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SCIENTIFIC ARTICLE

# Evaluation and management of ischiofemoral impingement: a pathophysiologic, radiologic, and therapeutic approach to a complex diagnosis

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**Abstract** Ischiofemoral impingement syndrome (IFI) is an underrecognized form of atypical, extra-articular hip impingement defined by hip pain related to narrowing of the space between the ischial tuberosity and the femur. The etiology of IFI is multifactorial and potential sources of ischiofemoral engagement include anatomic variants of the proximal femur or pelvis, functional disorders as hip instability, pelvic/spinal instability, or abductor/adductor imbalance, ischial tuberosity enthesopathies, trauma/overuse or extreme hip motion, iatrogenic conditions, tumors and other pathologies. Magnetic resonance imaging (MRI) is the diagnostic procedure of choice for assessing IFI and may substantially influence patient management. The injection test of the ischiofemoral space (IFS) has both a diagnostic and therapeutic function. Endoscopic decompression of the IFS appears useful in improving function and diminishing hip pain in patients with IFI but conservative treatment is always the first step in the treatment algorithm. Because of the ever-increasing use of advanced MRI techniques, the frequent response to conservative treatment, and the excellent outcomes of new endoscopic treatment, radiologists must be aware of factors that predispose or cause IFI. In addition, focused treatment in these conditions is often more important than in secondary impingement. In this article, we briefly describe the anatomy of the IFS, review the clinical examination and symptoms, assess the diagnostic imaging criteria and pathophysiological mechanisms, and develop an understandable classification of IFI, with particular focus on its etiology, predisposing factors, and associated musculoskeletal abnormalities. We also assess the role of the radiologist in the diagnosis, treatment, and preoperative evaluation of both primary and secondary IFI.

**Keywords** Ischiofemoral impingement · Impingement · Deep gluteal syndrome · Quadratus femoris muscle · External rotators · Sciatic nerve · Sciatic neuritis · Piriformis syndrome · Hip. Hip pain · Injection test

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## Introduction

Posterior hip pain is complex, and its etiology can be difficult to diagnose [1, 2]. Ischiofemoral impingement syndrome (IFI) is a more frequent than expected form of atypical, extra-articular hip impingement defined by hip pain related to the narrowing of the space between the ischial tuberosity (IT) and the femur [3–5]. Although IFI is increasingly being discussed in the medical literature, it remains a poorly recognized condition because symptoms are often nonspecific. Hence, imaging plays an important role in its diagnosis and treatment [2, 6].

The incidence of IFI is unknown and the diagnosis generally depends on both clinical and imaging evidence. The dominant findings of previous studies related to IFI are focused on the narrowing of the mentioned space and the abnormalities of the QFM [2, 3]. However, there are no detailed reviews about the etiology and predisposing factors of this syndrome.

The aims of this review are [1] to briefly describe the anatomy of the ischiofemoral space (IFS), [2] to assess the pathophysiological mechanisms and develop an understandable classification of IFI, particularly focusing on its etiology and predisposing factors, and [3] to assess the role of the radiologist in the diagnosis and treatment evaluation of both primary and secondary IFI.

## Anatomy

The quadratus femoris muscle (QFM) is a flat quadrilateral muscle that is situated within the subgluteal space of the hip [12]. This muscle has a somewhat striated appearance, and the fibers run along the axial plane and are more closely opposed along the femoral end of the muscle. Along the ischial aspect, the fibers are more loosely arranged and have more interspersed fat [2, 7] (Figs. 1, 2, 3).

The quadratus femoris nerve arises from the ventral surface of (L4), L5, and S1 in 79.4 % of the population. This nerve exits the pelvis through the greater sciatic notch, travels inferiorly along the anterior surface of the gemellus and obturator internus muscles, and enters the quadratus muscle along its anterior surface (Fig. 1) [8–10]. The QFM is bordered anteriorly by the obturator externus muscle, iliacus-psoas distal tendon, lesser trochanter and the posteromedial intertrochanteric area of the femur. Posteriorly, the QFM is bordered by subgluteal space fat, the hamstrings tendons and the anterior surface of the gluteus maximus muscle. Superiorly, the QFM is bordered by the obturator internus-gemelli complex and inferiorly by the mayor adductor (Fig. 3). The QFM serves as an adductor and external rotator of the thigh [11].

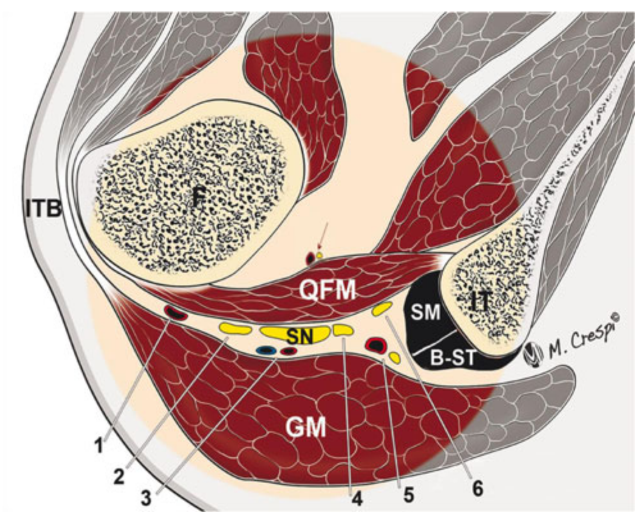



**Fig. 1** Normal anatomy of the IFS. Diagram illustrates the most important neurovascular, muscular, tendinous, and osseous structures within the IFS. *GM* gluteus maximus muscle, *QFM* quadratus femoris muscle, *SN* sciatic nerve, *SM* semimembranosus tendon, *B-ST* conjoint tendon of biceps femoris-semitendinosus, *ITB* iliotibial band, *1* ascending posterior circumflex femoral artery, *2* nerve to the short head of the biceps femoris, *3* vasa vasorum of the sciatic nerve, *4* posterior cutaneous nerve of the thigh, *5* inferior gluteal artery and nerve, *6* nerve to the long head of the biceps femoris. Note the QFM nerve entering the muscle along its anterior surface (*red arrow*)

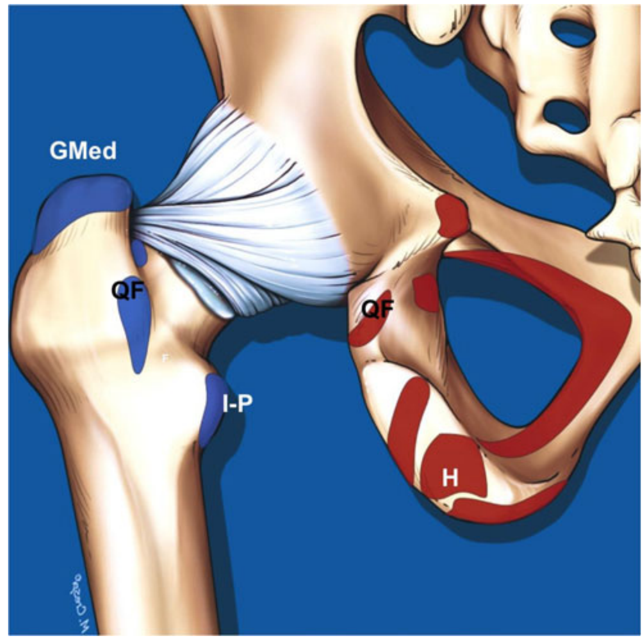



**Fig. 2** Normal anatomy of the IFS. Diagram illustrates the most important tendon footprints within the IFS. *GMed* lateral gluteus medius footprint, *QF* quadratus femoris insertions, *I-P* ilio-psoas footprint, *H* Hamstring. The QFM originates at the upper and anterior portion of the external border of the ischial tuberosity just anterior to the origin of the hamstring tendons, and inserts on the posteromedial aspect of the proximal femur into the quadrate tubercle of the intertrochanteric crest

## Clinical symptoms and examination

The clinical assessment of patients with IFI is difficult because the symptoms are imprecise and may be confused with other lumbar and intra- or extra-articular hip diseases, including deep gluteal syndrome [12].

Patients typically present with mild to moderate nonspecific chronic and sometimes gradually increased pain in the deep gluteal region. This pain can be also located lateral to the ischium, in the groin and/or in the center of the buttock. Limited sitting time and limitation of physical activities including long-stride walking are frequent. Duration of these symptoms vary between months and several years and usually there is no a precipitating injury (except trauma-related cases) [5, 13–16]. Moreover, these patients may suffer from snapping or an audible grating sensation, crepitation, and partial joint locking, and tingling/sciatica spreads down the leg in

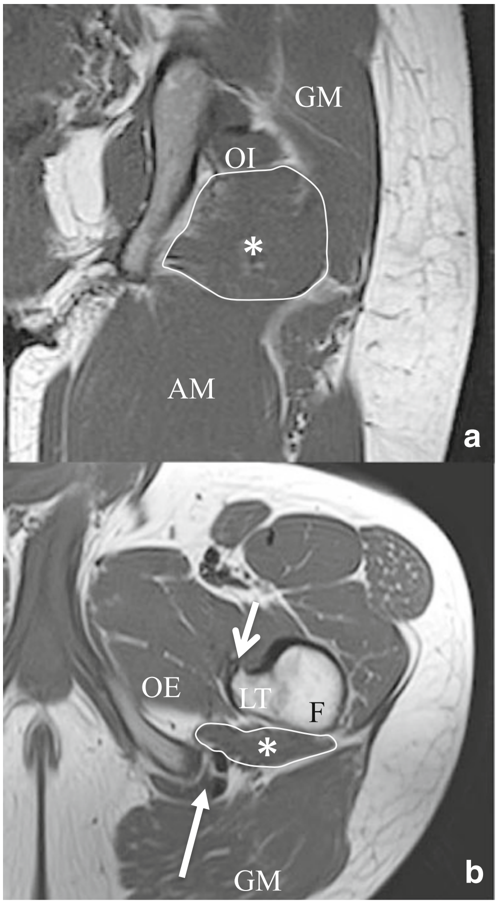



**Fig. 3** Normal anatomy of the QFM. Coronal (**a**) and axial (**b**) T1-weighted MR images illustrating the main anatomic relationship of the QFM. *GM* gluteus medius, *AM* adductor magnus, *OE* obturator externus, *QFM* quadratus femoris muscle, *LT* lesser trochanter. *Short arrow* iliopsoas tendon, *long arrow* hamstring tendons. The QFM (*white line* and *asterisk*) is often best evaluated on axial images, where the origin, insertion, and relations can be assessed. Because of the muscle's orientation in the coronal plane, the abnormal signal may be difficult to visualize on routine coronal images, particularly if the field of view is large

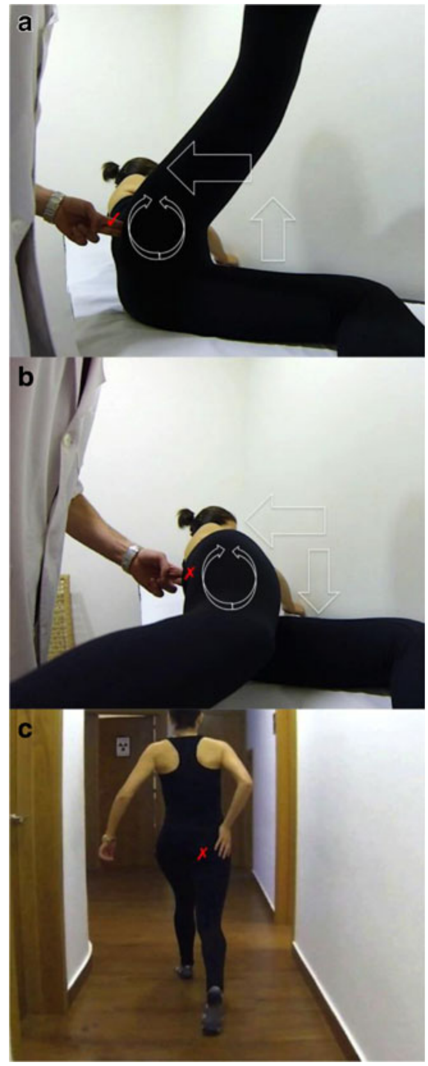



**Fig. 4** Specific physical examination test to assess IFI. Extension of the affected hip in abduction does not reproduce the symptoms (**a**). The IFI test is considered positive when symptoms are reproduced when the affected hip is taken into passive extension in adduction with the patient in the contralateral decubitus (**b**). The long-stride walking test is considered positive when posterior pain appears during the terminal stance phase of gait (**c**), and is relieved when walking with short strides or hip abduction

cases presenting with sciatic neuritis. The antalgic position, bearing weight on the healthy ischium while sitting, is typical [12]. In patients with other adjacent muscle, tendon, or bursal abnormalities (for example, psoas bursitis or hamstring tendinosis), other symptoms can be added, which makes it difficult to determine the primary contributor to the patient's symptoms [4, 12, 17–19]. Symptoms have been described in response to a wide range of hip positions especially during the full range of rotation [2, 6, 15, 18].

The specific physical examination test included the long-stride walking test and IFI test [12, 13, 20] (Fig. 4).

## Diagnostic imaging criteria

The presence of narrowed IFS and QFM space (QFS), as well as QFM edema represent the most significant indicators for IFI [3–5]. However, soft tissue magnetic resonance imaging (MRI) signal abnormalities are present within the IFS in 9.1 % of asymptomatic patients (edema in 1.4 % and fatty infiltration in 7.7 %) [21].

Arthroscopically, with the hip in adduction, external rotation, and extension, the lesser trochanter and ischial tuberosity are approximately 2.0 cm apart. This relationship allows the femur to rotate without contacting the ischial tuberosity or proximal hamstring tendons. Thus, any factor that alters this relationship can trigger IFI [22, 23].

Several studies have shown significant reductions of IFS and QFS with good-to-excellent intra- and interobserver reliability when comparing patients with QFM abnormalities and control individuals. Measures of the IFS of 13 ± 5/12.9 mm and QFS of 7 ± 3/6.71 mm have been identified in affected patients with the lower leg in internal and neutral rotation. These values in control subjects in internal rotation are significantly higher, corresponding to 23 ± 8 and 12 ± 4 mm, respectively [1, 6, 15] (Fig. 5).

Unfortunately, the resting position of the limb that is required for routine MRI does not reproduce the conditions leading to instability in daily life. Moreover, there is ≥10 % width difference between the right and left IF spaces in approximately half of asymptomatic individuals [21]. These measurements depend on the degree of hip rotation, adduction, and extension during MRI. Therefore, the validity of these values remains unclear in these retrospective studies [24, 25]. Nevertheless, these studies are not invalid. Using a cutoff of ≤ 15 mm, a sensitivity of 76.9 %, specificity of 81.0 %, and overall accuracy of 78.3 % have been reported. For QFS, a cutoff of ≤ 10.0 mm resulted in 78.7 % sensitivity, 74.1 % specificity, and 77.1 % overall accuracy [20].

Dynamic MRI utilizing a full range of rotation will help to confirm impingement, to evaluate the relationship between the QFM and adjacent structures, and better assess associated findings, such delineation of unnoticed partial tears of the anterior surface of the QFM. Currently, the sufficient time frame resolution with real-time demonstration of movements has been considered the main limitation of MRI [13, 24, 26, 27] (Video 1).

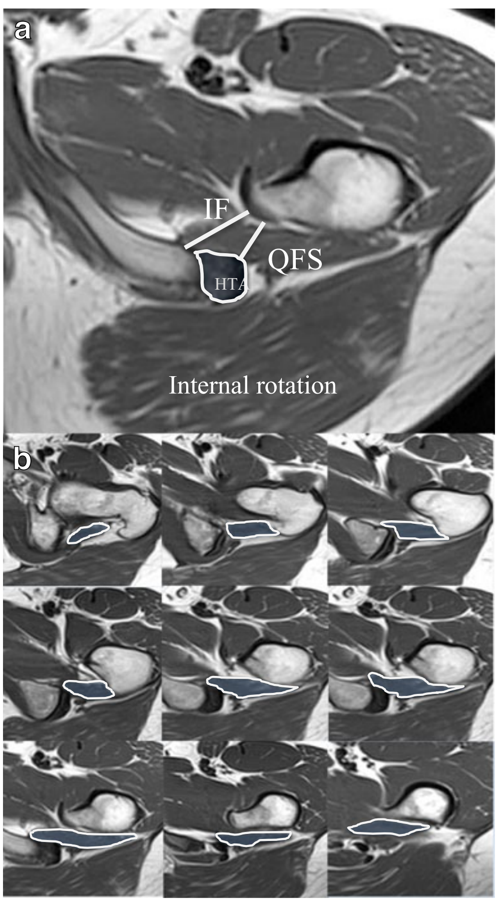



**Fig. 5** Quantitative assessment of IFI. Axial T1-weighted MR image at the tip of the lesser trochanter (LT) in internal rotation (**a**) shows normal right IFS, QFS and hamstring tendon area (HTA). IFS is defined as the gap between the ischium tuberosity and the iliopsoas tendon or the LT and QFS as the smallest gap between the superolateral surface of the hamstring tendons and the posteromedial surface of the iliopsoas tendon or the LT. HTA is measured by tracing the contours of the hamstring tendon where the QFS is measured. Highlighted muscle regions on sequential axial T1-weighted images (**b**) are used to perform total quadratus femoris muscle volume (TQFMV) measurement

### Etiology and predisposing factors

Existing studies are not prospective and do not include sufficient sample sizes or standardized protocols, so a direct cause-and-effect relationship between IFI and particular described etiologies cannot be established. However, the analysis of individual patients has established potential etiologies and predisposing factors [4, 19, 28] (Table 1).

## Coxa valga

The neck-shaft angle or inclination angle (IA) is the deviation of the femoral neck from the femoral diaphysis. In adults, the IA ranges from 120° to 130°, and its value is greater in newborns (150°) and smaller in elderly populations (120°) [29]. The IA differs with age, sex, stature, spinal deformities, and width of the pelvis, affecting the gait and increasing stress at the hip and knee joint. A higher prevalence of extra-articular impingement has been found for coxa valga. Patients with IFI show increased femoral neck and ischial angles compared with controls, suggesting that increased IA may lead to the narrowing of the IFS [2, 30] (Figs. 6 and 8).

**Table 1** Potential etiologies and predisposing factors of IFI according to the pathophysiological mechanisms

| |
|---|
| 1. Primary or congenital (orthopedic disorders): |
| 1.1. Coxa valga |
| 1.2. Prominence of the lesser trochanter |
| 1.3. Congenital posteromedial position of the femur |
| 1.4. Larger cross section of the femur |
| 1.5. Abnormal femoral antetorsion |
| 1.6. Coxa breva |
| 1.7. Variations of the pelvic bony anatomy |
| 2. Secondary or acquired: |
| 2.1. Functional disorders |
| a. Hip instability |
| b. Pelvic and spinal instability |
| c. Abductor/adductor imbalance |
| 2.2. Ischial tuberosity enthesopathies |
| 2.3. Traumatic, overuse and extreme hip motion |
| 2.4. Iatrogenic causes |
| 2.5. Tumors |
| 2.6. Other etiologies |

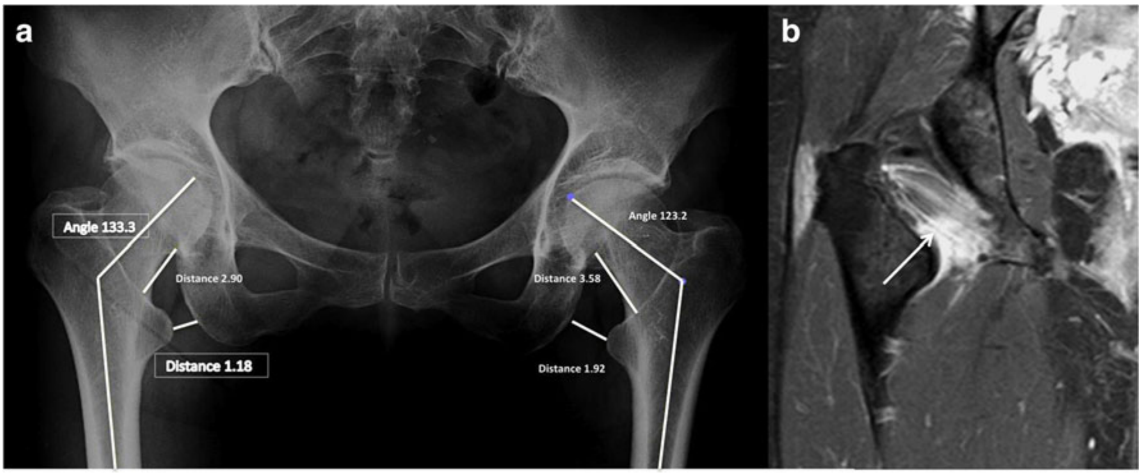



**Fig. 6** IFI secondary to coxa valga and breva (short neck) in a 55-year-old woman. The PA simple pelvic radiograph shows a shortening of the femoral neck, an increased neck-shaft angle (inclination angle), and a decreased IF on the right side with respect to the contralateral side (**a**). Coronal PD fat-suppressed MR image shows QFM edema (*arrow*) secondary to the entrapment in the same patient (**b**)

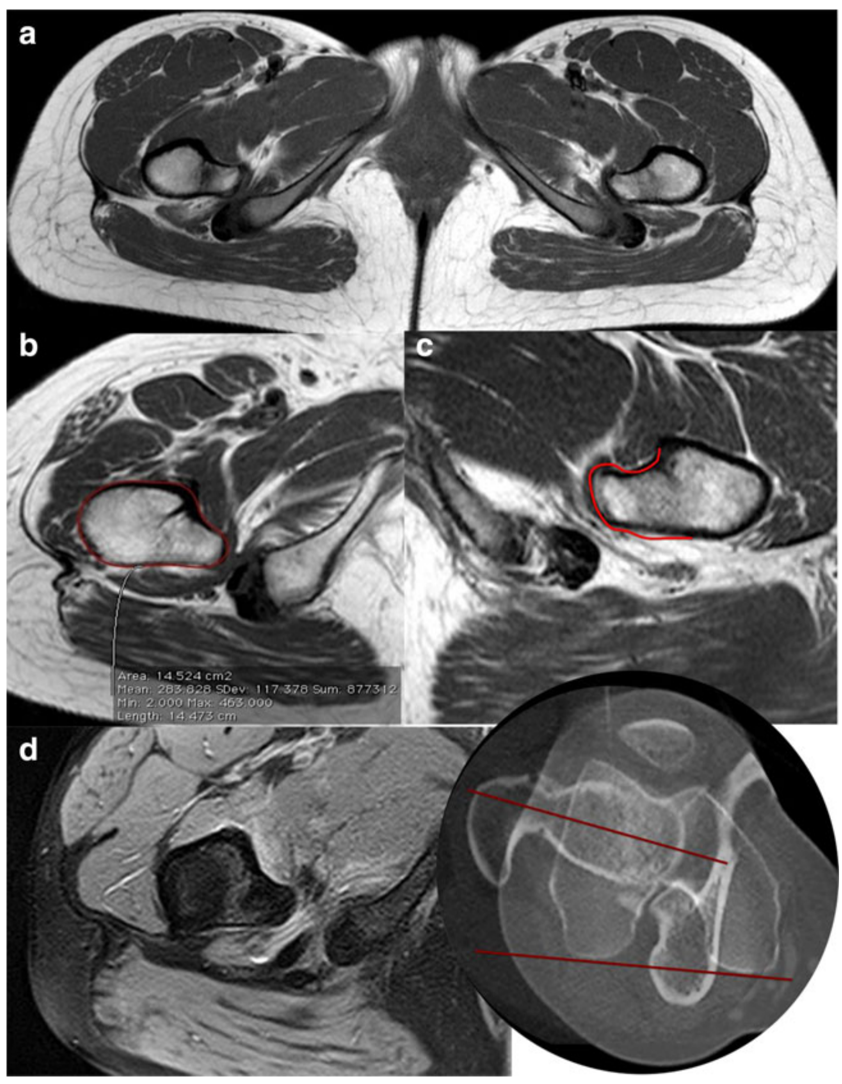



**Fig. 7** IFI secondary to congenital posteromedial position of the femur (**a**), larger cross section of the femur at the level of the lesser trochanter (**b**), prominence and hook-shaped lesser trochanter (**c**), and abnormal femoral antetorsion (**d**)

## Other proximal femur abnormalities

A congenital posteromedial position of the femur, larger cross section of the femur, prominence or hook-shaped lesser trochanter, abnormal femoral antetorsion or coxa breva are congenital conditions that could lead to the syndrome since they determine an approach to the lesser trochanter of the femur [6, 22, 23] (Figs. 6 and 7).

Coxa breva (short neck) decreases the abductor-resting length and lever arm, increases joint reaction forces, and causes abductor fatigue and Trendelenburg gait contributing to the reduction of IFS [31].

The abnormal femoral antetorsion angle is measured on pure axial computed tomography (CT) or MRI images over the proximal and distal femur. This angle is normally anteverted to the bicondylar femoral plane at an angle of 35° to 50° at birth and gradually decreases by 1.5 degrees per year and reaches an approximate value of 16° at 16 years of age and 10° in adults. Higher angles have been described in these patients compared to controls [12] (Fig. 7d).

## Variations of the pelvic bony anatomy: female pelvis

The incidence of IFI has been reported to be higher in women than men, and it has been hypothesized that this occurs because of the differing osseous configuration. In particular, the ischial tuberosities are prominent, more separated and have a wider positioning in women. Prominence of the lesser trochanter and lower ischio-pubic ramus with an angle closer to the coronal plane in the female pelvis may also explain why IFI is seen most commonly in women [30]. Projection of the ischial spines outwards in the female pelvis may be another explanation. In patients with IFI, the ischial angle is higher than in the control population [3, 30] (Fig. 8). Furthermore, there is a significant association between the degree of degenerative change observed in the QFM and (1) an increased approximation of the QF attachments sites and (2) a narrower intertuberous diameter [32].


**Fig. 8** Variations of the pelvic bony anatomy: female pelvis. Axial T1-weighted MR images of a woman (**a**) and a man (**b**) show an increased ischial angle (*red an*gle) and a more separated ischial tuberosities (*white line*) in the woman. The *white lines* in **a** and **b** are the same length

## Functional disorders predisposing to or causing IFI

### Hip instability

Hip dysplasia in adults causes chronic forces that exceed the level of tolerance causing bone deformation and articular soft tissue changes. The femoral head is displaced anteriorly and laterally, causing instability of the hip and the patient to adopt an exaggerated valgus position that contributes to IFS narrowing [33]. Some patients with IFI have a dysplastic-kind hip, but few corresponding to true dysplasia and most correspond to minor dysplasia or instabilities. These forms can be classified according to the measurement of the anterior and posterior acetabular sector angles (AASA and PASA, respectively) as instability of the anterior column, posterior column (or both columns), leading to anterior or posterior instability [33, 34] (Fig. 9).

### Pelvic and spinal instability

Abnormal pelvic tilt (PT) may promote the development of atypical impingement [35]. A close relationship has been described between the sagittal balance of the spine (SB), the PT, and hip impingement. PT can increase or reduce the IFS. Moreover, PT increases (5.5-10.6 %) when the effects of muscle damage on walking biomechanics at different speeds are studied [36].

Pelvic anteversion and retroversion movement are related to the position of the sacrum and ischium. When the pelvis is retroverted, the sacrum turns vertical, SI and lumbar lordosis decrease, and the ischial tuberosities come close to the lesser trochanters (Fig. 10). In clinical practice, cervical lordosis, thoracic kyphosis and the lumbar lordosis angles, pelvic incidence angle, pelvis version angle, sagittal line at T9 angle, tibio-femoral angle, plumbline of C7, vertical line of the external auditory canal, and leg length discrepancy are the commonly measured used to assess sagittal balance of the spine [37].

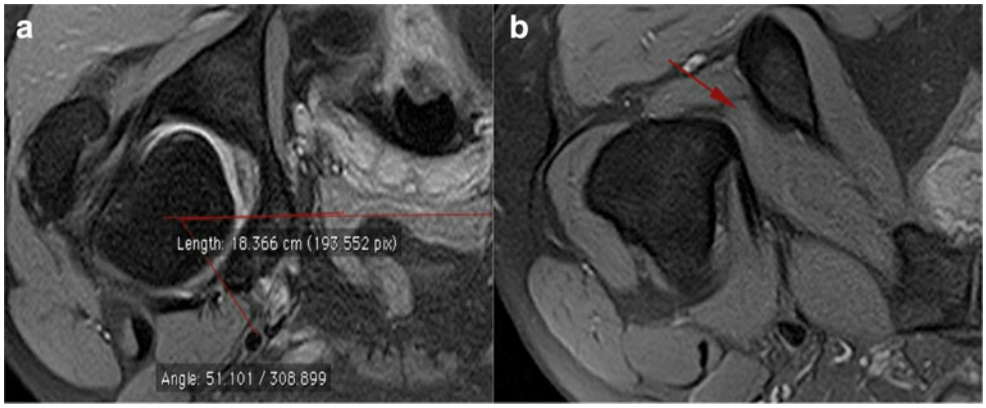



**Fig. 9** IFI secondary to anterior acetabular coverage deficit and femoral dysplasia. Axial PD fat-suppressed MR images show a decreased AASA angle and impingement (*arrow*) in a 45-year-old woman

## Abductor/adductor muscles imbalance

Abnormal gait that results from abductor dysfunction and lead to subsequent pathology in the QFM has been hypothesized. Cases of abductor muscle pathology that develop IFI have been recently described [4]. The reason why some patients are prone to impingement following injury to the abductor is an unresolved question, but such damage has the potential to disturb the quadratus femoris space either directly, via an abnormal gait, or due to the secondary atrophy of abductors muscles (retroverted pelvic imbalance approximates the ischial tuberosity to the lesser trochanter). If prolonged adduction occurs as a result of abductor impairment, the ischiofemoral gap will be narrowed. A wide spectrum of conditions in the hip, back, or any anatomical region could trigger IFI through this mechanism [4, 23] (Figs. 11, 12, 13, and 14).

Of note, different rates of atrophy have been encountered in synergistic muscles after bed rest secondary to any body pathology. The QFM has a unique response among the hip external rotators to unload, showing a faster rate of atrophy and greater loss of muscle volume, and, expectedly, takes longer to recover. Research on other joints suggests that the local, rather than global, muscles are well suited to provide subtle joint stabilization. Indeed, QFM atrophy itself might reduce IFS. Moreover, muscle injury and inflammation have been documented in resting patients after any pathology and have been found to be associated with fluid changes, masking a lack of recovery of muscle volume in the initial recovery scans (which can be confused with edema on MRI). Future unloading studies could reduce this uncertainty by monitoring the recovery of musculature at frequent intervals and/or using muscle biopsies to understand the underlying histology to these signal changes [38].

Thus, any injury of the abductor or adductor muscles can thus trigger impingement. Gluteal contractures require special attention because they have been related to IFI. Medial retraction of the muscle in advanced cases results in external rotation of the proximal femur that predisposes to IFI [39, 40].

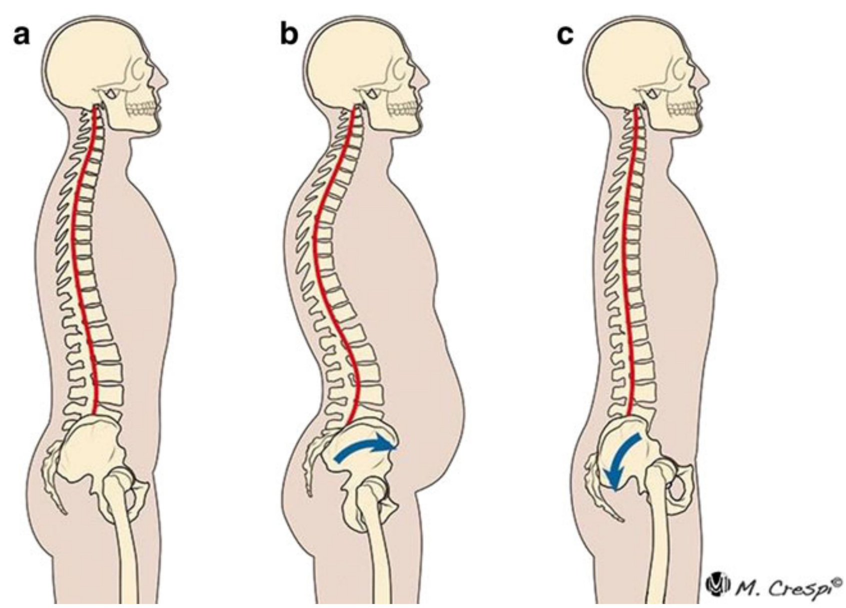



**Fig. 10** Pelvic instability. Normal pelvic alignment is shown in the **a**. Pelvic anteversion (**b**) and retroversion (**c**) movement are related to the position of the sacrum and ischium. When the pelvis is retroverted (**c**), the sacrum turns vertical, SI and lumbar lordosis decrease and the ischial tuberosities come close to the lesser trochanters, causing the impingement

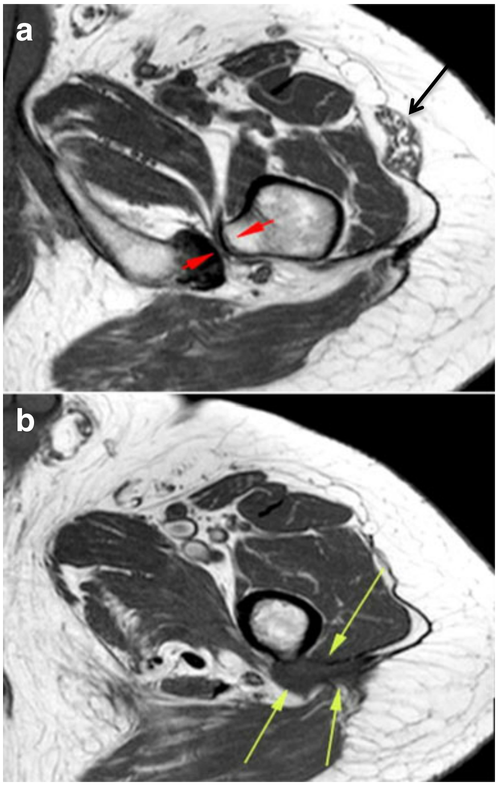



**Fig. 11** IFI secondary to abductor/adductor muscles imbalance. Axial T1-weighted images show a 39-year-old man with left IFI (*red arrows* in **a**) as a result of a degenerative tendinopathy and extensive partial tear of the distal insertion of the gluteus maximus muscle (*green arrows* in **b**). Note the atrophy of the abductor muscles, especially affecting the tensor fascia latae muscle (*black arrow* in **a**)

## Ischial tuberosity enthesopathies

Hamstring disorders, as a cause of impingement, have been recently described. Tendinosis leads to swelling and widening

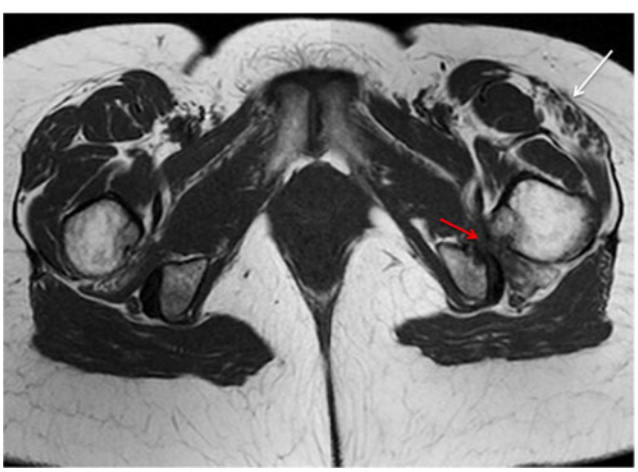


**Fig. 12** IFI secondary to abductor/adductor muscles imbalance. Axial T1-weighted MR image shows a case of left IFI (*red arrow*) secondary to pelvic muscle imbalance as a result of a partial tear of the proximal insertion of the left tensor fascia lata muscle (*white arrow*)

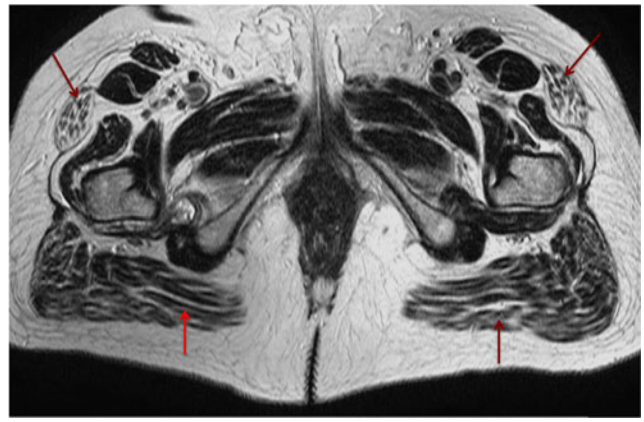


**Fig. 13** IFI secondary to abductor/adductor muscle imbalance. Axial T1-weighted MR image shows a case of bilateral IFI that is more pronounced on the right side, secondary to bilateral and symmetrical atrophy of abductor muscles (*red arrows*) in a 45-year-old man after 2 months of bed rest due to a cerebrovascular accident

of the proximal hamstring tendon insertion and results in narrowing of the QFS and thus impingement. Therefore, hamstring tendinosis might be the cause or the consequence of the dynamic changes described in IFI [2, 4, 6]. A wide spectrum of hamstring origin enthesopathies that are present in isolation or in combination may trigger IFI including partial/complete hamstring strain, tendon detachment, avulsion fractures, apophysitis, nonunited apophysis, proximal tendinopathy, calcifying tendinosis, and contusions. Imaging findings are specific to each type of injury [16] (Fig. 15).

## Injuries related to trauma, overuse or extreme movements of the hip

A history of traumatic injury to the pelvis is likely relevant to IFI. Progressive narrowing of the IFS and

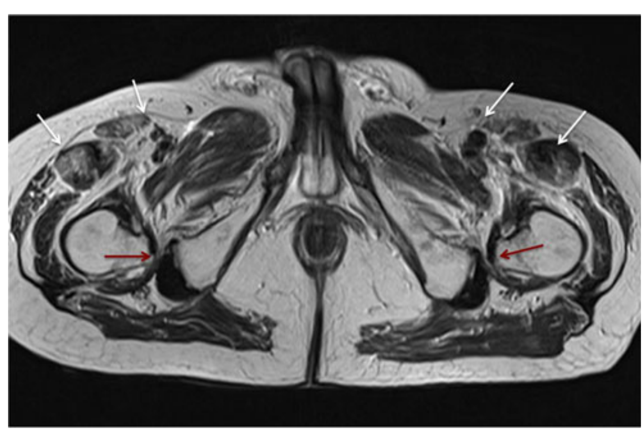


**Fig. 14** IFI secondary to abductor/adductor muscle imbalance. Axial T1-weighted and PD fat-suppressed MR images show a case of bilateral IFI (*red arrows*) secondary to bilateral and symmetrical atrophy of the adductor and flexor muscle groups (*white arrows*) in a 62-year-old man diagnosed with an advanced autoimmune myopathy

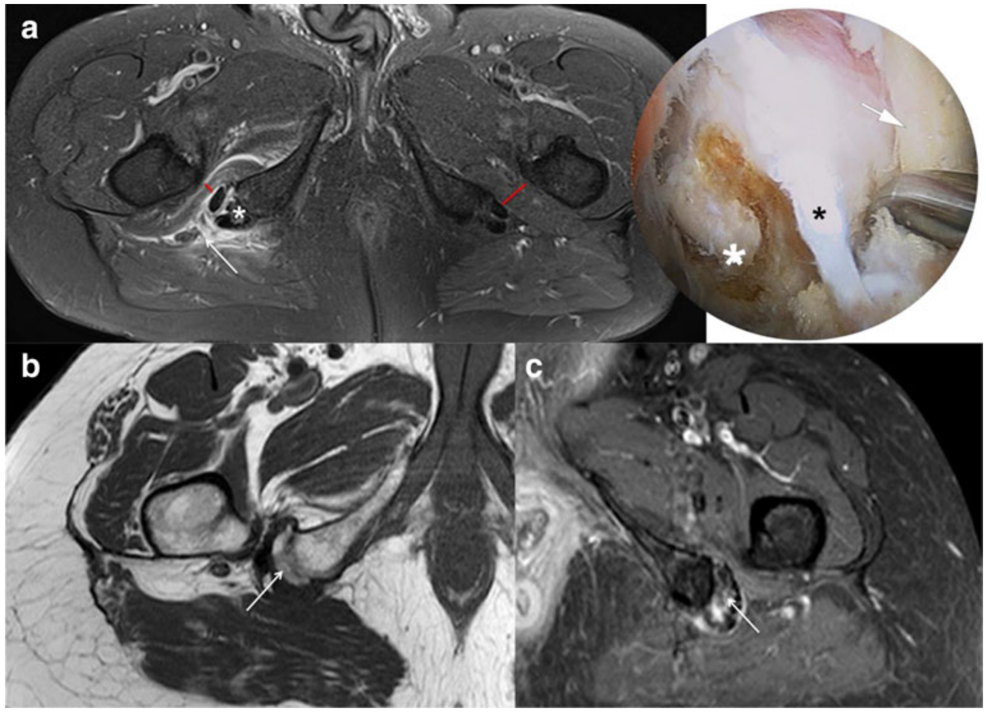



**Fig. 15** IFI secondary to hamstring enthesopathy as a result of decreased quadratus femoris space: **a** Axial PD fat-suppressed MR image and endoscopic image show a severe degenerative calcifying (*asterisk*) tendinopathy of hamstring tendons with reactive sciatic neuritis (*white arrow*); note the decrease of the right QFS compared to the contralateral side (*red line*); **b** Axial T1-weighted MR image shows a deformed ischial tuberosity secondary to an old hamstring avulsion (*arrow*) with secondary IFI in a 58-year-old man; **c** Extensive degenerative tendinopathy with partial tear of semitendinosus-biceps femoris conjoined tendon (*arrow*) causing IFI

quadratus femoris edema on MRI, over a long period, have been documented in patients who presented with post-traumatic hip pain and developed IFI. In particular, abnormal gait may have led to this IFS narrowing. IFI and other atypical forms of impingement may be associated with overuse or the extreme external rotation of the hip during extension in ballet, soccer players, martial arts and other sports [3]. Intense, sudden positional QFS narrowing during intensive training can cause acute

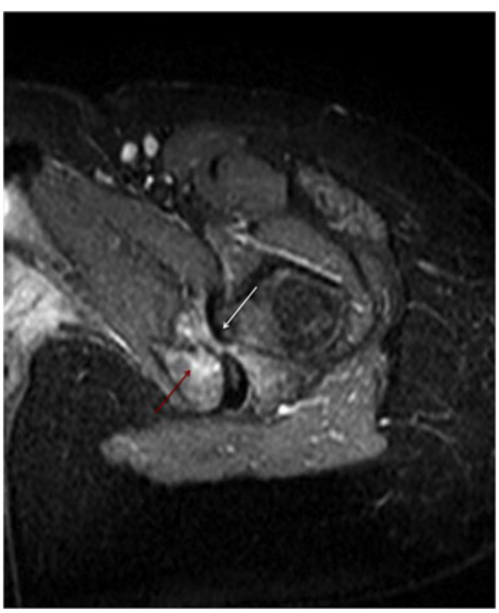


**Fig. 16** Acute traumatic IFI: extreme external rotation in the extension position. Axial short tau recovery (STIR) MR image shows a cortical disruption of the anterior ischial tuberosity aspect (*red arrow*) secondary to sudden and intense osseous ischiofemoral impingement (*white arrow*) in a 29-year-old man during an international karate competition

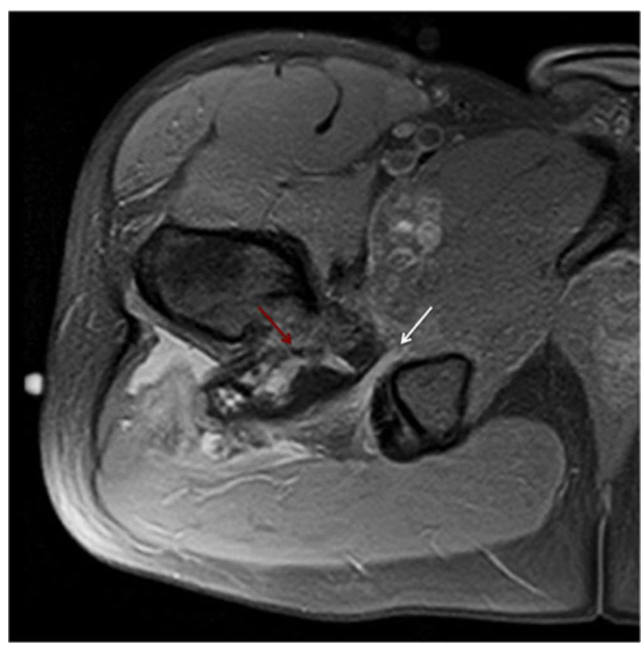


**Fig. 17** Osteochondroma as a cause of IFI. Axial fat-suppressed PD-weighted MR image in a 32-year-old man shows an exostosis arising from the medial aspect of the femoral metaphysis (*red arrow*) with signs of osseous impingement (*white arrows*) and a full tear of the QFM. Exostosis bursata (adventitious bursa) is also seen. Osteochondroma removal resulted in complete resolution of symptoms

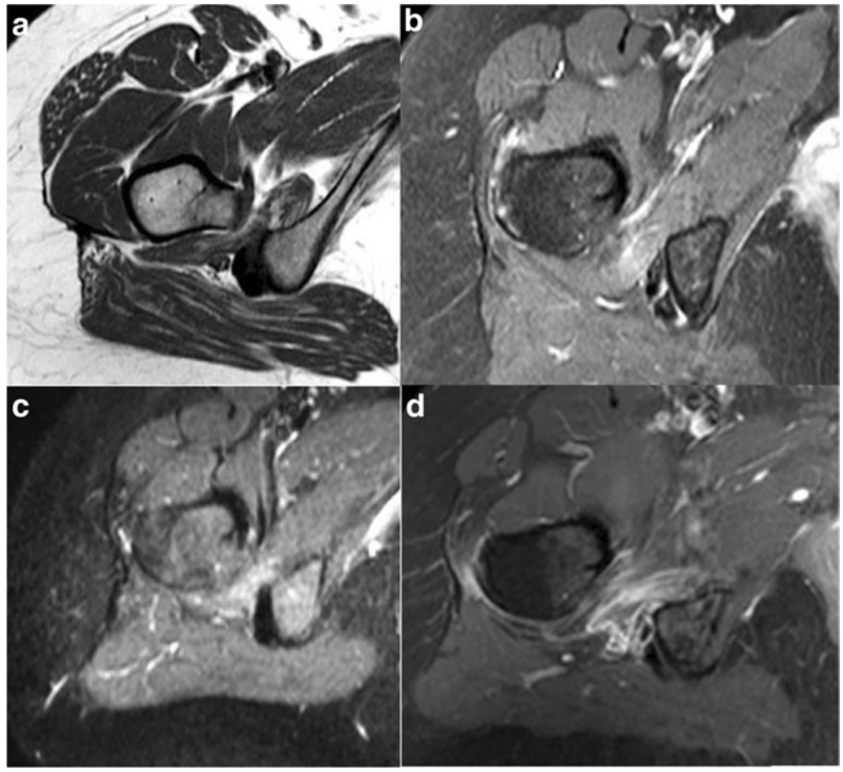


**Fig. 18** Edema stages affecting QFM in patients with IFI. Crowding of the anterior surface of the QFM fibers as it passes between ischium/hamstring tendons and the posteromedial femur is the minor stage that can be seen on MRI (**a**). The QFM edema may be considered mild or grade 1 if it consists of focal edema in the region where the narrowest IFS and QFS values are measured (**b**), moderate or grade 2 if diffuse edema extends outside the narrowest point (**c**), and severe or grade 3 if QFM edema extends to the surrounding soft tissues (**d**)

QFM damage and acute IFI (Fig. 16). Furthermore, intertrochanteric fractures with involvement of the lesser trochanter and post-fracture deformity may predisposes to or cause IFI [26, 41].

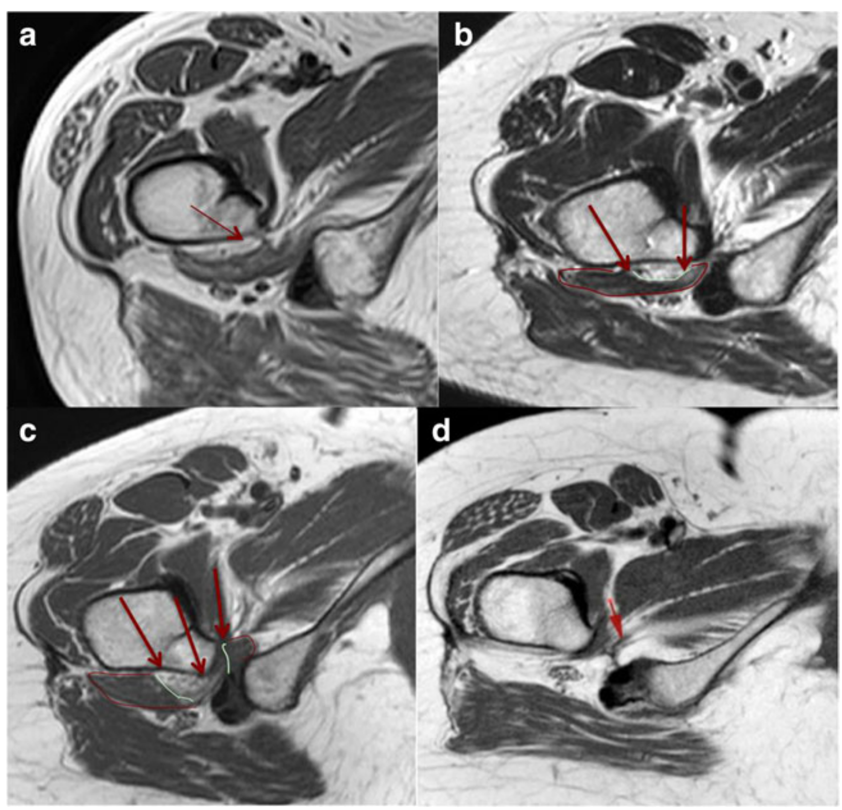


**Fig. 19** Tear stages affecting QFM in patients with IFI are best evaluated on axial T1-weighted MRI images: anterior myofascial disruption (**a**), anterior partial tear (**b**), full thickness partial tear (**c**) and complete atrophy (*short arrow*) (**d**). *Red lines* demarcate the normal limit of muscle fascia and *green lines* define tears. *Long arrows* mark the transition point between the normal fascia and the tear

## Iatrogenic causes

IFI was first described in patients after total hip joint replacement and after valgus-producing intertrochanteric osteotomies, but this is not a frequent cause. Although these and other iatrogenic causes are included in multiple articles, published cases are scarce [23].

## Tumors

Osteochondroma (OC) is the most common bone tumor involved in IFI development. OC may be solitary or multiple, the latter being associated with hereditary multiple exostoses (HME) [41, 42]. Complications are more frequent with HME and include deformity, fracture, vascular compromise, neurologic sequelae, overlying bursa formation, and malignant transformation (seen in 1 % of solitary OC and in 3-5 % of patients with HME). Exostoses may narrow the IFS and cause impingement, even without malignant transformation (Fig. 16). Pain is improved by resection of the ischial or femur exostoses [42–44].

## Other etiologies

Osteoarthritis leading to superior and medial migration of the femur has also been proposed as a possible mechanism for IFI in older women [23].

Furthermore, although quadratus femoris wasting may simply be part of impingement another possibility is that atrophy and edema-like signal alterations arises from denervation of the muscle, as the nerve runs in the area of space conflict. It is possible that any cause of QFM atrophy, such as injuries, burns, long-term corticosteroid therapies, immobilization, sciatic neuropathy, and spinal cord injury, may predispose an individual to IS narrowing because this muscle is a primary stabilizer of the hip joint. However, more functional studies need to be conducted to evaluate this hypothesis [4].

### Imaging findings

There are no specific radiographic findings for IFI. The IFS narrowing on radiographs is uncommon and has not been related to clinical findings or other imaging tests [6]. Although chronic osseous changes of the lesser trochanter and ischial tuberosity may be present, it is uncertain whether chronic contact between them represents the cause. However, hip and pelvic radiographs are useful to diagnose osseous abnormalities that may cause acquired IFI or to depict other causes of pain [15, 45] (Fig. 6).

Ultrasound (US) may show hyperemia within the IFS although normal results has been reported in patients found to have impingement changes on MRI (Video 1) [46–48].

Currently, 3D/4D high-resolution multidetector CT scans provide interesting images simplifying the image interpretation to better evaluate the relationship between QFM and adjacent osseous structures through a full range of hip motion. Specific software has been developed to generate models for dynamization and preoperative templating of extra-articular impingement. As a result, insight can be gained as to whether an arthroscopic, open, or combined approach is necessary, where the specific location of mechanical conflict is occurring and how much must be resected to eliminate this mechanical conflict (Video 2) [28, 49].

MR imaging is the gold standard method for diagnosing IFI. As Torriani and subsequently Tosun suggested, ischiofemoral narrowing can be evaluated by measuring the IFS, QFS, hamstring tendon area (HTA), and total QFM volume (TQFMV), with good-to-excellent intra/interobserver reliability for all measures. The IFS, QFS, and TQFMV values of patients have found to be significantly lower than those of

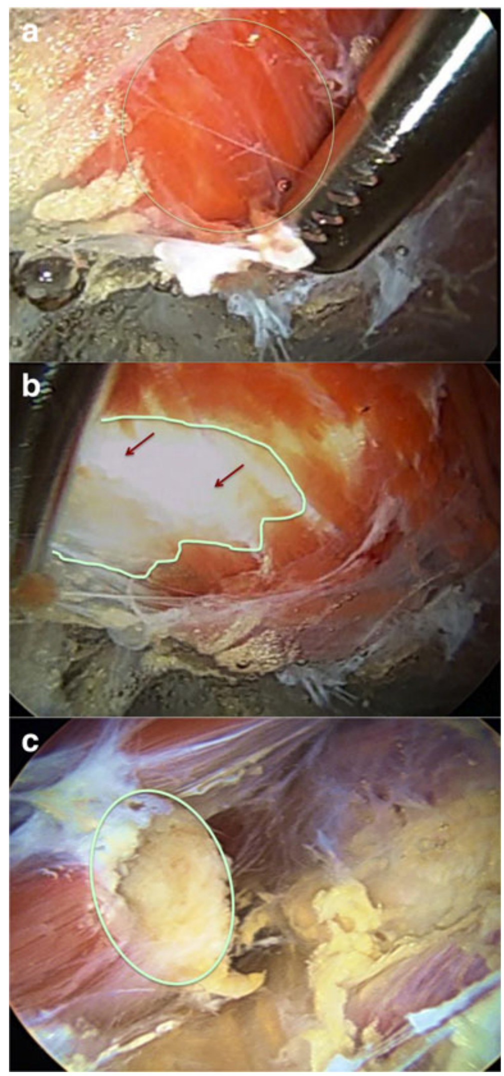



**Fig. 20** Tear stages affecting QFM in patients with IFI. Endoscopic images show an anterior myofascial disruption (*green lines* define tears) (**a**), a full-thickness partial tear (**b**) and a complete tear (**c**)

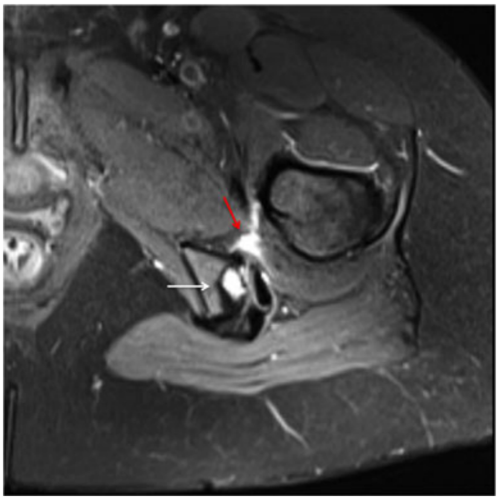


**Fig. 21** Subcortical bone changes in a patient with an evolved IFI. Subcortical simple cysts affecting the ischial tuberosity (*white arrow*) are not common. Note the complete tear of the medial portion of the QFM (*red arrow*)

controls, whereas the HTA and IA measurements are significantly higher [2, 6] (Fig. 5).

Possible visible MRI abnormalities are listed below:

1. Quadratus femoris muscle. The lesional spectrum description include crowding of the fibers (Fig. 17a), intramuscular edema at the maximal impingement point without disruption of the fibers [6] (Fig. 18b-d), anterior myofascial disruption and partial tear or full tear (Figs. 19a, c, and 20) and muscle wasting/fatty infiltration, which is best visualized on T1-weighted MRI images and usually occurs in patients with long-standing IFI. Muscle atrophy may be graduated as grade 1 (tiny linear fat signal intensity between muscle fibers), grade 2 (thicker and linear globular fat signal intensity occupying <50 % of the QFM) and grade 3 (>50 % of the muscle) [6] (Figs. 19d, 20).
2. Bones. Bone marrow edema and subcortical changes are extremely rare unless a complete atrophy of QFM and a direct osseous impingement exists. If bone marrow edema is present in the lesser trochanter or ischial tuberosity, it will likely be secondary to hamstring tendon abnormalities or spread by soft tissue edema [6, 15, 41] (Fig. 21).
3. Tendons. Cases of severe changes within the QFM are more likely to show edema surrounding the hamstring tendon attachments. However, adjacent inflammation, musculotendinous injury, unrelated enthesopathy, and overuse syndromes may also account for these findings [6]. The hamstring tendons of affected subjects may show edema, degenerative tendinopathy, partial tears and, more rarely, full-thickness tears (Fig. 22). Although no tears are usually seen involving the ilio-psoas tendon, edema surrounding its insertion and tendinosis are not uncommon [28].
4. Bursae and adipose tissue. Edema affecting the ischiofemoral fat is commonly seen in IFI. Bursa-like fluid collections (thickened bursal type tissue) surrounding the lesser trochanter in the area of the impingement may be present due to friction between it and overlying soft tissues [6, 50]. This finding can mimic iliopsoas, obturator externus, or ischial bursitis. Obturator externus and ischiogluteal, gluteofemoral, and iliopsoas bursae are the hip bursae that may be affected by IFI [28, 50–53] (Figs. 23, 24).
5. Nerve. The proximity of the sciatic nerve to an abnormal QFM may contribute to lower back pain [12, 45]. With severe edema in the perisciatic fat, irritation of the adjacent sciatic nerve may cause acute deep gluteal syndrome (sciatic neuritis). Chronic inflammatory changes and adhesions causing scar tissue between the muscle and the sciatic nerve result in entrapment during hip motion, which causes chronic deep gluteal syndrome [12] (Fig. 25).

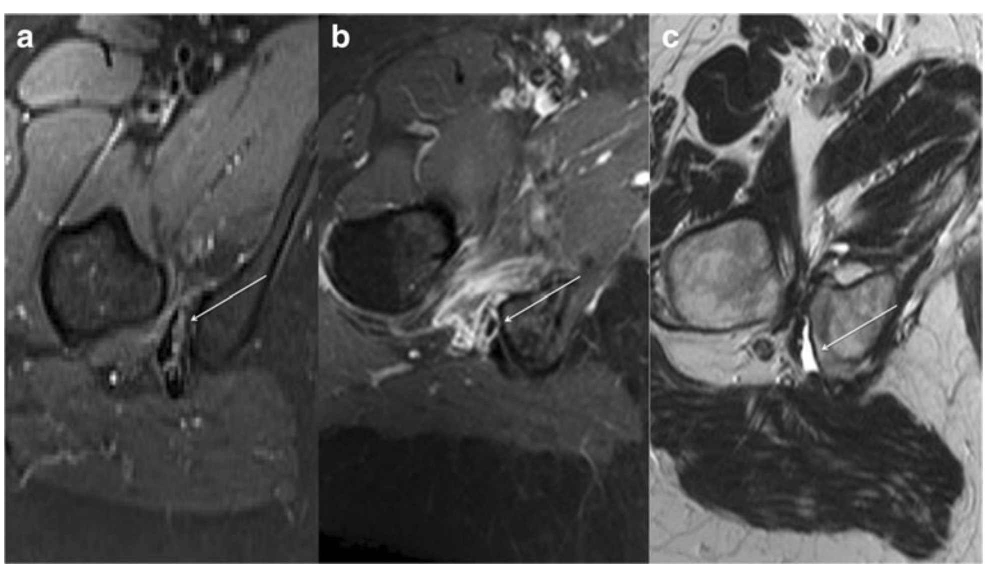



**Fig. 22** Tendon injuries in the context of IFI. Axial PD fat-suppressed MRI images show peritendinous edema of the hamstring secondary to IFI without signs of tear (**a**) and extensive partial tear of the semimembranosus tendon (**b**). Axial T1-weighted MR image shows a complete tear of the conjoined tendon and semimembranosus tendon (**c**)

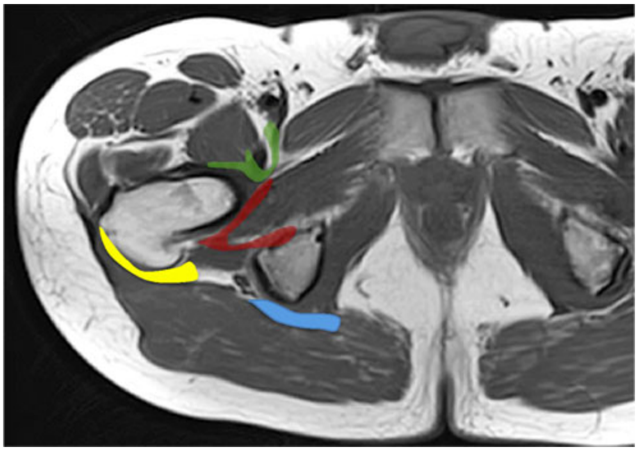


**Fig. 23** Normal bursae around the hip joint. Obturator externus (*red*), ischiogluteal (*blue*), gluteofemoral (*yellow*), and iliopsoas (*green*) are the most frequent bursae that may be affected in patients with IFI

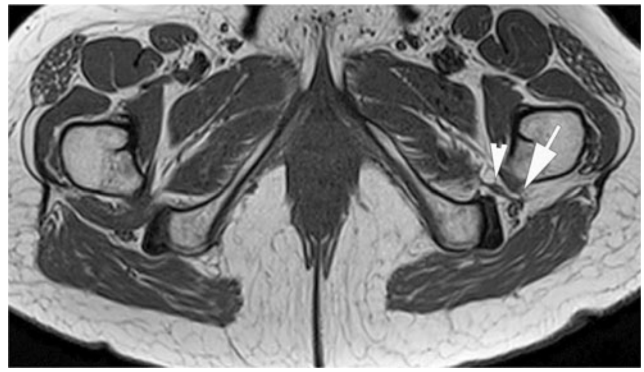


**Fig. 25** Left deep gluteal syndrome secondary to chronic IFI in a 53-year-old woman. Axial PD-weighted MR image shows bilateral narrowing of the IFS. On the left side, QFM atrophy and a residual fibrous type-2 band (*arrowhead*) anchored to the sciatic nerve (*arrow*) are seen

## Differential diagnosis

A wide range of conditions related to hip pain must be ruled out in the clinical and imaging differential diagnosis of IFI including deep gluteal syndrome [12], hamstring or iliopsoas injuries, femoroacetabular impingement (FAI), strain or tear of the QFM without narrowing of the IFS, bursitis without impingement, denervation patterns of the QFM, delayed-onset muscle soreness (DOMS), myotendinous tear of the obturator externus and more rarely, QFM tear, tendinosis, avulsion or agenesis [12, 54–57].

## Injection test

The injection test is a useful tool for IFI treatment and also enables diagnosis and the exclusion of disorders within other spaces [12]. Guided injections within and around the QFM, utilizing US or CT, have been used [18, 28, 46, 47, 58]. We recommend a CT-guided postero-lateral approach, to avoid the quadratus, sciatic and posterior femoral cutaneous nerves located in the subgluteal space. Obliquely oriented angles in a section located at the lower-third of the QFM, below the posterior circumflex artery, provides a path in a prone patient that is less difficult and painful and that carries less risk (Figs. 1 and 26) [59]. Most patients recognize the pain location when the needle is advancing into the IFS, and as an indicator of a successful injection, they experience a significant immediate post-injection decrease in symptomatology, which can last from 1 day to 9 months [18, 46, 58]. In summary, although the injection test is not always a definitive treatment, it is a nonsurgical alternative in selected patients that provides the palliative relief of symptoms, [15].

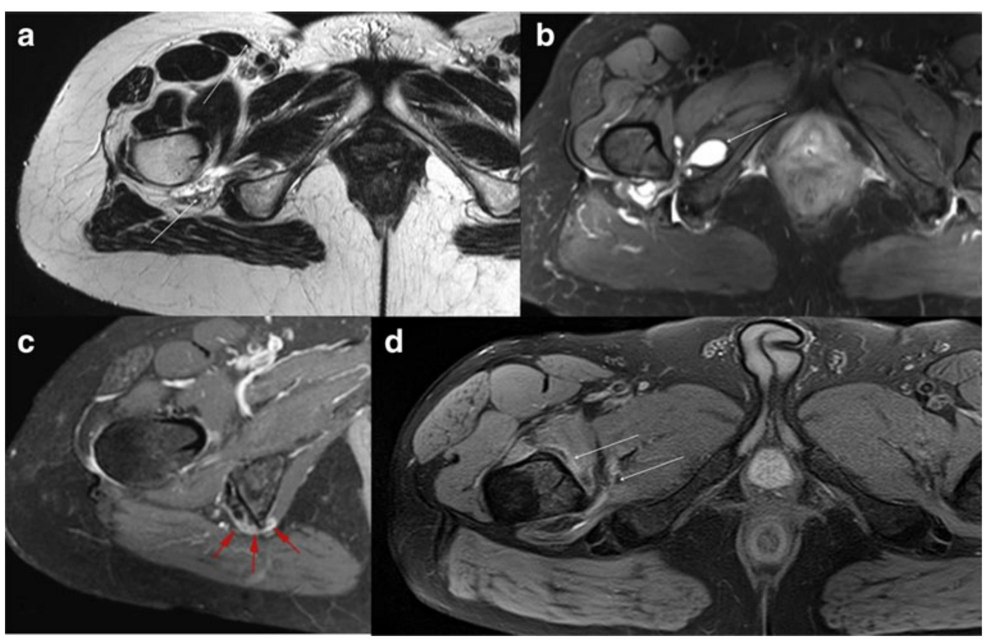



**Fig. 24** Bursal abnormalities in patients with IFI. Axial T1-weighted MR image shows an inflammatory reaction of the ischiofemoral fat with a pseudobursa formation by accumulation and encapsulation of edema. Note the inflammatory and granulation tissue, blood remnants, and muscle tissue remnants within the bursa-like collection (*white arrow*) (**a**). Axial PD fat-suppressed MR image demonstrates a moderate obturator externus bursitis (*arrow*) (**b**), a distended ischio-gluteal bursa (*red arrows*) (**c**) and a slight ilio-psoas bursitis (*arrows*) (**d**)

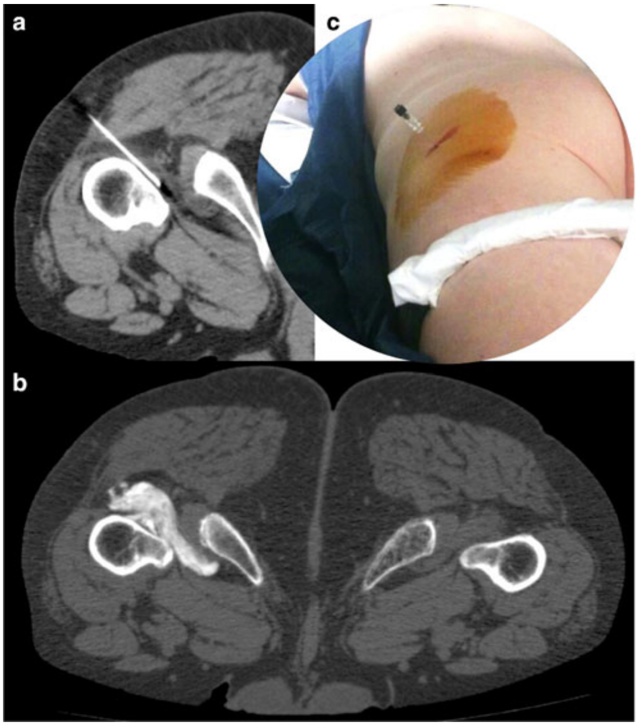


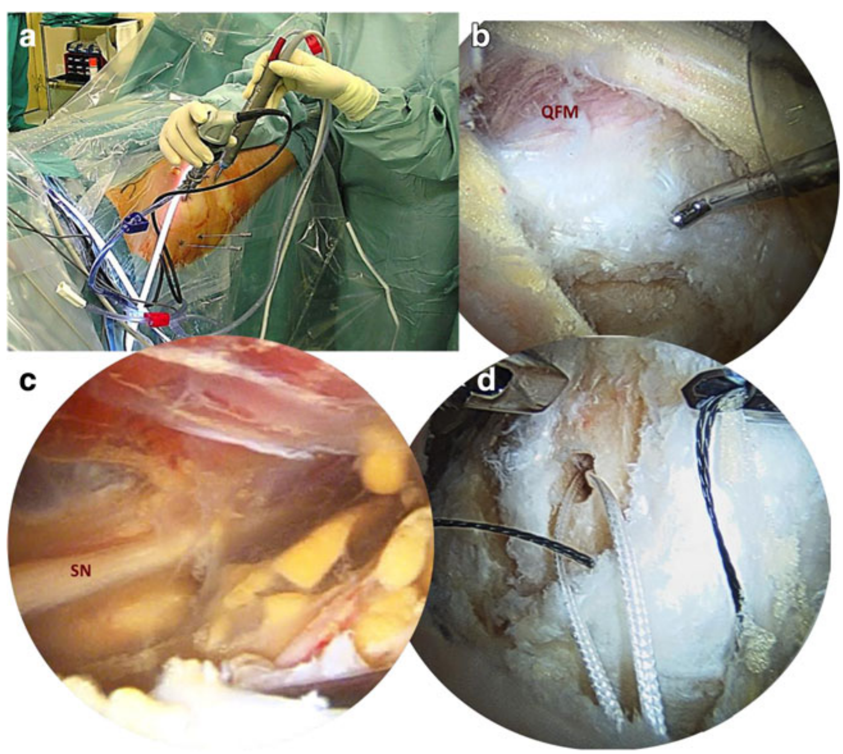
Fig. 26 Double injection of anesthetic and corticosteroid technique (infiltration test). Axial MDCT image (**a**) shows the sectional plane chosen for CT-guided infiltration of the peri-quadratus space using the postero-lateral approach. Note that it is located at the lower-third of the QFM, below the posterior circumflex artery (see Fig. 1). The solution contains a small amount of iodinated contrast to assess the location of the injection more accurately. Axial MDCT image (**b**) shows the final distribution of the solution. **c** The anatomical landmark

## Treatment

Several management strategies have been proposed for relieving symptoms, although no definitive treatment has been recommended. Initial management should be conservative. Several reports describe patients successfully treated with a non-surgical algorithm, which can normalize the range of motion in the hip joint. Stretching exercises and strengthening of the spine musculature and the hip muscles are essential. The exercise program must be targeted to the external rotators of the hip, specially the QFM and abductor musculature, to adequately reduce pain and increase range of motion in the hip joint and increase its stabilizing effect on the hip. This approach may be essential for solving cases secondary to atrophy or related to instability of the hip, pelvis, and spine. Although activity restriction and rest can prevent pain, they promote atrophy of the quadratus femoris and abductor muscles, which are suspected to be part of the pathophysiologic mechanism that prolongs and worsens the problem. Non-steroidal anti-inflammatory medications and an infiltration test may be beneficial as an adjunct to the exercise program [50, 51].

When conservative measures fail, surgery may be beneficial. Arthroscopic access to decompress the IFS, as an alternative to an open approach, has been recently described with high success rates because it managed to significantly improve clinical scores [59]. The posterolateral trans-quadratus approach seems to be the most appropriate route [60]. The anatomy of vascular structures suggests increased safety of

Fig. 27 Endoscopic treatment in patients affected by IFI. Arthroscopic access to decompress the IFS (**a**). A posterolateral trans-quadratus approach seems the most appropriate route (**b**). Assessment of the sciatic nerve (**c**). Hamstring repair: debridement with an oscillating shaver and suture (**d**)



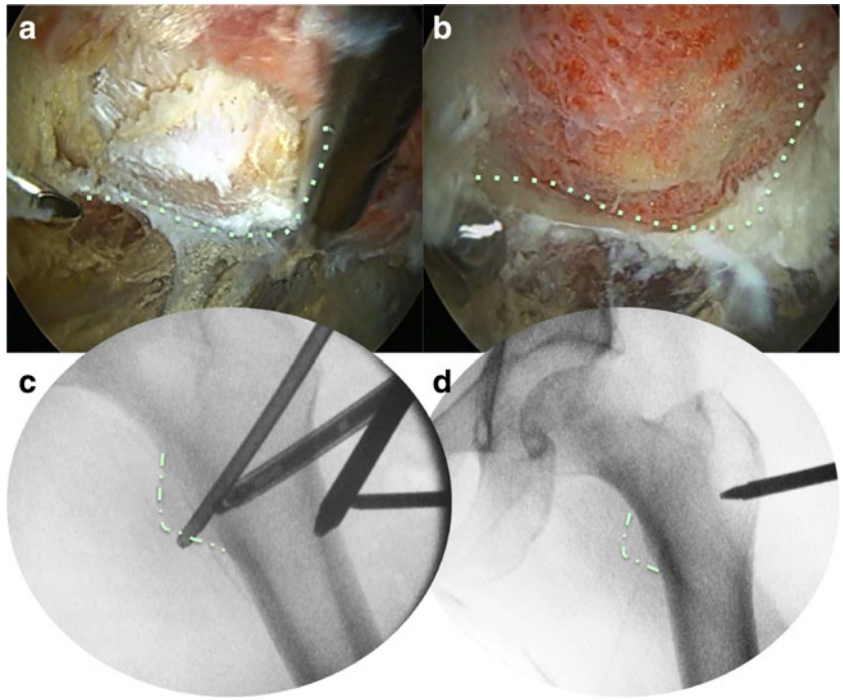


**Fig. 28** Endoscopic treatment in patients affected by IFI. Intraoperative endoscopic (**a**, **b**) and fluoroscopy (**c**, **d**) images show the lesser trochanter before (**a**, **c**) and after (**b**, **d**) performing the resection. The *dotted line* delineates the margins of the trochanter. The aim of the osteoplasty of the posterior one-third of the lesser trochanter is to obtain an IFS of at least 17 mm leaving non-impingement bone and the iliopsoas insertion intact

posterior access to the lesser trochanter [59, 61]. Assessment of the sciatic nerve within the subgluteal fat must be done to perform neurolysis in the case of entrapment [12]. QFM debridement is indicated when tears are present. If advanced degenerative changes exist, complete muscle resection may be effective. To protect the vessels, preservation of the proximal and distal muscle is recommended. Resection of the lesser trochanter under fluoroscopy control (bur approximately 3–7 mm) through a small window in the QFM to resect it between the medial circumflex femoral artery (proximal) and first perforating femoral artery (distal) is the procedure of choice [12, 61, 62]. The ilio-psoas insertion can typically be left intact with good clinical outcomes [20]. Excess bone debris must be evacuated to minimize heterotopic ossification risk. The aim of the osteoplasty of the posterior one-third of the lesser trochanter is to obtain an IFS of at least 17 mm, leaving non-impingement bone and the iliopsoas insertion intact. Intraoperative dynamic tests are necessary to avoid under or over resection. Partial resection can potentially decrease the risk of stress fracture when compared with complete resection and this fact may be particularly important for high-performance athletes [20, 59, 63]. If hamstring repair is necessary, partial tearing debridement with an oscillating shaver and suture (one suture anchor per centimeter of detachment) is required [20, 64] (Figs. 27, and 28).

## Conclusions

IFI is an underrecognized condition and its etiology is multifactorial. Potential sources of ischiofemoral engagement include anatomic variants of the proximal femur or pelvis, functional disorders such as hip instability, pelvic/spinal instability, or abductor/adductor imbalance, hamstring conditions, trauma, overuse, or extreme hip motion and tumors.

There is great difficulty in formulating a diagnosis of this condition because the history and physical examination are imprecise and difficult to interpret. Therefore, MR imaging is the diagnostic procedure of choice for assessing IFI and may substantially influence the management of these patients. This article reviewed the underlying pathophysiological mechanisms in IFI based on individual patients. Future prospective studies may establish a direct and statistically significant cause–effect relationship between the described mechanisms and IFI.

**Compliance with ethical standards**

**Conflict of interest** The authors declare that they have no conflicts of interest.

**Human and animal rights and informed consent** All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

Informed consent was obtained from all individual participants included in the study.

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