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Emerging topics on the hip: Ligamentum teres and hip microinstability

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ABSTRACT

Microinstability and ligament teres lesions are emergent topics on the hip pathology. These entities are an increasingly recognized cause of persistent hip pain and should be considered in the differential diagnosis of the patient with hip pain. Conventional (non-arthrographic) CT and MR have a very limited role in the evaluation of these entities. CTa and MRa have emerged as the modalities of choice for pre-operative imaging of ligamentum teres injuries and microinstability. To date, pre-operative imaging detection of these pathologies is not widespread but with appropriate imaging and a high index of suspicion, preoperative detection should improve. This article discusses current concepts regarding anatomy, biomechanics, clinical findings, diagnosis and treatment of ligament teres lesions and microinstability.

1. Introduction

Microinstability and ligament teres pathology are emergent topics on the hip pathology that are acquiring recognition as a source of pain and disability.

Abnormalities of the ligamentum teres and microinstability are important causes to consider in the differential diagnosis of the patient with hip pain.

To date, reports of lesions of the ligamentum teres and microinstability have been scarce. The number of hip arthroscopies has increased on the last ten years and with that the recognition of lesions of the ligamentum teres and its role in hip pain and hip stability.

MR arthrography and CT arthrography are the imaging techniques of choice for precise preoperative diagnosis of these entities. Treatment of these lesions is still evolving and has some controversy. Actually nowadays treatment of most injuries is limited to arthroscopic debridement in case of ligament teres and capsule shrinkage when microinstability.

2. Ligamentum teres

2.1. Anatomy and biomechanics of the ligamentum teres

The ligamentum teres of the hip has traditionally been considered as an embryonic remnant without relevant importance in adult hip biomechanics or vascularity. It is a strong intraarticular ligament and an important stabilizer of the hip, particularly in adduction, flexion and external rotation. It arises predominantly from the transverse acetabular ligament along the inferior margin of the acetabulum. It has two or three fascicles and is also attached to periosteum along the ischial and pubic margins of the acetabular notch. Its proximal insertion is in the fovea capitis, a focal depression in the femoral head, typically located slightly posterior and inferior to the center of the femoral head articular surface. There is no hyaline cartilage covering the fovea capitis. An anterior branch of the posterior division of the obturator artery provides blood supply to the ligamentum (Figs. 1–3) [1].

The exact function of the ligamentum teres is not yet clear, different theories have been proposed: first, ligamentum teres might have the same function in the hip that anterior cruciate ligament (ACL) in the knee, a strong intrinsic stabilizer that resists joint subluxation forces [2–4]. Patients with tears of the ligamentum teres develop hip microinstability and when combined with sporting activities (such as running, football, and tennis), results in damage to the labrum and cartilage, explaining the high association rate between tears of the ligamentum teres, labral tears, and cartilage lesions [5,6]. Second, the ligamentum teres may play a role in nociception and coordination of movements. Third, the ligamentum teres provides blood supply to the developing femoral head [2]. Finally, Gray and Villar theorize that the ligament um teres may help to distribute synovial fluid within the hip joint via a “windshield wiper effect” [7].

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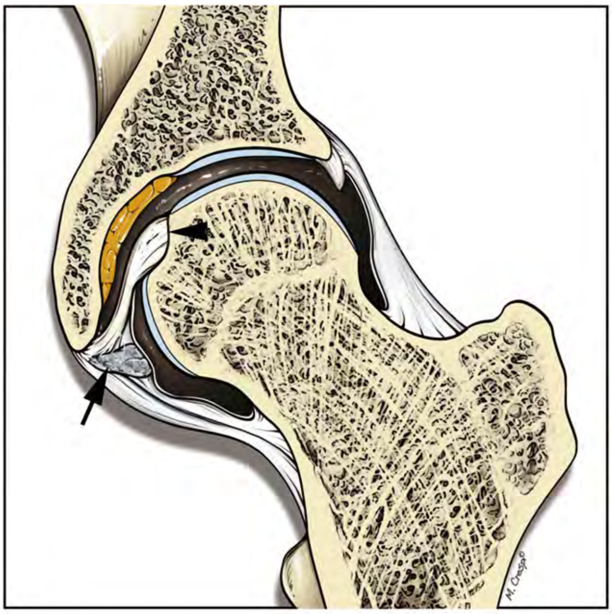

Fig. 1. (A) Cross sectional diagram shows the anatomy of the ligamentum teres. The ligamentum has a broad origin, blending with the transverse ligament of the Acetabulum (arrow). It attaches to the ischial and pubic sides of the acetabular notch by two bands and inserts in the *fovea capitis femoris* (arrowhead). Its arterial supply is provided by the anterior branch of the posterior division of the obturator artery.

2.2. Classification of ligamentum teres injuries

Based on their arthroscopic findings, Gray and Villar classified ligamentum teres tears into 3 types: type I: complete rupture; type II: partial rupture; type III: degenerative ligament tear [7].

Complete ligamentous tear (type I), is seen in patients with a history or traumatic or surgical joint disruption, this group also has high incidence of additional intraarticular pathology including chondral lesions and labral tears [5,6,8].

Partial ligamentous tear (type II), is seen in patients with a long history of symptoms and chronic vague hip pain without significant other findings.

Degenerative tear (type III), is typically associated with osteoarthritis [9,10].

2.3. The ligamentum teres in other conditions

Patients with developmental dysplasia of the hip (DDH) have been found to have thickened, hypertrophied, or elongated ligamentum, this may reflect adaptive changes to resist hip dislocation [11], also in Perthes disease, there is obliterative thickening of the arteries of the ligamentum teres with associated edema and perivascular infiltration.

In osteonecrosis of the femoral head, the ligament may become hypertrophied with an increased number of well-organized collagen fibers [2].

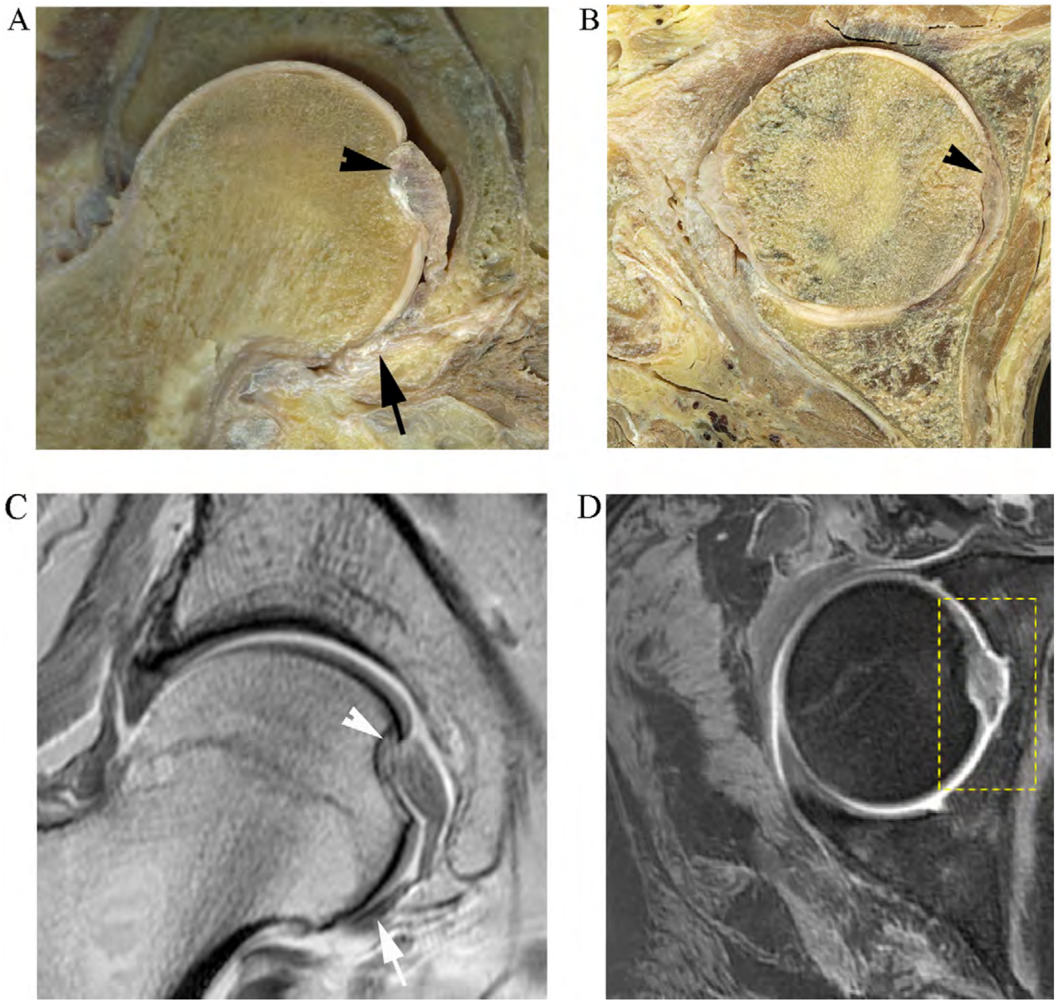

Fig. 2. (A–D) Coronal oblique (A) and axial (B) cadaveric slices and corresponding T1 and T1 fat-suppressed MR arthrogram images demonstrate the entire length of the ligamentum teres from its origin in the transverse acetabular ligament (arrows) to the fovea capitis (arrowheads).

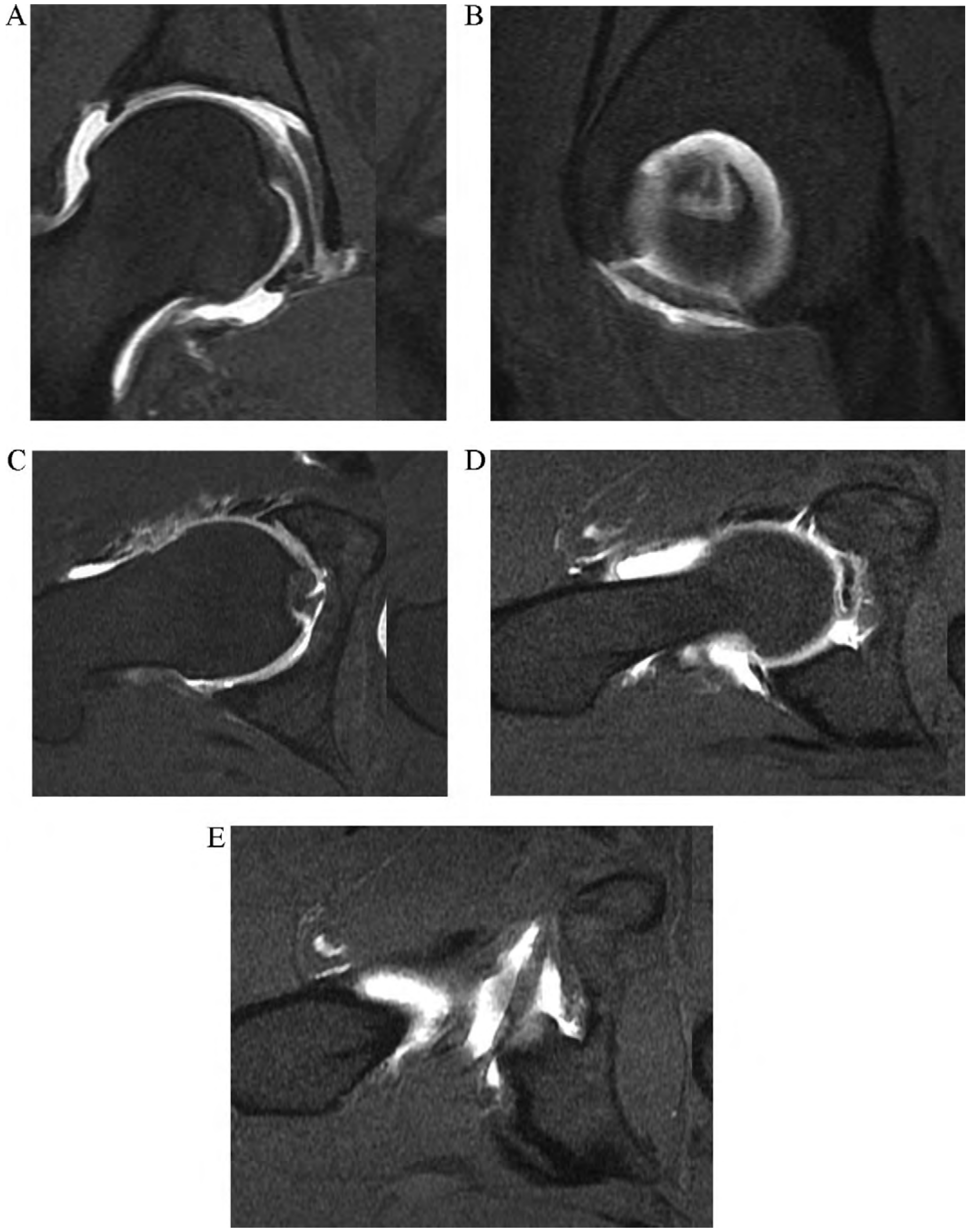

Fig. 3. Anatomy of the ligamentum teres. T1-weighted fat suppressed MR arthrogram images in the coronal (A), sagittal (B), and axial oblique plane (C, D and E consecutive images), show normal ligamentum teres as a band with smooth margins from the transverse acetabular ligament to the fovea capitis (A and B). The axial oblique consecutive images show the foveal insertion (C), the middle portion with two fascicles (D) and the transverse acetabular ligament (E).

2.4. Similarities between ligamentum teres and the anterior cruciate ligament of the knee

The ligamentum teres and the anterior cruciate ligament (ACL) join some common features [2]. Anatomically both ligaments are strong intraarticular ligaments, and share similar biomechanical properties at histopathological examination. Clinically, both have poor healing capacity and may become ossified in certain enthesopathies [1]. However, it should be noted that the ligamentum teres has better in vitro healing ability than ACL [2].

2.5. Mechanism of injuries and associated lesions

Although tear of ligamentum teres is usually associated with hip dislocation, partial or complete tears can also occur in the setting of other joint stresses such as a flexion–adduction stress which may occur with a fall on the ipsilateral knee with the hip flexed, or after a sudden twisting injury (typically external rotation) of the hip [2,8,12]. Given the proposed mechanisms of injury described above, ligamentum teres tears may appear in high impact sports (e.g. American football, hockey) or sports that require extreme ranges of motion (e.g. ballet, martial arts) [2,5,12]. Although there have been case reports of acute ligamentous injuries occurring during activities of daily living. These cases only described femoral avulsions of the ligament [13].

Surgical dislocation of the hip, which can be employed in open treatment of femoroacetabular impingement, may require disruption of the ligamentum teres to allow disarticulation of the hip and adequate access to the acetabular rim [1].

Congenital absence of the ligamentum teres has been reported in patients with developmental dysplasia of the hip or diastrophic dysplasia, to our knowledge there are no reports in the medical literature regarding the incidence or significance of congenital absence of the ligamentum teres in normal hips [14]. Those cases with congenital absence might have hypoplastic fovea capitis.

2.6. Clinical diagnosis

Clinical diagnosis of a tear of the ligamentum teres remains challenging, symptoms of ligamentum teres injury are nonspecific and can be encountered in the setting of other intraarticular pathology (hip and groin pain, locking, catching). On physical examination decreased extension, painful straight leg raise, locking of the joint and reduced or painful range of motion, may be found. No specific test exists for the detection of tears of the ligamentum teres [3,8,12,15].

A detailed clinical history with careful analysis of the mechanism of injury and a high index of suspicion are mandatory. Complete exam should be performed including log-roll, resisted straight leg raise and McCarthy's tests [2,8,12]. It should be noted that, particularly in athletes, disabling symptoms may not be present.

2.7. Diagnostic imaging

Although non-arthrographic MR is adequate for the evaluation of most joints, actually MR arthrography (MRa) and CT arthrography (CTa) have been shown to be superior assessing intraarticular lesions of the hip [9,16–19]. The advantage of MRa (and CTa) is that the contrast can flow between the individual structures and thus outline their margins and surfaces allowing detection of subtle lesions. Normal ligament has a smooth contour and is homogeneous with low signal intensity on all pulse sequences (Figs. 2 and 3) [9,16–19]. Abnormalities of the ligament that may be seen at MRa include: hypertrophy, fraying, discontinuity and increased signal intensity [9,16]. Conventional MR may show edema in the acetabular fossa, such edema may be difficult to appreciate at MRa due to the paradoxical effects of the intraarticular gadolinium. Partial and complete tears of the ligamentum teres are most common near the fovea capitis, close attention should be paid to this area when evaluating hip MR, MRa and CTa [5]. Accurate assessment for ligamentum teres tears requires the combined use of coronal and axial or axial oblique images. The axial oblique plane is particularly useful for differentiating grades of ligamentum teres injury. The axial oblique plane assessment increases MR, CTa, and MRa specificity in distinguishing partial from complete ligamentum teres tears since the ligament is seen in true cross-section (Fig. 3C–E) [1]. In acute ligamentum teres tear, there are primary signs of ligament rupture on MR, CTa, and MRa such as discontinuity of the ligament with a wavy or lax contour. The injured ligamentum teres usually demonstrates increased signal intensity on T2, fat suppressed proton density (PD), or T2*-weighted images. An edematous soft tissue mass may be seen surrounding the torn fibers (Fig. 4). Widening of the entire ligament with blurring of the ligamentum teres fascicles (due to edema or hemorrhage) is seen when there is an interstitial tear. Edema in the acetabular fossa, synovitis and joint effusion are secondary and non-specific signs of acute ligamentum teres tear. The diagnostic accuracy of CTa and, especially, MRa is far superior to MR in the evaluation of ligamentum teres tears. In chronic ligamentum teres tears where may be focal loss of continuity and elongation of the ligament which may itself have an irregular or lax contour. The ligamentum teres may also appear attenuated in chronic tears Figure [1].

Accurate assessment of partial ligamentous tears is more difficult than detection of complete disruptions. Partial ligamentum teres tears are characterized by intra-substance abnormal signal intensity with morphologic alteration such as thickening secondary to scar formation, attenuation of the ligamentum, or focal partial loss of continuity. CTa and MRa best delineate morphologic contour alterations and partial fluid-filled defects [1].

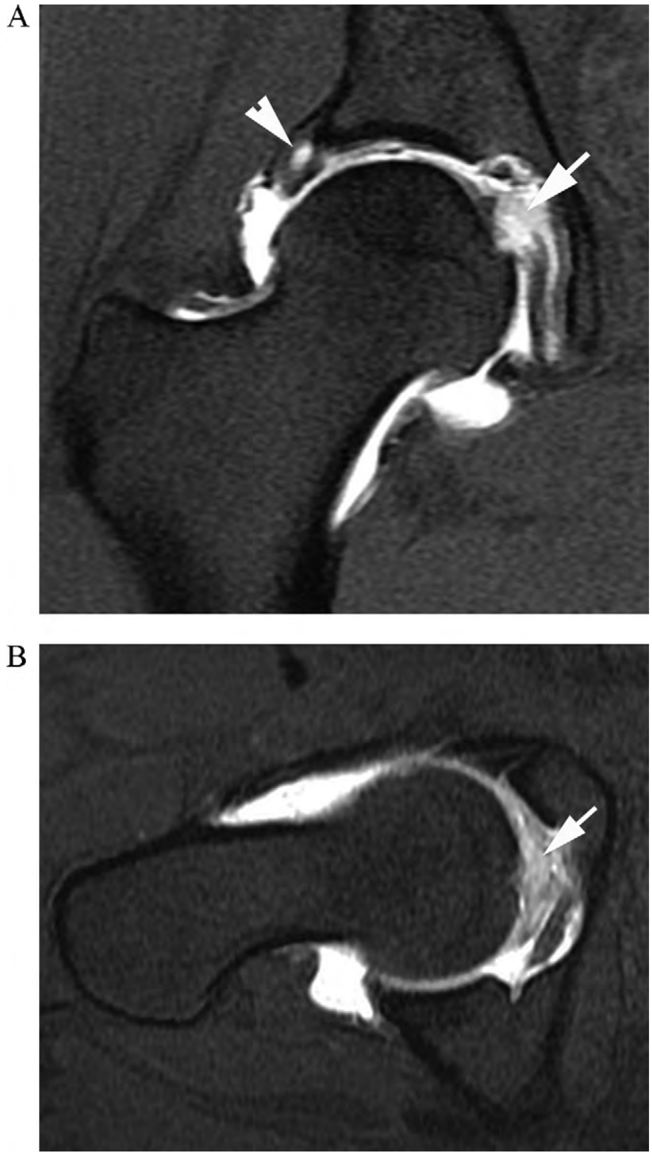

Fig. 4. Avulsion of the foveal attachment of the ligamentum teres. T1-weighted fat suppressed MR arthrogram images in the coronal (A) and axial oblique plane (B) show a chronic complete tear of the ligamentum teres at its foveal attachment (arrows). Note the existence of degenerative changes in the lateral acetabular labrum (arrowhead in A).

Mucoid degeneration represents the ligamentum teres response to degeneration and/or chronic tears. This is usually associated with other degenerative intraarticular joint pathology such as cartilage injuries and secondary subchondral changes (e.g. cysts, sclerosis). MR and MRa criteria of mucoid degenerative changes of the ligamentum teres include increased signal on T1- and T2-weighted sequences. Often these degenerative changes are associated with irregular ligament contours and focal areas of partial, or less commonly, complete loss of continuity (Fig. 5). It may be difficult to differentiate a degenerative tear from a traumatic tear. In these cases, clinical correlation is critical [1].

Avulsions of the foveal attachment of the ligamentum teres may be nondisplaced, partially displaced or completely displaced. Dis-

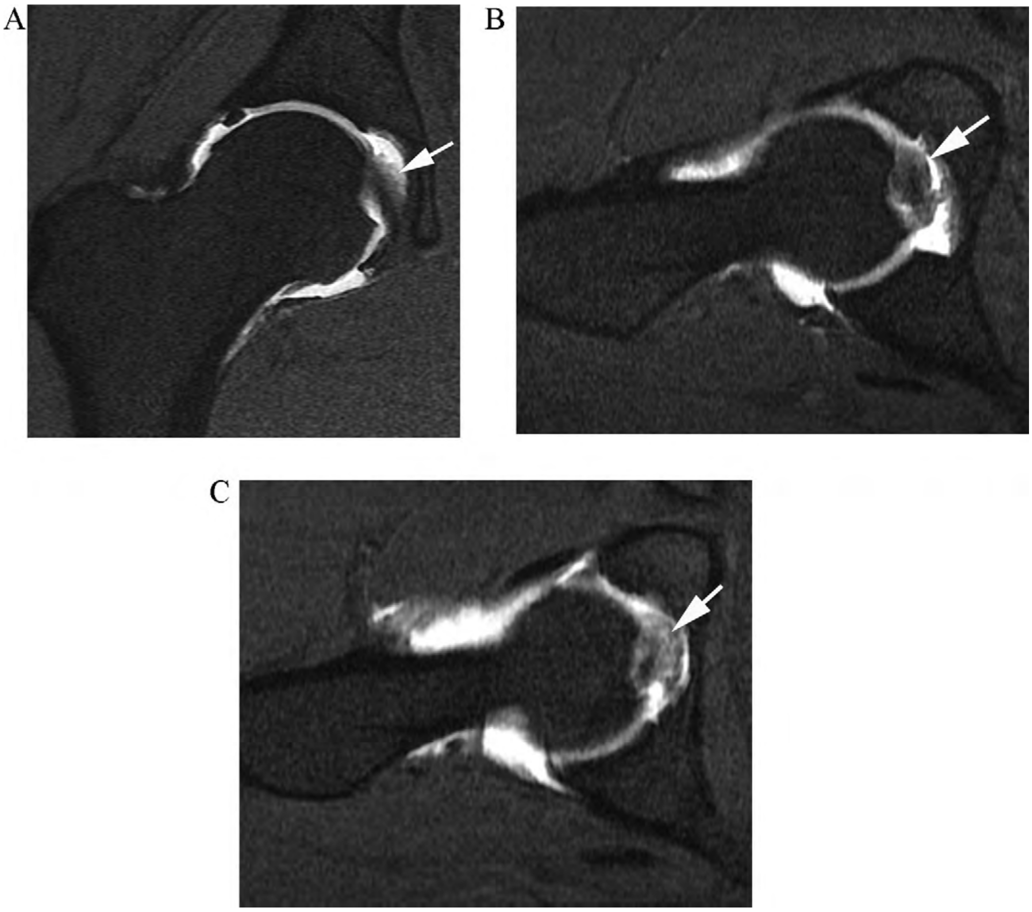

Fig. 5. Degenerative injury of the ligamentum teres. T1-weighted fat suppressed MR arthrogram images in the coronal (A) and axial oblique plane (B and C) show thickening, fraying and hyperintensity of the ligamentum teres along the perifoveal área (arrows).

placed avulsion fractures of the ligamentum teres may be clearly depicted on MRa. However, the diagnosis of minimal or nondisplaced avulsion fractures can be overlooked on MRa. In these cases careful evaluation of marrow signal on T2 or PD fat-suppressed sequences is essential. CTa allows better assessment of these nondisplaced bone fragments [1].

It is difficult to differentiate between congenital absence and chronic complete tear of the ligamentum teres. Complete absence of the ligamentum teres with a shallow fovea supports the diagnosis of congenital absence (Fig. 6) [1].

2.8. Management and arthroscopic treatment

Currently, ligamentum teres lesions are treated arthroscopically [10,20–22]. Although indications for treatment are evolving, common indications include pain or mechanical symptoms associated with MR evidence of ligamentous hypertrophy, ligamentous tears (partial or complete), or edema in the acetabular fossa [5,21]. Avulsion of the ligamentum with loose osteochondral fragments is another indication for surgery [23]. Treatment options for ligamentum teres lesions are currently limited to debridement and shrinkage of the ligament. Debridement of frayed and torn ligamentum teres fibers, or the stump in the case of complete tears, relieves mechanical symptoms and pain [5,21,22]. In cases of ligamentum teres stumps with an attached bone fragment, arthroscopic debridement has good results, particularly if there is no associated acetabular fracture or either femoral or acetabular osteochondral defect [23,24]. Given the relatively rapid progression of ACL reconstructions and the proposed similarities between the ACL and the ligamentum teres, it is possible that open or arthroscopic ligamentum teres reconstructions may be commonly performed in the near future. Complete ligamentum teres tears have a guarded prognosis because there is a high incidence of premature degenerative arthritis, presumably due to the original injury.

3. Hip microinstability

Hip microinstability is the inability to keep the femoral head centered within the acetabular fossa, without complete luxation or marked subluxation of the joint. Hip laxity is not equivalent to microinstability. The difference is the presence of symptoms associated with laxity when we classified as microinstability. Only when symptoms are present in the context of laxity can be classified as microinstability. An asymptomatic patient that is able to subluxate a joint has laxity, but not microinstability. Patients with microinstability often have laxity in both hips; only the symptomatic is classified as having microinstability.

3.1. Anatomy

Unlike the shoulder, the hip joint is intrinsically stable joint because of depth and conformity of the articulation between the femoral head and the acetabulum. Despite this intrinsic stability provided by the osseous anatomy, ligaments, capsule and musculotendinous structures surrounding the hip joint are important to give additional static and dynamic stability to this joint, particularly during rotation and extremes of motions associated with some sports [25].

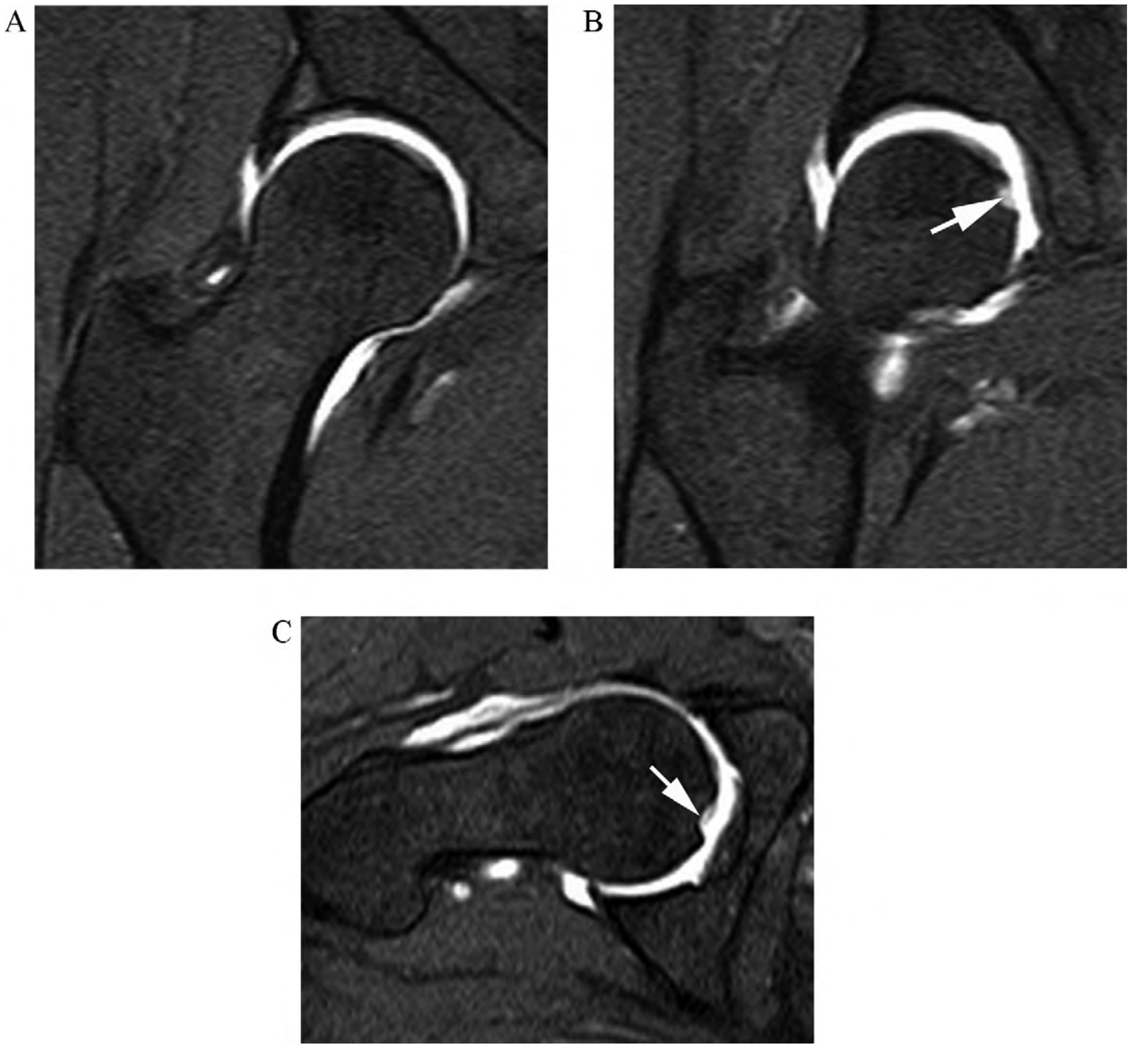

Fig. 6. Congenital absence of the ligamentum teres. T1-weighted fat suppressed MR arthrogram images in the coronal (A and B) axial oblique plane (C) show a complete absence of the ligamentum teres (A–C) with a shallow fovea (arrows in B and C).

The fibrous hip capsule has three thickenings which form the main capsular ligaments: the iliofemoral, the pubofemoral and the ischiofemoral. Other ligaments of the hip include the *zona orbicularis*, arcuate ligament and ligamentum teres. The iliofemoral ligament (Y-shaped-ligament of Bigelow) originates from the anterior inferior iliac spine and inserts on the intertrochanteric line. It is anterior to the femoral head and helps to resist anterior translation during extension and external rotation. The pubofemoral ligament originates from the pubic ramus and descends to merge with inferior fibers of the iliofemoral ligament, reinforcing the inferior and anterior joint capsule. Pubofemoral ligament has the same functional role as the iliofemoral ligament. The ischiofemoral ligament originates from the ischium and inserts on the intertrochanteric line of the femur and reinforces the posterior portion of the capsule. The arcuate ligament is in the posterior side of the capsule and reinforces the hip during extreme flexion and extension. The *zona orbicularis* is a circular ligament that surrounds the femoral neck, is inferior to the femoral head and resists inferior distraction forces. The ligamentum teres seems important maintaining the normal relationship between the femoral head and the acetabulum.

The acetabular labrum may also play a role in stability. It runs circumferencially around the acetabular perimeter and helps to contain the femoral head in extremes of range of motion. The psoas tendon covers and protects the anterior intermediate aspect of the hip capsule. It limits anterior translation of femoral head.

3.2. Microinstability, etiology, pathomechanics and associated lesions

Microinstability can be considered either traumatic or atraumatic in origin.

Traumatic microinstability may occur in athletic or active patients who have had repetitive microtrauma from axial loading and external rotation. Axial repetitive loading and external rotation in the hip joint are found in figure skating, tennis, football, baseball, golf, skating, martial arts, gymnastics and ballet.

Actually any joint pathology, with labral tears as quintessential example, may lead to microinstability, and potential lesion of other structures (capsule, ligaments, surrounding soft tissues, etc.).

Non traumatic microinstability of the hip can also occur in patients with generalized ligamentous laxity either congenital or acquired. Hypermobility syndromes are rare, include Ehlers–Danlos syndrome, Marfan syndrome and Down's syndrome [25–28]. Acquired joint laxity is related to lack of muscular support which is more common in young women. Microinstability is uncommon in elderly patients due to the natural stiffening of tissues around the hip.

Another mechanism of microinstability is the developmental dysplasia of the hip. It is caused by a hypoplastic acetabular fossa that leads to joint instability [29–31]. Overuse and repetitive motion is the most common cause of microinstability of the hip.

Fig. 7. Microinstability. Consecutive coronal T1-weighted images from MR arthrogram with leg traction show thickening and laxity of the iliofemoral ligament (arrows in A and B) and the joint capsule (arrows in C and D). A chronic complete tear of the ligamentum teres with significant joint distraction can also be appreciated (arrowheads in C and D).

Microinstability should not be dismissed in patients who present with symptoms following a traumatic event since trauma can precipitate this disorder in some cases.

Capsular microtrauma that occurs with repetitive external rotation and axial loading or the presence of generalized ligamentous laxity can generate capsular redundancy over time. The dynamic and transient joint incongruence resulting from hip capsular laxity can lead to abnormal joint forces that may predispose patients to labral injuries, worsening capsular redundancy, and femoral neck impingement symptoms at high flexion angles (secondary impingement) [27].

Once the static stabilizers of the hip including the iliofemoral ligament and labrum are injured, the hip must rely more on the dynamic stabilizers like the iliopsoas and hip abductors that should work harder to stabilize the hip. It is not uncommon for patients with capsular laxity to develop iliotibial band tightness, iliopsoas tendonitis and coxa saltans (hip snapping). Iliotibial band syndrome occurs when the iliotibial band displaces or subluxes posteriorly over the greater trochanter in internal rotation. Thus it is possible that many causes of recurrent and non healing iliotibial band tightness and iliopsoas tendonitis are a consequence of occult undetected hip microinstability.

Microinstability may also increase friction within the joint, cartilage consolidation and strain within the articular cartilage thereby possibly resulting in accelerated degeneration of the joint.

“Triple impingement” is a newly recognized entity that combines Pincer-type impingement, labral pathology and internal or psoas snapping hip. The symptoms arise from psoas tendon inflammation, when part of the tendinous area of the psoas tightens causing it to snap across the anterior overcoverage of the acetabulum. This friction generates anterior edge loading of the acetabular rim and labrum causing crushing or tearing. When patient presents with internal snapping hip, overcoverage of the acetabulum and labral tear, it is called triple impingement as stated before [32].

The clinical presentation of triple impingement overlaps with microinstability. Therefore acetabular overcoverage (Pincer-type impingement) may be the key feature to differentiate both entities.

Ligamentum teres injuries and microinstability are closely related to one another, ligamentum teres lesions can lead to microinstability and vice versa.

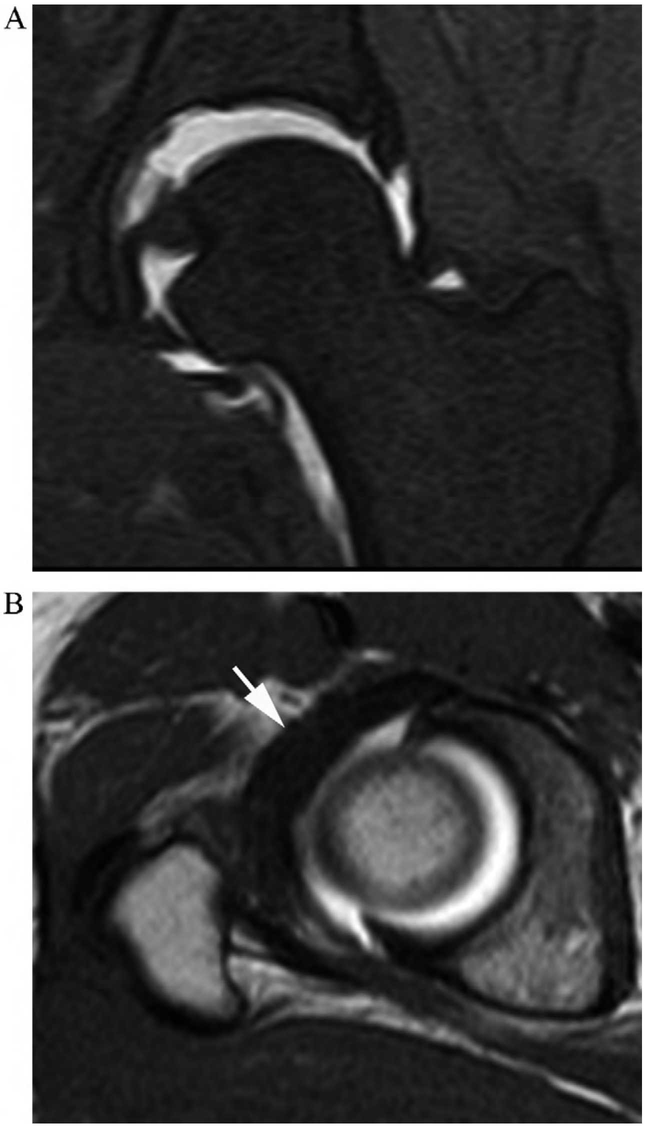

Fig. 8. (A and B) Hip joint microinstability. MR arthrogram with leg traction shows significant joint distraction (with only 6 kg traction). Thickening and irregularity of the iliofemoral ligament are also noted (arrow in B).

3.3. Clinical diagnosis

Clinical diagnosis of hip microstability is not easy. The appropriate diagnosis relies upon a combination of clinical suspicion, physical examination, and imaging findings. Patients present with widely varied symptoms. They commonly complain of "instability", their leg "giving-out" during walking or during sporting activities, snapping, apprehension, or recurrent instability episodes without a defined injury, many times with an insidious onset.

In addition, these patients may also present with hip pain, iliopsoas tendonitis or iliotibial band syndrome.

Furthermore, if a patient demonstrates symptoms of femoroacetabular impingement without osseous abnormalities, "non osseous" impingement from capsular laxity may be the cause [27].

Physical exam should find signs of muscle weakness around the hip.

Patients with instability commonly have an abnormal gait pattern (abductor lurch or a Trendelemburg gait).

Generalized ligamentous laxity should also be assessed in all patients with hip complaints (hyperextension of the elbows, hyper-

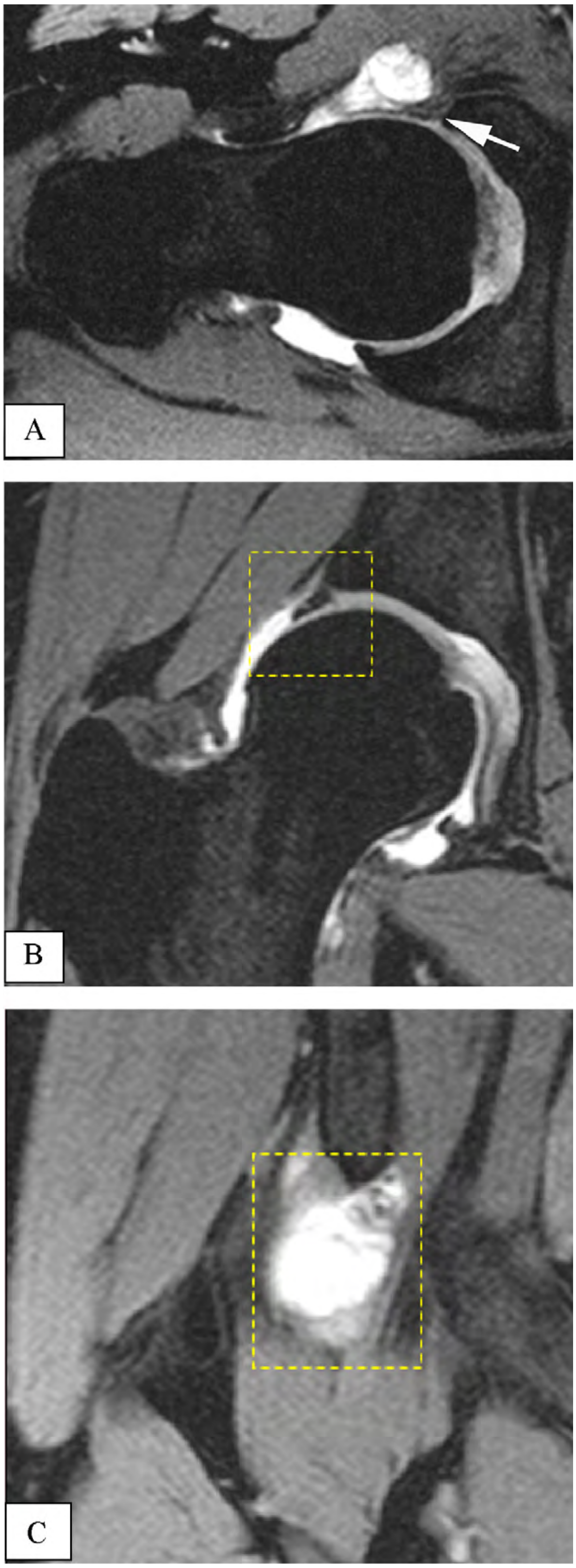

Fig. 9. Patient with hip developmental dysplasia presenting with microinstability. T1-weighted fat suppressed MR arthrogram images in the axial oblique plane (A) and coronal plane (B and C) show an antero-superior labrum rupture (arrow in A), paralabral cyst (arrowheads in A and C) and mild iliopsoas tendinosis.

mobility of the shoulders, and increased finger and wrist laxity) [25,33].

The specific motion or activity that reproduces the patient's instability is of particular interest to the clinicians. Physician also should know the maneuvers that elicit pain in patients with microinstability such as the axial distraction/apprehension test [34].

Hip capsular laxity should be also assessed: a complete assessment of active and passive hip range of motion is also performed. The posterior impingement test and the Dial test are also useful [34].

Physical examination should also look for late associated entities related to overload of surrounding structures in order to stabilize the joint: iliotibial such as iliotibial band tightness (Ober's test and trochanter palpation), iliopsoas tendinitis: pain (pain elicited with flexion of the hip against resistance with the knee flexed. Iliopsoas), iliopsoas snapping (taking the hip from the flexion, abduction, and external rotation position to an extended, adducted an internally rotated position or iliopsoas tightness (Thomas test) as secondary impingement signs [33].

3.4. Diagnostic imaging

AP radiograph is an essential tool in assessing the presence of acetabular dysplasia. Quantitative measurements of hip dysplasia include center edge angle of Wiberg, Sharp's angle and Tonnis angle. Wiberg angle lower than 20°, Tönnis angle smaller than 10° and Sharp angle greater 42° indicate acetabular dysplasia [35].

Traction view of the hip may be helpful to depict "vacuum" phenomena sign indicating abnormal distraction across the hip joint [28], similarly we have noted empirically that some hips during hip MRa with leg traction distract greater with smaller weight load applied [36].

In microinstability, in addition to plain radiographs, MRI and MRa are important tools for the further workup of unexplained hip pain. On MRa, a thick lateral margin of the anterior capsule (which corresponds to the iliofemoral ligament), along with irregularity of the undersurface on oblique axial images, correlates highly with clinical findings of capsular laxity (Figs. 7 and 8).

It has been also noted an association of capsular laxity in patients with ligamentum teres hypertrophy suggesting recruitment of this ligament.

As we stated before, internal and external snapping hip imaging findings can be seen in microinstability.

The spectrum of MRI findings in internal snapping hip syndrome (iliopsoas tendonitis), include: iliopsoas bursitis, with hyperintensity on T2-weighted or proton density images, also edema and fluid may be found within the musculotendinous unit (Fig. 9).

In external snapping hip syndrome (iliotibial band syndrome), fluid can be found in the greater trochanteric bursa. Also the iliotibial band and the anterior border of the gluteus maximus may show some degree of thickening and hyperintensity best seen on T2-weighted or proton density images.

3.5. Treatment

The management of atraumatic instability is still unclear. Is a difficult diagnosis, the advent of better diagnostic tools and therapeutic options will increase to recognize it as a real entity. The first treatment step includes physical therapy and anti-inflammatory drugs. This therapy helps to relieve pain in order to break the cycle of painful capsulolabral pathology. Acquired joint laxity is related to lack of muscular support which is more common in young women usually responds to a rehabilitation program. If this treatment fails and the patient has pain relief after an intraarticular anesthetic injection, as a sign that main pain is related to intraarticular pathology, then hip arthroscopy may be appropriate. Treatment for hip microinstability related to atraumatic capsular laxity has yet to gain widespread acceptance among hip surgeons.

The objective of arthroscopic treatment of microinstability is to directly reduce the volume of the hip joint capsule or tighten lax ligaments to reduce capsular redundancy and increase joint stability [25,37,38]. Thermal capsulorrhaphy and capsular plication are both effective means of reducing capsular volume to alleviate instability [25,33,39], if the patient demonstrates findings consistent with iliopsoas snapping, iliopsoas tendonitis or hip flexion contracture, an iliopsoas lengthening can be performed at the time of surgery. If the patient has pain over the greater trochanter or iliotibial band snapping, an iliotibial band lengthening can be included in the procedure [33].

If the patient has significant dysplasia, the role of hip arthroscopy is not well defined but several reports in the literature have shown excellent results in the management of labral pathology in patients with dysplasia [30,40]. In case of severe dysplasia, the role of reorientation osteotomy should be examined [41,42].

4. Conclusion

Microinstability and ligamentum teres lesions are an increasingly recognized cause of persistent hip pain and should be considered in the differential diagnosis even when imaging is negative. Conventional (non-arthrographic) CT and MR have a very limited role in the evaluation of these entities. CTa and MRa have emerged as the modalities of choice for pre-operative imaging of ligamentum teres injuries and microinstability. To date, pre-operative imaging detection of these pathologies is not widespread but with appropriate imaging and a high index of suspicion, preoperative detection should improve. More studies, with larger series and longer follow-up are needed for a better understanding of the anatomy, biomechanics, mechanisms of injury, role of imaging in decision making, and treatment of these pathologies.

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