Evolution of Femoroacetabular Impingement Treatment: The ANCHOR Experience

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Abstract
Our understanding of femoroacetabular impingement (FAI) as a cause of hip pain and secondary osteoarthritis has rapidly evolved since Ganz's description in 2003, which refined concepts described a half century earlier. The concepts of cam and pincer-type impingement continue to be better defined and have evolved from relatively simple concepts to more complex and variable disease patterns that are patient-specific. Ganz and colleagues described open treatment of FAI through the development of the surgical hip dislocation approach. Increased experience and advances in arthroscopic techniques have increasingly allowed for arthroscopic treatment of the most common FAI deformities. Yet, adequate bony correction of FAI continues to be a challenge for many surgeons and remains a common cause for revision surgery. Inferior outcomes after revision FAI surgery might indicate the importance of an accurate correction, regardless of the surgical approach, during the index surgery. Open surgical dislocation continues to play a role in the treatment of complex FAI where additional reconstruction is necessary or adequate bony correction may be inconsistently performed or inaccessible via an arthroscopic approach.

Femoroacetabular impingement (FAI) was described by Ganz and colleagues[1] in 2003 as a refinement of concepts introduced decades earlier. This description advanced our understanding of FAI as a mechanism for prearthritic hip pain and secondary hip osteoarthritis[1] (OA) and allowed for treatment of FAI. The concept of proximal femoral and acetabular/pelvic deformity contributing to OA had been previously speculated by Smith-Petersen,[2] Murray,[3] Solomon,[4] and Stulberg.[5] Early cases of overcorrection of dysplasia using the periacetabular osteotomy created iatrogenic FAI, which further stimulated early development of the FAI concept.[6] Improved anatomical characterization of the proximal femoral blood supply (medial femoral circumflex artery) allowed for development of the open surgical hip dislocation.[7] Through open surgical hip dislocation, an improved understanding of hip pathomechanics by direct visualization helped pave the way for a better understanding of FAI. Open surgical hip dislocation allows for global treatment of labrochondral pathology and deformity of the proximal femoral head–neck junction and/or acetabular rim in FAI.

Hip arthroscopy has further developed and improved our understanding of FAI. Early hip arthroscopy was generally limited to débridement of labral and chondral pathology, and management of the soft-tissue structures. Advances in the understanding of FAI through open techniques allowed for application of similar techniques to hip arthroscopy. Improvements in arthroscopic instrumentation and

Authors' Disclosure Statement: Dr. Nepple reports that he is a consultant to, a speaker for, and receives research support from Smith & Nephew. Dr. Clohisy reports that he receives research support from the National Football League grant, the Curing Hip Disease Fund, the International Hip Dysplasia Institute, and the Washington University Institute of Clinical and Translational Sciences (National Institutes of Health grant UL1RR024992). ANCHOR Study Group Members report that they receive research support from Zimmer Biomet and ANCHOR Research Fund.

techniques have allowed for treatment of labrochondral and acetabular-sided rim deformity in the central compartment and cam morphologies in the peripheral compartment through arthroscopic surgery. Appropriate bony correction by arthroscopic techniques has always been a concern, but improved techniques, dynamic assessment, and accurate use of intraoperative imaging have made this feasible and more predictable. Treatment of cam deformities extending adjacent and proximal to the retinacular vessels is possible but more technically demanding. Inadequate bony correction of FAI by arthroscopic means remains one of the most common causes of failure.[8-10]

In 2013, the Academic Network of Conservational Hip Outcome Research (ANCHOR) Study Group reported the characteristics of a FAI cohort of 1130 hips (1076 patients) that underwent surgical treatment of FAI across 8 institutions and 12 surgeons.[11] At that time, most ANCHOR surgeons (or surgeon groups) performed both open and arthroscopic surgeries and had significant referral volumes of complex cases that may have overrepresented the proportion of complex FAI cases in the cohort. During the 2008 to 2011 study period, FAI was treated with arthroscopy in 56% of these cases, open surgical hip dislocation in 34%, and reverse periacetabular osteotomy in 9%. FAI was characterized as isolated cam-type in 48%, combined cam–pincer type in 45%, and isolated pincer-type in 8%. Fifty-five percent of the patients were female. Patient-reported outcome studies in this cohort of patients are ongoing.

The FAI Concept

In 2003, after treating more than 600 open surgical hip dislocations over the previous decade, Ganz and colleagues[1] coined the term *femoroacetabular impingement* to describe a "mechanism for the development of early osteoarthritis for most nondysplastic hips." They reported surgical treatment focused on "improving the clearance for hip motion and alleviation of femoral abutment against the acetabular rim" with the goal of improving pain and possibly of halting progression of the degenerative process. FAI was defined as "abnormal contact between the proximal femur and acetabular rim that occurs during terminal motion of the hip" leading to "lesions of the acetabular labrum and/or the adjacent acetabular cartilage." Subtle, previously overlooked deformities of the proximal femur and acetabulum were recognized as the cause of FAI, "including the presence of a bony prominence usually in the anterolateral head and neck junction that is seen best on the lateral radiographs, reduced offset of the femoral neck and head junction, and changes on the acetabular rim such as os acetabuli or a double line that is seen with rim ossification." Ganz and colleagues[1] recognized that "normal or near normal" hips could also experience FAI in the setting of excessive or supraphysiologic range of motion. Cam-type and pincer-type FAI deformities were introduced as 2 distinct mechanisms of FAI. By 2003, arthroscopic hip surgery was increasingly being used as a treatment for labral tears but not bony abnormalities. These FAI concepts seemed to explain the prevalence of labral tears at the anterosuperior rim, which had been noted during hip arthroscopy, and paved the way for major changes in arthroscopic hip surgery during the next decade. The ANCHOR group reported the descriptive epidemiology of a cohort of more than 1000 patients with FAI.[11]

Cam-Type FAI

Cam-type impingement results from femoral-sided deformities. The mechanism was described as inclusion-type impingement in which "jamming of an abnormal femoral head with increasing radius into the acetabulum during forceful motion, especially flexion."[1] This results in outside-in abrasion of the acetabular cartilage of the anterosuperior rim with detachment of the "principally uninvolved labrum"[1] and potentially delamination of the adjacent cartilage from the subchondral bone.
Ganz and colleagues[1] recognized in their initial descriptions of FAI that cam-type FAI could involve decreased femoral version, femoral head–neck junction asphericity, and decreased head–neck offset. The complexity and variability in the topography and geography of the cam morphology have been increasingly recognized. Accurate understanding and characterization of the proximal femoral deformity are important in guiding surgical correction of the cam deformity.

Advances in understanding the prevalence of the cam morphology and the association with OA have been important to our understanding of the pathophysiology of FAI. Several studies[12] have established that a cam morphology of the

Take-Home Points

- Our understanding of FAI has evolved from cam-type and pincer-type impingement to much more complex disease patterns.
- Most surgeons are performing less aggressive acetabular rim trimming.
- Inadequate osseous correction is still the most common cause of the failed hip arthroscopy.
- Labral preservation is important to maintaining suction seal effect.
- Open surgical techniques have a role for more severe and complex FAI deformities.

proximal femur (defined by a variety of different metrics) is common among asymptomatic individuals. In light of this fact, a description of the femoral anatomy as a "cam morphology" rather than a cam deformity is now favored. Similarly, FAI is better used to refer to symptomatic individuals and is not equivalent to a cam morphology. The cam morphology seems significantly more common among athletes. Siebenrock and colleagues[13] demonstrated the correlation of high-level athletics during late stages of skeletal immaturity and development of a cam morphology. A recent systematic review of 9 studies found that elite male athletes in late skeletal immaturity were 2 to 8 times more likely to develop a cam morphology before skeletal maturity.[14]

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Several population-based studies[15,16] have quantified the apparent association of the cam morphology with hip OA. However, the studies were limited in their ability to adequately define the presence of cam morphology based on anteroposterior (AP) pelvis radiographs.

In a prospective study, Agricola and colleagues[15] found the risk of OA was increased 2.4 times in the setting of moderate cam morphology (α angle, >60°) over a 5-year period. Thomas and colleagues[16] found increased risk in a female cohort when the α angle was >65°.

Treatment of cam-type FAI is focused on adequate correction of the abnormal bone morphology. Inadequate or inappropriate bony correction of FAI is a common cause of treatment failure and is more common with arthroscopic techniques.[9,10,17] Inadequate bony resection may be the result of surgical inexperience, poor visualization, or lack of understanding of the underlying bony deformity. Modern osteoplasty techniques also focus on gradual bony contour correction that restores the normal concavity–convexity transition of the head–neck junction. Overresection of the cam deformity not only may increase the risk of femoral neck fracture but may result in early disruption of the hip fluid seal from loss of contact between the femoral head and the acetabular labrum earlier in the arc of motion. In addition, high range-of-motion impingement can be seen in various athletic populations (dance, gymnastics, martial arts, hockey goalies), and the regions of impingement tend to be farther away from classically described impingement. Impingement in these situations occurs at the distal femoral neck and subspine regions, adding a level of complexity and unpredictability from a surgical standpoint.

FAI can also occur in the setting of more complex deformities than the typical cam morphology. Complex cases of FAI caused by slipped capital femoral epiphysis (SCFE) and residual Legg-Calvé-Perthes disease are relatively common. Complex deformities may also result in extra-articular impingement of the proximal femur (greater/lesser trochanter, distal femoral neck) on the pelvis (ilium, ischium) in addition to typical FAI. Mild to moderate cases of residual SCFE may be adequately treated with osteoplasty by arthroscopic techniques. In the setting of more severe residual SCFE, presence of underlying femoral retroversion and retrotilt of the femoral epiphysis may prevent adequate deformity correction and motion improvement by arthroscopy. Surgical hip dislocation (with or without relative femoral neck lengthening) and/or proximal femoral flexion derotational osteotomy may be the best means of treatment in these more severe deformities but may be dependent on the chronicity of the deformity and associated compensatory changes occurring on the acetabular side. Similarly, in moderate to severe residual Legg-Calvé-Perthes disease, presence of coxa vara, high greater trochanter, short femoral neck, and ovoid femoral head may be better treated in open techniques to allow comprehensive deformity correction, including correction of acetabular dysplasia in some cases.

Pincer-Type FAI

Pincer-type FAI results from acetabular-sided deformities in which acetabular deformity leads to impaction-type impingement with "linear contact between the acetabular rim and the femoral head–neck junction."[1] Pincer FAI causes primarily labral damage with progressive degeneration and, in some cases, ossification of the acetabular labrum that further worsens the acetabular overcoverage and premature rim impaction. Chondral damage in pincer-type FAI is generally less significant and limited to the peripheral acetabular rim.

Pincer-type FAI may be caused by acetabular retroversion, coxa profunda, or protrusio acetabuli. Our understanding of what defines a pincer morphology has evolved significantly. Through efforts to better define structural features of the acetabular rim that represent abnormalities, we have improved our understanding of how these features may influence OA development. One example of improved understanding involves coxa profunda, classically defined as the medial acetabular fossa touching or projecting medial to the ilioischial line on an AP pelvis radiograph. Several studies have found that this classic definition poorly describes the "overcovered" hip, as it is present in 70% of females and commonly present (41%) in the setting of acetabular dysplasia.[18,19] Acetabular retroversion was previously associated with hip OA. Although central acetabular retroversion is relatively uncommon, cranial acetabular retroversion is more common. Presence of a crossover sign on AP pelvis radiographs generally has been viewed as indicative of acetabular retroversion. However, alterations in pelvic tilt on supine or standing AP pelvis radiographs can result in apparent retroversion in the setting of normal acetabular anatomy[20] and potentially influence the development of impingement.[21] Zaltz and colleagues[22] found that abnormal morphology of the anterior inferior iliac spine can also lead to the presence of a crossover sign in an otherwise anteverted acetabulum. Larson and colleagues[23] recently found that a crossover sign is present in 11% of asymptomatic hips (19% of males) and may be considered a normal variant. A crossover sign can also be present in the setting of posterior acetabular deficiency with normal anterior acetabular coverage. Ultimately, acetabular retroversion might indicate pincer-type FAI or dysplasia or be a normal variant that does not require treatment. Global acetabular overcoverage, including coxa protrusio, may be associated with OA in population-based studies but is not uniformly demonstrated in all studies.[16,24,25] A lateral center edge angle of >40° and a Tönnis angle (acetabular inclination) of <0° are commonly viewed as markers of global overcoverage.

FAI Treatment

Improvements in hip arthroscopy techniques and instrumentation have led to hip arthroscopy becoming the primary surgical technique for the treatment of most cases of FAI. Hip arthroscopy allows for precise visualization and treatment of labral and chondral disease in the central compartment by traction. Larson and colleagues[26] reported complication rates for hip arthroscopy in a prospective series of >1600 cases. The overall complication rate was 8.3%, with higher rates noted in female patients and in the setting of traction time longer than 60 minutes. Nonetheless, major complications occurred in 1.1%, with only 0.1% having persistent disability. The most common complications were lateral femoral cutaneous nerve dysesthesias (1.6%), pudendal nerve neuropraxia (1.4%), and iatrogenic labral/chondral damage (2.1%).

The importance of preserving the acetabular labrum is now well accepted from clinical and biomechanical evidence.[27-29] As in previous studies in surgical hip dislocation,[30] arthroscopic labral repair (vs débridement) results in improved clinical outcomes.[31,32] Labral repair techniques currently focus on stable fixation of the labrum while maintaining the normal position of the labrum relative to the femoral head and avoiding labral eversion, which may compromise the hip suction seal. With continued technical advancements and biomechanical support, arthroscopic labral reconstruction is possible in the setting of labral deficiency, often resulting from prior resection. However, the optimal indications, surgical techniques, and long-term outcomes continue to be better defined. Open and arthroscopic techniques have shown similar ability to correct the typical mild to moderate cam morphology in FAI.[33] Yet, inadequate femoral bony correction of FAI seems to be the most common cause for revision hip preservation surgery.[9,10,17]

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Mild to moderate acetabular rim deformities are commonly treated with hip arthroscopy. As our understanding of pincer-type FAI continues to improve, many surgeons are performing less-aggressive bone resection along the anterior rim. On the other hand, subspinous impingement was recently recognized as a form of extra-articular pincer FAI variant.[34] Subspine decompression without true acetabular rim resection has become a more common treatment for pincer lesions and may be a consideration even with restricted range of motion after periacetabular osteotomy. Severe acetabular deformities with global overcoverage or acetabular protrusion are particularly challenging by arthroscopy, even for the most experienced surgeons. Although some improvement in deformity is feasible with arthroscopy, even cases reported in the literature have demonstrated incomplete deformity correction. Open surgical hip dislocation may continue to be the ideal treatment technique for severe pincer impingement.

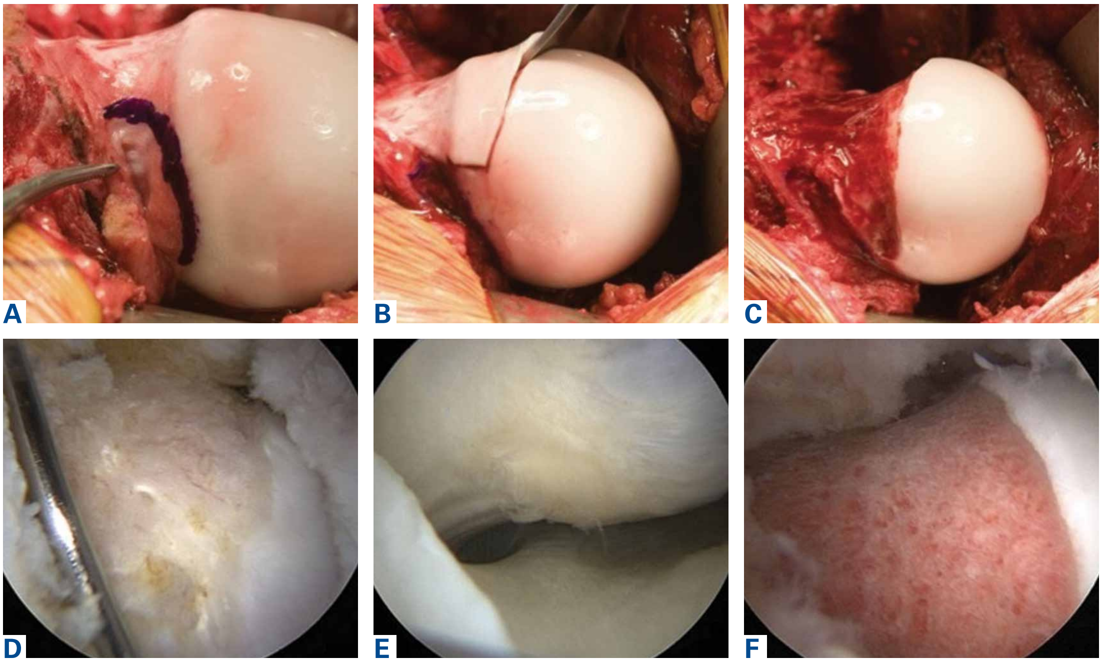

Figure. (A, B, C) Open and (D, E, F) arthroscopic appearance of proximal femoral cam deformity and femoral osteoplasty. Location of retinacular vessels is noted in figure A (open) and figure D (arthroscopic).

Cam-type FAI is commonly treated with hip arthroscopy (**Figures A-F**). Dynamic examination during hip arthroscopy, similar to that performed with open techniques, can also be helpful in demonstrating FAI in the typical anterosuperior location. It may be crucial to perform an arthroscopic dynamic assessment in various positions (flexion-abduction, extension-abduction, flexion-internal rotation) in order to more accurately evaluate potential regions of impingement. Fluoroscopic imaging is generally used to guide and confirm appropriate deformity correction.[35] Anterior and anterolateral head–neck junction deformity is well accessed in 30° to 45° of hip flexion. Both interportal and T-type capsulotomies can be used, generally depending on surgeon preference. FAI deformity extending distal along the head–neck junction can be more challenging to access without a T-type capsulotomy. FAI deformities that extend laterally and are visible on an AP pelvis radiograph remain the most challenging aspect of arthroscopic FAI surgery. These areas of deformity can be better accessed with the hip in extension and sometimes even with traction applied. Access to the more cranial and posterior extensions of these deformities is more difficult in the setting of femoral retroversion or relative femoral retroversion, which can often coexist. Fabricant and colleagues[36] found relative femoral retroversion (<5° anteversion) was associated with poorer outcomes after arthroscopic treatment of FAI.

Open surgical techniques will continue to have an important role in the treatment of severe and complex FAI deformities in which arthroscopic techniques do not consistently achieve adequate bony correction (Figures A-F). Surgical hip dislocation remains a powerful surgical technique for deformity correction in FAI. Sink and colleagues[37] reported rates of complications after open surgical hip dislocation in the ANCHOR study group. In a cohort of 334 hips (302 patients), trochanteric nonunion occurred in 1.8% of cases, and there were no cases of avascular necrosis. Overall major complications were observed in 4.8% of cases, with 0.3% having chronic disability. Excellent outcomes, including high rates of return to sports, have been reported after surgical hip dislocation for FAI.[38] Midterm studies from the early phase of surgical treatment of FAI have helped identify factors that may play a major role in optimizing patient outcomes.

Conclusion

Our understanding and treatment of FAI continue to evolve. Both open and arthroscopic techniques have demonstrated excellent outcomes in the treatment of FAI. Most cases of FAI are now amenable to arthroscopic treatment. Inadequate resection and underlying acetabular dysplasia remain common causes of treatment failure. Open surgical hip dislocation continues to play a role in the treatment of severe deformities that are poorly accessible by arthroscopy—including cam lesions with posterior extension, severe global acetabular overcoverage, or extra-articular impingement. The association of FAI with OA is most apparent for cam-type FAI. Future research will define the optimal treatment strategies and determine if they modify disease progression.

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Am J Orthop. 2017;46(1):28-34.

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