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Operative Techniques in
Orthopaedics

Periacetabular Osteotomy for the Treatment of Skeletally Mature Acetabular Dysplasia

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Acetabular dysplasia is a common cause of persistent hip pain and limited function in young mature patients. Literature has shown that these patients with acetabular dysplasia are an increased risk for early progression to osteoarthritis. Periacetabular osteotomy, with the appropriate indications, can significantly improve both pain and function, as well as help to prevent the development of early osteoarthritis. Throughout this review we will discuss the indications, surgical technique, and outcomes of periacetabular osteotomy for the treatment of acetabular dysplasia in mature patients.
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Introduction

Acetabular dysplasia is a well-recognized cause of hip pain and dysfunction with an associated risk of developing osteoarthritis (OA).[1-4] In this condition, insufficient coverage of the femoral head by the acetabulum leads to excessive joint contact pressures and subsequent accelerated joint degeneration. Quantification of femoral head coverage is historically based on the lateral center-edge angle (LCEA), described by Wiberg in 1939.[5] The magnitude of the LCEA has been linked to the progression of OA even in the absence of symptoms during early adulthood,[6] with 1 study noting a 13% increased likelihood of developing OA for each 1° loss of lateral coverage below 28°.[7]

The periacetabular osteotomy (PAO), first described by Ganz, has become the standard treatment of symptomatic acetabular dysplasia as it permits acetabular reorientation to optimize acetabular coverage while maintaining posterior column integrity.[8] The PAO, as an acetabular redirection procedure, does not directly augment the insufficient regions of the acetabulum area of the cartilaginous acetabulum and rim. The PAO improves hip mechanics by optimizing the position of the lunate cartilage available to transmit forces during weight-bearing activities, which effectively decreases contact stresses and forces to the acetabular rim and labrum. The PAO as a surgical procedure has distinct advantages in the treatment of acetabular dysplasia over other osteotomies (Salter, Triple, RAO). It is performed through a single anterior incision with approaches designed to spare the abductors and rectus femoris.[9,10] The PAO creates a relatively large acetabular fragment with sufficient vascularity to allow arthrotomy for intra-articular work while preserving a portion of the posterior column to maintain pelvic stability and minimize compromise of the birth canal.[11] Last, internal fixation with multiple screws complements the osteotomy's inherently stable geometry to permit early partial weight-bearing without need for external immobilization.

Patient Evaluation

History and physical examination are essential in the diagnostic evaluation of patients with acetabular dysplasia. Patients often describe lateral hip pain over the greater trochanter, indicative of abductor fatigue, along with capsulolabral symptoms (anterior groin) due to mechanical overload. Upright activities are traditionally more symptomatic than sitting activities. Historical features to explore include birth and familial histories of dysplasia, as well as previous treatments (Pavlik harness, bracing, prior hip surgeries).

The physical examination is essential to test the static and dynamic function of the hip to aid in treatment decision. Examination should focus on range of motion with respect to hip flexion, extension, internal rotation, and external rotation in both supine and prone positions. Relative provocative maneuvers such as impingement testing (flexion, adduction, and internal rotation), FABER testing (flexion, abduction

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external rotation), and apprehension testing (extension, external rotation) tests specific hip symptoms related to impingement and instability. A global sense of hip strength and function can be attained through observation of various activities such as gait, double leg squat, and single leg squat exercises. Care should be taken to assess abductor function as they provide significant dynamic support to the mechanically unstable dysplastic hip.

Imaging

Imaging is essential in the evaluation of acetabular dysplasia both for diagnostic purposes and for perioperative planning. Plain radiographs remain the gold standard for assessing structural hip abnormalities, including hip dysplasia.[12] The standard radiographic set used in the initial assessment of acetabular dysplasia includes a standing well-centered anteroposterior (AP) radiograph of the entire pelvis, false profile views and a 45° Dunn lateral radiograph.[12] The AP radiograph is evaluated with measures of lateral and anterior coverage (LCEA; Tönnis roof angle; attitude of anterior and posterior walls; Shenton line intact or broken). The false profile view assesses anterior coverage through the anterior CE angle. The Dunn lateral is used to evaluate femoral head and/or neck offset issues and highlights the 1:00-2:00 region of the head-neck junction where deformity is most commonly encountered. All radiographs should be evaluated for changes indicative of OA, including loss of joint space height and subchondral cyst formation.

Important technological advances in assessing hip deformity include low-dose CT and MRI. CT in particular has improved our 3D understanding of acetabular deformity in dysplasia. Nepple et al[13] and Wilkin et al[14] showed that acetabular dysplasia presents with a spectrum of acetabular insufficiency, and recognition of patient-specific deficiency is helpful when reorienting the acetabulum. MRI enables evaluation of the soft tissue structures impacted by acetabular dysplasia including the hip cartilage and acetabular labrum. The acetabular labrum should be assessed for chondrolabral tearing and global hypertrophy as both of these conditions are relative indications for a combined hip arthroscopy at the time of PAO. In cases with preoperative concern for cartilage health, cartilage specific sequences, such as delayed Gadolinium-enhanced MRI (dGEMRIC), can be instructive in quantifying the health of the femoroacetabular cartilage.[15]

Treatment Consideration

When determining candidacy for surgical correction of acetabular dysplasia, a few historical features are commonly encountered during the preoperative workup. Specific consideration of these issues are briefly discussed below.

Arthritis

Acetabular dysplasia has been shown to increase the risk of progression to hip OA. Not uncommonly, patients presenting for the evaluation of a painful hip in the setting of hip dysplasia have already shown changes indicative of OA. The Tönnis classification is a widely used scoring system when quantifying femoroacetabular arthritis.[16] A longitudinal natural history study tracking the progression of OA changes with and without redirectional acetabular osteotomy noted that patients with minimal preoperative OA (Tönnis 0-1) had predictably low rates of OA progression at midterm follow-up (5 and 10 years), while those with more advanced preoperative arthritis (Tönnis 2+) had less longitudinal protection from arthritis.[17] In cases with potential radiographic OA, preoperative dGEMRIC scores have been shown to have a predictive value in the survival of PAO.[18]

Obesity

Obesity is a commonly encountered medical comorbidity throughout orthopedic surgery and it has been documented to influence surgical outcomes across a spectrum of pathologies. Novais et al[19] evaluated the effects of obesity of postsurgical complications and survival, noting that obese patients (BMI > 30 kg/m^2) were 11 times more likely to experience a postoperative complication following PAO. Obese patients were also more likely to develop severe postoperative complications, such as infections or arthritis progression requires early total hip arthroplasty, when compared to nonobese patients. Discussion of these risks and developing and/or implementing a weight management plan is important prior to surgery in these individuals.

Coverage

Two acetabular coverage patterns, borderline dysplasia and acetabular retroversion, must be discussed individually as much literature is available on these 2 dysplasia variants. When Wiberg initially described the lateral center edge angle measurement of dysplasia, a category of "borderline" uncovered hips remained controversial with respect to treatment. These hips, with LCEA measurements between 18° and 25°, are routinely treated by either hip arthroscopy or PAO. Several studies have noted these borderline uncovered hips to respond well following PAO with improved functional outcomes and few postoperative complications.[20,21] Acetabular retroversion is another recognized variant of acetabular dysplasia, featuring a retroverted socket in addition to lateral undercoverage. Similarly, this group responds well to PAO, but increasing acetabular anteversion at the time of reorientation is essential to avoid postoperative impingement.[22]

Clinical Case

A 22-year-old female nurse presented for evaluation of longstanding (3-4 years) of left hip pain. Her pain had 2 components: achy anterior groin discomfort present most of the time and fatigue type lateral hip pain over her greater trochanter with prolonged upright activities. On examination she had excellent, if not excessive, range of motion and a positive anterior apprehension test. Her preoperative radiographs are shown in Figure 1 and are noteworthy for significant lateral undercoverage including LCEA 14 and a Tönnis angle of 15. She had failed several rounds of

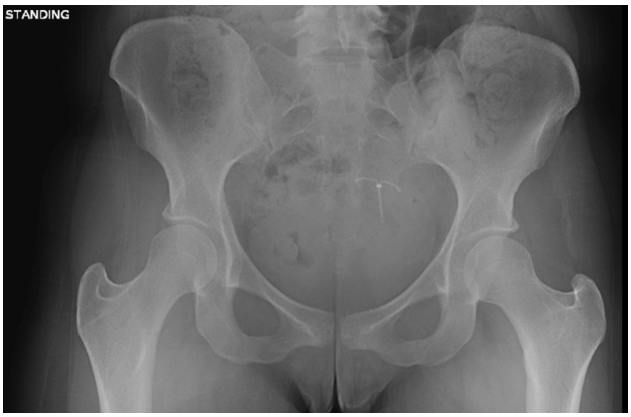

Figure 1 Preoperative standing AP pelvis radiograph shows a laterally undercovered femoral head with minimal osteoarthritic changes.

physical therapy, had minimal evidence of arthritis on both plain films and MR imaging, and responded extremely well to a diagnostic intra-articular anesthetic injection. She was thus considered a candidate for a PAO to improve acetabular coverage.

Surgical Technique

Detailed discussions of surgical technique for PAO are available in the literature.[23] The basic design for the PAO procedure, as developed by Ganz et al[8] in the 1980s, is still followed today, with sequential osteotomies of the anterior ischium; superior pubic ramus; supra-acetabular ilium; and posterior column.

Patient Setup

Routine preoperative preparation involves blood typing in the event of transfusion requirement. To mitigate this risk, we routinely use transexamic acid and cell-saver autotransfusion to limit overall blood loss. Anesthesia is typically accomplished through a combination of general anesthesia with a lumbar plexus block. Neuromuscular blockade is avoided to allow intraoperative monitoring of motor nerve function during the various osteotomies as the obturator (superior ramus) and sciatic nerves (ischium and posterior column) lie in proximity to certain osteotomy cuts. Any muscle contraction noted during the procedure suggests nerve irritation and prompts reassessment of technique to minimize the risk of nerve injury.

Fluoroscopy is used at various points during the PAO during both the osteotomy and acetabular correction portions of the procedure. The imaging arm should be positioned across the table from the operative hip and be stationed perpendicular to the patient's body. AP pelvis and oblique false profile views will be the most commonly obtained views during the procedure.

Surgical Approach and Osteotomies

The patient is positioned supine on a radiolucent Jackson type table, with the operative leg draped free. The trunk is prepped and draped to the midline and proximally to the costal margin. A bikini-type incision is utilized to create a limited direct anterior approach to the hip. The abductor muscles are routinely preserved through this approach. The abdominal obliques and sartorius are medialized after wafer osteotomy of the anterior superior iliac spine. The iliacus muscle is subperiosteally elevated from the inner table of the ilium exposing the anterior ilium, iliopectineal line, posterior column, quadrilateral surface and the superior ramus to and beyond the iliopectineal eminence. The rectus tendon origin is routinely preserved unless an extensive arthrotomy is required for access to the femoral head and neck, in which case the rectus tendon origin can be transected and later repaired.[10]

The anterior ischial osteotomy is accessed by elevation of the capsular iliacus from the anterior capsule and development of the interval between the medial capsule and psoas tendon distally. This enables development of an avascular passage to the anterior ischium which can be dilated with long scissors. Blunt bone levers are used to palpate the infracotyloid groove of the ischium, just distal to the inferior lip of the acetabulum. The bone levers can be used to mobilize the soft tissue (obturator externus) immediately anterior to this region of the ischium and dilate the pericapsular bursal passage tract. Once the anterior ischium is prepared, the bone lever is replaced with an angled chisel onto the proximal anterior ischium to perform the ischial osteotomy. This osteotomy, which cannot be directly visualized, begins just distal to the inferior lip of the acetabulum, leaving a bone bridge approximately 1 cm wide below the acetabulum (Fig. 2). The chisel is used to osteotomized the ischium in a series of anterior to posterior passes, starting at the medial cortex and progressing laterally. Typically, 3 passes are required (medial, central, and lateral). During the lateral chisel pass, the

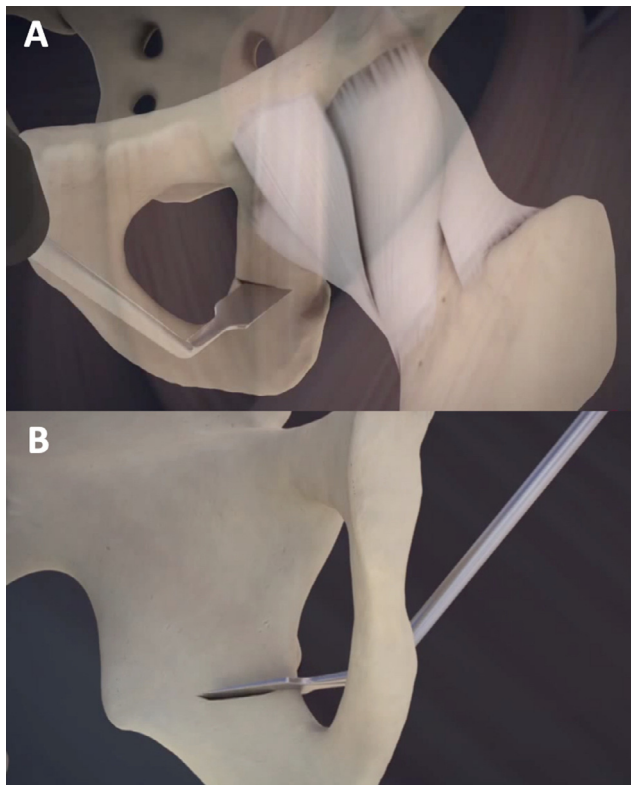

Figure 2 The anterior ischial osteotomy is performed with the Ganz chisel as seen from frontal (A) and medial (B) views of the hemipelvis.

leg should be in a position of abduction, extension, and external rotation to relax the sciatic nerve. Image intensifier control is useful both in initial placement of the chisel (AP and false profile views) and in confirmation of osteotomy depth (false profile).

The superior pubic ramus osteotomy is performed next. The proximity of the obturator nerve places it at risk during this osteotomy. The hip is flexed and abducted to protect the psoas and femoral neurovascular structures as the periosteum is dissected from the superior ramus. Retractors are placed around the ramus into the obturator foramen. Care is taken to keep the retractors within the developed periosteal sleeve to protect the obturator neurovascular bundle. The osteotomy is completed just medial to the iliopectineal eminence with either an osteotome, oscillating saw, or Gigli saw (Fig. 3).

The supraacetabular iliac osteotomy requires creation of a lateral subgluteal window along the lateral ilium at a level at or just distal to the anterior superior iliac spine (ASIS) osteotomy. Care is taken to avoid disruption of the abductor origin during development of this window. A small lateral retractor placed through this window gently retracts the abductors while a reverse Hohmann retractor placed on the quadrilateral plate is used to expose the medial iliac wing. An oscillating saw is used to osteotomize the ilium (Fig. 4). This osteotomy should traverse the ilium from the distal aspect of the ASIS osteotomy to a point 1 cm shy of the iliopectineal line. This osteotomy should be nearly perfectly vertical in orientation and will appear to parallel an imaginary floor when viewed on false profile imaging. The posterior extent of the iliac osteotomy should be templated prior to osteotomy creation. The endpoint of the iliac osteotomy will serve as the starting point for the posterior column cut, so it should be positioned to afford a safe trajectory across the posterior column to connect the iliac and ischial cuts.

The posterior column osteotomy is made entirely from within the pelvis. It begins at the posterior end of the iliac osteotomy and is directed toward the ischial spine. The posterior column osteotomy bisects the posterior column as it passes over the iliopectineal line, passing between the posterior acetabulum and the greater sciatic notch (Fig. 5). Straight osteotomes are used to create the medial pass of the osteotomy, typically to the level of the acetabular isthmus, or about 3 cm-4 cm into the true pelvis. The straight osteotome can be continued distally to connect with the ischial cut, or a curved osteotome can be inserted after passing the acetabular isthmus to direct the distal osteotomy more anterior. Once the medial cortex of the posterior column is cut, the junction of the iliac and posterior column osteotomies is completely freed by use of an angled chisel.

At this point, a laminar bone spreader may be placed in the anterior iliac osteotomy and gentle tension is placed across the posterior column. The lateral cortex of the posterior column is then osteotomized with the angle Ganz chisel to complete the osteotomy, at which point the acetabular fragment completely mobilizes. Again, when performing the lateral pass of the osteotomy, the leg should be brought into extension, abduction and external rotation as a means to relax and protect the sciatic nerve.

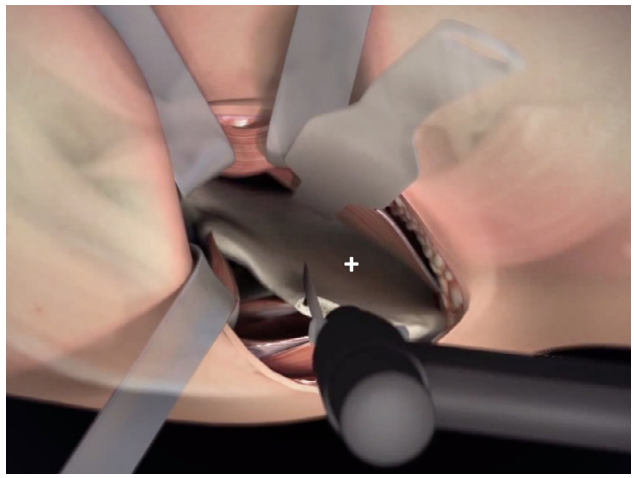

Figure 4 The iliac wing (+) osteotomy is performed with an oscillating saw.

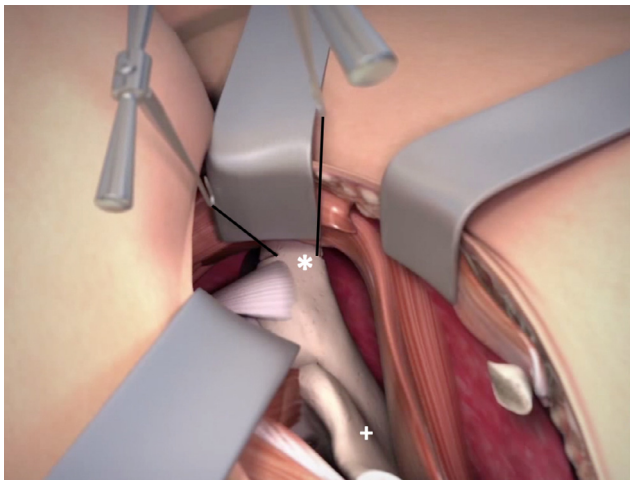

Figure 3 The pubic ramus osteotomy (white arrow) is performed with a Gigli saw just medial to the capsular insertion (*). The AIIS is denoted by the (+).

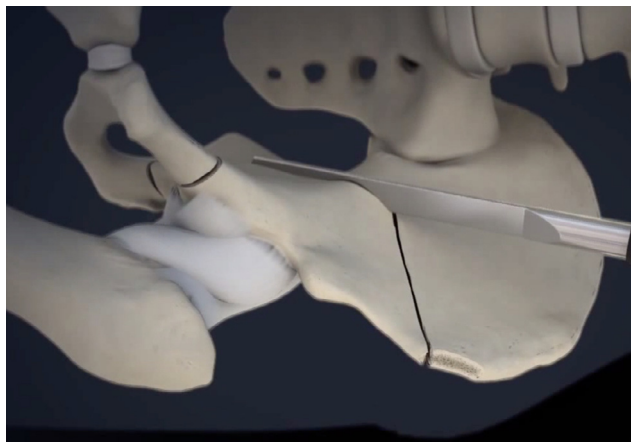

Figure 5 The posterior column osteotomy is performed to connect the iliac wing and anterior ischial osteotomy sites with a series of osteotomes.

Acetabular Correction

The acetabular reorientation typically involves improving lateral coverage, anterior coverage and posterior coverage, in varying proportions. Preoperative imaging and physical examination are crucial in developing a strategy for acetabular reorientation during surgery.

Prior to attempting acetabular reorientation, it is essential to confirm free movement of the osteotomized acetabular fragment. Often, manipulating the fragment by tensioning a pair of laminar spreaders is helpful in freeing up soft-tissue constraints or persistent small bone bridges. A threaded Schanz pin is routinely placed in the supraacetabular region and used to grip the acetabular fragment to control reorientation. We also find the supplemental use of a Weber bone clamp placed at the base of the superior pubic ramus osteotomy can provided added control, especially in cases where significant lateral coverage is desired.

After the desired reorientation is achieved, provisional fixation is obtained with multiple smooth Kirschner-wires drilled through iliac crest and into the acetabular fragment. The trajectory for placement is typically superior and posterior to the joint. The pins are typically used as pilot holes for future screw placement, so it is best to spread their trajectory across the acetabular fragment both on AP and false profile views for maximized stability.

With temporary fixation achieved, the adequacy of the correction is evaluated provisionally by fluoroscopic imaging. A well-centered AP pelvis image is essential in assessing well the adequacy of the correction. When using fluoroscopy, lowering the image intensifier as close to the body as possible will facilitate the widest field of view to replicate an AP pelvis view. General guidelines for an optimal correction on the AP pelvis image include a weight-bearing zone (sourcil) close to horizontal; no lateral translation of the hip center; no crossover sign; well-balanced anterior and posterior coverage as reflected by the anterior and posterior walls indices; and concentric reduction of the center of the femoral head under the weight-bearing zone of the acetabulum. On false profile images, anterior coverage can be assessed for a flat sourcil and the anterior inferior iliac spine (AIIS) should also be evaluated as a potential cause of extra-articular impingement in its new position.

After a radiographically satisfying correction is achieved, the Schantz pin can be removed to allow motion assessment. Passive range of movement should be checked, since impingement is a known source of early failure and poor outcomes following PAO. At least 95°-100° of flexion and 15°-20° of internal rotation in flexion should be preserved to ensure postoperative function without impingement. The degree of internal rotation will vary between patients, but postoperative motion should essentially mirror preoperative motion. Direct inspection and palpation of impingement is useful. Contact between the anterior hip structures—specifically between the neck and the anterior rim and AIIS—can be noted visually and by direct palpation during manipulation. If there is any question, the AIIS is readily accessible for osteoplasty. The femoral neck can be accessed through an anterior arthrotomy in cases concerning for postreorientation impingement.

If a satisfactory correction is achieved and confirmed on radiographic and impingement testing, definitive fixation can be performed. Routine adequate fixation adequate can be achieved by placing multiple screws (3.5 mm or 4.5 mm) through the iliac crest and into the acetabular fragment. Stability of the reconstruction must be critically assessed. Ideally, there is impaction of the posterosuperior corner of the acetabular fragment into the iliac osteotomy site, and there is direct contact at the superior ramus osteotomy. In cases concerning for inadequate fixation, a supplemental screw from the AIIS directed into the gluteal pillar can be used for added fixation.

Protruding edges are trimmed to reduce soft-tissue irritation, with the harvested bone graft subsequently packed into the interstices of the osteotomies. Hemostasis is usually satisfied at this point in the procedure, though moderate bleeding may occur from osteotomy surfaces while the fragment is being manipulated.

Soft-tissue closure must be secure, since early postoperative function is desirable. Closure begins with reattachment of the ASIS wafer osteotomy, typically with #2 braided nonabsorbable sutures. The external obliques are reapproximated to the iliac wing and the tensor and/or sartorial intervals are closed with running sutures, followed by skin closure.

Postoperative Care

Lumbar plexus blockade is used for 48 hours in typical cases to reduce the requirement of opiate pain medication. On the first postoperative day, patients typically sit in a chair in the morning and mobilize with an assistive device in the afternoon under the guidance of a physical therapist. By postoperative days 2-3, they continue work on a partial weight-bearing gait with crutches and are typically cleared for discharge home. Antithrombotic prophylaxis with low-dose aspirin is started the morning of postoperative day 1 and continued for 4 weeks. Prophylaxis against heterotopic ossification is done with naproxen, which is also used for 4 weeks. Resumption of full weight-bearing follows recovery of necessary muscle function and evidence of adequate osteotomy healing as confirmed by AP and false profile radiographs, typically occurring around 8 weeks postoperatively, dependent on patient age and degree of correction required. Routine radiographs are taken at monthly intervals until complete osteotomy healing. Patients are followed annually with clinical examinations and radiographs, or more frequently if required. Full activity, including sport, is resumed according to individualized protocols, though in general, at least 6-9 months is required before full return of maximum achievable function has taken place.[24]

Outcomes

PAO has a well-documented record of success in improving hip function and longevity for patient with acetabular dysplasia. The multicenter ANCHOR early prospective results of 391 consecutive PAOs at 2-5 years postoperatively showed a 99.2% hip survival rate and 93% early satisfaction rate.[25] The Bernese experience has

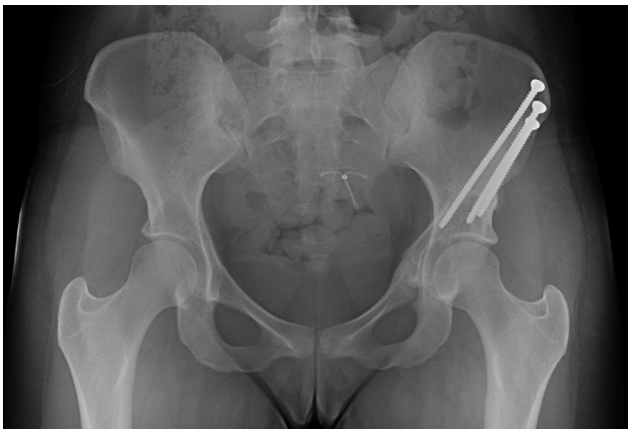

Figure 6 Six-month postoperative AP pelvis showing improved femoral head coverage with LCEA 31° and a flat sourcil. The osteotomy is fully healed.

provided the longest follow-up to date, with survival of 87.6% at 10 years, 60.5% at 20 years.[26,27] In cases with minimal preoperative arthritis (Tönnis 0-1), 80% of hips were free from pain and radiographic arthritis at 20-year follow-up. Similarly, results from Boston showed cumulative survival of 76% at 10-year follow-up and 74% at mean 18-year follow-up.[28] Increasing age, severe dysfunction, advanced radiographic OA and poor joint congruency prior to surgery were strong predictors of PAO failure in multiple studies.[28,29] Surgical sources of failure include acetabular malpositioning: undercoverage (instability), overcoverage (impingement) or retroversion and failure to recognize and treat femoral sided deformity in the form of diminished head and/or neck offset (impingement).[26,28-31]

Case Conclusion

Postoperatively the patient had a satisfactory recovery and no perioperative complications were encountered. She was able to begin full weight-bearing without crutches at 8 weeks following surgery and returned to work duties at 3 months. At 6-month follow-up she had resumed all preoperative activities including recreational running and hiking. Her 6-month postoperative film (Fig. 6) shows improved femoral head coverage and a healed osteotomy.

Conclusion

Acetabular dysplasia is a common cause of hip pain and dysfunction in young mature patients. Natural history studies have noted these hips are at risk for early progression to OA. PAO, when performed on well-indicated patients and in a technically sound manner, can greatly improve the function and longevity of these hips.

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