[Orthopaedic Surgery]

Interventions for Hip Pain in the Maturing Athlete: The Role of Hip Arthroscopy?

M. Mustafa Gomberawalla, MD,† Bryan T. Kelly, MD,‡ and Asheesh Bedi, MD*†‡

Context: Femoroacetabular impingement (FAI) alters hip mechanics, results in hip pain, and may lead to secondary osteoarthritis (OA) in the maturing athlete. Hip impingement can be caused by osseous abnormalities in the proximal femur or acetabulum. These impingement lesions may cause altered loads within the hip joint, which result in repetitive collision damage or sheer forces to the chondral surfaces and acetabular labrum. These anatomic lesions and resultant abnormal mechanics may lead to early osteoarthritic changes.

Evidence Acquisition: Relevant articles from the years 1995 to 2013 were identified using MEDLINE, EMBASE, and the bibliographies of reviewed publications.

Level of Evidence: Level 4.

Results: Improvements in hip arthroscopy have allowed FAI to be addressed utilizing the arthroscope. Adequately resecting the underlying osseous abnormalities is essential to improving hip symptomatology and preventing further chondral damage. Additionally, preserving the labrum by repairing the damaged tissue and restoring the suction seal may theoretically help normalize hip mechanics and prevent further arthritic changes. The outcomes of joint-preserving treatment options may be varied in the maturing athlete due to the degree of underlying OA. Irreversible damage to the hip joint may have already occurred in patients with moderate to advanced OA. In the presence of preexisting arthritis, these patients may only experience fair or even poor results after hip arthroscopy, with early conversion to hip replacement. For patients with advanced hip arthritis, total hip arthroplasty remains a treatment option to reliably improve symptoms with good to excellent outcomes and return to low-impact activities.

Conclusion: Advances in the knowledge base and treatment techniques of intra-articular hip pain have allowed surgeons to address this complex clinical problem with promising outcomes. Traditionally, open surgical dislocations for hip preservation surgery have shown good long-term results. Improvements in hip arthroscopy have led to outcomes equivalent to open surgery while utilizing significantly less invasive techniques. However, outcomes may ultimately depend on the degree of underlying OA. When counseling the mature athlete with hip pain, an understanding of the underlying anatomy, degree of arthritis, and expectations will help guide the treating surgeon in offering appropriate treatment options.

Keywords: hip pain; joint preservation; hip arthroscopy; femoroacetabular impingement

Hip pain can be a debilitating condition in athletes of all ages. Alterations in joint mechanics that contribute to hip pain have generally been attributed to "undercoverage" or dysplasia and, more recently, "overcoverage" or femoroacetabular impingement (FAI).[4] The bony abnormalities that result in FAI are a common cause of intra-articular hip pain and secondary osteoarthritis (OA),[1-3,6-9,11,13,16,17,22,23,27,31,35,36,39,42-46,51] especially in the active patient. Advances in surgical techniques such as hip arthroscopy have rapidly progressed to allow surgeons to address these conditions with minimally invasive procedures. However, identifying the appropriate treatment options in maturing athletes with variable severity of degenerative changes in the hip joint can be a challenge, as outcomes of joint preservation surgery can be compromised in this setting. As our knowledge base and treatment techniques of intra-articular hip pain evolve, treating surgeons are able to offer appropriate counseling and interventions to the maturing athlete presenting with hip pain with or without associated OA.

From †MedSport, Department of Orthopaedic Surgery, University of Michigan, Ann Arbor, Michigan, and ‡Center for Hip Preservation, Hospital for Special Surgery, New York, New York

*Address correspondence to Asheesh Bedi, MD, MedSport, University of Michigan, 24 Frank Lloyd Wright Drive, Lobby A, Ann Arbor, MI 48106 (e-mail: abedi@umich.edu).

The following authors declared potential conflicts of interest: Bryan T. Kelly, MD, is a consultant for Pivot Medical, A2 Surgical, and Smith & Nephew; Asheesh Bedi, MD, is a consultant for Smith & Nephew.

DOI: 10.1177/1941738113497678

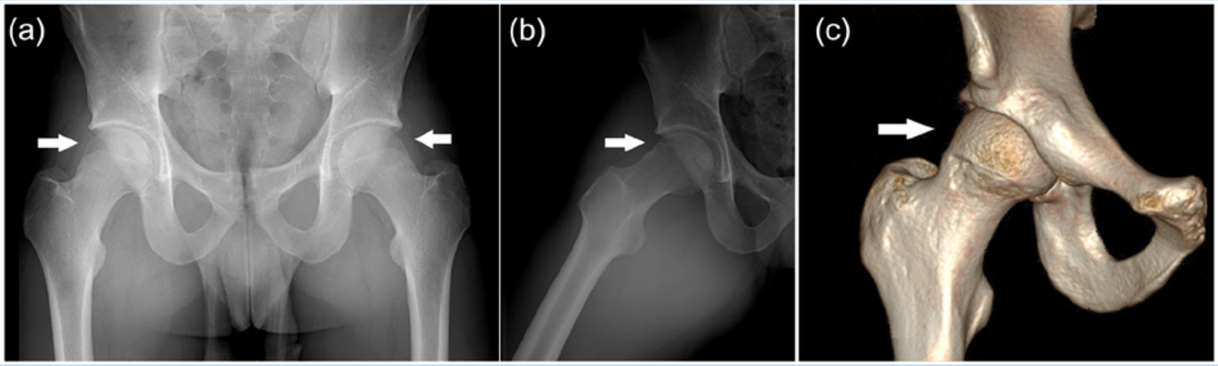

Figure 1. (a) AP pelvis radiograph demonstrating significant cam-type impingement lesions with loss of femoral offset in the bilateral hips. (b) Cam lesions are often located anterosuperiorly and are often better visualized on Dunn lateral views of the hip. (c) Three-dimensional CT scans of the cam lesion are used preoperatively to better define its margins.

ANATOMIC ABNORMALITIES

The clinical problem of FAI has been implicated in the development of early osteoarthrosis in the nondysplastic hip.[1-3,6-9,11,13,16,17,22,23,27,31,35,36,39,42-46,51] The bony abnormalities in FAI include deformities in the acetabulum such as "retrotilt"[39] and the "pistol-grip" deformity of the proximal femur.[49] These anatomic differences lead to repetitive collision and damage to the cartilage and labrum and regional loading of the femoral head-neck junction, which may lead to early osteoarthritic changes.[22,36]

The pistol-grip deformity is a cam-type lesion that decreases the femoral head-neck offset (Figure 1). The resultant asphericity of the femoral head-neck junction can result in impingement against the hemispherical acetabulum with terminal hip motion, particularly flexion and internal rotation. Repetitive loads from the cam lesion onto the chondrolabral junction result in abnormal shear forces, which then cause injury to the transition zone of the articular cartilage and acetabular labrum.[2,4,7,22,27,36,46] The zone of injury on the acetabulum correlates with the location of the cam lesion on the femoral head and is most commonly observed anterosuperiorly.[40,48]

Hip impingement may also be caused by acetabular overcoverage, leading to pincer-type FAI. This overcoverage typically arises from focal acetabular retroversion, often signified by the "crossover" sign on a well-positioned anterior-posterior (AP) radiograph of the pelvis (Figure 2). In these cases, labral tearing and shear forces on the chondral surfaces occur from repetitive direct compression of the labrum by the femoral neck.[2,4,7,22,32,36,47] Most patients present with variable severity of both cam- and pincer-type (combined) impingement.[22,24]

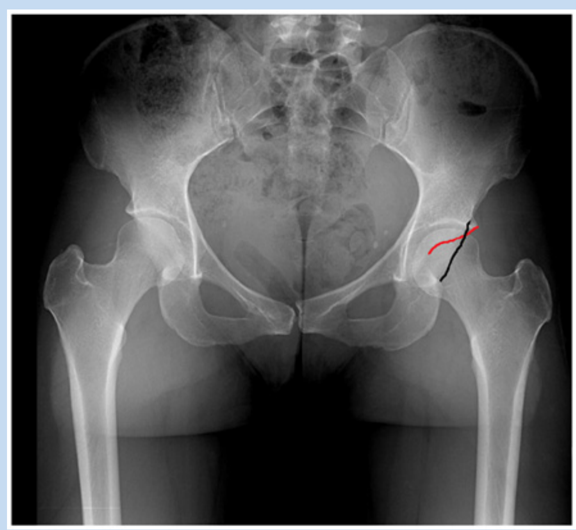

Figure 2. A well-positioned AP pelvis demonstrating a crossover sign in the left hip. Focal acetabular retroversion in pincer-type impingement lesions results in a radiographic projection of the anterior acetabular wall (red-line) that "crosses over" the posterior acetabular wall (black line).

TREATMENT OF FAI

The management of FAI has correspondingly improved with an advanced understanding of mechanical hip deformity. Initial treatment of the symptoms focused on the damaged labrum[3] and failed to address these underlying osseous lesions causing the impingement. Philippon et al[44] performed a retrospective study of 37 patients undergoing revision hip arthroscopy for persistent pain. In this series, the main reason for a failed hip arthroscopy requiring revision was persistent or unaddressed bony impingement.

Heyworth et al[25] reviewed a consecutive series of 24 patients undergoing revision hip arthroscopy. Imaging studies including radiography, magnetic resonance imaging (MRI),

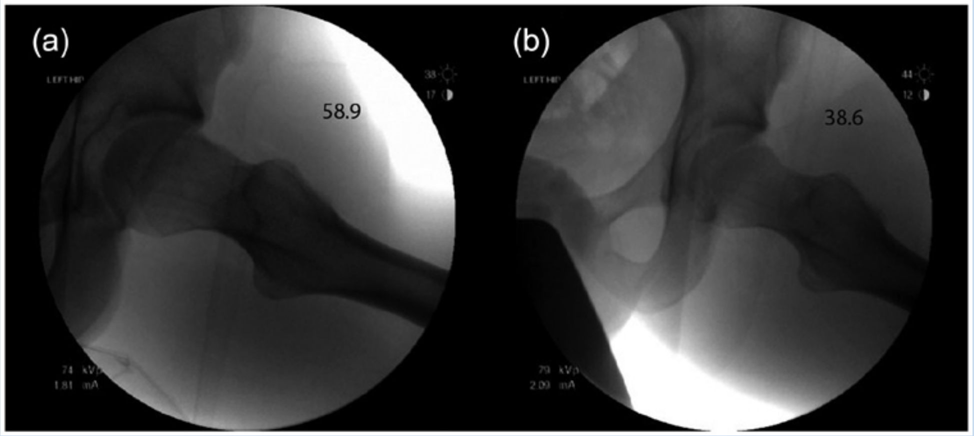

Figure 3. (a) Intraoperative fluoroscopic Dunn lateral view of the left hip demonstrating a preoperative loss of femoral offset and asphericity with an alpha angle of 58.9°. Confirmation of appropriate correction of multiple oblique fluoroscopic images is critical. (b) The postresection image with an alpha angle of 38.6° demonstrates appropriate restoration of the femoral head-neck offset.

and 3-dimensional computed tomography (CT) scans were evaluated prior to revision surgery to help identify anatomic abnormalities that may have contributed to failed index hip arthroscopy. Incomplete or unaddressed osseous impingement lesions were identified in 19 of 24 cases (79%). Eight of 24 cases had a failed labral repair—6 of which also had persistent bony impingement. The primary reason for revision surgery in this series was undertreated or untreated bony lesions causing persistent impingement. Bardakos et al[1] presented a retrospective case series of 2 groups of patients undergoing hip arthroscopy: 1 group underwent labral debridement and osteoplasty and the second underwent labral debridement alone. After 1-year follow-up, significantly more patients had good to excellent results in the osteoplasty and debridement group compared to those who underwent debridement alone (83% vs 60%, respectively). These studies highlighted the importance of identifying and addressing the underlying structural abnormalities responsible for hip impingement (Figure 3). Thus, the more contemporary approaches to FAI have focused on addressing the bony lesion(s) as well as the damaged labrum and chondral delamination (Figure 4).

It is not clear what impact addressing these impingement lesions has on the natural history of FAI and the progression toward arthritis.[5] The current literature supports the use of hip arthroscopy to relieve pain and improve function in individuals with symptomatic hip impingement. However, addressing FAI in asymptomatic individuals has not been supported. Population-based studies have shown a high prevalence of radiographic cam- and pincer-type deformities in young, healthy adults.[30] Although many individuals may have signs of FAI on imaging, there is currently no support for prophylactic surgery in the absence of pain and symptomatic impingement.

FAI AND OSTEOARTHRITIS

Although many studies have shown good to excellent results in younger patients without arthritis,[3,10] the outcomes in maturing athletes who have developed OA undergoing hip arthroscopy are more modest. Older patients with significant articular cartilage injury may have a fair or poor outcome with arthroscopic surgical procedures, as the correction of the osseous deformity may not address the pain generators and irreversible joint injury that has already been rendered. Studies have reported a significant incidence of persistent pain and an increased risk of progression to total hip arthroplasty, as high as 25% in a recent meta-analysis[14] (Table 1).

Farjo et al[20] presented a series of 28 patients with a mean age of 41 years who underwent hip arthroscopy and debridement. The patients were stratified into 2 groups based on radiographic evidence of OA. Only 21% of patients with arthritis had good to excellent results, and 42% of patients with arthritis went on to total hip arthroplasty by the final follow-up visit.

Walton et al[51] reported on 39 patients with a mean age of 47 years with chondral degeneration who underwent hip arthroscopy and labral debridement. Chondral degeneration was diagnosed either through imaging (radiographs or MRI) or by visualization at the time of arthroscopy. Twenty-eight patients (72%) had poor clinical outcomes, a rate significantly higher than that of patients with a labral tear or loose body without evidence of arthritis. They noted that radiographic or arthroscopic signs of osteoarthrosis were significantly associated with a poor postoperative outcome.

Philippon et al[41] reviewed 45 professional athletes (mean age, 31 years) with FAI and labral pathology who underwent

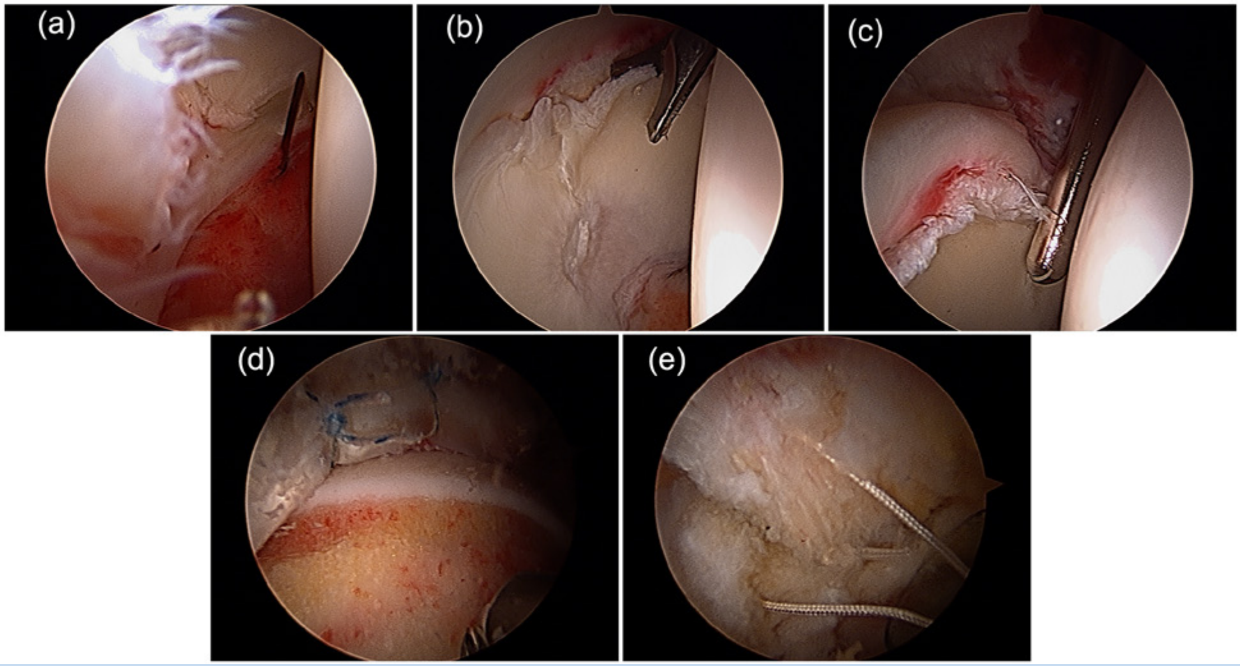

Figure 4. Advances in hip arthroscopy equipment and techniques have significantly improved visualization and instrumentation within the hip joint. (a) A capsulotomy is extended between the modified anterior (viewing) portal and proximal anterolateral portals (beaver blade). An interportal capsulotomy improves access to the extracapsular rim for resection and refixation without need for labral detachment. (b) Cam-type impingement can lead to chondral delamination and shearing injury. (c) An unstable flap anterosuperiorly in this case is being resected to a stable margin. Labral tear as visualized arthroscopically. (d) Note that the location of the injury is representative of the combination of acetabular and femoral deformity and secondary mechanical impingement. After treatment of all central compartment pathology, cam resection is performed in the peripheral compartment, taking great care to assure restoration of offset and sphericity in all planes. (e) If a T-capsulotomy is required for full exposure of the cam deformity, a side-to-side repair is performed to restore the integrity of the iliofemoral ligament.

hip arthroscopy. Forty-seven percent of these athletes had Outerbridge grade IV changes noted during arthroscopy, which were treated with either microfracture, thermal chondroplasty, or both. Forty-two athletes (93%) returned to their professional level of play, while the remaining 3 had diffuse osteoarthritic changes, as noted during arthroscopy.

In a larger series, Philippon et al[42] prospectively followed 112 patients (mean age, 41 years) with FAI who underwent hip arthroscopy, most of whom also underwent arthroscopic osteoplasty and/or acetabular rim resection with a mean 2.3-year follow-up. In this series, patients with less than 2 mm of joint space on radiographs were more likely to have a worse outcome and 39 times more likely to undergo hip arthroplasty.

Horisberger et al[26] published a prospective series of 20 patients with FAI and labral pathology. All patients had Outerbridge II or greater degenerative chondral changes noted at the time of arthroscopy. Interestingly, the preoperative radiographs underappreciated the severity of OA in 75% of patients. All patients with a Tönnis grade III or greater chondral injury on plain radiographs had progressed to total hip arthroplasty by the conclusion of the study.

In a long-term prospective study, Byrd and Jones[13] presented 50 patients with a mean age of 38 years who underwent hip arthroscopy and debridement. After 10 years of follow-up, 79% of patients with significant arthritis eventually progressed to hip arthroplasty. In patients without arthritis, significant improvements in the modified Harris Hip Score were maintained after arthroscopy and labral debridement alone. They noted arthritis and advanced age to be major predictors of a negative outcome following arthroscopy and debridement.

In a study with the greatest long-term follow-up to date, McCarthy et al[37] published their results of 106 patients with a mean age of 39 years who underwent hip arthroscopy, debridement, and microfracture at a mean of 13 years follow-up. They performed a multivariate analysis that showed that patients over 40 years of age with grade III or IV changes (per the Outerbridge classification) had a 90% chance of progressing to hip arthroplasty. Patients with Outerbridge grade II or less chondral changes had a 20% progression to hip replacement, whereas patients with grade III or IV changes had a 78% progression. Thus, advanced age and the development of chondral injury are predictive of the need for eventual conversion to total hip arthroplasty.

Table 1. Review of studies of hip arthroscopy in patients with osteoarthritis (OA)

Study	Level of Evidence	Number of Patients	Mean Patient Age, Years (Range)	Follow-up (Range)	Procedure	Results
Farjo et al[20]	IV	28	41 (14-70)	34 months (13-100)	Labral debridement	21% of patients with arthritis had good to excellent results; 42% underwent THA by final follow-up.
Walton et al[51]	IV	70 (39 with arthritis)	47 (22-87)	>4 months	Labral debridement	72% of patients with chondral degeneration had poor outcomes; radiographic or arthroscopic signs of chondral degeneration are significantly associated with poor outcomes.
Philippon et al[41]	IV	45 (professional athletes)	31 (17-61)	1.6 years (6 months-5.5 years)	Decompression of FAI, microfracture, and/or thermal chondroplasty	93% of athletes returned to their professional sport; 3 athletes with diffuse arthritis did not return to play.
Philippon et al[42]	IV	112	41	2.3 years (2.0-2.9)	Decompression of FAI, labral debridement/ repair	Harris Hip Score significantly improved postoperatively; 10 patients underwent conversion to THA; predictors of a better outcome include joint space narrowing >2 mm and labral repair (vs debridement); patients with <2 mm of joint space are 39 times more likely to undergo arthroplasty.
Horisberger et al[26]	IV	20	47.3 (22-65)	3.0 years (1.5-4.1)	Decompression of FAI, labral debridement/ repair	The degree of chondral damage (Outerbridge II or greater) was underappreciated on preoperative radiographs in 75%; all patients with Tönnis grade III or greater arthritis progressed to THA by final follow-up.
Byrd and Jones[13]	IV	50	38 (14-84)	10 years	Labral debridement	Presence of arthritis during arthroscopy was an indicator for poor prognosis; 79% of patients with arthritis were converted to THA.
McCarthy et al[37]	IV	106	39 ± 13	13 years (10-20)	Labral debridement, microfracture	Survivorship was better in patients without significant chondral damage (Outerbridge grade II or less); advanced age and advanced chondral changes predicted progression to THA.

FAI, femoroacetabular impingement; THA, total hip arthroplasty.

Overall, these studies suggest that hip arthroscopy in patients with significant chondral injury may result in a failure to relieve symptoms and early conversion to hip replacement. Studies also suggest that radiographic assessment of joint space narrowing may in fact underestimate the severity of chondral injury and that arthroscopy may not be indicated in this population. On the other hand, maturing athletes who are active but maintain a healthy joint space are not precluded from the favorable outcomes of a joint preservation procedure. Unfortunately, the majority of these studies are level IV evidence, stressing the need for higher levels of evidence in this patient group. Additionally, more long-term studies with larger cohorts and appropriate control groups are necessary to draw definitive conclusions.

Finally, it is important to note that many of these studies predate our current understanding of FAI. As established by Heyworth et al,[25] Philippon et al,[44] and Bardakos et al,[1] failure to address the underlying osseous lesions causing hip impingement is a major risk factor for persistent pain after hip arthroscopy. Much of the literature cited to date is often based on isolated treatment of the labral pathology alone and in this regard does not reflect our more modern and comprehensive arthroscopic approach to the management of FAI. On this basis, we cannot yet conclude what long-term effects these approaches will have.

ADDRESSING THE LABRUM

Our understanding of the labrum in this complex clinical problem also continues to evolve. In 2003, Ferguson et al[21] presented a biomechanical analysis identifying the suction seal the labrum provides and demonstrated changes in hydrostatic fluid pressurization following labrectomy. Crawford et al[15] demonstrated the biomechanical importance of an intact labrum in maintaining the stability of the hip joint. Espinosa et al[18,19] demonstrated the importance of labral refixation in the treatment of FAI with an open surgical dislocation. In a series of 52 patients undergoing either labral resection or labral refixation, the labral refixation group showed significantly better outcomes 2 years postoperatively. The labral resection group had significantly more prevalent radiographic signs of degenerative changes at 1 and 2 years postoperatively.

Larson and Giveans[33] presented 75 patients who underwent hip arthroscopy, in which 36 patients underwent labral debridement and 39 underwent labral repair. At a minimum of 1-year follow-up, good to excellent results were noted in two-thirds of patients who underwent labral debridement, whereas 90% of patients who underwent labral repair reported good to excellent results. This statistically significant improvement continued through a mean 3.5-year follow-up, with good to excellent results in 92% of patients who underwent repair versus 68% of those who underwent debridement.[34] Additionally, the Harris Hip Score was significantly improved in the labral repair group postoperatively. At 1 year postoperatively, there was a trend toward higher Tönnis grades of radiographic OA in the labral debridement group versus the labral repair group.

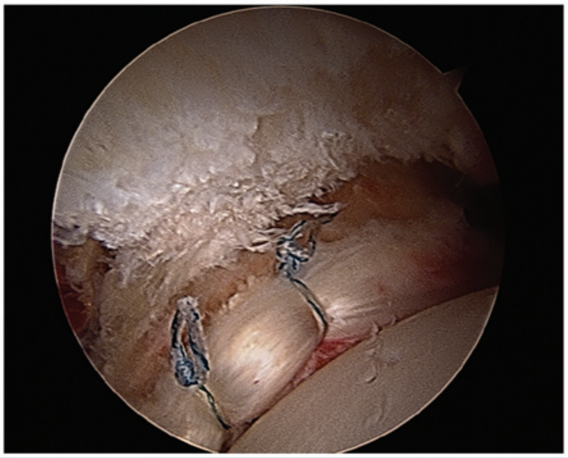

Figure 5. Evaluation of femoral head and labral interface after labral refixation. A noneverting stitch is placed to avoid any compromise of the suction seal. A preserved suction seal helps to maintain the fluid protection and distribute contact forces with loading of the hip joint.

In the large prospective study of 112 patients, Philippon et al[42] reported similar findings in patients undergoing labral repair versus debridement. Their multivariate analysis showed labral repair to be an independent predictor of a higher postoperative modified Harris Hip Score. They also reported that the degree of articular damage did not correlate with their ability to repair the labrum.

These findings *suggest* that preserving the labrum, even in cases of early arthritic changes, may prevent or decelerate the progression of chondral damage and OA. Repairing the labrum whenever possible *may* help preserve the kinematics of the hip joint and improve outcomes in the maturing athlete undergoing hip arthroscopy by preserving the suction seal and thereby preserving the contact pressure distribution and lubrication of the articular surfaces (Figure 5). These results, however, must be interpreted with caution, as the studies were not randomized. In this regard, the potential for selection bias of labral repair in the hip joints with less arthritic changes may have confounded the results.

HIP ARTHROPLASTY

For the active individual with advanced hip arthrosis that is refractory to nonoperative management, total hip arthroplasty may reliably provide pain relief. Arthroplasty generally results in good to excellent outcomes.[29] Implant design, fixation methods, and surgical techniques continue to improve longevity and survivorship. Despite these improvements, there are limitations inherent to the mechanical construct of hip replacements, including implant durability. Most arthroplasty surgeons recommend avoiding high-impact activities after arthroplasty, such as jogging, basketball, and contact sports.[28,50]

Table 2. Sport and activity recommendations and restrictions following total hip arthroplasty

Recommended	Golf, cycling, doubles tennis, weightlifting,[a] swimming, bowling, pilates,[a] ice skating,[a] cross-country or downhill skiing,[a] low-impact aerobics
Restricted	Contact sports (football, hockey, soccer), racquetball/squash, singles tennis, jogging/running, high-impact aerobics, waterskiing, handball

[a]Recommended with prior experience.

Low-impact activities such as cycling, swimming, and golf are permitted (Table 2). These guidelines are largely based on expert opinion, with little evidence available to help guide activity participation. When considering hip arthroplasty, the maturing athlete should be counseled regarding activity level and sports participation to appropriately guide expectations.

CONCLUSION

FAI consists of structural abnormalities of the proximal femur and acetabulum that can lead to repetitive chondral and labral injury with hip motion, resulting in significant hip pain and early degenerative changes.[1-3,6,7,9,11,13,16,17,22,23,27,31,35,36,39,42-46,51] The indications and management strategies for FAI have correspondingly evolved with our understanding of this complex clinical problem. Recent studies *suggest* that a comprehensive treatment of the underlying osseous abnormalities causing bony impingement and restoration of the suction seal with labral refixation when possible *may* relieve pain and allow for return to sport in the young or maturing athlete without significant arthritic changes.[1,8,10,12,13,31,33,38,42,44-46] On the other hand, hip arthroscopy in patients with significant chondral injury, irrespective of age, is associated with a significant failure rate of persistent pain, dysfunction, and conversion to hip arthroplasty. In this regard, the treatment plan of symptomatic hip pain in the maturing athlete must be individualized. The likelihood of a favorable result depends upon correcting the osseous deformities, addressing reparable chondral and labral injury, and most importantly, the degree of chondral damage.[3,13,20,26,37,41,42,45,51]

Currently, the quality of evidence-based literature regarding FAI is limited. While few level III studies and many level IV studies *support* addressing the bony abnormalities causing FAI, no high-level evidence-based recommendation can be made. Larger studies with longer follow-up are needed to better establish the natural history of FAI, its role in the development of secondary OA, and whether intervention with arthroscopic joint preservation surgery can help to halt or alter this progression.

REFERENCES

1. Bardakos NV, Vasconcelos JC, Villar RN. Early outcome of hip arthroscopy for femoroacetabular impingement: the role of femoral osteoplasty in symptomatic improvement. *J Bone Joint Surg Br.* 2008;90:1570-1575.
2. 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.
3. Bedi A, Chen N, Robertson W, Kelly BT. The management of labral tears and femoroacetabular impingement of the hip in the young, active patient. *Arthroscopy.* 2008;24:1135-1145.
4. Bedi A, Dolan M, Leunig M, Kelly BT. Static and dynamic mechanical causes of hip pain. *Arthroscopy.* 2011;27:235-251.
5. Bedi A, Kelly BT, Khanduja V. Arthroscopic hip preservation surgery: current concepts and perspective. *Bone Joint J.* 2013;95-B:10-19.
6. Browne JA. The mature athlete with hip arthritis. *Clin Sports Med.* 2011;30:453-462.
7. Byrd JW. Femoroacetabular impingement in athletes, part 1: cause and assessment. *Sports Health.* 2010;2:321-333.
8. Byrd JW. Femoroacetabular impingement in athletes, part II: treatment and outcomes. *Sports Health.* 2010;2:403-409.
9. Byrd JW, Jones KS. Arthroscopic management of femoroacetabular impingement. *Instr Course Lect.* 2009;58:231-239.
10. Byrd JW, Jones KS. Arthroscopic management of femoroacetabular impingement in athletes. *Am J Sports Med.* 2011;39(suppl):7S-13S.
11. Byrd JW, Jones KS. Arthroscopic management of femoroacetabular impingement: minimum 2-year follow-up. *Arthroscopy.* 2011;27:1379-1388.
12. Byrd JW, Jones KS. Hip arthroscopy in athletes: 10-year follow-up. *Am J Sports Med.* 2009;37:2140-2143.
13. Byrd JW, Jones KS. Prospective analysis of hip arthroscopy with 10-year followup. *Clin Orthop Relat Res.* 2010;468:741-746.
14. Clohisy JC, St John LC, Schutz AL. Surgical treatment of femoroacetabular impingement: a systematic review of the literature. *Clin Orthop Relat Res.* 2010;468:555-564.
15. Crawford MJ, Dy CJ, Alexander JW, et al. The 2007 Frank Stinchfield Award. The biomechanics of the hip labrum and the stability of the hip. *Clin Orthop Relat Res.* 2007;465:16-22.
16. Ejnisman L, Philippon MJ, Lertwanich P. Acetabular labral tears: diagnosis, repair, and a method for labral reconstruction. *Clin Sports Med.* 2011;30:317-329.
17. Ellis HB, Briggs KK, Philippon MJ. Innovation in hip arthroscopy: is hip arthritis preventable in the athlete? *Br J Sports Med.* 2011;45:253-258.
18. Espinosa N, Beck M, Rothenfluh DA, Ganz R, Leunig M. Treatment of femoro-acetabular impingement: preliminary results of labral refixation. Surgical technique. *J Bone Joint Surg Am.* 2007;89(suppl 2):36-53.
19. Espinosa N, Rothenfluh DA, Beck M, Ganz R, Leunig M. Treatment of femoro-acetabular impingement: preliminary results of labral refixation. *J Bone Joint Surg Am.* 2006;88:925-935.
20. Farjo LA, Glick JM, Sampson TG. Hip arthroscopy for acetabular labral tears. *Arthroscopy.* 1999;15:132-137.
21. Ferguson SJ, Bryant JT, Ganz R, Ito K. An in vitro investigation of the acetabular labral seal in hip joint mechanics. *J Biomech.* 2003;36:171-178.
22. Ganz R, Parvizi J, Beck M, Leunig M, Nötzli H, Siebenrock KA. Femoroacetabular impingement: a cause for osteoarthritis of the hip. *Clin Orthop Relat Res.* 2003;(417):112-120.
23. Gosvig KK, Jacobsen S, Sonne-Holm S, Palm H, Troelsen A. Prevalence of malformations of the hip joint and their relationship to sex, groin pain, and risk of osteoarthritis: a population-based survey. *J Bone Joint Surg Am.* 2010;92:1162-1169.
24. Guanche CA, Bare AA. Arthroscopic treatment of femoroacetabular impingement. *Arthroscopy.* 2006;22:95-106.
25. Heyworth BE, Shindle MK, Voos JE, Rudzki JR, Kelly BT. Radiologic and intraoperative findings in revision hip arthroscopy. *Arthroscopy.* 2007;23:1295-1302.
26. Horisberger M, Brunner A, Herzog RF. Arthroscopic treatment of femoral acetabular impingement in patients with preoperative generalized degenerative changes. *Arthroscopy.* 2010;26:623-629.
27. Johnston TL, Schenker ML, Briggs KK, Philippon MJ. Relationship between offset angle alpha and hip chondral injury in femoroacetabular impingement. *Arthroscopy.* 2008;24:669-675.
28. Klein GR, Levine BR, Hozack WJ, et al. Return to athletic activity after total hip arthroplasty. Consensus guidelines based on a survey of the Hip Society and American Association of Hip and Knee Surgeons. *J Arthroplasty.* 2007;22:171-175.

29. Labek G, Thaler M, Janda W, Agreiter M, Stöckl B. Revision rates after total joint replacement: cumulative results from worldwide joint register datasets. *J Bone Joint Surg Br.* 2011;93:293-297.
30. Laborie LB, Lehmann TG, Engesæter IØ, Eastwood DM, Engesæter LB, Rosendahl K. Prevalence of radiographic findings thought to be associated with femoroacetabular impingement in a population-based cohort of 2081 healthy young adults. *Radiology.* 2011;260:494-502.
31. Larson CM. Arthroscopic management of hip pathomorphology. *Instr Course Lect.* 2012;61:287-293.
32. Larson CM. Arthroscopic management of pincer-type impingement. *Sports Med Arthrosc.* 2010;18:100-107.
33. Larson CM, Giveans MR. Arthroscopic debridement versus refixation of the acetabular labrum associated with femoroacetabular impingement. *Arthroscopy.* 2009;25:369-376.
34. Larson CM, Giveans MR, Stone RM. Arthroscopic debridement versus refixation of the acetabular labrum associated with femoroacetabular impingement: mean 3.5-year follow-up. *Am J Sports Med.* 2012;40:1015-1021.
35. Larson CM, Giveans MR, Taylor M. Does arthroscopic FAI correction improve function with radiographic arthritis? *Clin Orthop Relat Res.* 2011;469:1667-1676.
36. Leunig M, Beaulé PE, Ganz R. The concept of femoroacetabular impingement: current status and future perspectives. *Clin Orthop Relat Res.* 2009;467:616-622.
37. McCarthy JC, Jarrett BT, Ojeifo O, Lee JA, Bragdon CR. What factors influence long-term survivorship after hip arthroscopy? *Clin Orthop Relat Res.* 2011;469:362-371.
38. McCarthy JC, Lee JA. History of hip arthroscopy: challenges and opportunities. *Clin Sports Med.* 2011;30:217-224.
39. Murray RO. The aetiology of primary osteoarthritis of the hip. *Br J Radiol.* 1965;38:810-824.
40. Nepple JJ, Martel JM, Kim YJ, Zaltz I, Clohisy JC. Do plain radiographs correlate with CT for imaging of cam-type femoroacetabular impingement? *Clin Orthop Relat Res.* 2012;470:3313-3320.
41. Philippon M, Schenker M, Briggs K, Kuppersmith D. Femoroacetabular impingement in 45 professional athletes: associated pathologies and return to sport following arthroscopic decompression. *Knee Surg Sports Traumatol Arthrosc.* 2007;15:908-914.
42. Philippon MJ, Briggs KK, Yen YM, Kuppersmith DA. Outcomes following hip arthroscopy for femoroacetabular impingement with associated chondrolabral dysfunction: minimum two-year follow-up. *J Bone Joint Surg Br.* 2009;91:16-23.
43. Philippon MJ, Schenker ML. Arthroscopy for the treatment of femoroacetabular impingement in the athlete. *Clin Sports Med.* 2006;25:299-308.
44. Philippon MJ, Schenker ML, Briggs KK, Kuppersmith DA, Maxwell RB, Stubbs AJ. Revision hip arthroscopy. *Am J Sports Med.* 2007;35:1918-1921.
45. Philippon MJ, Schroder E, Souza BG, Briggs KK. Hip arthroscopy for femoroacetabular impingement in patients aged 50 years or older. *Arthroscopy.* 2012;28:59-65.
46. Philippon MJ, Stubbs AJ, Schenker ML, Maxwell RB, Ganz R, Leunig M. Arthroscopic management of femoroacetabular impingement: osteoplasty technique and literature review. *Am J Sports Med.* 2007;35:1571-1580.
47. Philippon MJ, Wolff AB, Briggs KK, Zehms CT, Kuppersmith DA. Acetabular rim reduction for the treatment of femoroacetabular impingement correlates with preoperative and postoperative center-edge angle. *Arthroscopy.* 2010;26:757-761.
48. Rakhra KS, Sheikh AM, Allen D, Beaulé PE. Comparison of MRI alpha angle measurement planes in femoroacetabular impingement. *Clin Orthop Relat Res.* 2009;467:660-665.
49. Stulberg SD. Unrecognized childhood hip disease: a major cause of idiopathic osteoarthritis of the hip. In: Cordell LD, Harris WH, Ramsey PL, MacEwen GD, eds. *The Hip: Proceedings of the Third Open Scientific Meeting of the Hip Society, 1975.* St Louis, MO: CV Mosby; 1975:212-228.
50. Vogel LA, Carotenuto G, Basti JJ, Levine WN. Physical activity after total joint arthroplasty. *Sports Health.* 2011;3:441-450.
51. Walton NP, Jahromi I, Lewis PL. Chondral degeneration and therapeutic hip arthroscopy. *Int Orthop.* 2004;28:354-356.