The anatomy, diagnosis and pathology of femoroacetabular impingement

Femoroacetabular impingement is a significant cause of osteoarthritis in young active individuals, whose prognosis is directly and positively influenced by early intervention to prevent irreversible joint damage. This article discusses the anatomy, examination findings, radiological features and natural history of the condition.

Femoroacetabular impingement has only recently been widely recognized as a cause of early osteoarthritis of the hip, although it was first described by Smith-Petersen over 70 years ago (Smith-Petersen, 1936). More recent interest has been attributed to Stulberg who recognized that a 'pistol grip' deformity of the femoral head appeared to predispose to early osteoarthritis (Stulberg et al, 1975). It was, however, Ganz and co-workers who clarified the morphological appearance of the hip in relation to impingement problems and put forward a theory describing how the joint becomes damaged as a result of the morphological abnormality (Ito et al, 2001; Ganz et al, 2003; Beck et al, 2005). The pathoanatomy of the hip was characterized through careful documentation of the pattern of damage seen at the time of an open surgical dislocation of the hip performed to correct the underlying impingement.

Since that time, there has been widespread interest in the condition as it has been increasingly recognized as a common cause of athletic injury and disability. Alongside the increased understanding of the injury patterns surgical treatment has developed to try and address the underlying abnormalities via less invasive surgical techniques (Kim and Azuma, 1995; Ganz et al, 2001; Bardakos et al, 2008).

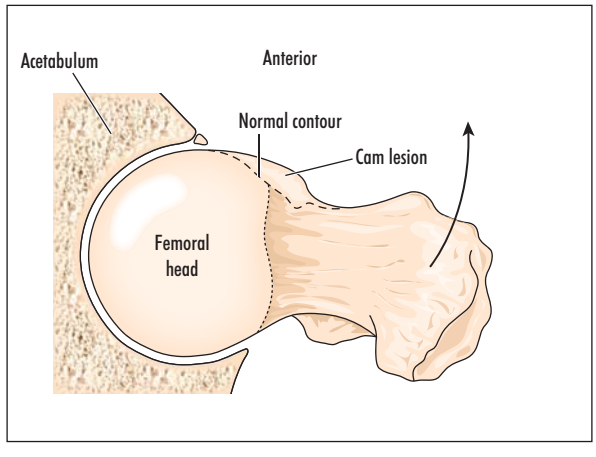
Morphology

The normal hip is described as a ball and socket, diarthrodial (synovial) joint. Its stability is based primarily on bony architecture. The acetabulum comprises the union of the ilium, pubis and ischium. These bones are joined in the floor of the acetabulum at the tri-radiate cartilage. At the acetabular rim, the joint is deepened by the fibro-cartilaginous labrum, which acts to increase the joint surface area, aid in lubrication and possibly also aid proprioception (Kim and Azuma, 1995). The orientation of the acetabulum is generally described as 15° anteverted (facing forwards) and obliquely 45° caudally. The proximal femur is composed of the head, neck and trochanters. The femoral neck is on average anteverted approximately 14° in the axial plane in relation to the shaft and distal femoral condyles, while the neck-shaft angle in the anteroposterior (AP) plane is around 130°.

The morphological changes causing femoroacetabular impingement have been broadly classified into two main categories: cam and pincer. Cam impingement is caused by the abnormal development of the femoral head–neck junction causing the pistol grip deformity. This type of deformity is characterized by a bony prominence on the anterosuperior femoral neck at the head–neck junction (*Figure 1*). These morphological changes result in an area of the head–neck junction that has an increased radius, which reduces the head–neck ratio. These changes are thought to resemble a cam, which is an eccentric part on a rotating device. This leads to joint damage as a result of the non-spherical femoral head being forced into the acetabulum mainly with flexion and/or internal rotation. This imparts compression and shear forces to the articular cartilage (Tanzer and Noiseux, 2004; Tannast et al, 2008). Cam impingement is most common in young athletic men (Beck et al, 2005).

This type of shape abnormality may arise as a result of abnormal re-modelling at the femoral head–neck junction, in particular at the junctions of the greater trochanteric and femoral head epiphyses. Other conditions can lead to the same end result, in particular slipped

Figure 1. Cam impingement.



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upper femoral epiphysis in which the femoral epiphysis slips posteriorly leading to a hump anteriorly at the head–neck junction (Leunig et al, 2000). Perthes' disease may also lead to an abnormal shape with a broad flat femoral head producing impingement problems.

Pincer impingement, on the other hand, is a result of the abnormality being on the acetabular side (Klaue et al, 1991). The acetabulum may have more posterior orientation than normal, acetabular retroversion, resulting in impingement of the femoral neck against the anterior wall of the acetabulum earlier than it would otherwise (Reynolds et al, 1999) (*Figure 2*). Other types of acetabular overcoverage may be caused by coxa profunda, or protrusio acetabuli where the femoral head extends up to or medial to the ilio-ischial line. Repeated contact between the femoral neck and the edge of the acetabulum may lead to damage to the labrum and adjacent articular cartilage and ossification of the labrum (*Figures 3* and *4*). There may also be reciprocal indentation changes in the femoral neck (Pitt et al, 1982). It is thought that this type of impingement may also predispose to the development of osteoarthritis. Pincer impingement is most common in middle-aged athletic women.

Figure 2. Pincer impingement.

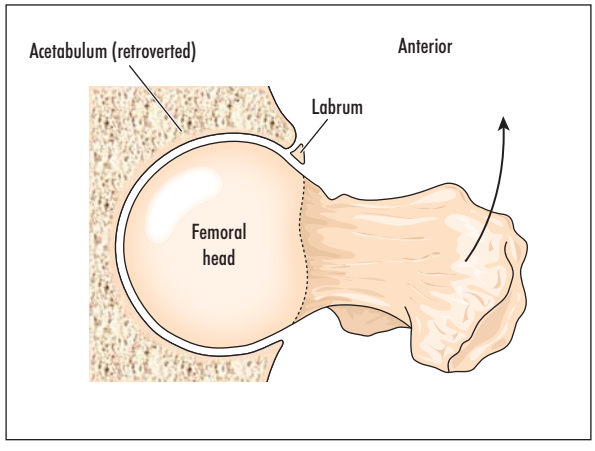


Figure 3. Pelvic radiograph showing ossified labrum, a cause of pincer impingement.

Symptoms

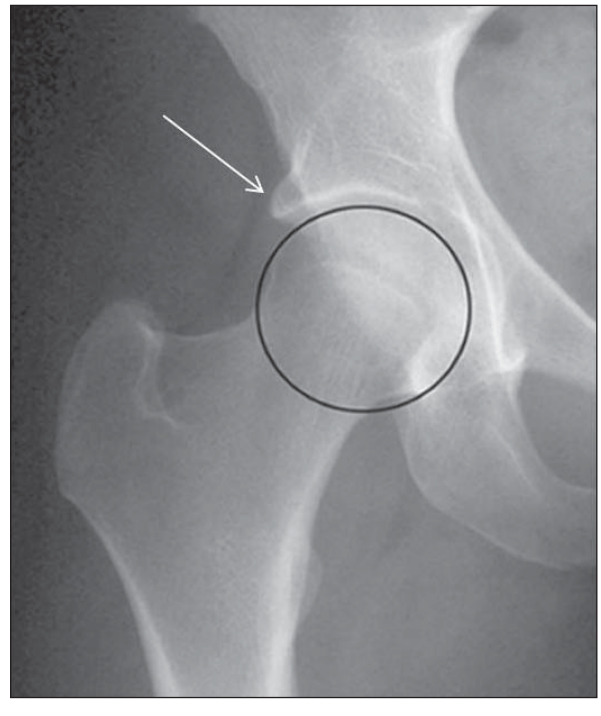
Femoroacetabular impingement must be in the differential diagnosis of any patient under the age of 55 years who presents with hip pain. Those who are older may well also have femoroacetabular impingement, but by that stage the natural progression of the impingement has usually taken its course and the patient may have developed frank osteoarthritis. It usually affects only one side, but may be bilateral, with the pain felt mainly in the groin or peritrochanteric area. Localization of the pain may be difficult and patients frequently cup their fingers around the greater trochanter to indicate the site of the pain. Onset of symptoms tends to be gradual and usually activity related. Initially the pain is intermittent but then may progress to a dull constant ache with acute exacerbations (Philippon et al, 2007). Conversely, sitting for long periods may also cause pain as a result of the pressure effects of the impingement anteriorly. There may be mechanical symptoms such as clicking, catching or even instability.

It should be remembered that hip pain may be referred to the knee via the sensory territory of the obturator nerve, and therefore the hip should always be examined in those who present with unexplained knee pain. In more advanced cases, night pain may also be reported. Owing to the intermittent and non-specific nature of the symptoms, several studies have shown delays in diagnosis of up to 5 years, with some patients undergoing multiple investigations and even surgery before the correct diagnosis is made (Ganz et al, 2003).

Examination

Examination of a patient with femoroacetabular impingement may only reveal a subtle alteration in

Figure 4. Overcoverage leading to pincer impingement.



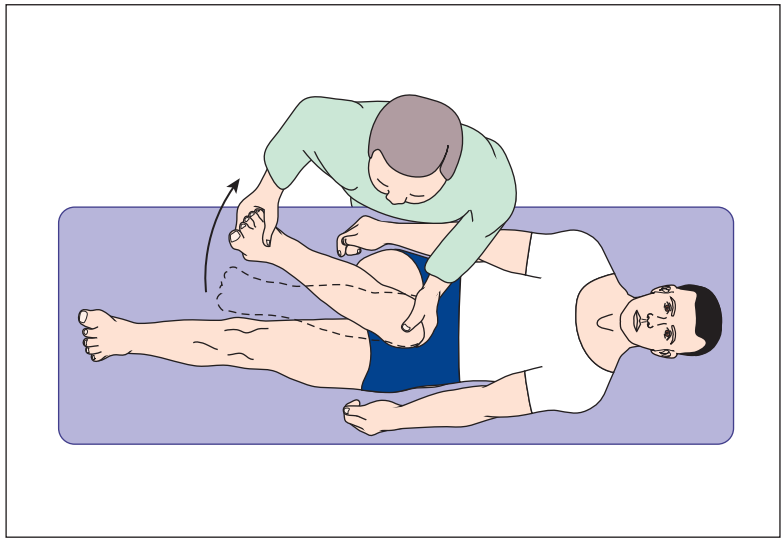


Figure 5. Impingement test.

range of motion. Attention to hip rotation, in particular a comparison of internal rotation with the hip in extension and then at 90° of flexion, is often revealing. Movements that tend to be affected first are internal rotation and adduction in flexion. The 'impingement test' is positive in up to 95% of patients and is a very sensitive test to detect pathology at the front of the hip. It is performed with the patient supine on a couch; the examiner should flex the hip to its maximum (or at least 90°) and bring it into adduction. At this point the hip is then rotated internally in a sharp but controlled manner (*Figure 5*). If the patient does have femoroacetabular impingement, this manoeuvre will bring the femoral neck into contact with the acetabular rim causing discomfort similar to the presenting pain in the groin.

Pincer impingement may also cause abutment at the posteroinferior margin of the acetabulum and this can be assessed clinically by externally rotating the patient's thigh when in extension (*Figure 6*). This usually produces pain felt in the posterior trochanteric region. The range of motion will also be decreased in certain directions, depending on the cause of the pincer. Retroversion will reduce the range of flexion, but other movements will be largely unaffected or even increased (i.e. extension). A protrusio hip, however, will have a global reduction in motion.

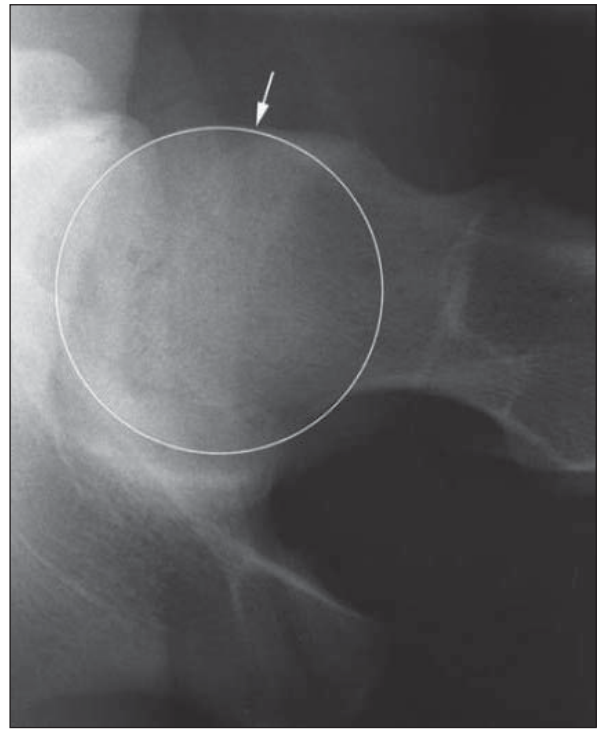
Figure 6. Examination of the hip in extension and external rotation.

Other symptoms such as a limp or a positive Trendelenburg sign may be present (Burnett et al, 2006). A generalized decrease in the range of motion in the hip joint on examination raises the possibility of early osteoarthritis, which may not yet be visible with plain radiography.

Radiographical appearances

The radiographical appearances of femoroacetabular impingement can be quite subtle and as a result can easily be missed by those who are not experienced in looking for its signs. The first view should always be a true AP pelvic radiograph. The ideal orientation is when the coccyx and pubic symphysis are in line, and there is approximately a 1–2 cm gap between the two. Another way of assessing whether the pelvis is straight is by determining the teardrops and ensuring they are symmetrical. The second view is a 'cross-table' lateral (Meyer et al, 2006). This X-ray is taken with the hip in approximately 15° of internal rotation, and is a good way of visualizing the anterior femoral neck in profile when assessing for a cam lesion (*Figure 7*).

Figure 7. Cross-table lateral radiograph of a hip joint demonstrating a cam lesion.



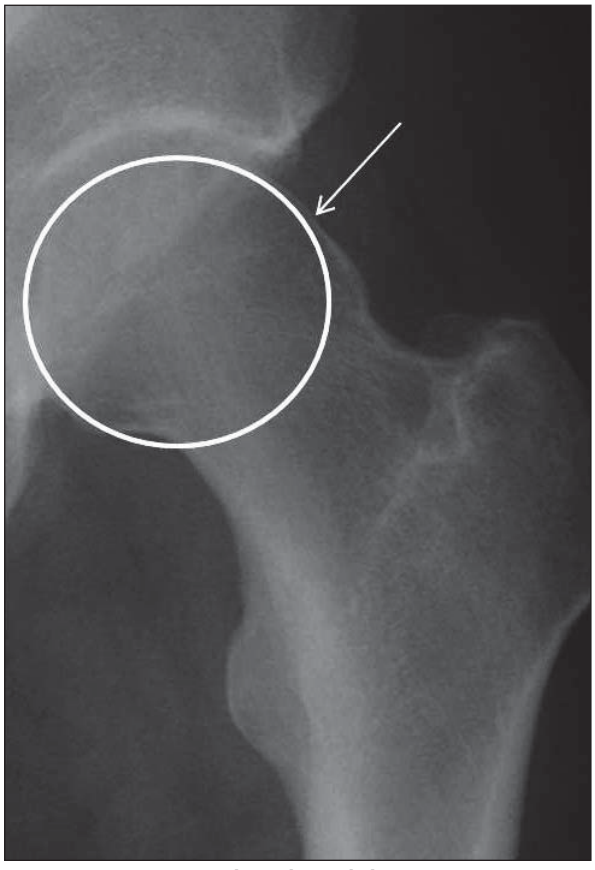


Figure 8. Antero-posterior hip radiograph demonstrating a cam lesion.

There are certain features to look for on the AP radiograph when assessing for femoroacetabular impingement. A congruent but non-spherical femoral head (pistol grip deformity) is the characteristic finding in cam type impingement. Other appearances that also point to this diagnosis are a small head–neck ratio or a short femoral neck. The pistol grip deformity is best demonstrated by looking at the sphericity of the femoral head (*Figure 8*). At the head–neck junction, reversal of the normally concave outline to the almost convex appearances can be seen. The appearances are almost as if the femoral head extends more laterally than normal resulting in a short femoral neck. When looking at the cross-table lateral, it may be possible to see the anterolateral deformity in profile. Other morphological features to look for are whether the femoral head is centred on the neck, and also for what has been described as the medial-hook (Eijer et al, 2001). This is where the head is positioned slightly posteriorly and inferiorly on the neck leading to an overhang medially.

The plain radiographical appearances of pincer impingement may not be so obvious. As stated above, it is associated with coxa profunda or protrusio plus possible ossification of the labrum (Beck et al, 2005) (*Figure 3*). The other main cause of this type of impingement is acetabular retroversion (*Figure 9*). This can be assessed by looking for what has been coined the 'cross-over sign' (Reynolds et al, 1999; Tönnis and Heinecke, 1999). In the normal hip, the anterior and posterior walls of the acetabulum should meet at the lateral margin of the acetabulum. In the case of a retroverted acetabulum the line of the anterior wall crosses that of the posterior wall medial to the lateral margin of the acetabulum, as seen on the AP radiograph of the pelvis. Another radiographical clue to acetabular retroversion on a pelvic AP view is the appearance of an unusually prominent ischial spine (*Figure 9*).

The use of computed tomography (CT) and magnetic resonance imaging has also increased both understanding of femoroacetabular impingement and diagnostic abilities. Radiographical three-dimensional reconstruction of the hip allows the visualization in greater detail of possible impingement lesions, plus allows more accurate measurements of the femoral and acetabular angles including version (Beaulé et al, 2005) (*Figure 10*). Other morphological abnormalities that CT can demonstrate are the cam impingement lesion (aspherity of the femoral head) and decreased offset (*Figure 11*). CT is also a more sensitive test than plain X-ray for early detection of osteo-arthritic changes such as preservation of joint

Figure 9. Acetabular retroversion with 'cross-over' sign and prominent ischial spine on left.

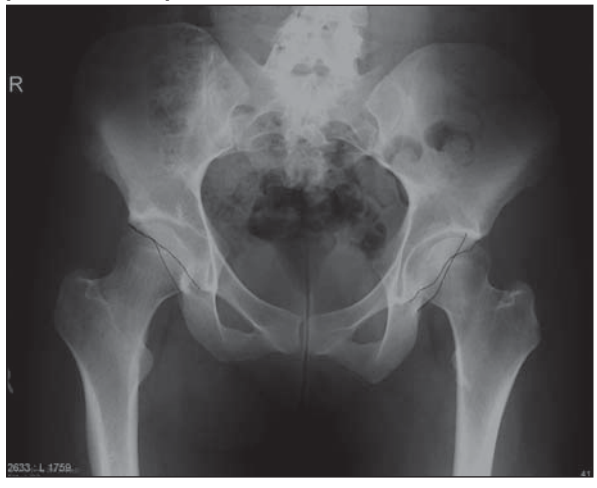
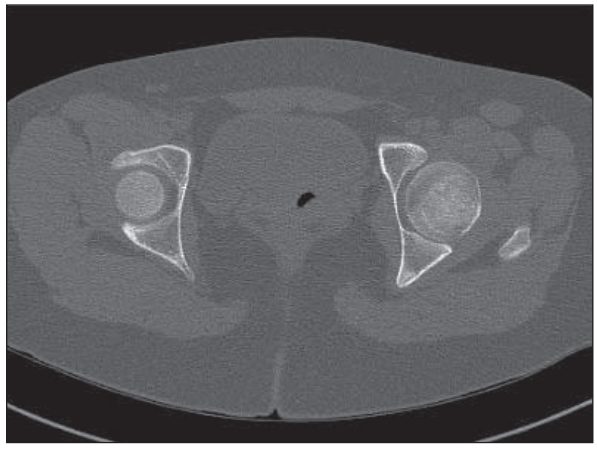


Figure 10. Computed tomography scan axial slice to assess acetabular retroversion.



space and subchondral cyst formation. This can be very helpful in both planning a treatment regimen and assessing prognosis.

Currently there has been development of specific software to assess the hip joint from CT data. Although this is still in its infancy, recent published work does look encouraging especially for assessing the acetabulum and femoral head coverage (Dandachli et al, 2008). Other programmes exist that allow the clinician to move the femur in relation to the acetabulum and simulate the impingement.

Magnetic resonance arthrography enhanced by gadolinium is a more invasive modality, which may yield valuable information with regards to the presence of labral pathology, cartilage degeneration, femoral head sphericity and the presence of herniation pits (Kassarjian et al, 2005). Magnetic resonance arthrography is not very sensitive at detecting cartilage delamination, however (see later), but it still yields higher results than plain, non-enhanced magnetic resonance imaging.

Natural history

Cam and pincer impingement types cause characteristically different patterns of articular damage. In patients with cam impingement, the majority of damage occurs at the '1 o'clock position' (Beck et al, 2005) (this refers to the right acetabulum as a clock-face when looking at it directly and therefore the 1 o'clock position corresponds to anterosuperior area of the acetabulum). The recurrent trauma resulting from the femoral neck abutment causes a sequence of events starting with separation of the cartilage from the labrum, despite the labrum remaining largely attached to the acetabular rim (in the normal hip the cartilage is continuous with the labrum) (Seldes et al, 2001). The cam causes both compression and shear of the labrum and cartilage as it forces its way in and out of the joint. The labrum is pushed away from the joint and the cartilage pushed in towards the fovea acetabuli. The cartilage then appears to become separated from the subchondral bone as a flap type tear.

A clue to this arthroscopically is the 'wave' or 'carpet' sign, where probing the edge of the articular cartilage or labrum causes a bulging out of the cartilage further centrally, indicating that it is not attached to the underlying bone (Beck et al, 2005) (*Figure 12*). First appearance of these flap tears may be falsely reassuring, as the extent of the cartilage damage may not be immediately apparent. As the damage progresses, the junction between labrum and articular cartilage separates, and the cartilage flap extends further into the joint. This may lead to exposed subchondral bone (*Figure 13*). The amount of damage is not reciprocated on the femoral head until late in the disease process.

Figure 11. Computed tomography three-dimensional reconstruction of a hip joint with a cam lesion (looking from inferior).

Figure 12. Acetabular 'wave' sign.

Figure 13. Extent of delamination.

Pincer impingement causes a more circumferential and peripheral pattern of joint damage. However, the area that appears to be damaged the most is between the 11 and 1 o'clock positions. The mechanism of damage is compression of the labrum from the femoral neck. These forces are transferred to the cartilage in a linear manner as the labrum is pushed against it, again debonding it from the subchondral bone. The area of cartilage that appears to be most affected is peripherally around the acetabular rim. The labrum itself may start to ossify as a result of the repeated trauma, worsening the condition. A theory regarding deep sockets is that of a 'contrecoup' lesion (Ganz et al, 2003), where the femoral neck levers against the acetabular rim anteriorly, forcing the femoral head to sublux posteriorly and damaging the both the head and the posterior acetabular cartilage. It is thought that this mechanism predisposes these hips to developing early osteoarthritis.

Conclusions

To date, we do not know what the prevalence is of hips with the morphological characteristics described, so it is not clear what proportion overall do go on to develop early osteoarthritis. What is clear, however, is that the articular cartilage lesions that have been identified in patients which have become symptomatic are often extensive and the hope is that with earlier recognition and intervention the risk of development of osteoarthritic changes can be reduced or prevented. BJHM

Conflict of interest: none.

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KEY POINTS

- Femoroacetabular impingement can be classified as cam, pincer or mixed.
- Femoroacetabular impingement is caused by morphological abnormalities of either the femoral head and/or acetabulum.
- Femoroacetabular impingement presents as groin or hip pain.
- Radiographical features of femoroacetabular impingement are commonly missed.
- Femoroacetabular impingement may lead to early osteoarthritis in athletic individuals.
- Joint damage is the result of abnormal compression and shear of the articular cartilage.