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Femoroacetabular Impingement: Treatment of the Acetabular Side

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Abstract

Over the past decade, femoroacetabular impingement (FAI) has become an increasingly recognized pathomechanism that may explain why some hips that were previously considered to have normal morphology fail early in life. Subtle morphologic alterations in the acetabulum or femur, as well as the degree of hypermobility or impact on the hip, affect the potential for joint damage. The most frequent location of FAI is the anterosuperior acetabular rim, and the most critical motion is internal rotation of the hip in flexion. Because medication, activity restrictions, and physical therapy are rarely successful in treating symptoms caused by FAI, surgery has become a mainstay of treatment. Acetabular causes of FAI, called pincer FAI, can be treated by improving hip clearance. Independent of whether local or global overcoverage is present, rim reduction should be combined with labral preservation whenever possible.

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Morphologic abnormalities in the osseous structures about the hip joint can lead to femoroacetabular impingement (FAI).[1,2] Repetitive impingement predisposes patients to the development of early osteoarthrosis.[2] The causative morphologic abnormality may exist on the femoral side, the acetabular side, or both. Structural abnormalities on the femoral side may result in asphericity, a decreased femoral head-neck ratio, leading to a cam-type impingement pattern. The primary injury is to the anterosuperior marginal articular cartilage and typically occurs during flexion and internal rotation. Shear forces at the junction of the labrum and articular cartilage first delaminate and then detach the cartilage. Labral injury and eventual detachment occur secondarily. Increased recognition and understanding of the consequences of these impinging structural abnormalities of the femur have led to treatment strategies aimed at improving the head-neck offset and preserving the native hip joint.[3,4]

Architectural abnormalities in the acetabulum that predispose to FAI can be described generally as patterns of overcoverage that lead to a pincer type of impingement. Patterns of overcoverage include anterior overcoverage with acetabular retroversion, coxa profunda, and protrusio acetabuli. In contrast to cam impingement, the primary injury mechanism is a repetitive, direct crush of the labrum and marginal articular cartilage. With time, the posteroinferior joint cartilage becomes abraded as a result of leverage of the head against the anterior rim. Overall, the degenerative process is much slower in pincer impingement than in the cam process. Similar to the approach to the femur in cam impingement, treatment strategies have been developed for correcting the acetabulum in pincer impingement. This chapter outlines an approach to the diagnosis and treatment of acetabular morphologies that predispose to impingement.

Diagnosis

Symptoms of the pincer type of FAI typically have a gradual onset and often are first noticed after vigorous physical activity (impact sports, sports demanding hypermobility) or, less commonly, after distortional trauma.[2,4] Pain is most commonly localized to the groin but may occur over the greater trochanter or in the gluteal region. The location of the pain often relates to the sites of impingement or the areas of overcoverage. Provocative maneuvers during physical examination will re-create the symptoms at the extremes of range of motion. For example, a maneuver that combines flexion, adduction, and internal rotation of the hip is provocative in patients with

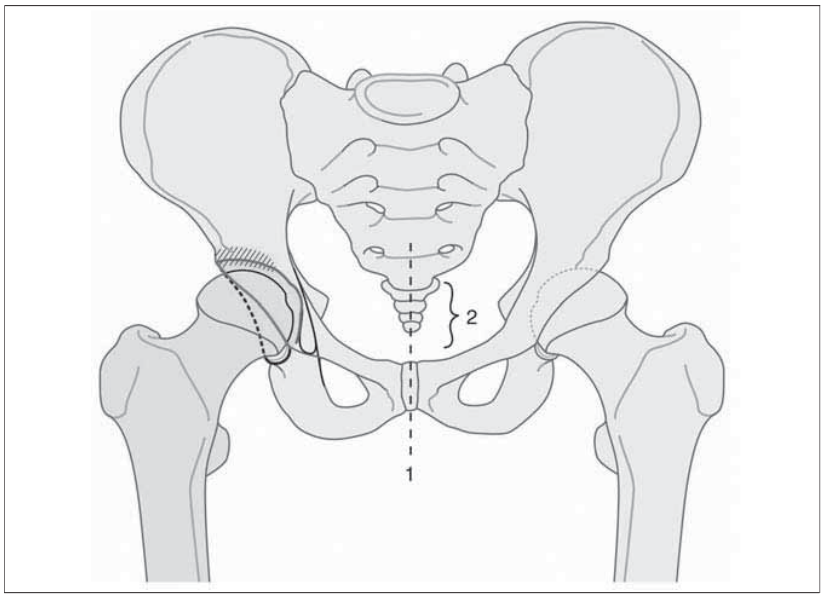

Figure 1 Accurate radiographic diagnosis is predicated on a standardized AP pelvic radiograph, as indicated. A proper orthograde AP pelvic radiograph must control flexion/extension and rotation of the pelvis. Criteria for an adequate radiograph include (1) a midline sacrum with the coccyx pointing to the symphysis pubis, and (2) the space between the sacrococcygeal joint and symphysis pubis should range between 2 and 4 cm (men) and 4 and 6 cm (women). Unless distorted by the disease process, the obturator foramina, teardrops, and iliac wings should appear symmetric.

anterolateral overcoverage, whereas extreme extension and external rotation are provocative in patients with posteroinferior overcoverage. Patients with coxa profunda or true protrusio may have impingement in all directions of hip motion. The clinical picture in these patients can include dramatic pain from the contused, inflamed, and sensitized labrum, in contrast to that of patients with cam impingement, where the labrum is not involved in the first stage of impingement.

The radiographic workup begins with a standardized set of plain radiographs. Radiographic features of FAI are also discussed in chapter 21. A correctly oriented AP pelvic radiograph (Figure 1) is evaluated for the acetabular index or Tönnis angle, the lateral center-edge angle, and posterior wall and crossover signs. The crossover sign is created when the projection of the superior portion of the anterior wall is lateral to the superior portion of the posterior wall. The crossover sign has been proposed as a sign of retroversion[5] but rather indicates anteversion of less than 4° on AP pelvic radiographs.[6] The anterior rim of the acetabulum courses medially, in a more horizontal direction than the vertically oriented posterior rim, creating the crossover. The posterior wall sign is present when the outline of the posterior wall lies medial to the center of the femoral head. The posterior wall sign is indicative of relative undercoverage posteriorly and may or may not be present with retroversion.[5] The radiographic diagnosis of protrusio is made when the femoral head lies medial to the Kohler line. Another parameter for quantification of femoral overcoverage is the femoral head extrusion index, which defines the percentage of the femoral head that is uncovered when a horizontal line is drawn parallel to the interteardrop line.[7,8] A normal extrusion index is less than 25%.[9] Although there is no defined minimal value for extrusion in the literature, less than 10% to 15% may indicate lateral overcoverage.

In a patient with a history, physical examination, and plain radiographs consistent with FAI, advanced imaging is warranted. High-resolution MRI of the hip with intra-articular gadolinium only is the imaging modality that provides the best visual representation of surrounding soft tissue structures.[10] Magnetic resonance arthrography of the hip is not only superior to plain pelvic hip MRI to detect labral pathology, it also is able to detect articular cartilage pathology that cannot be seen with plain radiographs.[11,12] MRI is less sensitive in detecting articular cartilage damage than it is for labral pathology, but it is specific. Radial cuts show bone appositions at the rim as well as potential contributions to the impingement by a femoral abnormality. Moreover, acetabular depth can be quantified based on radial sequences.[13] Considering all these aspects is crucial in developing a proper treatment plan. If there are still doubts whether all symptoms come from inside the joint, an intra-articular injection of local anesthetic can help to confirm the diagnosis.

Treatment

Impingement of hypermobile hips can occur without a specific morphologic abnormality. Patients with a type of extra-articular impingement are less likely to benefit from surgical in-

tervention. Conversely, patients with anatomic intra-articular impingement are not likely to respond to nonsurgical treatment and are candidates for surgery. The surgical treatment of acetabular causes of impingement includes redirectional periacetabular osteotomy and trimming of the acetabular rim in combination with a labral refixation technique. The safety of these techniques is based on the results of detailed anatomic studies of the blood supply to the osseous structures of the hip.[14]

Retroversion

Retroversion is defined as an acetabulum that opens with a partially (cephalad portion only) or totally posterior orientation relative to the sagittal plane.[5,15-17] Retroversion can exist as a primary deformity, in association with bladder exstrophy,[18] or with posttraumatic dysplasia.[19,20] It is also seen in all functional hips with proximal femoral focal deficiency,[21] those with Perthes disease,[22] and in combination with slipped capital femoral epiphysis.

The prominence of the anterolateral rim of the retroverted acetabulum predisposes to impingement with hip flexion, adduction, and internal rotation.[23,24] A diagnosis of retroversion can be confirmed by an orthograde plain AP pelvic radiograph by the presence of crossover and, sometimes, posterior wall signs.[25] Magnetic resonance arthrography is useful for assessing the extent of bony abnormality and the status of the labrum and articular cartilage. Special attention must be paid to the posteroinferior joint; sometimes the best information about this area comes from a false profile radiograph.[26]

Siebenrock and associates[24] reported the results of periacetabular osteotomy (PAO) for the treatment of FAI caused by retroversion. In their series, 26 of 29 patients had a good or excellent outcome at an average of 30 months after surgery. Failures reportedly were caused by overcorrection, undercorrection, and loss of reduction (one patient each), and were corrected to a good or excellent outcome with subsequent procedures using surgical dislocation of the joint. Capsulotomy at the time of PAO is recommended to allow labral pathology and femoral head-neck offset abnormalities to be corrected.

Although PAO can successfully treat symptomatic anterior impingement associated with acetabular retroversion and an insufficient posterior coverage of the femoral head (positive posterior wall sign; Figure 2), it is not required in all patients with this pathology. Patients with retroversion but adequate posterior wall coverage may benefit equally with surgical dislocation of the hip, combined with trimming of the anterolateral prominence with labral refixation (Figure 3). These patients can be identified radiographically with a positive crossover sign and a negative posterior wall sign. In these patients, PAO creating anteversion could create a posterior impingement. Similarly, if preoperative MRI demonstrates extensive

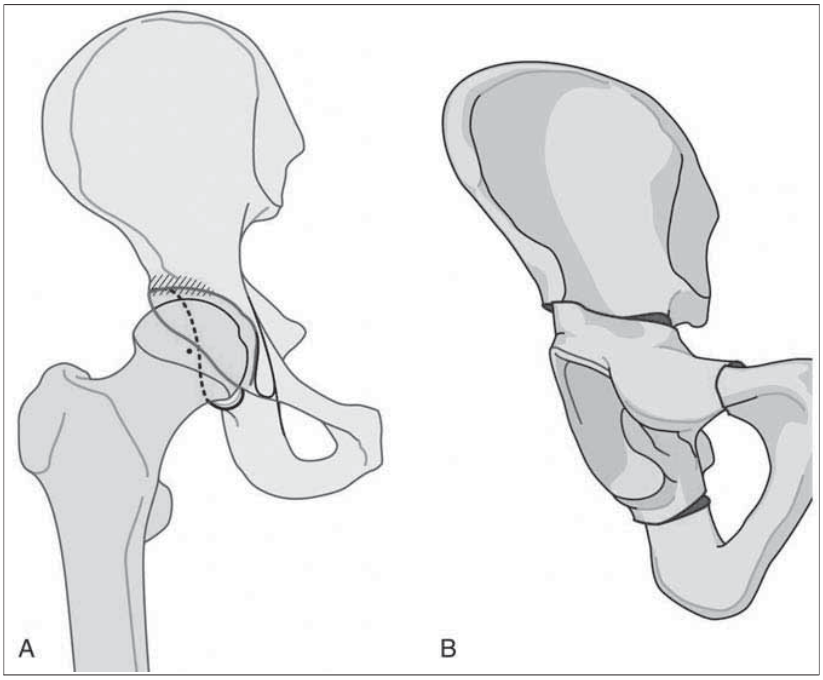

Figure 2 Local overcoverage: retroversion with a posterior wall sign is shown. **A,** Representation of a portion of an AP pelvic radiograph, showing a hip with the features of retroversion. The anterior wall (solid grey line) lies lateral to the posterior wall (dashed black line) in the cephalad portion of the acetabulum. The anterior wall courses in a more transverse direction than the vertically coursing posterior wall, creating the crossover sign. The center of the femoral head is marked (dot) and lies lateral to the posterior wall, creating the posterior wall sign. **B,** Reorientation of the retroverted acetabulum by periacetabular osteotomy (reverse PAO) with (flexion and) internal rotation can alleviate the anterior impingement and restore posterior coverage. Severe damage to the articular cartilage is a contraindication to this procedure.

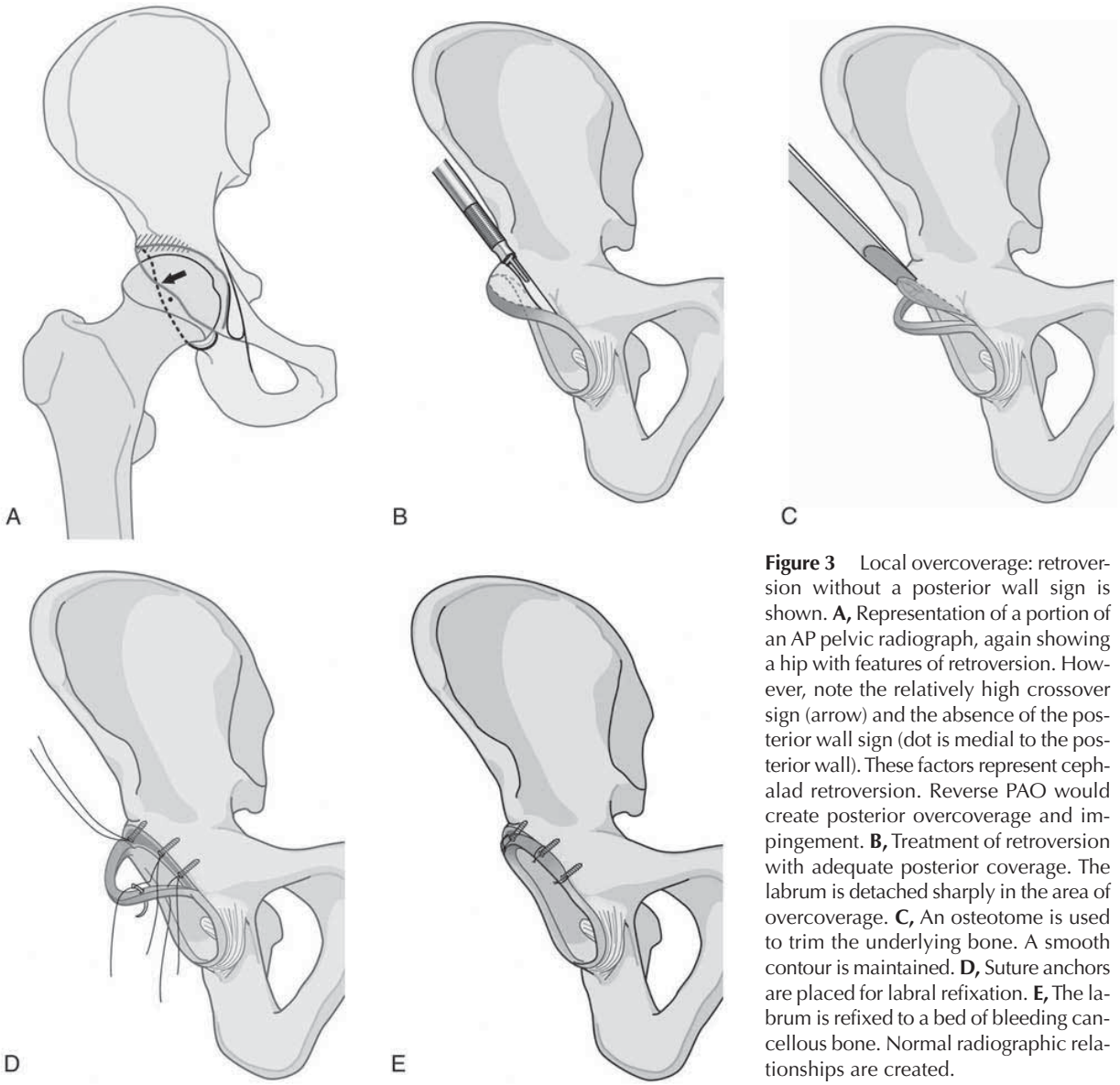

Figure 3 Local overcoverage: retroversion without a posterior wall sign is shown. **A,** Representation of a portion of an AP pelvic radiograph, again showing a hip with features of retroversion. However, note the relatively high crossover sign (arrow) and the absence of the posterior wall sign (dot is medial to the posterior wall). These factors represent cephalad retroversion. Reverse PAO would create posterior overcoverage and impingement. **B,** Treatment of retroversion with adequate posterior coverage. The labrum is detached sharply in the area of overcoverage. **C,** An osteotome is used to trim the underlying bone. A smooth contour is maintained. **D,** Suture anchors are placed for labral refixation. **E,** The labrum is refixed to a bed of bleeding cancellous bone. Normal radiographic relationships are created.

damage to the articular cartilage in the area of overcoverage, a reverse PAO would rotate this diseased area into the area of primary weight bearing and is, therefore, not indicated.

Coxa Profunda

Coxa profunda represents a global deepening of the acetabulum and a medialization of the femoral head. The ultimate pattern of the associated impingement is affected by the depth of medialization along with the orientation of the acetabular opening. In patients with coxa profunda, the surgical treatment of choice is trimming the bony rim of the acetabulum in areas of overcoverage while preserving the labrum (Figure 4). Knowing which area of the rim to reduce, and to what extent, is dictated by the degree of damage to the acetabular cartilage and the degree of overcoverage; however, excessive resection of the bony rim leading to undercoverage and its associated complications should be avoided.[27] With an open surgical dislocation technique, the impingement can be dynamically assessed under direct visualization, as can the adequacy of resection.

Preservation of the labrum is as

critical as making an appropriate bony resection. Espinosa and associates[27] emphasized the importance of the technique of labral refixation. They retrospectively reviewed and compared the results between patients treated with labral resection and those of patients treated with labral refixation. Two years after surgery, only 28% of the resection group had excellent results, compared with 80% of the refixation group. With labral refixation, the preserved labrum is repaired (or refixed) with suture anchors to a base of bleeding cancellous bone, where the bony rim has been resected. The suction seal and lubricating fluid film are dependent on an intact labrum.

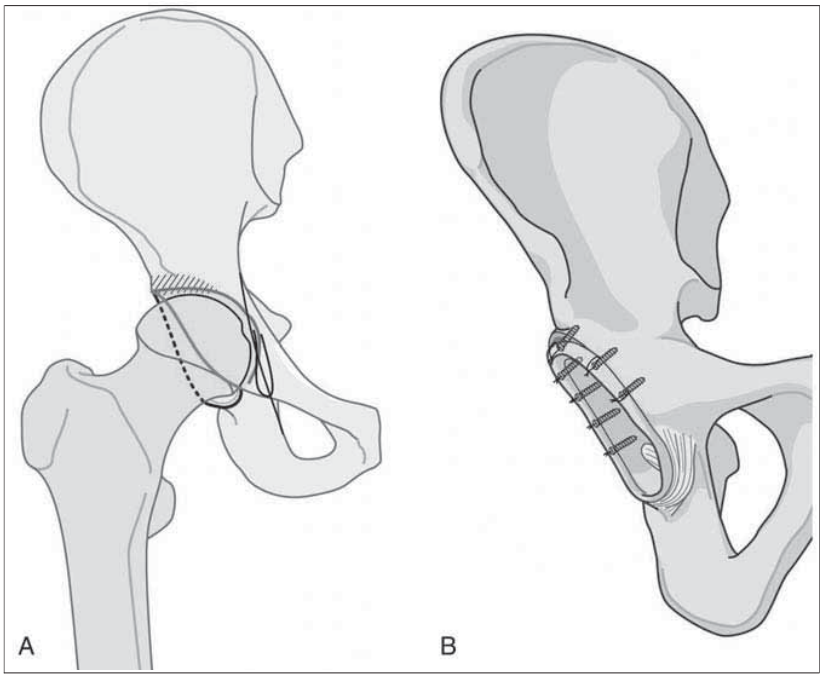

Figure 4 Global overcoverage: coxa profunda is shown. **A,** Medial femoral head and global overcoverage. The acetabular index is neutral. **B,** Treatment with near circumferential trimming of the acetabular rim and labral refixation. Normal radiographic relationships are created.

Protrusio

Coxa profunda may exist on a spectrum of pathology that ultimately becomes acetabular protrusio, with the femoral head migrating medial to the Kohler line. The medial migration of the femoral head is seen in patients with rheumatoid arthritis, osteomalacia, or Marfan syndrome and is believed to be the result of repeated stress fracture.[28] For protrusio associated with autoaggressive arthritis, total hip arthroplasty is indicated. However, protrusio also can be seen as a developmental or posttraumatic deformity in young people, with the articular cartilage in a healthy but prepathologic state. These patients are candidates for joint preservation if the posteroinferior joint space is maintained, but the surgery is challenging, especially if the acetabular roof inclination is negative. The mechanical situation must be normalized, the impingement alleviated, and the roof orientation corrected to between neutral and +5°.

The first step in the surgical treatment often is a circumferential trimming of the acetabular rim accessed by surgical dislocation of the hip (Figure 5), sometimes combined with relative lengthening of the femoral neck and distal advancement of the greater trochanter. In the absence of pelvitrochanteric impingement with the femur in varus, an intertrochanteric valgus osteotomy may be considered. The second step is a PAO that, if possible, is done during the same surgical session after repositioning of the patient from lateral decubitus to supine. During the first step of the procedure, with the patient in a lateral decubitus position, the first incomplete cut of the PAO into the ischium can be made with direct visual observation of the sciatic nerve. The goal is to lateralize the acetabular fragment and rotate it toward the midline (clockwise in a right hip; counterclockwise in a left hip) so that the roof angle and the acetabular version become normal. This is a technically difficult procedure, and the proximal displacement of the acetabular fragment can put the femoral nerve at risk of injury. As the femoral nerve courses with the iliopsoas tendon, these structures become draped over the step created by the rotation of the fragment, and the nerve is susceptible to a tension injury. Direct observation of the nerve and optimal rotation of the fragment are possible with an inguinal extension of the Smith-Peterson approach, allowing a ball spike to be placed onto the pubic portion of the acetabular fragment.[29] In this manner, the formation of a medial step is prevented while the osteotomized fragment is rotated with a supraacetabular Schanz screw.

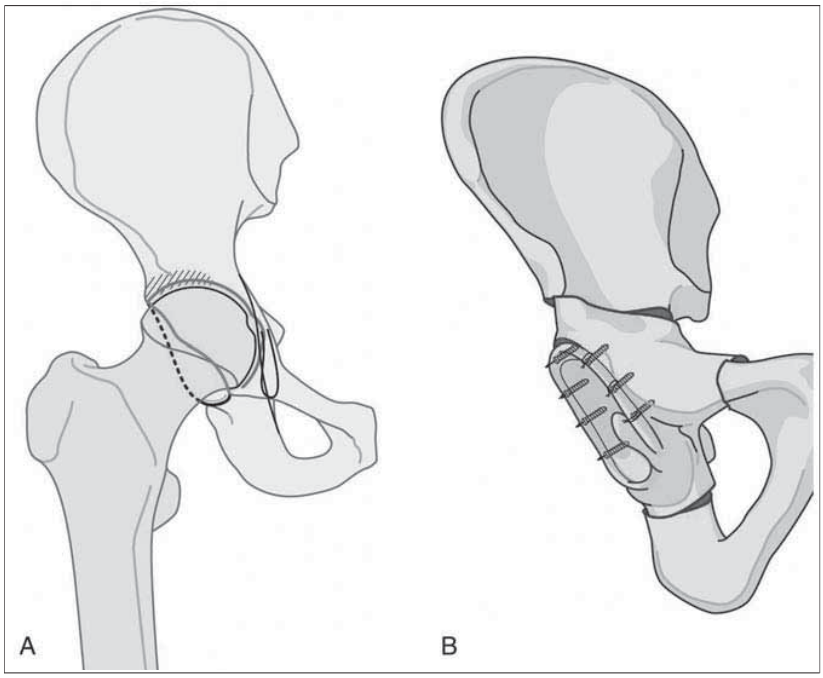

Figure 5 Global overcoverage: protrusio is shown. **A,** The head-extrusion index is approximately 10% to 15% only. The acetabular index is negative. **B,** The acetabular rim is trimmed circumferentially with labral refixation, and a PAO is used to correct the acetabular index to 0° to +5°. An intraoperative AP pelvic radiograph is obtained before definitive fixation. Trochanteric advancement is not shown.

Another important technical consideration is the horseshoe of articular cartilage in the acetabulum. The fact that there is global overcoverage does not mean that excess articular cartilage is present. In fact, often the opposite is true. The cotyloid fossa in patients with protrusio is typically enlarged, and the horseshoe may even be narrowed. In such patients, especially with a negative Tönnis angle, conservative trimming of the acetabular rim is indicated, and a PAO must be used to reposition and conserve the horseshoe.

Summary

This chapter presents a simplified, algorithmic approach to the diagnosis and treatment of acetabular causes of FAI. It is critical that individual treatment plans are based on the entire clinical picture of each patient. The understanding of these disease processes has evolved through experience with surgical dislocations, and the approach to the treatment of intra-articular impingement has been based on this technique. This is not meant to dismiss an emerging role for arthroscopy in some situations. The goals of treatment are the same regardless of approach: to safely and exactly correct morphologic abnormalities, to alleviate the symptomatology of FAI, and to stop or slow the progression to early osteoarthritis.

References

1. Beck M, Kalhor M, Leunig M, Ganz R: Hip morphology influences the pattern of damage to the acetabular cartilage: Femoroacetabular impingement as a cause of early osteoarthritis of the hip. *J Bone Joint Surg Br* 2005;87:1012-1018.
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. Ganz R, Gill TJ, Gautier E , Ganz K, Krugel N, Berlemann U: Surgical dislocation of the adult hip: A technique with full access to the femoral head and acetabulum without the risk of avascular necrosis. *J Bone Joint Surg Br* 2001;83:1119-1124.
4. Espinosa N, Rothenfluh D, Beck M, Ganz R, Leunig M: Treatment of femoroacetabular impingement: Preliminary results of labral refixation. *J Bone Joint Surg Am* 2006;88:925-935.
5. Reynolds D, Lucas J, Klaue K: Retroversion of the acetabulum: A cause of hip pain. *J Bone Joint Surg Br* 1999;81: 281-288.
6. Jamali AA, Mladenov K, Meyer DC, et al: Anteroposterior pelvic radiographs to assess acetabular retroversion: High validity of the "cross-over-sign." *J Orthop Res* 2007;25:758-765.
7. Murphy SB, Kijewski PK, Millis MB, Harless A: Acetabular dysplasia in the adolescent and young adult. *Clin Orthop Relat Res* 1990;261:214-223.
8. Murphy SB, Ganz R, Müller ME: The prognosis in untreated dysplasia of the hip. *J Bone Joint Surg Am* 1995; 77:985-989.
9. Li PLS, Ganz R: Morphologic features of congenital acetabular dysplasia. *Clin Orthop Relat Res* 2003;416: 245-253.
10. Werlen S, Leunig M, Ganz R: Magnetic resonance arthrography of the hip: Evolution of the Bernese technique of radial sequencing. *Oper Tech Orthop* 2005;15:191-203.
11. Toomayan GA, Holman WR, Major NM, Kozlowicz SM, Vail TP: Sensitivity of MR arthrography in the evaluation of acetabular labral tears. *AJR Am J Roentgenol* 2006;186: 449-453.

12. Schmid MR, Notzli HP, Zanetti M, Wyss TF, Hodler J: Cartilage lesions in the hip: Diagnostic effectiveness of MR arthrography. *Radiology* 2003;226: 382-386.

13. Pfirrmann CW, Mengiardi B, Dora C, Kalberer F, Zanetti M, Hodler J: Cam and pincer femoroacetabular impingement: Characteristic MR arthrographic findings in 50 patients. *Radiology* 2006;240:778-785.

14. Gautier E, Ganz K, Krugel N, Gill T, Ganz R: Anatomy of the medial femoral circumflex artery and its surgical implications. *J Bone Joint Surg Br* 2000;82:679-683.

15. Reikeras O, Bjerkreim I, Kolbenstvekt A: Anteversion of the acetabulum and femoral neck in normals and in patients with osteoarthritis of the hip. *Acta Orthop Scand* 1983;54:18-23.

16. Tonnis D: *Congenital Dysplasia and Dislocation of the Hip in Children and Adults.* New York, NY, Springer, 1987, pp 113-130, 156-161.

17. Tonnis D, Heinecke A: Acetabular and femoral anteversion: Relationship with osteoarthritis of the hip. *J Bone Joint Surg Am* 1999;81:1747-1770.

18. Sponseller PD, Bisson LJ, Gearhart JP, Jeffs RD, Magid D, Fishman E: The anatomy of the pelvis in the extrophy complex. *J Bone Joint Surg Am* 1995; 77:177-189.

19. Dora C, Zurback J, Hersche O, Ganz R: Pathomorphologic characteristics of posttraumatic acetabular dysplasia. *J Orthop Trauma* 2000;14: 483-489.

20. Murphy SB, Kijewski PK, Millis MB, Harless A: Acetabular dysplasia in the adolescent and young adult. *Clin Orthop Relat Res* 1990;261:214-223.

21. Dora C, Buhler M, Stover MD, Mahomed MN, Ganz R: Morphologic characteristics of acetabular dysplasia in proximal femoral focal deficiency. *J Pediatr Orthop B* 2004;13: 81-87.

22. Ezoe M, Naito M, Inoue T: The prevalence of acetabular retroversion among various disorders of the hip. *J Bone Joint Surg Am* 2006;88:372-379.

23. Myers SR, Eijer H, Ganz R: Anterior femoroacetabular impingement after periacetabular osteotomy. *Clin Orthop Relat Res* 1999;363:93-99.

24. Siebenrock KA, Schoeniger R, Ganz R: Anterior femoroacetabular impingement due to acetabular retroversion. *J Bone Joint Surg Am* 2003;85: 278-286.

25. Siebenrock KA, Kalbermatten DF, Ganz R: Effect of pelvic tilt on acetabular retroversion: A study of pelves from cadavers. *Clin Orthop Relat Res* 2003;407:241-248.

26. Lequesne M, deSeze S: Le faux profil du bassin: Nouvelle incidence radiographique pour l'étude de la hanche: Son utilité dans les dysplasies et les differentes coxopathies. *Rev Rhum* 1961;28:643-652.

27. Espinosa N, Beck M, Rothenfluh D, Ganz R, Leunig M: Treatment of femoroacetabular impingement: Preliminary results of labral refixation: Surgical technique. *J Bone Joint Surg Am* 2007;89:36-53.

28. Van De Velde S, Fillman R, Yandow S: The aetiology of protrusio acetabuli: Literature review from 1824 to 2006. *Acta Orthop Belg* 2006;72:524-529.

29. Letournel E: The treatment of acetabular fractures through the ilioinguinal approach. *Clin Orthop Relat Res* 1993;292:62-76.