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Review Article

Femoroacetabular Impingement and Acetabular Labral Tears

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Educational objectives

A

Although a common topic in orthopedic literature, awareness of idiopathic acetabular labral tears and associated femoroacetabular impingement (FAI) is still in its infancy. Recently it was noted, “In 1996, a review article reflected the clinical experience in the treatment of acetabular labral pathology and summarized the world’s literature, which consisted of 10 articles.” The concept of FAI was first described by Myers et al,2 although other less subtle forms of impingement had been reported much earlier. Cheilectomy for slipped capital femoral epiphysis was first described in 19133 and in 1935 Smith-Peterson4 reported on impingement due to severe acetabular protrusio. Later, pistol grip deformity as a potential cause of osteoarthritis was proposed by Stulberg et al in 1975. Still, the concept of more subtle

bony morphological differences as a cause of idiopathic primary hip arthritis and the ability to treat these lesions is a product of the innovative work of Ganz et al.2

Due to its relative novelty, much literature is now devoted to FAI each year. In fact, since its introduction in 1999, the number of published articles has increased almost exponentially. As the body of literature grows, review articles become necessary to stay abreast of the appropriate diagnosis, treatment, and outcomes associated with the evolving field of FAI.

LABRAL ANATOMY & PATHOPHYSIOLOGY

The acetabular labrum is a fibrocartilaginous ring attached to the rim of the bony acetabulum and its associated articular cartilage. At its base near the 5 and 7 o’clock positions it becomes contiguous with the transverse acetabular ligament. The attachment of the articular cartilage to the labrum differs anteriorly and posteriorly. Anteriorly, the chondrolabral junction is sharp and abrupt with only a marginal attachment site. This contrasts with the posterior chondrolabral junction, where the transition is gradual and interdigitated.6

The sharp chondrolabral junction and marginal attachment site may contribute to the tendency of idiopathic labral tears to be predominately anterior lesions, although other factors likely contribute as well. For instance, as most daily hip activity occurs from a neutral position to 90° of flexion, the at-risk area of the hip for bony impingement becomes predominately anterior. Perhaps most importantly, the location of labral tears correlates with the location of the bony morphologic abnormalities described with cam impingement. Recently several authors have noted that previously diagnosed “idiopathic” labral tears were associated with subtle bony abnormalities consistent with hip impingement 79% to 87% of the time.7,6

The vascular supply to the acetabular labrum has been well described and is analogous to the meniscus (Figure 1). The inner, articular two-thirds is essentially avascular while the outer one-third has a robust blood supply from the hip capsule.10 This is theorized to have implications in attempts at labral repair and has prompted surgeons to create a bleeding bed of subchondral bone for reattachment during attempted repairs.

Initially, the labrum was thought to primarily be a load bearing structure. It was felt to effectively deepen the acetabular socket, theoretically improving tracking stability as well as decreasing joint reaction forces by increasing the functional surface area over which these forces act. While the labrum appears to function somewhat in this capacity, load bearing appears to be a principal function only in dysplastic hips.11

With more normal anatomy, the primary function of the labrum is to create a sealing mechanism to trap synovial fluid. As the joint is loaded, an increase in fluid pressure separates the femoral and acetabular articular surfaces.12 Ferguson et al12 found that if the labrum was resected, joint contact stresses were 92% higher and creep rate was 40% greater.

FEMOROACETABULAR IMPINGEMENT

Cam impingement is best thought of as a femoral sided lesion causing the abnormal femur to impinge on the acetabular labrum and articular cartilage with daily activities.13 This bony “bump” effectively creates decreased femoral head-neck offset. When isolated, it most often occurs in young men in their 20s to 40s. The non-spherical portion of the femoral head is usually found anterosuperiorly and correlates with the anatomic location of the majority of “idiopathic” labral tears.15 It is felt that with flexion and internal rotation, the raised lesion on the femoral neck contacts the acetabulum and causes a delaminating effect on the articular cartilage. The labrum is displaced outwardly and superiorly, eventually causing a relatively clean, articular-sided labral tear perpendicular to the joint surface (Figure 2).16 Although this type of labral tear is the most ame-
nable to repair, the fact that the articular cartilage has usually started to delaminate by the time a labral tear occurs may be an early and irreversible precursor to arthritis. The overall area of cartilage damage found in pure cam lesions is much greater than that associated with isolated pincer impingement.  

Pincer impingement, however, is best thought of as an acetabular sided problem. It can be due to either focal overcoverage (acetabular retroversion) or global overcoverage (coxa profunda or protrusio) of the acetabulum on the femoral head and neck. With isolated pincer impingement, the patient tends to be a middle-aged woman. Unlike cam impingement, the labral lesion tends to occur before the articular cartilage damage. The femoral neck makes contact with the acetabulum during normal hip range of motion due to the overcoverage. This effectively “crushes” the labrum causing multiple intrasubstance cleavage tears and occasionally associated paralabral cysts (Figure 2). As the labrum becomes incompetent, a focal area of articular cartilage behind it becomes damaged. However, the damaged cartilage tends not to delaminate like those cartilage lesions associated with cam impingement. At times, the damaged labrum tries to heal back to the underlying bone, creating an ossified rim, further worsening the acetabular overcoverage. With advanced disease, the posterior-inferior portion of the femoral head begins to lever out of the acetabulum creating a counter-coup lesion. This is a late finding and is a poor prognostic sign.  

Patients presenting with more mixed patterns (the majority of patients) tend to report slow onset of groin pain. This initially tends to be during athletic activity, but eventually progresses to a point where sitting in a chair for long periods is painful. This is because impingement tends to occur with hip flexion and internal rotation. The presence of mechanical problems in the hip such as catching or snapping has been shown to be nonspecific for the presence of a labral tear. The impingement test should correlate with the patient’s pain; the provocative maneuver is invoked with hip flexion, internal rotation, and adduction. Table 1 further characterizes the appropriate physical examination for, and findings associated with, labral tears and FAI.  

**IMAGING**

The lesions found in FAI tend to be subtle findings and it is imperative to ensure that proper radiographs are taken to consistently identify impingement pathologies. In order to accurately evaluate for pincer impingement a true anteroposterior (AP) pelvis view should be obtained: the center of the sacrum and coccyx should be in line with the center of the pubic symphysis. In addition, the sacroccygeal junction should be within 3.2 cm of the top of the pubic symphysis in men and 4.7 cm in women. Mild deviations into Inlet/Outlet or Judet views will alter the ability to accurately assess the anterior and posterior acetabular walls. In addition, centering the x-ray beam on the hip instead of the pelvis also alters radiographic accuracy; a true AP pelvis view is necessary and an AP of the hip alone will not suffice (Figures 3-6).
In pincer impingement, radiographic findings can be divided into those causing focal impingement (acetabular retroversion) and those causing global overcoverage (profunda, protrusio). When considering acetabular retroversion, perhaps the most common radiographic finding is the crossover sign, sometimes also called the figure-of-eight sign (Figure 7). Normally, the posterior wall should always be lateral to the anterior wall on an AP view of the pelvis. If the anterior wall appears to “cross over” the posterior wall, the acetabulum is retroverted. The degree of retroversion can be inferred from where the crossover occurs. If the crossover occurs in the top third of the acetabulum it is mild, in the middle third moderate, and in the inferior third it is severe retroversion. Difficulty can sometimes arise in identifying which wall is which. If one starts in the most inferior part of the acetabulum, the most lateral wall should be the posterior wall. This simple fact can be very helpful when evaluating for crossover.

The ischial spine sign is a secondary sign of acetabular retroversion. When viewing a true AP image of the pelvis, the ischial spines should not project into the pelvis; if so, this should prompt one to look further for other signs of retroversion. The posterior wall sign evaluates whether the posterior wall of the acetabulum is medial or lateral to the center of the femoral head, effectively noting how much posterior wall coverage exists.

Recent controversy has been raised over the accuracy of the crossover sign. Originally, the crossover sign was noted to have a positive predictive value of 90% and a specificity of 95% using a standardized radiograph arrangement with cadaveric pelvis. This has been criticized as difficult to reproduce in the clinical setting. Recently, Dandachli et al found the crossover sign to be 92% sensitive but only 55% specific when comparing plain radiographs of the pelvis to three-dimensional computed tomography scans. Of note, the authors did not standardize pelvic tilt, which could skew their results. This same article verified that there was no significant difference in total femoral head coverage between normal and retroverted acetabuli, proving that the entire acetabulum becomes retroverted; ie, there is not simply a deepening of the anterior acetabulum relative to the posterior acetabulum in focal overcoverage.

The authors pointed out that the resultant posterior femoral head will have less coverage and increased joint reaction forces will occur in this area. They speculated that joint damage in that portion of the hip may be due to an increase in joint reaction forces instead of due to a counter-rotation lesion. Therefore, the authors suggest that a redirecting pelvic osteotomy may be the best treatment for a retroverted acetabulum, as this treatment will best normalize the increased joint reaction forces.

When considering global overcoverage, such as coxa profunda or protrusio, the radiographic evaluation is slightly different. In a normal hip, the floor of the acetabulum, as represented by the acetabular teardrop, should be lateral to the
illioschial line (Figure 7). If the teardrop touches or crosses over the illioschial line but the femoral head does not, coxa profunda exists. If the femoral head crosses over the illioschial line, a more rare and severe form of global overcoverage exists, protrusio acetabuli.

Values of the pelvis for acetabular overcoverage to protrusio acetabuli exist. If the femoral head crosses over the illioschial line, a more rare and severe form of global overcoverage exists, protrusio acetabuli. Those values of 21°/H11034 ered normal while those of 24°/H11034 are considered borderline.

It is also important while assessing the pelvis for acetabular overcoverage to rule out subtle forms of hip dysplasia. The center-edge angle is useful for this as seen in Figure 8. Values of >25° are considered normal while those of ≤20° qualify as dysplasia. Those values of 21° to 24° are considered borderline.

When evaluating for cam impingement, radiographic attention is turned to the femur. The junction of the femoral head and neck should have a smooth contour from a concave to a convex morphology. The most obvious violation of this is seen in the pistol grip deformity initially described by Stulberg et al (Figure 9). More subtle lesions can be better appreciated by drawing a circle to fill the femoral head to highlight the head-neck junction. Any bony protrusion beyond this circle is suggestive of a cam lesion. Most lesions are not obvious and are usually found on the anterosuperior aspect of the femoral neck. To highlight this, special lateral views of the femoral neck are needed as a normal cross table lateral cannot visualize this area adequately. Several views have been described to achieve this including a 15° internally rotated lateral, the Dunn view, and the modified Dunn view. All are adequate for screening purposes, although the modified Dunn view is the most sensitive, 83% to 96%. It is taken as an AP view of the hip in neutral rotation, 45° of flexion, and 20° of abduction.

The alpha angle is perhaps the most common way to quantify the degree of bony morphologic abnormality. Although originally described on magnetic resonance imaging (MRI) and most accurate when measured this way, the orthopedist needs a screening tool to use in the office to diagnose and quantify cam impingement. On a 15° internally rotated lateral or a Dunn type view, a line is drawn down the center of the femoral neck to the center of the femoral head. Another line is drawn from the center of the femoral head to the head-neck junction (Figure 10). The resulting angle is the alpha angle. In the general population this averages 42° while in cam impingement it averages 74°.

Although still in the process of being defined, most clinicians are using either 50° or 55° as the upper limit of normal. Another radiographic tool is the femoral head-neck offset. A secondary finding in cam impingement is subchondral cysts found in the superior and anterior aspects of the femoral neck. Table 2 summarizes the above-mentioned findings for easier reference when comparing and contrasting the primary radiographic findings of cam and pincer impingement.

As noted above, the alpha angle is best measured on MRI. The ideal cuts to evaluate this are on specially formatted radial views of the femoral neck, as opposed to the more normal oblique views taken at most MRI sessions. Magnetic resonance arthograms are effective at visualizing labral tears, from 92% to 100% sensitive and 93% to 96% accurate. Unfortunately, articular cartilage lesions are more difficult to identify in this manner. This is important as the presence of these lesions carries a worsened prognosis.

In a study by Anderson et al, magnetic resonance arthograms were taken of 64 hips prior to hip arthroscopy. At the time of surgery, 28 of 64 hips showed cartilage delamination. When the preoperative arthograms were retrospectively shown to blinded radiologists, the reviewers were only 22% sensitive at identification of the cartilage damage, although they were 100% specific.

### TREATMENT OF LABRAL TEARS AND FEMORACETABULAR IMPINGEMENT

#### Types of Treatment

Currently, as with many other orthopedic problems, nonoperative treatment is trialed first. This, despite the fact that there is no literature available to support its use or effectiveness. Some feel that this may be inadvisable as lesions are felt to worsen over time. The optimal timing of surgical intervention is likewise simply unknown at this point. In addition, when both cam and pincer lesions present in the same patient, it is difficult to know whether both lesions should be treated concurrently or whether treatment of just the cam or pincer component of the problem will suffice. Despite these limitations, several surgical treatment options are available.

### Summary of the Primary Radiographic Signs of Cam and Pincer Impingement as Seen on Plain Radiographs

<table>
<thead>
<tr>
<th>Primary Radiographic Signs of Cam FAI</th>
<th>Primary Radiographic Signs of Pincer FAI</th>
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</thead>
<tbody>
<tr>
<td>Pistol grip deformity</td>
<td>Coxa profunda/Protrusio acetabuli</td>
</tr>
<tr>
<td>CCD angle &lt;125°</td>
<td>Acetabular retroversion (crossover sign)</td>
</tr>
<tr>
<td>Horizontal growth plate</td>
<td>Posterior wall sign</td>
</tr>
<tr>
<td>Alpha angle &gt;50°</td>
<td>Ischial spine sign</td>
</tr>
<tr>
<td>Dunn view or 15° internally rotated</td>
<td>Decreased extrusion index</td>
</tr>
<tr>
<td>lateral view of hip</td>
<td></td>
</tr>
<tr>
<td>Femoral retroversion</td>
<td>Neutral acetabular index</td>
</tr>
<tr>
<td>Femoral head-neck offset &lt;8 mm</td>
<td>Counter-coup lesion</td>
</tr>
</tbody>
</table>

Abbreviations: CCD, collodiaphyseal; FAI, femoroacetabular impingement.

*The CCD angle is equivalent to the femoral neck-shaft angle.*
The gold standard of treatment for these pathologies is the Ganz surgical dislocation. It provides excellent exposure of both the femur and acetabulum and has proven safe. It allows for osteochondroplasty (femoroplasty or cheilectomy) of the cam lesion as well as labral takedown with bony acetabular rim trimming and labral repair for treatment of pincer lesions. The main problems associated with this form of treatment are painful hardware used to secure the trochanteric osteotomy site and nonunions of the osteotomy. This has led to a more recent modification of the osteotomy from a flat cut to a step cut, which has decreased the nonunion rate substantially.

Although effective and safe, the Ganz dislocation is invasive. Because of this, more minimally invasive treatments have been devised. An all-arthroscopic approach has been described to both cam and pincer lesions. These are technically challenging procedures and have limited visualization when compared to surgical dislocation. Although osteochondroplasty of cam lesions is performed in the peripheral compartment and does not require traction, rim trimming and labral fixation requires surgical traction and access to the central compartment of the hip. Therefore, traction time limitations and the technical nature of the procedure make this approach demanding on both the treating surgeon and the patient. As a result, treatment of cam lesions via arthroscopy has become more common than treatment of pincer lesions. Still, due to limitations of visualization it can be difficult to know how much bone one is resecting and it seems less morbid than periacetabular osteotomy.

Inaccurate surgical resection is not without consequence as Mardones et al found that resection >30% of the anterosuperior aspect of the femoral neck puts the patient at increased risk of femoral neck fracture. The possibility of this complication has led some to limit postoperative weight bearing for 3 to 4 weeks after both open and arthroscopic procedures.

In France, surgeons have described a variation of the all arthroscopic approach termed the Haeter approach. It involves hip arthroscopy combined with a mini open anterior approach to the hip. This combination can improve visualization and working room when compared to an all arthroscopic approach. While it does not carry the problems of nonunion and painful hardware associated with surgical dislocation, it provides less access and visualization when compared to the Ganz approach.

Acetabular retroversion deserves special mention as 2 different types of treatment are available. One can perform a labral takedown and rim trimming as described above or a periacetabular osteotomy can be done to redirect the entire acetabulum. Both options are viable although periacetabular osteotomy is more technically demanding. Currently, it is felt that if the center of the femoral head is medial to the posterior acetabular wall, there is likely sufficient posterior coverage and a rim trimming is preferred. However, if the center of the femoral head is lateral to the posterior acetabular wall, then posterior coverage is insufficient and a redirecting periacetabular osteotomy is recommended.

Although acetabular rim trimming seems less morbid than periacetabular osteotomy, it is not without its own set of risks. If too much of the bone is resected, one can create iatrogenic hip dysplasia. Phillippon et al reported that for every 1 mm of bony acetabular resection, the center edge angle is decreased by 1.92°.

Outcomes
Short-term results for debridement of labral tears alone have shown mostly good to excellent results at 1 to 2 years. Many of these studies were done prior to when knowledge of FAI was commonplace and therefore do not comment on how often these tears were associated with cam or pincer impingement. The longest study in terms of outcome is from Byrd and Jones where patients were followed for 10 years. Twenty-nine hips in 26 patients initially increased their Harris Hip Score (HHS) from 52 to 81. At 10 years, 18 patients...
who were noted to have no arthritis at the time of initial surgery had a HHS >70. Of the other 8 hips, all of which showed signs of arthritis at arthroscopy, 7 had converted to a total hip arthroplasty (THA) by an average of 63 months.

When attempting to compare labral debridement to repair, 2 published English language articles are available. The first by Espinosa et al in 2006 was a nonconcurrent retrospective comparison of surgical dislocation with osteochondroplasty with either labral debridement or repair. At 2 years those treated with debridement had 28% excellent and 48% good results, while those treated with repair had 80% excellent and 14% good results. Less arthritis was visible at 2-year follow-up on radiographs in the labral repair group as well.

More recently, Larson and Giveans compared arthroscopic debridement of the labrum to repair. At 21 months the debridement group had 66% good to excellent results with a HHS of 89, while the repair group at 16.5 months had 89.7 good to excellent results with a HHS of 94. Although both of these studies are retrospective, and thus potentially subject to bias, there is some evidence that repair may be superior to debridement. A prospective comparison study is needed to clarify this issue.

Several studies exist looking at the short-term outcomes of open osteochondroplasty for cam lesions. Beck et al in 2004 reviewed 19 patients at 4.7 years from surgical dislocation. Overall, they found >65% good to excellent results including 5 of 19 patients who went on to have THA at an average of 3.1 years postoperatively. Those requiring THA correlated with the amount of articular cartilage damage found at the time of surgical dislocation. Peters and Erickson in 2006 reviewed 33 hips at 32-month follow-up. Patients were treated with surgical dislocation and osteochondroplasty and mixed treatment of the labrum. The HHS improved from 70 to 87 with >80% good to excellent results. This despite 18 hips that showed articular cartilage damage at the time of surgical dislocation.

Several outcome studies exist evaluating the results of arthroscopic treatment of cam lesions. These have short-term outcomes with low levels of evidence. Larson and Giveans looked at 100 hips treated at 10 months of follow-up and noted >75% good to excellent results. Ilizaliturri et al looked at 19 patients treated with chellectomy and noted 16 patients had marked improvement of their WOMAC scores. In a systematic review of open and arthroscopic treatment of cam lesions published in October of 2008, Bedi et al found only 1 level 3 study and 15 level 4 studies worthy of inclusion. They found 65% to 85% satisfaction with treatment in the open group and 67% to 100% satisfaction in the arthroscopic group; all studies had only short-term outcomes.

Currently no direct comparison studies exist to compare surgical dislocation with arthroscopic treatments. The current studies available are hampered by poor design and short term follow-up.

**ON THE HORIZON**

**Femoracetabular Impingement as a Cause of Idiopathic Hip Arthritis**

Perhaps the most exciting concept associated with FAI is its proposed association with idiopathic hip arthritis. Although no prospective comparison study exists to prove causality of FAI in the etiology of hip arthritis, the evidence that it may be a factor is compelling. However, some questions remain. As shown by Yamamura et al, the Japanese place themselves in physiologic positions causing hip impingement daily due to social norms and toilet habits, yet the Japanese have a low rate of hip arthritis. Allen et al in May 2009 looked at 113 patients with cam impingement and noted bilateral cam deformity in 77.8%, yet only 26.1% of these patients had bilateral symptoms. The presence of a deformity is not an indication of a painful hip. Will the non-painful side ever become symptomatic and if so, how long will it take? Will those patients become arthritic?

Bardakos and Villar attempted to predict which patients with pistol grip deformities will eventually become arthritic. They reviewed 2 AP pelvis views taken 10 years apart. Forty-three patients were initially found to have a pistol grip deformity and mild to moderate Tonnis arthritis. Ten years later, 28 of those patients showed progression of arthritis; however, this meant that approximately one-third of those patients did not progress at 10 years. Only a posterior wall sign and the medial proximal femoral angle correlated with progression of arthritis although the crossover sign approached significance. Interestingly, the alpha angle was not found to be correlative.

Clearly, although compelling, the data surrounding FAI as a cause of idiopathic hip arthritis is incomplete and long-term studies are needed to establish the incidence of FAI and to determine how many patients become symptomatic and when. It is still needed to establish that these lesions cause arthritis, as well as to verify that treatment of the lesions can alter the natural history of “idiopathic” hip arthritis. Unfortunately, the results of such a study are at least a generation away.

**Labral Reconstruction**

Labral reconstruction is a recently proposed treatment for patients with irreparable labral tears. The theory is that if labral repair is superior to debridement, than perhaps, in a patient with an irreparable labrum, reconstruction may be superior to labral resection alone. To date, only 2 published studies in the literature look at this: one by Sierra and Trousdale and another by Philippon et al. The authors used the ligamentum teres and fascia lata respectively for their reconstructions. In the study by Philippon et al, thirty-four of 46 patients were available for follow-up at an average of 17 months postoperatively. Modified Harris Hip Scores improved from 62
to 84. Lower satisfaction was noted with joint space narrowing and older patients. Of note, the author remarks that at the time of publication he had completed a total of 95 reconstructions, although only 46 had the minimum required 1 year of follow-up. Further studies are needed to determine if labral reconstruction will have use in the treatment of labral tears and FAI.

**Conclusion**

Treatment of acetabular labral tears and FAI is an exciting and novel concept but it is still in its infancy. Future work is necessary to determine when intervention is needed, how to intervene, and how effective our interventions will be. If FAI turns out to be causative of idiopathic hip arthritis and if surgical intervention can prevent its occurrence, then hip impingement may be the most important orthopedic breakthrough of this millennium. Only time and long-term studies will be able to sort this out in its entirety.

**References**


