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Innovations in Joint Preservation Procedures for the Dysplastic Hip "The Periacetabular Osteotomy"

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ABSTRACT

The Bernese periacetabular osteotomy is an effective treatment for symptomatic developmental dysplasia in the prearthritic young adult hip. Refinements in the periacetabular osteotomy technique and perioperative management have markedly improved the clinical outcomes and recovery in these patients. We will review the clinical presentation of acetabular dysplasia, indications for surgery, perioperative management, and contemporary refinements in technique including refined acetabular reduction, adjunctive hip arthroscopy, femoral head-neck osteochondroplasty, femoral procedures, and rapid recovery protocols. In well-selected patients, this reconstructive osteotomy should be considered safe and effective in alleviating pain and improving hip function in patients with symptomatic acetabular dysplasia.

Developmental dysplasia of the hip (DDH) is a common condition associated with pain and functional limitations [1,2]. DDH is also a known risk factor for secondary osteoarthritis (OA), being found in an estimated 20%-40% of secondary OA cases and increasing a patient's risk for OA by 4.3-fold [3,4]. The complex structural deformities of the dysplastic hip can involve both the acetabulum and proximal femur. Acetabular dysplasia is commonly the dominant deformity and is characterized by insufficient femoral head coverage and superolateral inclination of the articular surface. This deformity may result in instability of the joint with overload of the acetabular rim, leading to labral and cartilage damage, and ultimately OA [5,6].

A variety of hip preservation procedures have been developed and proposed for the treatment of symptomatic DDH [7–12]. In 1988, Ganz et al [8] introduced the Bernese periacetabular osteotomy (PAO) for acetabular reorientation. This procedure is performed through 1 incision, maintains posterior column integrity, preserves the acetabular blood supply, enables versatile multiplanar acetabular reorientation, and provides reliable healing. However, this technique involves a substantial learning curve. Major complications have been reported, especially in the surgeon learning curve phase [13]. Recent innovations in PAO surgery and other joint preservation procedures have had a tremendous positive impact on clinical outcomes of this surgery in the treatment of symptomatic, acetabular dysplasia [14–16].

Here, we present specific protocols which we and others have developed and implemented with a multidisciplinary approach to PAO surgery. These refined protocols have substantially improved the surgical care and postoperative recovery of patients treated with the PAO. The approach includes a consistent plan for pain management, anticoagulation, and active recovery, as well as contemporary refinements to the PAO surgical procedure.

Indications for PAO

The presenting symptoms in patients with symptomatic, acetabular dysplasia can be variable, and radiographic analysis can be challenging, especially in individuals with mild acetabular deformities. Most patients with hip dysplasia present with an insidious onset of activity-related pain localized to the groin and/or the lateral aspect of the hip. Patients normally report

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Table 1
PAO Perioperative Pain Management Protocol.

Preoperative	Intraoperative	Postoperative
(a) Day before surgery: Naprosyn 500 mg PO × 2 tablets (b) Scopolamine patch (if history of motion sickness or nausea after previous surgery) × 72 h	(a) General anesthesia (b) Time of incision: Tylenol 1 gm IV (c) Time of skin closure: Toradol 30 mg IVP	PACU: (a) Oxycodone 5 mg 1-2 tablets PO × 1 (b) Zofran 4 mg IV × 1 (c) IV Narcotic medication for breakthrough pain as needed Discharge medications: (a) Naprosyn 500 mg PO bid × 2 wk postoperatively (b) Percocet 5/325 1-2 tablets PO 4-6 h PRN—script from hospital (c) Hydrocodone/APAP (Norco) 5/325 mg 1-2 tablets PO q 4-6 h PRN after Percocet.

PAO, periacetabular osteotomy; PO, per os; IV, intravenous; PACU, post-anesthesia care unit; PRN, pro re nata; APAP, Acetaminophen; IVP, intravenous push.

moderate-to-severe pain daily and are physiologically young and otherwise healthy. Physical examination findings normally reveal a limp with a positive Trendelenburg sign and a positive impingement test [6].

Acetabular dysplasia pathomorphology is best confirmed using anteroposterior and lateral pelvic radiographs. The modified Dunn view (with hip flexed at an angle of 45° and abducted 20°) is used to detect asphericity of the femoral head and/or head-neck junction deformities, which are known to be common in the dysplastic hip [17–19]. Specifically, patients with a lateral center-edge angle <20°, anterior center-edge angle <18°, and acetabular index >10 are classified as dysplastic [20]. The false-profile view allows further examination of anterior coverage of the femur, confirming dysplasia in those patients with an anterior center-edge angle <18°. False-profile view also helps rule out joint space narrowing in those patients with an anterior subluxation of the femoral head. Additional findings may include rim fractures and fovea alta. Lower surgical threshold should be indicated in patients with DDH and associated laxity, excessive femoral valgus, and/or femur anteversion. For patients with confirmed symptomatic acetabular dysplasia, PAO is indicated for those who are symptomatic, active, and have preserved articular cartilage (Tonnis grade 0-1) after closure of the physis [14,16].

Pain, Anticoagulation, and Blood Loss Management

A preoperative, perioperative, and postoperative pain management protocol has been established to reduce pain before surgery, eliminate the need for an epidural, minimize postoperative nausea and vomiting, and manage clotting risks. Preoperatively, patients are prescribed nonsteroidal anti-inflammatories (eg, Naprosyn, Roche Laboratories, Indianapolis, IN) for at least 24 hours before surgery (Table 1).

Antinausea medication (eg, scopolamine patch) is also prescribed for 72 hours before surgery to reduce postoperative nausea and vomiting. Intraoperatively, local infiltration anesthesia has been proven to be more effective at controlling pain 12 hours after surgery in comparison with intravenous patient-controlled analgesia [21]. Our protocol consists of general anesthesia with specific timing of intraoperative analgesia followed by patient-controlled analgesia for 12-24 hours. Postoperatively, all patients are managed with intravenous pain medication and progress to oral pain medication as tolerated (Table 1). Multimodality pain management has been a substantial improvement, allowing our patients to have general anesthesia with no epidural. Without the need for an epidural and with minimized postoperative nausea and vomiting, normal discharge time has been expedited to 1-2 days postoperatively.

All patients are indicated to take enteric-coated aspirin 325 mg twice a day for 6 weeks postoperatively for anticoagulation. Intraoperatively, a mobile pneumatic compression device is used on the contralateral leg. In addition, all patients receive tranexamic acid (TXA). TXA inhibits clot breakdown and significantly reduces perioperative blood loss and blood transfusion [22]. Patients with normal renal function normally receive 1 g of TXA, intravenously infused over 10 minutes before skin incision and 1 g infused over 10 minutes at the start of the wound closure [23]. Close monitoring of postoperative hematocrit and hemoglobin is performed in all patients. Cell saver could also be used as an autologous blood recovery system during the procedure.

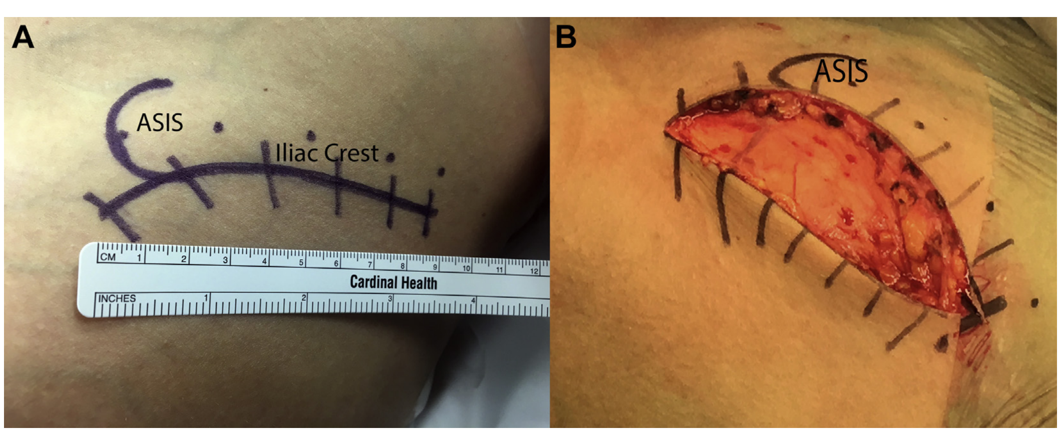

Fig. 1. Note the minimal incision for periacetabular osteotomy (PAO). (A) Marking pen is used to mark ASIS and iliac crest. Incision is located slightly lateral to the iliac crest. Distally, the incision will be extended further if an additional osteochondroplasty is needed. (B) Open wound after incision is performed. ASIS, anterior superior iliac spine.

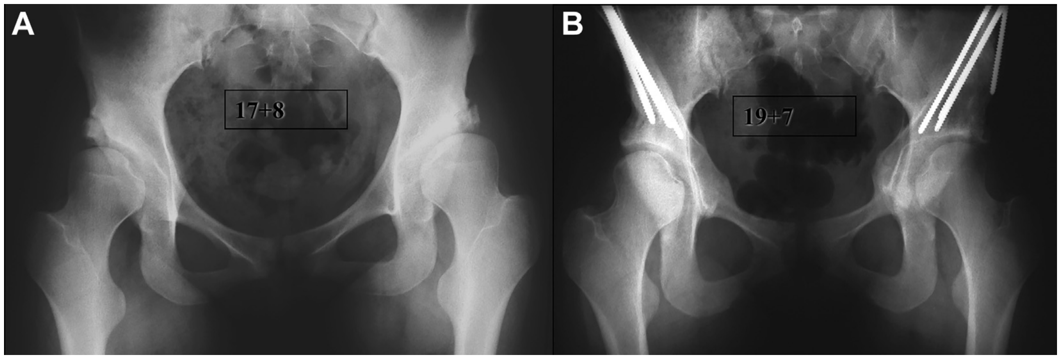

Fig. 2. Anteroposterior (AP) pelvis showing bilateral severe hip dysplasia. (A) Note the severe anterolateral undercoverage of the femoral head, the presence of a valgus femur, and the existence of a fatigue "rim fracture" or os acetabuli. (B) At 2 years after PAO, note the excellent correction with preservation of the joint space, good femoral head coverage, and good acetabular inclination and hip center translated medially (low head index extrusion).

Active Recovery

Active recovery for PAO patients includes ambulation with a walker 4-6 hours after operation. Patients are instructed to stay within 30% of full weight bearing for 4 weeks. If the rectus femoris was detached and repaired, to protect the muscle during healing, no active hip flexion exercises or straight leg raises are allowed. However, if the PAO was "rectus sparing" (vast majority of cases), the patient may perform gentle active hip flexion exercises. A continuous passive movement machine is used in all patients for 6 h/d (within comfort level) for 4 weeks with hip flexion to 60°. Patients are not allowed to drive until they are fully weight bearing with active control of the surgical extremity, normally between 6 and 8 weeks. It is also recommended that patients use a raised toilet seat to prevent hip flexion >90°. All patients receive home health physical therapy during the first 4 weeks postoperatively. Patients are then referred to outpatient physical therapy for a total of 20 weeks. Athletic patients are allowed to jog and start impact activities at 3 months. Return to full sport is progressive with a target of full sport at 4 months.

Contemporary Refinements to the PAO Surgical Technique

Advantages of the Bernese PAO originally described by Ganz et al [8], over previous osteotomy techniques, continue to be realized. This review is not intended to have a comprehensive surgical technique section, and as such, the reader is referred to another more comprehensive review on surgical techniques [24].

We perform the PAO with the patient supine on a radiolucent table through a modification of the Smith-Peterson approach (Fig. 1) [25]. Variations of the skin incision and surgical approach exist and are also effective in performing the procedure.

The procedure consists of 4 orthogonal periacetabular cuts that are technically reproducible and allow for substantial multidirectional correction of the mobilized acetabulum. Acetabular reduction should be performed under intraoperative fluoroscopy. Femoral head coverage, acetabular inclination, congruency (joint space), acetabular version, and medial translation of the femoral head should be reestablished (Fig. 2) [20,26,27]. The acetabular blood supply is preserved, which promotes reliable bone healing and minimizes incidents of avascular necrosis of the acetabular fragment [24,28]. Preservation of the posterior column facilitates pelvic and acetabular fragment stability after correction and screw fixation [8].

Contemporary refinements to the surgical technique have focused mostly on improved perioperative management, assessment of acetabular fragment reduction and deformity correction, and treating other hip deformities concomitantly. Additional surgical refinements involve muscle-sparing approaches, with preservation of the abductor muscles (gluteus maximus and medius) and maintenance of the rectus femoris attachment, to improve postoperative recovery [27,29–33]. Concomitant corrective surgeries often involve repair of intraarticular soft tissue (labrum repair and cartilage restoration), femoral osteochondroplasty, decompression of the anterior inferior iliac spine (AIIS), and proximal femoral osteotomy (PFO) to correct femoral dysplasia or severe femoral head deformities.

Intraarticular pathologic changes are a common finding in patients with symptomatic DDH [29]. For addressing and treating intraarticular pathology, arthroscopy can provide suitable visualization and access to address labral, chondral, and ligamentum teres injuries, using a less-invasive approach than open arthrotomy (Fig. 3) [30,34,35]. Still, there is little information about the benefits or risks of performing hip arthroscopy concomitantly with

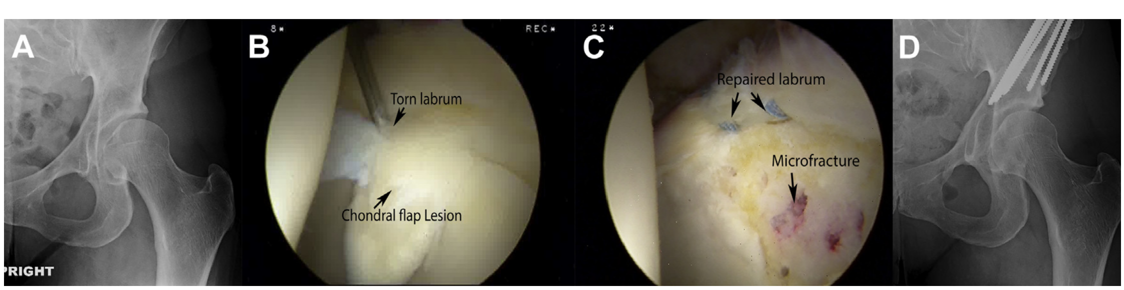

Fig. 3. Adjunctive hip arthroscopy in a 38-year-old female with left hip dysplasia. (A) Note the left hip with undercoverage of the left femoral head, (B) hip scope confirmed a torn labrum and full-thickness chondral defect, (C) labrum repair and microfracture was performed during arthroscopy, and (D) PAO was performed, immediately after hip arthroscopy, reestablishing good acetabular inclination and lateral coverage of the femoral head.

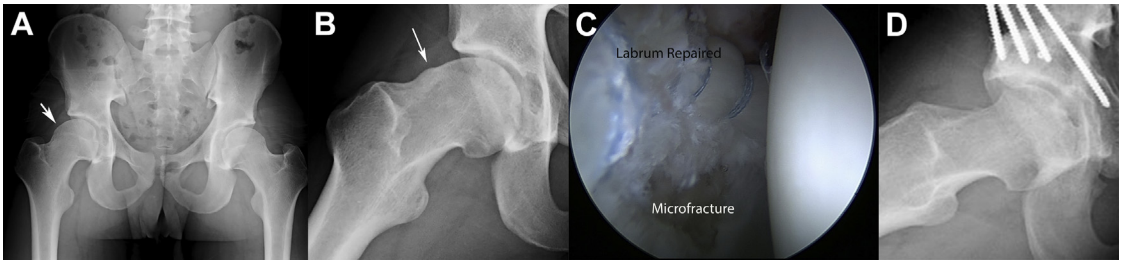

Fig. 4. Patient with right acetabular dysplasia and associated femoral head-neck offset deformity. Labrum repair, chondroplasty, and microfracture were performed during hip arthroscopy before PAO. Osteochondroplasty of the femoral head-neck junction was performed via anterior arthrotomy at the time of PAO. (A) Note the AP pelvis with right hip dysplasia, (B) Dunn view confirms a cam lesion, (C) arthroscopic microfracture and labrum repair, and (D) femoral head-neck osteochondroplasty is evident.

the PAO as standard of care for the treatment of acetabular dysplasia, and the practice remains controversial [30]. A recently published study, which retrospectively compared PAO alone vs a combined arthroscopy/PAO for the treatment of DDH, suggested better clinical results in those patients with the combined approach [30]. Based on personal preference, some surgeons may perform hip arthroscopy in conjunction with PAO, especially if the patient reports mechanical symptoms, such as catching and popping, but there is a need for a well-conducted, randomized, controlled trial in patients with DDH to confirm the efficacy of this approach. In our practice, we perform hip arthroscopy immediately before PAO, to treat the central compartment, only if the patient reports mechanical symptoms (eg, impingement) and if labral-chondral dissociation has been confirmed by magnetic resonance imaging.

Abnormalities of the femoral head and neck are also common in patients with DDH, and secondary femoroacetabular impingement (FAI) is a frequent mechanism of failure after PAO [17,18,36,37]. Osteochondroplasty is used to alleviate FAI caused by deformities at the femoral head and head-neck junction. Osteochondroplasty can be performed either arthroscopically or through open arthrotomy (Fig. 4) during the PAO procedure by minimal extension of the Smith-Peterson approach distally. Both arthroscopic and open osteochondroplasty have been demonstrated to be safe and effective for managing femoral head-neck deformities [17,38,39]. At our institution, we normally perform an open osteochondroplasty after PAO. Even in the absence of preoperative FAI, it is critical to assess range of motion after acetabular correction during a PAO. If limited range of motion is detected after acetabular correction (limited flexion and internal rotation), open osteochondroplasty is indicated.

Subspine syndrome can be a source of extra-articular impingement in patients with DDH. In these cases, terminal hip flexion results in impingement of the caudad prominence (ie, most distal extension) of the AIIS against the femoral neck and/or anterosuperior greater trochanter [40]. Radiographs and a computed tomography scan are necessary to confirm this pathology and indicate subspine decompression after acetabular fragment correction. Decompression of a prominent AIIS results in improved hip motion and hip function [40,41]. Subspine decompression can be performed arthroscopically or during PAO procedure through a minimal extension of the modification of the Smith-Peterson approach distally (Fig. 5).

In addition, for patients with severe femoral deformities, such as sequelae of Legg-Calve-Perthes disease or “Perthes-like deformities” or coxa valga with anteverted femurs, an adjunctive PFO may also be required to optimize correction, joint stability, and congruency [7,42–44]. The decision to add a PFO may be made before, during, or after performing PAO [45]. We contemplate adjunctive PFO in 2 clinical situations. First, in the severely dysplastic hip with coxa valga (femoral neck-shaft angle >140°) and persistent instability and/or suboptimal congruency with a persistent high head extrusion index after the PAO. Normally, the second main indicator for a PFO is a varus deformity or “Perthes-like” abnormality of the proximal femur. These hips may have a combination of structural and clinical impingement problems, including an aspheric femoral head, short, wide femoral neck, high greater trochanter, limited abduction motion, and leg length discrepancy. Iatrogenic varus deformities are a relatively common indication for concurrent valgus-producing PFO. In these last patients, the PFO is performed first in association with relative femoral neck lengthening, distalization of the trochanter, and valgus osteotomy [46]. The clinical results for patients undergoing concomitant PAO and PFO to address severe hip deformities are comparable with those for isolated PAO [7]. For an in-depth description of surgical correction for patients with DDH and complex femoral deformities, the reader is referred to more comprehensive review articles [7].

Clinical Results

Clinical outcomes after PAO have shown improvement in pain relief and hip function compared with presurgical baselines [18,36,47–51]. However, there is a substantial risk of major complications after PAO, especially during the anticipated surgeon learning curve associated with this procedure [13,52]. Regarding survivorship, recently published literature suggests rates of

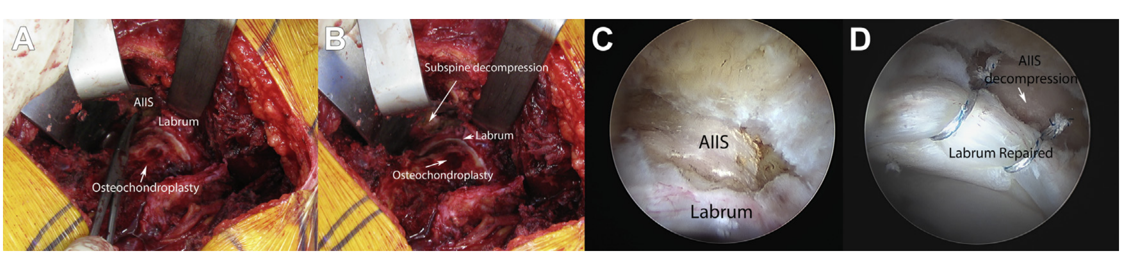

Fig. 5. Subspine decompression. (A) Prominent AIIS is evident during open arthrotomy after PAO was performed, (B) open subspine decompression was performed using a burr, (C) arthroscopic view of a prominent AIIS, and (D) arthroscopic decompression and associated labrum repair was performed. AIIS, anterior inferior iliac spine.

Table 2
Clinical Outcomes After PAO at 10 y of Follow-Up or More.

Author	Hips (n)	Age (y)	Follow-Up Years	Survivorship
Wells J; CORR 2017 [18]	121	27 (10-45)	18	85% at 10 y, 80% at 15 y, and 74% at 18 y
Lerch TD; CORR 2016 [49]	75	29 (13-56)	30	29% at 30 y
Matheney T; JBJS 2010 [53]	135	26.7	10	76% at 10 y

CORR, Clinical Orthopaedics and Related Research; JBJS, The Journal of Bone & Joint Surgery; PAO, periacetabular osteotomy.

75%-85% at 10 years and 61% at 20 years follow-up [18,50,53]. When considering long-term outcomes (30 years), only one-third of the hips have shown no progression to OA (Table 2) [49]. However, current long-term outcome data originated from procedures performed in the 1980s when PAO approaches were newly developed and did not have the benefits of the contemporary refinements discussed previously. Most factors that have been associated with progression to OA at 30 years after PAO include the following: older age (>40 years), high preoperative Tonnis grade, decreased preoperative internal rotation, and malcorrection of the acetabular fragment including acetabular overcoverage, or acetabular retroversion [49]. Current post-PAO patient-reported outcome data from the multicenter, prospective Academic Network of Conservational Hip Outcomes Research (ANCHOR) group include 391 hips with a minimum 2-year follow-up and show statistical improvements in clinical score in 93% of patients with a failure rate of 0.8%. Clinical outcomes analysis demonstrated important clinical improvements in pain, function, quality of life, overall health, and activity level. Major complications (classified as modified Clavien-Dindo grades III-IV) were reported in 7% patients including transient nerve palsy, pulmonary emboli, and deep venous thrombosis [16].

Conclusions

Treatment of DDH has advanced remarkably in the past 10 years. Refined patient selection, adequate perioperative management, improved pain management, and contemporary surgical approaches, including the treatment of combined intra-articular pathology and associated impingement, have substantially impacted the outcomes and recovery of patients treated with the PAO. Continued investigation is needed to further refine hip preservation strategies for the dysplastic hip. Identification of predictors of treatment success, failure, and disease modification will further enhance our ability to effectively treat prearthritic and early arthritic dysplastic hip disease.

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