Hip-Femoral Acetabular Impingement

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KEYWORDS

• Hip • Magnetic resonance imaging • Femoroacetabular impingement
• Magnetic resonance arthrography • Cam impingement • Pincer impingement
• Acetabular labral tears

KEY POINTS

- Femoroacetabular impingement is caused by repetitive abutment of a morphologically abnormal proximal femur and/or acetabulum during terminal range-of-motion of the hip.
- The abnormal pathomechanical impingement seen in femoroacetabular impingement results in damage to the labrum and acetabular cartilage.
- Magnetic resonance imaging of the hip requires high field imaging (1.5 or 3 T) and a dedicated hip protocol to ensure appropriate quality of images.
- Magnetic resonance arthrography increases contrast resolution and is important for evaluating the acetabular labrum and articular cartilage.
- Assessment of both normal and pathologic magnetic resonance imaging anatomy requires a systematic evaluation of bony structures, acetabular labrum, femoral and acetabular cartilage, chondrolabral junction, and other soft tissues including the ligamentum teres.

INTRODUCTION

Femoroacetabular impingement (FAI) was first described in the 1990s,[1,2] and since that time has been increasingly recognized as a source of hip pain and dysfunction.

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Extensive work by Ganz and colleagues[3] has demonstrated that FAI is caused by repetitive abutment of a morphologically abnormal proximal femur and/or acetabulum during terminal range-of-motion of the hip. This pathomechanical process eventually results in characteristic damage to the labrum and acetabular cartilage, depending on the location of the osseous abnormality.[3] The 2 most common osseous abnormalities that lead to FAI are a loss of the normal femoral head-neck offset, resulting in cam impingement, and acetabular overcoverage, resulting in pincer impingement.[3] A third type of FAI has components of both cam and pincer and is referred to as mixed or combined impingement.

Cam Impingement

- Most common form of isolated FAI (17% of all FAI types)[4]
- Typically seen in young adult men 20 to 30 years old[5]
- The loss of normal femoral head-neck contour can be due to an abnormal extension of the proximal femoral epiphysis,[6] short or long femoral neck, varus femoral neck, or residual deformity from femoral neck fracture, perthes, or slipped capital femoral epiphysis
- The nonspherical portion of the anterolateral femoral head produces a shear force at the chondrolabral junction as it enters the acetabulum during hip flexion[3]
- Over time, repetitive shearing results in chondrolabral separation, acetabular chondral delamination from the subchondral bone, and labral detachment (**Fig. 1**).[3,4,7,8]

Pincer Impingement

- Most commonly seen in women[9] 30 to 40 years old[10]
- Acetabular overcoverage can be caused from focal overcoverage at the anterosuperior acetabular rim, relative anterior overcoverage (acetabular retroversion), or global overcoverage (coxa profunda, protrusio acetabuli)
- Overcoverage of the acetabulum results in crushing the labrum against the normal femoral neck in hip flexion and internal rotation (**Fig. 2**).[3]

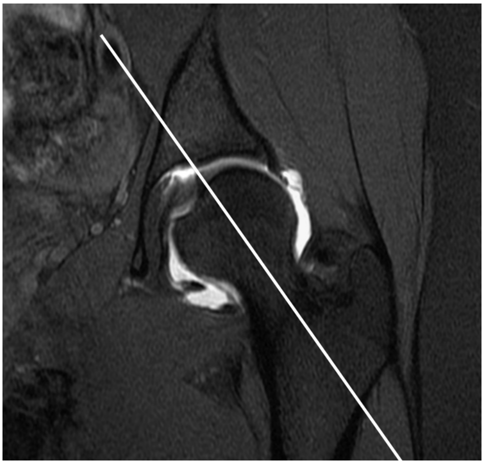

Fig. 1. Orientation to prescribe the oblique axial sequence. Coronal T1-weighted fat-suppressed MR arthrogram image demonstrates the plane used to obtain the oblique axial sequence.

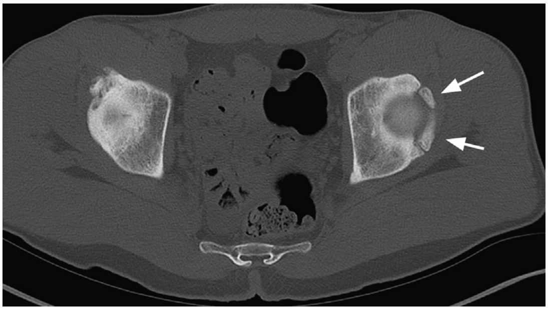

Fig. 2. Axial CT scan of the pelvis shows 2 bony fragments adjacent to the acetabulum (*arrows*).

- Continued abutment results in labral degeneration, with limited chondral injury, and possible ossification of the rim[3,11]
- Can result in damage to posterior femoral head and acetabulum as a result of contracoup mechanism of the femoral head levering on the acetabulum and shearing posteriorly.

Combined Impingement

- Most common form of FAI (72% of all FAI types)[4]
- Has components of both cam and pincer morphology; however, one type of intra-articular pathologic condition usually predominates

The diagnosis of FAI relies on patient history, physical examination, selective intra-articular anesthetic injection, and radiographic studies, including plain radiograph, magnetic resonance imaging (MRI), and computed tomography (CT). MRI and magnetic resonance arthrography (MRA) have been used with increasing frequency to identify the pathomorphologies associated with FAI and are important to a successful treatment and outcomes.

MRI TECHNICAL CONSIDERATIONS

MR Imaging Techniques for the Hip

- The hip remains one of the most challenging joints to image. This challenge is related to its unique orientation that does not conform to the standard planes of the body and the variation in orientation from person to person. In addition, the hip cannot be surrounded by a radiofrequency coil and is relatively deep from the skin surface. Because of these challenges, optimization of image quality is critical for the evaluation of hip pathologic condition related to femoroacetabular impingement.
- High field imaging is preferred (1.5 or 3.0 T). The use of 3.0 T systems offer a higher signal-to-noise ratio.
- A dedicated hip protocol should be used when there is a question of femoroacetabular impingement, optimizing images of the hip at the expense of excluding other areas of the pelvis and the contralateral hip. For this reason it is crucial to denote the side of interest in the imaging request.
- Imaging of the hip for the evaluation of femoroacetabular impingement typically includes 3 planes using a variety of MR sequences. For nonarthrographic imaging, a combination of T1-weighted, proton-density, and T2-weighted images with fat suppression is used. Because conventional anatomic planes (transverse, coronal, and sagittal) do not optimally demonstrate the pathologic condition,

particularly of the labrum, oblique sequences have been developed. These sequences include the following:
  - Axial oblique, obtained parallel to the long axis of the femoral neck (see **Fig. 1**).
  - Radial sequences, obtained perpendicular to the long axis of the femur. These radial sequences are helpful for determining the α angle, particularly when the osseous prominence is not evident on the oblique axial views.
- Other important factors include using a small field of view (16–20 cm) and a dedicated phased-array surface coil.

Use of Intra-articular Arthrography

The use of intra-articular arthrography (direct arthrography) is useful to distend the joint, separate the soft tissues, and increase contrast resolution, factors important to evaluating the labrum and cartilage structures. For MRA, a combination of fat-suppressed T1-weighted images and fluid-sensitive sequences is important to distinguish between fluid in the joint and extra-articular collections. The technique at the authors' institution consists of using a mixture of 5 mL Lidocaine 1%, 5 mL Ropivacaine 0.5%, 1 mL Omnipaque 240, and 0.1 mL Gd-DTPA (Magnevist) in a 20 mL syringe. A total of 5 to 10 mL is injected into the hip joint.

MRI NORMAL ANATOMY

Key Structures to Identify in the Assessment of Femoroacetabular Impingement

- Interpretation of a hip MRI for femoroacetabular impingement requires a through assessment of the following structures:
  - Bony structures, including acetabular morphology, femoral head morphology, head-neck junction morphology, and the presence of osseous bumps, osteophytes, and fibrocystic changes.
  - Acetabular labrum.
  - Acetabular articular cartilage and chondrolabral junction.
  - Femoral head articular cartilage.
  - Other soft tissues including the ligamentum teres.

Bony Structures

- Acetabular morphology: The acetabular version is best assessed on an anteroposterior radiograph of the pelvis (pelvic radiography is routinely used at the authors' institution as part of the workup for femoroacetabular impingement). On the MRI examination, the acetabulum is best assessed on the oblique axial images.
- The femoral head-neck junction can be assessed on the oblique axial images; however, the use of radial imaging can provide a more comprehensive assessment.[12]
- Bony fragments adjacent to the acetabular rim: The presence of bony fragments adjacent to the acetabular rim can be due to an ununited secondary acetabular ossification center. Other possible causes include ununited acetabular fractures (see **Fig. 2**), fragmentation of osteophytes, or labral ossification.[13]
- Juxta-articular fibrocystic changes at the anterosuperior femoral neck.
- Notching of the femoral neck in pincer FAI.

Cartilage

- Evaluation of cartilage is one of the most important reasons for imaging a patient with femoroacetabular impingement. The cartilage can be difficult to assess because it is thin and the articular surfaces are closely applied. The curvature of the acetabulum also contributes to the difficulty.

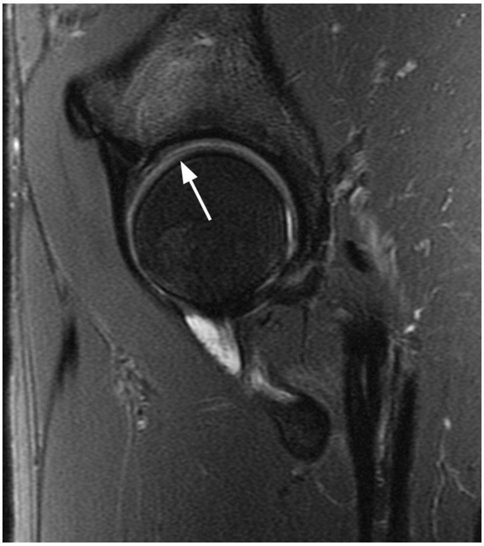

Fig. 3. Normal femoral head cartilage. Sagittal T1-weighted fat-suppressed MR arthrogram image shows the normal smooth femoral head cartilage (*arrow*).

- The femoral head articular cartilage should appear smooth and well defined (**Fig. 3**).

Labrum

- The labrum should appear as a dark, well-defined triangular structure. Although the anterior labrum generally appears sharp, the posterior can normally have a more rounded appearance (**Fig. 4**).
- The addition of a radial sequence to the standard planes can be helpful in the detection of labral pathologic condition.

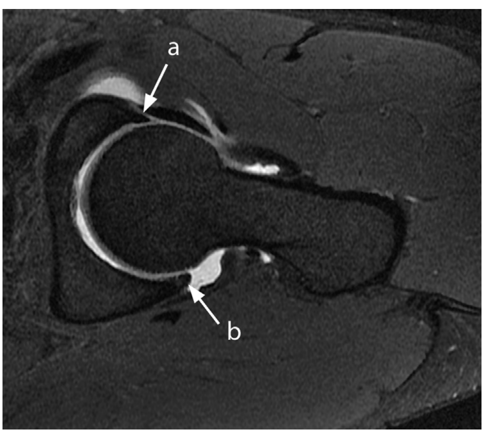

Fig. 4. Normal acetabular labrum. Oblique axial T1-weighted fat-suppressed MR arthrogram image shows the normal anterior (a *arrow*) and normal posterior (b *arrow*) acetabular labrum. Note the round appearance of the posterior labrum compared with the sharp well-defined anterior labrum.

- The chondral labral junction is also best evaluated on the coronal sequence and should appear smooth without defects (Fig. 5).

Normal Variants

- Supra-acetabular fossa represents a focal depression in the superior acetabulum that should not be mistaken for a cartilage defect. The absence of adjacent marrow signal and its characteristic location are helpful for identification (Fig. 6). Similarly, a stellate crease (stellate lesion) represents a normal focus of cartilage absence or thinning at the superomedial acetabulum, more medial to the supra-acetabular fossa, that is continuous with the acetabular notch.[13–15]
- The presence of a sublabral sulcus is much debated. These sublabral sulci have been described as representing variants in all labral locations.[16] Although it remains unclear which of these lesions is truly a normal variant, based on the locations of tears found at arthroscopy, it is more likely that a linear signal intensity at the base of the anterosuperior labrum represents a tear, whereas those in the posteroinferior labral cartilage junction more likely represents a sublabral sulcus or a foramen.[14]

MRI PATHOLOGIC ANATOMY ASSOCIATED WITH FEMOROACETABULAR IMPINGEMENT

Although the diagnosis of femoroacetabular impingement is primarily based on radiographs and clinical findings, MRI is important in confirming the diagnosis and assessing the labrum and cartilage.

Findings Associated with Cam Impingement

- The loss of normal femoral head-neck contour with asphericity of the femoral head (Fig. 7) and elevated α angle (Fig. 8).
- Chondrolabral separation (Fig. 9)
- Acetabular chondral loss (Fig. 10)

Fig. 5. Normal femoral head cartilage. Coronal T1-weighted fat-suppressed MR arthrogram image shows the normal superior chondrolabral junction (*arrow*).

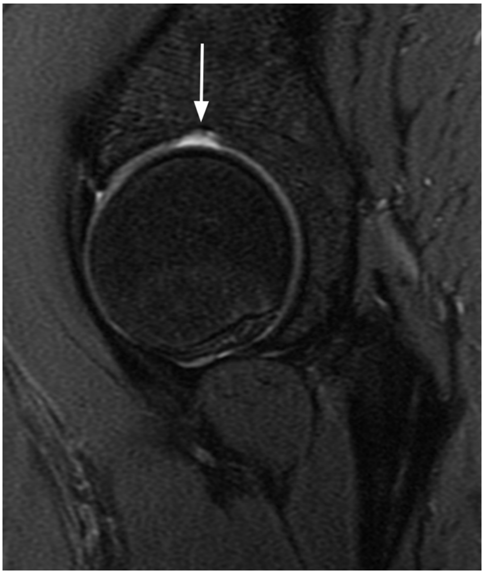

Fig. 6. Supra-acetabular fossa. Sagittal T1-weighted fat-suppressed MR arthrogram image shows supra-acetabular fossa at the superior acetabulum (*arrow*) that should not be mistaken for a focal chondral defect.

Findings Associated with Pincer Impingement

- Acetabular overcoverage
  - Focal overcoverage at the anterosuperior acetabular rim
  - Relative anterior overcoverage (acetabular retroversion)
  - Global overcoverage (coxa profunda, protrusio acetabuli)

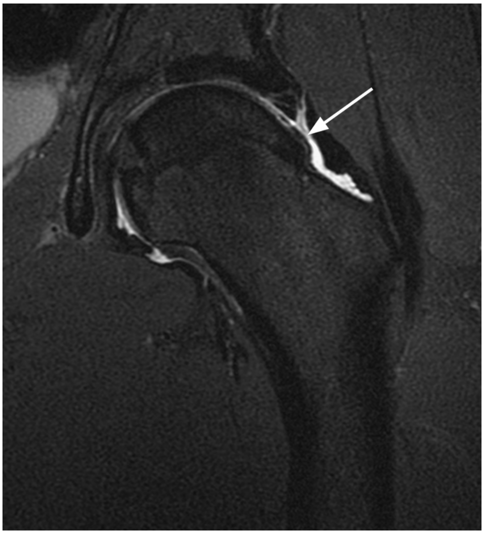

Fig. 7. Loss of normal femoral head-neck contour with asphericity of the femoral head. Oblique coronal T1-weighted fat-suppressed MR arthrogram image shows an ossoeus prominence with loss of the femoral head-neck contour (*arrow*).

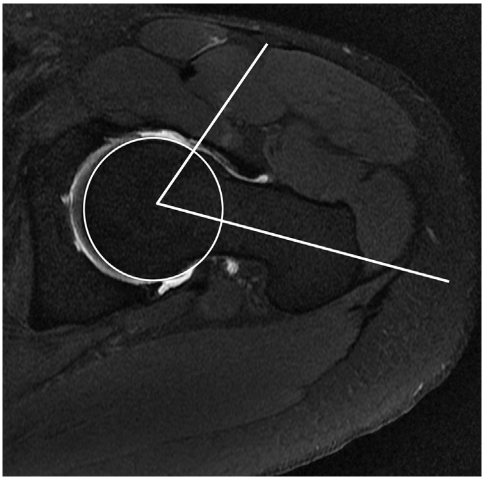

Fig. 8. Elevated α angle. Oblique axial T1-weighted fat-suppressed MR arthrogram image demonstrates an elevated α angle (66°).

- Labral degeneration (**Fig. 11**)
- Limited chondral injury
- Ossification of the rim (see **Fig. 2**)
- Contracoup injury to the posterior femoral head and acetabulum.

CASE EXAMPLES

Case 1. Pincer Impingement with Labral Tear and Synovial Proliferation

A 27-year-old woman presented with a 2-month history of left groin pain that began spontaneously after an extended walk. Physical examination was consistent with

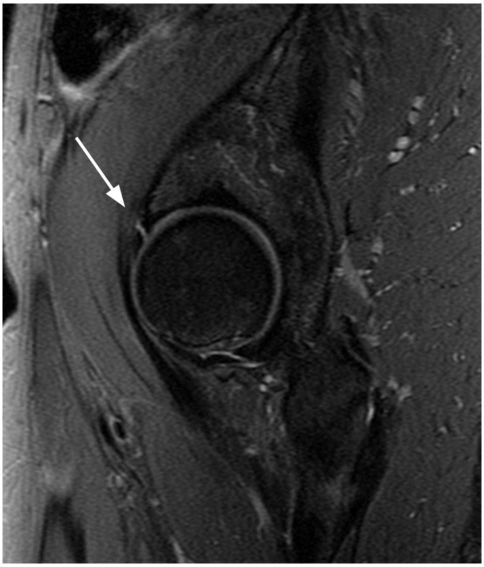

Fig. 9. Chondrolabral separation. Sagittal T1-weighted fat-suppressed MR arthrogram shows a linear signal at the base of the anterior superior labrum (*arrow*).

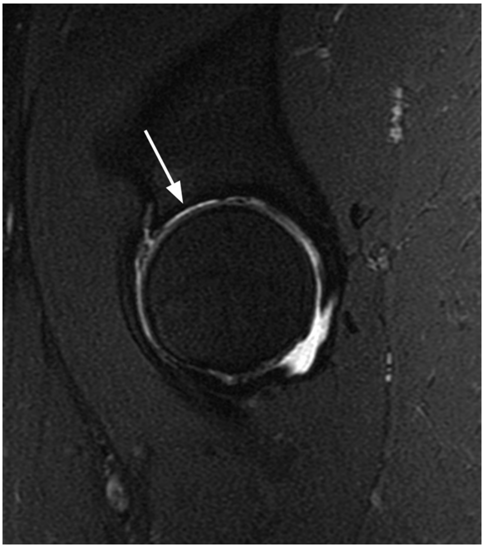

Fig. 10. Acetabular cartilage loss. Sagittal T1 weighted fat-suppressed MR arthrogram shows a large focus of full thickness cartilage loss of the anterior aspect of the superior acetabulum (*arrow*), and an anterior labral chondral separation.

the diagnosis of FAI. Roentgenography demonstrated radiographic features of pincer FAI. MRA revealed an anterosuperior labral tear and nonenhancing synovial mass inferior to the femoral head-neck junction. Intra-articular anesthetic injection provided immediate relief of her symptoms. Treatment consisted of arthroscopic acetabular rim reduction and labral refixation, followed by intra-articular excisional biopsy of hypertrophic synovial tissue (**Fig. 12**).

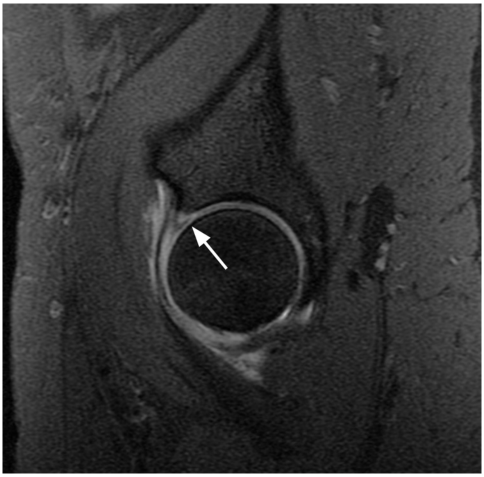

Fig. 11. Labral degeneration. Sagittal T1-weighted fat-suppressed MR arthrogram shows abnormal signal within the anterior aspect of the superior labrum compatible with degeneration (*arrow*).

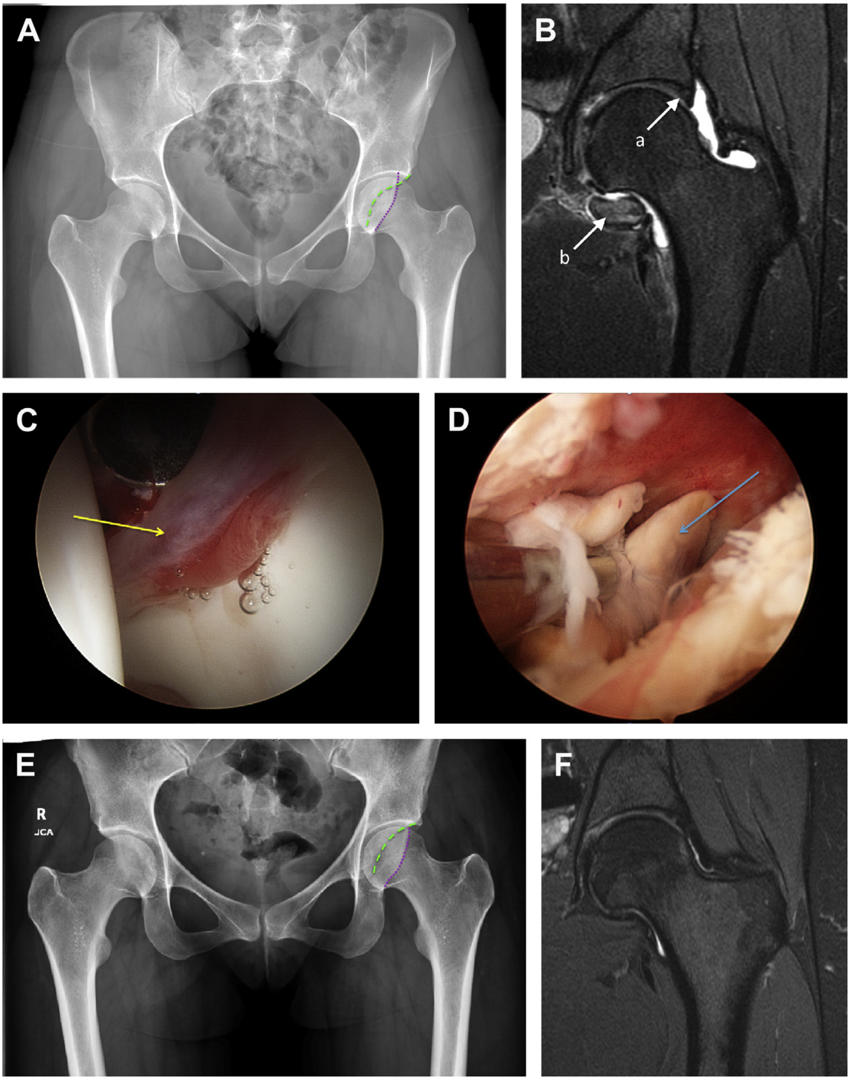

Fig. 12. (*A* and *E*) AP Pelvis with dotted line outlining the posterior acetabular wall and the dashed line outlining the anterior wall. (*B*) MRA of an anterosuperior labral tear (*arrow* a) and nonenhancing synovial mass (*arrow* b) inferior to the femoral head-neck junction. Intra-articular anesthetic injection provided immediate relief of her symptoms. Treatment consisted of arthroscopic acetabular rim reduction and labral refixation, followed by intra-articular excisional biopsy of hypertrophic synovial tissue. (*C*) Arrow represents the anterior labral tear with synovitis. (*D*) Arrow represents the soft tissue mass in the peripheral compartment/inferior medial femoral neck. (*F*) 1 year follow up MRI demonstrating repaired labrum and no mass in the inferior femoral neck region.

Case 2. Combined Pincer and Cam Impingement with Acetabular Rim Stress Fracture

A 22-year-old man presented with a 6-year history of bilateral hip pain, worsening on the left side over a 3-month period before his visit. A positive labral stress test and impingement test, as well as restricted range-of-motion with flexion and internal

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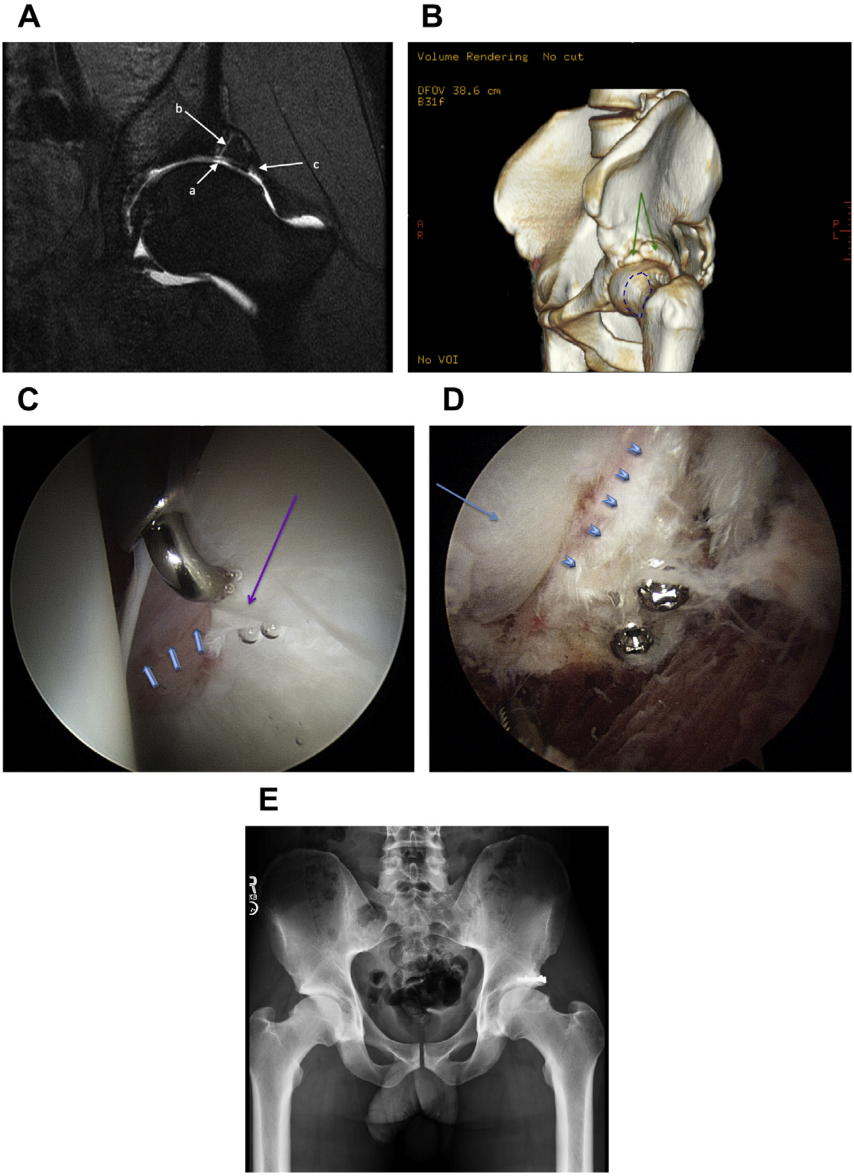

Fig. 13. (*A*) MRA demonstrating (*arrow* a) with articular cartilage thinning, (*arrow* b) demonstrating the fibrous line at the acetabular bony rim fracture and (*arrow* c), labral degeneration. (*B*) 3D CT scan reconstruction showing the bipartite acetabular rim fragments (*arrows*) and cam lesion (dashed line encircling the lesion). (*C*) Arthroscopic view from within the central compartment, demonstrating the acetabular rim injury (*short arrows*) and chondral lesion (*long arrow*). (*D*) Arthroscopic view from the peripheral compartment demonstrated the screws fixing the acetabular rim injury, with the long arrow pointing to the femoral head reduced in the joint, and the short arrowheads pointing to the labrum attached to the rim fragment, and sealing the joint over the femoral head. (*E*) Post op radiograph demonstrating the screws fixing the acetabular rim injury and restoration of femoral head-neck offset.

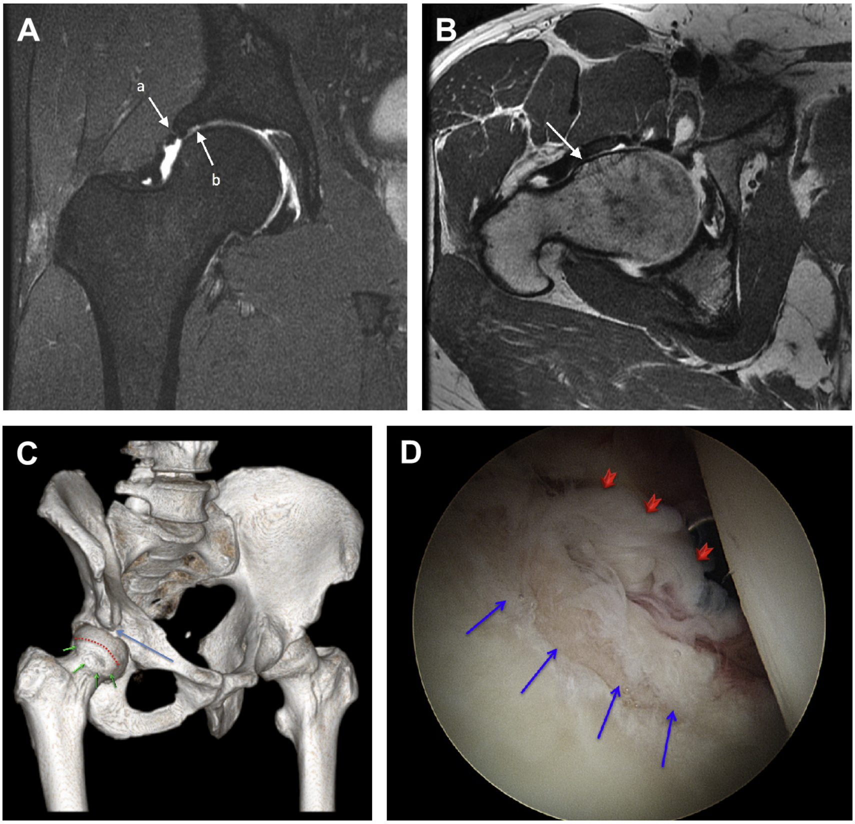

Fig. 14. (*A*) Coronal MRA demonstrating labral degeneration and tearing (*arrow* a) while (*arrow* b) points to the articular cartilage degeneration. (*B*) Axial MRI demonstrating anterior loss of femoral head neck offset (*arrow*). (*C*) A 3D CT Scan reconstruction demonstrating the elongated AIIS (*long arrow*), cam lesion (*short arrows*) and the outline of the normal location for the femoral head neck offset. (*D*) Arthroscopic view of the anterior acetabulum. The arrows point to the margin of damaged articular cartilage, while the stars highlight the badly damaged labrum. (*E*) Another arthroscopic view of the anterior supraacetabular region with the solid long arrow pointing to the femoral head, the dashed arrow to the anterior acetabular rim, after acetabuloplasty, and the arrowheads outlining the enlarged AIIS. (*F*) An arthroscopic view of the peripheral compartment demonstrating a crease in the femoral head, with the small arrows outlining the demarcation from normal femoral head and the cam lesion. The dashed arrow demonstrates the anterior acetabulum after acetabuloplasty, while the large arrow points to the cam lesion resulting in loss of anterior femoral head neck offset. (*G*) Arthroscopic view in the peripheral compartment demonstrating the anterior femoral head neck region after femoral osteoplasty (chielectomy) (*arrow*).

rotation, were demonstrated on physical examination. Radiographs revealed acetabular retroversion with a positive posterior wall and ischial spine signs, as well as an acetabular rim stress fracture and cam lesion of the proximal femur. CT scanning revealed a nondisplaced bipartite bony fragment located at the anterolateral acetabular rim. Anesthetic injection given at the time of MRA gave immediate relief of symptoms. MRA demonstrated elevated α angle, anterosuperior labral degeneration, and thinning of acetabular cartilage. Treatment consisted of debridement of delaminated

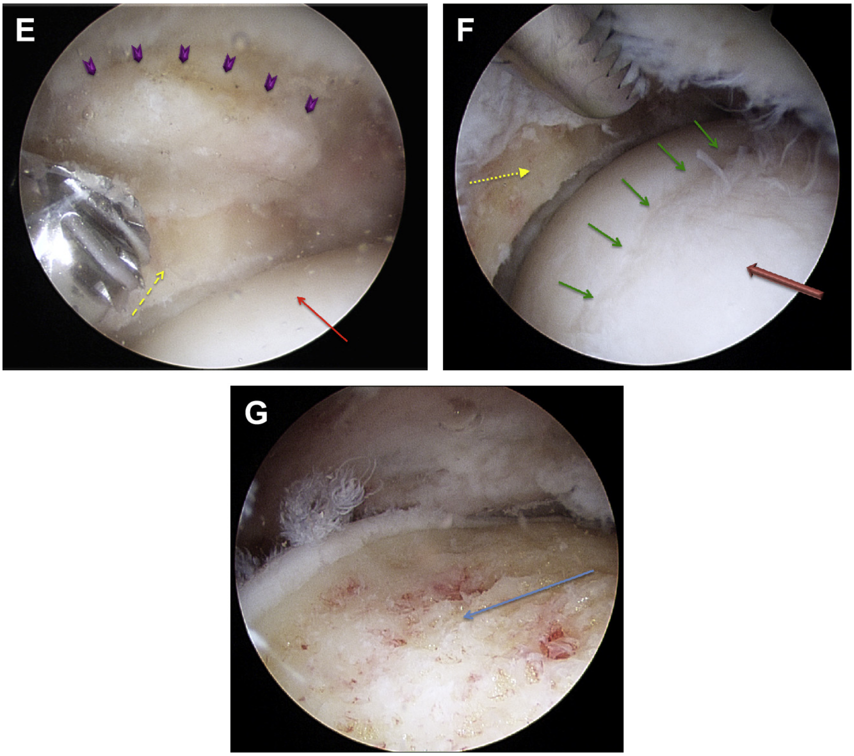

Fig. 14. (*continued*)

acetabular cartilage and microfracture to the corresponding area, acetabuloplasty, arthroscopic fixation of acetabular rim stress fracture, labral refixation, and femoral head osteoplasty (see **Fig. 2**; **Fig. 13**).

Case 3. Combined FAI with Anterior Inferior Iliac Spine Impingement

A 30-year-old man presented with a 13-year history of right-sided hip pain that started after a fall while snowboarding. Physical examination was consistent with femoroacetabular impingement and restricted range-of-motion. Radiographs revealed loss of anterolateral femoral head-neck contour, mild acetabular retroversion, and an enlarged anterior inferior iliac spine impingement (AIIS). Anesthetic intra-articular injection gave immediate partial pain relief. MRA was consistent with both cam and pincer pathologies and demonstrated anterosuperior labral tear and chondral thinning. CT scanning confirmed enlargement of the AIIS. Treatment consisted of arthroscopic partial labrectomy, removal of delaminated acetabular cartilage, acetabular rim resection, proximal femoral osteoplasty, and AIIS osteoplasty (**Fig. 14**).

Case 4. Combined Pincer and Cam Impingement

A 35-year-old man presented with a 4-month history of right groin and lateral-sided hip pain after falling down the stairs. On physical examination, the patient had pain with flexion and internal rotation of the hip. Radiographic analysis revealed anterolateral acetabular overcoverage and a cam lesion of the proximal femur. MRA demonstrated

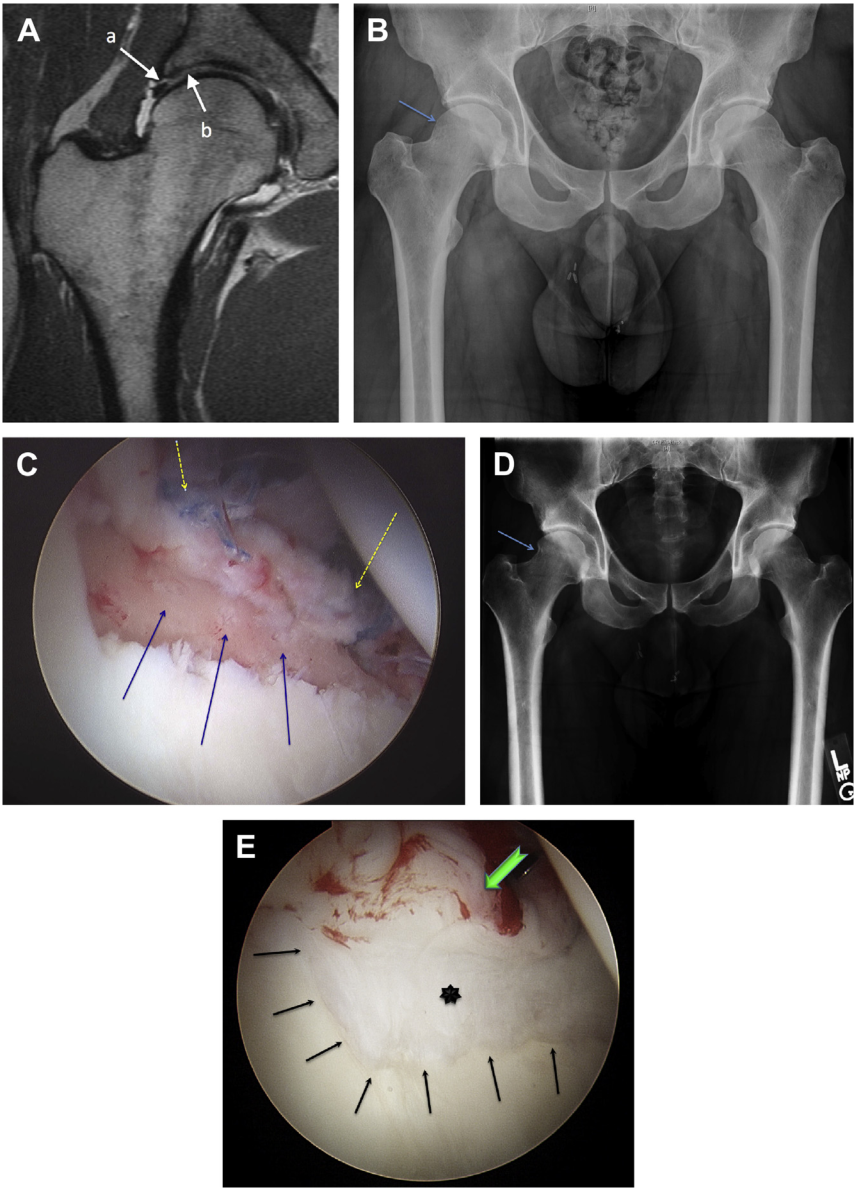

Fig. 15. (*A*) An MRA of the right hip. (*arrow* a) points to the anterolateral labral-chondral separation while (*arrow* b) points to an area of articular cartilage irregularity. (*B*) An AP pelvis radiograph demonstrating the loss of lateral femoral head-neck offset pre-operatively (*arrow*). (*C*) An arthroscopic view from the central compartment. The dashed arrows point the labrum which was refixed (blue sutures seen). The long solid arrows point to the area of chondral damage (exposed bone) which has undergone microfracture. (*D*) A post operative AP Pelvis radiograph demonstrating restoration of lateral femoral head neck offset (*arrow*). (*E*) Follow up arthroscopic image of this patient. The large, 3D arrow points to the healed labrum, with synovialization of the sutures (sutures not seen), while the star is in the center of the fibrocartilage at the anterior acetabulum as a result of the microfracture, and the multiple arrows outlining the demarcation between normal hyaline cartilage and the residual fibrocartilage resulting from the microfracture.

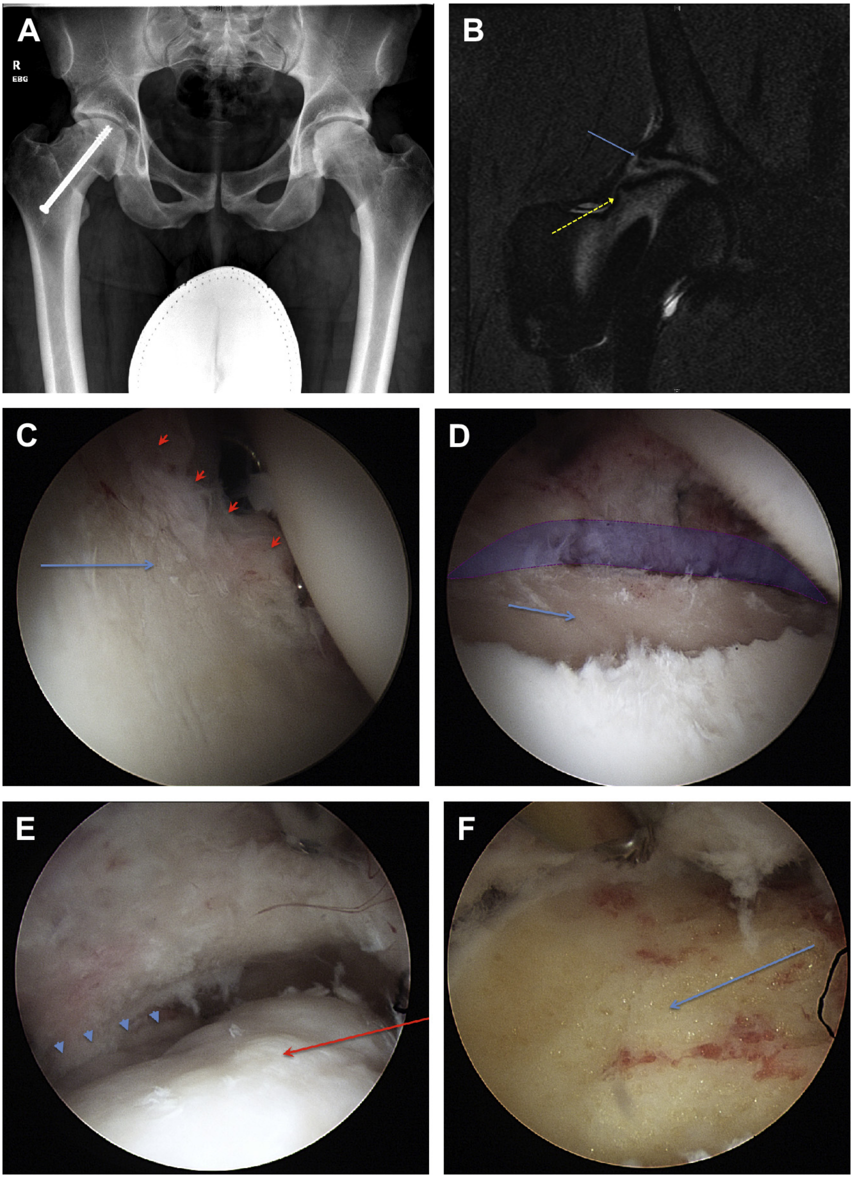

Fig. 16. (*A*) An AP Pevlish radiograph demonstrating a single screw used to internally fix a SCFE. The hip is in varus, with loss of femoral head neck offset. There is also acetabular retroversion as seen with the ischial spine and cross over signs, bilaterally. (*B*) Metal suppression MRI with the dashed arrow showing the loss of femoral head neck offset (cam lesion) and the solid arrow highlighting the anterolateral labral tear. (*C*) An arthroscopic view of the intra-articular acetabular chondral (*long arrow*) and labral tearing (*small arrows*). (*D*) Another arthroscopic view demonstrates the anterior acetabulum after partial labrectomy, acetabular rim reduction (shaded area) and chondroplasty wtih the arrow pointing to exposed acetabular bone. (*E*) An arthroscopic view of the peripheral compartment demonstrating the irregular anterior femoral neck with bumps, resulting in cam impingement, and the small arrows demarcating the acetabular rim after acetabuloplasty. (*F*) An arthroscopic view demonstrating the peripheral compartment after femoral osteoplasty, restoring the femoral head neck osteoplasty (*arrow*).

an anterolateral chondrolabral separation and an elevated α angle. CT reconstruction further delineated the cam deformity. The patient underwent arthroscopic labral takedown and chondroplasty of the delaminated acetabular cartilage, followed by acetabular microfracture and labral refixation. After addressing the pathologic condtion of the central compartment, a femoral head-neck osteoplasty was performed to debulk the existing cam deformity (**Fig. 15**).

Case 5. FAI from Residual SCFE Deformity

A 21–year-old collegiate football player with a history of right-sided slipped capital femoral epiphysis presented with hip pain since an in situ screw fixation at the age of 15. Physical examination demonstrated limited hip flexion and internal rotation and positive impingement testing. Intra-articular anesthetic injection resulted in complete relief of symptoms. MRA with metal suppression demonstrated anterolateral labral tearing and asphericity of the femoral head. Treatment consisted of arthroscopic partial labrectomy, acetabular rim reduction, and femoral osteoplasty (**Fig. 16**).

SUMMARY

FAI has been recognized with increasing frequency as a source of hip pain and dysfunction. MRI is useful for detecting both the morphologic features of and the pathologic changes associated with FAI. Understanding both normal and abnormal MRI anatomy of the hip is important for accurately diagnosing and treating FAI. An understanding of the technical considerations involved in MRI is essential for obtaining the appropriate imaging studies required for diagnosis.

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