used as a reference. Improvements in physical function and physical component score subsets of the SF-36 decreased with time in the study group. The authors estimated a 16.3% prevalence of hypermobility in the study group and noted no significant difference between postoperative PRO scores in this subset of the study group compared with the subset without hypermobility.

The study by Kain et al.[25] was the only eligible study in this systematic review to report on outcomes of patients undergoing PAO and hip arthroscopy. It was a retrospectively matched-cohort study that compared 17 patients undergoing arthroscopic labral debridement before PAO (arthroscopy group) with 34 patients who underwent PAO alone without arthroscopy (nonarthroscopy group). There was no clinically relevant difference between the 2 groups regarding radiographic findings, except the preoperative LCEA, which was 10° in the arthroscopy group and 5° in the nonarthroscopy group. There was no significant difference in the change in WOMAC scores from preoperatively to postoperatively between the 2 groups. Three patients in the arthroscopy group (17.6%) and one patient in the nonarthroscopy group (2.9%) required conversion to THA. The authors concluded that previous arthroscopic labral debridement might not have a negative effect on functional outcomes after subsequent PAO in patients with hip dysplasia.

There has been a high prevalence of intra-articular hip lesions using hip arthroscopy compared with arthrotomy at the time of PAO. In a systematic review by Redmond et al.,[14] the authors found that the prevalence of labral tears was 84% by arthroscopy and 21% by arthrotomy at the time of PAO. Furthermore, arthroscopy was useful in identifying 73% of acetabular injuries and 27% of femoral chondral injuries. These findings underscore the potential utility of concurrent hip arthroscopy to identify and address intra-articular lesions at the time of PAO. Our review included one article[25] that shed light on the outcomes of such a combined approach with 17 patients. Although this is a small sample size, in our opinion this approach to management of true dysplasia is gaining popularity[5,30-32] and is our preferred technique when treating patients with true dysplasia who are candidates for PAO.

Further studies are needed to delineate the benefit of hip arthroscopy in the setting of acetabular dysplasia. Based on this systematic review, we proposed to look at acetabular dysplasia in 2 categories: borderline dysplasia (LCEA between 20° and 25°) and true dysplasia (LCEA < 20°). When evaluating a patient with any degree of dysplasia in whom nonoperative management has failed, symptomatic borderline dysplasia without radiographic signs of OA may be treated with hip arthroscopy with a focus on labral preservation (to maintain the suction seal) and capsular plication (to address soft tissue laxity) while addressing any intra-articular chondral pathology. Symptomatic true dysplasia without radiographic signs of OA may be managed with a combination of hip arthroscopy to address the aforementioned points and subsequent PAO to unload the labrum and juxta-articular region by addressing the greater bony deformity.

Limitations

There are a number of limitations to this systematic review. First, the number of articles reporting the use of hip arthroscopy in the setting of dysplasia is limited compared with that reporting PAO in the same patient population. This may result from hip arthroscopy being a newer technique predominantly gaining popularity in the 21st century compared with PAO. Second, we chose to exclude studies that looked at patients with pre-existing OA of Tonnis grade 2 or higher. In so doing, we tried to reduce the heterogeneity of articles reporting outcomes of these 2 techniques. This exclusion may have added to the lack of power in our statistical analyses looking at conversion rates to THA. The indications for hip arthroscopy continue to be refined, one of which is pre-existing OA.[33] Third, we chose only the Bernese PAO as the open procedure to be assessed in this review and excluded all articles that used other acetabular reorientation procedures. This procedure is the preferred osteotomy for symptomatic hip dysplasia in North America and has had favorable outcomes.[34] However, there are other procedures to obtain acetabular coverage that were not assessed in this review, which also have had good outcomes.[30,35-38] We chose to exclude those studies to reduce the heterogeneity in our articles. Fourth, we excluded patients who had undergone proximal femoral osteotomies before, during, or after one of the 2 techniques examined in this review. Clohisy et al.[39] found a high incidence of femoral deformities in dysplastic hips undergoing PAO at their institution; however, they noted that proximal femoral osteotomies were used less commonly (10% of cases) and only in the setting of coxa valga or coxa vara.

There were limitations within the literature itself that made it difficult to draw comparisons between the different surgical approaches. There were 60 and 54 patients who underwent arthroscopy for true and borderline dysplasia, respectively. The outcomes within each dysplasia type were not clearly delineated. For example, Byrd and Jones[22] reported on conversion to

THA in the entire dysplasia cohort; however, the type of dysplasia in these patients was not reported. Additionally, the literature reviewed did not have any PAOs performed in patients with borderline dysplasia, making comparison of outcomes between PAO and hip arthroscopy difficult for the borderline dysplasia group. Finally, there was only one article discussing the role of hip arthroscopy along with PAO in dysplasia that met the inclusion criteria for this review. Hence, we were able to evaluate the outcomes of only 17 patients who underwent a combined surgical approach.[25] Although this is a small sample size in this category, we chose to include it because it is gaining popularity as a means to address intra-articular pathologic conditions while concurrently correcting bony pathoanatomy.[5,30-32] Finally, the PRO scores used in all the articles reviewed were not consistent to make a meaningful comparison between the patient populations.

Conclusions

The management of hip dysplasia may entail hip arthroscopy, PAO, or a combined approach. Arthroscopy has resulted in improved outcomes in borderline dysplastic cases (LCEA between 18° and 25°). PAO has primarily been used in true dysplasia with continued success. There were too few combined procedures of arthroscopy with PAO to reach a reliable conclusion in this subgroup.

References

1. Ginnetti JG, Erickson J, Peters CL. Periacetabular osteotomy: Intra-articular work. *Instr Course Lect* 2013;62:279-286.
2. Ganz R, Parvizi J, Beck M, Leunig M, Notzli H, Siebenrock KA. Femoroacetabular impingement: A cause for osteoarthritis of the hip. *Clin Orthop Relat Res* 2003;417:112-120.
3. Murphy SB, Ganz R, Muller ME. The prognosis in untreated dysplasia of the hip. A study of radiographic factors that predict the outcome. *J Bone Joint Surg Am* 1995;77:985-989.
4. Clohisy JC, Carlisle JC, Beaule PE, et al. A systematic approach to the plain radiographic evaluation of the young adult hip. *J Bone Joint Surg Am* 2008;90:47-66 (suppl 4).
5. 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;472:674-680.
6. 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;473:615-622.
7. Millis MB, Murphy SB, Poss R. Osteotomies about the hip for the prevention and treatment of osteoarthrosis. *Instr Course Lect* 1996;45:209-226.
8. Santore RF, Dabezies EJ Jr. Femoral osteotomy for secondary arthritis of the hip in young adults. *Can J Surg* 1995;38:S33-S38 (suppl 1).
9. 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.
10. Armiger RS, Armand M, Tallroth K, Lepisto J, Mears SC. Three-dimensional mechanical evaluation of joint contact pressure in 12 periacetabular osteotomy patients with 10-year follow-up. *Acta Orthop* 2009;80:155-161.
11. Armand M, Lepisto J, Tallroth K, Elias J, Chao E. Outcome of periacetabular osteotomy: Joint contact pressure calculation using standing AP radiographs, 12 patients followed for average 2 years. *Acta Orthop* 2005;76:303-313.
12. Biedermann R, Donnan L, Gabriel A, Wachter R, Krismer M, Behensky H. Complications and patient satisfaction after periacetabular pelvic osteotomy. *Int Orthop* 2008;32:611-617.
13. 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;88:1920-1926.
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;30:382-388.
15. Byrd JW, Jones KS. Arthroscopic management of femoroacetabular impingement: Minimum 2-year follow-up. *Arthroscopy* 2011;27:1379-1388.
16. 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;91:16-23.
17. Nho SJ, Magennis EM, Singh CK, Kelly BT. Outcomes after the arthroscopic treatment of femoroacetabular impingement in a mixed group of high-level athletes. *Am J Sports Med* 2011;39:14S-19S (suppl).
18. Parvizi J, Bican O, Bender B, et al. Arthroscopy for labral tears in patients with developmental dysplasia of the hip: A cautionary note. *J Arthroplasty* 2009;24:110-113 (6 suppl).
19. Kalore NV, Jiranek WA. Save the torn labrum in hips with borderline acetabular coverage. *Clin Orthop Relat Res* 2012;470:3406-3413.
20. 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;41:2591-2598.
21. Yamamoto Y, Ide T, Nakamura M, Hamada Y, Usui I. Arthroscopic partial limbectomy in hip joints with acetabular hypoplasia. *Arthroscopy* 2005;21:586-591.
22. Byrd JW, Jones KS. Hip arthroscopy in the presence of dysplasia. *Arthroscopy* 2003;19:1055-1060.
23. Birch S, Liljensoe A, Hartig-Andreasen C, Soballe K, Mechlenburg I. No correlations between radiological angles and self-assessed quality of life in patients with hip

dysplasia at 2-13 years of follow-up after periacetabular osteotomy. *Acta Radiol* 2015;56:196-203.
24. 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;93:17-21 (suppl 2).
25. Kain MS, Novais EN, Vallim C, Millis MB, Kim YJ. Periacetabular osteotomy after failed hip arthroscopy for labral tears in patients with acetabular dysplasia. *J Bone Joint Surg Am* 2011;93:57-61 (suppl 2).
26. Schoenecker PL, Clohisy JC, Millis MB, Wenger DR. Surgical management of the problematic hip in adolescent and young adult patients. *J Am Acad Orthop Surg* 2011;19:275-286.
27. Ferguson SJ, Bryant JT, Ganz R, Ito K. The acetabular labrum seal: A poroelastic finite element model. *Clin Biomech* 2000;15:463-468.
28. Nepple JJ, Philippon MJ, Campbell KJ, et al. The hip fluid seal—Part II: The effect of an acetabular labral tear, repair, resection, and reconstruction on hip stability to distraction. *Knee Surg Sports Traumatol Arthrosc* 2014;22:730-736.
29. Philippon MJ, Nepple JJ, Campbell KJ, et al. The hip fluid seal—Part I: The effect of an acetabular labral tear, repair, resection, and reconstruction on hip fluid pressurization. *Knee Surg Sports Traumatol Arthrosc* 2014;22:722-729.
30. Fujii M, Nakashima Y, Noguchi Y, et al. Effect of intraarticular lesions on the outcome of periacetabular osteotomy in patients with symptomatic hip dysplasia. *J Bone Joint Surg Br* 2011;93:1449-1456.
31. Ginnetti JG, Pelt CE, Erickson JA, Van Dine C, Peters CL. Prevalence and treatment of intraarticular pathology recognized at the time of periacetabular osteotomy for the dysplastic hip. *Clin Orthop Relat Res* 2013;471:498-503.
32. 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;93:732-737.
33. Domb BG, Gui C, Lodhia P. How much arthritis is too much for hip arthroscopy: A systematic review. *Arthroscopy* 2015;31:520-529.
34. Ross JR, Clohisy JC, Baca G, Sink E, Anchor Investigators A. Patient and disease characteristics associated with hip arthroscopy failure in acetabular dysplasia. *J Arthroplasty* 2014;29:160-163 (9 suppl).
35. Suzuki C, Harada Y, Mitsuhashi S, et al. Repair of cartilage defects and torn acetabular labrum in hip joints after conventional osteotomy: Evaluation by follow-up arthroscopy. *J Orthop Sci* 2005;10:127-132.
36. Naito M, Nakamura Y. Curved periacetabular osteotomy for the treatment of dysplastic hips. *Clin Orthop Surg* 2014;6:127-137.
37. Bartonicek J, Vavra J, Chochola A. Bosworth hip shelf arthroplasty in adult dysplastic hips: Ten to twenty three year results. *Int Orthop* 2012;36:2425-2431.
38. Girard J, Springer K, Bocquet D, Cotten A, Duquennoy A, Migaud H. Influence of labral tears on the outcome of acetabular augmentation procedures in adult dysplastic hips. Prospective assessment with a minimum follow-up of 12 years. *Acta Orthop Belg* 2007;73:38-43.
39. Clohisy JC, Nunley RM, Carlisle JC, Schoenecker PL. Incidence and characteristics of femoral deformities in the dysplastic hip. *Clin Orthop Relat Res* 2009;467:128-134.