NIH Public Access
Author Manuscript
Arthritis Rheumatol. Author manuscript; available in PMC 2016 January 01.

Published in final edited form as:
Arthritis Rheumatol. 2015 January ; 67(1): 17–27. doi:10.1002/art.38887.

Femoroacetabular Impingement

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Introduction

The etiology of hip pain in an older adult is frequently from osteoarthritis (OA), and the etiology is generally either "wear and tear" or idiopathic. Hip OA can also result from morphometric abnormalities of the hip, including congenital hip dislocation, Legg-Calve-Perthes disease and slipped capital femoral epiphysis (SCFE). However, research over the past fifteen years have found that idiopathic hip OA may be due to more subtle abnormalities of the proximal femur and acetabulum (1–3) that can lead to premature degeneration of the hip joint. Overtime, these morphometric abnormalities can put stress on the hip joint and the clinical syndrome of femoroacetabular impingement (FAI) can develop.

The review criteria for this manuscript included searching the ISI and Pubmed databases for published original and review articles related to FAI. Search terms included FAI in combination with cam impingement, pincer deformity, epidemiology, imaging, treatments both nonsurgical and surgical. The citations from these articles were used to identify other articles.

Definition

FAI is a clinical syndrome in which the anatomic abnormalities of the femoral head and/or the acetabulum result in an abnormal contact between the two during hip motion, especially in positions of hip flexion and rotation, leading to cartilage and labral damage and hip pain (3). Three types of morphologic abnormalities can occur in FAI: Cam, Pincer, and Mixed. Cam deformity is characterized by an abnormal/aspherical morphology of the proximal femur. Pincer deformity is characterized by focal or general overcoverage of the femoral head by the acetabulum. The third type of FAI, mixed, is a combination of cam and pincer impingement characteristics (3–12). Abnormal contact between the femoral head and acetabular rim results in supraphysiologic stress that tears the acetabular labrum and delaminates the acetabular articular cartilage from the underlying bone (2, 13). Over time

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this repetitive mechanical insult to the articular tissues leads to hip degeneration and development of hip OA (14).

Epidemiology

Multiple large cohort studies have reported the prevalence of cam and pincer deformities in the population using different radiologic criteria [described in imaging section]. The magnitude of the cam deformity of the femoral head is most commonly assessed with the radiologic alpha angle and the magnitude of the pincer deformity of the acetabulum is most commonly assessed with the radiologic lateral center edge angle (LCEA). Using a cut-off of MRI measured alpha angle of > 50.5° for defining the presence of a cam deformity, Hack et al. studied a cohort of 400 hips from 200 of asymptomatic adults without a history of childhood hip disease (mean age 29.4 years, 79 % white, 55.5 % women) (7) and reported a prevalence of cam deformity of 14%, of which 79 % were men. In a study of 3,620 adults (mean age 60 years, predominantly white, 63.2 % women) without a history of childhood hip disease, Gosvig et al. reported a prevalence of 19.6 % and 5.2 % for cam deformity in men and women respectively (15) using a radiographic measure they developed called the triangular index (16). In a cohort of older men with an average age of 77 years, Nardo et al. reported cam deformity prevalence of 57.2% using a definition of impingement angle < 70° and the caput-collum diaphyseal (CCD) angle < 125°; a pincer deformity prevalence of 29% using a definition of lateral center edge angle (LCEA) > 39° and the Tönnis angle > 0°; and a mixed cam/pincer type deformity of 13.7% (17). The epidemiology of symptomatic FAI was recently evaluated in a cross-sectional study of 1076 subjects from clinical practices in the United States that underwent surgery. The authors reported that 55% of the population were female, average age of 28 years, 47.6% had cam type impingement, 44.5% had combined cam/pincer, and 7.9% had pincer deformity (18).

Developmental anatomic variations of the acetabulum and proximal femur have long been associated with the development of hip OA (20–22). Recently, Agricola et al. estimated the association of cam and pincer deformities with hip OA in a cohort of 1002 subjects with early hip or knee idiopathic OA (19, 20) and reported than an alpha angle > 60° was associated with an odds ratio (OR) of 3.67 for end-stage hip OA and an alpha angle > 83° with an OR of 9.66 (19). A combination of alpha angle > 83° and hip internal ≤ 20° had a positive predictive value of 52.6 % for end-stage hip OA. They did not find pincer deformity (LCEA > 40°) to be associated with hip OA (20). Contrary to this, Nardo et al. reported that both pincer and mixed types were associated with prevalent radiographic hip OA in elderly men, but not cam deformity (17).

Currently, the radiologic definitions used to assess morphometric deformities, different radiologic views and the selection of the study population differ in the published studies and they may explain the different associations reported for risk of hip OA.

Pathogenesis

The pathogenesis of FAI is currently still under investigation. However, certain factors including pediatric hip diseases, high-impact athletic activities during growth, and genetic factors have been proposed. SCFE has been proposed to be a risk factor for development of cam type FAI (21–23); and in some cases surgical over-correction of a hip dysplasia may lead to a pincer type FAI (24). Recently, there have been reports that athletes with excessive participation in high-impact sports, like soccer, basketball and ice hockey during adolescence when the skeleton matures, have a higher prevalence of FAI when compared to non-athletes (25–30). Agricola et al. studied elite soccer players, mean age 14.4 years, for 2 years and observed (31) an increased prevalence of cam deformity defined by an increase in the alpha angle (59.4° to 61.3°) (37). The increase in severity or prevalence of the cam deformity was not seen after closure of proximal femoral growth plate. They suggested that an alteration of athletic activities during skeletal growth may prevent formation of cam deformities. Other investigators have reported similar observations of elevated alpha angle in both high level ice hockey and basketball players compared to age-similar controls (27–29). The mechanism for development of the cam deformity in adolescent athletes is thought to be either new bone formation at the anterosuperior head-neck junction or changes in the shape of the growth plate due to high shear forces at the growing hip during these athletic activities.

The genetic contribution of FAI has also been evaluated. Pollard et al. observed a relative risk ≥ 2 for having a cam or pincer deformity in siblings of patients with cam or pincer-type FAI (32). Dudda et al. reported that morphometric evidence of FAI was more common in white women compared to Chinese women (33). Baker-Lepain reported that allele variants in wnt/Beta catenin signaling antagonists, a cell signaling pathway that directs the development of both bones and joints, are associated with the shape of the proximal femur and that also later in life with hip OA. These studies suggest a genetic influence on the pathogenesis of FAI and further work in this area is warranted (34).

Clinical Presentation

The clinical presentation of FAI is most often anterior or anterolateral hip pain that refers to the groin and occasionally radiates down the anterior thigh (35–37). Patients may use the "C sign" and grasp the affected hip with their hand indicating both anterior and posterior hip pain. Children can have difficulty describing the location of symptoms and hip pathology may be described as thigh or knee pain, or a limp after activity. Adults often relate the hip discomfort to associated "stiffness". Accordingly, the hip pain is increased in positions and activities requiring hip flexion and/or internal rotation. Activities such as sitting, driving, and squatting can aggravate symptoms. If enough intra-articular damage has occurred, such as a labral tear or chondral damage, then mechanical symptoms such as clicking or catching of the hip may be present. Occasionally, a patient may present with a tight psoas tendon or a tight iliotibial band that on physical examination will have a palpable or audible snapping on range of motion of the hip with or without hip pain.

On physical examination, gait patterns, hip range of motion, and lower extremity muscle strength are assessed on both lower extremities so that comparisons can be made (38, 39). During gait, an abductor lurch or Trendelenberg test may indicate hip abductor weakness on the affected side. Hip range of motion is assessed with the patient supine. Decreased hip flexion less than 90° and decreased internal rotation of the hip are associated with FAI (36, 37, 40, 41). Clohisy and colleagues have described the average hip flexion in FAI is 97° and average internal rotation in flexion is 9° (37). Agroicola et al. reported that hip internal rotation < 20°(at 90°of knee flexion) in presence of an alpha angle > 83°was highly predictive of the development of hip OA (19). The anterior impingement test, in which the hip is flexed to 90°, internally rotated and adducted, will elicit pain in the anterior hip or groin when a compromised acetabular labrum is pinched between the acetabular rim and the femoral neck in this position (38, 42). Eight-eight percent of patients with FAI will have a positive anterior impingement test (37). There is often pain from trochanteric bursitis that results from a tight iliotibial band.

It is important throughout the focused hip examination to verify with the patient that each provocative test recreates the specific symptoms that typically bother them. Not infrequently, palpation of bony prominences such as the greater trochanter or stretching of the hip flexor or hamstring muscles will create discomfort that is distinctly different from the typical deep, anterior or anterolateral groin pain resulting from FAI.

It is also important to keep in mind that the presentation and positive physical examination findings of FAI can also be found in other types of hip pathology such as acetabular dysplasia. The patient with acetabular dysplasia can also have an abductor lurch and a positive anterior impingement test indicative of labral pathology. However, hip range of motion in flexion and internal rotation is more severely restricted in FAI as compared to acetabular dysplasia.

Diagnostic Imaging

Plain Radiography

When the history and physical examination suggests that pain is from an intra-articular location, then plain radiographs should be the next step in evaluation of the patient with hip pain. Plain radiographs provide a simple method of assessing acetabular and femoral anatomy, and to identify the presence of hip OA (43). Standardized anteroposterior (AP) pelvis radiographs are obtained with the patient positioned supine with the legs internally rotated 15°and the x-ray beam centered between the femoral heads. Standing AP pelvis radiographs can reveal the functional position of the hips, as patients may adjust pelvic tilt while standing in a weight-bearing position to compensate for suboptimal hip function. On an adequately properly positioned AP pelvis with appropriate pelvic tilt, the distance between the superior border of the pubic symphysis and the sacrococcygeal joint should measure approximately three to five centimeters (44).

Several different hip radiographic views are helpful to evaluate proximal femoral morphology in presence of suspected cam deformity. The 45° Dunn lateral view (Fig. 1a) best demonstrates the area of greatest cam deformity at the anterolateral region of the femoral head neck junction, whereas frog-leg lateral hip radiographs (Fig. 1b) best demonstrate any anterior cam deformity (5, 45, 46). The alpha angle (Fig. 1a), which measures the degree of asphericity at the femoral head neck junction, is assessed on these lateral radiographs (5, 45–47) (Fig 1a). The alpha angle was first described on an axial MR image (47) but has been since described for radiographs and CT. Varying thresholds (50° – 83°) for the alpha angle have been suggested with 55° being the most common (15, 16, 47–

50). Increasing alpha angle beyond 60° has been correlated with both decreased hip internal rotation in flexion as well as more severe acetabular articular cartilage damage seen during surgery (51–53).

In pincer deformity, global acetabular overcoverage may be demonstrated by an LCEA greater than 40°and a Tönnis angle that is less than 0°. The LCEA and Tönnis angle are assessed on an AP pelvis radiograph. The LCEA is an angle that quantifies lateral femoral head coverage (Fig. 2a) and the Tönnis angle quantifies the obliquity of the acetabular roof (Fig. 2b). A normal acetabulum demonstrates an LCEA between 25° and 35°and a Tönnis angle between 0° and 10°(54, 55).

Acetabular retroversion leads to antero-superior over-coverage of the femoral head (56, 57). Reynolds et al. described this deformity as a potential cause of labral and chondral damage and hip pain (56). Normal acetabular version is defined by the posterior wall of the acetabulum passing through the middle of the femoral head, and the anterior and posterior walls of the acetabulum meeting at the lateral acetabular rim. An illustration of acetabular retroversion by Reynolds et al. (61) is worth a review. Acetabular retroversion presents with a positive cross-over sign (Fig. 2c) a positive posterior wall sign (Fig. 2d), and a positive ischial spine sign (Fig. 2e) (58).

These skeletal deformities lead to damage to other articular tissues in the hip joint with repeated hip motion during daily and athletic activities. However, radiography is ineffective at detecting cartilage or labral defects in individuals with FAI necessitating the use of MRI or MRA.

Clinical Magnetic Resonance Imaging (MRI)

When plain radiographs show signs of morphometric abnormalities of the proximal femur or acetabulum and the history and examination suggest FAI, MRI and MR arthrography (MRA) can demonstrate associated labral (Fig 3a) and articular cartilage damage (Fig 3b), provide 3D assessment of the bony deformity and presence of impingement cysts (Fig 3c), and aid in appropriate in surgical planning. MRI protocols are available for the evaluation of FAI of the hip (59–64). Alternatively, MRI can be helpful in distinguishing other causes of hip pain from FAI, especially in cases where the clinical presentation, physical exam and plain radiographs are non-diagnostic. Diagnoses such as psoas tendinitis, abductor tendinopathy, and greater trochanteric bursitis will appear with increased signal on T2 weighted images in the affected anatomic regions.

A pre-operative MRI imaging study was performed in 28 patients at 1.5 Tesla field strength and found MRA (sensitivity 81% and 69% and specificity 50–100% for 2 readers), to be superior to conventional non-contrast MRI (sensitivity and specificity of 50% for both readers) for detection of labral tears that were confirmed at arthroscopy (65). A meta-analysis was performed on 19 studies of the ability of MRI and MRA to accurately detect labral tears at 1.5 Tesla, and found that MRA (83%) had higher sensitivity for detection of labral tears compared to conventional MRI (70%) (66).

The difference between MRI and MRA for the detection of cartilage defects in the femur and acetabulum found MRA (sensitivity of 71% and 92%, specificity of 100% and 25% for 2 readers) to be superior to MRI (sensitivity of 58% and 83%, specificity of 100% and 50% for 2 readers) for detection of acetabular cartilage defects but no difference for detecting femoral cartilage defects confirmed at arthroscopy.

Variability in the results of these studies could be related to differences in the patient populations, MRI pulse sequences, and reader experience. However, based on these studies, an MRA is recommended for evaluation and assessment of severity of cartilage and labral involvement in FAI with a 1.5 Tesla MRI scanner (64). Recent advances have been made in clinical MRI pulse sequences at 3.0 Tesla and use of dedicated hip coils has also increased. Blankenbaker et al used a cartilage sensitive sequence at 3.0 Tesla in 67 patients and reported sensitivity and specificity for the detection of cartilage lesions within the hip joint on both the acetabular and femoral cartilage (of 70% and 84% for MRA and 74% and 77% for non-contrast MRI) (67). However, the non-contrast MRI had greater accuracy for grading the severity of cartilage lesions than the MRA. Studies in larger populations are needed to further investigate the accuracy of 3.0 Tesla non-contrast MRI at the hip.

Quantitative Biochemical MRI

Quantitative biochemical MR imaging techniques provide assessment of the proteoglycan, collagen, and water content of the cartilage. Early articular cartilage degeneration in hip OA is characterized by loss of proteoglycans, disruption of collagen network, and an increase in water (68, 69). These early changes cannot be detected by conventional radiography or MRI techniques and need techniques for quantitative assessment cartilage matrix composition (64).

These MRI techniques include delayed gadolinium enhanced MRI of cartilage (dGEMRIC), and non-contrast techniques of T1ρ, T2 or T2* relaxation time mapping. In dGEMRIC, the loss of glycosaminoglycans (GAG) in early OA is a shortened T1 relaxation time (T1Gd) due to higher concentration of the contrast agent in the cartilage (70). In the non-contrast techniques, a loss of proteoglycans is detected as an increase in cartilage T1ρ relaxation times and a disruption of the collagen orientation with increased water content is detected as an increase in the cartilage T2 relaxation times (71–73). T2* is similar to T2 but is more sensitive to susceptibility artifacts; and hence may be able to detect the deposition of calcium hydroxyapatite and fibrocartilagenous transformation at the osteochondral junction (74). These changes lead to shortening of the T2* times. Using these biochemical MRI techniques studies have reported (a) lower T1Gd values from dGEMRIC in the anterosuperior region in cam-type FAI, lower T1Gd values globally in pincer-type FAI, and negative correlations between alpha angle and T1Gd of the anterosuperior region (75–78), (b) higher T1ρ and T2 of both the femoral and acetabular cartilage in subjects with symptomatic FAI compared to controls, especially in the anterosuperior region (79), and (c) lower T2* in regions of acetabular cartilage damage identified during arthroscopy in symptomatic FAI subjects without radiographic OA (74) and in subjects with cartilage lesions (80–83).

Currently, there are technical challenges associated with quantitative hip imaging including a lack of standardization of data acquisition across sites and scanners that limit their use to a few research groups.

Functional Movement Patterns

Since mechanical loading during functional activities contributes to the pathogenesis of FAI, objective biomechanical evaluation of functional movement patterns may benefit the assessment of patients with FAI. Studies using motion analysis techniques report lower hip joint moments, an estimate of loading across the hip joint and reduced joint motion during walking and squatting activities in symptomatic FAI (cam, pincer, and mixed) populations when compared with healthy controls (84–86). These biomechanical deviations have been attributed to the presence of cartilage lesions (87), soft-tissue fibrosis/scarring, pain, stiffness, and movement compensations due to muscular weakness (84).

Treatment Options

Non-surgical

The symptoms in individuals with FAI may arise from damage to soft-tissues like the labrum and cartilage during daily or athletic activities. Hence, there may be a role for conservative care to reduce hip pain, improve symptoms, and reduce disability by focusing on activity modification, movement pattern retraining, muscle flexibility, muscle strengthening, and pain management (88, 89). Wall et al. performed a systematic review of the literature of non-surgical interventions for FAI (89). The authors concluded that staged exercise-based physical therapy programs, along with analgesic therapy and education, can benefit patients with FAI. However, the quality of studies was either low or very low.

Clinical practice guidelines for non-arthritic hip joint pain have recently been published by the Orthopaedic section of the American Physical Therapy Association (APTA) (90). The hip pain conditions include FAI, structural instability, labral tears, chondral lesions and ligamentous tears. Due to the paucity of randomized controlled trials of physical therapy for FAI and hip pain, these recommendations are based on theoretical/foundational evidence and expert opinion. The APTA recommendations include (a) patient education and counseling on joint protection strategies and avoidance of symptom-provoking activities (b) manual therapy for capsular restrictions while avoiding end-range flexion and internal rotation, (c) therapeutic exercises and activities including stretching strengthening (based on any observed asymmetry in rotation), and cardio-respiratory endurance exercises, and (d) neuromuscular re-education that focuses on multi-joint patterns to improve movement coordination. There may also be a role for physical therapy post-arthroscopic surgery for individuals with FAI with at least one randomized controlled trial currently underway (91). However, validation of these recommendations will require randomized trials of conservative care in the individuals with FAI.

Surgical

Surgical treatment of FAI is aimed at correcting the anatomic abnormalities causing pathologic mechanics of the hip joint and to repair any associated soft tissue damage. The goal of surgical correction is to halt degeneration of the joint and to prevent hip OA. Success of surgical treatment is most dependent on the amount of pre-existing joint damage.

Hip arthroscopy is a minimally invasive technique for recontouring the acetabulum and proximal femur, and for addressing intra-articular damage. Arthroscopic techniques have been developed to decompress both the prominent bone along the femoral head-neck junction in cam FAI (Fig. 4a and 4b) as well as to trim the acetabular rim in pincer FAI. Short- and moderate term outcomes of hip arthroscopy for correction of FAI deformities have been published. Corrective femoral osteochondroplasty to resect a cam deformity from a mean alpha angle of 59.8°to 36.4°improved significantly improved hip range of motion in flexion (3.8°; $P = .002$) and internal rotation (9.3°; $P = .0002$) (92). Similarly, femoral osteochondroplasty with selective acetabular rim resection improved internal rotation of the hip from 9.9° ± 6.6° preoperatively to 30.1° ± 5.3° at 3 months after surgery ($P < .001$) and hip flexion from 115.7° ± 13.3° preoperatively to 127.9° ± 6.6° at 3 months postoperatively ($P < .003$) (52).

Arthroscopic labral repair (Fig. 4c and 4d) has been shown to be superior to labral debridement in short and moderate term studies. Schilders and colleagues demonstrated that in 96 patients at mean follow-up of 2 years, the labral repair group had a mean Harris hip score (HHS) improvement of 7.3 points greater than in the labral debridement group (93). Larson and colleagues similarly demonstrated in a case control study that subjective outcomes were significantly improved for both groups compared with preoperative scores, but the HHS, SF-12 and Visual Analog Scale (VAS) pain scores were all significantly better in the labral repair group compared to the labral resection group at mean 3.5 years' follow-up (94).

Surgical dislocation of the hip, in which the femoral head is surgically dislocated from the acetabulum, providing 360° access to FAI pathology, is a useful technique to address global acetabular overcoverage and femoral cam deformity that is not easily accessible by arthroscopic means. Safe surgical dislocation of the hip with low rates of complications was first described by Ganz and colleagues, and allows for global access to intra- and extra-articular deformities of the hip (95). Moderate term follow-up at 3–5 years shows that surgical dislocation of the hip for femoral osteochondroplasty, acetabular rim-trim, and labral repair or debridment leads to significantly improved hip range of motion, radiographic parameters, and clinical outcomes comparable to hip arthroscopy (96–100).

In cases of acetabular retroversion causing pincer FAI, reverse periacetabular osteotomy (PAO) is a surgical method of completely reorienting the acetabulum to alleviate the anterior impingement. The reverse PAO involves cutting the bone around the acetabulum, freeing it from the rest of the pelvis, and then re-positioning the acetabulum to decrease both lateral and anterior femoral head coverage, as well as to antevert the acetabulum. Siebenrock and colleagues reported significant clinical and radiographic improvements thirty months after reverse periacetabular osteotomy to antevert the acetabulum. There was a significant increase in the average range of internal rotation (10°, $p = 0.006$), flexion (7°, $p = 0.014$), and adduction (8°, $p = 0.017$) and improvement in the average Merle d'Aubigne score (101). This technique may be especially useful in hips with a positive posterior wall sign indicating a deficient posterior acetabular wall, in which case an acetabular rim-trim would potentially decrease the size of the acetabulum and create iatrogenic instability of the hip.

When FAI has resulted in severe hip OA with joint space width of less than 2 mm, then the outcome of hip preservation surgery is much less successful. In patients 50 years of age and older, minimum joint space as measured on pre-operative radiographs is the most accurate predictor of early failure from hip arthroscopy. Joint space of 2 mm or less predicted with 81% accuracy that 31 out of 96 patients aged 50 and older undergoing hip arthroscopy eventually needed a subsequent total hip replacement by median 54 month follow-up (102). In patients with moderate to severe radiographic and clinical symptoms of hip OA, a total hip replacement remains the treatment of choice for a long-lasting solution for symptomatic and functional improvement.

In summary, FAI is a common cause of hip pain that may begin in adolescence and continue through adulthood and overtime may accelerate the development of hip OA. The diagnosis of FAI requires both a physical examination and imaging. Currently the efficacy of the surgical procedures is limited to a hip joint with little or no evidence of OA. Questions remain on the epidemiology, diagnostic imaging, and treatments for FAI and more research is needed to better comprehend this entity. To assist patients with FAI in receiving appropriate treatment; education of primary health care providers to recognize FAI and refer the patients to specialists in a timely manner is warranted.

Acknowledgments

This work was supported by NIH grants AR048841, AR052000, and P50 AR060752 P50 AR063043 to NEL.

The authors would like to acknowledge Marcie Harris Hayes, PT, Associate Professor of Physical Therapy, Washington University School of Medicine St. Louis for her thoughtful comments about recommendations for physical therapy for FAI. This work is supported by National Institutes of Health award numbers AR048841, AR052000, P50 AR063043 and P50 AR060752 to NEL. The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health.

References

1. Beck M, Kalhor M, Leunig M, Ganz R. Hip morphology influences the pattern of damage to the acetabular cartilage: femoroacetabular impingement as a cause of early osteoarthritis of the hip. J Bone Joint Surg Br. 2005; 87(7):1012–8. [PubMed: 15972923]
2. Ganz R, Leunig M, Leunig-Ganz K, Harris WH. The etiology of osteoarthritis of the hip: an integrated mechanical concept. Clin Orthop Relat Res. 2008; 466(2):264–72. [PubMed: 18196405]
3. Ganz R, Parvizi J, Beck M, Leunig M, Notzli H, Siebenrock KA. Femoroacetabular impingement: a cause for osteoarthritis of the hip. Clin Orthop Relat Res. 2003; (417):112–20. [PubMed: 14646708]
4. Anderson SE, Siebenrock KA, Tannast M. Femoroacetabular impingement: evidence of an established hip abnormality. Radiology. 2010; 257(1):8–13. [PubMed: 20851934]
5. Domayer SE, Ziebarth K, Chan J, Bixby S, Mamisch TC, Kim YJ. Femoroacetabular cam-type impingement: diagnostic sensitivity and specificity of radiographic views compared to radial MRI. Eur J Radiol. 2011; 80(3):805–10. [PubMed: 21074343]
6. Giori NJ, Trousdale RT. Acetabular retroversion is associated with osteoarthritis of the hip. Clin Orthop Relat Res. 2003; (417):263–9. [PubMed: 14646725]
7. Hack K, Di Primio G, Rakhra K, Beaule PE. Prevalence of cam-type femoroacetabular impingement morphology in asymptomatic volunteers. J Bone Joint Surg Am. 2010; 92(14):2436–44. [PubMed: 20962194]

8. Jaberi FM, Parvizi J. Hip pain in young adults: femoroacetabular impingement. J Arthroplasty. 2007; 22(7 Suppl 3):37–42. [PubMed: 17919591]
9. Jager M, Wild A, Westhoff B, Krauspe R. Femoroacetabular impingement caused by a femoral osseous head-neck bump deformity: clinical, radiological, and experimental results. J Orthop Sci. 2004; 9(3):256–63. [PubMed: 15168180]
10. Kassarjian A, Brisson M, Palmer WE. Femoroacetabular impingement. Eur J Radiol. 2007; 63(1): 29–35. [PubMed: 17485190]
11. Parvizi J, Leunig M, Ganz R. Femoroacetabular impingement. J Am Acad Orthop Surg. 2007; 15(9):561–70. [PubMed: 17761612]
12. Pulido L, Parvizi J. Femoroacetabular impingement. Semin Musculoskelet Radiol. 2007; 11(1):66–72. [PubMed: 17665352]
13. Leunig M, Casillas MM, Hamlet M, Hersche O, Notzli H, Slongo T, et al. Slipped capital femoral epiphysis: early mechanical damage to the acetabular cartilage by a prominent femoral metaphysis. Acta Orthop Scand. 2000; 71(4):370–5. [PubMed: 11028885]
14. Sankar WN, Nevitt M, Parvizi J, Felson DT, Agricola R, Leunig M. Femoroacetabular impingement: defining the condition and its role in the pathophysiology of osteoarthritis. J Am Acad Orthop Surg. 2013; 21 (Suppl 1):S7–S15. [PubMed: 23818194]
15. 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(5):1162–9. [PubMed: 20439662]
16. Gosvig KK, Jacobsen S, Palm H, Sonne-Holm S, Magnusson E. A new radiological index for assessing asphericity of the femoral head in cam impingement. J Bone Joint Surg Br. 2007; 89(10):1309–16. [PubMed: 17957069]
17. Nardo L, Parimi N, Liu F, Jungmann PM, Nevitt M, Link TM, et al. The Prevalence of morphometric abnormities of Femoral Acetabular Impingement and their relation with radiographic hip osteoarthritis and hip pain in Elderly Men - The Osteoporotic Fractures in Men (MrOS) Study. Skeletal Radiol. 2014 [In Review].
18. Clohisy JC, Baca G, Beaule PE, Kim YJ, Larson CM, Millis MB, et al. Descriptive epidemiology of femoroacetabular impingement: a North American cohort of patients undergoing surgery. Am J Sports Med. 2014; 41(6):1348–56. [PubMed: 23669751]
19. Agricola R, Heijboer MP, Bierma-Zeinstra SM, Verhaar JA, Weinans H, Waarsing JH. Cam impingement causes osteoarthritis of the hip: a nationwide prospective cohort study (CHECK). Annals of the rheumatic diseases. 2013; 72(6):918–23. [PubMed: 22730371]
20. Agricola R, Heijboer MP, Roze RH, Reijman M, Bierma-Zeinstra SM, Verhaar JA, et al. Pincer deformity does not lead to osteoarthritis of the hip whereas acetabular dysplasia does: acetabular coverage and development of osteoarthritis in a nationwide prospective cohort study (CHECK). Osteoarthritis Cartilage. 2013; 21(10):1514–21. [PubMed: 23850552]
21. Dodds MK, McCormack D, Mulhall KJ. Femoroacetabular impingement after slipped capital femoral epiphysis: does slip severity predict clinical symptoms? J Pediatr Orthop. 2009; 29(6): 535–9. [PubMed: 19700979]
22. Fraitzl CR, Kafer W, Nelitz M, Reichel H. 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. 2007; 89(12):1592–6. [PubMed: 18057358]
23. Wensaas A, Gunderson RB, Svenningsen S, Terjesen T. Femoroacetabular impingement after slipped upper femoral epiphysis: the radiological diagnosis and clinical outcome at long-term follow-up. J Bone Joint Surg Br. 2012; 94(11):1487–93. [PubMed: 23109627]
24. Ziebarth K, Balakumar J, Domayer S, Kim YJ, Millis MB. Bernese periacetabular osteotomy in males: is there an increased risk of femoroacetabular impingement (FAI) after Bernese periacetabular osteotomy? Clin Orthop Relat Res. 2011; 469(2):447–53. [PubMed: 20848246]
25. Agricola R, Bessems JH, Ginai AZ, Heijboer MP, van der Heijden RA, Verhaar JA, et al. The development of Cam-type deformity in adolescent and young male soccer players. Am J Sports Med. 2012; 40(5):1099–106. [PubMed: 22415206]

26. Kapron AL, Anderson AE, Aoki SK, Phillips LG, Petron DJ, Toth R, et al. Radiographic prevalence of femoroacetabular impingement in collegiate football players: AAOS Exhibit Selection. J Bone Joint Surg Am. 2011; 93(19)(1–10):e111. [PubMed: 22005872]
27. Siebenrock KA, Ferner F, Noble PC, Santore RF, Werlen S, Mamisch TC. The cam-type deformity of the proximal femur arises in childhood in response to vigorous sporting activity. Clin Orthop Relat Res. 2011; 469(11):3229–40. [PubMed: 21761254]
28. Siebenrock KA, Kaschka I, Frauchiger L, Werlen S, Schwab JM. Prevalence of cam-type deformity and hip pain in elite ice hockey players before and after the end of growth. Am J Sports Med. 2013; 41(10):2308–13. [PubMed: 23911701]
29. Siebenrock KA, Behning A, Mamisch TC, Schwab JM. Growth plate alteration precedes cam-type deformity in elite basketball players. Clin Orthop Relat Res. 2013; 471(4):1084–91. [PubMed: 23247816]
30. Yuan BJ, Bartelt RB, Levy BA, Bond JR, Trousdale RT, Sierra RJ. Decreased range of motion is associated with structural hip deformity in asymptomatic adolescent athletes. Am J Sports Med. 2013; 41(7):1519–25. [PubMed: 23698387]
31. Agricola R, Heijboer MP, Ginai AZ, Roels P, Zadpoor AA, Verhaar JA, et al. A cam deformity is gradually acquired during skeletal maturation in adolescent and young male soccer players: a prospective study with minimum 2-year follow-up. Am J Sports Med. 2014; 42(4):798–806. [PubMed: 24585362]
32. Pollard TC, Villar RN, Norton MR, Fern ED, Williams MR, Murray DW, et al. Genetic influences in the aetiology of femoroacetabular impingement: a sibling study. J Bone Joint Surg Br. 2010; 92(2):209–16. [PubMed: 20130310]
33. Dudda M, Kim YJ, Zhang Y, Nevitt MC, Xu L, Niu J, et al. Morphologic differences between the hips of Chinese women and white women: could they account for the ethnic difference in the prevalence of hip osteoarthritis? Arthritis Rheum. 2011; 63(10):2992–9. [PubMed: 21647861]
34. Baker-Lepain JC, Lynch JA, Parimi N, McCulloch CE, Nevitt MC, Corr M, et al. Variant alleles of the Wnt antagonist FRZB are determinants of hip shape and modify the relationship between hip shape and osteoarthritis. Arthritis Rheum. 2012; 64(5):1457–65. [PubMed: 22544526]
35. Bedi A, Dolan M, Leunig M, Kelly BT. Static and dynamic mechanical causes of hip pain. Arthroscopy. 2011; 27(2):235–51. [PubMed: 21035993]
36. Sink EL, Gralla J, Ryba A, Dayton M. Clinical presentation of femoroacetabular impingement in adolescents. J Pediatr Orthop. 2008; 28(8):806–11. [PubMed: 19034169]
37. Clohisy JC, Knaus ER, Hunt DM, Lesher JM, Harris-Hayes M, Prather H. Clinical presentation of patients with symptomatic anterior hip impingement. Clin Orthop Relat Res. 2009; 467(3):638–44. [PubMed: 19130160]
38. Martin HD, Kelly BT, Leunig M, Philippon MJ, Clohisy JC, Martin RL, et al. The pattern and technique in the clinical evaluation of the adult hip: the common physical examination tests of hip specialists. Arthroscopy. 2010; 26(2):161–72. [PubMed: 20141979]
39. Martin HD, Shears SA, Palmer IJ. Evaluation of the hip. Sports Med Arthrosc. 2010; 18(2):63–75. [PubMed: 20473124]
40. Audenaert EA, Peeters I, Vigneron L, Baelde N, Pattyn C. Hip morphological characteristics and range of internal rotation in femoroacetabular impingement. Am J Sports Med. 2012; 40(6):1329–36. [PubMed: 22472271]
41. Wyss TF, Clark JM, Weishaupt D, Notzli HP. Correlation between internal rotation and bony anatomy in the hip. Clin Orthop Relat Res. 2007; 460:152–8. [PubMed: 17290151]
42. Prather H, Harris-Hayes M, Hunt DM, Steger-May K, Mathew V, Clohisy JC. Reliability and agreement of hip range of motion and provocative physical examination tests in asymptomatic volunteers. PM R. 2010; 2(10):888–95. [PubMed: 20970757]
43. Clohisy JC, Carlisle JC, Beaule PE, Kim YJ, Trousdale RT, Sierra RJ, et al. A systematic approach to the plain radiographic evaluation of the young adult hip. J Bone Joint Surg Am. 2008; 90 (Suppl 4):47–66. [PubMed: 18984718]
44. Siebenrock KA, Kalbermatten DF, Ganz R. Effect of pelvic tilt on acetabular retroversion: a study of pelves from cadavers. Clin Orthop Relat Res. 2003; (407):241–8. [PubMed: 12567152]

45. Meyer DC, Beck M, Ellis T, Ganz R, Leunig M. Comparison of six radiographic projections to assess femoral head/neck asphericity. Clin Orthop Relat Res. 2006; 445:181–5. [PubMed: 16456309]
46. 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(12): 3313–20. [PubMed: 22930210]
47. Notzli HP, Wyss TF, Stoecklin CH, Schmid MR, Treiber K, Hodler J. The contour of the femoral head-neck junction as a predictor for the risk of anterior impingement. J Bone Joint Surg Br. 2002; 84(4):556–60. [PubMed: 12043778]
48. Fraitzl CR, Kappe T, Pennekamp F, Reichel H, Billich C. Femoral head-neck offset measurements in 339 subjects: distribution and implications for femoroacetabular impingement. Knee surgery, sports traumatology, arthroscopy : official journal of the ESSKA. 2013; 21(5):1212–7.
49. Jung KA, Restrepo C, Hellman M, AbdelSalam H, Morrison W, Parvizi J. The prevalence of cam-type femoroacetabular deformity in asymptomatic adults. J Bone Joint Surg Br. 2011; 93(10): 1303–7. [PubMed: 21969426]
50. Pollard TC, Villar RN, Norton MR, Fern ED, Williams MR, Simpson DJ, et al. Femoroacetabular impingement and classification of the cam deformity: the reference interval in normal hips. Acta orthopaedica. 2010; 81(1):134–41. [PubMed: 20175650]
51. Beaule PE, Hynes K, Parker G, Kemp KA. Can the alpha angle assessment of cam impingement predict acetabular cartilage delamination? Clin Orthop Relat Res. 2012; 470(12):3361–7. [PubMed: 23001504]
52. Kelly BT, Bedi A, Robertson CM, Dela Torre K, Giveans MR, Larson CM. Alterations in internal rotation and alpha angles are associated with arthroscopic cam decompression in the hip. Am J Sports Med. 2012; 40(5):1107–12. [PubMed: 22392560]
53. Larson CM, Sikka RS, Sardelli MC, Byrd JW, Kelly BT, Jain RK, et al. Increasing alpha angle is predictive of athletic-related “hip” and “groin” pain in collegiate National Football League prospects. Arthroscopy. 2013; 29(3):405–10. [PubMed: 23357573]
54. Wiberg G. Studies on dysplastic acetabula and congenital subluxation of the hip joint. With special reference to the complication of osteo-arthritis. Acta Chirurgiae Scandanavica. 1939; 83(58 Suppl):5–135.
55. Tonnis, D. Congenital Dysplasia and Dislocation of the Hip in Children and Adults. New York, NY: Springer; 1987.
56. Reynolds D, Lucas J, Klaue K. Retroversion of the acetabulum. A cause of hip pain. J Bone Joint Surg Br. 1999; 81(2):281–8. [PubMed: 10204935]
57. Kopydlowski NJ, Tannenbaum EP, Bedi A, Smith MV, Sekiya JK. An Increase in Cranial Acetabular Version With Age: Implications for Femoroacetabular Impingement. J Arthroplasty. 2014
58. Kalberer F, Sierra RJ, Madan SS, Ganz R, Leunig M. Ischial spine projection into the pelvis : a new sign for acetabular retroversion. Clin Orthop Relat Res. 2008; 466(3):677–83. [PubMed: 18264856]
59. Kubo T, Horii M, Harada Y, Noguchi Y, Yutani Y, Ohashi H, et al. Radial-sequence magnetic resonance imaging in evaluation of acetabular labrum. J Orthop Sci. 1999; 4(5):328–32. [PubMed: 10542035]
60. Plotz GM, Brossmann J, von Knoch M, Muhle C, Heller M, Hassenpflug J. Magnetic resonance arthrography of the acetabular labrum: value of radial reconstructions. Arch Orthop Trauma Surg. 2001; 121(8):450–7. [PubMed: 11550831]
61. Stelzeneder D, Hingsammer A, Bixby SD, Kim YJ. Can radiographic morphometric parameters for the hip be assessed on MRI? Clin Orthop Relat Res. 2013; 471(3):989–99. [PubMed: 23100186]
62. Stelzeneder D, Mamisch TC, Kress I, Domayer SE, Werlen S, Bixby SD, et al. Patterns of joint damage seen on MRI in early hip osteoarthritis due to structural hip deformities. Osteoarthritis Cartilage. 2012; 20(7):661–9. [PubMed: 22469848]
63. Yoon LS, Palmer WE, Kassarjian A. Evaluation of radial-sequence imaging in detecting acetabular labral tears at hip MR arthrography. Skeletal Radiol. 2007; 36(11):1029–33. [PubMed: 17712555]

64. Gold SL, Burge AJ, Potter HG. MRI of hip cartilage: joint morphology, structure, and composition. Clin Orthop Relat Res. 2012; 470(12):3321–31. [PubMed: 22723242]

65. Sutter R, Zubler V, Hoffmann A, Mamisch-Saupe N, Dora C, Kalberer F, et al. Hip MRI: how useful is intraarticular contrast material for evaluating surgically proven lesions of the labrum and articular cartilage? AJR Am J Roentgenol. 2014; 202(1):160–9. [PubMed: 24370140]

66. Smith TO, Hilton G, Toms AP, Donell ST, Hing CB. The diagnostic accuracy of acetabular labral tears using magnetic resonance imaging and magnetic resonance arthrography: a meta-analysis. European radiology. 2011; 21(4):863–74. [PubMed: 20859632]

67. Blankenbaker DG, Ullrick SR, Kijowski R, Davis KW, De Smet AA, Shinki K, et al. MR arthrography of the hip: comparison of IDEAL-SPGR volume sequence to standard MR sequences in the detection and grading of cartilage lesions. Radiology. 2011; 261(3):863–71. [PubMed: 21900621]

68. Lohmander LS. Articular cartilage and osteoarthrosis. The role of molecular markers to monitor breakdown, repair and disease. J Anat. 1994; 184 (Pt 3):477–92. [PubMed: 7928637]

69. Pearle AD, Warren RF, Rodeo SA. Basic science of articular cartilage and osteoarthritis. Clin Sports Med. 2005; 24(1):1–12. [PubMed: 15636773]

70. Kim YJ, Jaramillo D, Millis MB, Gray ML, Burstein D. Assessment of early osteoarthritis in hip dysplasia with delayed gadolinium-enhanced magnetic resonance imaging of cartilage. J Bone Joint Surg Am. 2003; 85-A(10):1987–92. [PubMed: 14563809]

71. Li X, Benjamin Ma C, Link TM, Castillo DD, Blumenkrantz G, Lozano J, et al. In vivo T(1rho) and T(2) mapping of articular cartilage in osteoarthritis of the knee using 3 T MRI. Osteoarthritis Cartilage. 2007; 15(7):789–97. [PubMed: 17307365]

72. Li X, Cheng J, Lin K, Saadat E, Bolbos RI, Jobke B, et al. Quantitative MRI using T1rho and T2 in human osteoarthritic cartilage specimens: correlation with biochemical measurements and histology. Magn Reson Imaging. 29(3):324–34. [PubMed: 21130590]

73. Regatte RR, Akella SV, Lonner JH, Kneeland JB, Reddy R. T1rho relaxation mapping in human osteoarthritis (OA) cartilage: comparison of T1rho with T2. J Magn Reson Imaging. 2006; 23(4): 547–53. [PubMed: 16523468]

74. Ellermann J, Ziegler C, Nissi MJ, Goebel R, Hughes J, Benson M, et al. Acetabular Cartilage Assessment in Patients with Femoroacetabular Impingement by Using T2* Mapping with Arthroscopic Verification. Radiology. 2014:131837.

75. Pollard TC, McNally EG, Wilson DC, Wilson DR, Madler B, Watson M, et al. Localized cartilage assessment with three-dimensional dGEMRIC in asymptomatic hips with normal morphology and cam deformity. J Bone Joint Surg Am. 2010; 92(15):2557–69. [PubMed: 21048174]

76. Jessel RH, Zilkens C, Tiderius C, Dudda M, Mamisch TC, Kim YJ. Assessment of osteoarthritis in hips with femoroacetabular impingement using delayed gadolinium enhanced MRI of cartilage. J Magn Reson Imaging. 2009; 30(5):1110–5. [PubMed: 19856439]

77. Bittersohl B, Steppacher S, Haamberg T, Kim YJ, Werlen S, Beck M, et al. Cartilage damage in femoroacetabular impingement (FAI): preliminary results on comparison of standard diagnostic vs delayed gadolinium-enhanced magnetic resonance imaging of cartilage (dGEMRIC). Osteoarthritis Cartilage. 2009; 17(10):1297–306. [PubMed: 19446663]

78. Mamisch TC, Kain MS, Bittersohl B, Apprich S, Werlen S, Beck M, et al. Delayed gadolinium-enhanced magnetic resonance imaging of cartilage (dGEMRIC) in Femoacetabular impingement. J Orthop Res. 2011; 29(9):1305–11. [PubMed: 21437964]

79. Subburaj K, Valentinitsch A, Dillon AB, Joseph GB, Li X, Link TM, et al. Regional variations in MR relaxation of hip joint cartilage in subjects with and without femoralacetabular impingement. Magn Reson Imaging. 2013; 31(7):1129–36. [PubMed: 23684960]

80. Apprich S, Mamisch TC, Welsch GH, Bonel H, Siebenrock KA, Kim YJ, et al. Evaluation of articular cartilage in patients with femoroacetabular impingement (FAI) using T2* mapping at different time points at 3.0 Tesla MRI: a feasibility study. Skeletal Radiol. 2012; 41(8):987–95. [PubMed: 22057581]

81. Bittersohl B, Hosalkar HS, Hughes T, Kim YJ, Werlen S, Siebenrock KA, et al. Feasibility of T2* mapping for the evaluation of hip joint cartilage at 1.5T using a three-dimensional (3D), gradient-

echo (GRE) sequence: a prospective study. Magn Reson Med. 2009; 62(4):896–901. [PubMed: 19645008]

82. Bittersohl B, Miese FR, Hosalkar HS, Herten M, Antoch G, Krauspe R, et al. T2* mapping of hip joint cartilage in various histological grades of degeneration. Osteoarthritis Cartilage. 2012; 20(7): 653–60. [PubMed: 22469845]
83. Bittersohl B, Miese FR, Hosalkar HS, Mamisch TC, Antoch G, Krauspe R, et al. T2* mapping of acetabular and femoral hip joint cartilage at 3 T: a prospective controlled study. Invest Radiol. 2012; 47(7):392–7. [PubMed: 22627944]
84. Hunt MA, Guenther JR, Gilbart MK. Kinematic and kinetic differences during walking in patients with and without symptomatic femoroacetabular impingement. Clin Biomech (Bristol, Avon). 2013; 28(5):519–23.
85. Kennedy MJ, Lamontagne M, Beaule PE. Femoroacetabular impingement alters hip and pelvic biomechanics during gait Walking biomechanics of FAI. Gait Posture. 2009; 30(1):41–4. [PubMed: 19307121]
86. Lamontagne M, Kennedy MJ, Beaule PE. The effect of cam FAI on hip and pelvic motion during maximum squat. Clin Orthop Relat Res. 2009; 467(3):645–50. [PubMed: 19034598]
87. Kumar D, Dillon A, Nardo L, Link TM, Majumdar S, Souza RB. Differences in the Association of Hip Cartilage Lesions and Cam-Type Femoroacetabular Impingement With Movement Patterns: A Preliminary Study. PM R. 2014
88. Emara K, Samir W, Motasem el H, Ghafar KA. Conservative treatment for mild femoroacetabular impingement. J Orthop Surg (Hong Kong). 2011; 19(1):41–5. [PubMed: 21519074]
89. Wall PD, Fernandez M, Griffin DR, Foster NE. Nonoperative treatment for femoroacetabular impingement: a systematic review of the literature. PM R. 2013; 5(5):418–26. [PubMed: 23419746]
90. Enseki K, Harris-Hayes M, White DM, Cibulka MT, Woehrle J, Fagerson TL, et al. Nonarthritic Hip Joint Pain: Clinical Practice Guidelines Linked to the International Classification of Functioning, Disability and Health From the Orthopaedic Section of the American Physical Therapy Association. J Orthop Sports Phys Ther. 2014; 44(6)
91. Bennell KL, O’Donnell JM, Takla A, Spiers LN, Hunter DJ, Staples M, et al. Efficacy of a physiotherapy rehabilitation program for individuals undergoing arthroscopic management of femoroacetabular impingement - the FAIR trial: a randomised controlled trial protocol. BMC musculoskeletal disorders. 2014; 15:58. [PubMed: 24571824]
92. Bedi A, Dolan M, Hetsroni I, Magennis E, Lipman J, Buly R, et al. Surgical treatment of femoroacetabular impingement improves hip kinematics: a computer-assisted model. Am J Sports Med. 2011; 39 (Suppl):43S–9S. [PubMed: 21709031]
93. Schilders E, Dimitrakopoulou A, Bismil Q, Marchant P, Cooke C. Arthroscopic treatment of labral tears in femoroacetabular impingement: a comparative study of refixation and resection with a minimum two-year follow-up. J Bone Joint Surg Br. 2011; 93(8):1027–32. [PubMed: 21768624]
94. 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(5):1015–21. [PubMed: 22307078]
95. Ganz R, Gill TJ, Gautier E, Ganz K, Krugel N, Berlemann U. Surgical dislocation of the adult hip a technique with full access to the femoral head and acetabulum without the risk of avascular necrosis. J Bone Joint Surg Br. 2001; 83(8):1119–24. [PubMed: 11764423]
96. Bedi A, Zaltz I, De La Torre K, Kelly BT. Radiographic comparison of surgical hip dislocation and hip arthroscopy for treatment of cam deformity in femoroacetabular impingement. Am J Sports Med. 2011; 39 (Suppl):20S–8S. [PubMed: 21709028]
97. Domb BG, Stake CE, Botser IB, Jackson TJ. Surgical dislocation of the hip versus arthroscopic treatment of femoroacetabular impingement: a prospective matched-pair study with average 2-year follow-up. Arthroscopy. 2013; 29(9):1506–13. [PubMed: 23992988]
98. Naal FD, Miozzari HH, Schar M, Hesper T, Notzli HP. Midterm results of surgical hip dislocation for the treatment of femoroacetabular impingement. Am J Sports Med. 2012; 40(7):1501–10. [PubMed: 22556199]

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99. Peters CL, Erickson JA. Treatment of femoro-acetabular impingement with surgical dislocation and debridement in young adults. J Bone Joint Surg Am. 2006; 88(8):1735–41. [PubMed: 16882895]

100. Steppacher SD, Huemmer C, Schwab JM, Tannast M, Siebenrock KA. Surgical hip dislocation for treatment of femoroacetabular impingement: factors predicting 5-year survivorship. Clin Orthop Relat Res. 2014; 472(1):337–48. [PubMed: 24014286]

101. Siebenrock KA, Schoeniger R, Ganz R. Anterior femoro-acetabular impingement due to acetabular retroversion. Treatment with periacetabular osteotomy. J Bone Joint Surg Am. 2003; 85-A(2):278–86. [PubMed: 12571306]

102. Philippon MJ, Briggs KK, Carlisle JC, Patterson DC. Joint space predicts THA after hip arthroscopy in patients 50 years and older. Clin Orthop Relat Res. 2013; 471(8):2492–6. [PubMed: 23292888]

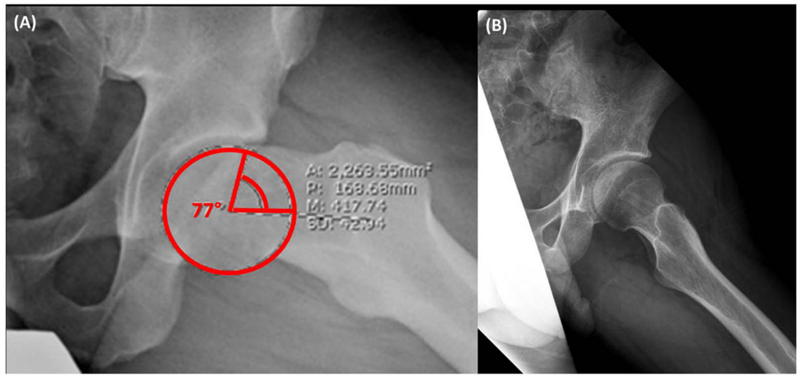

Fig. 1.

Lateral Hip Radiograph (A) 45°Dunn Lateral Hip Radiograph with alpha angle measurement. First the femoral neck axis (line connecting the center of the femoral head and the mid point of the narrowest part of the femoral neck) is defined. Next a circle is fit to the femoral head. Alpha angle is then measured as the angle between the femoral neck axis and the line from the center of the circle to the point where the bony contour first appears outside the best-fit circle, and (B) Frog Leg Lateral Radiograph

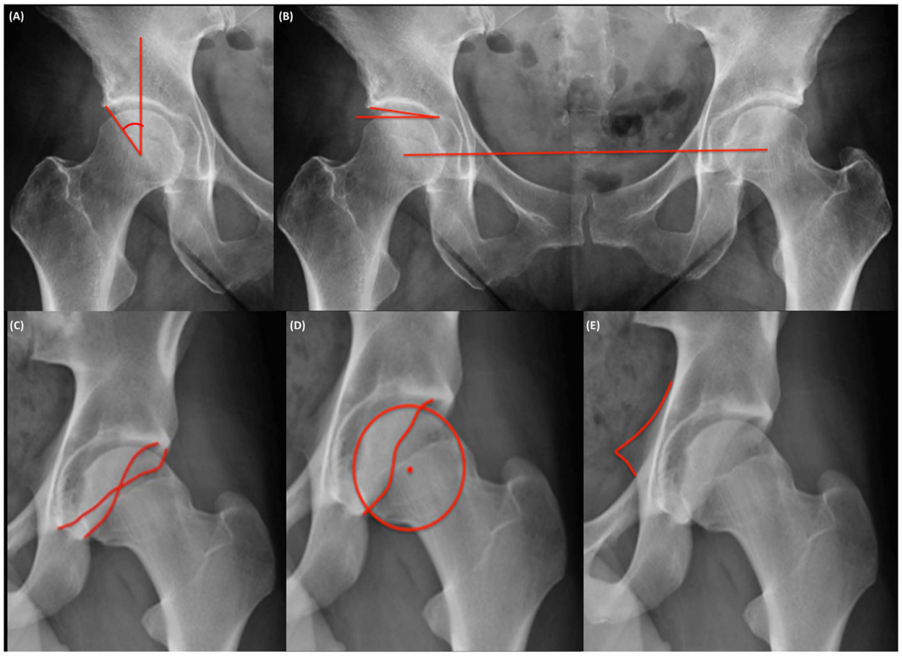

Fig. 2.

Acetabular measures on AP Pelvis radiographs (cropped) (A) Lateral center edge angle (LCEA), with its vertex at the center of the femoral head, and is the angle between a vertical line to the pelvis and another line that extends to the lateral extent of the acetabular roof, and (B) Tönnis angle is between a horizontal line connecting the two femoral heads and a line connecting the medial and lateral extents of the acetabular roof (C) Crossover sign in which the anterior wall projects lateral to the posterior wall before converging at the lateral acetabular sourcil,, (D) Posterior wall sign in which the posterior acetabular wall is medial to the center of the femoral head, and (E) Ischial spine sign in which the ischial spine is visible within the pelvic inlet on the AP pelvis.

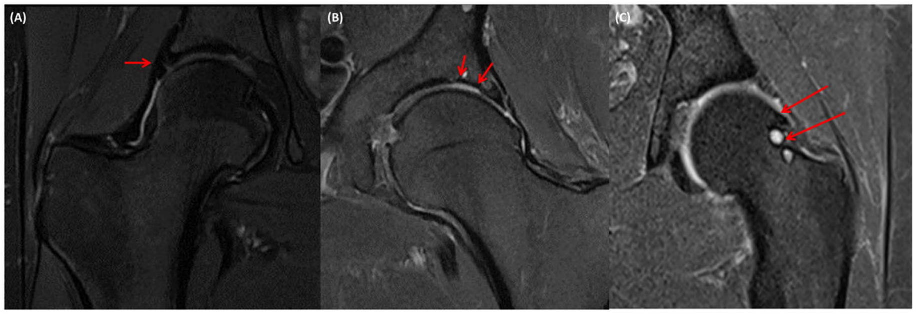

Fig. 3.

Coronal MRI of the hip (A) labral tear, (B) Cartilage lesion, and (C) Radial reformatted MRI showing cam deformity and impingement cysts at femoral head-neck junction

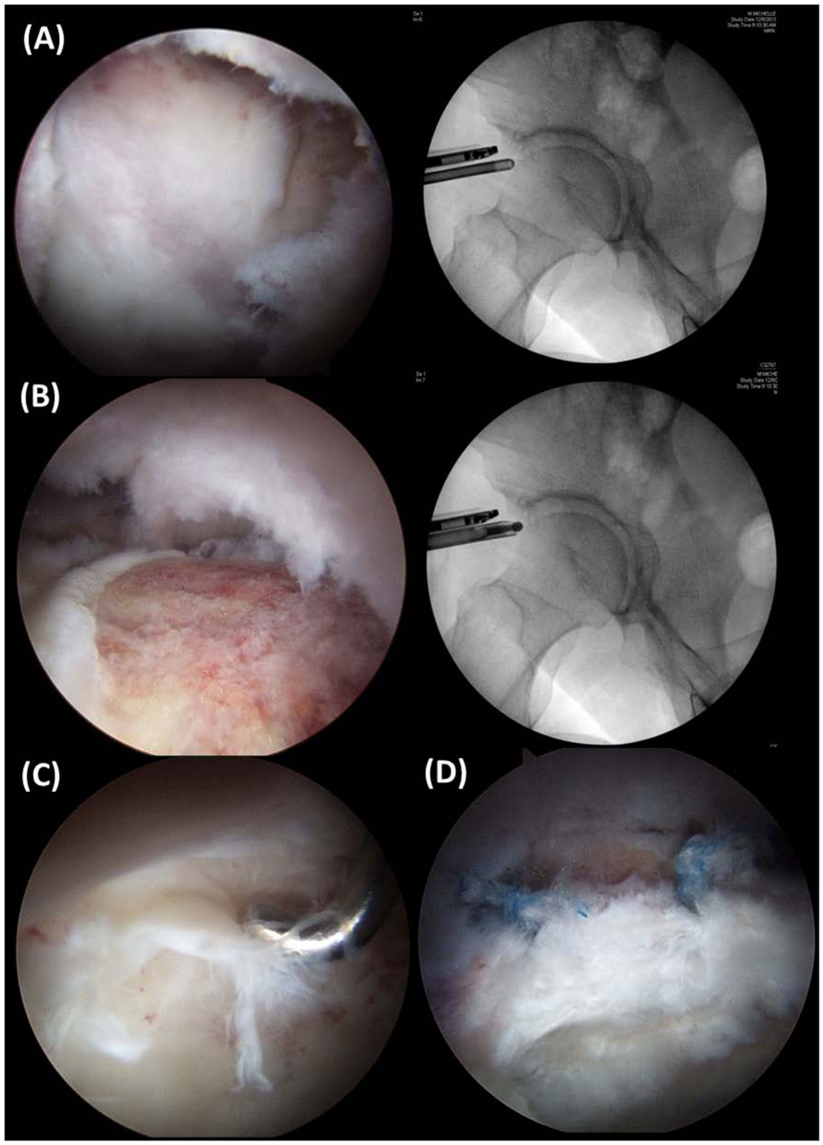

Fig 4.

Hip arthroscopy for FAI (A) Cam deformity seen during hip arthroscopy with overlying chondromalacia and asphericity of the femoral head-neck junction, and corresponding fluoroscopic image, (B) After hip arthroscopy for femoral osteochondroplasty to restore femoral head-neck offset, (C) Acetabular labrochondral separation before repair, and (D) After arthroscopic labral repair of labrochondral separation