Periacetabular Osteotomy in the Treatment of Severe Acetabular Dysplasia

Surgical Technique

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INTRODUCTION
The Bernese periacetabular osteotomy was initially described by Ganz et al. and is now recognized as an extremely effective reconstructive osteotomy for the treatment of acetabular dysplasia. Nevertheless, the efficacy of this osteotomy for the treatment of severely dysplastic hips has not been emphasized in the literature. After our initial satisfactory experience with the use of this technique for the treatment of mild to moderate acetabular dysplasia, we extended the indications to the treatment of severe acetabular deformities (Group IV or V according to the Severin classification). Our early radiographic and clinical results have been encouraging and have persuaded us to continue with this technique for the surgical correction of severely dysplastic acetabula. In the current report, we present a step-by-step surgical technique for the correction of severe acetabular dysplasia with use of the Bernese periacetabular osteotomy.

SURGICAL TECHNIQUE
Combined epidural and general anesthesia is used for patients undergoing the Bernese periacetabular osteotomy. Prophylactic antibiotics are administered prior to the incision, continuous electromyographic peripheral nerve monitoring is used throughout the procedure, and a Cell Saver (Haemonetics, Braintree, Massachusetts) is utilized for blood collection and reinfusion. Intraoperative fluoroscopy confirms the position of the osteotomy cuts and assists in evaluating the acetabular reduction and fixation. The patient is positioned supine on a ra-

ABSTRACT

BACKGROUND:
The optimal treatment of severe acetabular dysplasia with subluxation of the femoral head or the presence of a secondary acetabulum remains controversial. The purpose of this study was to analyze the extent of surgical correction and the early clinical results obtained with the Bernese periacetabular osteotomy for the treatment of severely dysplastic hips in adolescent and young adult patients.

METHODS:
Sixteen hips in thirteen patients with an average age of 17.6 years (range, 13.0 to 31.8 years) were classified as having severe acetabular dysplasia.
(Group IV or V according to the Severin classification). Eight hips were classified as subluxated, and eight had a secondary acetabulum. Preoperatively, all patients had hip pain and sufficient hip joint congruency on radiographs to be considered candidates for the osteotomy. All sixteen hips underwent a Bernese periacetabular osteotomy, and six of them underwent a concomitant proximal femoral osteotomy. Postoperatively, the hips were assessed radiographically to evaluate correction of deformity, healing of the osteotomy site, and progression of osteoarthritis. Clinical results and hip function were measured with the Harris hip score at an average of 4.2 years postoperatively.

RESULTS:
Comparison of preoperative and follow-up radiographs demonstrated an average improvement of 44.6° (from −20.5° to 24.1°) in the lateral center-edge angle of Wiberg, an average improvement of 51.0° (from −25.4° to 25.6°) in the anterior center-edge angle of Lequesne and de Seze, and an average improvement of 25.9° (from 37.3° to 11.4°) in acetabular roof obliquity. The hip center was translated medially an average of 10 mm (range, 0 to 31 mm). All iliac osteotomy sites healed. The average Harris hip score improved from 73.4 points preoperatively to 91.3 points at the time of the latest follow-up. Eleven of the thirteen patients...
A dioluent table with a small bump under the involved hip (Fig. 1-A). This elevates the hemipelvis approximately 5° from the horizontal. A foot rest, used to assist in holding the extremity in a position of hip flexion, is secured to the table. The arm on the involved side is draped over the chest. The contralateral lower extremity is stabilized. The hip is prepared and draped to allow wide access to the hemipelvis. Continuous peripheral nerve monitoring has been effective for identifying specific maneuvers during the procedure that are associated with nerve irritation. To minimize the risk of nerve injury, we continue to use intraoperative monitoring in all cases. Nerve-monitoring leads are placed on the involved extremity, secured, and overwrapped with stockinette and an adhesive wrap.

A modified Smith-Petersen approach to the hip is used for exposure. The incision begins proximally and extends distally, just lateral to the iliac crest and the anterior superior iliac spine, and gradually curves distally and laterally to approximately 10 cm inferior to the anterior superior iliac spine (Fig. 1-B). Subcutaneous flaps are raised medially and laterally, and care is taken to avoid the lateral femoral cutaneous nerve. The fascia over the tensor fasciae latae muscle belly is incised in line with the muscle fibers.
fibers. The tensor fasciae latae muscle belly is reflected laterally, and the interval between it and the sartorius is developed, which protects the lateral femoral cutaneous nerve (within the sartorius fascia). This dissection is extended deep onto the origin of the rectus femoris (Figs. 2-A, 2-B, and 2-C). Proximally in the wound, the aponeurosis of the external oblique muscle is reflected medially off the iliac crest. The anterior superior iliac spine (bone or cartilage) is osteotomized and is reflected medially with the origin of the sartorius. A small wafer of bone is also
FIG. 3-B
This plane is followed inferiorly and then posteriorly onto the anterior ischium for the first osteotomy cut.

FIG. 3-C and 3-D
Figs. 3-C and 3-D The position of the osteotomy can be confirmed with anteroposterior (Fig. 3-C) and 45° iliac oblique (Fig. 3-D) fluoroscopy views.
released with the iliacus origin off the anterior aspect of the ilium and is reflected medially. The conjoint tendon of the rectus muscle is identified and transected, leaving a stump of tendon for later repair.

The rectus tendon is reflected distally, and the dissection is continued inferiorly along the anterior hip capsule. The iliocapsularis muscle fibers are reflected off the anterior hip capsule, and the interval between the anterior hip capsule and the iliopsoas tendon is developed inferomedially. Hip flexion assists in exposure of the anterior hip capsule. This plane is followed inferiorly and then posteriorly onto the anterior aspect of the ischium. The infracotyloid groove of the ischium is first palpated with a large pair of Metzenbaum scissors (Fig. 3-A). This interval is further developed by blunt dissection. A small hip skid is inserted into the interval onto the anterior aspect of the ischium. In a severely dysplastic hip or in the presence of a false acetabulum, the infracotyloid groove is more distal with respect to the femoral head and neck because of the superior position of the proximal part of the femur. Care is taken

CRITICAL CONCEPTS

INDICATIONS:
- Symptomatic severe acetabular dysplasia (Grade IV or V according to the Severin classification) (Figs. 11-A through 11-D)
- Minimal or no secondary osteoarthritis
- Young, healthy patient (all patients in our reported series were less than thirty-two years of age)
- Adequate congruency of the hip joint
- Adequate hip flexion ($\geq 100^\circ$) and abduction ($\geq 30^\circ$)

CONTRAINDICATIONS:
- Moderate to advanced secondary osteoarthritis
- Older age
- Major hip joint incongruity
- Obesity
- Major restriction of hip motion (hip flexion of $<100^\circ$ or abduction of $<30^\circ$; unless a proximal femoral procedure is planned to address femoroacetabular impingement)
- Major medical comorbidities
- Patient noncompliance

FIG. 3-E
Care is taken not to overextend the posterolateral aspect of the cut due to the proximity of the sciatic nerve.

continued
not to enter the anteroinferior aspect of the hip joint inadvertently. A curved (or angled), pronged, half-inch (1.27-cm) osteotome is positioned by following the path of the hip skid. The osteotome is positioned

**CRITICAL CONCEPTS**

**PITFALLS:**
- Acetabular overcorrection (retroversion) and secondary anterior femoroacetabular impingement
- Acetabular undercorrection
- Progressive secondary osteoarthritis
- neurovascular injury
- Loss of fixation, nonunion, or delayed union
- Intra-articular acetabular fracture
- Femoral neck fracture (associated with head-neck junction osteoplasty)

continued
The iliac osteotomy is performed from the anterior superior iliac spine directly toward the sciatic notch and stops approximately 1 cm superolateral to the pelvic brim. A high-speed burr is used to make a target hole for the iliac cut.

Figs. 5-B and 5-C The osteotomy is then performed with an oscillating saw. ASIS = anterior superior iliac spine.
in the infracotyloid groove (Fig. 3-B), and the location of the osteotome is checked with anteroposterior and 45° oblique fluoroscopy views (Figs. 3-C and 3-D). The infra-acetabular osteotomy starts just distal to the inferior lip of the acetabulum and aims toward the middle of the ischial spine as visualized on the 45° oblique fluoroscopy view. The osteotome is first inserted along the medial cortex and is advanced to the level of a trajectory bisecting the posterior column (approximately 1 cm anterior to the posterior cortex of the posterior column). It is then passed centrally and laterally in the ischium (Fig. 3-C). The lateral cut is only 15 to 20 mm deep because of the narrowing of the posterior column laterally and the proximity of the sciatic nerve (Fig. 3-E). The lateral cortex cut is made with the involved lower extremity abducted to minimize the risk of sciatic nerve injury.

Attention is then turned more proximally in the wound, and the soft-tissue sleeve overlying the superior pubic ramus is mobilized. The iliopsoas and the femoral neurovascular bundle are retracted medially, but excessive force or prolonged traction is avoided to minimize tension on the femoral neurovascular bundle. Hip flexion and adduction facilitates exposure of the ramus. Dissection is carried out onto the superior pubic ramus, which is exposed subperiosteally with a small elevator. Narrow, blunt, curved retractors are placed subperiosteally around the anterior and posterior aspects of the pubic ramus. A narrow pointed Homan retractor is then advanced onto the superior pubic ramus, medial to the osteotomy site, and is impacted into the superior cortex. Fluoroscopy can be used to confirm adequate medial placement of the ramus osteotomy (Fig. 4-A). The superior pubic ramus osteotomy is performed with a small oscillating saw to the deep cortex (Fig. 4-B) and is completed with a half-inch (1.27-cm) angled osteotome (Fig. 4-C). The osteotomy is angled away from the joint and is oriented from anterolateral to posteromedial. Mobility between the two fragments of the ramus is confirmed with the osteotome to ensure completion of the osteotomy. The periosteum in this region is evaluated. If an intact periosteal band traverses the osteotomy site (in younger patients), it is released to facilitate mobilization of the acetabular fragment at the time of reduction.

The ilium and the posterior column are then exposed in anticipation of the iliac and posterior column osteotomies. The ilium and the quadrilateral surface of the pelvis are stripped subperiosteally. The sciatic notch is identified with a large Homan retractor. A straight cobra retractor is placed along the inner aspect of the true pelvis toward the ischial spine. The hip is flexed and adducted to improve visualization. The iliac cut is made from just proximal to the osteotomy of the anterior superior iliac spine directly toward the sciatic notch (Figs. 5-A, 5-B, and 5-C). A high-speed burr is used to make a target hole 1 cm superolateral to the pelvic brim, in line with the proposed iliac cut toward the sciatic notch (Fig. 5-A). This recess also functions as the intersection of the iliac and posterior column cuts. The iliac cut is then made with an oscillating saw, first along the medial cortex (Fig. 5-B). The lower extremity is then abducted, and the outer iliac cut is made with the oscillating saw. In a severely dysplastic hip, the iliac cut may be made more superiorly to ensure adequate supra-acetabular bone stock for reduction and fixation. A 45° oblique fluoroscopy image will verify optimal orientation and a superior position of the iliac osteotomy (Fig. 5-C).

The posterior column is exposed with the straight cobra retractor, and the posterior column cut is made with the goal of bisecting the posterior column between the articular surface anteriorly and the posterior cortex (Figs. 6-A, 6-B, and 6-C). This cut is made at an angle of 120° to the iliac cut. A calibrated quarter-inch (0.64-cm) osteotome is used to make a preliminary pass along the medial cortex (Fig. 6-A). The position and orientation of this cut is monitored with fluoroscopy (Fig. 6-B). The cut is then completed with a calibrated half-inch (1.27-cm) osteotome and typically extends 5 to 6 cm down the posterior column. Three passes are made: one me-
dial, one central, and one lateral. The lateral pass of the osteotome is only extended for 4 cm because of thinning of the posterior column distally and the proximity of the sciatic nerve. A Schanz pin is placed into the acetabular fragment in the supra-acetabular region. The mobility of the fragment is tested. At this point, the osteotomy cuts are completed with a half-inch (1.27-cm) 45° angled osteotome (Fig. 6-C). Frequently, the osteotomy through the very thick bone at the 120° pivot point will require completion with an angled osteotome. A large universal reduction clamp is placed around the iliac portion of the acetabular fragment and the Schanz pin. The acetabular fragment is then mobilized. Manipulation of the fragment is performed to optimize mobility for reduction of the acetabulum. For severely dysplastic acetabula, the osteotomized acetabulum must be extremely mobile to achieve extensive corrections. If the acetabulum is not adequately mobile, we first inspect the periosteum around the superior pubicramus to verify that the fragment is not tethered in this region. The ramus osteotomy is then displaced to ensure that it is not “locked” at this site. Subsequently, the posterior cortex at the 120° pivot point and the infra-acetabular cut are tested as potential sites of incomplete

Fig. 6-A The posterior column cut is directed at a 120° angle from the iliac cut. Fig. 6-B The orientation of this cut can be assessed with a 45° iliac oblique fluoroscopic view.
The acetabulum is repositioned to optimize the surgical correction. With severely dysplastic acetabular deformities, this reduction is very challenging and clearly is the most demanding aspect of the procedure. First, the superior pubic ramus is accessed and the acetabular fragment is tilted anterolaterally to ensure that it can be completely displaced. If the osteotomy cut of the superior pubic ramus is not mobile, it can be displaced by placing a right-angle clamp around the ramus and translating the acetabular side of the ramus superiorly to unlock it from its medial aspect. After this is accomplished, the acetabulum is repositioned with internal rotation and some forward tilt extension (Figs. 7-A through 7-E). The fragment is then translated medially. If necessary, direct pressure from the lateral side with a pointed Homan retractor can enhance medial translation. Care is taken to maintain anteversion of the acetabular fragment. This is accomplished by maintaining internal rotation of the acetabulum. Finally, the acetabular fragment is translated superiorly in an attempt to achieve bone-to-bone contact with the overlying ilium. This proximal translation also minimizes lengthening of the extremity with extensive corrections. The fragment is then fixed with three or four 3/32-inch (0.24-cm) Kirschner wires.

The acetabular reduction is carefully assessed intraoperatively. To ensure accurate assessment of the reduction, the entire pelvis is viewed with fluoroscopy. Care is taken to make a high-quality anteroposterior radiograph centered over the symphysis pubis. The symphysis pubis is positioned in line with the sacrococcygeal joint, with the obturator foramen symmetric and the pelvis horizontal. The fluoroscopy unit is angled anterosuperior to posteroinferior to accomplish an appropriate, relative pelvic tilt with the sacrococcygeal joint being approximately 3 cm superior to the symphysis pubis. The acetabular reduction is then assessed. On the anteroposterior fluoroscopic view, we evaluate the lateral center-edge angle, acetabular inclination, medial translation of the hip-joint center, the position of the teardrop, and version of the acetabulum. Version is assessed by the relative positions of the anterior and posterior lips.
Figs. 7-A through 7-E Sawbones model of periacetabular cuts and acetabular reduction for a severely dysplastic hip. It is important to note that the reduction depicted in this sawbones model characterizes the type of aggressive reduction needed for correction of a severely dysplastic acetabulum. Specifically, the iliac gap may lack bone-to-bone contact between the acetabular fragment and the ilium (Fig. 7-C) because of the extensive reorientation that is required. Additionally, the apparent excessive anterior correction in the model (Fig. 7-E) would not be present in a hip with severe anterior acetabular insufficiency. Figs. 7-A, 7-B, and 7-C The goal of reorientation is to enhance anterolateral femoral head coverage, to maintain or obtain acetabular anteversion, and to translate the hip center medially if indicated. We perform the acetabular reduction with (1) internal rotation (lateral coverage and anteversion), (2) forward tilt or extension (anterior coverage), and (3) medial translation (medialization of joint center). Periacetabular cuts are demonstrated in Figures 7-B and 7-C. Figs. 7-D and 7-E The osteotomy site is usually fixed with four screws, and the iliac gap is grafted with the resected prominent anterior superior iliac spine.
AUTHOR UPDATE:
The most important change in our technique since the time of the initial report involves the routine arthrotomy and the handling of proximal femoral deformities. The arthrotomy allows for inspection of the acetabular labrum as well as assessment of the anatomy of the femoral head-neck junction. We seldom perform labral repair, although we do consider repair if there is a major, unstable tear. In this case, the labrum is secured with suture anchors along the anterolateral acetabular rim. Commonly, the anterolateral head-neck junction lacks a normal offset and requires an osteoplasty to optimize impingement-free hip flexion motion and to reduce the risk of secondary anterior femoroacetabular impingement. We now commonly perform an osteoplasty of the anterolateral head-neck junction to optimize hip flexion and internal rotation motion. Specifically, at the time of arthrotomy, hip motion and anterior femoroacetabular impingement are carefully assessed. It is imperative that at least 90° (preferably >100°) of passive, unobstructed hip flexion and at least 10° of internal rotation at 90° of flexion are present after acetabular reorientation. If anterior impingement of the acetabular rim and a prominent anterolateral head-neck junction are observed, osteoplasty of the anterior femoral neck is performed.

FIG. 8
The acetabular fragment is fixed provisionally with Kirschner wires and definitively with 4.5-mm screws inserted from the iliac crest into the reduced acetabulum.

FIG. 9-A
Figs. 9-A, 9-B, and 9-C Femoral head-neck junction osteoplasty. Fig. 9-A Intraoperative frog-leg lateral view of a moderately dysplastic acetabulum after periacetabular osteotomy, demonstrating a nonspherical femoral head (arrow) at the anterolateral head-neck junction.
The location of the anterior lip can also be verified by palpation with a long pointed hemostat and fluoroscopic visualization. A false-profile view is made, and the anterior coverage of the femoral head is assessed. It is important that the acetabulum not be overreduced or retroverted. Specifically, the anterior and posterior acetabular lips are identified and evaluated to ensure that a head-neck junction is performed. This decision is made intraoperatively and is based on the goal of optimizing hip flexion motion and minimizing the risk of secondary anterior femoroacetabular impingement. In our hands, the osteoplasty is a relatively new component of the operation, and femoral neck fracture associated with the osteoplasty is a potential complication of concern. To our knowledge, this complication has not been reported in the literature, but future studies are necessary to investigate the safety and efficacy of this technique. In our experience with seventy-five femoral head-neck junction osteoplasties (performed alone or in combination with a Bernese periacetabular osteotomy), there have been no associated femoral neck fractures.

Second, we have also become more aggressive in filling the iliac gap with bone graft substitute as well as available autogenous graft. This supplemental grafting is performed in patients who are more than eighteen years of age, and we believe that it results in more complete filling of the iliac gap and near-complete restoration of pelvic bone stock. This is particularly beneficial for severely dysplastic acetabula requiring extensive deformity correction that can create a large iliac gap.

FIG. 9-B
This deformity was associated with anterior femoroacetabular impingement at 100° of flexion as observed during arthrotomy.

FIG. 9-C
Osteoplasty of the head-neck junction was performed to optimize an impingement-free range of motion of the hip.
“cross-over” sign is not present. Slight undercorrection is preferred to excessive correction. If necessary, the acetabulum is repositioned to achieve optimal deformity correction. The acetabulum is then fixed with three or four 4.5-mm cortical screws (Fig. 8). One screw is placed into the anterolateral aspect of the acetabular fragment to act as a “blocking” screw. Two or three additional screws are placed progressively more medially. If needed, a screw can also be placed from the anterior acetabular fragment into the ilium. In severely dysplastic hips, the acetabular fragment may require additional fixation because of the extensive correction required and the osteoporotic-like bone resulting from chronic disuse. We recommend supplemental fixation with small-fragment pelvic reconstruction plates when necessary. These plates are placed along the inner aspect of the ilium down onto the anteromedial aspect of the acetabular fragment. After definitive fixation is achieved, fluoroscopic images are then made again to confirm the acetabular reduction and the position of fixation hardware.

After reorientation of the acetabulum, the prominent aspect of the anterior acetabular fragment is removed with an oscillating saw and is used to fill the iliac gap. Hip flexion motion is then checked. It is imperative that at least 90° of hip flexion can be obtained with the patient on the operating room table after reduction of the acetabular fragment. If this is not the case, the acetabular fragment should be repositioned or an appropriate femoral procedure should be performed to relieve secondary anterior femoroacetabular impingement (Figs. 9-A, 9-B, and 9-C). After evaluation of the range of motion, we now routinely perform an anterior I-shaped arthrotomy. Medial and lateral flaps of capsule are raised off the acetabular rim to achieve

**FIG. 10**

Passive hip flexion motion is checked after hip reconstruction to ensure that at least 90° (preferably >100°) of hip flexion is present.
visualization of the acetabular labrum and the femoral head-neck junction (Fig. 9-B). The acetabular labrum is inspected and probed. Large, unstable labral tears are repaired with suture anchors. If the tear is stable, we do not recommend surgical repair. The junction of the femoral head and neck is inspected. Lack of femoral head-neck offset is treated with osteoplasty10. This is a common deformity in dysplastic hips that can result in anterior femoroacetabular impingement postoperatively. The osteoplasty is performed with a half-inch (1.27-cm) curved osteotome and an angled quarter-inch (0.64-cm) osteotome. The wedge of bone is resected at the anterolateral head-neck junction to create improved offset (Fig. 9-C). After the osteoplasty, hip flexion motion is checked with finger palpation of the anterior hip space. The osteoplasty is performed to prevent anterior impingement, and decompression of the impingement is confirmed by intraoperative examination. In cases of severe femoral deformity, a proximal femoral osteotomy may be necessary as determined preoperatively. In severely dysplastic hips, a valgus proximal femoral deformity may have to be treated with a varus-producing intertrochan-
teric osteotomy. In hips with a “Perthes-like” deformity or an iatrogenic varus deformity, a proximal femoral valgus osteotomy may be considered. After addressing femoral disease and deformity, final intraoperative radiographs and range of motion are assessed (Fig. 10). The hip must have at least 90° of passive hip flexion and, ideally, we strive to maintain >100° of passive hip flexion.

The anterior hip capsule is approximated with absorbable suture. The rectus tendon origin is repaired with nonabsorbable suture. The site of the anterior superior iliac spine osteotomy is repaired with nonabsorbable suture through drill-holes in the ilium. Deep and superficial wound drains are placed. The remainder of the superficial wound is closed in a routine fashion.

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