# 5 Imaging of the Hip

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**Learning Objectives**
- Understand different osseous pathologies of the hip joint.
- Know the key imaging findings of the different types of impingement of the hip joint.
- Explain typical patterns of intra-articular damage of the hip joint.

## 5.1 Introduction

In the last two decades, hip imaging has changed substantially. While hip joint damage was commonly evaluated in conditions such as developmental dysplasia of the hip or osteoarthritis, an additional condition for early onset hip osteoarthritis has been discovered since: femoroacetabular impingement (FAI). New biomechanical insights and improved techniques for hip preservation surgery have triggered the need for imaging evaluation of patients with suspected FAI [1].

Imaging technology has also changed quite a bit over these last two decades. Magnetic resonance imaging (MRI) sequences have become faster, and at the same time, the image resolution is much better than at the turn of the century, allowing for a more accurate evaluation of labrum and cartilage. And computed tomography (CT) datasets are now increasingly being used for preoperative 3D planning, e.g., with the use of patient-specific instruments modeled to the individual anatomical deformity.

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## 5.2 Imaging Evaluation

The radiographic examination is a critical component in the diagnostic evaluation and treatment decision-making process and considered the first-line imaging technique in the evaluation of hip pain. Anteroposterior view of the pelvis is standard, and dedicated views of the symptomatic hip are often performed in the athletic hip which include cross- table lateral, frog-leg lateral, or Dunn lateral. According to the American College of Radiology Musculoskeletal Imaging Criteria [2], MRI is the next appropriate imaging method in those individuals with negative radiographs. For symptoms of generalized pain or nonspecific physical exam findings, imaging is best performed with conventional MRI of the pelvis and hip. If symptoms or clinical exam findings suggest intra-articular pathology, dedicated small field-of-view (FOV) MR arthrography of the hip is considered the imaging method of choice. Recently, high-resolution conventional MR imaging is replacing MR arthrography at many centers.

## 5.3 Osseous Disease

### 5.3.1 Stress Fractures

Stress injuries are due to a mismatch between native bone strength and chronic mechanical load applied on bone over time [3]. However, because stress injuries may progress to complete fracture and result in prolonged recovery or career-ending complications, it is imperative to identify these injuries early. Stress injuries are most commonly seen in endurance athletes, such as runners and military recruits, as well as recreational athletes with sudden increase in activity [4]. Stress fractures are classified as fatigue, resulting from normal bone being subjected to abnormal repetitive forces, and insufficiency, due to normal stress placed on abnormal bone [3].


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The repetitive overloading stimulates bone remodeling, beginning with osteoclastic activity that is not matched by reparative osteoblastic activity and periosteal maturation, which lag 10–14 and 20 days, respectively. This causes temporary weakening of the marrow and cortical bone, leading to microtrabecular fractures (stress reaction) and cortical failure (stress fracture). Radiographs are not very sensitive in the identification of stress injuries of the femoral neck. Classic MRI features include ill-defined focal or diffuse high T2 bone marrow signal due to microtrabecular fractures and intramedullary edema, with or without corresponding low T1 signal and/or periosteal edema (Fig. 5.1). With any of these findings, one should carefully evaluate for a hypoin- tense band in the marrow or focal cortical abnormality,indicating stress fracture and necessitating prolonged non- weight-bearing or rest from sporting activity. Because of thesevere consequences of undiagnosed femoral neck stress fractures, the diagnosis is based on combined imaging find- ings of periosteal edema, endosteal edema, and high corticalsignal, regardless of visible fracture line [4].

### 5.3.2 Osteonecrosis

Femoral head osteonecrosis (ON) is a common disease and potentially disabling disorder affecting mainly middle-aged adults that can lead to early osteoarthritis due to femoral head collapse and joint incongruity. It is estimated that the rate of symptomatic femoral head ON is 2–4.5 cases per patient year, resulting in 10,000–20,000 new cases annually in the United States. However, this incidence markedly underestimates the true prevalence of ON, as the majority of patients are asymptomatic [5]. Various conditions have been associated with the development of ON, with idiopathic causes, trauma, corticosteroid use, and alcohol consumption implicated in most cases. Other causes include metabolic and hematologic disorders, marrow storage disorders, pancreatitis, radiation, drug therapy, occlusive vascular disease, infection, renal disease, Caisson disease, and rheumatologic conditions [5].

Fig. 5.1 Coronal T2 fat-suppressed MR image in a 40-year-old runner with hip pain shows edema along the medial femoral cortex and endosteal edema representing a stress fracture (arrow)

The initial phase of ON is cell death, interruption of cell enzymes, and loss of cell metabolic activity. The next pathologic phases represent a continuum of development of a reactive interface in an attempt to wall off and repair the area of ON. Over time, the reactive interface continues to develop and mature as a discrete zone at the margin of the area of ON. This reactive interface zone is essentially a vascularized granulation tissue attempting to repair the area of ON. Within the epiphysis, the junction of the reactive zone with the articular subchondral bone plate undergoes increased bone resorption which can lead to early fracture of the overlying cartilage at these locations and subsequent subchondral fracture. This is often the earliest manifestation of an impending articular collapse [6, 7]. Progressive fragmentation of the articular surface and secondary osteoarthritis are almost inevitable due to cortical flattening and collapse.

Diagnosis of femoral head ON depends on the combination of clinical symptoms and evaluation of radiographs and/or MRI (Fig. 5.2). Imaging has an important role in ON evaluation, allowing early detection, assessment of severity and prognosis, treatment options, and postoperative follow-up [7]. Radiographs are the initial imaging method in the evaluation of the patient with hip pain, however, are insensitive for early changes of ON [6]. In late stage ON, the radiographic features are often characteristic and usually do not require further imaging workup. At ini- tial stages, nonspecific patchy areas of lucency and sclero- sis can be identified on radiographs. As the disease progresses, a subchondral fracture with a crescentic appearance (crescent sign) may be visualized. Eventually this will lead to articular surface collapse and development of secondary osteoarthritis [6].

MR imaging is the most sensitive method for detecting early ON. There are two conditions involving the femoral head that can mimic ON leading to misdiagnosis and require imaging distinction: bone marrow edema syndrome (transient osteoporosis of the hip) and subchondral insufficiency fracture. A missed diagnosis and delay in appropriate treatment may result in disease progression and significant morbidity. Therefore, extra care in differentiating this process from other causes of femoral head or neck edema is important.

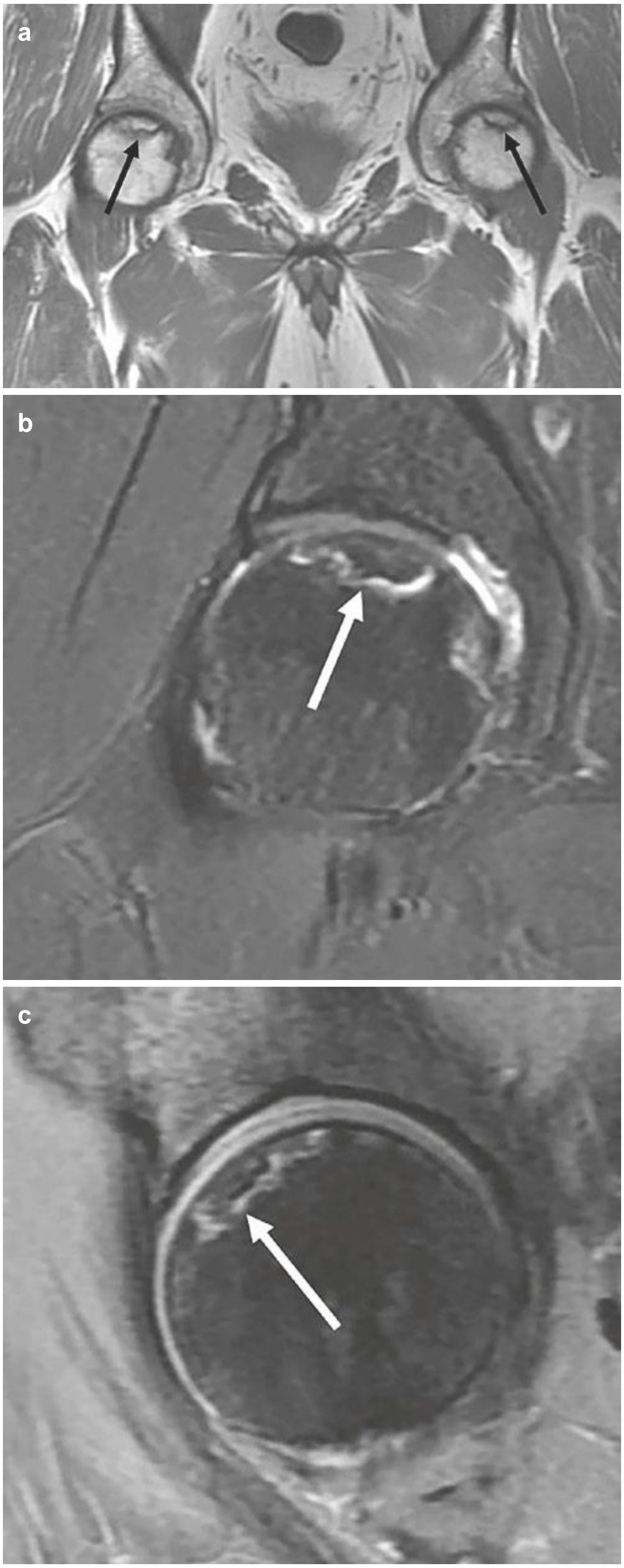

**Fig. 5.2** Coronal T1 (**a**) MR shows bilateral femoral head serpentine low signal foci representing osteonecrosis in this 61-year-old man (arrows). Small field-of-view coronal T2 fat-suppressed (**b**) and sagittal PD fat-suppressed (**c**) images show the amount of involvement of the femoral head (arrows)

The MR appearance of ON is most commonly described as a geographic subchondral bone marrow signal abnormality, including band-like or linear T1 hypointensity representing the demarcation/transition zone [8]. The "double line sign" on T2-weighted images, described as a low-intensity outer rim with inner rim of hyperintense granulation tissue, is pathognomonic for this process [9]. Subchondral collapse, which is often underestimated on MR imaging, is not seen until late in the disease process and is a sign of poor prognosis. The continuous linear low signal abnormality with generally convex contour helps differentiate this entity from femoral head insufficiency fractures. Bone marrow edema is found with higher stages of ON and not considered an early finding [10]. The late stage imaging findings include edema around the transition zone, edema and/or sclerosis in the necrotic zone, subchondral fractures, collapse, and osteoarthritis. The edema has been shown to correlate with pain and more likely to progress to collapse [11].

Various staging systems have been developed for assessment of adult femoral head ON [12, 13]. All of these staging systems have in common progression from radiologically occult disease to positive imaging findings of ON to femoral head collapse and finally development of secondary osteoarthritis. The clinical significance of epiphyseal ON is almost entirely dependent on articular surface collapse [5]. The femoral head volume that is involved by ON appears to be the most important imaging predictor of subsequent articular collapse. ON affecting more than 25–50% of the femoral head volume is more likely to progress to articular collapse, while femoral head ON involving less than 25–30% of the femoral head is unlikely to progress to artic- ular surface collapse [5].

### 5.3.3 Subchondral Insufficiency Fracture

Subchondral insufficiency fractures (SIF) of the femoralhead are a cause of marked mechanical hip pain and typi- cally occur in the older, osteoporotic population. These frac-tures may progress to advanced collapse and therefore should be recognized on imaging and distinguished from osteonecrosis [6]. The MR imaging findings of SIF are that of a low signal subchondral line that parallels the articular surface and extensive bone marrow edema of the femoral head/neck (Fig. 5.3). The presence of the typical band of low signal intensity in the subchondral bone, convex to the articular surface, has been suggested as specific for an insuf- ficiency fracture, distinguishing it from the well-definedzonal pattern of signal abnormality found in osteonecrosis. Additionally, contrast-enhanced MR imaging may be help- ful to distinguish SIF from osteonecrosis where hips with SIF will enhance proximal to the low signal intensity band in the femoral head, while osteonecrosis does not enhance proximally [14].

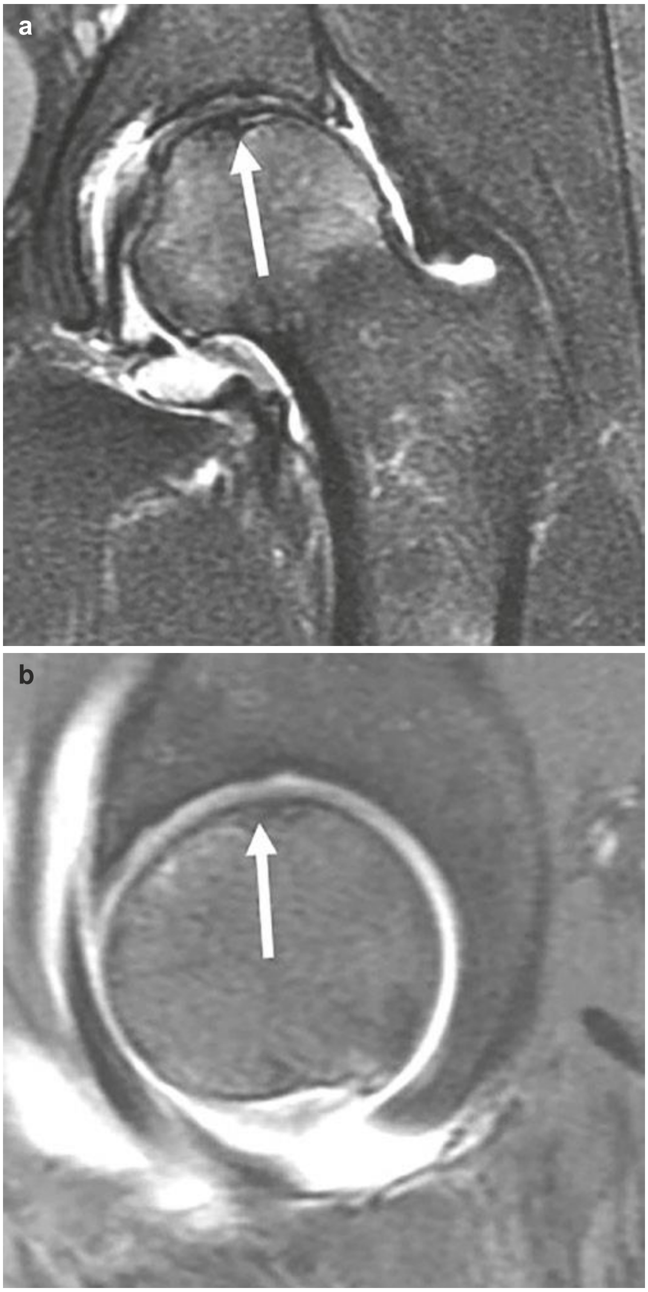


**Fig. 5.3** Coronal T2 fat-suppressed (**a**) and sagittal PD fat-suppressed (**b**) MR images in a 51-year-old woman demonstrates subchondral insufficiency fracture (arrows). A subchondral linear band of low signal is present beneath the femoral head with surrounding bone marrow edema

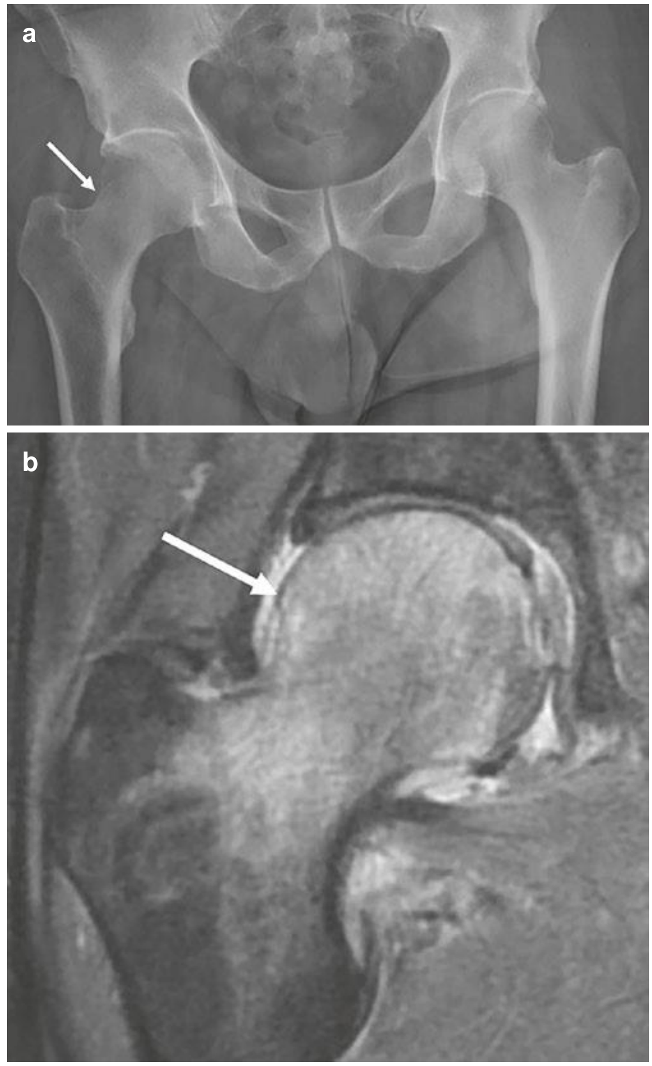


**Fig. 5.4** Anteroposterior radiograph (**a**) of the pelvis in a 52-year-old man shows lucency of the right femoral head/neck (arrow). Coronal T2 fat-suppressed MR image (**b**) shows diffuse bone marrow edema within the femoral head/neck (arrow). There is no subchondral fracture line or findings of osteonecrosis

### 5.3.4 Bone Marrow Edema Syndrome

The term transient bone marrow edema syndrome describes two clinical entities, transient osteoporosis of the hip (TOH) and regional migratory osteoporosis (RMO). Many consider this to be a "transient painful marrow edema." These conditions have basic characteristics which include sudden onset of pain in middle-aged men and in pregnant/post-partum women, spontaneous with gradual resolution of symptoms with conservative treatment (6–8 months), and presence of bone marrow edema on MRI [6]. This is typically a unilateral process but, however, can involve the contralateral side. Radiographs may show severe osteopenia of the proximal femur and require at least 5 weeks from the onset of symptoms to become evident [15]. The MR imaging findings include bone marrow edema within the femoral head/neck and hip joint effusion (Fig. 5.4). There should not be a double line or demarcation sign as seen with osteonecrosis or subchondral changes. Insufficiency fractures may occur. Our recommendation is if you see diffuse edema on MR within the femoral head/neck, the patient may be vulnerable to insufficiency fracture. If a fracture line is present, just describe this as an insufficiency fracture.

## 5.4 Hip Impingement

There are several types of intra- and extraarticular impingement of the hip. While this chapter covers femoroacetabular impingement (FAI), abnormal femoral torsion, and subspine impingement, other types of extraarticular impingement exist, such as ischiofemoral impingement, greater trochanter impingement, or impingement due to extreme hip motion, such as in ballet dancers or kickboxers [16].

### 5.4.1 Biomechanical Concepts

Femoroacetabular impingement (FAI) is typically seen in young and athletic individuals who report hip or groin pain and present with reduced internal rotation of the hip joint [17]. At imaging there are two well-recognized osseous hallmarks of FAI: the cam deformity at the head-neck junction of the femur is the first hallmark (Fig. 5.5), and the second is an increased osseous coverage of the acetabulum known as pincer deformity, either due to a generally increased coverage or due to focal retroversion of the upper portion of the acetabulum. If these osseous deformi- ties are present, a mechanical conflict may occur during internal rotation, with an increased mechanical impact between the proximal femur and the acetabular bone and subsequent damage to the acetabular labrum and to thearticular cartilage of the hip.

There is however a third major osseous factor in the pathogenesis of FAI: femoral torsion, also termed femoral version, is the angle between the orientation of the femoral head and neck proximally versus the orientation of the femoral condyles distally, at the level of the knee. While increased femoral antetorsion has long been recognized as a part of the osseous deformities in developmental dysplasia of the hip, the discovery that abnormal femoral torsion plays a substantial role in the development of FAI is much more recent [18].

The three major osseous factors for the development of FAI are often seen in combination and not as isolated entities [19]. When evaluated individually, the literature shows that the risk of subsequent hip osteoarthritis is highest in the presence of a cam deformity, while this association is less well established for isolated pincer deformities and abnormal femoral antetorsion [1].

**Key Point**

- The three major osseous factors in the pathogenesis of femoroacetabular impingement (FAI) are thecam deformity, pincer deformity, and abnormal femoral antetorsion.

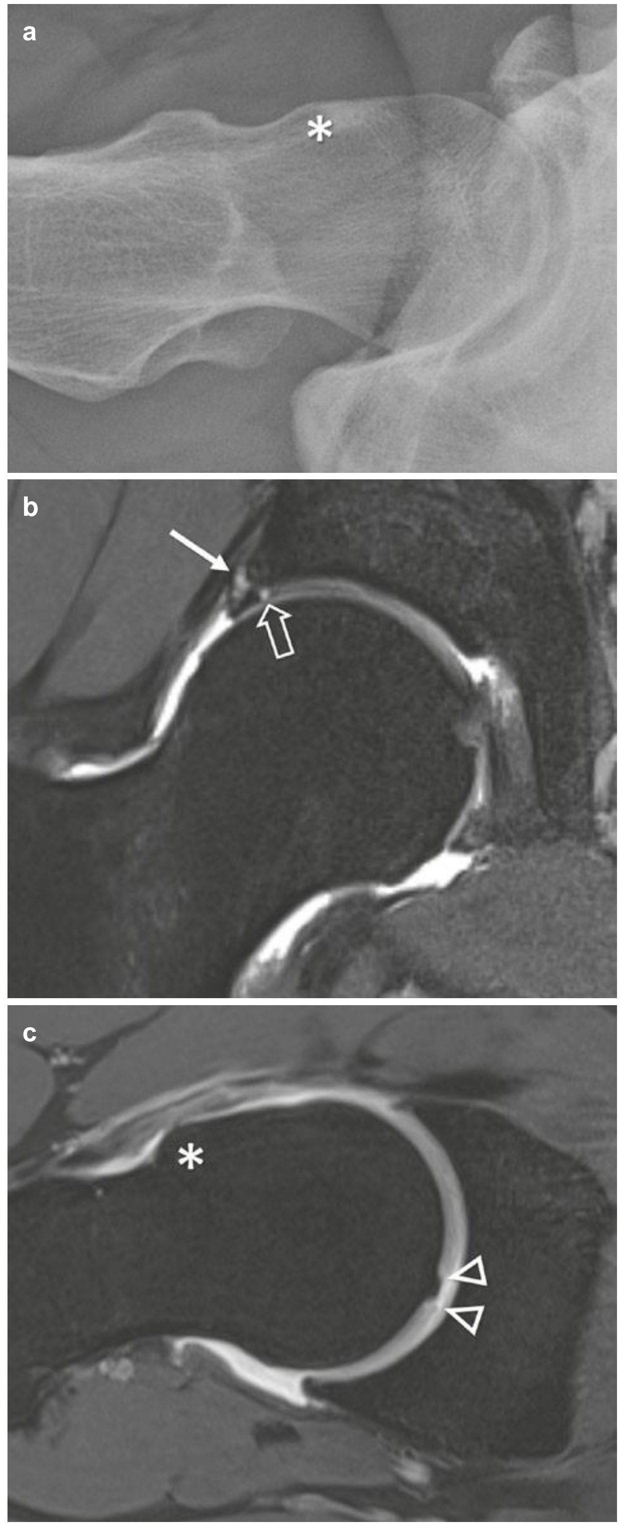


**Fig. 5.5** Cross-table lateral radiograph (**a**) of the right hip in a 32-year old male competitive fencer with femoroacetabular impingement showing a large anterior cam deformity (asterisk). Coronal PD fat-suppressed (**b**) MR image demonstrates full-thickness labral tear with intra-substance ganglion (thin arrow) and adjacent peripheral defect of acetabular cartilage (outline arrow). Oblique axial T2 fat-suppressed (**c**) MR image shows an intra-cartilaginous osteophyte and adjacent central cartilage defects of the femur (arrowheads) as well as the cam deformity (asterisk)

### 5.4.2 Imaging Evaluation of FAI

After clinical examination, patients with suspected FAI are evaluated with radiographs as the first step of the imaging workup. On standard anteroposterior pelvic radiographs,the osseous coverage of the acetabulum is assessed, in order to detect the presence of a pincer morphology of the hip joint. A general increase of acetabular coverage is indi- cated by an increased lateral center edge (LCE) angle. An LCE angle of more than 40° indicates a deep acetabulum or coxa profunda. Alternatively, the depth of the acetabulum can be assessed visually, by identifying the presence orabsence of an intersection between the acetabular fossa and the ilioischial line [20].

Apart from a generally increased osseous coverage, the orientation of the acetabulum can also be abnormal: if the acetabulum is retroverted, this results in an increased mechanical conflict between the femur and the acetabulum during internal rotation. Typically, it is the upper portion of the acetabulum where this retroversion occurs, which can be readily assessed on anteroposterior pelvic radiographs. The following three signs are indicative of acetabular retroversion: the crossover sign (or figure-of-eight sign), the posterior wall sign, and the ischial spine sign. While both the quantitative and qualitative assessment of pincer deformities on radiographs are easy to perform, it is important to know that to some degree these osseous deformities can also be detected in asymptomatic individuals. While the radiographic evaluation is an important part of the assessment of patients with FAI, there is noclear threshold that reliably allows identifying patients with pincer-type FAI [20].

Some cam deformities can be seen on radiographs, but typically MRI or CT with radial reformations is needed for the detection and assessment of cam deformities, especially in the location where they most commonly occur, the anterosuperior aspect of the femur. Over the years, many measurements have been proposed to assess cam-type deformities, such as the alpha-angle, femoral offset, and femoral distance measurements. The best-known measurement is the alpha-angle, which was introduced 20 years ago for assessing cam deformities at the anterior location of the femoral head. The initially proposed threshold for the alpha-angle was 55°, but later data showed that in a clinical setting, this results in a substantial number of false-positive cases [21, 22]. Raising the threshold to 60° or an evenhigher value reduces the rate of false positives but also sub- stantially reduces the sensitivity of the measurement, asthere is a large overlap in the presence of osseous deformi- ties between asymptomatic healthy individuals and patients with FAI. There is no clear threshold that reliably allows identifying patients with cam-type FAI.

### 5.4.3 Assessing Joint Damage in FAI

An important part of the imaging evaluation in patients with suspected FAI is the assessment of any damage to the labrum and articular cartilage, which is described later in this chapter. Importantly, the assessment of joint damage allows accurate preoperative planning in those patients that need surgery. Moreover, in patients scheduled for surgery, the assessment of joint damage allows the stratification of patients into those with only minor and peripheral joint damage – these individuals can expect a good long-term outcome after arthroscopic surgery. Patients with more central lesions of the articular cartilage or widespread joint damage may choose to undergo surgery for pain relief, but the surgical procedure will not allow to prevent or delay osteoarthritis in those patients [1].

### 5.4.4 FAI Treatment

Exercise therapy is considered a good first option in patients with symptomatic FAI, with half of patients benefiting from a 12-week regimen of progressive exercise therapy. However, exercise therapy usually is not successful in patients with severe cam deformities, and in those patients, surgery is often advised [23]. Surgical treatment of symptomatic patients with FAI has a good success rate, with 80% of all patients reporting a good outcome and with a high rate of return to sport for professional athletes: in a recent meta- analysis, 94% of professional athletes returned to sports after arthroscopic hip surgery [17]. Those professional athletes with a shorter duration of symptoms before surgery had a significantly higher rate of return to sports than those with long-standing preoperative symptoms. The rate of conversion to hip arthroplasty after previous FAI surgery is 10% at 10-year follow-up, and patients with labral reattachment show a better clinical outcome than patients with a resected labrum, but without a difference in progression of osteoarthritis or conversion to hip arthroplasty [24].

### 5.4.5 Femoral Torsion

Decreased femoral antetorsion results in an additional mechanical impaction during internal rotation of the hip, worsening the symptoms of FAI patients with a cam or pincer deformity [18]. Femoral antetorsion tends to be lower in patients with cam-type FAI, but the range of femoral torsion seen in patients with FAI is large, with an average femoral torsion of 13° and a normal range of 4°–20°. Consequently, in some patients femoral torsion plays an important role in the development of FAI, while in other patients this factor is

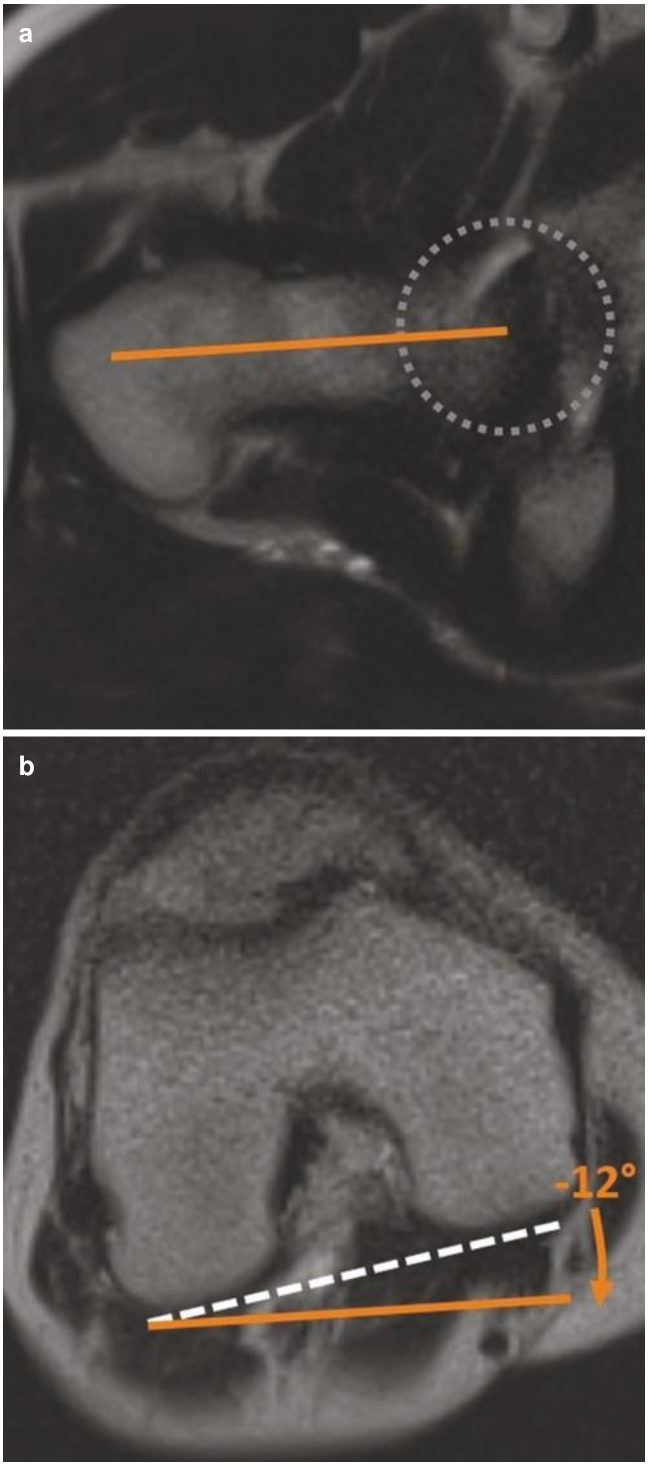


**Fig. 5.6** Femoral retrotorsion in a 33-year-old man with hip pain. Axial T2 MR images over the proximal (**a**) and distal (**b**) femur show that the femoral neck axis (orange line in **a**) is oriented in 12° retrover-sion compared to the tangent at the femoral condyles (dashed white linein **b**). No cam or pincer deformities were seen in this patient

not relevant. On the other hand, abnormal femoral torsion (Fig. 5.6) can also cause symptoms in patients without cam or pincer deformities [16].

Femoral torsion needs to be measured at CT or MRI, because the clinical assessment of femoral torsion is notoriously unreliable [25]. Both CT and MRI are feasible for measuring femoral torsion, with MRI being the favored imaging method due to the lack of radiation.

**Key Point**

- Decreased femoral antetorsion results in increased mechanical impact during internal rotation of the hip, while increased femoral antetorsion can result in posterior extraarticular impingement.

Several reproducible measurement methods have been described, and it is advisable to use a consistent method that is both accepted by the radiologists and the surgeons or sport physicians treating the patient. Care should be taken however to employ only strictly axial images for femoral torsion measurements, as the use of axial oblique images results in divergent measurements [26]. While in most patients decreased femoral torsion is associated with reduced range of motion due to intra-articular impingement, in about a third of patients, reduced femoral torsion is associated with subspine impingement [27].

In FAI patients with abnormal femoral torsion, often the surgical removal of the cam deformity and acetabular rim trimming increase the range of motion of the hip joint sufficiently to also compensate for the abnormal femoral torsion. In patients with severe torsional abnormalities, or in patients with abnormal femoral torsion without concomitant FAI, a de-rotation osteotomy of the femur can be performed to normalize femoral torsion.

### 5.4.6 Subspine Impingement

Before the closure of the apophysis at the anterior inferior iliac spine (AIIS), apophyseal avulsion may occur in young athletes with repeated heavy loads on the hip such as soccer players (Fig. 5.7). Specifically, it is the origin of the rectus femoris tendon at the AIIS that is affected, either due to a single traumatic injury or due to repeated traction injuries [28].

The AIIS is typically enlarged in these patients, with a prominent osseous protrusion at the origin of the rectus femoris tendon. There is mechanical impaction between the AIIS and the proximal femur in these patients during hip flexion, and the disorder has been termed subspine impingement due to the impingement of soft tissues between the anterior inferior iliac spine and the femoral neck.

The apophyseal injuries of the AIIS typically affect adolescents, but the sequelae can persist into adulthood, as is

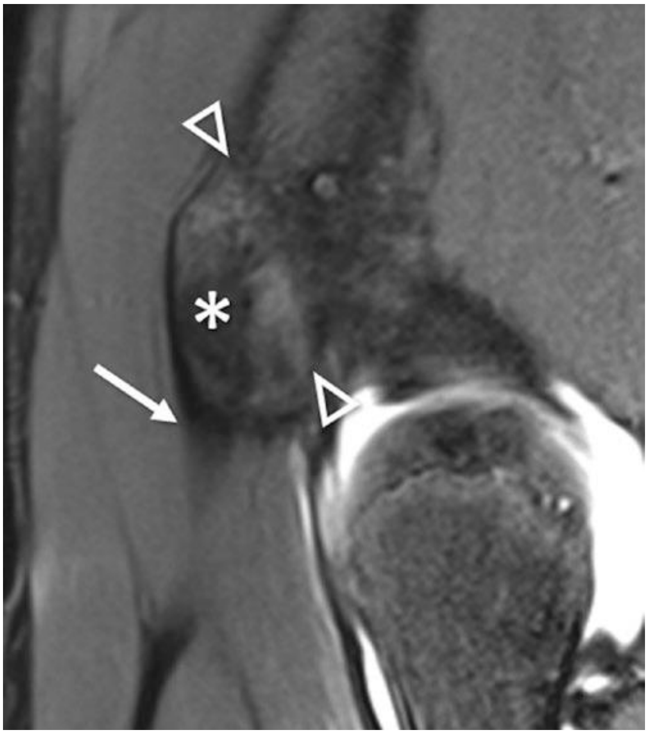


**Fig. 5.7** Subspine impingement in a 14-year-old female soccer player with previous apophyseal avulsion. Sagittal PD fat-suppressed MRI shows widened and irregular aphophyseal gap (arrowheads) and displacement and enlargement of the anterior inferior iliac spine (asterisk). Note origin of the rectus femoris tendon (arrow)

evident in a recent report of patients who were surgically treated for subspine impingement at an average age of 43 years [29]. However, most patients respond well to conservative treatment.

**Key Point**

- Subspine impingement is a mechanical impaction between an enlarged anterior inferior iliac spine (AIIS) and the anterior aspect of the femoral neck in patients with previous apophyseal avulsion injury of the rectus femoris tendon.

Subspine impingement is often seen in patients who also suffer from FAI, possibly because both disorders are more commonly seen in athletes involved in high-level sports at a young age, just before the closure of the growth plates [30]. In adolescents, a widened and irregular growth plate may be seen at imaging, with adjacent bone marrow edema at MRI. In adult patients with long-standing subspine impinge-ment, imaging signs in addition to an enlarged AIIS may include an osseous bump at the distal femoral neck and supe-rior capsular edema adjacent to the AIIS. A distal location of a cam deformity at the anterior aspect of the femoral neck is an independent risk factor for symptomatic subspine impingement [29].

## 5.5 Intra-articular Damage

### 5.5.1 Acetabular Labrum

The acetabular labrum is a fibrocartilaginous structure attached to the rim of the bony acetabulum. The transverse ligament creates a complete ring inferiorly, attaching to the anterior and posterior margins of the inferior labrum. Despite a limited vascular supply, there is an ample network of nerve endings with nociceptive and proprioceptive functions, explaining why labral tears may be painful [31]. The labrum is thought to increase stability at the hip joint, deepening the acetabulum which helps to resist lateral and vertical translation for the femoral head. The labrum also provides a seal for the joint, enhancing fluid lubrication, maintaining synovial fluid pressure, and preventing direct contact of the joint surfaces.

The shape of the labrum is triangular in the majority of individuals with the base attached to the bony acetabulum and acetabular cartilage [32], although it can have a rounded or irregular configuration. These variations from the expected triangular shape have been correlated with increasing age, suggesting typical degeneration. Labral hypoplasia or absence is described by some as a normal phenomenon, reportedly found in 1–10% of the population [32]. In general, however, absence of the labrum is more commonly seen in older individuals and is considered abnormal, likely due to degeneration or a chronic tear. The MR appearance of the normal labrum is triangular in morphology and hypointense on all pulse sequences. A normal transition zone of 1–3 mm between the labrum fibrocartilage and adjacent articular hyaline cartilage is important to recognize in MR interpretation so as not to confuse the appearance for a labral tear [33].

The etiology of labral tears includes trauma (posterior dislocation, twisting injury), underlying bony abnormality (hip dysplasia or FAI morphology), anterior capsule laxity, and idiopathic or age-related tears. Of these, the most important in athletes is the presence of FAI morphology. The relationship between FAI morphology and labral tears has been well documented in studies of many athletes, including rowers, football players, and dancers [34]. Thus, labral pathology should be considered in any athlete with radiographic bony morphologic abnormalities.

There are several surgical and MR-based classifications for description of labrum tears that have been proposed [33, 35]. Due to the lack of agreement between these classifications, the imaging assessment should instead focus on an accurate descriptive report including tears, size (extent),

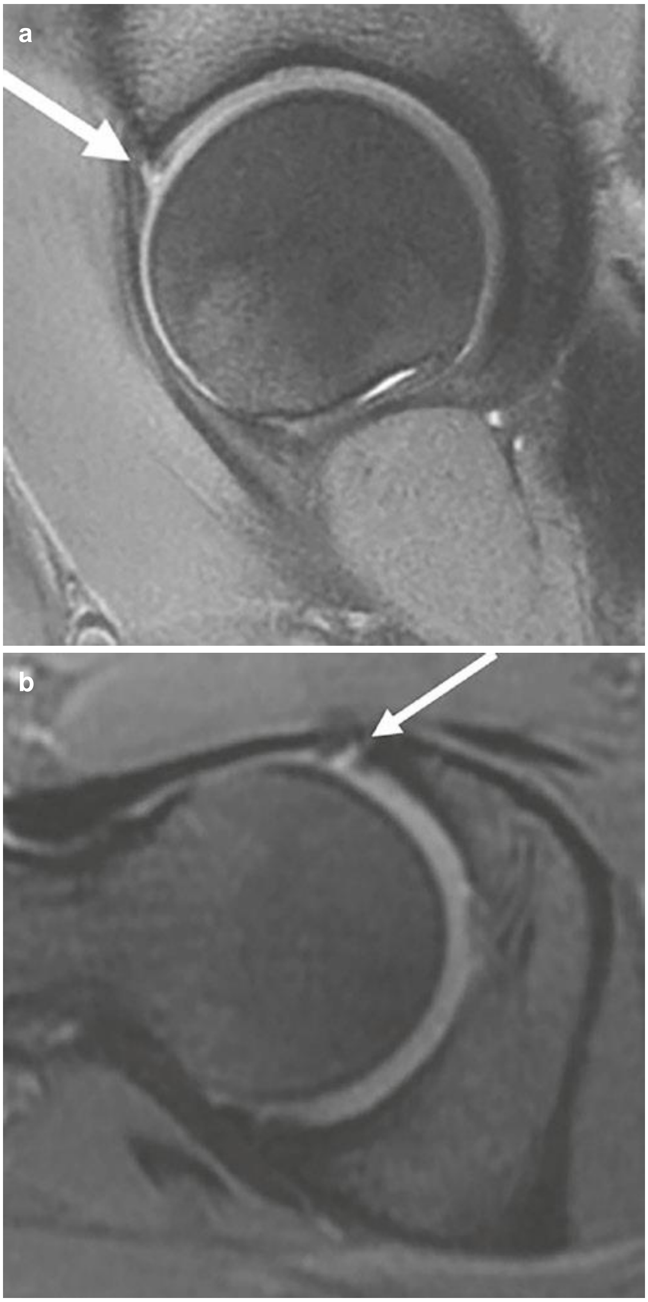


**Fig. 5.8** Sagittal (**a**) and axial oblique (**b**) PD fat-suppressed MR images in a 22-year-old woman with hip pain shows linear high signal across the labral base representing labral injury (arrow)

and associated osseous changes at the acetabular rim. The MR imaging features of labral tears include contrast orhigh signal extending into the substance of the labrum,most often from the articular surface; blunting or irregular- ity of the labral apex or undersurface; or complete detach- ment from the acetabulum [35, 36] (Fig. 5.8). Thedescription should include whether there is an intra-sub- stance tear or detachment and whether there is a partial- thickness or full-thickness tear. Additional descriptions may include frayed (irregular labrum margins without discrete tear), flap tear (contrast extending into or through labrum substance), thickened/distorted, or complex [35].The extent of the tear can be determined using a clockface or quadrant localization. An associated secondary finding isa paralabral cyst, which is most common on the capsular surface of the labrum and may extend into the subchondral bone of the acetabulum.

**Key Point**

- Imaging assessment of the labrum should focus on tears and their extent; the description should differentiate between intra-substance tears or detachment and partial- or full-thickness tears. Possible additional features such as labrum fraying, flap tear, as well as associated osseous changes at the acetabular rim should also be described.

There are several anatomic variants that mimic labral pathology and may be mistaken for tears if not recognized. High signal at the chondrolabral junction is a commonly misinterpreted imaging finding. Mildly hyperintense sig-nal at the articular surface of the labral base may be seen with cartilage undercutting and the previously describedtransition zone of the labral attachment to the articular car- tilage. The hyaline cartilage has higher signal intensity than the labrum and may extend beneath the labral base, resulting in linear intermediate to hyperintense signal atthe chondrolabral junction. This can be distinguished froma labral tear because the signal is hypointense to fluid or contrast and smoothly parallels the labral base and acetab- ular rim. Another cause of high signal at the chondrolabral junction may be due to a sublabral sulcus. This normal variant is located where the labrum meets the adjacent car- tilage but is not directly attached at the articular surface. This sulcus is present in approximately 20–25% of the nor- mal population and should not be confused with a labraltear [37]. A sublabral sulcus is a shallow, smooth defect at the labral base along the articular surface, involves less than 1/3 of the labral thickness, and often has a largerwidth than depth. The key to differentiating the normal variant sulcus from a tear includes its smooth contour, lim- ited depth, and lack of secondary abnormalities, such as cartilage damage or paralabral cysts. Sublabral sulci aremost commonly found at the posterior and anteroinferior labrum, but have been described in a variety of locations. Another smooth, shallow cleft at the chondrolabral basemay be seen at the junction of the labrum and transverse ligament: labroligamentous sulcus. This is found in up to one third of normal, asymptomatic individuals [37].

### 5.5.2 Articular Cartilage

Unlike the fibrocartilage of the labrum, the articular cartilage of the acetabulum and femoral head is composed of hyaline cartilage, which is made up of predominantly water reinforced by chondrocytes and a type II collagen and proteoglycan matrix. The cartilage covers the majority of the femoral head, sparing only the fovea superomedially where the ligamentum teres attaches. The acetabular cartilage covers the osseous surface, except at the acetabular fossa. The articular cartilage is thickest at the superolateral acetabulum and anterosuperior femoral head, where there is greatest contact and need for load-bearing support.

Cartilage injuries are commonly found in combination with other abnormalities, specifically in association with labral tears and femoroacetabular impingement and following subluxations and dislocations [38]. Therefore, those who are predisposed to labral pathology, underlying FAI morphology, and subluxation or dislocation of the hip are also considered at risk for cartilage injury. Cartilage damage may be caused by shearing, impact, or routine wear on an incongruent joint. Because of its high water content, cartilage is generally hyperintense on T2-weighted images and intermediate signal on proton density images. On MR imaging cartilage injury manifests as generalized thinning, surface irregularity, fissures, delamination, chondral flaps, or full-thickness cartilage defects (Figs. 5.9 and 5.10). A specific, although not sensitive, sign for cartilage delamination is the presence of fluid or injected contrast material undermining the cartilage layer on MR arthrography [39]. Hypointense areas in the acetabular cartilage have been shown to correlate with cartilage delamination [40]. Most cartilage injuries involve the anterior acetabulum, followed by the superior and posterior acetabulum, and cartilage lesions are often accompanied by labral pathology, particularly when higher-grade cartilage damage is present. As the

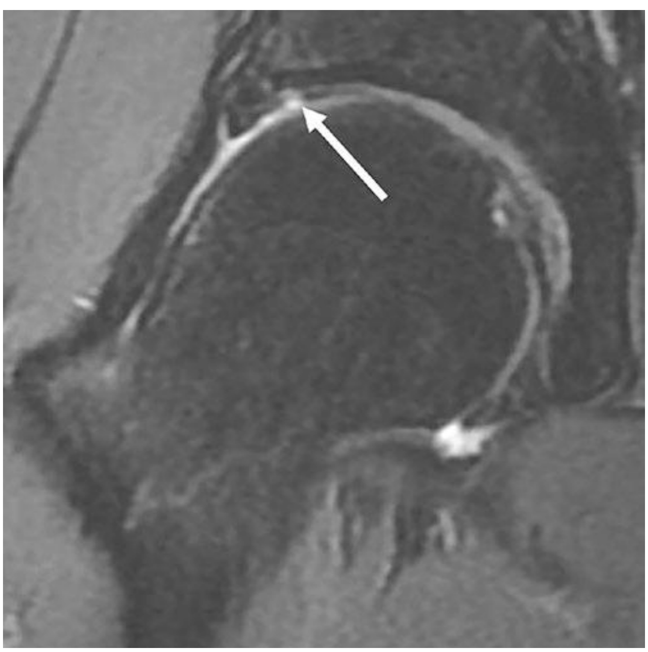

**Fig. 5.9** Coronal T2 fat-suppressed MR image in a 34-year-old man shows a focal cartilage defect near the labral base (arrow). Additionally, adjacent linear low signal may represent cartilage delamination. At arthroscopy, this was confirmed as delamination

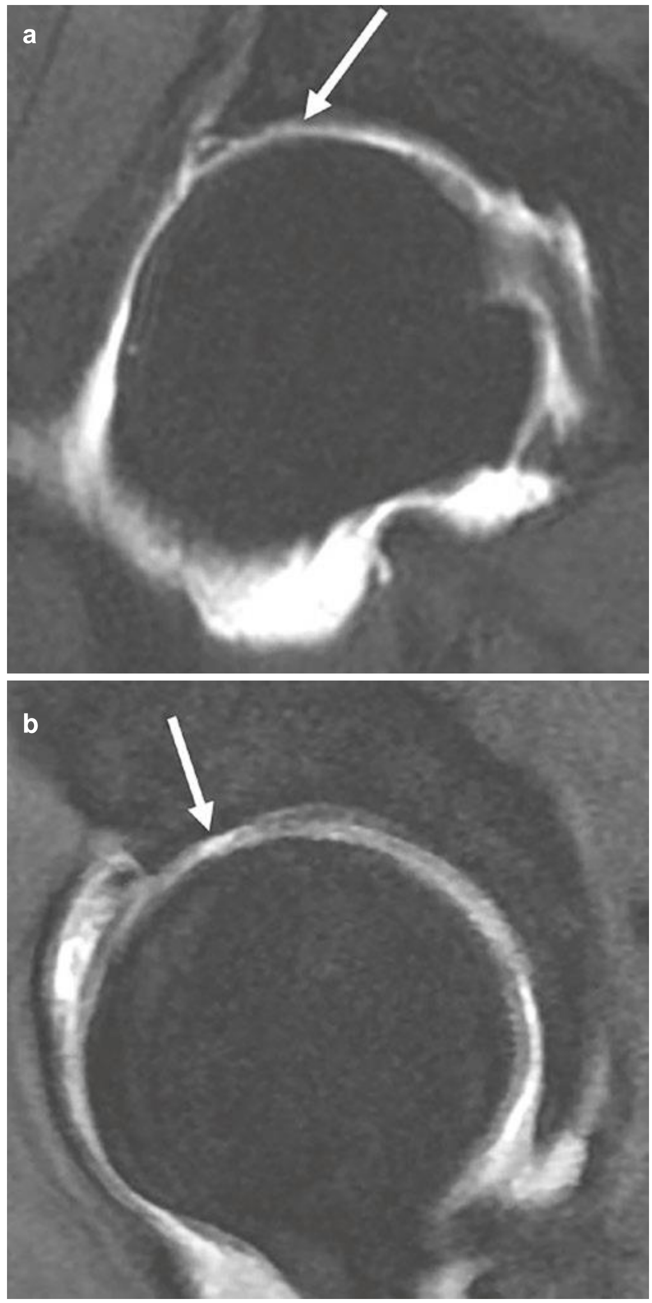


**Fig. 5.10** Coronal (**a**) and sagittal (**b**) T1 fat-suppressed MR arthrogram images in a 43-year-old man show superficial and deep multifocal cartilage loss (arrows) predominantly involving the acetabulum. Note adjacent labral tear

cartilage status is considered to be one of the most important predictors for a favorable outcome of joint preserving hip surgery for hip dysplasia and FAI, close scrutiny and evaluation of the articular cartilage are key in the evalua- tion of the hip joint.

**Key Point**

- Articular cartilage lesions are important outcome predictors and can manifest as generalized thinning, surface irregularity, fissures, delamination, chondral flaps, or full-thickness defects; additionally, the exact location of cartilage defects at the acetabulum and femoral head should be given.

### 5.5.3 Ligamentum Teres

The ligamentum teres (LT) is an intra-articular ligament, comprised of two to three bands, connecting the fovea capitis of the medial femoral head and the transverse ligament of the inferior acetabular notch [41]. This ligament may have a role in stabilization of the adult hip and has been recognized as a potential source of pain and instability if torn [42]. The most common known etiology of ligamentum teres injury is trauma, ranging from dislocation to extreme abduction to relatively minor twisting or external rotation of the hip. Thus, sports with relatively high impact or twisting movements, including football, ice hockey, snow skiing, and dance, predispose athletes to LT injuries [42]. Symptoms of ligamentum teres tears are typically nonspecific, including deep anterior groin or hip pain, and often accompanied by mechanical snapping or catching sensations [42].

Noninvasive diagnosis of LT tears is challenging, not only because of a lack of specific symptoms but also due to poor visualization on imaging. Recent studies have shown that ligamentum teres abnormalities are detected in up to 51% of hip arthroscopies [43].

The normal appearance of the LT on MRI is a hypointense band on all sequences due to its fibrous nature and composition of tightly packed collagen bundles. Tears are most easily identified when complete, demonstrating absence when chronic and a redundant displaced band of tissue when acute. Other appearances of a torn LT include thickened, intermediate signal with degeneration or degenerative intrasubstance tearing, irregularity of the fibers with fraying, and disrupted fibers or fluid signal intensity within a distorted ligament with partial tears (Fig. 5.11). Even though there is limited accuracy, MRarthrography is still considered the best imaging methodfor diagnosis [43].

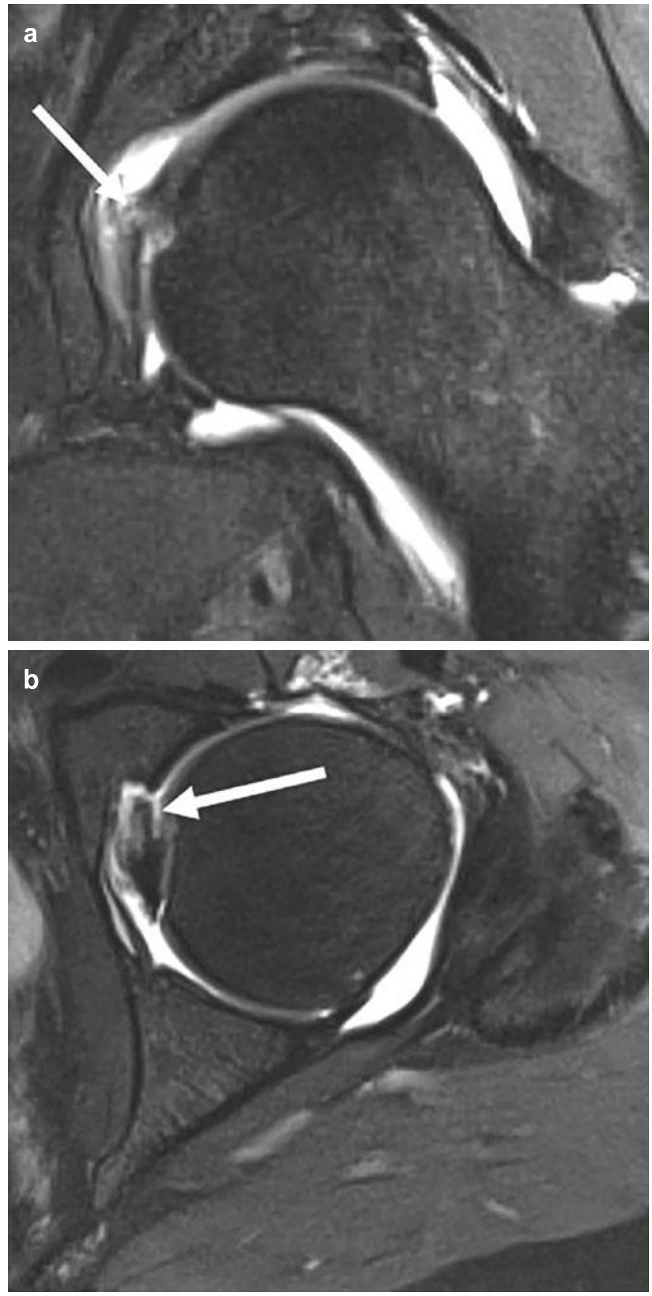


**Fig. 5.11** Coronal (**a**) and axial (**b**) T2 fat-suppressed MR arthrogram images in a 42-year-old woman show irregular appearance and disruption of the proximal fibers of the ligamentum teres, near the fovea (arrows). This was a partial tear at arthroscopy and was subsequently debrided

## 5.6 Concluding Remarks

State-of-the art imaging of the hip joint allows good assessment of osseous and soft tissue damage of the hip joint. Knowledge of specific injury patterns aids in identifying damage to the labrum and articular cartilage lesions.

**Take Home Messages**

- Evaluation of the osseous morphology is the first cornerstone of hip imaging; this includes assessing diseases such as stress fractures or osteonecrosis, as well as detecting abnormal osseous morphology of the hip joint, such as seen in femoroacetabular impingement.
- Femoral torsion abnormalities are more common than previously thought and cannot only be seen in developmental dysplasia of the hip but also in patients with hip impingement; we recommend to acquire additional fast transverse MR sequences over the proximal and distal femur to measure femoral torsion and identify those patients with abnormal femoral antetorsion.
- Intra-articular damage of the labrum and cartilage can be readily assessed with MRI; the exact description of the localization and extent of any intra-articular damage is an important predictor for outcome, especially in patients with femoroacetabular impingement.

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