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Femoroacetabular Impingement in the Adolescent Athlete

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Femoroacetabular impingement syndrome (FAIS) is a source of hip pain that can present in adolescent athletes and is related to sports participation and extreme use in these patients. FAIS is characterized by morphologic abnormalities of the acetabulum and/or proximal femur that leads to pathologic contact within the hip joint. FAIS is classified as cam-type, pincer-type, or combined. Early sports participation is a factor in the development of symptomatic FAIS. Adolescent patients with FAIS are also more likely to have associated extra-articular pathologies. History and physical exam findings in adolescents with FAIS are not considerably different than corresponding findings in adults with FAIS and include activity-related groin pain aggravated by pivoting and flexion activities. FAIS can be treated conservatively or surgically. In refractory cases, outcomes after surgical intervention have been shown to be significantly better than nonsurgical treatment. Surgical intervention involves repairing damage to the labrum and/or cartilage and decompressing the bony impingement. Open and arthroscopic approaches have been shown to be safe and effective in adolescents with good outcomes. Most adolescent athletes are able to return to participation in their sport and a majority returning to their preinjury level of play after surgical intervention.
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Introduction

Femoroacetabular impingement syndrome (FAIS) is a clinical condition of the hip that leads to pain and progressive joint damage.[1] FAIS has long been recognized as a cause of early osteoarthritis in adults.[2] Recent research has shown that FAIS also affects a younger population,[3] and it has been suggested that early intervention for symptomatic FAIS among adolescents will lead to better long-term outcomes.[4] Additionally, up to 96% of adolescent FAIS patients participate in sports underlying potential role that athletic participation has in the development of symptomatic FAIS in adolescents.[5]

Reported incidence of cam, pincer, and combined morphology varies widely across studies. Combined morphology is most common in both adolescent and adult patient populations, as well as in athlete and nonathlete patients.[5-7] Morphology consistent with FAIS is more common in athletes than nonathletes.[7] It is worth noting that the mean alpha angle is lower in athletes than nonathletes with symptomatic FAIS reflecting the potential causative relationship of athletic participation to development of symptoms.[7]

As patients age, the incidence of cam morphology increases.[6,8] It has been shown that high levels of physical activity and participation in competitive sports (ice hockey, soccer, and basketball) at a young age increases the prevalence of cam morphology in the asymptomatic population.[8,9] Participants in these sports are at a 1.9-8 times greater risk of developing cam morphology than nonparticipants.[8] In adolescent populations, male patients are more likely to have a cam deformity than female patients.[10] There is also support for a genetic component of FAIS. Siblings of cam-type FAIS patients have a 2.8 times greater risk for cam morphology compared to unrelated controls, while siblings of pincer-type FAIS patients have a 2.0 times greater risk of pincer morphology.[11]

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Legg-Calve-Perthes disease (LCPD) and slipped capital femoral epiphysis (SCFE) are 2 pediatric conditions that can be additional risk factors for the development of FAIS as an adolescent.[12] Impingement after LCPD is most commonly due coxa magna and plana deformities of the femoral head with decreased femoral head-neck offset and coxa breva[12-14] (Fig. 1). SCFE can also lead to morphologic changes that lead to the development of femoral neck retroversion and cam morphology. This can occur even in the case of mild or silent SCFE.[15,16] However, chances are much greater in severe SCFE, as most of these patients will develop cam morphology (85.7%).[15] LCPD and SCFE present an additional challenge to surgical planning and treatment because they often present with complex deformities. These cases must be recognized and differentiated from idiopathic FAIS.[12,13] LCPD can also present with extra-articular impingement between the proximal femur and pelvis that must be differentiated from intra-articular FAIS.[13]

Pathophysiology

Femoroacetabular impingement is caused by abnormal contact between the proximal femur and the rim of the acetabulum.[1,2] Repetitive impingement within the hip joint leads to progressive cartilage and labral damage. Morphologic abnormalities of the proximal femur cause cam-type impingement while acetabular deformities may result in pincer-type impingement.[2] Often, the 2 impingement types coexist and lead to mixed-type impingement. Cam morphology indicates a loss of sphericity of the femoral head as defined by an increased alpha angle or decreased femoral head-neck offset.[17,18] Pincer morphology is an over coverage of the femoral head and neck by the anterior acetabulum.[2]

Figure 1 A radiograph showing the femoral head and acetabular deformities seen in Legg-Calve-Perthes disease.

Repetitive pathologic impingement between the femoral neck and acetabulum causes significant damage to articular structures. Significant deformities may lead to impingement during physiological activities while athletic participation may lead to impingement during supraphysiological activities. Cam-type deformities result in shearing forces across the acetabular cartilage and chondrolabral junction of the anterosuperior acetabulum by the aspherical femoral head.[19] Frequently, silent articular cartilage damage occurs early in the process and symptoms progress with increasing labral involvement with failure of the chondrolabral junction. In pincer deformities, the labrum is pinched between the acetabulum and femoral neck, causing more circumferential labral damage. Pincer morphology can also lead to labral ossification.[19]

At the time of arthroscopy, the majority of adolescent FAIS patients had labral tears (91%-100%), which was not significantly different than adult FAIS patients (84%).[5,6] FAIS also damages the cartilage surfaces of the acetabulum and femur, in particular cam FAIS. A high percentage of patients undergoing arthroscopy for FAIS have chondral lesions. Damage to the acetabular chondral surface is more common than femoral chondral damage.[5] The aspherical femoral head shears the cartilage of the acetabulum as it enters the joint leading to delamination at the interface between the cartilage and subchondral bone. Full thickness cartilage lesions may be present early in the disease process. In a recent study comparing adolescent to adult patients undergoing hip arthroscopy, the majority of adolescent patients had cartilage damage, although to a lesser extent compared to their adult counterparts (acetabular: 83% vs 92%, femoral: 2.5% vs 14%).[5]

FAIS is an intra-articular syndrome but is frequently associated with extra-articular conditions.[20] FAIS can present with iliotibial band snapping or iliopsoas tendon snapping. These conditions occur more frequently in the athletic population.[20] Adolescent FAIS patients are more likely to have symptomatic extra-articular pathologies that require iliotibial band release or iliopsoas tendon fractional lengthening concurrently with FAIS surgical intervention (12.3% vs 4.1%).[5] Additionally, patients, especially athletes, can develop compensatory disorders due to reduced hip range of motion, the gradual onset of symptoms, and delayed treatment for FAIS.[20] Research has linked cam morphology of the hip to lumbar spine disorders, athletic pubalgia, osteitis pubis, and elbow injuries in baseball players.[21-23]

There is also evidence to support an association between FAI morphology and ACL tears.[24] ACL tears commonly occur as noncontact injuries during lateral cutting or pivoting. The proposed mechanism is that reduced hip internal rotation causes more strain to be put on the ACL due to a compensatory increase in tibial internal rotation, abduction, and anterior translation.[24] However, there is debate surrounding the causality of these effects on ACL tears and knee injury due to hip morphology.[25]

Clinical Evaluation

The history for FAIS in adolescent athletes can be variable. Onset may be gradual or after an acute inciting incident; however, athletes with sudden onset of FAIS will often have previous nonspecific hip and groin complaints. Many athletes with FAIS state they have never been as flexible as their peers. Symptoms of FAIS are usually present in the groin region. Pain is exacerbated by full flexion of the hip and extension from a flexed position. Patients may describe their deep anterior hip pain with a "C-sign." In a "C-sign," the hand is cupped above the greater trochanter with fingers gripping into the anterior groin.[20]

Physical exam is important in identifying FAIS; however, it is important to note that the forces generated across the hip during sport are significantly greater than those elicited on physical exam. The characteristic exam finding in FAIS is decreased internal rotation. Often patients will have symmetrically reduced range of motion despite asymmetric symptoms. The reduction in range of motion and differences in underlying morphology can be highly variable in symptomatic FAIS patients. Two important exam maneuvers for FAIS are the anterior impingement test (FADDIR) and log roll test (Fig. 2). The impingement test is highly sensitive for hip irritation, but nonspecific for FAIS. The log roll test is much less sensitive but more specific for hip joint pathology. It is important to determine whether these exam maneuvers recreate the typical pain that patients experience with activity, as this further suggests FAIS. In FAIS patients, these tests may or may not be positive on the asymptomatic side.[20]

When assessing the hip for FAIS, it is important to assess for coexisting disorders, compensatory disorders, and coincidental findings. Coexisting disorders include lumbar spinal pathology and athletic pubalgia. Compensatory disorders include gluteal or abductor irritability and trochanteric bursitis. Coincidental findings include snapping hip which is present in up to 10% of the asymptomatic population.

Figure 2 The technique used in performing the anterior impingement test (FADDIR).

Imaging

Careful interpretation of imaging studies is also important in the evaluation and treatment of FAIS. Plain radiographs are the foundation of the imaging algorithm and should be obtained on all patients with suspected FAIS.[18] The standard series of radiographs include an anteroposterior pelvis centered on the pubic symphysis as well as a lateral view of the proximal femur and a false profile view of the acetabulum. Lateral proximal femoral views include frog-lateral, 45°, and 90° Dunn lateral views (Fig. 3).

The classic indicators of cam morphology FAIS are increased alpha angle (>50°) and reduced femoral head-neck offset.[17,18,26] A head-neck offset ratio of less than 0.17 indicates the presence of cam morphology.[18] Acetabular over-coverage in pincer-type FAIS can be evaluated by radiography as well. Generalized over-coverage is measured by a lateral center-edge angle on AP radiographs with an angle greater than 40° considered a sign of lateral overcoverage.[17,26] The crossover sign, when the superior portion of the anterior edge of the acetabulum passes lateral to the posterior edge is indicative of pincer morphology.[20] Coxa profunda, os acetabulum, and ischial spine sign are also radiographic findings associated with pincer morphology.[20,26]

Advanced imaging is also useful in the diagnosis of FAIS. Both magnetic resonance imaging (MRI) and MRI arthrography with gadolinium contrast (MRA) are useful for assessment of FAIS.[20,27] MRI is sensitive for detecting joint effusion and labral pathology. MRI can also detect early cartilage changes

Figure 3 This radiograph demonstrates a bilateral Dunn view of an adolescent pelvis. Cam morphology with loss of femoral head-neck offset can be seen bilaterally.

and is important for early diagnosis of FAIS.[27] MRA is more sensitive for labral pathology and can better visualize joint surface anatomy but is less sensitive detecting subchondral changes and cannot detect effusion.[20,27] CT can also be useful in diagnosis and preoperative planning for FAIs because of the ability to visualize a 3-dimensional representation of the bony anatomy of the hip.[27] CT can also be used in circumstances where MRI is contraindicated. However, there remains controversy over the usefulness of advanced imaging in FAIS.[28,29] Some authors suggest that MRI is an unnecessary medical expense and adds little value to a quality history, physical exam, and radiographic imaging.[28] Others argue that MRI remains the gold standard for diagnosis and is an important tool in the diagnosis of FAIS, especially for less-specialized general practitioners.[29] Ultrasound has been shown to be effective in detecting cam morphology in patients presenting with FAIS symptoms but depends heavily on operator experience and skill.[30] The use of intra-articular injections of short acting anesthetic has also been proposed as a method to aid diagnosis of pathology localizable to the hip joint.[28,29]

Imaging studies on adolescents should be evaluated for markers of skeletal immaturity and specific conditions related to skeletal immaturity that can mimic or complicate FAIS. The proximal femoral physis closes around age 14 to 16 and the triradiate cartilage generally closes around age 16.[31,32] It is not uncommon to see an incompletely fused physis or physeal remnant during arthroscopy in skeletally immature patients (Fig. 4). An os acetabuli, a bony fragment at the acetabular rim, is proposed to be caused by incomplete fusion of secondary ossification centers of the acetabulum or repeated microtrauma due to impingement in either cam or pincer anatomy.[33] Os acetabuli can be resected during hip arthroscopy or repaired via internal fixation if large.[34] A common variant seen in skeletally immature patients is a supraacetabular fossa (SAF), an accessory bony fossa in the roof of the acetabulum, usually at the 12 o'clock position. The SAF is present in 10.5% of patients undergoing hip MRI and may be misinterpreted as an acetabular cartilage defect[35] (Fig. 5). Most disappear by the third decade, as it has been suggested that the SAF is a normal variant of the immature skeleton that fills in with skeletal maturation.[36]

Apophyseal avulsion fractures may occur at the anterior inferior iliac spine (AIIS), anterior superior iliac spine, or lesser trochanter of the femur.[37-39] Although uncommon, these injuries can cause hip pain and should be included in the differential for FAIS in adolescent patients. Additionally, this pathology can contribute to and complicate hip impingement. AIIS hypertrophy and overgrowth after apophyseal avulsion fracture has been proposed as a mechanism of subspine impingement; an extra-articular hip impingement, where the overhanging AIIS contacts the neck of the femur limiting flexion[40] (Fig. 6). Similar pathology can occur after ischial tuberosity or lesser trochanter avulsion causing ischiofemoral impingement, although this is less common.[38]

It is also important to note that there is a high prevalence of impingement morphology in the asymptomatic population. In adolescents from 10 to 18 years old without hip pain 17% met criteria for cam impingement, with a higher prevalence in males than females (24% vs 10%). In the same study, 32% met criteria for pincer morphology, with no significant difference between genders. Among these 6% had combined morphology. These data are similar to reported prevalence of impingement morphology in asymptomatic adults.[41] The prevalence of impingement morphology may be even higher in adolescent athletes. A study of asymptomatic competitive youth soccer players found a prevalence of cam and pincer morphology of 78% and 11%, respectively.[9]

Treatment

Many cases of FAIS in adolescent patients improve with conservative treatment.[42,43] Conservative management involves

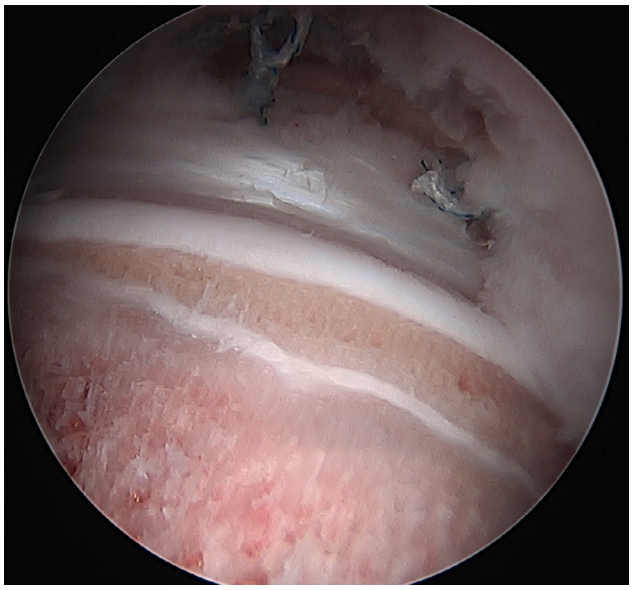

Figure 4 This arthroscopic image shows the appearance of the open physis in an adolescent patient during femoroplasty.

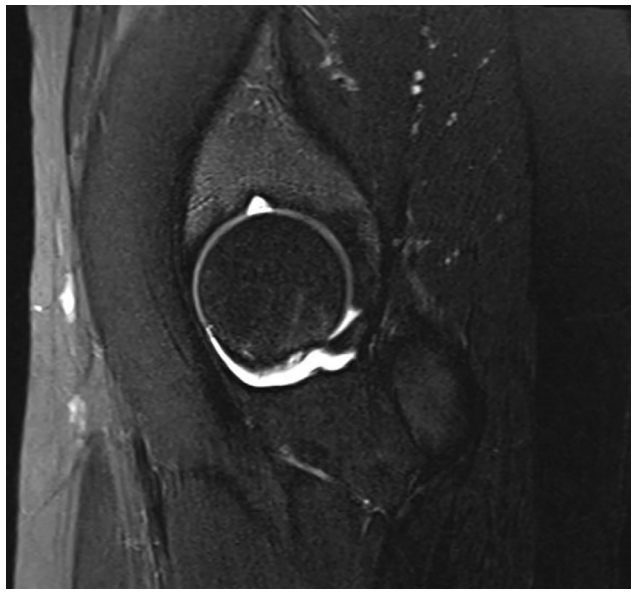

Figure 5 An MRI arthrogram with intra-articular gadolinium contrast demonstrates the appearance of a supraacetabular fossa.

Figure 6 This radiograph shows an AIIS avulsion, with significant overgrowth, likely causing impingement.

a stepwise approach that included rest, anti-inflammatory medication, physical therapy, and modification of activities of daily living and sports activities.[43] Conservative therapy for FAIS does not necessarily improve patient range of motion but did improve function and symptoms. Physical therapy for FAIS includes stretching and strengthening of hip adductors and external rotation muscles. Lifestyle modification includes avoidance of running and cycling or modification of these activities to adopt a technique involving more external rotation and less internal rotation and extreme flexion.[43] Intra-articular cortisone injections are also a common treatment for patients with FAIS; however, current research suggests that these injections have limited benefit in some cases.[44] While conservative treatment is the mainstay of treatment for FAIS, adolescent patients with large deformities and significant damage may ultimately require surgical treatment. One study concluded that in adolescent athletes undergoing conservative treatment for labral tear and FAIS, including PT, intra-articular injections, and activity modification, only 9.2% avoided surgical intervention.[45]

Surgical treatment for FAIS has been shown to be safe and effective in adolescents. Surgical techniques for FAIS include open surgical dislocation, a limited anterior decompression (mini-open), or arthroscopy.[46-48] These methods have been shown to be effective and safe in adolescent populations.[49,50] Arthroscopic treatment has grown in utilization and efficacy. It has been shown to have lower reoperation and complication rates than open procedures.[49,51] For most cases of FAIS in adolescents, arthroscopic treatment is now considered the gold standard.

The fundamental surgical concept in the treatment of symptomatic FAIS is the correction of the morphology leading to impingement (Fig. 7). Residual deformity is among the most common reasons for failed surgery and need for revision.[52,53] Labral tears, present in 91.4%-100% of adolescent athletes with FAIS undergoing surgical intervention, may be treated with repair, refixation, or debridement.[5,6] Labral preservation is essential to the function of the hip and inferior results have been reported after labral debridement.[54] Chondral damage and delamination are also often present in FAIS patients.[5] Low-grade lesions are more common and treated with chondroplasty; full thickness lesions are relatively uncommon (3%-4%) and can be treated with microfracture although additional treatment options are under investigation.[5,55]

In adolescent patients, the overall risk of complications from surgical intervention for FAIS is low, a rate of 3.6% was reported for all complications and most were minor.[50] This rate is similar to the reported complication rate in adults.[50] There are certain risks to surgical intervention for FAIS in adolescent patients that do not exist in the adult population. These include the potential to cause premature physeal closure, iatrogenic SCFE, or femoral head avascular necrosis.[12,50] These complications are extremely rare in practice, with no incidence reported in a review of 435 hips.[50] Femoral neck fracture after excessive femoroplasty has been reported in the adult patients but very rarely (0.6%).[56] Increasing age has been shown as a risk factor.[57] Limiting the femoroplasty to less than 30% of femoral head diameter helps to avoid this complication.[58] Neurapraxia after hip arthroscopy (16.4%) is commonly seen although usually transient and not clinically significant.[56] Other complications include impaired wound healing, dyspareunia, and deep vein thrombosis.[56]

Outcomes

Surgical treatment for FAIS in adolescents has good outcomes. In a study of 122 consecutive hips, Byrd et al reported a 96% rate of improvement in symptoms among adolescents after hip arthroscopy. Mean modified Harris Hip Scores (mHHS) improvement was 25.9 points. Additionally, 75% of patients had a final mHHS above 95, this compared favorably to 30% among the adult control group. Only 4

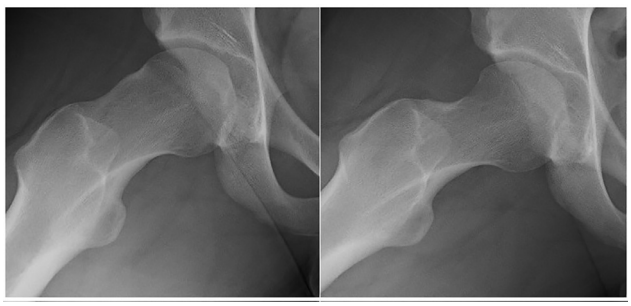

Figure 7 This set of Dunn lateral radiographs shows the femoral head morphology in a FAIS patient before and after arthroscopic femoroplasty. The goal of surgical intervention is to restore femoral head sphericity.

adolescent patients required revision surgery.[5] Perets et al. report similarly positive outcomes among adolescents. This study reported an average mHHS improvement of 16.4 and mean satisfaction score of 7.5 out of 10. Additionally, they reported an 85% rate of return to sport.[59] Phillipon's study of 60 patients also showed significant improvement in mHHS from 60 to 91 on average.[6] This study also noted worse outcomes in female adolescent patients, and an increased rate of revisions for female patients.[6] An additional factor in outcomes for adolescent patients compared to adult counterparts is continued clinical improvement reported more longer than 2 years after surgery.[5,6]

In reviews, surgical treatment for adolescents with FAIS is highly effective, 100% of patients treated arthroscopically reached near normal or normal levels of function post surgically 79%-100%.[50] Ninety eight percent of adolescents were able to return to activity.[50] Among athletes, a high percentage are able to return to sport, 88%-93%, and a majority are able to return to their preinjury level of competition, 74%-89%.[60,61,9] Additionally, in studies of pediatric athletes, 95% were able to return to sport.[60] However, athletic performance after FAIS surgical intervention remains largely unreported.[61] There was no meaningful difference in outcomes between male and female adolescent patients.[62,63]

Conclusion

FAIS is an important source of hip pain among adolescent athletes. The repeated pathologic impingement seen in FAIS can lead to acetabular labrum and hip joint damage joint damage. FAIS causes symptoms in adolescent athletes as well as early onset osteoarthritis of the hip. It is important that physicians recognize and properly evaluate FAIS including natural history, physical exam, and imaging studies. Imaging findings consistent with cam or pincer lesions on plain film radiographs remain the foundation for diagnosis of adolescent athletes presenting with FAIS. Arthroscopic treatment for FAIS in adolescents has been shown to be safe and effective, with overall good outcomes and low complication rates. Arthroscopy for FAIS has been effective in allowing adolescent athletes return to competitive sport.

References

1. Griffin DR, Dickenson EJ, O'Donnell J, et al: The Warwick agreement on femoroacetabular impingement syndrome (FAI syndrome): An international consensus statement. Br J Sports Med 50:1169-1176, 2016
2. Ganz R, Parvizi J, Beck M, et al: Femoroacetabular impingement: A cause for osteoarthritis of the hip. Clin Orthop Relat Res 417:112-120, 2003
3. Byrd JW, Jones KS: Arthroscopic femoroplasty in the management of cam-type femoroacetabular impingement. Clin Orthop Relat Res 467:739-746, 2009
4. Zhang C, Li L, Forster BB, et al: Femoroacetabular impingement and osteoarthritis of the hip. Can Fam Physician 61:1055-1060, 2015
5. Byrd JW, Jones KS, Gwathmey FW: Arthroscopic management of femoroacetabular impingement in adolescents. Arthroscopy 32:1800-1806, 2016
6. Philippon MJ, Ejnisman L, Ellis HB, et al: Outcomes 2 to 5 years following hip arthroscopy for femoroacetabular impingement in the patient aged 11 to 16 years. Arthroscopy 28:1255-1261, 2012
7. Lovett-Carter D, Jawanda AS, Hannigan A: Meta-analysis of the surgical and rehabilitative outcomes of hip arthroscopy in athletes with femoroacetabular impingement. Clin J Sport Med (In Press). Epub ahead of print.
8. de Silva V, Swain M, Broderick C, et al: Does high level youth sports participation increase the risk of femoroacetabular impingement? A review of the current literature. Pediatr Rheumatol Online J 14, 2016. 16-016-0077-5
9. Yepez AK, Abreu M, Germani B, et al: Prevalence of femoroacetabular impingement morphology in asymptomatic youth soccer players: Magnetic resonance imaging study with clinical correlation. Rev Bras Ortop 52:14-20, 2017. (suppl)
10. Hooper P, Oak SR, Lynch TS, et al: Adolescent femoroacetabular impingement: Gender differences in hip morphology. Arthroscopy 32:2495-2502, 2016
11. Packer JD, Safran MR: The etiology of primary femoroacetabular impingement: Genetics or acquired deformity? J Hip Preserv Surg 2:249-257, 2015
12. Wenger DR, Kishan S, Pring ME: Impingement and childhood hip disease. J Pediatr Orthop B 15:233-243, 2006
13. Kim YJ, Novais EN: Diagnosis and treatment of femoroacetabular impingement in Legg-Calve-Perthes disease. J Pediatr Orthop 31:S235-S240, 2011. (suppl)
14. Accadbled F, Pailhe R, Launay F, et al: "Femoroacetabular impingement". Legg-Calve-Perthes disease: From childhood to adulthood. Orthop Traumatol Surg Res 100:647-649, 2014
15. Fraitzl CR, Kafer W, Nelitz M, et al: Radiological evidence of femoroacetabular impingement in mild slipped capital femoral epiphysis: A mean follow-up of 14.4 years after pinning in situ. J Bone Joint Surg Br 89:1592-1596, 2007
16. Ulici A, Carp M, Tevanov I, et al: Outcome of pinning in patients with slipped capital femoral epiphysis: Risk factors associated with avascular necrosis, chondrolysis, and femoral impingement. J Int Med Res 46:2120-2127, 2018
17. Sankar WN, Nevitt M, Parvizi J, et al: Femoroacetabular impingement: Defining the condition and its role in the pathophysiology of osteoarthritis. J Am Acad Orthop Surg 21:S7-S15, 2013. (suppl)
18. Clohisy JC, Carlisle JC, Beaule PE, et al: A systematic approach to the plain radiographic evaluation of the young adult hip. J Bone Joint Surg Am 90:47-66, 2008. (suppl)
19. Beck M, Kalhor M, Leunig M, et al: 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 87:1012-1018, 2005
20. Byrd JW: Femoroacetabular impingement in athletes, part 1: Cause and assessment. Sports Health 2:321-333, 2010
21. Gebhart JJ, Weinberg DS, Conry KT, et al: Hip-spine syndrome: Is there an association between markers for cam deformity and osteoarthritis of the lumbar spine? Arthroscopy 32:2243-2248, 2016
22. Birmingham PM, Kelly BT, Jacobs R, et al: The effect of dynamic femoroacetabular impingement on pubic symphysis motion: A cadaveric study. Am J Sports Med 40:1113-1118, 2012
23. Saito M, Kenmoku T, Kameyama K, et al: Relationship between tightness of the hip joint and elbow pain in adolescent baseball players. Orthop J Sports Med 2:2325967114532424, 2014
24. Boutris N, Byrne RA, Delgado DA, et al: Is there an association between noncontact anterior cruciate ligament injuries and decreased hip internal rotation or radiographic femoroacetabular impingement? A systematic review. Arthroscopy 34:943-950, 2018
25. Harris JD: Editorial commentary: The hip bone's connected to the knee bone, but correlation does not equal causation-the association of hip motion, femoroacetabular impingement, and anterior cruciate ligament injury. Arthroscopy 33:326-328, 2017
26. Brian P, Bernard S, Flemming D: Femoroacetabular impingement: Screening and definitive imaging. Semin Roentgenol 45:228-237, 2010
27. Bittersohl B, Hosalkar HS, Hesper T, et al: Advanced imaging in femoroacetabular impingement: Current state and future prospects. Front Surg 2:34, 2015
28. Cunningham DJ, Paranjape CS, Harris JD, et al: Advanced imaging adds little value in the diagnosis of femoroacetabular impingement syndrome. J Bone Joint Surg Am 99:e133, 2017

29. Philippon MJ, Bolia IK: Intra-articular hip injection is a valuable and cost-effective diagnostic tool but replacing advanced diagnostic methods is not currently the way to go: Commentary on an article by Daniel J. Cunningham, MD, MHS, et al.: "Advanced imaging adds little value in the diagnosis of femoroacetabular impingement syndrome". J Bone Joint Surg Am 99:e138, 2017
30. Lerch S, Kasperczyk A, Warnecke J, et al: Evaluation of cam-type femoroacetabular impingement by ultrasound. Int Orthop 37:783-788, 2013
31. Patterson JT, Tangtiphaiboontana J, Pandya NK: Management of pediatric femoral neck fracture. J Am Acad Orthop Surg 26:411-419, 2018
32. Grissom LE, Harty MP, Guo GW, et al: Maturation of pelvic ossification centers on computed tomography in normal children. Pediatr Radiol 48:1902-1914, 2018
33. Martinez AE, Li SM, Ganz R, et al: Os acetabuli in femoro-acetabular impingement: Stress fracture or unfused secondary ossification centre of the acetabular rim? Hip Int 16:281-286, 2016
34. Pascual-Garrido C, Schrock JB, Mitchell JJ, et al: Arthroscopic fixation of os acetabuli technique: When to resect and when to fix. Arthrosc Tech 5:e1155-e1160, 2016
35. Dietrich TJ, Suter A, Pfirrmann CW, et al: Supraacetabular fossa (pseudodefect of acetabular cartilage): Frequency at MR arthrography and comparison of findings at MR arthrography and arthroscopy. Radiology 263:484-491, 2012
36. Byrd JW: Supraacetabular fossa. Radiology 265:648, 2012
37. Serbest S, Tosun HB, Tiftikci U, et al: Anterior inferior iliac spine avulsion fracture: A series of 5 cases. Medicine (Baltimore) 94:e562, 2015
38. Ruffing T, Ruckauer T, Bludau F, et al: Avulsion fracture of the lesser trochanter in adolescents. Injury 49:1278-1281, 2018
39. Naylor JA, Goffar SL, Chugg J: Avulsion fracture of the anterior superior iliac spine. J Orthop Sports Phys Ther 43:195, 2013
40. Larson CM, Kelly BT, Stone RM: Making a case for anterior inferior iliac spine/subspine hip impingement: Three representative case reports and proposed concept. Arthroscopy 27:1732-1737, 2011
41. Li Y, Helvie P, Mead M, et al: Prevalence of femoroacetabular impingement morphology in asymptomatic adolescents. J Pediatr Orthop 37:121-126, 2017
42. Wall PD, Fernandez M, Griffin DR, et al: Nonoperative treatment for femoroacetabular impingement: A systematic review of the literature. PM R 5:418-426, 2013
43. Emara K, Samir W, Motasem el H, et al: Conservative treatment for mild femoroacetabular impingement. J Orthop Surg (Hong Kong) 19:41-45, 2011
44. Krych AJ, Griffith TB, Hudgens JL, et al: Limited therapeutic benefits of intra-articular cortisone injection for patients with femoro-acetabular impingement and labral tear. Knee Surg Sports Traumatol Arthrosc 22:750-755, 2014
45. Bedi A, Chen N, Robertson W, et al: The management of labral tears and femoroacetabular impingement of the hip in the young, active patient. Arthroscopy 24:1135-1145, 2008
46. Ganz R, Gill TJ, Gautier E, et al: 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 83:1119-1124, 2001
47. Clohisy JC, McClure JT: Treatment of anterior femoroacetabular impingement with combined hip arthroscopy and limited anterior decompression. Iowa Orthop J 25:164-171, 2005
48. Philippon MJ, Stubbs AJ, Schenker ML, et al: Arthroscopic management of femoroacetabular impingement: Osteoplasty technique and literature review. Am J Sports Med 35:1571-1580, 2007
49. Harris JD, Erickson BJ, Bush-Joseph CA, et al: Treatment of femoroacetabular impingement: A systematic review. Curr Rev Musculoskelet Med 6:207-218, 2013
50. de Sa D, Cargnelli S, Catapano M, et al: Femoroacetabular impingement in skeletally immature patients: A systematic review examining indications, outcomes, and complications of open and arthroscopic treatment. Arthroscopy 31:373-384, 2015
51. Larson CM, Stone RM: Current concepts and trends for operative treatment of FAI: Hip arthroscopy. Curr Rev Musculoskelet Med 6:242-249, 2013
52. Gwathmey FW, Jones KS, Byrd JWT: Revision hip arthroscopy: Findings and outcomes. J Hip Preserv Surg 4:318-323, 2017. 11
53. Ross JR, Larson CM, Adeoye O, et al: Residual deformity is the most common reason for revision hip arthroscopy: A three-dimensional CT study. Clin Orthop Relat Res 473:1388-1395, 2015
54. 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 40:1015-1021, 2012
55. Mella C, Nunez A, Villalon I: Treatment of acetabular chondral lesions with microfracture technique. SICOT J 3:45, 2017
56. Schuttler KF, Schramm R, El-Zayat BF, et al: The effect of surgeon's learning curve: Complications and outcome after hip arthroscopy. Arch Orthop Trauma Surg 138:1415-1421, 2018
57. Horner NS, Khanduja V, MacDonald AE, et al: Femoral neck fractures as a complication of hip arthroscopy: A systematic review. J Hip Preserv Surg 4:9-17, 2017
58. Mardones RM, Gonzalez C, Chen Q, et al: Surgical treatment of femoroacetabular impingement: Evaluation of the effect of the size of the resection. Surgical technique. J Bone Joint Surg Am 88:84-91, 2006. (suppl)
59. Perets I, Hartigan DE, Chaharbakhshi EO, et al: Outcomes of hip arthroscopy in competitive athletes. Arthroscopy 33:1521-1529, 2017
60. Memon M, Kay J, Hache P, et al: Athletes experience a high rate of return to sport following hip arthroscopy. Knee Surg Sports Traumatol Arthrosc (In Press). Epub ahead of print
61. Reiman MP, Peters S, Sylvain J, et al: Femoroacetabular impingement surgery allows 74% of athletes to return to the same competitive level of sports participation but their level of performance remains unreported: A systematic review with meta-analysis. Br J Sports Med 52:972-981, 2018
62. Cvetanovich GL, Weber AE, Kuhns BD, et al: Clinically meaningful improvements after hip arthroscopy for femoroacetabular impingement in adolescent and young adult patients regardless of gender. J Pediatr Orthop 38:465-470, 2016
63. Shibata KR, Matsuda S, Safran MR: Arthroscopic hip surgery in the elite athlete: Comparison of female and male competitive athletes. Am J Sports Med 45:1730-1739, 2017