Hip and Groin Pain in the Athlete

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Yiğit Umur Cırdı, Selim Ergün, and Mustafa Karahan

1.1 Introduction

Hip and groin pain is a frequent complaint among the competitive athletes. Even though it is commonly encountered in various branches of sports, there is increased prevalence of groin pain present in sports with sudden direction or momentum changes like pivoting, kicking, and over-limit rotation. The incidence of groin pain is relatively increased among football, rugby, and hockey players; however it may be seen in other sport branches with different levels of activity from amateurs to experts. Pain-related disability and undesired effect on athletic performance significantly increase the popularity and number of athletes seeking medical treatment.

Management of groin pain remains challenging for clinicians because of its complex nature and broad range of underlying etiologies (Table 1.1). Abnormal findings in asymptomatic athletes contribute to the complexity. Even with improved physical examination methods, advanced imaging techniques, and detailed muscle strength measurements, it is not always possible to make an accurate diagnosis, which remains a concern for athletes. It is shown that groin pain may have more than one underlying pathology; therefore athletes with groin pain should be evaluated comprehensively and systematically to narrow the differential diagnosis [1].

Groin injuries account for 3–5% of all sports-related injuries [2, 3]. Incidence varies depending on the sports performed and level of competence. One large study pointed out that groin injury represents 12% of all injuries in professional football players [4, 5]. It has to be kept in mind that 50% of groin injuries result in a delay in returning to sport of more than a 1-week period, and reinjuries cause significantly longer delays than the index injury [6]. Considering the high recurrence rate and

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Table 1.1 Differential diagnosis of pain in groin and hip region

Intra-articular pathologies	Extra-articular pathologies	Other (non-musculoskeletal) pathologies	Red flags
Labral tears	Athletic pubalgia	*Intra-abdominal reasons*	Femur fracture
Femoroacetabular impingement	Strain/tendinitis	Aneurysm, inguinal or femoral hernia, diverticulosis, inflammatory bowel disease	Septic arthritis
Chondral damage	Snapping hip		Malignancies
Arthritis	Iliotibial band syndrome	*Genitourinary reasons*	Appendicitis
Loose bodies	Bursitis	Urinary tract İnfection, epididymitis, testicular torsion, endometriosis, nephrolithiasis, pelvic inflammatory disease	Pregnancy
Avascular necrosis	Lumbar spine pathology		Unexplained weight loss
Femoral neck stress fracture	Referred pain		Trauma
Synovitis	Peripheral nerve compression		Fever
Lig. teres rupture	Sacroiliitis		Hematuria
	Myositis ossificans		

negative effect on activity level, complaints of the athletes should not be neglected, and appropriate diagnostic algorithm must be started immediately to prevent premature ending of their competitive careers [7–9].

Previously groin pain was taught to be generated mostly secondary to basic muscular strains and minor soft-tissue trauma. Increased understanding of the patho-anatomic features of the hip joint and surrounding anatomic structures with additional knowledge of how the hip joint reacts during sports has led to an evolution of the evaluation of groin pain in the athlete. As a result of the increased focus on the ongoing advancements and increased importance of groin pain evaluation in athletes, clinicians organized a meeting in 2014 to clarify the terminology and definitions for groin pain and categorized the underlying pathologies to create a consensus of simple explanations which are convenient for use in clinical practice and research. Search of the literature and common experience by these experts allowed evaluation of collective data, and below are some highlights for better comprehension:

- Careful history taking and physical examination covering more than the musculoskeletal system alone with additional appropriate investigations or referrals are critical for identifying other possible causes.
- Carefully taken history along with a clinical examination and assessment comprising palpation, stretching and resistance testing is critical in acute groin injuries.
- Groin pain in athletes are divided into three main categories:

– Adductor-related, iliopsoas-related, inguinal-related, and pubic-related groin (extra-articular) pain
– Hip-related (intra-articular) groin pain
– Other causes of groin pain in athletes

1.2 Pathoanatomy of the Groin

Hip joint is the largest joint in the body and able to produce multi-directional thrust during competition by complex muscular and neurologic interactions. Since the groin area is surrounded by many significant anatomical structures, the origin of the pain might be confusing. In addition, it should be kept in mind that the underlying cause of groin pain in athletes might be multifactorial. Anatomic features of tendons, ligaments, muscles, cartilage, and osseous structures should be understood well to establish an accurate diagnosis. Clinicians should be aware of the anatomic structures and related sources of pain which may radiate into groin area.

1.3 Clinical Assessment

1.3.1 Patient History

Successful evaluation of the patient begins with a detailed history-taking process. Since there are numerous underlying pathologies that may cause groin pain, it is important to obtain sufficient data to help narrowing the differential diagnosis and reach to the correct diagnosis. Medical information of the patient's pain must include location, time of onset, characteristics of pain, relieving and exaggerating factors, age, sport branch, competitive level, and impact on performance. Duration of the pain should be questioned whether it is acute, subacute, or chronic. Considering many potential causes of groin pain, it is crucial to have a wide range of differential diagnoses before refining the diagnosis and planning the treatment strategy.

Obtained data will guide clinicians to discriminate the intra-articular, extra-articular or non-muscular pathologies. Each verbal clue should be interpreted wisely to eliminate irrelevant causes. Complaints should be processed by the clinician to reach the diagnosis and determine the origin. For instance, acute onset of groin pain accompanying with popping sound is likely to be musculotendinous in origin, whereas dull and long-lasting pain alleviated by activity corresponds an intra-articular origin [10]. Uninterrupted, low-scale pain with constant burning sensation might be interpreted as having a spinal pathology.

Aggravating factors and specific activities must be documented carefully such as pivoting, twisting, and sprinting. These data provide valuable information about the origin of pain and should create a scenario in mind for mechanism of injury and possible damaged anatomic structures causing pain. Pain aggravated by hip flexion and terminal internal rotation would suggest there is high probability of labral pathology. The symptoms of an athlete complaining of snapping sensation with sudden onset of pain might be caused by intra-articular loose body.

Previous medical interventions must be noted including medications, manual therapies, arthroscopies, and surgical dislocations. Documentation of previous injections is crucial. Most athletes tend to skip information about injections. Questioning the type, localization, and purpose of the injection is valuable for evaluating the athletic status, as is whether there was any relief from the injection and the timing of the relief. Consequently, clinicians should create their own well-constructed step-by-step questioning to obtain data about underlying pathology and determine which imaging modalities will be required to make an accurate diagnosis depending on patient's history.

The examination of the hip sometimes can be confusing and challenging. However, with a systematic approach, possible diagnoses can be narrowed down. Appropriate treatment protocol is essential for returning to prior activity level and hinge on the clues obtained during physical examination [11].

1.3.2 Physical Examination

Examination of athlete should be comprehensive and made systematically. Comprehensive examination of the athlete takes place in different positions like standing, seated, supine, lateral, and prone as outlined by Martin et al. [12] (Table 1.2). In the standing position, evaluation begins with inspection. Various vital pieces of information can be gathered by just inspecting the patient carefully. Skin disturbances, ecchymosis, swelling, asymmetry, stance (equal weight bearing),

Table 1.2 Physical examination modalities and tests for patients with hip or groin pain in five different positions

Patient position				
Standing	Seated	Supine	Lateral decubitis	Prone
Posture	Neurologic	Passive ROM, palpation, tenderness	Palpation of greater trochanter	Evaluation of hip extension
Spine for scoliosis, lordosis	Circulation	FABER (flexion, abduction, external rotation)		Palpation of ischial tuberosity and sacroiliac joint
Walking pattern	Lymphatics	Resisted adduction	Ober test	
Shoulder asymmetry	Hip rotation	Thomas test	FADIR (flexion, adduction, internal rotation)	Ely's test
Trendelenburg test	Off-loading 1 buttock	Impingement tests		Evaluation of hip extension
Ecchymosis	Slouching to reduce hip flexion	Stinchfield test		Craig's test
Limb length discrepancy		Thigh thrust test		

leg-length discrepancy, and other observable disturbances should be inspected. Assessment of posture is crucial and might be an indicator of underlying pathology. Knowledge of normal gait biomechanics and frequently encountered compensatory mechanics are essential for integrating this information into the clinical picture. For instance, dysfunction of gluteal muscles may lead to drop in contralateral side of pelvis (Trendelenburg). Arthritic hip or slipped femoral head or osteonecrosis of the femoral head may manifest themselves as a gait abnormality. Any sort of muscle wasting, probably caused by nerve entrapment and other anatomical variations need to be documented.

Limitations in range of movement (ROM) can also be assessed by questioning about limitations in daily life activities. Ascending and descending stairs require 30–44° of hip flexion, sitting on a chair requires 112° of flexion, and putting on socks requires 120° of flexion [13]. Athletes with femoroacetabular impingement or other intra-articular pathologies may have limited ROM while performing their daily activities.

In a seated position, movement capability and neurologic functions can be assessed. Hip internal and external rotation of the hip can be evaluated, while pelvis is stabilized in the seated position.

Comprehensive range of motion assessment test and provocative pain tests are mostly performed in supine position. Examination should start with general range of motion assessments to high sensitivity pathology-specific tests to narrow differential diagnosis depending on the clinical suspicion. Intensity of pain on a provocative test is noted, and these findings should navigate the clinician to the underlying pathology. Frequently used examination tests in supine position are listed below:

1. *Resisted adduction test*: Resisted adduction is tested with the patient in the supine position and the hips and knees brought into flexion. The test is positive if the patient experiences pain in the proximal aspect of the adductor muscles while trying to bring the legs together against the examiner's resistance (Fig. 1.1). In an experimental induced groin pain study, the 0° adduction test (same test

Fig. 1.1 Resisted adduction test

done with hips at 0° flexion, as a neutral position) showed the best positive likelihood ratio (sensitivity (SN), 93%; specificity (SP), 67%) to detect adductor longus-related groin pain [14].

2. *Thomas test*: While the patient is in supine position, he or she is instructed to flex both the knee and hip joint on one side and pull the leg to the chest. A flexion contracture would be indicated by passive flexion of the contralateral straight leg lifting off the exam table (Fig. 1.2a, b). Thomas test is a good screening test (SN 89%; SP 92%) to predict intra-articular pathology without indicating specific diagnosis (labral tear, loose bodies, chondral defect, and arthritic changes) [15, 16]. This test would also be positive in the setting of iliopsoas tightness or hip flexion contracture.
3. *Anterior impingement test*: Anterosuperior part of the labrum is more susceptible to injury because of its anatomic features mentioned previously. Anterior impingement test is described for diagnosing anterosuperior labral lesions and femoroacetabular impingement (FAI). The hip is dynamically flexed to 90°, adducted and

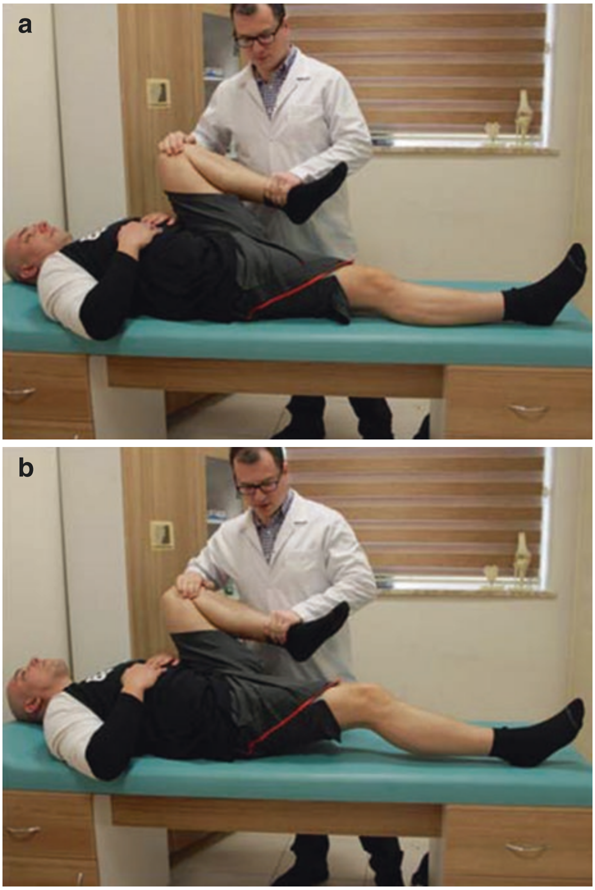

Fig. 1.2 Thomas test; (**a**) negative Thomas test, (**b**) positive Thomas test

internally rotated. Deep anterior groin pain replicating the patient's symptoms means the test is positive (Fig. 1.3). Positive anterior impingement test indicates whether the labrum has a lesion (SN, %59; SP, 100%; positive predictive value, 100%). Although the sensitivity of the anterior impingement test does not appear sufficient to detect anterosuperior quadrant labral lesions in patients with hip pain, the high positive predictive value makes the test useful [17, 18].

4. *Posterior impingement test*: The patient is in supine position, and the unaffected hip is slightly flexed. Affected limb is extended, abducted, and externally rotated by the examiner. When the femoral head contacts the posterior acetabular cartilage and rim, pain at the back side (buttock) indicates posterior impingement, especially the labrum (Fig. 1.4).
5. *Anterior instability/apprehension test*: Repetitive microtrauma to the hip capsuloligamentous structures may also result in symptomatic microinstability. This

Fig. 1.3 Anterior impingement test

Fig. 1.4 Posterior impingement test

results in increased movement of the femoral head relative to the acetabulum and eventual damage to the labrum, cartilage, and capsular structures [19]. Philippon et al. stated that 35% of patients undergoing revision hip arthroscopy required capsulorrhaphy, suggesting that undiagnosed hip microinstability may have contributed to the need for revision surgery [20]. Anterior instability test gives information about the congruency of hip joint. This test is similar to posterior impingement test with extension, abduction, and external rotation of the affected hip. A feeling of apprehension, subluxation or instability is positive for the test and may point structural instability. Test showed high sensitivity (80.6%), specificity (89.4%) and negative predictive value (77.8%) during evaluation of the microinstability following hip arthroscopy [21].

6. *Posterior apprehension test*: While the patient is in supine position, the examiner flexes the hip to 90°, adducts, internally rotates, and then applies a posterior force on the knee. Test is positive with posterior pain or sensation of instability (Fig. 1.5).
7. *Stinchfield test*: The patient performs a straight leg raise and resists downward pressure by the examiner. Groin pain means the test is positive and indicates an intra-articular etiology, as the psoas muscle puts pressure on the anterolateral labrum (SN, 59%; SP, 32%; positive likehood ratio (+LR), 0.87) [22, 23]. Pathology-specific testing should be chased depending on the targeted suspicious intra-articular pathology (Fig. 1.6). However this test may also be positive in the setting of hip flexor tendinitis.
8. *The McCarthy hip extension test*: While the patient is in supine position with the hips and knees flexed, the affected hip is taken from flexion into extension and rolling it in arcs of internal and external rotation. The test is positive if pain and/or a "click" is reproduced indicating an acetabular labral tear (Fig. 1.7a, b).
9. *Internal snapping hip test*: Bringing the hip from a flexed, abducted, and externally rotated position to an extended, adducted, and internally rotated position

Fig. 1.5 Posterior apprehension test

Fig. 1.6 Stinchfield test

Fig. 1.7 The McCarthy hip extension test. (**a**) Start, (**b**) end

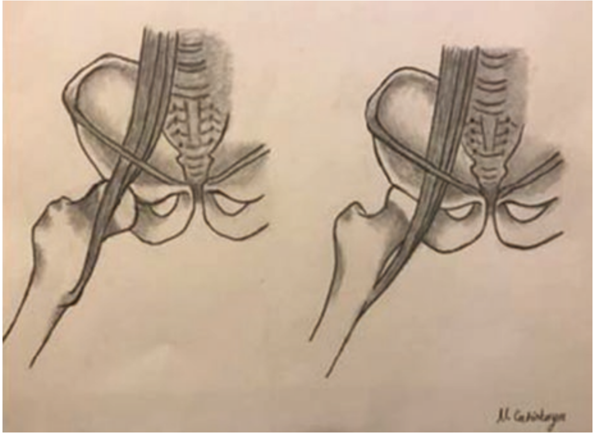

Fig. 1.8 Iliopsoas tendon snapping over the femoral head in internal snapping of the hip

frequently reproduces the anterior clunk or snap (Fig. 1.8). This usually is the result of the iliopsoas snapping over the anterior structures of the hip.

Gluteal muscles, iliotibial band and trochanter-related pathologies are best examined in lateral position. Iliotibial band snapping (external snapping) and abductor muscle group examinations are performed while the athlete is lying on his/her side. Frequently used examination tests in lateral decubitus position are listed below:

1. *Ober test*: This test is useful for evaluating the iliotibial band, tensor fascia lata, and greater trochanteric bursa. The patient is placed in a lateral decubitus position, while the upper knee and hip are flexed to 90°. Initially, the examiner passively abducts and extends the upper leg until the thigh is in line with the trunk, followed by passive adduction. Leg maintained in relative abduction with patient having discomfort indicates that the test is positive. If excessive tightness of the iliotibial band is present, this may show inflexibility. Focal pain overlying the trochanter points toward a possible trochanteric bursitis (Fig. 1.9).
2. *FADIR test*: Flexion-adduction-internal rotation test is performed with the upper leg flexed to 60° and the lower leg maintained in full extension. The examiner passively moves the leg into full flexion first and then into adduction and internal rotation. "Shooting" pain elicited by direct impingement of the sciatic nerve by the tight piriformis muscle shows the test is positive (Fig. 1.10). The pooled data of this test showed 99% sensitivity and 0.15 -LR [24]. In a review study, the SN values for this test ranged from 59 to 100%, and the SP values ranged from 4 to 75% for various intra-articular pathologies, and it showed 99% sensitivity and 7% specificity for detection of intra-articular pathologies when compared with arthroscopic diagnosis [15, 25].

Prone position is useful for examining sacroiliac joint and posterior thigh muscles and assessing femoral anteversion. Tenderness on sacroiliac joint may be the

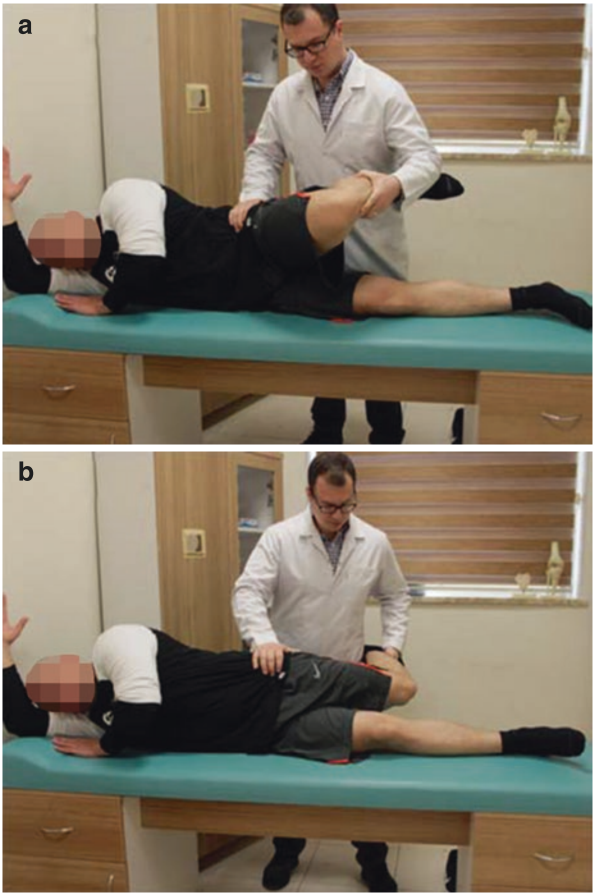

Fig. 1.9 Ober test. (**a**) Start, (**b**) end

Fig. 1.10 FADIR test

indicative for rheumatologic diseases. Femoral anteversion is best examined while patient is lying on prone position and knees flexed to 90 degrees and greater trochanter placed horizontally to the ground plane. Angle between the axis and tibia corresponds to femoral anteversion angle. Examination should be done bilaterally to compare both sides. Ely's test is also performed in prone position to assess tightness in the rectus femoris muscle. Frequently used examination tests in prone position are listed below:

1. *Craig's test*: The patient lies prone on the exam table with the knee flexed to 90°. The examiner palpates the greater trochanter to keep it in its most lateral position by internally and externally rotating the hip (Fig. 1.11). The degree of femoral anteversion can be estimated using a goniometer with one arm perpendicular to the floor and the other the angle of the leg.
2. *Ely's test*: The patient is instructed to lie in the prone position with both legs fully extended. The examiner then passively hyperflexes the knee, taking care to avoid rotation or extension of the hip joint, and observes the ipsilateral hip for vertical separation from the exam table (Fig. 1.12). Test is positive if buttocks are elevated for touching to the heel when knee is terminally flexed to compensate rectus femoris tightness.

Physical examination tests to rule out pelvic girdle-related pain:

1. *Thigh thrust test*: The hip joint is flexed to 90° when patient is lying on supine position to stretch the posterior structures. By applying an axial pressure along the length of the femur, the femur is used as a lever to push to the ilium posteriorly. One hand is placed beneath the sacrum to fix its position, while the other hand is used to apply a downward force on the femur. Longitudinal load force is applied for up to 30 s and repeated 3–5 times. If applied force provokes pain at the back of the pelvic girdle, then the test is positive for SI joint pathology (Fig. 1.13).

Fig. 1.11 The Craig's test

Fig. 1.12 Ely's test

Fig. 1.13 Thigh thrust test

2. *FABER (flexion, abduction, external rotation) test*: The patient lies supine, and the affected leg is placed in a flexed, abducted, and externally rotated position, as if creating the number 4, with the foot of the leg being tested resting on the contralateral knee (Fig. 1.14). From this position, the examiner places gentle downward pressure on the ipsilateral knee. Pain or a decreased range of motion indicates a positive FABER test which is commonly utilized as a provocative test to detect intra-articular, lumbar spine, or sacroiliac joint pathology. Diagnostic value of FABER test compared to MR arthrography (MRA) in labral tears showed 41% sensitivity and 100% specificity [25]. Another study also supports this evidence and states that the sensitivity values for this test ranged from 42 to 81%, while the specificity values ranged from 18 to 75% [15]. Therefore, clinical signs of a painful, restricted hip quadrant and a positive FABER test should suggest the need for MR arthrography.

Fig. 1.14 FABER test

1.4 Diagnostic Imaging

Injuries of the hip and groin may lead to significant disability if left untreated [6, 7, 26, 27]. Imaging is the key assistant for accurate diagnosis, but it should be always accompany a well-constructed physical examination and thorough history. Many factors influence the decision-making process as to which is the most suitable radio-diagnostic modality for accurate diagnosis. All different imaging modalities have distinctive superiority on different tissues. Therefore, the optimal modality depends on the clinical suspicion of the involved tissue.

Conventional radiography (CR) may provide great amount of data to assess osseous structures, but it might be inadequate to diagnose tendinous, ligamentous, and chondral pathologies. Consequently, different imaging modalities with their strengths should be taken in consideration to create most suitable combination of imaging for each individual.

There has been huge evolution in technology in radiographic imaging studies in the past 30 years. Clinicians are now able to get tremendous amount of knowledge from anatomic structures around the groin area. Additionally, the understanding of potential pathologies causing groin pain has increased. Working with a radiologist experienced in musculoskeletal imaging may provide a significant advantage. Informing the interpreting radiologist about the clinical findings and preliminary diagnosis is crucial and cannot be overemphasized [28].

1.4.1 Conventional Radiography

Despite the ongoing advancement in imaging studies, CR remains one of the most important examination tools for groin pain. Advantages of the CR include relative low cost, high specificity and wide availability. Detailed analysis of CR can inform clinicians about many underlying pathologies. Subtle manifestations of underlying pathologies should be well recognized for proper interpretation.

CR is still a fundamental approach to imaging of the hip joint. Preparation and positioning of the patient is important to obtain proper images to increase diagnostic accuracy. In order to evaluate a plain radiography, confirmation of appropriate position is required. In a standard anteroposterior (AP) view, the coccyx and symphysis pubis should be straight and aligned with the midline (over the pubic symphysis), both obturator foramina and iliac wings should be symmetrical and pelvic tilt and rotation should be avoided [28, 29]. In addition, the legs are rotated 15° internally to accommodate femoral anteversion instead of the neutral position as is a common mistake (Fig. 1.15) [30]. Note that the lesser trochanter is barely seen on the AP view if internal rotation is well adjusted [31]. Joint space narrowing and assessment of neck-shaft angle, coxa vara/valga, center-edge angle, overcoverage, and femoral sphericity can be observed with standard AP view. Other than the hip joint, assessment of the sacroiliac joint, symphysis pubis, sacral vertebrate, and surrounding soft tissue should be done.

Various radiographic findings may help to identify underlying pathology. On an AP view, assessment of teardrop provides information about the location of femoral head. A wide teardrop corresponds to shallow acetabulum, whereas a narrow teardrop or teardrop located medial to ilioischial line can indicate deeper acetabulum and related overcoverage.

Stress fracture should be considered in athletes with recently increased athletic performance duration or intensity. Repetitive exposure to excessive load in chronic fashion is mostly the cause [32, 33]. Radiographic findings include sclerosis and periosteal reaction. However, CR has low sensitivity for stress fractures. Therefore, if there is strong clinical suspicion, MRI should be ordered.

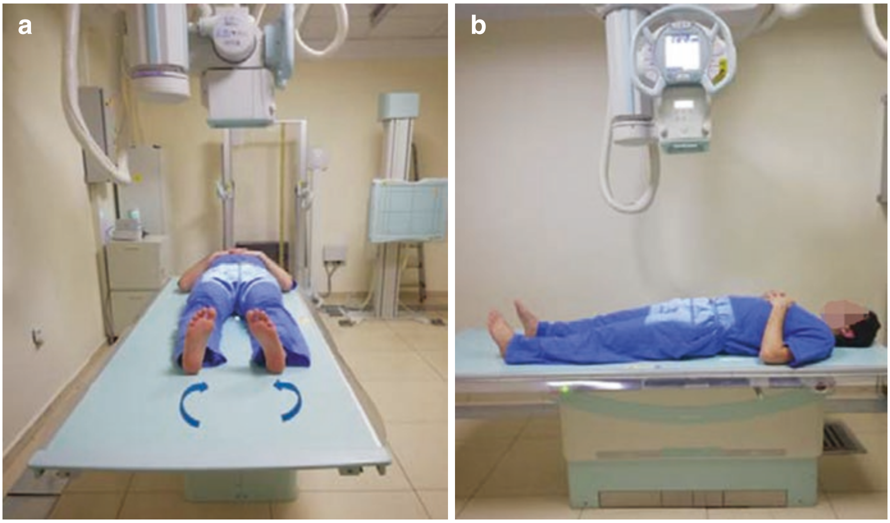

Fig. 1.15 In a standard AP view, legs are rotated 15° internally (**a**) to accommodate femoral anteversion, while patient is in supine position (**b**)

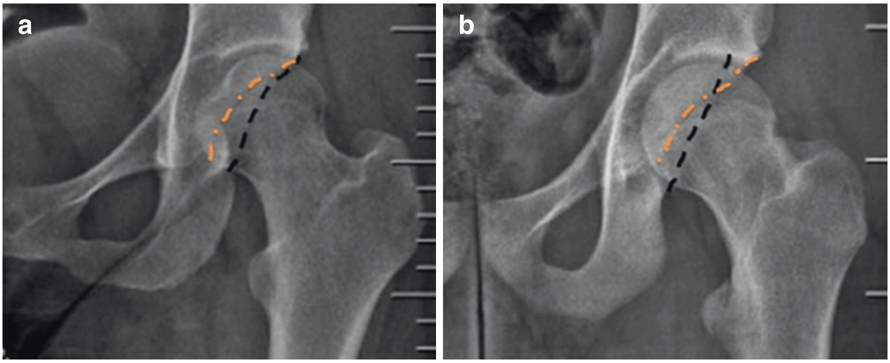

Fig. 1.16 Crossover sign; (**a**) normal anteversion, (**b**) retroverted acetabulum

Assessment of acetabular version is relatively difficult on CR as it can vary considerably by tilt or rotation of the pelvis and imaging techniques [34]. In a normally anteverted acetabulum, posterior and anterior walls reach each other at the lateral (superior) edge; thus lines representing anterior and posterior walls do not intersect each other (Fig. 1.16a). If there is posterior overcoverage of the femoral head secondary to a retroverted acetabulum, the line representing the posterior wall will likely to intersect with the line representing the anterior wall of the acetabulum (Fig. 1.16b). In this situation, a crossover sign is present and may indicate pincer-type impingement. In addition, a prominent ischial spine on a true AP view also indicates femoral retroversion.

Slipped capital femoral epiphysis (SCFE) is a significant pathology in young athletes. The involved epiphysis tends to displace medially and inferiorly (in fact the femoral neck actually is displaced laterally and superiorly). On an AP view, a line drawn at the lateral edge of the femoral neck (Klein's line) should contact femoral epiphysis. If intersection fails, displacement of the femoral epiphysis is likely present.

Avascular necrosis (AVN) is an osseous cell death causing disintegration of the normal weight-bearing structure of the femoral head. Even it might be asymptomatic at the beginning, progression to subchondral collapse is likely if left untreated. Imperfect sphericity of the femoral head and coexisting arthritic findings may indicate avascular necrosis of the femoral head (AVN). If clinical suspicion is present, MRI must be ordered to better illustrate the ongoing pathology.

There are various types of lateral radiographs available. Each has specific advantages and limitations in terms of diagnostic accuracy. Cross-table lateral view, frog leg and lateral Dunn view provide information for calculating alpha angle and assessment of femoral neck sphericity. Frog leg view is performed with the patient in supine position with hip flexion, abduction and external rotation. It is suitable for general diagnostic purposes. Cross-table lateral view is performed with the patient in supine position and unaffected hip elevated to 90° flexion and affected lower extremity 20° internally rotated. The cross-table lateral view is performed to assess femoral head-neck junction step-off and may provide a better estimate of the femoral version. Dunn lateral views are obtained with the patient in supine position, while symptomatic hip flexed at 90° or 45° and slightly abducted (20°) to evaluate anterolateral head-neck junction. Dunn lateral view has greater sensitivity for calculation of alpha angle than other views [35]. The false profile view of Lequesne is a weight-bearing oblique view that does demonstrate the anterior wall of the acetabulum and an anterolateral view of the femoral head, making it useful for the evaluation of dysplasia (undercoverage anteriorly) and CAM lesions and to evaluate the AIIS. All lateral views are used for detection of asphericity of the femoral head and to demonstrate abnormal alpha angle corresponding to pathologic cam-type impingement. While each of these aforementioned lateral views are lateral views of the femoral head, only the cross-table lateral is a lateral view of the acetabulum. The alpha angle is calculated as the angle between a line drawn from the center of the femoral head through the central axis of the femoral neck and a second line drawn from the center of the femoral head to the point anteriorly where the radius of the femoral head first exceeds the radius of the more centrally located portion of the femoral head. An absolute cutoff value for pathologic alpha angle is still controversial. It is still questionable whether it discriminates symptomatic and asymptomatic impingement. Generally, values greater than 55–60° strongly suggest that cam impingement is likely, and further MRI or CT scan may be required to confirm the diagnosis [36, 37].

1.4.2 Computed Tomography

Computed tomography (CT) is a valuable tool for evaluation of static osseous pathologies in athletes with hip pain. As mentioned before, CR does not provide exact value of acetabular version and predicted values are highly dependent on the technique and position of the beam. Femoral version is also relatively calculated which represents the spatial position of the femoral head relative to the epicondylar axis of distal femur. Therefore, radiologic findings in CR are advisory, but reliable measurement of the femoral version is made by CT.

CT offers excellent delineation of cortical bone and is the ideal diagnostic tool for evaluation of fracture or blunt trauma. Even though it offers valuable information in suspected fractures, it has very limited value in the assessment of soft tissue-related differential diagnosis of sports injuries.

CT scan with three-dimensional (3D) reconstruction is an invaluable tool for visualizing the femoroacetabular relationship. Exact localization of overcoverage areas, morphologic abnormalities, and dimensions of the deformity can be easily evaluated by CT scans. Morphologic assessment of cam-type impingement is crucial for the selection of the suitable surgical approach. For instance, cam-type impingement that expands posteriorly through the retinacular vessels means that it is risky to reach the resection site arthroscopically without risking damage to the vasculature. Preoperative 3D reconstruction of CT scans provides the insight about the localization and size of the resection area prior to surgery to restore the sphericity of the femoral head. Moreover, localization of the pincer-type FAI and visualization of possible intra-articular loose bodies can be detected accurately. It is recommended to include the whole pelvis during the scan to measure the *alpha angle, center-edge angle, and femoral version precisely [38].

Dynamic animation of the impingement during movement is now possible with individual software. Relevant anatomic sites causing impingement during motion of the hip joint can be visualized by 3D construction and provide valuable preoperative information by pointing out the anatomic localization to be corrected. With dynamic software animation, expected improvements in range of motion can be simulated prior to surgery. Yet, authors expect to see this simulation as an intraoperative navigation tool in future [39].

1.4.3 Ultrasound

Considering the wide spectrum of differential diagnosis of groin pain in athletes, ultrasound imaging offers a rapid and cost-effective evaluation, and it can serve as a guide for percutaneous intervention. Ultrasound is especially useful for evaluating dynamic pathologies, such as snapping hip syndrome and hernias. The observer is able to demonstrate pathology simultaneously by simulating the precipitating movement [40]. It is also useful for monitoring the condition of the muscles and showing injury-related findings, such as edema along the fibers and discontinuity of tendons or ligaments. However, some deep muscle groups around the hip girdle are less accessible to ultrasound evaluation. Labral pathologies are also visualized by ultrasound, but only anterior part of the labrum is reachable. In a recent study on labral tears, ultrasound showed significantly high sensitivity (94%) when compared with MR arthrography (MRA) and clinical impingement tests [18].

Ultrasound-guided injection is a valuable replacement for fluoroscopy-guided injections since it is radiation-free. In addition, young athletes displayed higher satisfaction rates and less pain with ultrasound-guided intra-articular hip injections than fluoroscopy guided following the intervention [41].

1.4.4 Magnetic Resonance Imaging

Magnetic resonance imaging (MRI) of the hip is an invaluable tool for diagnosis of sports-related hip and groin injuries in the setting of other imaging studies. With its sensitive soft-tissue contrast and multiplanar capabilities and ability to distinguish musculotendinous, osseous, cartilaginous, and labral pathologies, MRI is unique in the noninvasive diagnosis of both intra-articular and extra-articular pathologies. Although expensive and time consuming, MRI provides many diagnostic benefits by assessing different tissues and related pathologies simultaneously. Groin pain in athletes may be due to many different reasons, and generally more than one pathology may cause the symptoms. Therefore, a global examination of the hip and groin area in a competitive athlete is essential to evaluate concurrent abnormalities.

MRI is superior to other imaging modalities in the evaluation of the acetabular labrum, articular cartilage and surrounding soft tissues such as bursae and tendons [42]. Considering the wide range of differential diagnoses, a comprehensive evaluation of both intra- and extra-articular pathologies should be performed at the same time to determine the underlying pathology. MRI imaging of the hip and pelvis can provide a prompt and specific diagnosis, which allows for early diagnosis and return to previous activity level [43].

Due to the complex anatomy and mostly complicating source of the groin pain, clinicians should always inform the radiologist of the suspected diagnosis and physical examination findings. Keeping good communication with your radiologists would provide huge advantage in obtaining an accurate diagnosis. From the radiologist's point of view, it has to be kept in mind that proper examination is done with appropriate equipment; therefore a well-done MRI greatly increases the diagnostic accuracy [28].

In a recent review, it has been shown that over 80% of athletic groin pain requiring surgery is attributable to five pathologies: FAI, athletic pubalgia, and adductor-related, inguinal-related, and labral-related pathologies [44]. MRI is the most valuable tool for evaluation of the chondrolabral complex in the athlete's hip, where the information obtained is crucial to devise a treatment plan or to help make a decision for surgical intervention.

There are several newly developed techniques available to provide quantitative information about the quality of the cartilage tissue [45]. T2 mapping and gadolinium-enhanced techniques are the popular imaging techniques. With T2 mapping, pathologic injury to the chondral tissue can be accurately determined even though morphologically it appears normal (Fig. 1.17).

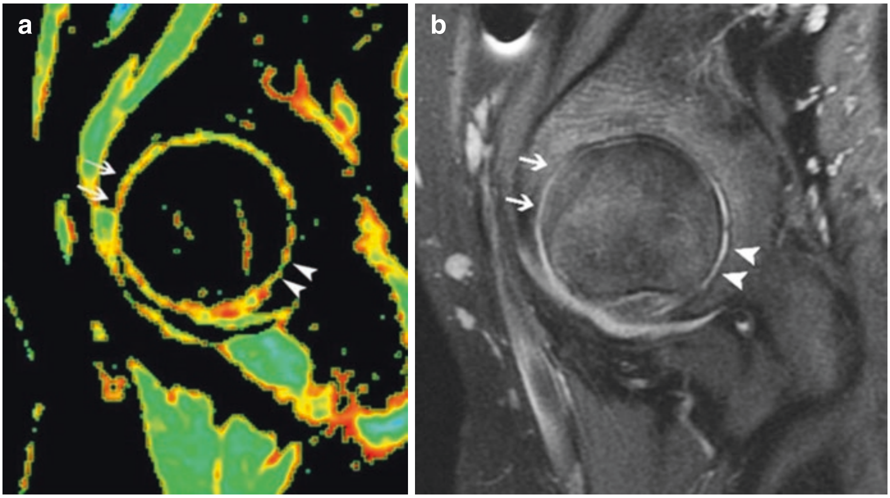

Fig. 1.17 14-year-old FAI patient. (**a**) Sagittal cut of the T2 mapping MR image indicates loss of cartilage tissue which represented by red and orange colors. Anterior (arrow) and posteroinferior (arrowheads) localization of the defect is highly considered to be pincer-type impingement due to protrusio acetabuli. (**b**) Sagittal fat-saturated MR image of the same patient. Arrows and arrowheads mark the thinned articular cartilage layer. (Reprinted by the permission of Springer-Verlag, Radiologic analysis of femoral acetabular impingement: from radiography to MRI, Dwek, J.R., Monazzam, S. & Chung, C.B. Pediatr Radiol (2013) 43(Suppl 1): 61. https://doi.org/10.1007/s00247-012-2588-7)

Moreover, it detects anatomic localization of the injury with great accuracy as well as facilitating preoperative evaluation and long-term cartilage monitoring without requiring invasive contrast injection [46, 47]. Ellermann et al. compared the injury localization results of T2 mapping with direct visualization via arthroscopy and pointed out that there is a 91% true positive rate under the threshold specified [48].

Gadolinium-enhanced MRI of cartilage (dGEMRIC) is a modality that relies on penetrance of negatively charged gadolinium into the injured cartilage tissue where lack of negatively charged glycosaminoglycans (GAGs) repels the contrast agent. Thus, it can show early cartilage injury before it becomes evident grossly. All acquired information collected by different imaging studies may assist the surgeon in decision-making and preoperative assessment for building treatment plan [49]. Bittersohl et al. observed lower gadolinium intake in FAI patients in comparison with asymptomatic volunteers [50]. Consequently, biochemically sensitive MR imaging is expected to bridge the gap in between asymptomatic FAI morphology and symptomatic pathology [51].

Most commonly seen pathologies causing groin and hip pain in athletes and their radiologic findings are listed below.

1.4.4.1 Extra-articular Hip Impingement

Ischiofemoral Impingement

Extra-articular hip impingement refers to a variety of increasingly recognized hip disorders causing pain and limited function in young, non-arthritic patients. Specific disorders include psoas impingement (PI), subspine impingement (SSI), ischiofemoral impingement [52] (IFI), and greater trochanteric/pelvic impingement (GTPI).

Ischiofemoral impingement is caused by impingement of soft tissues (especially the quadratus femoris muscle) in between proximal femur and the ischium (Fig. 1.18). It is more common in elderly and rarely seen in athletes.

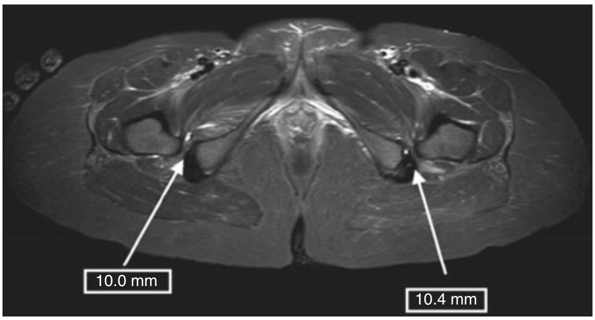

Fig. 1.18 MRI of the pelvis, axial cut, and T2-weighted image without contrast. White arrows represent the restricted ischiofemoral space between femur and ischium. (Reprinted by permission From Springer-Verlag Berlin, Ischiofemoral impingement syndrome: a case report redefining this condition, Hotait, M., Makki, A. & Sawaya, R. Neurosurg Rev. (2016) 39: 707. https://doi.org/10.1007/s10143-016-0766-z)

Subspine Impingement

Subspine impingement is a more commonly seen pathology in athletes, mostly soccer and tennis players. SSI is caused by soft-tissue impingement between anterior inferior iliac spine (AIIS) and the femoral head-neck junction during hip flexion. Usually avulsion fracture of the AIIS and caudally healed avulsed fragment is the cause.

1.4.4.2 Stress Fracture

Stress fractures are described as accelerated bony remodeling in response to repetitive submaximal trauma. Incidence of the stress fracture is increasing with weight-bearing activities and higher competitive level. In a typical sports medicine practice, bone stress injury accounts for 10–20% of cases [32, 33, 53]. Some authors state that in reality, the prevalence may actually be higher as a result of underdiagnosis [54]. Acetabulum and femur are the common sites for stress fracture in athletes, and mostly they are seen in endurance athletes. Athlete with a history of anterior hip or groin pain that is worsened with activity and insidious in onset often related to a change in type or intensity of workouts is highly suggestive for stress fracture.

Periosteal new bone formation can be seen in CR a few weeks after the fracture begins. MRI or bone scintigraphy is recommended if there is high clinical suspicion with a normal CR [55]. Bone marrow edema seen in fluid-sensitive MRI scans is the early finding of stress fracture. It is manifested as a hypointense line on T1- and T2-weighted images (Fig. 1.19). Bone marrow edema will diminish with healing.

1.4.4.3 Labral Pathologies

Acetabular labral tear is recognized as a source of groin pain in athletes and can be observed in a variety of sports such as football, basketball, hockey, ballet, golf and tennis. Acute labral tears can be misdiagnosed as a muscle strain and cause delay in appropriate treatment. Labral tears may be associated with significantly decreased athletic performance and prolonged periods of missed play [56]. Evidence suggests that labral tears are associated with corresponding osteochondral lesions of the femoral head and may lead to early degenerative joint changes [57].

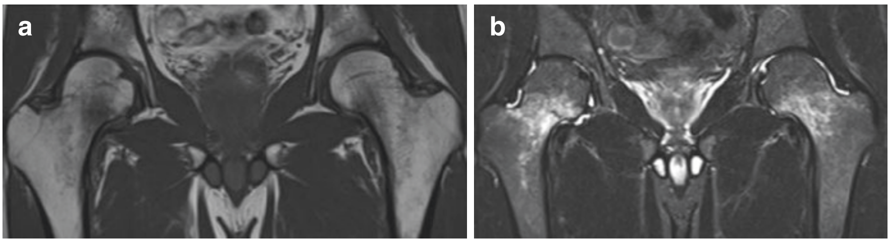

Fig. 1.19 30-year-old male weightlifter with a sudden onset of bilateral groin pain. MRI shows hypointense line in right femoral neck in T1 (**a**)- and T2 (**b**)-weighted images. Bone marrow edema is seen bilaterally in T2-weighted images

MR arthrography is the best imaging modality for evaluation of labral pathologies. Evaluation should also include chondral, capsular, and ligamentous pathologies. Although MR arthrography is a powerful tool for diagnostic accuracy, it is still not superior to arthroscopic evaluation. By the way, diagnosis of the labral tear might require confirmation via arthroscopy [58].

The labrum demonstrates low-intensity signals on both T1 and T2 images like organized collagen elsewhere in the body. Anterosuperior part of the labrum has lower compressive force durability and lower tensile modulus when compared with the other parts; therefore labral tears are likely to occur in this area. Increased intensity in the labrum in an asymptomatic athlete mostly signifies labral degeneration. However, significantly increased signal intensity with or without extravasation of the contrast agent inside the cartilage tissue is suggestive for a torn labrum (Fig. 1.20). MR arthrography shows high sensitivity and specificity for diagnosing labral injuries when compared with arthroscopy [59].

There is a normal perilabral recess between the capsule and hip. This recess may not be seen in conventional MRI due to lack of capsular distension and might be confusing for evaluation. Moreover, small sub-labral sulcus in the posteroinferior site of the labrum may be seen and reported as a normal finding. It has also been shown that anterosuperior part of the labrum might be absent in older individuals; however identical findings in young and active athletes are highly suggestive for torn labrum [60]. Conclusively, normal variants and unique structure of the labrum should be known for accurate diagnosis.

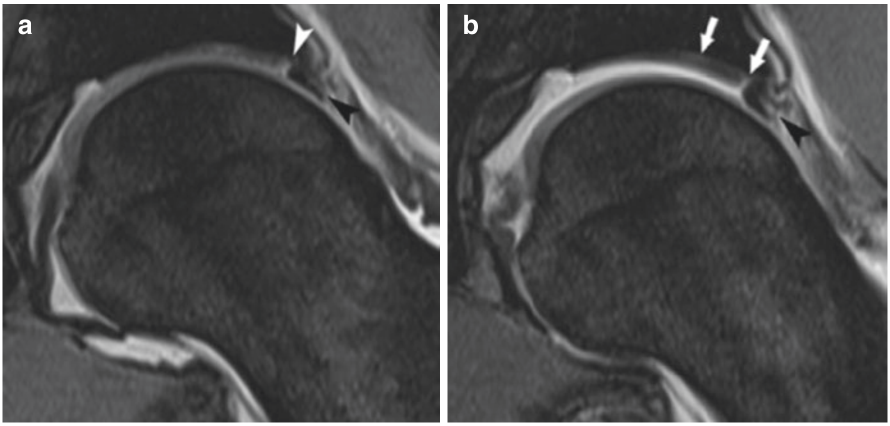

Fig. 1.20 43-year-old man with cam-type FAI. (**a**) Black and white arrowheads indicate complex labral tear in coronal T1-weighted MR arthrogram (MRA) image. (**b**) Articular cartilage layers became more distinguishable with traction. White arrows indicate the delamination tear of the acetabular cartilage, and black arrowhead indicates dislocation of intrasubstance labrum component of the complex labral tear. (Reprinted by the permission of Springer Berlin Heidelberg, Diagnostic performance of direct traction MR arthrography of the hip: detection of chondral and labral lesions with arthroscopic comparison. Schmaranzer F, Klauser A, Kogler M, Henninger B, Forstner T, Reichkendler M, Schmaranzer E. Eur Radiol. 2015 Jun;25(6):1721–30. https://doi.org/10.1007/s00330-014-3534-x)

1.4.4.4 Tendinous and Ligamentous Injuries

Among the athletes, myotendinous injuries are common and mostly are the result of a single traumatic event rather than overuse trauma. Gallo et al. concluded that return to sport rates following muscle strain and tendinosis are relatively high in professional athletes (90%) in asymptomatic athletes with incidental findings [61]. However, the contribution of the myotendinous injury to hip pain should be carefully evaluated, and the severity of the injury should be determined. In general, thickening and intratendinous signal enhancement is observed on T1-weighted images of injured tendons. Inflammatory response and surrounding edema can be detected around the affected tendon or fluid-filled defects inside the tendons in fluid-sensitive sequences like T2 and short tau (inversion time) inversion recovery (STIR) can be noted in partial tears [62]. Complete discontinuity of a tendon with accompanying tendon retraction denotes probable full-thickness tear.

Ligamentum Teres Injury

Tears of the ligamentum teres was first described by Gray and Villar in 1997 [63]. Ligamentum teres injury is a possible source of pain in an athlete. It may be identified in up to 51% of all arthroscopic interventions possibly because of increased awareness [64]. With increased understanding, the diagnosis of ligamentum teres pathologies has gained popularity. Arthroscopically, ligamentum teres ruptures are classified as complete, partial rupture or degeneration. The normal ligamentum teres is hypointense, homogenous and smooth in all MR sequences. Discontinuity of the normal appearance and lax positioning of the ligament instead of normal taut look refer to complete rupture. Partial tears and degeneration are shown to be similar to other ligamentous injuries with increased intraligamentous signal intensity (Fig. 1.21). MR imaging and MR arthrography both offer high sensitivity for the detection of complete ruptures; however, partial tears can be spotted more easily with MR arthrography [65]. On the other hand, some authors report that preoperative identification of ligamentum teres injuries is insufficient even with high-resolution MRI [66]. In another study, nine hips were diagnosed with LT tears based on preoperative MRI (seven of nine are according to MRA). Of these nine cases, LT tears were identified in only five at the time of arthroscopy; the remaining four were considered false positives when correlated with arthroscopy [64].

Hamstrings Injury

The hamstring tendon complex is formed by the biceps femoris, semitendinosus, and semimembranosus muscles. In professional football players, adductor injury is the most common type of injury and corresponds to 12% of all injuries with high (15%) reinjury rate [2, 67]. In addition, 10% of hamstring injuries are classified as severe (injury causing absence of over 28 days from training and playing) [2]. Therefore, such injuries are major concern for professional athletes representing large portion of time loss for return to sport.

As a normal tendinous structure, hamstring tendons are observed to be hypointense on T1 views. Modified Peetrons classification system is defined to evaluate severity of hamstring injuries [67, 68]. MRI evaluation as grade I (only edematous

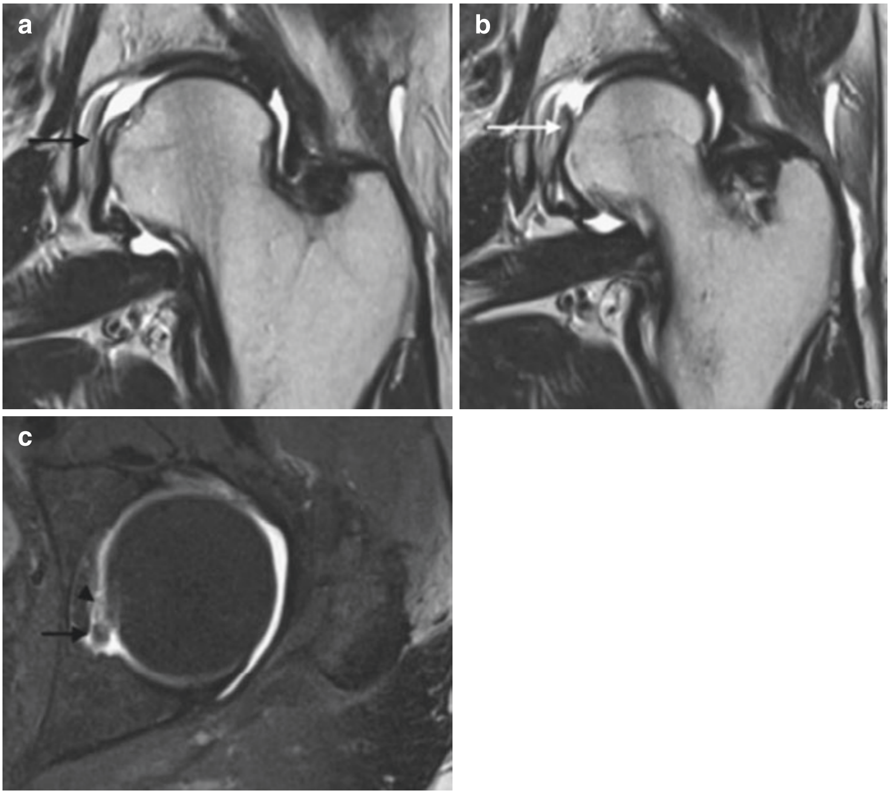

Fig. 1.21 65-year-old female with arthroscopically confirmed partial ligamentum teres tear. Coronal T2-weighted MRA images. (**a**) Black arrow shows undamaged part of the ligament. (**b**) White arrow points out the partially torn ligamentum teres. (**c**) Note the increased intraligamentous signal intensity which is the indicator of partial tear in axial proton density-weighted MR image with fat suppression (black arrowhead) and the partially intact ligamentum teres structure (black arrow). (Reprinted by the permission of Springer Berlin Heidelberg, Use of MR arthrography in detecting tears of the ligamentum teres with arthroscopic correlation, Chang, C.Y., Gill, C.M., Huang, A.J. et al. Skeletal Radiol (2015) 44: 361. https://doi.org/10.1007/s00256-014-2082-4)

changes and ill-defined high-signal abnormality on T2-weighted sequences, "feathery" pattern), grade II (in addition to the edema, a partial tear is depicted, represented by a well-defined high-signal abnormality on PD-weighted and T2-weighted sequences), and grade III (complete tear) (Fig. 1.22). More than 50% of hamstring injuries occur in the biceps femoris muscle and mostly at the proximal muscle tendon junction [69, 70].

According to mechanism of injury, type I injuries are observed during high-speed running, and type II hamstring strains are mostly secondary to excessive lengthening of the hamstrings and mostly observed in sports such as dancing, slide tackling, and high kicking that combine hip flexion with knee extension [69].

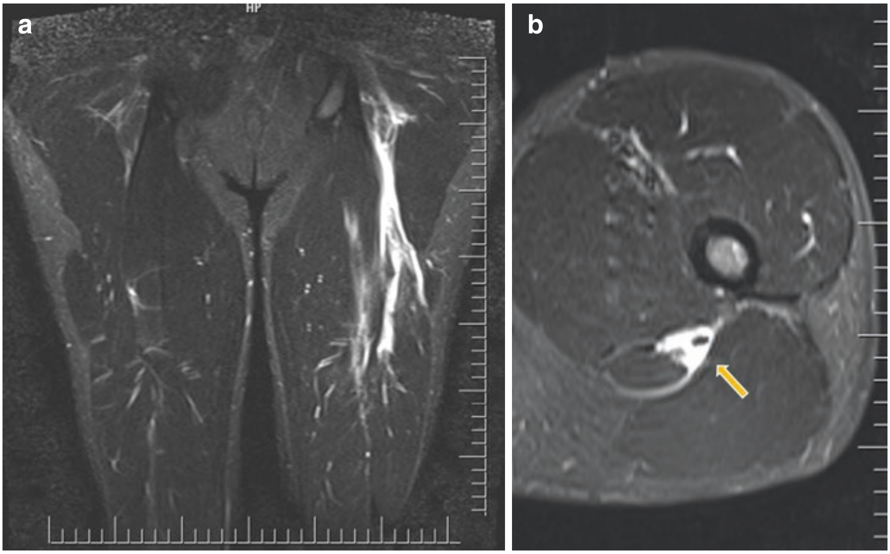

Fig. 1.22 MR image in a 23-year-old professional male football player with a sudden onset of posterior hip pain. T2-weighted coronal image shows longwise extending edema and hemorrhage (**a**); axial image (**b**) shows complete tear of the hamstring tendon (arrow) proximally close to its origin at ischial tuberosity

Recovery from type II injuries has been shown to be prolonged when compared with type I injuries.

Many authors investigated the correlation between return-to-play time and severity of the hamstring injury on MRI. Schneider-Kolsky stated that only moderate and severe hamstring injuries are possible predictors of long rehabilitation period [71]. In another study, no association between time necessary to return back to sport and extent of edema-like changes on MRI in athletes with grade I hamstring injuries was found, probably because grade I injuries may show large variations of size and extent of edematous changes [72]. The British Athletics Muscle Injury Classification System was proposed in 2004 by evaluating not only extent of the injury but also the localization [73]. This classification system was developed to provide reliable information on player readiness to return back to play.

Proximal Rectus Femoris Injury

As a powerful knee extensor and hip flexor, the rectus femoris muscle is most frequently injured by excessive stretching [74]. The rectus femoris is located at anterior compartment of thigh as the most superficial muscle of the quadriceps muscles complex. Rupture occurs during the acceleration phase of running, jumping, and kicking or during contraction against resistance [75]. The myotendinous junction is the most common location of the tear; however imaging should include both origin and insertion of the tendinous parts to evaluate the extent of the edema. The rectus

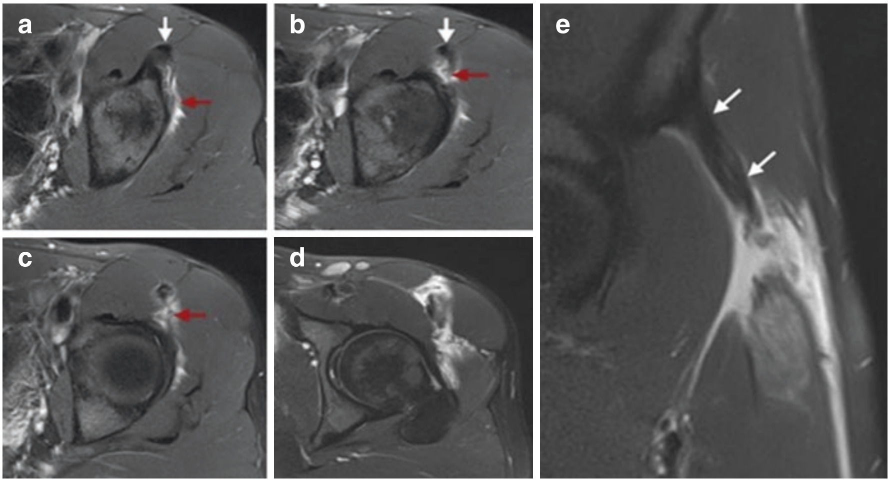

Fig. 1.23 A 25-year-old woman with sudden onset of hip pain that occurred while sprinting. T2-weighted MR images with fat saturation in (**a**–**d**) axial cuts show fluid collection around the direct (white arrows) and indirect (red arrows) heads of rectus femoris which is observed in severe injuries. (**e**) Coronal plane shows complete rupture (white arrow) of the rectus femoris. (Reprinted by the permission of Springer Berlin Heidelberg, Imaging of rectus femoris proximal tendinopathies, Pesquer, L., Poussange, N., Sonnery-Cottet, B. et al. Skeletal Radiol (2016) 45: 889. https://doi.org/10.1007/s00256-016-2345-3)

femoris has two tendinous origins, the direct or straight head, which arises from the AIIS, and the indirect or reflected head, which arises from the superior acetabular ridge and the posterolateral aspect of the hip joint capsule. The two heads join and form a conjoined tendon. Proximal rectus femoris strains mostly occur at the junction of the conjoint tendon with the muscle belly. Fluid collection and gap between the fibers might be observed in severe injuries (Fig. 1.23) [76].

Athletic Pubalgia

Athletic pubalgia is an umbrella term which accounts for pain originated from pubic symphysis area and radiates into groin region such as rectus abdominis insertion, hip adductor tendons, and symphysis pubis joint. The term was formerly used as “sports hernia,” as well as “Gilmore’s groin,” “hockey gut,” “slap shot gut,” and “core muscle injury.”

The pubic symphysis is formed by two bones and a hyaline cartilage disc in between them [62]. There are numerous ligaments and tendons attaching to the pubic complex to provide stability. Evaluation of the underlying pathology is only possible by understanding the dynamic relations of associated ligaments and tendons. For this reason, use of the term “osteitis pubis” in athletes simply describes an empiric sign or a radiologic finding rather than an actual diagnosis [77]. Athletic pubalgia accounts for around 4% of groin injuries in professional soccer players [2]. A wide aponeurotic plate provides numerous connecting points for tendons and

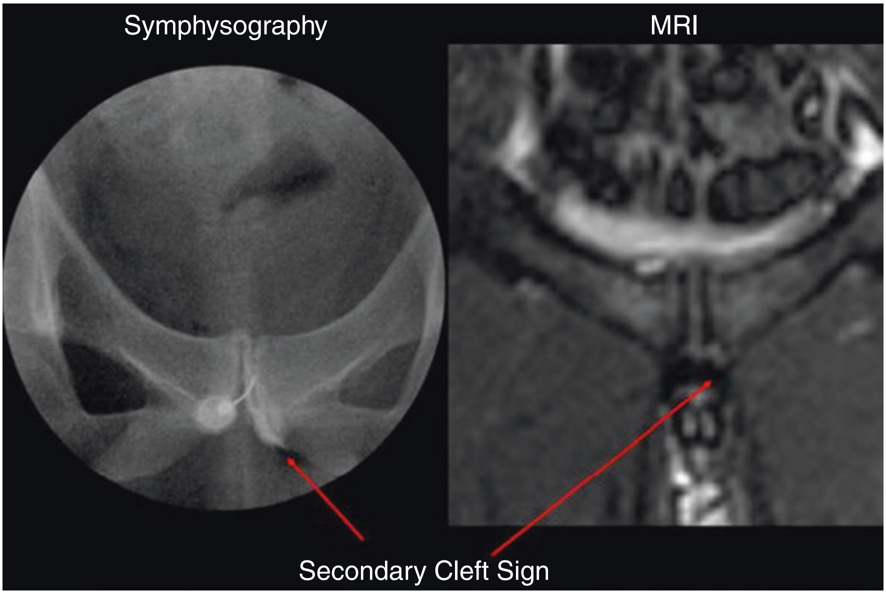

Fig. 1.24 Patient with left thigh pain; (**a**) symphysography shows the accumulation of contrast medium into the cleft at inferior pubic ramus. (**b**) Coronal T1 MR image in the same patient confirms left-sided secondary cleft sign. (Reprinted by the permission Springer-Verlag, "Superior cleft sign" as a marker of rectus abdominus/adductor longus tear in patients with suspected sportsman's hernia, Murphy, G., Foran, P., Murphy, D. et al. Skeletal Radiol (2013) 42: 819. https://doi.org/10.1007/s00256-013-1573-z)

ligaments. In case of injury, partial avulsion of the plate or related damage should be evaluated carefully.

Tears or surrounding edema of the aponeurosis and attached muscles can be observed in fluid-sensitive MRI images (STIR-T2) [78]. Separation of the aponeurotic plate forms a cleft shape containing fluid inside and named as the secondary cleft sign. Pathology can be demonstrated by performing a symphysography. Filling of the cleft following contrast injection can be visualized (Fig. 1.24). However, visualization of secondary cleft sign on MRI has only moderate sensitivity (57%) and specificity (60%) for diagnosing aponeurotic injury [62, 79].

Tendon avulsion and related retraction of the tendon should be carefully assessed. Bone marrow edema inside pubic bones can be observed as hyperintense signals which are present in almost 50% of athletes with athletic pubalgia and can be a significant clue for recognizing the pathology [79]. Reduced tendon diameter and observable muscle atrophy compared with the contralateral side are mostly seen in tendinopathies and often associated with aponeurotic injuries.

Chronic changes of pubic complex secondary to injury should be well recognized by the physician for both follow-up measurements and performance evaluation. Osteophyte formation, osseous asymmetries, and sclerosis accompanying with or without aponeurotic plate damage might possibly be observed in athletes with osteitis pubis. Osteitis pubis is a painful overuse stress injury of pubic symphysis and parasymphyseal bone due to chronic overloading stress [80]. Usually there is no precipitating event and begins insidiously. Because of the frequency of concomitant pelvic pathologies, a variety of clinical tests may be positive on clinical exam, but tenderness to palpation over the symphysis, positive resisted adduction test, and the hop test are most sensitive to osteitis pubis [81]. Osteitis pubis is most commonly presented as a hyperintense T2 signal within the symphysis and parasymphyseal bone [80, 82].

1.5 Conclusion

Hip and groin pain in athletes is becoming more common, likely due to increased understanding of differing pathologies about the hip and groin but also possibly due to early sports specialization. As the area is deep and has complex and overlapping anatomy, evaluation of the hip and groin may be difficult. A careful history and physical examination are critical to the evaluation of the athlete with hip and/or groin pain. An understanding of the pathophysiology of these injuries is also helpful. Properly performed conventional radiographs are essential in the evaluation of these athletes. Appropriate imaging, such as MRI, MRA, CT, and ultrasound, can be essential in the evaluation, diagnosis, and then planning of management of these patients.

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Portal Anatomy and Patient Positioning

2

Hao-Che Tang and Michael Dienst

2.1 Introduction

Positioning and arthroscopic access to the hip joint are challenging. This is related to the demanding requirements for arthroscopy of both the central compartment with traction and most of the peripheral compartment without traction and motion of the hip. In addition, the surgeon is confronted by various anatomic features: a thick soft tissue mantle, a strong articular capsule, the constrained ball and socket architecture of the joint, a relatively small intra-articular volume, and the additional sealing of the deep, central part of the joint by the acetabular labrum.

The following chapter describes positioning techniques, portal placement, and different strategies for accessing the hip.

2.2 Positioning

Hip arthroscopy can be performed using either the lateral decubitus or the supine position [1–3]. In 1987, Glick et al. published a series of patients receiving hip arthroscopy in the lateral decubitus position. Portals to the central compartment were described in detail, and the central compartment was clearly visualized under adequate distraction of the femoral head from the acetabular socket [1]. In 1994, Byrd et al. showed that hip arthroscopy also can be successfully performed using the supine position [2].

For both positions, advantages and disadvantages were claimed. A potential benefit of the lateral approach is a thinner soft tissue mantle in obese patients because

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gravity allows soft tissues to fall away from the greater trochanter. In addition, access to the peritrochanteric space directly prior to or after hip arthroscopy may be easier. One potential disadvantage of the lateral decubitus position may be the need for a specialized traction device and longer time for the setup.

Hip arthroscopy in the supine position can be performed on the standard fracture table. However, some surgeons prefer specialized traction tables and accessories for supine positioning. It appears that the patient setup in the supine position is more familiar and friendly to surgeons and staff in the operative room. In addition, it may be easier to mobilize the hip intraoperatively, especially during procedures in the peripheral compartment without traction. In obese patients, however, posterolateral access to the hip joint is likely more difficult.

According to a systemic review, clinical outcomes and complication rates for the lateral decubitus and supine positions are similar [3]. As a result, the decision of whether to use the lateral or supine position is more a matter of individual training and habit of use. The authors prefer the supine position because of the abovementioned aspects. In addition, hip pathologies are frequently located in the anterolateral parts of the peripheral and central compartment, while rarely in the posterolateral areas. Thus, anterolateral and anterior portals are used most of the time.

2.3 Supine Position

Hip arthroscopy in the supine position can be performed under spinal or general anesthesia. The authors prefer the use of general anesthesia with complete muscle paralysis in order to reduce the traction forces that are needed for sufficient hip distraction. In addition, blood pressure can be managed more effectively by the anesthetist.

The patient is placed in the supine position on the traction table (Fig. 2.1). Both feet are secured in padded boots with a tape wrapping reinforcement. A well-padded wide perineal post is used. The diameter of the post should measure at least 9 cm in order to distribute the force over a greater area as well as to allow for adequate lateralization [4]. The authors prefer a post with a diameter of 18 cm. In males, compression to the scrotums and penis must be avoided.

Moderate traction is first applied to the nonoperative hip, which is positioned in about 20° abduction, neutral rotation, and 0° extension. Traction on the abducted nonoperative hip helps to lateralize the pelvis, so that the perineal post is situated more against the inner thigh of the operative hip. The operative hip is positioned in about 10° abduction, neutral rotation, and slight flexion of about 10°, and manual traction is applied by lengthening of the traction table booms. Lateralization of the perineal post and adduction of the thigh against the post create a vector approximately in line with the femoral neck axis. This oblique vector pulls the femoral head both distally and laterally [2].

After adequate positioning and manual traction on both hips, incremental traction is applied to the operative hip by turning the traction module. An image intensifier is introduced from the nonoperative side and is used to monitor distraction of

Fig. 2.1 Supine position

the operative hip. The "unsterile traction test" without fluid or air distension of the joint results in different findings (Fig. 2.2):

- Distraction and development of a "vacuum sign" between the head and socket (Fig. 2.2a): This is the most common finding. Frequently, during turning the traction module, a sudden "pop" and increase of leg length indicate breakage of the labral seal and development of the vacuum sign.
- Distraction without development of a "vacuum sign": According to our experience, this finding is pathognomonic of significant intra-articular effusion. Frequently, a "pop" is missing, and distraction of the hip is continuous.
- "Normal" distraction with a gap between the head and socket of about 10 mm (Fig. 2.2a): This indicates the most common finding, and a high possibility of safe access to the central compartment is anticipated [2, 5]
- "Large" distraction with a gap of 15–20 mm and more (Fig. 2.2b): Frequently, those hips already show a vacuum sign by manual traction only. This finding may be a sign of hip instability.
- "Small" distraction with a gap of less than 8 mm (Fig. 2.2c): Small hip distraction is frequently found in patients with early osteoarthritis, capsular thickening and fibrosis, and reduced preoperative hip range of motion. The surgeon needs to be prepared for a more difficult hip arthroscopy with less distraction and reduced maneuverability of instruments. Release of the intra-articular negative pressure prior to the first portal placement to the central compartment is mandatory [6]. In addition, there may be the need for a more extensive capsular release in order to

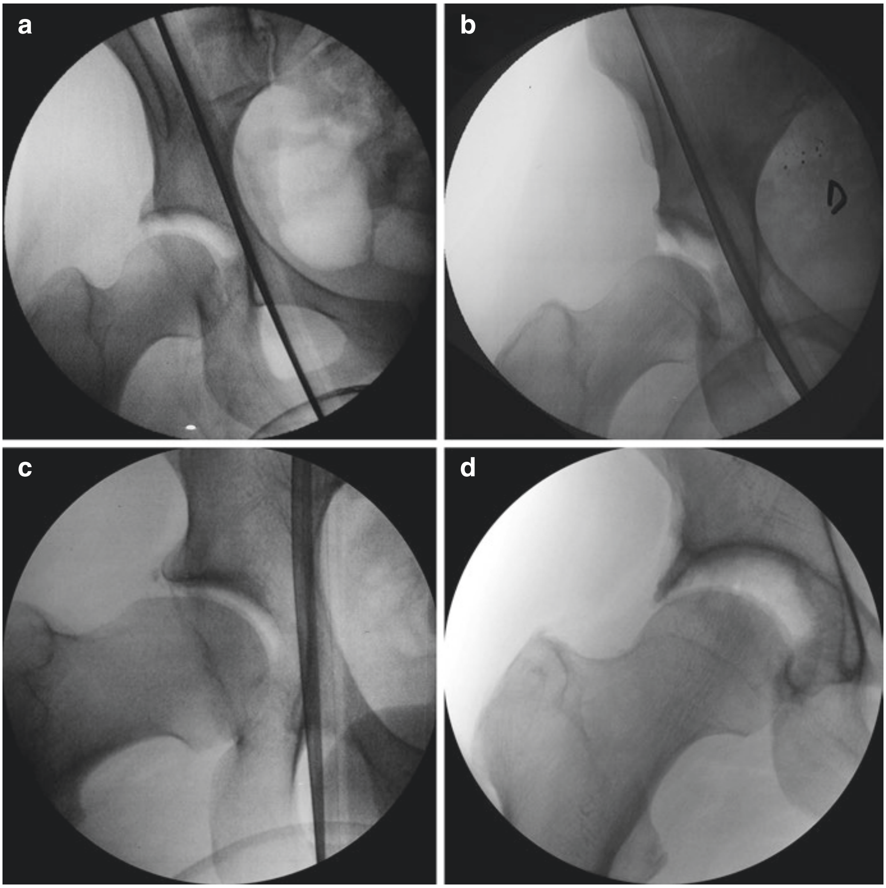

Fig. 2.2 Fluoroscopic findings of the "unsterile" traction test: normal amount of distraction with a vacuum sign (**a**). Wide distraction in dysplasia (**b**). Small distraction in early secondary osteoarthritis (**c**). Incongruent distraction in coxa profunda (**d**)

improve both distraction and instrument handling. Even so, sufficient distraction and arthroscopy of the central compartment may not be possible.

- "No" distraction: Occasionally, the head cannot be distracted at all from the socket by application of normal traction. In those cases, the authors do not apply more extensive traction forces in order to avoid a forceful "popping" of the joint. It has been reported that such a forceful breakage of the joint seal may lead to intra-articular damage. The authors recommend rotating the hip several times back and forth which frequently leads to a breakage of the joint seal without the application of higher traction forces. If that is not achieved, breakage of the joint seal should be performed invasively after prepping and draping.
- "Congruent" distraction of the head and socket: This is the finding for most hips with normal or reduced acetabular coverage.

- "Incongruent" distraction of the head and socket (Fig. 2.2d): This pictures appear to be almost pathognomonic of a coxa profunda or when the labrum is significantly ossified.

The "unsterile traction test" is very helpful to confirm preoperative diagnoses, such as coxa profunda or hip instability, as well as to plan capsular management and the algorithm for joint access. One should consider that distraction can be further improved by distension with air or fluid after prepping and draping of the operative area [6]. This technique should be used before the central compartment is accessed for the first time. After the traction test, the traction applied to the operative hip is completely released in order to save traction time and unnecessary pressure to soft tissues at the perineum, ankle, and foot. The operative field is prepared and draped with a standard shower curtain drape.

2.4 Portal Anatomy

The hip joint is divided into two compartments. The central compartment (CC) comprises the lunate cartilage, the acetabular fossa, the ligamentum teres, and the loaded articular surface of the femoral head. The peripheral compartment (PC) refers to the unloaded cartilage of the femoral head, the femoral neck, the medial, anterior, and posterolateral synovial folds, and the articular capsule with its intrinsic ligaments, including the zona orbicularis. The two compartments are separated by the acetabular labrum [7]. Several portals with accesses to both compartments have been published in the literature [1, 2, 8–14]. Portals commonly used will be described in detail in this section (Fig. 2.3). In the following paragraphs, the clock-face position is used for geographic description for a right hip. The 6:00 o'clock represents the center of the transverse acetabular ligament, while 9:00 o'clock refers to the posterior, 12:00 o'clock to the lateral, and 3:00 o'clock to the anterior position [10].

2.5 Anterolateral Portal (ALP)

The skin incision for the ALP is made near the anterosuperior corner of the greater trochanter, about 1 cm proximal and 1 cm anterior to the tip of the greater trochanter [10]. From this portal, arthroscope or instruments enter the capsule at about 12:00 by passing the intermuscular interval between the posterior tensor fasciae latae (TFL) and the anterior gluteus medius [15]. For placement of the ALP to the CC (ALP^{CC}), the capsular perforation is adjacent to the free edge of the lateral labrum. For placement of the ALP to the PC (ALP^{PC}), the capsular perforation is 1–2 cm distal to the head equator. The ALP lies centrally in the safe zone of hip arthroscopy. The closest neurovascular structure to this portal is the superior gluteal nerve, with the mean distance from 42 ± 8 mm to 69.4 ± 11 mm [8, 15, 16].

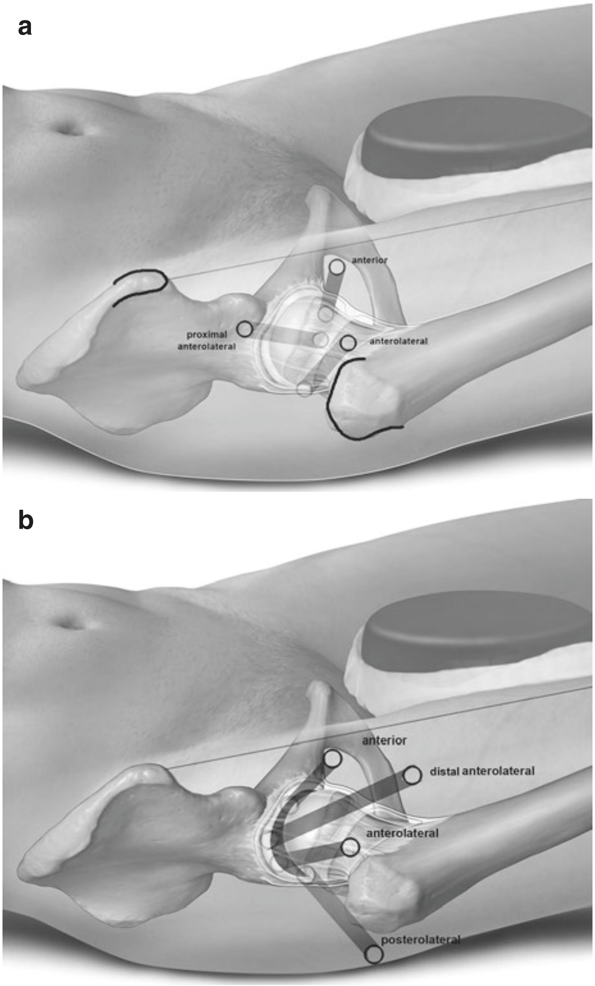

Fig. 2.3 Portals to the peripheral (**a**) and central compartment (**b**). (From Dienst, Lehrbuch und Atlas Hüftarthroskopie, 1. Auflage 2009 © Elsevier GmbH, Urban & Fischer, München)

Introduction and anterior rotation of a 70° arthroscope via the ALP^{CC} allows inspection of the labrum within the CC from 1:30 to 5:00 o'clock, the anterior part of the ilium, and, if distraction is adequate, the complete pubis. With additional lateral movement of the tip of the arthroscope, good visualization of the whole fossa acetabuli, the fovea centralis, ligamentum teres, and the central and anterolateral part of the femoral head can be achieved. With posterior rotation, the lateral part of the ischium, posterior part of the ilium, and the posterolateral labrum from about 8:00 to 10:30 o'clock can be visualized. Instruments through this portal can access the lateral part of the joint including the lateral labrum and adjacent cartilage of the lateral ilium.

Insertion of a 70° arthroscope via the ALP^{PC} allows visualization of the labrum, femoral head, zona orbicularis, and the anterolateral femoral neck from about 11:00 to 5:00 o'clock of the PC. Instruments can access the lateral labrum, femoral head, femoral neck, and zona orbicularis from about 11:00 to 02:00 o'clock [16].

2.6 Anterior Portal (AP)

Placement of the AP is usually guided by direct visualization from either the ALP^{CC} in the CC or from the proximal anterolateral portal in the PC ($PALP^{PC}$). A variety of locations of the skin incision for this portal have been described. The traditional AP to the CC (AP^{CC}) is placed at the intersection of two lines: a sagittal line drawn distally from the anterior superior iliac spine (ASIS) and a line drawn anteriorly from the superior margin of the greater trochanter [2, 10, 16]. In concern of potential iatrogenic damage to the lateral femoral cutaneous nerve and direct penetration of the origin of the rectus femoris tendon, some surgeons prefer to place the portal lateral to the sagittal line from the ASIS [13, 15] or lateral and distal to the traditional AP [11, 12, 15], which is named as the mid-anterior portal (MAP). Because most hip pathologies are located in the anterolateral aspect of the head-neck junction and acetabular rim, it is beneficial to place the AP at a more lateral location. The authors identify the site of the skin incision for both the AP^{CC} and AP^{PC} according to the position of the PALP: the AP lies about 4–5 cm (the diameter of two to three fingers) distal and 30° anterior to the PALP [13].

Arthroscope and instruments via the traditional AP pierce the sartorius muscle and then the rectus femoris before entering the hip joint at about 3:00 o'clock [8]. The route from the modified AP to the hip joint penetrates the medial part of the TFL, eventually medial fibers of the gluteus minimus, and lateral fibers of the rectus femoris before penetration of the anterior capsule [15]. Using the same skin incision, the directions for the AP^{CC} and AP^{PC} are different: For the AP^{CC} the needle is directed toward the anterior capsule near the free edge of the anterior labrum, and for the AP^{PC} the needle is directed toward the anterior capsule 1–2 cm distal to the equator of the femoral head and proximal to the zona orbicularis.

Via the AP^{CC}, the 70° arthroscope can view the medial and lateral part of the CC from about 8:30 to 1:30 o'clock and from 4:00 to 6:00 o'clock, respectively. It allows a complete view of the acetabular fossa including the course of the ligamentum teres down to the transverse ligament. Instruments through the AP^{CC} can access the anterior parts of the labrum and adjacent lunate cartilage between about 1:00 and 5:00 o'clock, the anterolateral part of the fossa acetabuli, the fovea centralis, and the femoral side of the ligamentum teres.

Via the AP^{PC}, the 70° arthroscope allows visualization of the PC from about 12:00 to 6:00 o'clock. The AP^{PC} is the main working portal in PC: Most pathologies between 2:00 and 5:30 o'clock can be accessed, including the anterior portion of the cam deformity, synovial diseases, cartilage lesions, and ossifications of the anterior labrum and iliopsoas compartment [16].

Establishment of the AP carries a higher risk of injury to a branch of the lateral femoral cutaneous nerve (LFCN). The LFCN passes underneath the inguinal ligament and then proceeds to the lateral border of sartorius at 2.2–11.3 cm distal to the ASIS and 12 ± 8 mm medial to the line drawn distally from the ASIS. In 27.6% of the cases, the nerve divides up to five branches before crossing the inguinal ligament [17]. The average distance between the traditional AP and the branch of LFCN is from 3 mm to 8 ± 7 mm [8, 16]. If the portal is placed 1 cm lateral to the sagittal line from the ASIS and in line with the AL portal, the mean distance from AP to the LFCN is 15.4 ± 9.7 mm. However, if the LFCN had divided into two or more branches by the level of the portal, the modified AP would still locate within 10 mm of the most lateral branch of LFCN [15]. For the MAP, the mean distance to the LFCN increases to 25.2 ± 9.3 mm and 30.2 ± 11.1 mm when placed into the central and peripheral compartments, respectively [15]. The incidence of LFCN neuropraxia after hip arthroscopic surgeries ranges from 0% to 4%, but permanent LFCN lesions are rare [13, 17, 18]. Because the LFCN is vulnerable to laceration as making the stab wound, it is recommended to cut the skin only and avoid getting into the deeper subcutaneous tissue [8, 19].

The femoral neurovascular bundle is another concern for the establishment of the AP. The most lateral part of the structure is the femoral nerve, which locates medial to the traditional AP at a mean distance of 37 to 44 ± 8 mm, measured at the level of the joint capsule [8, 16]. The mean distance between the femoral nerve and the modified AP (1 cm lateral to the ASIS) is 35.4 ± 10.2 mm at the level of the capsule [15]. The distance between the femoral nerve and the MAP is similar to the traditional and modified AP, averaging 39.9 ± 9.2 mm measured at the joint capsule level. The MAP has the advantage of the increasing safe distance to the LFCN and equivalent distance to the femoral nerve when comparing with the traditional and modified AP. However, it is closer to the terminal branch of the ascending lateral circumflex femoral artery (LCFA). The distance between the MAP and the terminal branch of the ascending LCFA is 10.1 ± 8.2 mm and 14.7 ± 10.8 mm as accessing to the CC and PC, respectively [15]. Although the MAP is in close proximity to the ascending lateral circumflex femoral artery, the clinical significance is unclear. The LCFA is not the major blood supply to the femoral head, and the long-term sequelae associated with the vessel damage are unlikely [15, 20].

2.7 Posterolateral Portal (PLP)

The PLP is placed under direct arthroscopic visualization and is mostly used for procedures in CC under traction. Access to the posterior area of the PC is possible by the same portal after limited posterolateral capsulotomy. The skin incision is made at about 3 cm posterior to the posterolateral corner of the greater trochanter. Before entering the posterolateral capsule, it penetrates the gluteus maximus or both the gluteus medius and minimus [8].

From this portal, the visualization of the CC is feasible from about 6:00 over 12:00 to 2:00 o'clock, and instruments can access the area between 7:00 and 11:00

o'clock, including the posterior and posterolateral labrum, the posterolateral part of the fossa acetabuli, the acetabular half of the ligamentum teres, and eventually the posterior part of the ligamentum transversum. In the PC, the posterior area can be accessed after posterolateral capsulotomy.

This portal is considered a relative safe portal. The closest important neurovascular structure to the portal is the sciatic nerve. The mean distance of the sciatic nerve to the PLP in the CC is from 21.8 ± 8.9 mm to 35 ± 8 mm [8, 15, 16]. In the PC, the sciatic nerve is 33.6 ± 9.7 mm in average away from the portal [15].

2.8 Proximal Anterolateral Portal (PALP)

The PALP is the authors' main portal for inspection of the PC. The skin incision is made at the soft spot between the anterior border of the gluteus medius and the lateral border of the TFL. It is placed at about one-third of the distance from the ASIS to the tip of greater trochanter [9, 16]. The arthroscope penetrates the gluteus medius and minimus before entering the anterolateral capsule at about 1:00 at the head-neck junction. With the 70° arthroscope, the PC can be visualized from about 9:00 over 12:00 to 6:00 o'clock [16]. The portal is close to a branch of LCFN and the superior gluteal nerve, with the mean distance of 10 ± 4 mm and 20 ± 4 mm, respectively [16].

2.9 Distal Anterolateral Portal (DALP)

The DALP is an important portal for working at the anterolateral acetabular rim. It offers an adequate angle for suture anchor placement and allows better access to acetabular cartilage lesions. The skin incision is about 4 cm distal to the midpoint between the AP and the ALP and is in line with the PALP [5, 16]. It penetrates the TFL and the rectus femoris before passing through the capsule.

2.10 Arthroscopic Approaches to the Hip

There are different strategies to access the hip with arthroscopy [1, 2, 9, 21–23]. The CC first approach is the most popular technique in the world. After traction is applied to the operative hip, the CC is first accessed under fluoroscopic control, and the PC and extra-articular areas are approached later. The PC first approach is the authors' preferred technique. Without traction, the PC is accessed at the anterolateral head-neck junction under fluoroscopic control. Then portal placement to the CC is performed under arthroscopic control. This approach theoretically reduces the risk of iatrogenic damage to the acetabular labrum and femoral head cartilage, particularly in the hips with acetabular osseous or labral overcoverage as well as smaller distraction between the femoral head and acetabulum. The extra-articular compartment first technique is advocated by some other surgeons [22, 23]. Portals to the extracapsular space are established without traction, and then an outside-in capsulotomy is performed for access to the hip joint. Compared to the CC first technique, this technique also reduces the risk of iatrogenic damage to the acetabular labrum and femoral head cartilage.

2.11 Peripheral Compartment First (PC1st) Technique

The operative hip is placed in about 10° flexion, neutral rotation, and 10° abduction without traction. The PALP^{PC} is established first. After the skin incision, the needle is directed perpendicular to the neck axis and about 20° posteriorly and aimed to the anterolateral head-neck junction under the fluoroscopic guidance. The anterolateral capsule should be penetrated at about 1:00 o'clock.

The following tests allow *confirmation of a correct intra-articular position* of the needle:

- The bevel of the needle's tip is directed toward the bone. After capsular perforation, the surgeon can feel the needle sliding over the anterior surface of the femoral head-neck junction.
- Fluid reflux after distension of the PC with 20 ml of saline.
- After insertion of the nitinol guide wire, there is hard resistance of the wire because of bouncing against the medial capsule.

The operative hip is brought to about 30° flexion and slight internal rotation to relax the iliofemoral ligament and hide most of the femoral head cartilage under the socket. Then a 70° arthroscope is introduced via the PALP^{PC} with cannulated instruments. Fluoroscopy should be used to avoid kinking of the wire which carries the risk of breakage during introduction of the cannulated sheath. The 70° arthroscope is retracted to the lateral capsule, so a maximum overview of the anterolateral PC can be obtained.

For AP^{PC} placement, the anterior capsule is viewed with the 70° arthroscope lying in the PALP. The needle is directed about 10° cranial and 10–20° posterior in order to perforate the anterolateral capsule between 2:00 and 3:00 o'clock (Fig. 2.4). If instrumental access to the lateral and posterolateral PC structures is necessary, the ALP^{PC} is placed (Fig. 2.5). The operative hip is brought to slight flexion or 0° of extension, depending on the visibility at the lateral head-neck area. The puncture needle is directed about 10° cranially and 10–20° posteriorly in order to penetrate the lateral capsule at 12:00 o'clock, 1–2 cm distal to the equator of the femoral head. A limited capsulotomy of about 10 mm is made in line with the equator of the femoral head. Instruments can be inserted for posterolateral cam resection, treatment for the posterolateral labrum and rim, and synovectomy or loose body removal within the posterolateral PC cavity. In order to address the more posterior parts of the head-neck-junction and acetabular rim, the hip is slowly brought to 0° of extension and distracted.

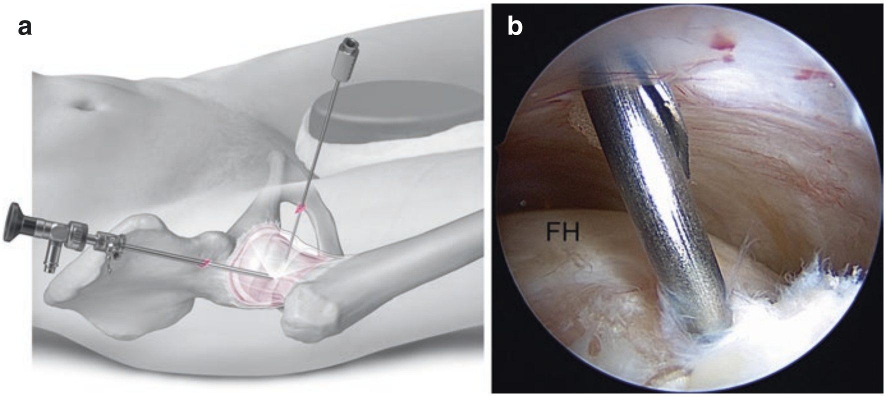

Fig. 2.4 Placement of the AP^{PC} under arthroscopic control via the $PALP^{PC}$. Illustration (**a**) and arthroscopic view (**b**); FH, femoral head. (From Dienst, Lehrbuch und Atlas Hüftarthroskopie, 1. Auflage 2009 © Elsevier GmbH, Urban & Fischer, München)

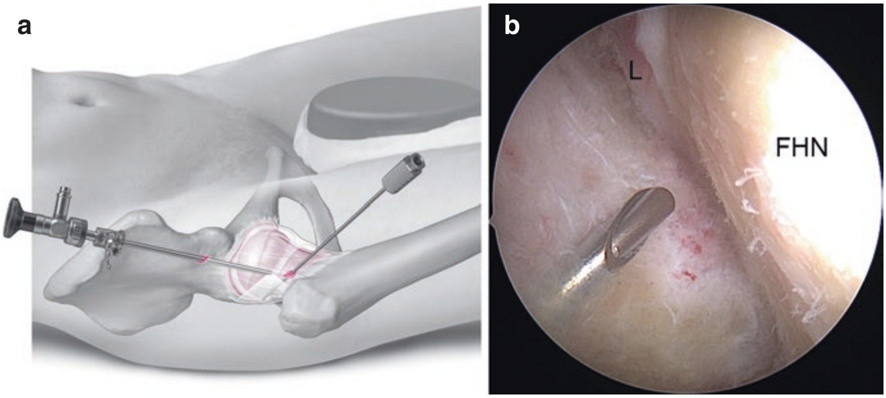

Fig. 2.5 Placement of the ALP^{PC} under arthroscopic control via the $PALP^{PC}$. Illustration (**a**) and arthroscopic view (**b**); FHN, femoral head-neck junction; L, labrum (From Dienst, Lehrbuch und Atlas Hüftarthroskopie, 1. Auflage 2009 © Elsevier GmbH, Urban & Fischer, München)

After completion of PC treatment, the CC is accessed under arthroscopic control. With the 70° arthroscope inserted via the $PALP^{PC}$, the gap between the femoral head and lateral labrum is viewed. Another arthroscopy sheath is introduced via the ALP^{PC} and is advanced into the central compartment under arthroscopic control (Fig. 2.6). The 70° arthroscope is switched to the ALP^{PC} and rotated anteriorly in order to visualize the anterior capsule, labrum, and femoral head. From the skin incision of the AP^{PC}, the needle is directed more cephalad to perforate the anterior capsule near the free edge of the labrum at about 3:00 o'clock and establish the AP^{CC} (Fig. 2.7). A limited capsulotomy parallel to the labrum of 1–2 cm is performed.

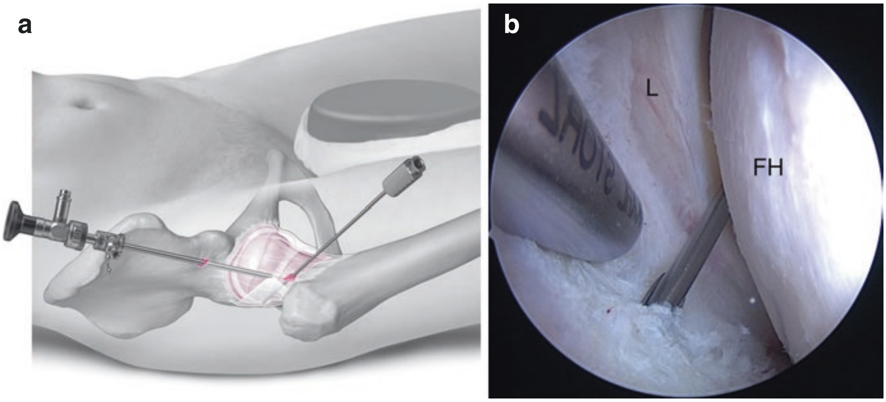

Fig. 2.6 Placement of the ALP^{CC} under arthroscopic control via the PALP^{PC}. Illustration (**a**) and arthroscopic view (**b**); FH, femoral head; L labrum. (From Dienst, Lehrbuch und Atlas Hüftarthroskopie, 1. Auflage 2009 © Elsevier GmbH, Urban & Fischer, München)

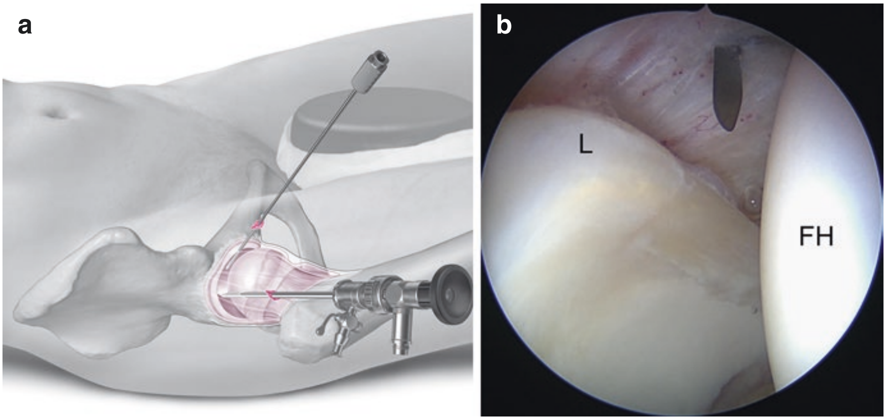

Fig. 2.7 Placement of the AP^{CC} under arthroscopic control via the ALP^{CC}; Illustration (**a**) and arthroscopic view (**b**); FH, femoral head; L, labrum

The 70° arthroscope is switched to the AP^{CC} and rotated laterally to view the lateral capsule as well as capsular perforation and position of the ALP^{PC}. Frequently, the capsular perforation is too distal, and the pressure from soft tissues is high. Therefore, the portal direction and capsular perforation should be corrected under the arthroscopic control to optimize the position and establish the ALP^{CC} (Fig. 2.8). Similarly, a small capsulotomy of about 1–2 cm parallel to the labrum is performed.

The ALP^{CC} and AP^{CC} are the standard portals for arthroscopy of the CC and are always established. Additional portals, such as the DALP and PLP, should be placed according to the pathologic location (Fig. 2.9).

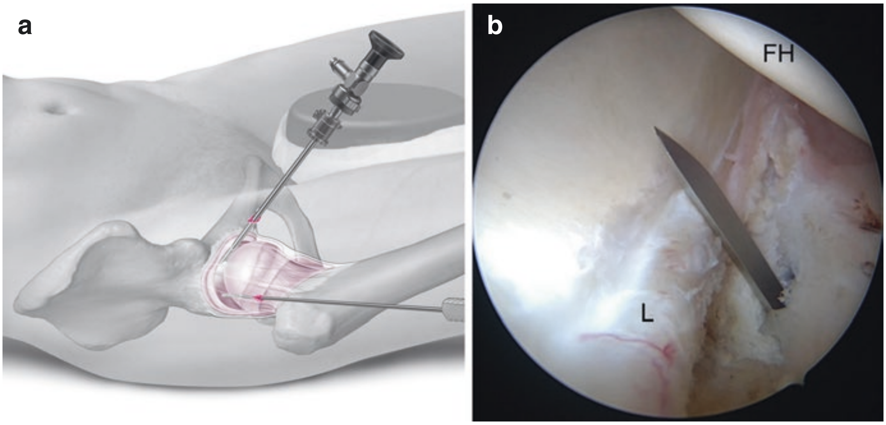

Fig. 2.8 Inspection of the insertion site of the ALP^{CC} under arthroscopic control from the AP^{CC}. Illustration (**a**) and arthroscopic view of the capsulotomy at the capsular insertion (**b**); FH, femoral head; L, labrum. (From Dienst, Lehrbuch und Atlas Hüftarthroskopie, 1. Auflage 2009 © Elsevier GmbH, Urban & Fischer, München)

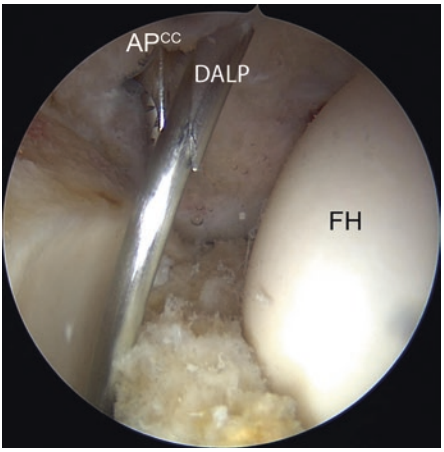

Fig. 2.9 DALP placement under arthroscopic control via the ALP^{CC}. Note the better angle for anchor placement to the rim and access to the rim cartilage in comparison to the AP^{CC}

2.12 Central Compartment First (CC1st) Technique

Traction is applied to the operative hip. Joint distension by intra-articular injection of saline or air can significantly reduce the traction force and obtain better distraction [6, 24]. In order to reduce the risk of iatrogenic damage to the femoral head cartilage and acetabular labrum, 8–10 mm distraction of the hip joint is recommended and should be confirmed by the fluoroscopy [2, 5].

For placement of the ALP^{CC}, a needle is directed about 15° cranial and 15° posterior under fluoroscopic guidance toward the lateral capsule [10, 15]. It should penetrate the capsule under the lateral lip of the acetabulum. If it lies too close to the acetabulum, it may penetrate the acetabular labrum. On the other hand, the needle should be kept close to the free edge of the labrum to prevent the damage to the femoral head cartilage [2]. The following tips help decrease the risk of iatrogenic damage to the acetabular labrum during placement of the ALP^{CC} [25]:

- *Soft tissue resistance*: There should be almost no further resistance after the needle has penetrated the capsule. If high resistance is felt, perforation of the labrum needs to be considered.
- *Distension*: Distention of the hip joint with saline or air frequently improves the degree of distraction. In consequence, distension and breakage of the vacuum is mandatory prior to introduction of the arthroscopy sheath.
- *Air arthrogram*: After entering the joint with the needle, removal of the fluid and filling with air can be a helpful technique in order to visualize the surfaces of the labrum, femoral and acetabular labrum, acetabular fossa, the pulvinar, and the teres ligament. Particularly, the silhouette of the lateral acetabular labrum and its relation to the position of the needle needs to be analyzed. If there is a concern of perforation of the labrum, the needle must be retracted and directed in a more distal position.
- The position of the ALP^{CC} should be evaluated from the AP^{CC} once the AP^{CC} is established.

Once the arthroscope is introduced into the central compartment via the ALP, portals of AP^{CC}, PLP^{CC}, and DALP^{CC} are performed under the arthroscopic control and are identical to the techniques described for the PC1st technique.

After treatment of CC pathologies, the PC and potentially extra-articular compartments are accessed without traction most of the time. The technique of switching into the PC significantly depends on the extent of capsulotomy. If a large interportal capsulotomy is performed and eventually combined with a vertical cut toward the femoral neck, the arthroscope can be easily moved toward the PC via the existing CC portals. If only limited capsulotomies are done, the portals to the PC should be established as described before.

2.13 Extra-articular Compartment First (EA^{1st}) Technique

The operative hip is placed in slight flexion without traction. A blunt trocar is advanced via the ALP and directed medially through the gap between the TFL and the gluteus minimus muscle. When it is in contact with the anterior surface of the hip capsule, the arthroscope is introduced, and the anterior capsule with the fatty tissue can be visualized. The AP is then created under arthroscopic control, and the instrument is introduced to create a longitudinal capsulotomy along the axis of the femoral neck. Care should be taken to avoid damage to the acetabular labrum as the capsulotomy extends proximally. The following steps of arthroscopy are similar to the description of the PC^{1st} technique [22, 23].

2.14 Evacuation with/Without Capsular Closure

The decision whether the capsule needs to be repaired, how much of the capsular incision has to be closed, or if a capsular plication is beneficial depends on the extent of capsulotomy and stability of the hip. Stability of the hip is influenced by both osseous coverage and orientation and soft tissue structures, including acetabular labrum, ligamentum teres, and the capsuloligamentous complex [26–30]. So, cases of iatrogenic instability of the hip following arthroscopic capsulotomy without capsular closure occurred particularly in concurrent hip dysplasia [31–34]. In cadaveric studies, a longer capsulotomy is associated with increasing hip joint mobility, whereas complete capsular closure can restore hip joint stability comparable to the intact condition [35, 36]. In vivo, patients who underwent complete repair of the T capsulotomy had better clinical outcome and lower revision rates than those receiving partial repair of the T capsulotomy [37]. For patients with borderline hip dysplasia, capsular plication leads to a better clinical outcome and lower failure rate compared with those without receiving capsular plication [38]. In conclusion, capsular closure should be considered if capsulotomy is extensive, especially when bony undercoverage, such as in patients with dysplasia, is found.

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Hip Arthroscopy: Anatomy and Techniques

3

Leandro Ejnisman and Marc Safran

3.1 Introduction

The first description of hip arthroscopy was in 1931 by Burman [1]. In this classic paper, the author investigates the feasibility of arthroscopic examination in multiple joints. With respect to the hip, the paper states “it is manifestly impossible to insert a needle between the head of the femur and the acetabulum.” However, the author was able to visualize a portion of the anterior femoral neck and the femoral head and neck transition. At that time, this was not considered an important region because femoroacetabular impingement (FAI) and cam lesions were yet to be described, and the relative infrequency of rheumatologic disorders affecting the hip only diminished its need as well.

The past two decades have seen an explosion on the number of hip arthroscopies performed per year. Development of techniques to access the hip joint reproducibly and safely, better instrumentation, and improving understanding of surgical indications are the main reasons for this growth. However, even with this advancement in knowledge, hip arthroscopy is still a skillful procedure with a very prolonged learning curve. It is recommended that surgeons attend hip arthroscopy courses and observe experts performing hip arthroscopy before starting their own cases. Cadaveric training is worthwhile and extremely helpful to orthopedic surgeons, especially in their early technical stages. Adequate knowledge of arthroscopic

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anatomy and technique is paramount to successful outcomes and keeping complications rates low.

3.2 Surgical Technique

In hip arthroscopy, the hip joint is divided into central and peripheral compartments [2]. The division of the compartments is determined by the outer edge of the acetabular labrum. The central compartment contains the acetabular articular cartilage, the labrum, the medial part of the femoral head, and the cotyloid fossa. In cases of pincer FAI, the pincer lesion is also often considered to be in the central compartment. The peripheral compartment contains the non-weight-bearing area of the femoral head, the femoral neck, the zona orbicularis, and the medial and lateral synovial folds – essentially the rest of the intracapsular joint outside of the acetabular articular surface and labrum. In cases of cam FAI, the cam lesion will be in the peripheral compartment. This division is important because each compartment will be visualized at different times during the surgery, so the surgeon should know when to address each anatomical structure. In basic terms, the central compartment is visualized with traction applied, to distract the joint, while the peripheral compartment is visualized with traction off to relax the capsule, often in conjunction with hip flexion to relax the anterior capsule to see more anteriorly and medially.

Traction is used to obtain a separation between the femoral head and the acetabulum in order to access the central compartment. This is most commonly performed using a fracture table, though other techniques to separate the femoral head from the acetabulum may be used, including using femoral distractor. Some variation in patient positioning and arthroscopic techniques can be found in the literature. First, the patient can be positioned supine or lateral [3, 4]. Second, some surgeons start hip arthroscopy from the central compartment first, while others start in the peripheral compartment. Studies have shown there is no clear advantages to any of the aforementioned techniques, and the decision will mainly depend on surgeon's preference and experience. This chapter will focus on the supine technique with the central compartment being addressed first, as this is the senior author's preferred technique. Other considerations include some surgeons doing hip arthroscopy with only two portals for the whole surgery, or just for the central compartment, and accessory portals at other times, such as for peripheral compartment surgery and/or labral repair. The senior author's preferred technique involves three portals for the central compartment and occasionally one or two accessory portals for labral repair and an additional portal for peripheral compartment arthroscopy.

The patient is positioned supine on the fracture table. Extra padding is used to protect the perineum and the dorsum of the feet. The perineal post should be larger than the normal post used for trauma, should be well padded, and is lateralized toward the affected hip. This facilitates the creation of a lateral distraction force (in addition to distally) when the leg is being pulled distally. Body weight traction is applied to both feet in order to approximate the perineum to the post, starting with slight body weight traction being applied to the non-operative leg first, as this assures lateralization. At this moment, a fluoroscopy image is obtained. In some patients there will be some distraction of the femur just from the application of body weight, and this finding strongly suggests hip instability. Then, fine traction is applied until a distraction of 10 mm is obtained. The number of turns of the distraction device on the fracture table may be used to estimate ease of distractibility, which may be suggestive of hip laxity or microinstability. Few turns to get the hip adequately distracted suggest instability of the joint.

After adequate distraction of the joint is established, the joint should be vented to remove the negative intra-articular pressure. The anterolateral hip region is prepped, and a spinal needle is inserted inside the joint guided by fluoroscopy. An air arthrogram of the hip can be seen after venting (Fig. 3.1). After removal of the needle, the traction is then released and another fluoroscopic image is obtained. It is important to note if the hip has completely reduced, because incomplete reduction after joint venting may be another sign of hip microinstability.

Next the patient is prepped and draped, and all the arthroscopic equipment is set up. It is preferred to re-establish traction only once all the equipment is ready and tested to avoid unnecessary traction time. The first portal is the anterolateral portal, and it is done under fluoroscopic visualization (Fig. 3.2). The starting point is usually 1–2 cm medial and proximal to the anterior superior greater trochanter edge. A spinal needle is introduced into the hip joint aiming at the most medial aspect of the acetabular sourcil (Fig. 3.3). A long nitinol wire is introduced through the spinal needle, and the needle is removed. A small skin incision is performed, and an arthroscopic cannula is introduced using the nitinol wire as a guide. The cannula is introduced slowly while gently twisting. The cannula will encounter resistance when it reaches the capsule. Caution must be taken to rotate the bevel of the cannula away from the femoral head, with the objective of decreasing the risk of injury to the femoral articular cartilage. The same guided technique using the spinal needle and the nitinol wire is used for the subsequent portals. Once the cannula is inside the joint, the trocar is

Fig. 3.1 Fluoroscopic view of a left hip under traction. A spinal needle is inserted between the acetabulum and the femoral head. The goal is for the needle to be as close to the femoral head as possible, to reduce the likelihood of penetrating the labrum. It is possible to observe an arthrogram demonstrating the elimination of negative intra-articular pressure

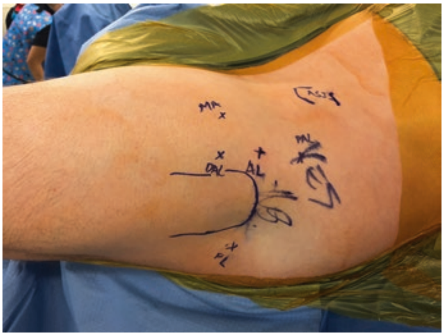

Fig. 3.2 Left hip after patient is prepped and draped. Picture demonstrates portal positioning in relationship to the anterosuperior iliac spine (ASIS) and the greater trochanter *MA* mid-anterior portal, *DAL* distal anterolateral portal, *AL* anterolateral portal, *PAL* proximal anterolateral portal, *PL* posterolateral portal

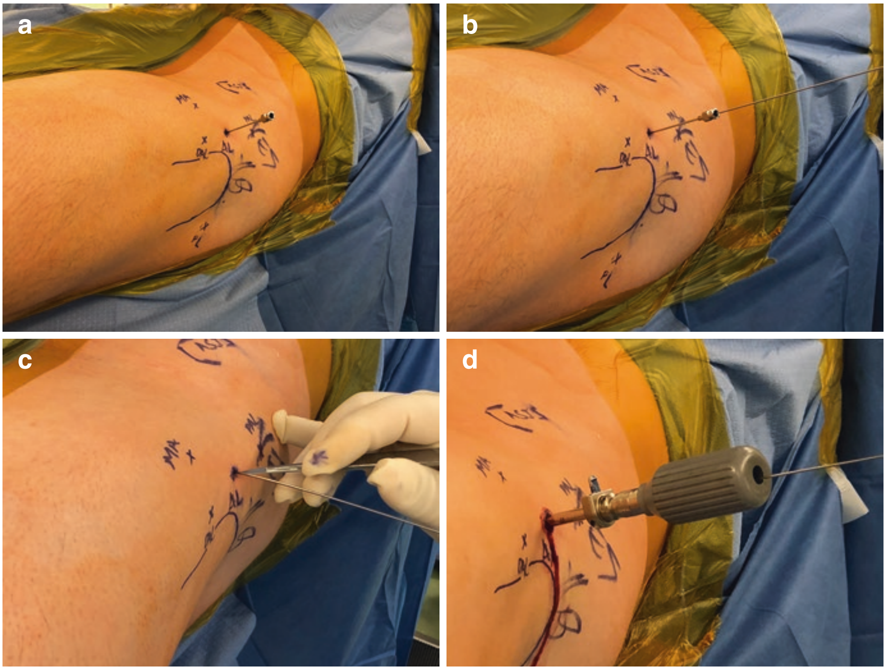

Fig. 3.3 Sequential pictures of the guided portal technique. (**a**) Spinal needle through the proposed anterolateral (AL) portal (first portal). (**b**) Nitinol wire inserted through the spinal needle. (**c**) Incision adjacent to the nitinol wire after retrieval of the spinal needle. (**d**) Cannula insertion guided over the nitinol wire

exchanged for the camera. Commonly a 70° lens will be used for the central compartment, and a 30° lens will be used for the peripheral compartment. However, this may change according to surgeon's preference, specific patient anatomic variations, or the procedure being performed.

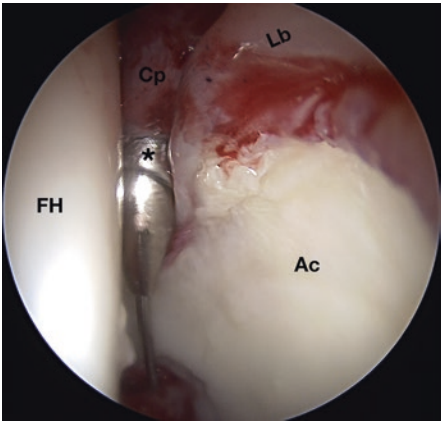

Fig. 3.4 Left hip, view from the anterolateral portal with a 70° arthroscope. The anterior portal cannula (black star) is inserted under arthroscopic visualization using the nitinol wire as a guide, aiming the triangular region formed by the femoral head, labrum, and the border of the lens. *FH* femoral head, *Cp* capsule, *Lb* labrum, *Ac* acetabulum

The next portals are established through direct arthroscopic visualization. Fluoroscopy may be used to help in difficult cases or at the beginning of the learning curve; however, it is important that the surgeon watches arthroscopically as the needle penetrates the joint so as to not injure the labrum or articular cartilage. Before the second portal, the surgeon visualizes the anterior capsule in a triangular shape. The triangle is formed by the acetabular labrum, the femoral head, and the border of the lens. The surgeon's goal is to perforate this triangle with the needle, avoiding injury to the femoral head and labrum, establishing the mid-anterior portal (Fig. 3.4). The skin entry point for the mid-anterior portal is 5–7 cm from the anterior portal on a line 45° distal and medial to the anterior portal, being sure to stay lateral to a line draw distal to the ASIS. Then, the camera is exchanged to the mid-anterior portal to assess the position of the anterolateral cannula, assuring that the cannula has not penetrated the labrum, as the anterolateral portal was performed using fluoroscopic visualization only, and the labrum may be perforated by the cannula. If this happens, the cannula needs to be repositioned. In some cases it is possible to back the cannula and simply readvance it avoiding the labrum. However, it may be necessary to take the cannula out and start again with the needle.

At this moment, another variation of the arthroscopic technique is possible. An interportal capsulotomy can be performed connecting the anterolateral and mid-anterior portals. The interportal capsulotomy has the advantage of performing the entire surgery (peripheral and central compartments) with only two portals. Its main disadvantage is that joining these two portals necessitates cutting the iliofemoral ligament, which is one of the main stabilizers of the hip joint. Another possible technique is to dilate the portals to pass the cannulas and not perform a capsulotomy. The main advantage of this latter technique is not injuring the iliofemoral ligament, while its main disadvantage is the need for multiple portals in order to reach and visualize the entire joint. No technique has been proven superior in the literature, and capsular management is a controversial, and currently frequently discussed, topic in hip arthroscopy. This chapter will focus on the technique without interportal capsulotomy [5].

Until the first two portals are established, the arthroscopy is performed dry without injecting fluid in the joint, as the second portal allows for outflow. If fluid is put into the joint without an outflow portal, mixture with blood will obscure visualization, making it difficult to visualize the second portal being made. After the second portal, fluid flow is instituted, which improves visualization. The posterolateral portal is performed third, looking posteriorly from the anterolateral portal. The starting point is 2 cm posterior to the posterior edge of the greater trochanter, just distal to a line drawn straight posterior from the anterolateral portal. It is important that the foot is in neutral rotation while establishing the posterolateral portal—external rotation or internal rotation will increase the risk of injury to the sciatic nerve when making this portal. Moving the camera lens' direction is more common in hip arthroscopy than in arthroscopy of another joints and can be helpful to achieve proper visualization.

3.3 Arthroscopic Anatomy

3.3.1 Central Compartment

After all portals are in place, an inventory of the joint can be performed. Each surgeon must have his/her own protocol to analyze the whole joint. Being systematic will avoid missing injuries and skipping steps. During most of central compartment arthroscopy, the posterolateral portal will be used as the camera portal, while the anterolateral and mid-anterior portal are used as working portals. However, exchanging viewing portals can aid in visualization. Also, for less experienced surgeons, exchanging portals will help to better understand the anatomy and localization of the structures.

First, the capsule is evaluated in regard to synovitis, which is common in FAI patients. It is possible to observe the capsule all around the acetabular rim and close to the labrum. The acetabular labrum is a fibrocartilage structure that runs around the acetabular rim. It is visible through all three portals and is important to evaluate all labral regions (Fig. 3.5). A clockface system is commonly used to facilitate location of tears. Twelve o'clock is directly lateral/superior, 3 o'clock is anterior, and 9 o'clock is posterior. Noting the aspect of the labrum is important to understand possible causes of tearing and determine treatment [6]. Tears caused by cam impingement are typically anterosuperior, the labral tissue is healthy, and a separation between the cartilage and the labrum is observed. In pincer impingement a more diffuse tear will be found, and the labral substance will be degenerated. The most anterior portion of the labrum can be visualized both from the anterolateral and posterolateral portals, while the posterior labrum will be better visualized from the anterolateral portal.

The acetabular cartilage is visualized from the central compartment. Similar to the labrum, its anterior portion will be better seen from the anterolateral and posterolateral portals, while the posterior region will be better seen from the anterolateral portal. A thorough examination of the cartilage is paramount, and the surgeon

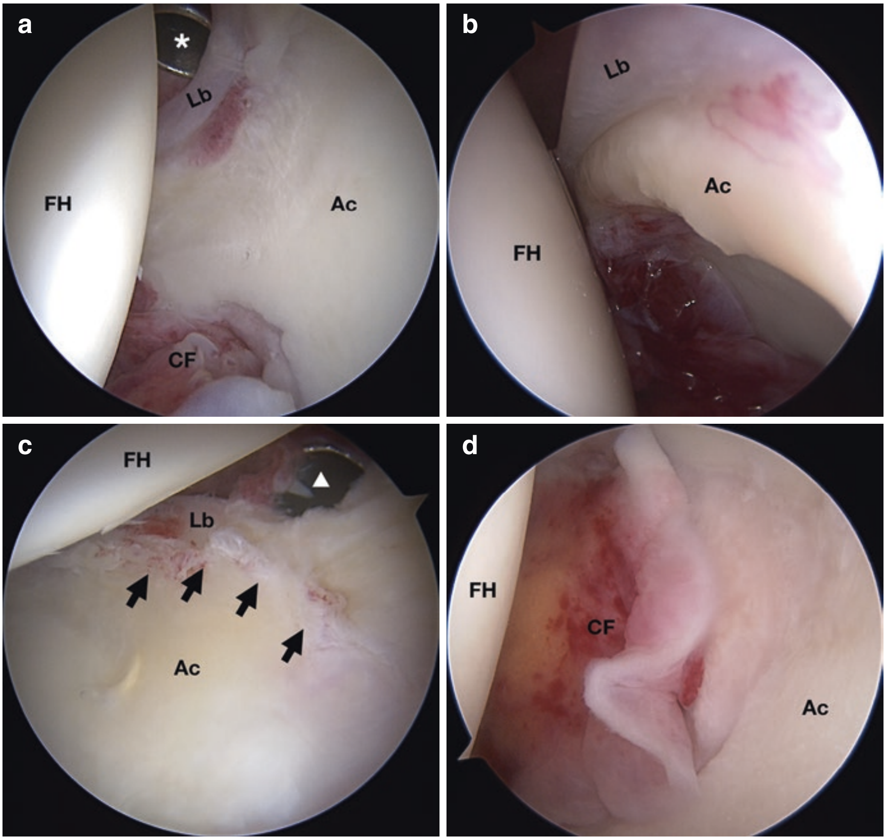

Fig. 3.5 Different views of the central compartment in a left hip. (**a**) View from the anterolateral portal with a 70° arthroscope. (**b**) View from the mid-anterior portal with a 30° arthroscope. (**c**). View from the posterolateral portal with a 70° arthroscope demonstrating the superior labrum and acetabular chondral damage (black arrows). (**d**) View from the posterolateral portal with a 30° arthroscope demonstrating the ligamentum teres and the cotyloid fossa with moderate synovitis *FH* femoral head, *Lb* labrum, *Ac* acetabulum, CF cotyloid fossa, *white star* cannula in the mid-anterior portal, *white triangle* cannula in the anterolateral portal)

has to be meticulous in probing the entire surface because carpet delamination may be underappreciated. Carpet lesions happen most commonly in association with cam lesions and are characterized by detachment of the articular cartilage from the labrum and subchondral bone (Fig. 3.6). Bubble lesions can also occur, and they are characterized by a detachment of the subchondral bone in a circumscript area without "opening" of the pocket to the joint. Areas of chondromalacia, noted as softening of the cartilage, can also be observed and should be recorded. The clockface system can also be used to localize acetabular cartilage injuries. However, another system has been described where the acetabulum is divided in geographic zones [7]. Two vertical lines and one horizontal line divide the acetabulum in six regions. The authors suggest this method is more reproducible than the clockface method.

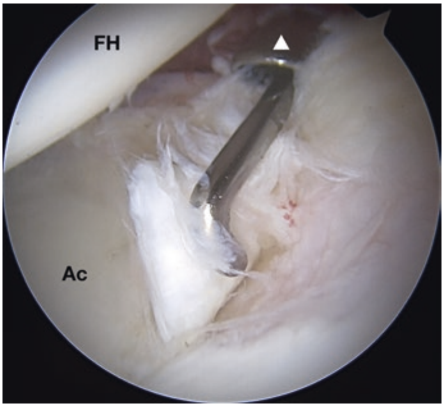

Fig. 3.6 View from the posterolateral portal with a 70° arthroscope demonstrating a carpet lesion of the acetabular cartilage being probed *FH* femoral head, *Ac* acetabulum, *white triangle* cannula in the anterolateral portal

Regardless of the location system used, it is essential to document all chondral damage in a systematic manner, as it may have treatment and prognostic consequences.

Attention is then turned to the cotyloid fossa and the ligamentum teres. This region is usually evaluated from the posterolateral portal. The anterolateral portal may also be used for visualization of the superior portion of the ligamentum teres. It is helpful to exchange to a 30° lens to facilitate a direct visualization of this region. Possible tears to the ligamentum teres are noted which may be partial or complete. The ligamentum teres and cotyloid fossa are also evaluated for synovitis, which is frequently observed in this area.

Finally, the femoral head is evaluated. From the central compartment, it is possible to observe the medial portion of the femoral head and the superior weight-bearing zone. The same geographic method can be used to record lesions on the femoral head [7]. Cartilage lesions on the femoral head are less common than acetabular lesions, and they are considered to have worse prognosis. Medial cartilage wear can be seen in cases of microinstability and appear to have a better prognosis. This damage is thought to occur during episodes of femoral head subluxation and is often accompanied by ligamentum teres tears and direct anterior acetabular labrum tears [8].

Two possible caveats in the central compartment anatomy are the psoas-U and the stellate crease. The psoas-U is a recess in the anterior margin of the acetabulum, where the psoas tendon crosses just anterior to the acetabular labrum. It can be used as a landmark for the 3 o'clock position [9]. A psoas tenotomy can be performed in this region [10]. The stellate crease is a reminiscent of the triradiate cartilage and can be seen both on MRI and arthroscopically [11]. During surgery it will appear as an area devoid of cartilage above the cotyloid fossa and should not be confused with chondral damage. It is more common in younger patients.

The pincer lesion is observed in the central compartment. In order to appreciate its location it is possible to use fluoroscopic guidance and direct observation. The labral and chondral damage will be markers of the impingement area, and will help to guide osseous resection. In cases of subspine impingement, the anteroinferior iliac spine (AIIS) may be visible from the central compartment. It can be seen in the anterosuperior acetabular region, approximately between 1 and 2 o'clock, behind the labrum.

Correction of the pincer lesion and labral treatment are performed from the central compartment. Accessory portals may be necessary to achieve this goal. Common portals used include the anterior portal and the distal anterolateral accessory portal. The decision on which portals will be used should be tailored to each patient's anatomy and pathology.

3.3.2 Peripheral Compartment

When the central compartment portion of the surgery is finished, attention is turned to the peripheral compartment. Ideally, traction time should be kept less than 2 h to decrease the risk of traction-related complications. All cannulas are removed from the central compartment, and traction is released from both legs. A fluoroscopic image should confirm the hip is completely reduced. The cannula and trochar are inserted in the anterolateral portal and are introduced to the femoral head-neck junction or site of maximal deformity of the femoral head. A 30° lens is used for the peripheral compartment. An auxiliary portal is made approximately 3–4 cm proximal and 1 cm posterior to the anterolateral portal. This portal will be used as a working portal in the peripheral compartment. Fluoroscopy is used to aim the cannula and trochar toward the apex of the femoral head deformity, holding the cannula against the capsule. The trochar is exchanged for the 30 degree arthroscope, and a shaver is brought to the tip of the camera from the proximal anterolateral portal (Fig. 3.7). In this region, a partial small capsulectomy (up to 6–8 mm in width and 15 mm in length for capsular plications) is performed using the shaver. This area is considered the "bare area" of the hip capsule, between the iliofemoral and ischiofemoral ligaments. The capsulectomy is continued until proper

Fig. 3.7 Fluoroscopy image of a left hip. The arthroscope and the shaver are placed against the capsule at the femoral head-neck junction

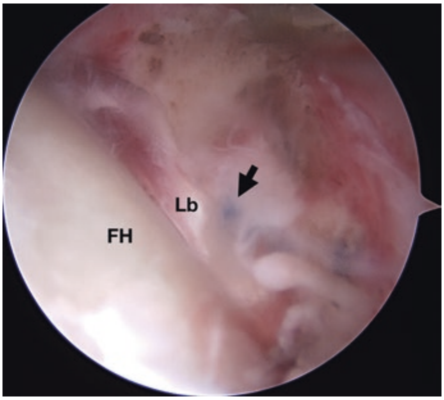

Fig. 3.8 View from the anterolateral portal with a 30° arthroscope in the peripheral compartment. The labrum sits nicely on top of the femoral head restoring the suction seal. It is possible to observe one stitch from the labral repair (arrow). *FH* femoral head, *Lb* labrum

visualization of the head-neck junction is observed. Observing the width of the capsule and if it is patulous may help in hip microinstability investigation.

In patients presenting cam impingement, the cam lesion should be visualized right upon entering the peripheral compartment. It is possible to observe the labrum (and its repair if it was performed) from the peripheral compartment (Fig. 3.8). Observing the relationship between the femoral head and the labrum is essential to confirm the suction seal was restored. The anterior portion of the femoral head is visible in its area not covered by the acetabulum. All the anterior neck is observed as distal as the intertrochanteric ridge.

When addressing the peripheral compartment, moving the leg can be extremely helpful to navigate the joint (Fig. 3.9). Hip flexion will relax the anterior capsule and make instrument maneuverability easier, and straight flexion brings the more distal and medial femoral neck into view. Likewise, hip rotation may facilitate access to the medial or lateral region. For example, internal rotation is useful to access the posterolateral portion of the femoral head-neck junction.

The anterior capsule can be noted, and similar to the central compartment, synovitis can be observed and treated. In the midportion of the capsule, the zona orbicularis can be seen as a transverse band going around the base of the femoral neck (Fig. 3.10). It is critical not to violate the zona orbicularis, as previous biomechanical work has demonstrated its importance in hip stability [12]. It is also possible to observe the impression of the psoas tendon on the anterior capsule, and a psoas tenotomy can be performed in this region (Fig. 3.10).

The medial synovial fold can be found on the medial portion of the femoral neck, which serves as an important landmark in the peripheral compartment. Flexion or external rotation may facilitate its visualization. The lateral synovial fold can be

Fig. 3.9 The operated leg is freed from the operating table and hold by the assistant. This allows flexion and rotation of the leg to help adequate visualization

found on the lateral portion of the femoral neck. Sometimes the pulsation of the lateral retinacular vessels is visible along the posterior and posterolateral femoral neck. One can also see the reflection and insertion of the proximal capsule on the acetabulum, above the labrum.

After a proper inventory of the peripheral compartment, a femoral osteoplasty can be performed in cases of cam FAI. A dynamic assessment of impingement should be performed at the end of the case to check for possible residual deformities and impingement. At the end of the procedure, the capsule may be closed or plicated if the patient presented hip laxity or microinstability. A bulky dressing is used after skin closure because liquid extravasation is common in the first 24 h. Hip arthroscopy can be safely performed as an outpatient procedure.

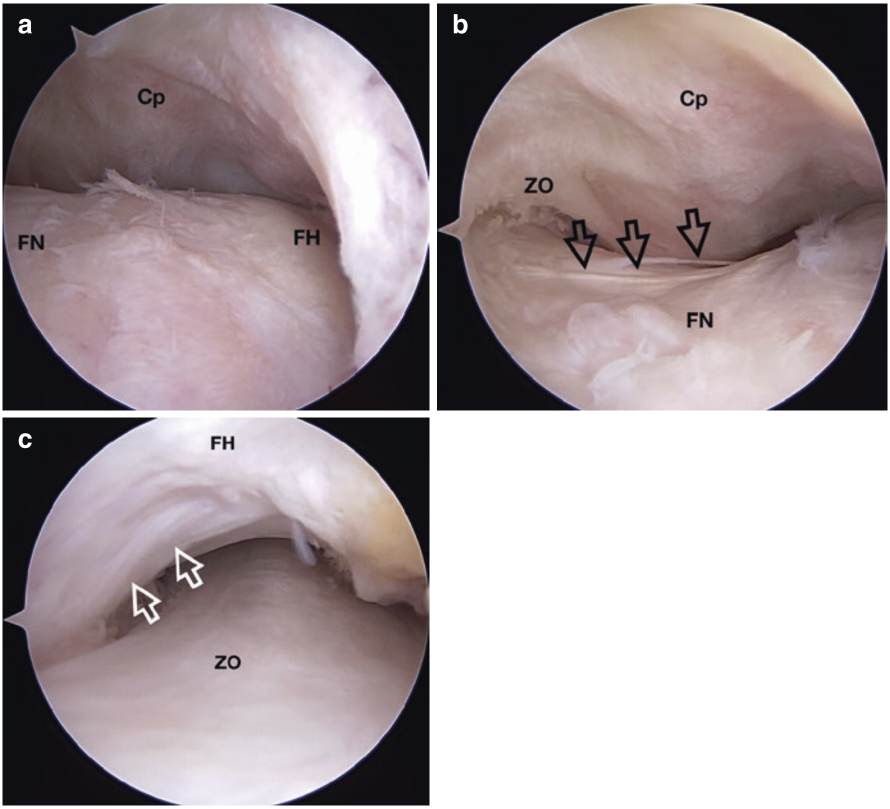

Fig. 3.10 View from the anterolateral portal with a 30° arthroscope in the peripheral compartment. (**a**) The cam lesion is observed in the femoral head-neck transition. (**b**) Medial synovial fold (black arrows) and the zona orbicularis. The back of the black arrow furthest to the right is where the iliopsoas tendon is indenting the capsule. Cutting the capsule at this point can expose the iliopsoas tendon for a psoas tenotomy. (**c**) Lateral synovial fold (white arrows) and the zona orbicularis posteriorly. *FH* femoral head, *FN* femoral neck, *Cp* anterior capsule, *ZO* zona orbicularis

3.4 Conclusion

Hip arthroscopy is a difficult procedure with a prolonged learning curve. Understanding the local anatomy is crucial to obtain satisfactory results and decrease the number of complications. A systematic approach for evaluation of the anatomic structures should be used by surgeons performing hip arthroscopy.

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Endoscopic Peritrochanteric Space: Evaluation and Treatment

4

Hal David Martin

4.1 Introduction

The endoscopic technique for the assessment of the peritrochanteric space has made significant contributions to further our understanding of lateral hip anatomy and biomechanics, diagnosis, and treatment. Since the original description by Dr. Bryan Kelly et al. [1] in 2007, numerous publications have reported good outcomes and have helped refine techniques for treatment of peritrochanteric space disorders. Lateral-based hip pain pathology includes greater trochanter bursitis, snapping iliotibial band (external coxa saltans), and tears of the gluteus medius and/or minimus. Accurate diagnosis and treatment strategies can improve patient function and pain [2].

4.1.1 Physical Examination

A complete standardized history and physical must be utilized in all cases of hip pain [3, 4]. Lateral-based pain may be associated with intra- or extra-articular aspects, and key physical examination tests include assessment of the greater trochanter, abductor musculotendinous strength/contracture, and hip biomechanics. A thorough physical examination will distinguish pain location (anterior/lateral/posterior and intra-articular versus extra-articular pathology). Posterior and posterior-superior hip pain requires a thorough evaluation in differentiating hip and back pain [5–8].

Gait abnormalities often help detect hip pathology [9]. The patient is taken into the hallway to observe a full gait of six to eight stride lengths. Key points of gait evaluation include foot progression angle, pelvic rotation, stance phase, and stride length. The following abnormal gait patterns can be associated with hip

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pathologies: winking gait with excessive pelvic rotation in the axial plane; abductor deficient gait (Trendelenburg gait or abductor lurch); antalgic gait with a shortened stance phase on the painful side; or short leg gait with dropping of the shoulder in the direction of the short leg with pain occurring on the long or high side.

In addition to body habitus and gait evaluation, the single-leg stance phase test (Trendelenburg test) is performed during the standing evaluation of the hip. The single-leg stance phase test is performed on both legs, with the non-affected leg examined first, to establish a baseline (Fig. 4.1). If the abductor musculature is weak or the neural loop of proprioception is disrupted on the bearing side, the pelvis will drop toward the nonbearing side or shift more than 2 cm toward the bearing (affected) side. Trunk inclination for the bearing (affected) side is also noted in a positive single-leg stance test. This assessment is performed in a dynamic fashion by some examiners.

The lateral examination begins with the patient on the contralateral side and palpating the areas of the suprasacroiliac area, sacroiliac (SI) joint, gluteus maximus origin, piriformis muscle, and sciatic nerve. The greater trochanter is palpated on its facets: anterior, lateral, superoposterior, and posterior. The gluteus minimus insertion is palpated at the anterior facet, the gluteus medius at the superoposterior and lateral facets, and the trochanteric bursa at the posterior facet.

Strength is assessed with any type of lateral-based hip complaint. The tests are performed in lateral decubitus with the patient actively abducting the hip against resistance. The gluteus medius strength test (Fig. 4.2a) is performed with the knee in flexion to release the gluteus maximus contribution for the iliotibial band. The overall abductor strength (Fig. 4.2b) is evaluated with the knee in extension, and the gluteus maximus is tested asking the patient to abduct and extend the hip posterior. This test can also be done in the prone position.

A set of passive adduction tests (similar to Ober's test) is performed with the leg in three positions—extension (tensor fascia lata contracture test) (Fig. 4.3a), neutral (gluteus medius contracture test) (Fig. 4.3b), and flexion (gluteus maximus contracture test) (Fig. 4.3c).

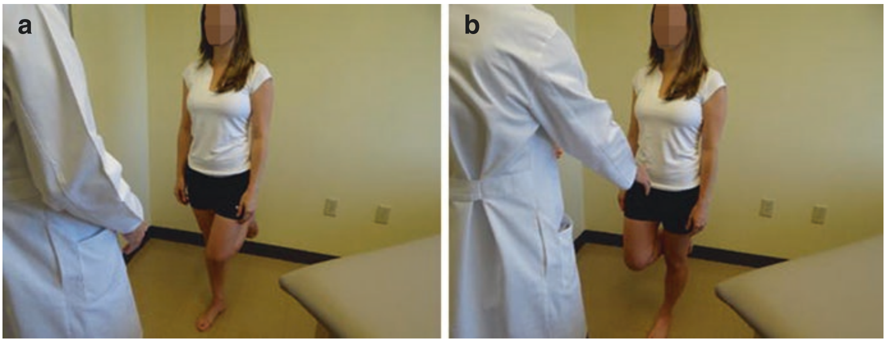


Fig. 4.1 Single-leg stance phase test. (**a**) Right side. (**b**) Left side. Bilateral assessment, observed from behind and in front of the patient. The patient holds this position for 6 s. Reprint with permission from Springer [4]

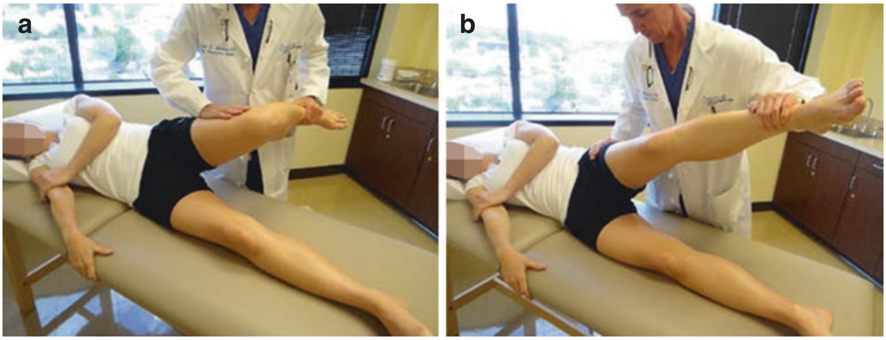


Fig. 4.2 Abductor strength assessment. The patient actively abducts the limb against the examiner, who utilized his weight as the force of resistance. (**a**) Gluteus medius strength is evaluated by having the patient perform active hip abduction with the knee flexed. (**b**) Overall abductor strength evaluation. Reuse with permission from Springer [4]

Fig. 4.3 Passive adduction tests. (**a**) The tensor fascia lata contracture test: with the knee in extension, the examiner passively brings the hip into extension and then adduction. (**b**) Gluteus medius contracture test is performed with knee flexion, thus excluding the gluteus maximus contribution for the iliotibial band. The examiner passively adducts the hip toward the examination table. (**c**) The gluteus maximus contracture test is performed with the ipsilateral shoulder rotated toward the examination table. With the examined leg held in knee extension, the examiner passively brings the hip into flexion and then adduction. Reuse with permission from Springer [4]

External snapping hip tests include the bicycle test and the hula hoop maneuver. The bicycle test is performed with the patient in the lateral position. The motion of a bicycle pedaling pattern is recreated as the examiner monitors the iliotibial band for the detection of coxa saltans externus. A hula hoop maneuver, in which the patient stands and twists, can also help to distinguish the pop due to the subluxing iliotibial band over the greater trochanter.

4.2 Peritrochanteric Space Disorders

Peritrochanteric pain was originally described as trochanteric bursitis with pain over the proximal greater trochanter reproduced by palpation or resisted abduction [10]. Peritrochanteric space disorders now include trochanteric bursitis, external coxa saltans, and gluteus medius/minimus tears, also termed greater trochanteric pain syndrome (GTPS) [11]. Trochanteric bursitis does not usually occur in isolation and is often present with other conditions such as gluteal tendon tears, lumbosacral disease, osteoarthritis of the hip, and overuse injuries [2]. Each of these conditions can effect gait and lead to the development of trochanteric bursitis. Patients will present with a gradual onset of lateral hip pain, pain on palpation over the greater trochanter, and a positive adduction contracture tests.

External coxa saltans or external snapping hip is a dynamic extra-articular impingement occurring at the greater trochanter by the iliotibial band (ITB) [12]. The ITB arises from the fascia of the tensor fascia lata muscle (originating at the iliac crest) and the gluteus maximus tendon and inserts distally on the lateral tibia. ITB biomechanically provides hip stability and moves from anterior to posterior with hip flexion to extension or hip external to internal rotation. The ITB crosses the greater trochanter with hip motion and may cause friction or "snapping" with activity. Patients may be pain-free with a complaint of sudden hip instability, or they may present with a painful snapping hip. Chronic symptoms may include pain when lying on the affected side and associated back pain. A recent investigation on the relationship between ITB thickness and recalcitrant GTPS determined a statistically significant increased thickness of the ITB compared to controls (Fig. 4.4) [13].

Gluteus medius and minimus tears are often a cause of lateral-based hip pain [1, 14]. The gluteus medius and minimus each have several insertion sites on the greater trochanter distinct to the superoposterior and lateral facets. Insertion sites of the gluteus medius are the superoposterior and lateral facets, and insertion sites of the gluteus minimus are the lateral facet and joint capsule. Between the gluteus medius and minimus attachments is a "bald spot" on the greater trochanter, an important boney landmark (Fig. 4.5) [15, 16]. Tears of the gluteal tendons are often a gradual degenerative process. Subtle gait alterations and hip abductor weakness occur, and over time as the weakness progresses, significant gait changes arise and possibly leg length discrepancies from excessive pelvic tilt.

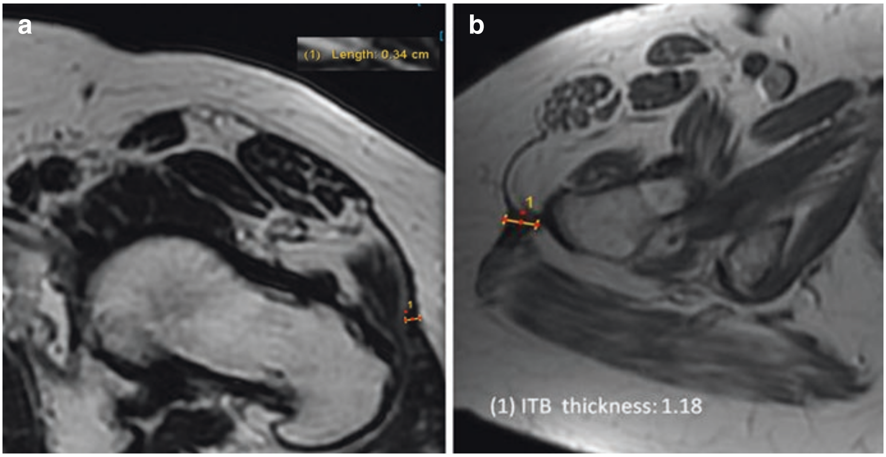


Fig. 4.4 ITB measurement. The ITB measurement location was considered as the region of greatest thickness between the most proximal image of the greater trochanter and the most proximal sequence showing the lesser trochanter. (**a**) Asymptomatic subject measurement. ITB thickness was measured to be 0.34 cm. (**b**) Increased ITB thickness measurement. ITB thickness was measured to be 1.18 cm. Reuse with permission from JHPS [13]

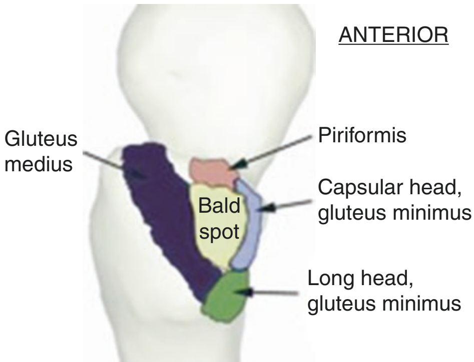


Fig. 4.5 Computer-generated replica of cadaveric specimen. This superolateral view of the right proximal femur and its soft tissue attachments was produced by morphing the cadaveric specimen and digitizing the periphery of its tendinous attachments. Reprinted with permission from Robertson, W. et al. Anatomy and Dimensions of the Gluteus Medius Tendon Insertion. 2008. Arthroscopy 24(2):130–136 [15]

4.3 Peritrochanteric Space Endoscopy

Utilizing the supine approach, entry into the hip joint is obtained through three standardized portals [17, 18] with visualization using a 70° arthroscope alternating between anterior and anterolateral portals. The key to adequate visualization in the peritrochanteric space is the location of the greater trochanteric bursa (Fig. 4.6), which is located posterocentral upon the proximal femur [19]. The best hip position for visualization is slight traction with hip 0° extension, neutral abduction, and neutral rotation. The fluoroscope is brought into place to identify the central region prior to the development of the anterolateral portal into this position. This portal is utilized by placing the scope

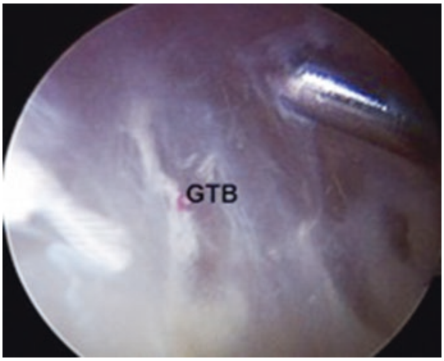


Fig. 4.6 Initial view upon entering the peritrochanteric space of the greater trochanteric bursa (GTB)

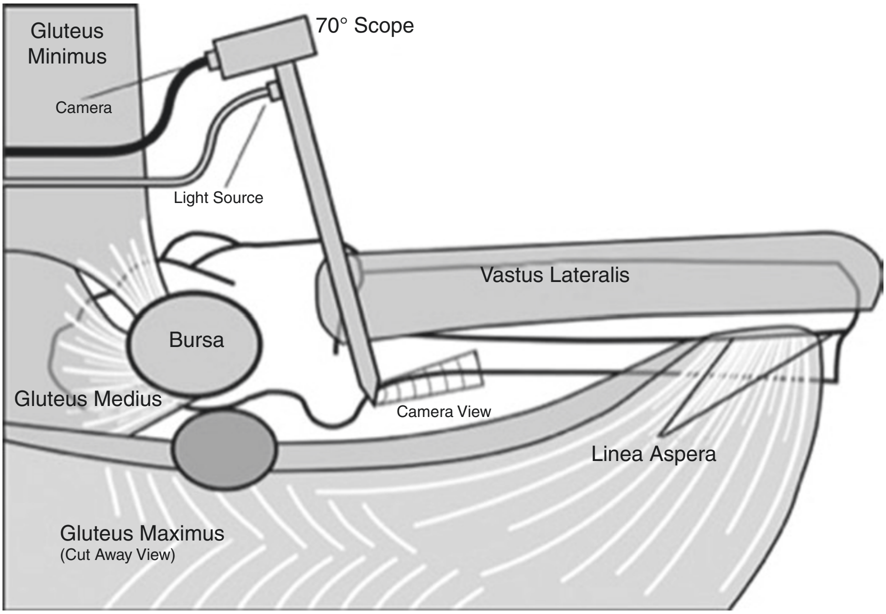


Fig. 4.7 Peritrochanteric space and anatomical landmarks with orientation of arthroscope and light source

above the gluteus minimus and beneath the proximal iliotibial band. The central operative portal is created midway between the tip of the greater trochanter and the insertion point of the gluteus maximus into the linea aspera. The scope is held with the lens oriented distally, and the curved shaver and radiofrequency probe is brought into place for retraction and resection of the greater trochanteric bursa as required in each individual case (Fig. 4.7). Looking distally with the 70° scope, oriented like a flag with the light cord proximal along with the lens focus distal, the insertion of the gluteus maximus into the linea aspera is most easily recognized (Fig. 4.7).

At this point, the examination progresses as previously outlined [1]. Beginning distally and posteriorly at the gluteus maximus insertion into the linea aspera and

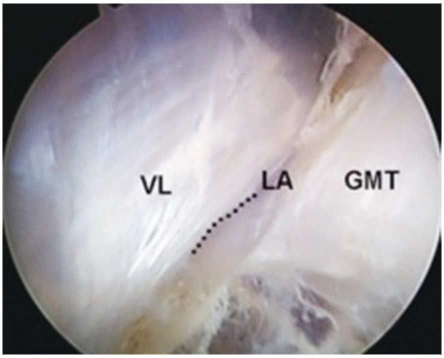


Fig. 4.8 View of the insertion of the gluteus maximus tendon (GMT) into the linea aspera (LA, dashed line) and vastus lateralis (VL)

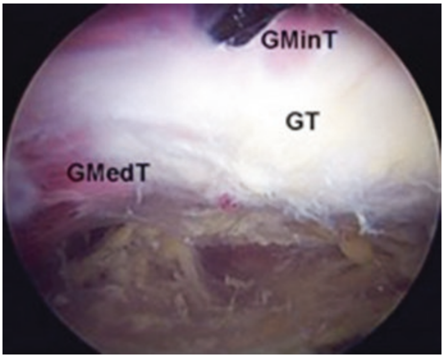


Fig. 4.9 View of the insertions of the gluteus medius (GMedT) and gluteus minimus (GMinT) tendons onto the greater trochanter (GT)

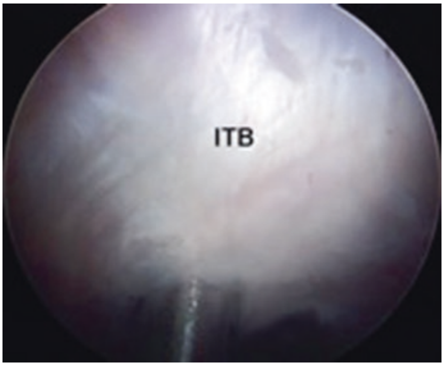


Fig. 4.10 View of the iliotibial band (ITB) looking distally

vastus lateralis (Fig. 4.8), inspection moves proximally and anteriorly toward the vastus lateralis and then proximally to the gluteus minimus. Located posterior to the gluteus minimus, the gluteus medius is thoroughly inspected and probed (Fig. 4.9). The orientation of the gluteus medius has been further delineated and can be distinguished between the insertion of the gluteus minimus [15] (Fig. 4.5). Finally, the iliotibial band and gluteus maximus are probed with either a probe or a blunt nonoperative shaver (Fig. 4.10). With the scope placed directly laterally, the iliotibial band can be assessed from the gluteus maximus down past the linea aspera. Palpation through a small window can aid in the detection of abnormal scar tissue especially in revision iliotibial band surgery. If any loss of orientation is encountered, it is important to return to the base position of looking distal along the vastus lateralis to the linea aspera insertion of the gluteus maximus, thus resuming arthroscopic evaluation.

4.4 Treatment

Conservative treatment includes rest, physical therapy, nonsteroidal anti-inflammatories, and local corticoid injections if necessary. Failed conservative treatment for more than 6–12 months may be an indication for operative treatment. Endoscopic greater trochanteric bursectomy, ITB release, and gluteal tendon repair can be performed utilizing the described portals and inspection of the peritrochanteric space [2]. A five out of five hip abductor strength is the key to success.

Persistent greater trochanteric bursitis can be treated endoscopically with trochanteric bursectomy and ITB release [20]. An arthroscopic shaver is used to debride the fascia and soft tissues overlying the ITB for visualization of any perforating vessels. A release of the ITB is performed at the midportion of the tendon 2 cm in a longitudinal direction and 2 cm in a horizontal direction. The edges are debrided to allow for access to the greater trochanteric bursa for bursectomy with the arthroscopic shaver. Extensive posterior tissue debridement requires caution due to the sciatic nerve anatomical location. A dynamic hip examination is performed [20].

Surgical treatment of external snapping hip has multiple techniques for ITB release that can be characterized as release or resection of a portion of the ITB and ITB lengthening. In 1991, Brignal et al. described the "Z" ITB lengthening [21]. A longitudinal incision is made from the center of the greater trochanter extending proximally, and the tight iliotibial band is identified. An 8 cm longitudinal incision is made in the fascia lata just anterior to the tight band. The incision should be sufficiently proximal to ensure that, if the suture line fails, the greater trochanter would not protrude through the defect. A second incision is then made at the proximal end of the first incision and directed anteriorly and distally. A third incision is made at the distal end of the first incision, cutting through the tight band posteriorly. The flaps are then dissected free from the underlying tissue, transposed, and then sutured with interrupted polyglactin 910 suture [21]. Success outcomes have been reported utilizing the Z-plasty technique [21–23].

Ilizaliturri et al. described an endoscopic procedure in 2006 [12]. After the ITB is identified within the peritrochanteric space, a hooked radiofrequency probe is used to start a 4–5 cm retrograde vertical cut distal to the greater trochanter and directed proximally. A shaver is utilized to further dissect the edges of the cut. Hip abduction will relax the ITB tension and allow for better visualization of the edges. At the center of the vertical cut, a horizontal cut is directed anteriorly, and another horizontal cut is directed posteriorly. The cross-shaped cut has four flaps (anterior-superior, anterior-inferior, posterior-superior, and posterior-inferior) that are resected with a shaver and radiofrequency probe. A diamond-shaped defect (Fig. 4.11) is created over the greater trochanter, and the trochanteric bursae can be

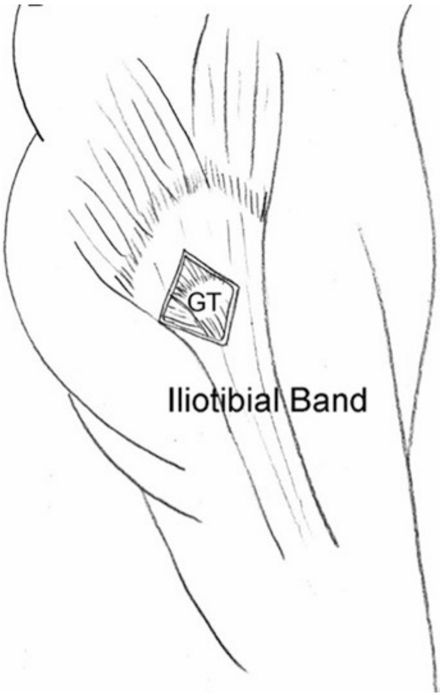


Fig. 4.11 Endoscopic ITB release depicting the final diamond-shaped defect after resection of the four flaps (right hip). Reuse with permission from Elsevier [12]

resected using a shaver and radiofrequency probe. Dynamic hip examination must be performed throughout the procedure to ensure no friction or snapping. Endoscopic ITB release has shown good outcomes similar to open procedures [12, 24–26]. In our practice at Baylor University Medical Center, only the thickest part of the ITB is released. A dynamic spring test, bringing the hip into adduction, is performed to determine the degree of release required for establishment of normal soft tissue tension. The degree of release is variable on a case-to-case basis.

Endoscopic abductor tendon repair can be performed after assessing retraction and tissue mobility and quality [27]. The repairable tendon edge (Fig. 4.12) is debrided to healthy tissue. Identify the tendon footprint on the greater trochanter, and prepare a bleeding bone bed for anchor placement (Fig. 4.13). Position of the anchor and trajectory is confirmed with a spinal needle and fluoroscopy (Fig. 4.14). Anchors are spaced evenly across the tendon footprint (2–4 anchors are generally used for gluteus medius tears off the lateral facet). Sequentially, the sutures are passed through the free edge of the tendon, with sutures passed through cannulas to avoid soft tissue entrapment (Fig. 4.15). Using arthroscopic knot tying techniques, tie the sutures to secure the tendon edge to the footprint (Fig. 4.16) [27]. High-grade partial thickness tears may be taken down and repaired. Partial-thickness undersurface tears can be difficult to see endoscopically or open, due to the intact tendon covering the pathology. Domb et al. (2010) have developed a transtendinous debridement and repair technique [14]. A review of this critical work is recommended. Recent studies have reported excellent outcomes following endoscopic abductor tendon repairs [28–32].

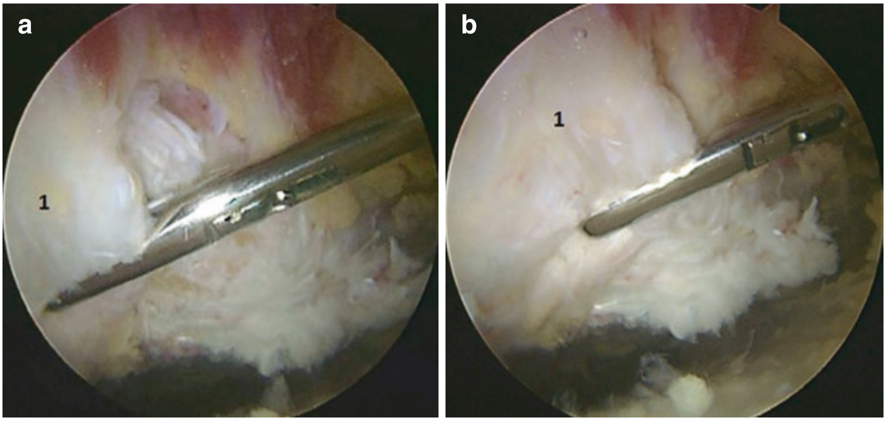


Fig. 4.12 (**a**) Once the tendon edge is clearly demarcated, the degenerated tendon is debrided, and the free edge of the tendon (*1*) is assessed for mobility. (**b**) The edge of the gluteus medius (*1*) is being held by a suture grasper and pulled distally to its normal insertion site at the footprint of the lateral facet. If the tendon is retracted and cannot be mobilized, then conversion to an open procedure may be necessary, although this can usually be determined preoperatively based upon the MRI findings. Reuse with permission from Springer [27]

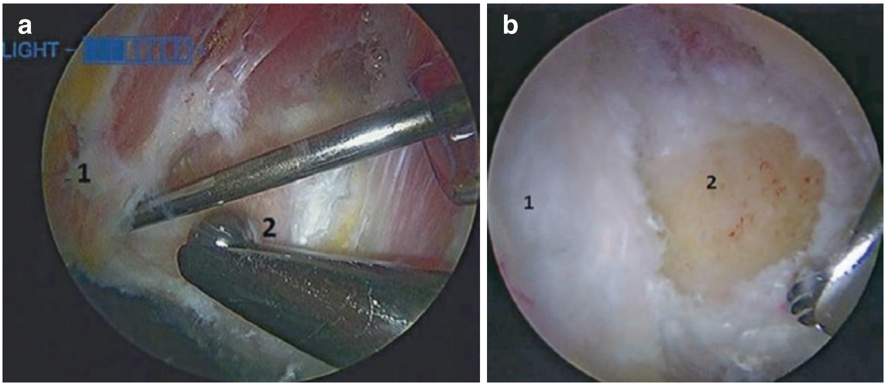


Fig. 4.13 (**a**) The torn edge of the gluteus medius tendon can be retracted to allow direct access to the bony footprint of the tendon. (**b**) Once the footprint is clearly exposed and the gluteus medius tendon (*1*) is protected, the footprint should be abraded with a motorized burr or shaver to create a bleeding bed of bone to facilitate tendon healing (*2*). Reuse with permission from Springer [27]

4.4.1 Tips and Pearls

- Understand the osseous, ligamentous, musculotendinous anatomy, and biomechanics of the hip.
- Perform a comprehensive history and physical examination of the hip designed to interpret the anatomy and the biomechanics.

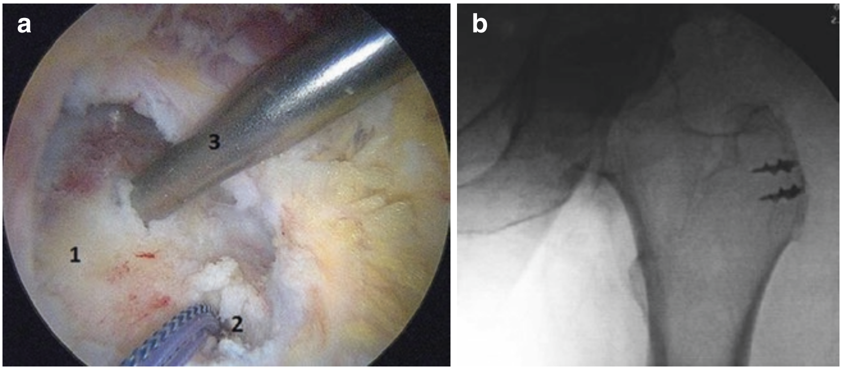


Fig. 4.14 (**a**) Placement of the anchors requires clear visualization of the footprint (*1*). In this example, the first more posterior anchor has been placed, seen with the double-loaded sutures coming out of the bone (*2*). The second anchor is being placed percutaneously (*3*). (**b**) Fluoroscopic imaging should be used during anchor placement to confirm that they are placed perpendicular to the trochanter. Reuse with permission from Springer [27]

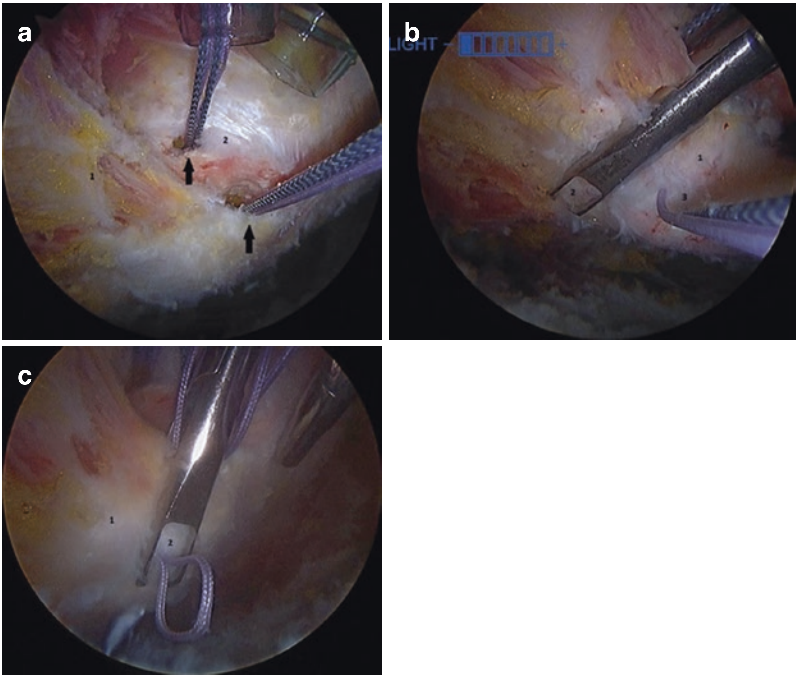


Fig. 4.15 (**a**) In this example, two anchors (*arrows*) are placed just distal to the torn edge of the gluteus medius tendon (*1*) in the anterior and posterior regions of the lateral facet (*2*). (**b**) Once the anchors are strategically placed within the prepared bony footprint, the sutures are passed through the free edge of the tendon (*1*) using a standard suture passing device (*2*). Placement of the sutures should be planned to maximize tendon apposition against the bone (*3*). (**c**) Although each tear requires individualized planning, a combination of horizontal mattress and simple suture passage through the free edge of the gluteus medius (*1*) typically allows for a "double row" equivalent suture fixation (*2*), with good, strong, anatomic footprint restoration. Reuse with permission from Springer [27]

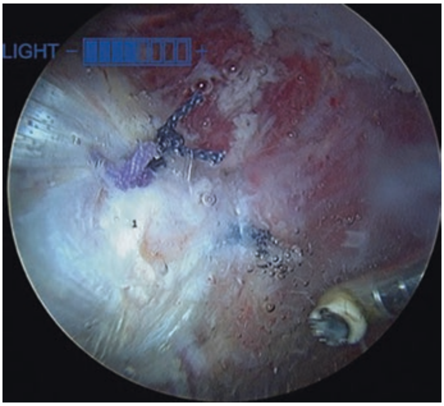


Fig. 4.16 Once the sutures are tied and tensioned, final inspection should ensure that the footprint of the tendon (*1*) lies anatomically against the involved facet. Reuse with permission from Springer [27]

- Following a structured examination will help in establishing a framework through which the vast hip pathologies can be interpreted.
- Use all arthroscopic portals for safe hip access, which is dependent upon the acetabular and femoral three-planer osseous geometry.
- Utilize the peritrochanteric space landmarks for orientation.
- Closely monitor abdominal, systolic, and local tissue pressures during hip arthroscopy.
- A dynamic examination in the peripheral compartment will aid in detecting the location of presenting pathologic conditions.
- A standardized form for recording the arthroscopic findings will aid in patient follow-up and documentation of arthroscopic pathology (Fig. 4.17).
- Always record preoperatively the neck shaft angle, acetabular version, femoral version, acetabular index, center edge angle, lateral rim shape, and internal/external rotation with 90° of hip flexion for initial portal placement.
- Education and practice of hip arthroscopy is aided by a hip arthroscopy mentor, the Arthroscopic Association of North America, or with a hip arthroscopy fellowship.

4.4.2 Pitfalls

Pitfalls may be encountered if looking too far posterior or if prior iliotibial band surgery has been performed. Multiple adhesions and abnormal healing may bring the sciatic nerve into close approximation (Fig. 4.18). The epineural fat is easily visualized in internal rotation. Other pitfalls involve placement of the scope beneath the gluteus minimus into the gluteus minimus and gluteus medius bursa. This loss of orientation can be easily recognized by the absence of the longitudinal fibers of the vastus lateralis directing to the insertion point of the gluteus maximus into the linea aspera. Posterior assessment through the peritrochanteric space is possible. As with any hip arthroscopic examination, the patient's intra-abdominal, systolic, and

Post-Operative Findings and Rehab
Please fax reports to:
Patient Name: ________________
Date: ____________________

Age: _____ Sport: ________

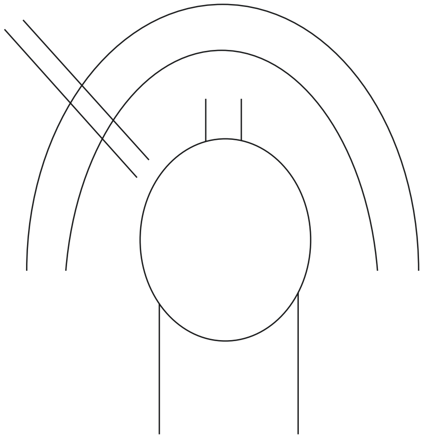
<u>Operative Findings</u>
Status-post Right_____Left_____Hip Arthroscopy

Labrum__________

Capsule__________

Articular Cartilage __________

Procedure:



____Labral Debridment _____Labral Plasty/Repair ____Chondroplasty

____Capsular Thennal Modification ___Capsular Plication ____Capsulotomy ____Loose bodies

____Synovectomy _____ Bursectomy: ___GT ____Psoas ____Ligamentum Obicularis

____Microfracture

____Exploration of Sciatic Nerve ____Excision of HO ____Teres Debridment ____Cheilectomy

____Core Decompression _____ Rim Trim ____Ligamentum Teres Reconstruction
____Gluteus Medius Repair

____Releases/
Resections: ___Psoas ___IT Band ___Bursa ___Loose Body

Fig. 4.17 A standardized form for recording arthroscopic findings in illustration and text formats

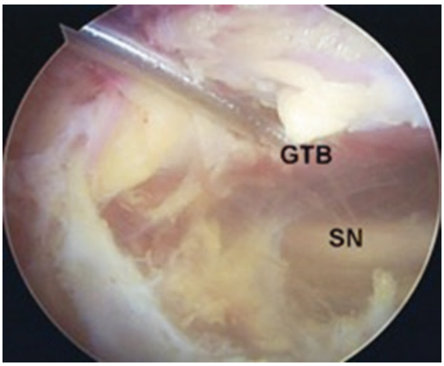


Fig. 4.18 View of the greater trochanteric bursa (GTB) and sciatic nerve (SN)

arthroscopic system pressures are closely monitored. The ideal pressure for the compartment is maintained between 50 and 70 mm of mercury and may be intermittently required to increase to 100 mm or above for short periods of time. Safe peritrochanteric space arthroscopic examination can be accomplished by patient selection, maintenance of proper orientation, systematic examination, and close intraoperative pressure monitoring.

4.5 Summary

Lateral-based peritrochanteric hip pain can include trochanteric bursitis, external coxa saltans, and tears of the gluteus medius/minimus. A thorough understanding of hip joint anatomy, biomechanics, clinical presentation, and physical examination will aid in the proper diagnosis and treatment plan. Many cases of peritrochanteric space disorders respond well to conservative therapy. When indicated, recalcitrant cases of peritrochanteric space pathology can be directed toward endoscopic evaluation and treatment with good outcomes and return to normal function.

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Clinical Examination and Diagnosis of Extra-Articular Hip and Groin Pain

5

Per Hölmich and Lasse Ishøi

5.1 Introduction

Terminology and definitions of athletes with longstanding groin pain have been a considerable issue with lack of consensus in the past. This has led to widespread use of unspecific terms such as athletic pubalgia, core muscle injury, pubic aponeurosis injury, and osteitis pubis both clinically and in the literature [1]. Such unspecific and not-agreed-upon terms may hinder scientific progress and cause uncertainty for clinicians working in the field of hip and groin pain as well as for patients who can easily be labeled with many different diagnoses from different clinicians. In an attempt to create uniformity on the diagnosis of groin pain in athletes, the Doha agreement paper was published in 2015 [2]. The study group consisted of experts from all over the world including general and orthopedic surgeons, physiotherapists, sports physicians, and radiologists who agreed to adopt the concept of clinical groin entities (Table 5.1). To keep terminology more clear and support both clinical and scientific communications, the consensus group chose not to recommend the use of the following terms: adductor and iliopsoas tendinitis or tendinopathy, athletic groin pain, athletic pubalgia, biomechanical groin overload, Gilmore's groin, groin disruption, hockey-goalie syndrome, hockey groin, osteitis pubis, sports groin, sportsman's groin, sports hernia, and sportsman's hernia. The authors of this chapter fully support this recommendation. The main focus of the consensus meeting was to define and describe the diagnoses in relation to the most common groin injuries including adductor-related, iliopsoas-related, inguinal-related, and

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Table 5.1 Clinical entities as defined at the Doha agreement meeting 2014 [2]

Clinical entities	Clinical symptoms and signs
Adductor-related groin pain	Adductor tenderness and pain on resisted adduction testing
Iliopsoas-related groin pain	Iliopsoas tenderness plus, more likely if pain on resisted hip flexion and/or pain on hip flexor stretching
Inguinal-related groin pain	Pain located in the inguinal canal region and tenderness of the inguinal canal. No palpable inguinal hernia is present. More likely if aggravated by abdominal resistance or Valsalva/cough/sneeze
Pubic-related groin pain	Local tenderness of the pubic symphysis and the immediately adjacent bone. No particular resistance tests to test specifically for pubic-related groin pain

pubic-related groin pain [2]. These entities are common as the primary source of pain in athletes presenting with groin pain; however, these diagnoses may also coexist in subjects with clinical and radiological signs of intra-articular hip joint pathology, such as femoroacetabular impingement syndrome, acetabular labral pathology, or acetabular dysplasia, and a thorough understanding of these musculotendinous sources of hip and groin pain is therefore important to keep in mind when evaluating subjects with suspected intra-articular hip joint pathology [3–5]. The purpose of this chapter is therefore to provide an overview of diagnosis of extra-articular causes of hip and groin pain potentially present in subjects with suspected intra-articular hip joint pathology. In the second part (Chap. 6), a basic understanding of muscular function around the hip in relation to intra- and extra-articular hip and groin pain will be presented in conjunction with evidence-based treatment strategies for the most commonly seen clinical groin entities.

5.2 Extra-Articular Causes of Hip and Groin Pain

The cardinal symptom in subjects with either intra- or extra-articular hip joint pathology is pain located in the groin area. Consequently, several diagnoses may manifest with a similar pain pattern making specific diagnosis of patients with longstanding hip and groin pain challenging [2, 6]. Furthermore, the clinical tests for diagnosing intra-articular hip joint pathology, such as the Flexion-Adduction-Internal Rotation (FADIR) test for femoroacetabular impingement syndrome, have been shown to be very sensitive but not very specific, indicating that a positive test response may not only be elicited due to femoroacetabular impingement syndrome but also in the presence of extra-articular pathology such as pain related to the adductors or iliopsoas muscle-tendon unit [7]. Therefore, a systematic examination of the surrounding structures in the hip and groin area is paramount when examining subjects with longstanding hip and groin pain, even in cases where a suspicion of intra-articular hip joint pathology exists.

5.2.1 Musculotendinous Injuries

5.2.1.1 Adductor-Related Groin Pain

Adductor-related injuries are considered the most common cause of longstanding groin pain in athletes [2]. Although the hip adductor muscles include five muscles (pectineus, gracilis, adductor brevis, adductor magnus, and adductor longus), the most common type of longstanding adductor-related injuries involves the adductor longus muscle [8]. The pain is typically present during athletic activities, such as sprinting and change of direction, and is located medially in the groin in the region around the origin of the adductor longus muscle at the pubic bone. During activities such as kicking, acceleration and deceleration, and change of direction, the hip adductors are exposed to large eccentric forces, typically combined with an abduction, external rotation, and extension movement of the femur putting further stress on the adductor muscle-tendon unit [9]. Over time this may result in repetitive microtrauma to the structures potentially leading to development of longstanding adductor-related pain [10].

According to the DOHA agreement, adductor-related groin pain is diagnosed as tenderness with palpation at the origin of the adductor longus and/or the gracilis muscle at the inferior pubic ramus and pain on resisted hip adduction [2]. Subjects with current and/or previous longstanding adductor-related groin pain may also experience reduced hip adduction strength and/or reduced range of motion in passive abduction and bent-knee fallout [11].

Link Between Adductor-Related Groin Pain and Intra-articular Hip Joint Pathology

The link between intra-articular hip joint pathology and adductor-related pain is not fully elucidated; however, in recent years there has been emerging evidence suggesting a potential link between these two entities. Although, the implications for a clinical finding of adductor-related groin pain in subjects with suspected intra-articular hip joint pathology, and vice versa, are not fully understood, it is important to consider the presence of adductor-related groin when examining subjects with radiological features of intra-articular hip joint pathology, as this may guide a potential rationale for conservative management strategies to help alleviate symptoms.

In a study of 34 athletes with longstanding adductor-related groin pain, the prevalence of radiological signs of femoroacetabular impingement syndrome was noted to be 94%, highlighting that without a systematic examination of the adductor muscles, these subjects could easily have been diagnosed with femoroacetabular impingement syndrome instead, potentially leading to surgical management [5] rather than exercise therapy [12]. In another study, 74 patients (83 symptomatic hips) with a diagnosis of femoroacetabular impingement syndrome underwent dynamic ultrasound examination for signs of groin herniation and/or proximal adductor tendinopathy with a subset of patients (63 hips) also undergoing diagnostic hip injection [13]. Overall, 23% showed signs of proximal adductor tendinopathy on ultrasound, and higher prevalence of adductor tendinopathy (29% vs. 20%) was observed in subjects responding to the diagnostic hip injection compared to those who did not respond.

Interestingly, 75% of the subjects who responded to the diagnostic injection underwent surgery for femoroacetabular impingement syndrome, whereas 87% of the non-responding group underwent successful conservative management. Although the prevalence of proximal adductor tendinopathy was equal between those patients ending up with surgery vs. conservative management, this highlights the importance of considering adductor-related groin pain as a potential primary source of pain in a subset of subjects diagnosed with femoroacetabular impingement syndrome [13]. However, it is also important to note that the presence of adductor-related groin pain in subjects with femoroacetabular impingement could represent a secondary problem as the pain may arise from increased load on the adductors due to the injury to the hip joint and the altered hip joint morphology and biomechanics [13, 14].

The presence of adductor-related groin is not only relevant in subjects with femoroacetabular impingement but may also be prevalent in subjects with hip dysplasia [3]. In a study of 100 patients with hip dysplasia, 14% showed a sign of adductor-related groin pain prior to undergoing periacetabular osteotomy (PAO), and this was correlated to worse self-reported hip and groin function. The presence of adductor-related groin pain in patients with hip dysplasia may well be due to increased load on the adductor muscles due to reduced bony hip joint stability, and only focusing the treatment on the adductor muscle-tendon unit is unlikely to result in satisfactory treatment outcomes. However, the study highlights the importance of addressing extra-articular sources of pain during the pre- and/or postoperative rehabilitation as continued pain in the groin region in spite of seemingly successful surgery might be caused by these sources.

5.2.1.2 Iliopsoas-Related Groin Pain

Iliopsoas-related groin injuries are considered the second most common source of groin pain in athletes affecting up to 35% presenting with groin pain [8]. The pain is typically present during athletic activities, such as sprinting and change of direction, and is located in the anterior aspect of the thigh, lateral to the adductor-related pain. According to the DOHA agreement, iliopsoas-related pain is diagnosed as tenderness with palpation of the proximal part of the muscle through the lower abdominal wall and/or the distal part just distally to the inguinal ligament in the triangle medial to the sartorius muscle and lateral to the femoral artery [2]. Furthermore, pain in the iliopsoas muscle may also arise on passive stretching of the muscle during the Thomas test or when tested isometrically with 90° of hip flexion. Due to the location of pain most often being on the anterior thigh, iliopsoas-related pain is an important differential diagnosis in subjects with suspected intra-articular hip joint pathology.

Iliopsoas-related pain is frequently observed in conjunction with adductor-related groin pain [15, 16] and in patients presenting with intra-articular hip joint pathology [3].

Link Between Iliopsoas-Related Groin Pain and Intra-articular Hip Joint Pathology

Iliopsoas-related pathology is a recognized source of pain in subjects with intra-articular hip joint pathology, and surgery to the iliopsoas tendon (tenotomy or lengthening) in conjunction with a hip arthroscopy for intra-articular hip joint pathology is not uncommon [17]. However, limited information exists regarding the clinical implications of iliopsoas-related groin pain and intra-articular hip joint pathology, as no studies to date have examined this in a structured way. Psoas pathology is reported to be present in up to 13% of hips undergoing revision hip arthroscopies. Although it is unknown how many of these revision procedures are mainly due to psoas pathology, it still provides emerging evidence for the importance of diagnosing potential iliopsoas-related groin pain in subjects with suspected intra-articular hip pathology [18].

The impact of iliopsoas-related groin pain has also been investigated in a study including 100 patients with hip dysplasia. Interestingly 56% showed signs of iliopsoas-related groin pain prior to undergoing periacetabular osteotomy (PAO), and this was correlated to worse self-reported hip and groin function [3]. This prevalent coexistence of iliopsoas-related groin pain may be due to overload of the iliopsoas muscle-tendon unit in order to compensate for altered hip joint stability [3], and thus focusing only on addressing the iliopsoas-related pain may not result in satisfactory results. However, as a PAO procedure (or FAI surgery) is unlikely to address pathology in the iliopsoas muscle-tendon unit, per se, it is important to address extra-articular sources of pain during the pre- and/or postoperative rehabilitation as continued pain in the groin region in spite of seemingly successful surgery might be caused by these sources.

5.2.1.3 Inguinal-Related Groin Pain

Inguinal-related groin injury is a rare diagnosis in the groin region, only affecting up to 4–8% of all injuries to the hip and groin in male elite soccer players [19, 20]. However, it should be noted that inguinal-related groin pain often results in a significant time loss with the majority of soccer players being absent from soccer for more than 4 weeks [19]. Patients with inguinal-related groin pain typically complain of pain over the inguinal canal and at the pubic tubercle that may radiate to the medial groin and the scrotum.

In most cases, inguinal-related groin pain is thought to develop as an overuse injury, due to accumulation of the large shear forces acting across the pelvis, trunk, and leg during athletic movements. This may lead to lesions of the fascia transversalis and the conjoined tendon or dilatation of the inguinal rings. It has also been suggested that restricted hip range of motion due to femoroacetabular impingement syndrome may result in altered rotational pattern of the symphysis leading to excessive stress on the inguinal region [10].

According to the DOHA agreement, inguinal-related groin pain is diagnosed as tenderness at the insertion of the conjoined tendon at the pubic tubercle and pain when palpating the inguinal canal through the scrotum with the patient standing [2].

Link Between Inguinal-Related Groin Pain and Intra-articular Hip Joint Pathology

It is important to consider the presence of inguinal-related groin pain in subjects with radiological signs of intra-articular hip joint pathology. In one study, 74 patients

(83 symptomatic hips) with a diagnosis of femoroacetabular impingement syndrome underwent dynamic ultrasound examination for signs of groin herniation and/or proximal adductor tendinopathy with a subset of patients (63 hips) also undergoing diagnostic hip injection [13]. Overall, 41% showed signs of groin herniation on ultrasound, and lower prevalence of groin herniation (27% vs. 80%) was observed in subjects responding to the diagnostic hip injection compared to those who did not respond, indicating that a subset of subjects with radiological findings of intra-articular hip joint pathology may have groin pain due to groin herniation and not necessarily due to intra-articular injury. In line with this, five subjects were successfully treated with hernia repair without treating the bony abnormalities of the hip joint [13]. In another study the results of operative treatment of athletes with both intra-articular hip joint pathology and sports hernia (inguinal-related groin pain) were examined in 37 hips. The results showed that addressing either the hip joint or the sports hernia resulted in inferior return to sport rates compared with treating both sources at the same or concurrent times [21].

5.2.1.4 Pubic-Related Groin Pain

Pubic-related groin pain is considered a rare condition that remains poorly explored in the literature. As such, the epidemiological data related to this entity is scarce; however, a recent report evaluating 100 athletes presenting to a multidisciplinary sports groin pain clinic showed that four athletes (4%) had pubic-related groin pain, but it was only considered as the primary cause of pain in one athlete [16]. According to the DOHA agreement, pubic-related groin pain is diagnosed as tenderness with palpation of the pubic symphysis and the immediately adjacent bone [2].

Link Between Pubic-Related Groin Pain and Intra-articular Hip Joint Pathology

Although pubic-related groin pain may be rare as the primary cause of hip and groin pain in athletes, it has been suggested to be prevalent in subjects with intra-articular hip joint pathology, where it has been observed that up to 70% may present with symptoms that at least partly are covered by the entity pubic-related groin pain [21]. Awareness of pubic-related pain is therefore advised when evaluating subjects with intra-articular hip joint pathology.

5.2.2 Other Extra-Articular Sources of Hip and Groin Pain Not to Be Missed

5.2.2.1 Pubic Apophysitis

Pubic apophysitis is a newly described groin entity, and very limited data exist. It should be suspected as a potential source of pain in skeletally immature athletes (up to 21 years old) presenting with longstanding adductor-related groin pain. It has been hypothesized that the development of pubic apophysitis may be due to a combination of traction and compressive forces, leading to excessive apophyseal plate stress in young athletes with non-fusion of the secondary ossification center of the pubic symphysis [22].

The diagnosis of pubic apophysitis is based on tenderness of the adductor longus insertion on the pubis on palpation. For radiographic confirmation, CT scan would be necessary, but due to the radiation, it is in most cases not indicated in these young patients [22]. MRI (1.5 T) is not considered to be helpful to confirm the diagnosis but can be used to rule out other pathologies [22].

5.2.2.2 Sacroiliac Joint Pain/Dysfunction

The sacroiliac joints act as the primary structure transferring load between the trunk and the lower extremities. It is considered a highly stable joint with only a few degrees of rotational movement due to the bony peaks and valleys and strong ligaments. Sacroiliac joint pain/dysfunction has mainly been described in conjunction with low back pain; however, it is also recognized as a potential cause of groin pain and should therefore be screened for as part of the examination of patients with longstanding hip and groin pain [23, 24].

Patients with sacroiliac joint pain may typically describe a deep-seated diffuse pain in the buttock area, but pain may also be reported in lower back, upper anterior and/or lateral thigh, and groin [23]. Therefore being able to rule out the sacroiliac joint as a potential source of pain is paramount when evaluating subjects with hip and groin pain [24]. The diagnosis of sacroiliac joint pain/dysfunction relies primarily on a systematic clinical examination including a cluster of tests: distraction provocation test, thigh thrust provocation test, compression provocation test, and sacral thrust provocation test (these tests are described in more detail later in this chapter). It has been suggested that sacroiliac joint pain is present when two of the four tests yield positive pain responses in the sacroiliac joint. As the thigh thrust test yields the best individual diagnostic properties, it is advised to start with this. Sacroiliac joint pain is unlikely if all tests are negative [25]. Imaging is thought to add little value to the diagnosis but may serve to rule out other pathologies such as a fracture, a tumor, sacroiliitis, or potential infection [23]. Conversely, ultrasound-guided anesthetic injection may be valuable to confirm the diagnosis [25].

5.2.2.3 Referred Pain from the Low Back

Although referred pain from the low back may be more relevant to screen for in patients presenting with sacroiliac joint pain/dysfunction, the clinician should be aware that potential structures in the back, such as facet joints, intervertebral discs, and spinal nerves (radiculopathy), may refer pain to the hip and groin area. A general screening of the most likely pain-generating structures in the low back is therefore advised when evaluating patients with longstanding hip and groin pain [24].

Screening for facet joint-related pain, with the primary goal of ruling out the involvement of this, can easily be performed by instructing the patient to lie down and ask for any changes in pain intensity. No pain relief suggests that the likelihood of facet joint-related pain is very unlikely, while pain relief may prompt further examination of the facet joints as a potential source of pain [26].

Screening for intervertebral disc-related pain, with the primary goal of ruling out the involvement of this, can be easily performed by instructing the patient to perform repeated motions of both lumbar extensions and flexions while monitoring any changes in pain location. No centralization in pain (i.e., pain is not moving toward the lumbar spine) suggests a low likelihood of involvement from the intervertebral discs, while centralization may prompt further examination of the intervertebral discs as a potential source of pain [26].

Screening for radiculopathy arising from nerve root pathology, such as entrapment, can be easily performed by conducting a passive straight leg raise test of both the affected and the unaffected leg while monitoring any changes in pain including significant leg-to-leg differences in range of motion at the onset of potential pain. No increase in pain intensity in the low back or in the groin area accompanied by no significant leg-to-leg differences in range of motion suggests a very low likelihood of radiculopathy [26].

5.2.2.4 Stress Fracture of the Femoral Neck

Stress fractures of the femoral neck represent <5% of all stress fractures and thus are considered a rare diagnosis in subjects with hip and groin pain. However, as patients with a femoral neck stress fracture typically present with an insidious onset of deep anterior hip and groin pain, the presence of femoral neck stress fractures can easily masquerade as either femoroacetabular impingement syndrome or musculotendinous sources of groin pain. In a retrospective study evaluating a cohort of 24 patients with a stress fracture of the femoral neck, a high prevalence of both cam and pincer morphology including labral tears was observed [27]. As some stress fractures of the femoral neck require surgical management, awareness of this diagnosis is important to keep in mind even in the presence of morphological findings associated with femoroacetabular impingement [27].

Stress fractures of the femoral neck can be divided into low-risk compression-sided injuries occurring at the inferomedial neck or high-risk tension-sided injuries occurring at the superolateral neck. As the tension-sided injuries have a high risk of displacement, awareness of these is critical to avoid future complications. Appreciation of effective screening tools for femoral neck stress fractures is therefore important as part of the clinical examination to secure appropriate management in case of a stress fracture [28, 29].

Although, the diagnosis of a femoral neck stress fracture requires a radiological assessment, with MRI and bone scintigraphy as the most sensitive investigations, the clinician is advised to screen for a potential femoral stress fracture during the subjective and objective examination. As a general rule, the clinician should pay extra attention to athletes, specifically females, involved in sports with a high degree of repetitive monotonous loading of the lower extremities such as long-distance running. Furthermore, pain with single-leg standing or impact activities, such as single-leg jumping and landing, will normally elicit pain. The clinician should however be aware that high-impact activities (single-leg jump/land) can result in worsening of the injury [28, 29].

5.2.2.5 Stress Fracture of the Inferior Pubic Ramus

Stress fractures of the inferior pubic ramus typically occur in female athletes exposed to monotonous loading such as distance running. Pain is typically located in the groin but is also frequently observed in the buttock or thigh. There is often localized tenderness. As fractures are typically non-displaced, they can easily be overlooked at plain radiographs, and a MRI may be necessary to confirm the diagnosis [30]:

5.3 Diagnosis of Coexisting Pathology

5.3.1 Musculotendinous Injuries

5.3.1.1 Adductor-Related Groin Pain

According to the DOHA agreement, longstanding adductor-related groin pain is diagnosed as tenderness with palpation at the origin of the adductor longus and/or the gracilis muscle at the inferior pubic ramus and pain on resisted hip adduction [2].

With the patient lying supine with the hip flexed, abducted, and externally rotated, and the knee slightly flexed, the adductor longus tendon can be easily palpated. The examiner, using the right hand on the right leg and left hand on the left leg, palpates the adductor longus tendon with two fingers and follows the tendon to the insertion at the pubic bone. The insertion area, including the bone, is tested with firm pressure to a radius of about 1 cm. Pain on palpation suggests adductor-related groin pain (Fig. 5.1) [8].

Pain on resisted hip adduction is examined using a long-lever hip adduction squeeze test, as this has been shown to elicit the largest torque output, hence stressing the muscle-tendon unit of the adductors the most [31]. The examiner stands at the end of the examination table with hands and lower arms between the feet placed just proximal to the medial malleolus. The feet of the subject are pointing straight-up, and the subject squeezes the legs together with maximal force without lifting the legs or pelvis. The test is positive if it reproduces pain from the insertion site of the adductor longus where the patient also was tender at palpation (Fig. 5.2) [8, 32].

Fig. 5.1 Palpation at the origin of the adductor longus

Fig. 5.2 Resisted hip adduction

5.3.1.2 Iliopsoas-Related Groin Pain

According to the DOHA agreement, longstanding iliopsoas-related pain is diagnosed as tenderness with palpation on the proximal part of the muscle through the lower abdominal wall and/or distal part just distally to the inguinal ligament in the triangle medial to the sartorius muscle and lateral to the femoral artery [2].

When palpating the iliopsoas muscle-tendon, the subject is lying supine. The iliopsoas can be palpated both (1) proximal to the inguinal ligament at the level of the ASIS and (2) under the inguinal ligament, medial to the sartorius muscle and lateral to the femoral artery. Abdominal palpation is performed with both hands using soft gentle fingers. The fingers are gently pressed posteriorly while pushing the abdominal structures away to reach the iliopsoas muscle. The patient is then asked to elevate the leg 5 cm, and the psoas can be felt and palpated for any pain (Fig. 5.3a). The palpation of the distal iliopsoas tendon is most easily performed by first locating the proximal part of the sartorius muscle just distal from the inguinal ligament and then moving the fingers just medially. The patient is then asked to elevate the examined leg 5 cm; the fingers position is adjusted until the tendon is clearly felt under the fingers. Then the patient relaxes, and the tendon can be palpated for any pain (Fig. 5.3b) [8].

5.3.1.3 Inguinal-Related Groin Pain (Groin/Sport Hernia)

According to the DOHA agreement, longstanding inguinal-related groin pain is diagnosed as tenderness at the insertion of the conjoined tendon at the pubic tubercle and pain when palpating the inguinal canal through the scrotum with the patient standing [2].

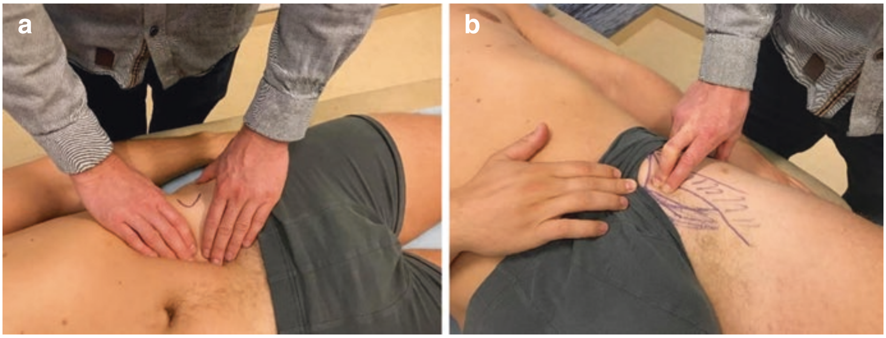

Fig. 5.3 Palpation of the iliopsoas muscle (**a**) at proximal part through the lower abdominal wall and (**b**) at the distal part just distally to the inguinal ligament and medially to the sartorius muscle

Fig. 5.4 Palpation at the insertion of the conjoined tendon at the pubic tubercle

Palpation of the conjoined tendon insertion at the pubic tubercle is performed with the subjects lying supine. The examiner locates the proximal part of the pubic tubercle and follows the rim until reaching just medial to the inguinal ligament (Fig. 5.4) [8]. The inguinal canal is approximately the size of a fingertip and can be palpated with the patient standing through the scrotum invaginating the skin.

5.3.1.4 Pubic-Related Groin Pain

According to the DOHA agreement, longstanding pubic-related groin pain is diagnosed as tenderness with palpation of the pubic symphysis and the immediately adjacent bone [2].

Fig. 5.5 Palpation of the pubic symphysis

Palpation of the pubic symphysis is performed with the subject lying supine. The examiner locates the upper part of the pubic bone by palpating with a gentle finger followed by palpation of the pubic symphysis distally. It is important to note that most athletes are tender at the top of the pubic bone and proper palpation at the distal part is therefore important to decrease the risk of a false-positive test (Fig. 5.5) [32].

5.3.2 Other Extra-Articular Sources of Hip and Groin Pain

5.3.2.1 Pubic Apophysitis

The diagnosis of pubic apophysitis is based on a history of increasing pain during and after even careful adductor exercises in adolescents or younger adults and tenderness of the adductor longus insertion on the pubis on palpation including radiographic confirmation, preferable using CT scan [22].

With the patient lying supine with the hip flexed, abducted, and externally rotated, and the knee slightly flexed, the adductor longus tendon can be easily palpated. The examiner, using the right hand on the right leg, and left hand on the left leg, palpates the adductor longus tendon with two fingers and follows the tendon to the insertion at the pubic bone. The insertion area, including the bone, is tested with firm pressure to a radius of about 1 cm [8].

It has been suggested that CT scan allows for the best visualization of the pubic apophysis, with 1.5 T MRI adding no value to the diagnosis. However, 3.0 T MRI may be promising and thus should be considered due to no radiation [22].

5.3.2.2 Sacroiliac Joint Pain/Dysfunction

The diagnosis of sacroiliac joint pain/dysfunction is considered present if two of the four following clinical tests reproduce the known pain: distraction provocation test, thigh thrust provocation test, compression provocation test, and sacral thrust provocation test. It is the authors' perception that sacroiliac joint pain/dysfunction is a rare cause of hip and groin pain in athletes, and therefore the aim of the examination is to rule out the sacroiliac joint as a potential source of pain [24]. Based on the high sensitivity of 0.88 and the low likelihood ratio of 0.18 for the thigh thrust provocation test, this test is recommended as a quick screening for sacroiliac joint pain with a negative test response indicating a low probability of the diagnosis [25].

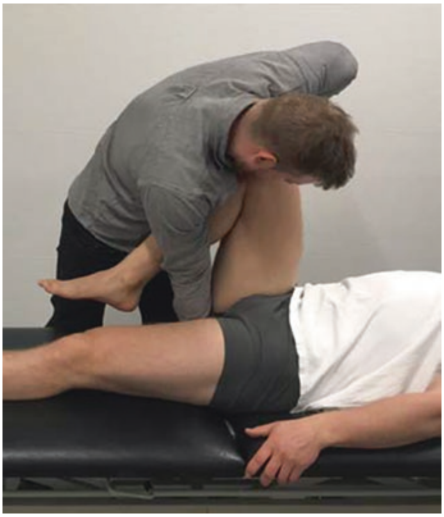

Fig. 5.6 Thigh thrust test. Used as a screening procedure to rule out hip and groin pain arising from sacroiliac joint pain

Thigh Thrust Provocation Test

With the patient lying supine and the hip flexed to 90°, the examiner applies a firm thrust in the vertical direction with one hand, while the other hand is used to stabilize the sacrum. The test is considered positive if it reproduces the patient's familiar pain/symptoms (Fig. 5.6).

5.3.2.3 Referred Pain from the Low Back

Screening tests for facet joint-related pain and intervertebral disc-related pain can easily be conducted by instructing the patient to take a recumbent position or perform repetitive lumbar extensions or flexions, respectively. No relief in pain in recumbent position or no centralization of pain during repetitive lumbar extensions or flexions suggests that these diagnoses can be ruled out [26].

Screening for radiculopathy can be performed with the patient lying supine. The examiner passively performs a straight leg raise of the unaffected leg followed by the affected leg by lifting the patient's leg. If no exacerbation in pain intensity in the low back or hip and groin area is noted and/or no-to-minimal between-limb difference in range of motion the test is considered negative and the likelihood of radiculopathy minimal. It should be emphasized that a feeling of tightness and/or posterior thigh/knee pain is a normal response and not indicative of a positive test (Fig. 5.7).

5.3.2.4 Stress Fracture of the Femoral Neck

General screening for a stress fracture of the femoral neck can be done by establishing the risk profile of the athlete during a subjective examination. Several potential risk factors have been described including sudden reduction in weight and lower extremity muscle mass, increase in training load, and athletes involved in high-impact sports or sports with monotonous loading such as long-distance running. Furthermore, special attention should be paid to female athletes, especially if

Fig. 5.7 Passive straight leg raise test. Used as a screening procedure to rule out hip and groin pain arising from nerve root pathology

diagnosed with the female triad athlete. Furthermore, pain elicited during single-leg standing could also indicate the presence of a stress fracture of the femoral neck. However, it should be noted that assessment with MRI or bone scintigraphy is the preferred investigation [28, 29].

5.3.2.5 Stress Fracture of the Inferior Pubic Ramus

General screening for a stress fracture of the inferior pubic ramus can be done by establishing the risk profile of the athlete during a subjective examination, typically, a female athlete performing long-distance running and reporting an increase in running load preceding the onset of groin pain. There is usually no pain on passive abduction or resisted adduction increased. A MRI or bone scintigraphy may be necessary to confirm the diagnosis, as these types of fractures are easily overlooked at plain radiographs [30].

5.4 Summary

Intra-articular hip joint pathology, such as femoroacetabular impingement syndrome, and extra-articular hip joint muscle-tendinous pathology are most often characterized by groin pain. This sometimes makes diagnosis of a specific primary source of hip and groin pain difficult. Although extra-articular sources of hip and groin pain may not be the primary cause of pain in many patients with suspected intra-articular hip joint pathology, there is emerging evidence to suggest that successful management of patients with femoroacetabular impingement syndrome requires concomitant treatment of potential extra-articular sources of hip and groin pain. Therefore, a systematic examination of the structures in the groin, the sacrum, and low back is paramount when evaluating patients with suspected intra-articular sources of hip joint pathology.

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6 Muscular Function and Treatment of Musculotendinous Groin Pain

Per Hölmich and Lasse Ishøi

6.1 Introduction

The movement of the hip joint is controlled by many muscles. The primary role of these is to generate and absorb forces acting on the hip joint as well as providing stability to the hip joint. Consequently, alteration of muscle activity or reduced muscle function may compromise hip joint stability and alter the distribution of forces across the articular surfaces of the hip joint and the musculotendinous structures [1]. Over time, this may lead to damage of the acetabular labrum, articular cartilage, or surrounding musculotendinous structures due to prolonged overload. A basic understanding of the muscles acting across the hip joint, including an understanding of (1) how reduced muscular function may potentially affect the surrounding intra- and extra-articular structures and (2) how to evaluate hip muscle function, is therefore paramount when evaluating subjects presenting with femoroacetabular impingement syndrome. As highlighted in part 1 (Chap. 5), musculotendinous causes of hip and groin pain may coexist in patients with suspected intra-articular hip joint pathology. A basic understanding of treatment for musculotendinous groin pain is therefore often important when planning the treatment strategy. The purpose of this chapter is therefore (1) to provide an overview of the muscular function around the hip joint in relation to intra- and extra-articular hip and groin pain and (2) to present evidence-based treatment strategies for the most commonly seen clinical groin entities.

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6.2 Muscular Function Around the Hip and Groin and Relation to Pain

6.2.1 Hip Flexion

Several muscles contribute to generating hip flexion torque including iliopsoas, sartorius, tensor fascia lata, and rectus femoris. Furthermore, part of the hip adductor muscle group may also act as synergists during hip flexion depending on the position of the hip joint and activation of the iliopsoas muscle [1, 2]. The most important hip flexor muscle is considered to be the iliopsoas muscle with the two main portions, psoas major and iliacus. As the muscle spans both the hip joint and parts of the axial skeleton, the iliopsoas muscle is able to generate hip and trunk flexion torque [1]. Furthermore, as the iliopsoas muscle crosses the hip joint anteriorly and medially, it has been hypothesized that the iliopsoas is a major contributor to providing anterior stability of the hip joint. Lewis et al. [2] used a musculoskeletal model to estimate anterior hip joint forces during supine hip flexion, with varying degrees of simulated muscle activity of hip flexor muscles. The model revealed an inverse relationship between force production of the iliopsoas muscle and maximum anterior hip joint force. As the hip flexion motion is thought to increase the strain of the anterior part of the acetabular labrum [3], reduced function of the iliopsoas muscle may compromise anterior hip joint stability. Consequently, reduced force production of the iliopsoas muscle may increase the force distribution on the anterior part of the hip joint potentially leading to excessive strain of the acetabular labral resulting in labral tear over time [2]. Reduced activation of the iliopsoas muscle during hip flexion has also been hypothesized to increase the activation of the tensor fascia lata and adductor longus. Excessive activation of the tensor fascia lata may lead to internal rotation of the femur elevating the strain at the acetabular labrum [3], whereas overuse of the adductor longus muscle may lead to development of adductor-related groin pain.

Subjects with intra-articular hip joint pathology often display reduced hip flexion muscle strength [4, 5]. Typically, hip flexor strength is also observed to be reduced in subjects with iliopsoas-related groin pain. Given the potential of the hip flexor muscles to increase hip joint stability and reduce the anterior forces on the hip joint and strain at anterior part of the acetabular labrum, assessment of hip flexion muscle strength and function is therefore advised as part of the evaluation of patients with hip and groin pain [6].

6.2.2 Hip Extension

Several muscles contribute to generating hip extension torque with the primary hip extensors being the gluteus maximus, the posterior head of the adductor magnus, biceps femoris, semitendinosus, and semimembranosus (the hamstring muscles). The hip extensor muscle group is considered capable of producing the greatest amount of torque across the hip joint compared to any other muscle group [1]. The hip extensor muscle group is highly activated during tasks such as squatting, lunging, and stair climbing and therefore is considered a major contributor to athletic performance. Given this potential to produce and absorb high load of forces acting across the hip joint, the hip extensor muscles are considered important hip stabilizers. Lewis et al. [2] used a musculoskeletal model to estimate anterior hip joint forces during prone hip extension, with varying degrees of simulated muscle activity of gluteal hip extensor muscles. The model revealed an inverse relationship between force production of the gluteal muscles and maximum anterior hip joint force. As the hip extension motion is thought to increase the strain of the anterolateral aspect of the acetabular labrum [3], reduced function of the gluteal muscles may compromise hip joint stability increasing the force distribution of the anterolateral part of the hip joint potentially leading to excessive strain of the acetabular labral resulting in labral tear over time [2].

Subjects with intra-articular hip joint pathology often display reduced hip extension muscle strength [4, 5]. This may, in part, manifest as reduced athletic performance given the great contribution to torque production across the hip joint [7] but more importantly may result in impaired hip joint stability and thus may be a contributing factor to the symptoms. Assessment of hip extension strength and function is therefore advised as part of the evaluation of patients with hip and groin pain [6].

6.2.3 Hip Adduction

Several muscles contribute to generating hip adduction torque including the pectineus, gracilis, and adductor longus, brevis, and magnus. One of the unique features of the adductor muscle group is the ability to contribute significantly to both hip flexion and extension force production depending on the position of the femur. Thus in a flexed femur position, the adductor muscles will have a line of force posterior to the rotational center hence contributing to hip extension torque, while the adductor muscles will be able to produce a hip flexion torque when the femur is in an extended position [1]. Besides the ability to assist in hip flexion and extension torque production, the hip adductors are considered important for optimal athletic performance and pelvic stabilization. During a maximal soccer kick, the adductors of the kicking leg are highly eccentrically activated [8], while the stance leg is working predominantly isometrically to control the pelvis over pelvic-on-femoral motion in association with the hip abductors [1]. The role of the hip adductors is further illustrated using data derived from a laboratory study investigating the hip adductor muscle activity during unanticipated 45° run-to-maneuvers. In this study, high hip adductor muscle activity was observed in the stance phase from the precontact phase to the final push-off phase, with muscle activity peaking during the weight-acceptance phase. This highlights the importance of the hip adductors as force absorbing and producing during explosive movements [9].

Subjects with hip and groin pain have consistently been shown to possess reduced hip adduction strength [10]. Given the importance of this muscle group to act as synergist during hip flexion and extension, providing pelvic-on-femoral stabilization, and absorb forces during explosive movements, impairment of hip adduction muscle strength is likely to affect hip and groin symptoms and should therefore be assessed when evaluating hip and groin pain patients.

6.2.4 Hip Abduction

The primary hip abductor muscle is considered to be the gluteus medius. Additionally, the tensor fascia lata acts as an important hip abductor and is commonly seen to be overactive in subjects with longstanding hip and groin pain. Identification of this is most pronounced during resisted side-lying hip abduction, where the overactive tensor fascia lata tends to flex and internally rotate the hip/leg. Collectively, the gluteus medius and tensor fascia lata are considered to be important lateral stabilizers of the hip joint and pelvis. With the origin on the upper portion of the ilium and insertion at the lateral and superior-posterior aspects of the greater trochanter, the line of force of the gluteus medius muscle acts to prevent the pelvis from dropping during single-leg stance activities. Consequently, optimal functioning of the gluteus medius muscle could help to prevent excessive hip adduction and internal rotation during single-leg stance, a position which has been hypothesized to cause excessive stress to the intra-articular hip joint structures [1, 11, 12].

Optimal hip abductor strength is considered important in relation to the patients presenting with either intra- or extra-articular hip joint pain, with several reports showing decreased hip abductor strength in patients with intra-articular hip joint pathology [13–15].

6.2.5 Hip Rotation

The deep external hip rotator muscles (piriformis, superior and inferior gemelli, quadratus femoris, and external obturator) of the hip joint are thought to play a vital role in providing hip joint stability. The line of force for the majority of these muscles is directed so that the muscles could act to compress the joint surfaces of the femoral head and acetabulum, hence optimizing joint stability [1].

The role of external hip rotation strength in relation to hip and groin pain is not fully understood, and contradictory results exist regarding hip external rotation muscle strength in subjects with intra-articular hip pain with studies showing both impaired and normal external rotation strength [14, 15]. However, due to the potential important role of providing hip joint stability, improving muscle strength and endurance in patients with hip and groin pain is advisable.

6.2.5.1 Quantification of Hip Muscle Strength

Given the importance of the hip muscles for the function of the hip and groin complex, objective evaluation of hip muscle strength is an important part of the examination of patients with hip and groin pain. Measures of hip muscle strength can be

Table 6.1 Testing protocol for measuring isometric hip muscle strength with handheld dynamometer

Hip flexion	The person being tested is in the sitting position, with the hip in 90° of flexion. The person being tested holds on to the sides of the table with both hands. The HHD is placed 5 cm (width of two fingers) proximal to the proximal edge of the patella
Hip extension	For hip extension the person being tested is in the prone position, with the hip in the neutral position. The person being tested holds on to the sides of the table with both hands. The HHD is placed on the lower leg 5 cm proximal (width of two fingers) to the proximal edge of the medial malleolus
Hip adduction/ abduction	For hip adduction and abduction, the person being tested is in the supine position, with the hip in neutral position. The opposite leg is slightly flexed. The person being tested holds on to the sides of the table with both hands. The HHD is placed 5 cm proximal to the proximal edge of the medial malleolus (for adduction) or lateral malleolus (for abduction) and fixated by the tester's hand/arm. The person being tested exerts a maximum hip adduction or abduction effort against the dynamometer

used to monitor progression during treatment including pre- and post-operation rehabilitation.

A widespread method to examine hip muscle strength is by manual muscle testing grading the strength from 0 to 5. However, this does not allow for a quantification of hip muscle strength and is therefore not advisable to use in physically active subjects with hip and groin pain. Instead, a reliable and easy way to quantify isometric and eccentric hip muscle strength in clinical practice is by using a handheld dynamometer (HHD). A reliable testing protocol for measuring isometric hip muscle strength can be found in Table 6.1 and Fig. 6.1a–d [16, 17]. If performing between-subject comparisons, normalization of the force output should be done using the lever arm (measured in supine as the distance from the anterior superior iliac spine to the placement of the center of pressure pad of the dynamometer) and body weight.

6.3 Treatment of Groin Pain

6.3.1 Monitoring of Groin Function and Pain During Treatment

Effective and simple monitoring of groin function and pain before, during, and after the treatment period should be conducted to assess and guide progression of the treatment.

As patients with longstanding groin pain typically present with impaired hip muscle function [10], assessment of muscle strength with a HDD (see above) should be conducted regularly to identify muscular deficits to be targeted as part of the treatment and to monitor progression of these deficits.

In conjunction with assessment of objective measures of groin function, such as hip muscle strength, assessment of self-reported hip and groin function serves as a

Fig. 6.1 Test setup for measuring isometric hip muscle strength. (**a**) hip abduction; (**b**) hip adduction; (**c**) hip extension; (**d**) hip flexion. Please see Table 6.1 for description of testing procedure

valuable tool to establish the severity of the injury and track progression. The Copenhagen Hip and Groin Outcome Score (HAGOS) is the only validated patient-reported outcome measure to establish self-reported hip and groin function in patients presenting with groin pain arising from musculotendinous structures [18].

HAGOS is self-explanatory, takes 10 min for the athletes to fill in, and consists of 37 questions divided into six subscales: pain, symptoms, physical function in daily living, function in sport and recreation, participation in physical activities, and quality of life. As such HAGOS measures hip and groin function in relation to different constructs, such as sport function which is highly relevant for athletes [18].

Another quick assessment of the hip and groin function can be performed with the Copenhagen five-second squeeze test [19]. The test is performed as a regular long-lever squeeze test with the athlete instructed to score the experienced pain in the groin region on a Numerical Rating Scale going from 0 to 10 subsequent to a maximum adductor squeeze for 5 s. Based on the experienced pain level, the athlete can be given a green (0–2), yellow (3–5), or red (6–10) light representing an approximation of readiness to progress load during treatment or participate in training or matches [19]. For a more comprehensive evaluation, assessment of hip adduction squeeze force during the Copenhagen five-second squeeze test can easily be conducted using a HHD. In combination with the pain response, this provides a valuable and more in-depth evaluation. For example, no change in pain but increased squeeze force during the Copenhagen five-second squeeze test over a given treatment period suggests that the pathological structures in the groin are able to tolerate more load without this causing an exacerbation in pain. Such progression is likely to be unnoticed if concomitant strength measures are not performed.

6.3.2 Treatment of Adductor-Related Groin Pain

Consistent evidence suggests that athletes with longstanding groin pain present with reduced hip adduction strength specifically when measured during eccentric contractions [10, 20]. Consequently, treatment is based upon active exercise therapy aiming to restore optimal hip adductor muscle function and increase load capacity [21]. In line with this, rest alone or passive treatment modalities do not seem to resolve symptoms effectively [21, 22].

The treatment of longstanding groin pain in athletes is based on a high-quality randomized controlled trial showing exercise therapy to be highly effective in comparison to passive treatment modalities, such as massage or laser therapy [21]. It should be noted that bony morphologies related to femoroacetabular impingement syndrome do not seem to prevent a successful treatment outcome at long-term follow-up [23]. The treatment program consists of two modules, with the first module lasting approximately 2 weeks and aiming to teach the patient to reactivate the adductor muscles using isometric and low-load exercises. The second module includes more demanding exercises targeting both the adductor muscles specifically and the stability of lumbo-pelvic region. The patient and clinician should be aware that at least 8–12 weeks of focused exercise therapy may be needed to resolve symptoms and allow return to previous sporting activities [21]. In addition to exercise therapy, manual therapy may be used as a supplement [24]. Although this may allow athletes to return to sport faster, manual therapy has not been shown to increase the proportion of athletes able to return to sport [24]. It is important to note that close supervision of exercises and progression provided by a qualified health professional should be prioritized to facilitate a successful treatment outcome [21, 24]. Following return to sport activities maintenance of eccentric hip adductor strength is important, which can easily be secured by performing the Copenhagen adduction exercise [25] or hip adduction with an elastic band [26].

As the hip adductor muscles are able to assist in hip flexion and extension, any impairment in these muscles should also be addressed as part of treatment for adductor-related groin pain, to secure that the adductor muscles are not continuously overloaded due to poor muscular function of other muscle groups [1].

6.3.3 Treatment of Iliopsoas-Related Groin Pain

There is no evidence-based treatment of longstanding iliopsoas-related groin pain; however, it is advised to adopt an active exercise program focusing on strengthening the iliopsoas muscle using isometric, concentric, and eccentric contractions. This can be done using a systematic and gradual strengthening program with a simple hip flexion exercise using an elastic band as external resistance [27]. In most of cases, return to sport is expected within 4–6 weeks. Iliopsoas-related groin pain often coexists with other clinical groin entities, and thus successful treatment of iliopsoas-related pain often includes treatment of potential other clinical groin entities [28]. Furthermore, as the iliopsoas muscle works in close synergy with the hip extensors to provide stability of the hip and pelvis, any muscular impairments of the hip extensor muscle should also be addressed as part of rehabilitation. If pain hinders the ability to perform the exercise program, an ultrasound-guided injection along the distal iliopsoas tendon with cortisone can sometimes be helpful to settle pain allowing the patient to perform the exercises without pain.

6.3.4 Treatment of Inguinal-Related Groin Pain (Groin/Sport Hernia)

There is no evidence-based treatment of longstanding inguinal-related groin pain using a conservative treatment approach [29]; however it is advised to adopt an active exercise program focusing on strengthening the abdominal muscles including the muscles surrounding the hip joint. The exercise program used for adductor-related groin pain [21] can be used as a base and potentially supplemented with more high-load abdominal exercises such as long-lever planks and sit-ups lying on a Swiss ball. Similar to adductor-related groin pain, treatment of inguinal-related groin pain often lasts for at least 8–12 weeks. Aggravating activities stressing the inguinal area such as kicking and forceful rotational movements of the trunk should be minimized during the initial treatment period and gradually reintroduced as the treatment progresses.

In cases where exercise therapy fails, surgery, either open or laparoscopic hernia repair, should be considered as a viable option. In a systematic review published in 2015, 38 studies regarding surgical treatment of inguinal-related pain were identified; however, only one study was deemed high quality [29]. In that study, 60 patients were randomized to either surgery (laparoscopic totally extra-peritoneal repair) or conservative treatment consisting of exercise therapy, corticosteroid injections, and oral anti-inflammatory analgesics [30]. Almost all athletes (97%) returned to sport at 12 months following surgery compared to 50% of athletes treated conservatively. While this study suggests that surgery is superior to conservative treatment for athletes with inguinal-related groin pain, approximately one in two athletes can expect to return to sport following conservative exercise therapy, and thus it is our opinion this should be considered the initial choice of treatment.

6.3.5 Treatment of Pubic-Related Groin Pain

There is no high-level evidence to suggest the most appropriate treatment strategy for longstanding pubic-related groin pain. However, evidence from a case series study including professional Australian football players have reported favorable outcomes using an approach consisting mainly of load management and pelvic stability exercises. During the initial 12 weeks following the diagnosis, the athlete should refrain from all weight-bearing running activities, whereas stationary cycling may be introduced at week 4 given that no pain is elicited by the activity. After 12 weeks, running activities should be gradually introduced [31].

6.4 Summary

The hip muscles act to generate and absorb forces distributed across the hip joint as well as provide stability to the hip joint. Alteration of muscle activity or reduced muscle function may compromise hip joint stability and alter the distribution of forces across the joint potentially leading to overload of intra- and/or extra-articular hip joint structures. Thus, optimal hip muscle function is considered important in the evaluation and treatment of patients with hip and groin pain. Treatment of longstanding groin pain relies primarily on exercise therapy and load management with the aim of optimizing muscle-tendon load tolerance. Several methods exit to monitor progression of treatment including quantification of hip muscle strength using a handheld dynamometer or measures of self-reported hip and groin function using the Copenhagen Hip and Groin Outcome Score.

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7 Surgical Dislocation for FAI in Athletes

Lorenz Büchler, Simon D. Steppacher, and Klaus A. Siebenrock

7.1 Introduction

The hip joint plays a crucial role in the generation and transmission of forces during athletic activity. To meet the requirements of ambulation, the hip differs in design from the more common hinge joints and is characterized by a high amount of inherent bony stability and extensive ligamentous and muscular support. Regardless of this stability, the hip joint maintains a wide functional range of movement. The high physical demands placed on the hip as well as repetitive forced movements to the limits of the physiological range of motion required in many sports make the athlete's hip especially vulnerable to morphological changes that reduce the range of motion. The resulting abutment between the femur and acetabulum during motion of the hip can lead to symptoms and can severely reduce the performance of high-level athletic activity. Since the first publication of the concept of femoroacetabular impingement (FAI) [1, 2] and the technique of surgical dislocation of the adult hip by Ganz and colleagues [3], the understanding of the etiology and long-term consequences of FAI has considerably progressed. It has become clear which pathological changes are best treated conservatively, arthroscopically, or with open surgery. Numerous publications have shown that both operative techniques are safe and reliable treatment options for many causes and sequelae of FAI. The aim of this article is to give an overview of the most common causes of FAI and to suggest when surgical dislocation should be selected for successful treatment of the athletic hip with FAI.

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7.2 Etiology of FAI

7.2.1 Primary FAI

7.2.1.1 Genetic Predisposition

The specific anatomy and biomechanics of the human hip joint is a consequence of the evolution of permanent bipedal gait [4]. Unlike most other mammals, a common feature of the hip joints of humans is a spherical femoral head (coxa rotunda) with a long and narrow femoral neck [5]. This enables a large range of motion of the hip, allowing the individual to sit, stand, run, and climb. The gluteus maximus muscle, a relatively minor muscle in large apes, was transformed into the largest muscle in the body as a hip extensor to stabilize the upright torso and act as the major propulsive muscle in upright walking. The increase of forces exerted on the femoral neck favored a sturdier hip with a femoral neck less prone to fracture and might explain the genetic basis for the high prevalence of coxa recta (or idiopathic cam morphotype) in physically active individuals. Radiographic studies on asymptomatic European and Canadian population found evidence of cam deformity in 24% of men and 5% of females [6, 7]. In a study investigating the role of genetics in the development of FAI, siblings of patients with cam-type FAI were compared to a spouse control group. Compared to the control group, siblings had an increased 2.8-fold risk of having a cam deformity [8].

7.2.1.2 Activity-Induced FAI

There is increasing evidence that participating in high-impact sports such as football, ice hockey, basketball, or soccer during growth plays an important role in the development of a cam deformity [9, 10]. One explanation is that high stresses lead to adaptive changes of the open physis with reactive lateral epiphyseal extension and bone formation at the anterior-superior femoral neck [11] (Figs. 7.1 and 7.2).

In a study of elite basketball players, there was a significant increase in epiphyseal extension and a correlation with alpha angles >55° in athletes with open physis compared with the control group [10]. Overall, the athletes had a tenfold increased likelihood of having an alpha angle >55° in at least one measurement position around the femoral neck (prevalence of 89% compared to 9% in the control group) [9]. Further studies support the hypothesis that cam lesions develop during a critical period of adolescence and that new lesions are not formed after epiphyseal closure [12]. For pincer impingement, however, there is no evidence linking increased acetabular coverage with developmental stresses.

7.2.1.3 Acetabular Retroversion

Acetabular retroversion is defined as a posterior rotation of acetabulum [13]. Mild forms present as a focal cranial retroversion of an otherwise normal acetabulum. In severe cases, the malposition is caused by retroversion of the entire hemipelvis with

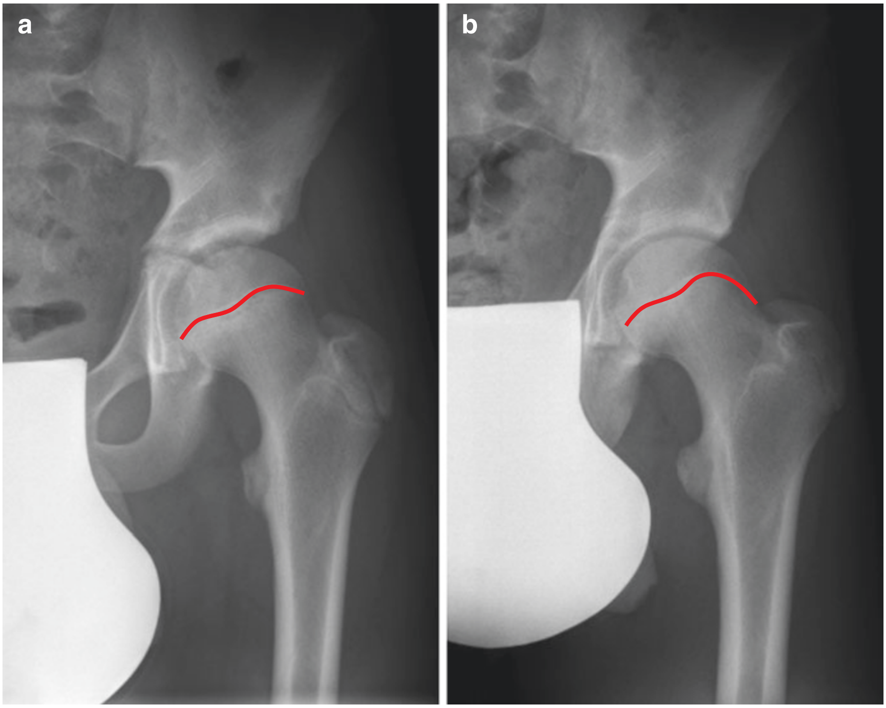

Fig. 7.1 Adaptive changes of the shape of the femoral head physis in a boy participating in vigorous soccer training several times a week. Between the age 13 (**a**) and 15 (**b**), the epiphysis has significantly extended laterally, resulting in a cam-type deformity

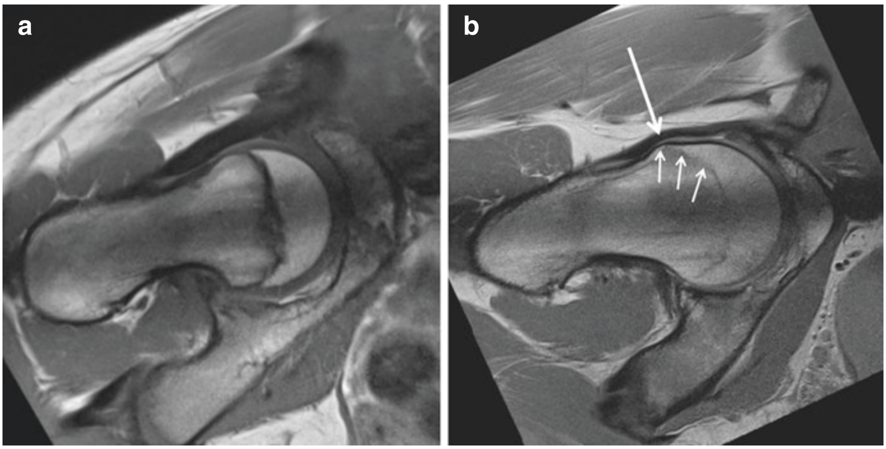

Fig. 7.2 Radially reconstructed MRT of an elite-level ice hockey player, lateral view of the hip. (**a**) At the age of 13, the patient performed a vigorous training with at least three training units or competitive games a week (**b**) After physeal closure, there is a significant increase of the epiphyseal extension and alpha angle in the anterosuperior head-neck junction (white arrows)

a retroversion index of 30–100%, a large-appearing ilium, and a prominent ischial spine on the pelvic overview. The prominent anterior wall results in a pincer-like impingement between the acetabular rim and femoral neck in hip flexion with corresponding damage to the labrum and acetabular cartilage. The lateral coverage (LCE) is often in the lower normal range. The joint-bearing surface is reduced compared to a normal hip, as the increased anterosuperior coverage is associated with posterior hypoplasia [14].

7.2.1.4 Protrusio Acetabuli

Protrusio acetabuli is a rare pathomorphology of the hip with significantly increased acetabular coverage of the femoral head, causing pincer-like restrictions of range of motion and damage to the acetabular labrum. Compared to a normal joint, the size of the facies lunata is increased. There is however often a central dysplasia with the tendency of medial head migration due to an enlarged acetabular fossa and a negative acetabular index [14, 15].

7.2.2 Secondary FAI

7.2.2.1 Slipped Capital Femoral Epiphysis (SCFE) and Slip-Like Morphology

Untreated SCFE or after pinning in situ leads to a femoral epiphysis that is tilted posteroinferiorly. The metaphyseal bone becomes exposed anterosuperiorly, creating a roughened surface with possible callus formation. The loss of the normal concavity of the anterior head-neck junction leads to a cam-type FAI and substantial damage of the cartilage and labrum. This can result in hip pain and is a risk factor for progression of osteoarthritis [16, 17]. The slip-like morphology is the second most frequent pathomorphology in hips with cam deformity and distinctly differs from hips with idiopathic cam with extension of the epiphysis [18].

7.2.2.2 Legg-Calvé-Perthes Disease

Residual changes following Perthes disease can lead to complex extra- and intra-articular impingement with symptomatic functional limitations and risk for development of secondary arthritis [19]. The deformities usually consist of a large aspherical femoral head, a short femoral neck, coxa vara, and a high-riding trochanter major. In addition, there is often instability and subluxation of the femoral head due to acetabular dysplasia.

7.2.2.3 Torsional Deformities of the Proximal Femur

Femoral torsion deformities are common in FAI [20]. Increased femoral torsion can lead to extra-articular ischiofemoral impingement and hip instability, while a decreased femoral torsion aggravates any anterior impingement.

7.2.2.4 Extra-Articular Impingement

Any periarticular structure that reduces the range of motion of the hip can cause impingement, such as a prominent inferior iliac spine, impingement of the greater trochanter, ischiofemoral impingement, or heterotopic ossifications.

7.2.2.5 Secondary Impingement After Surgical Intervention

Intra-articular adhesions after open or arthroscopic surgery or acetabular overcoverage after reorientation procedures frequently cause symptomatic impingement and are significant risk factors for poor outcomes after hip-preserving surgery [21, 22].

7.2.2.6 Post-Traumatic Impingement

The concept of FAI was developed after observations of morphological changes after femoral neck fractures [1, 23] (Fig. 7.3). Other traumatic reasons for FAI are avulsion fractures of the inferior iliac spine and heterotopic ossification in the tendon of the rectus femoris [24].

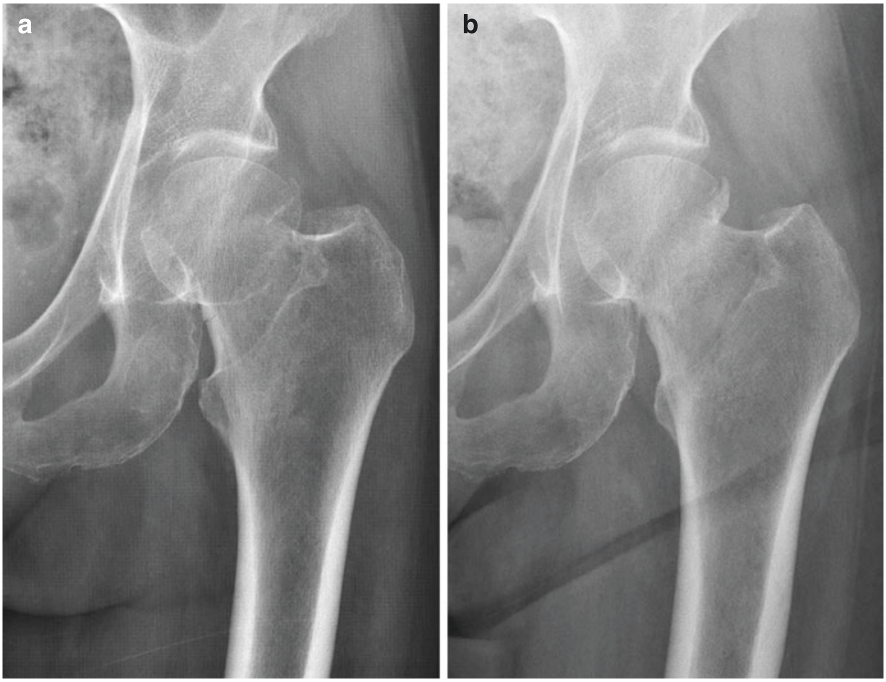

Fig. 7.3 (**a**) A 75-year-old female patient with a minimally displaced medial femoral neck fracture. (**b**). After conservative treatment, the fracture healed without further dislocation or signs of avascular necrosis. The patient however suffered from impingement due to the prominent osseous spur on the head-neck junction

7.3 Treatment

The aim of treatment of FAI is a subjectively content patient without restrictions during work and athletic activities. Because FAI is a dynamic problem of the joint, conservative treatment to improve postural habits, strengthening exercises and modification of sport activity can reduce symptoms. In active athletes however, acceptable limitations to the mechanical demands of the hip are often limited. In addition, there is evidence that hip arthroscopy is more clinically effective than personalized hip therapy in short-term follow-up [25].

The aim of surgery is to normalize the biomechanical function of the hip by removing any causes of mechanical conflicts. The surgical technique with the highest probability for success and lowest complication rate should be used. The decision which operative approach is selected largely depends on the underlying pathology. The most important factors are the extent of the acetabular coverage and the femoral head-neck asphericity, the condition of the acetabular labrum, and the combination with additional pathologies. Additional parameters that influence the decision whether to proceed by arthroscopy or open surgery are obesity, extensive heterotopic ossifications, limitations to traction on the leg as well as the experience of the surgeon with open or arthroscopic techniques.

Hip arthroscopy is ideal for trimming of the anterolateral acetabular rim and femoral neck. In addition, most apparent damages to the hyaline cartilage or the acetabular labrum can be evaluated and treated if possible and reasonable. If FAI concurs with more complex deformities, a thorough diagnostic evaluation is of particular importance. In addition to the usual radiological examinations, radially reconstructed MRT with intra-articular contrast and traction, measurement of femoral torsion, as well as 3D animations can add valuable information. Regularly, open procedures are necessary to achieve a normal load transmission and a stable hip. The treatment is defined by the most severe anatomical change of the hip joint and can require staged procedures with the combination of several operative interventions.

Numerous publications show that both arthroscopic and open techniques are safe and reliable in the treatment of hip pathologies [26]. Long-term follow-up after hip-preserving surgery, regardless of the surgical technique, shows specific negative predictive factors, such as mild forms of arthritis or advanced age of the patient [21, 27]. In such cases, conservative treatment with adequate analgesia followed by THA in case of persisting symptoms should be considered.

7.3.1 Indications for Surgical Hip Dislocation

Surgical dislocation of the hip is a versatile and safe approach to the hip that offers unrestricted view and access to the entire joint, especially the dorsal and medial parts of the central, peripheral, and extracapsular compartment [3]. In addition, proximal femoral rotation and head reduction osteotomies can be performed, and fractures of the femoral head, proximal femur, and acetabulum can be treated.

7.3.1.1 Pincer-Type Impingement

In hips with extensive pincer-type morphology such as *protrusio acetabuli*, the impingement is usually treated by a pure rim trim [28]. This however does not entirely resolve the pathomorphology in protrusio hips, as the long-term results are clearly inferior compared with surgical hip dislocation for FAI without severe overcoverage [29]. For hips with signs of cartilage degeneration, the lateral coverage can be reduced with an acetabular reorientation. As a result of the increase in the acetabular index, this also improves the central stability and reduces medial head migration. The resulting increased inferior coverage should be addressed by a trim in this area [28]. In *focal cranial retroversion* with a retroversion index of less than 30%, the acetabulum is otherwise normal; a trimming of the retroverted section of the rim with labrum refixation can be performed with open or arthroscopic surgery. In a *severely retroverted acetabulum* however, anterior rim trim is contraindicated, as this would result in an additional reduction of the weight-bearing cartilage surface. The adequate treatment is an anteverting acetabular reorientation [30].

7.3.1.2 Cam-Type Impingement

The treatment of simple cam-type impingement and resulting damages to the acetabular cartilage and labrum is best performed with hip arthroscopy. In *severe cam-type impingement*, particularly in far medial or dorsal bumps as well as pistol grip deformities lateral to the retinacular vessels, surgical hip dislocation will allow a better and safer access to the deformity (Fig. 7.4).

Residual deformities after Perthes disease are best treated in a stepwise treatment algorithm [31, 32]. After surgical dislocation of the hip, femoral offset improvement and if necessary head reduction osteotomy and relative femoral neck extension with distalization of the greater trochanter are performed. In dysplastic hips, acetabular reorientation can then improve the structural stability and congruence of the joint [33].

7.3.1.3 Extra-Articular Impingement

Extra-articular impingement can cause severe restrictions to hip joint movement and pain. Due to the unrestricted access to the extra-articular compartment of the hip joint with surgical hip dislocation, this approach is ideal to evaluate and treat causes for extra-articular impingement, especially a prominent inferior iliac spine, ischiofemoral impingement or impingement of the greater trochanter [34].

7.3.1.4 Torsional Deformities

Torsional deformities of the femur should be addressed if femoral osteochondroplasty and acetabular rim trim are not sufficient for impingement-free range of motion [20]. In hips with a reduced femoral antetorsion, a rotating femur osteotomy is indicated to achieve an impingement-free internal rotation of at least 30°. If posterior impingement persists, an increased femoral torsion should be reduced, if necessary in combination with a varus osteotomy. All interventions can ideally be performed via surgical hip dislocation.

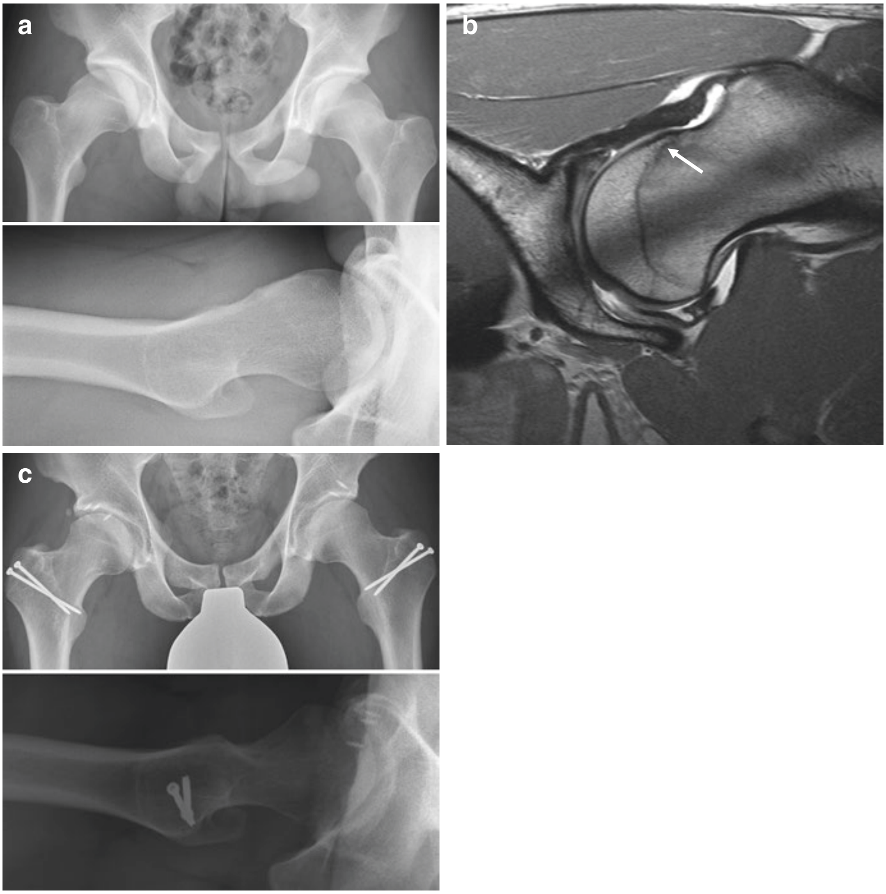

Fig. 7.4 17-year-old professional ice hockey player. (**a**) AP pelvis and cross-table lateral view of the right hip show severe bilateral cam-type impingement with pistol grip deformity and focal acetabular retroversion. (**b**) The radially reconstructed arthro-MRT reveals a distinct lateral epiphyseal extension (white arrow) at the 2 o'clock position. (**c**) Eight years after bilateral surgical hip dislocation for offset improvement at the femoral neck, acetabular rim trim, and reattachment of the labrum, there are no signs of arthritis, and the patient was asymptomatic

7.3.2 Revision FAI Surgery

The preoperative workup in revision FAI surgery and the decision process to which operative technique is selected do not significantly differ from that prior to primary operative interventions. The most important question is if FAI was the correct diagnosis for the primary procedure and if the deformities were adequately addressed. In addition, potential complications from the index procedure, such as adhesions, iatrogenic instability, as well as the overall status of the hip including the extent of secondary osteoarthritis need to be considered as the source of ongoing symptoms. In general, open surgery allows solutions of more global pathologies, whereas arthroscopy is ideal for treatment of adhesions or limited persisting impingement (Table 7.1).

Table 7.1 Good indications for surgical hip dislocation for treatment of FAI

	Pathology	Treatment
General		
Indications for open surgery	– Very obese patient – Contraindications for leg traction – Complex revisions	
Femur		
Cam	Posterolateral (pistol grip), inferior, posterior	Offset correction [3]
Post-SCFE	Severe tilt (SA > 30°)	Extended retinacular flap, subcapital osteotomy [35]
LCPD	Deformed femoral head Short femoral neck Acetabular dysplasia	Staged procedure (can include): Relative femoral neck lengthening, offset correction, head reduction [36], PAO
Femoral neck torsional deformities [20]	Severe retrotorsion (<0°)	Proximal femoral rotation osteotomy
	High antetorsion (>30°)	Proximal femoral derotation osteotomy
Acetabulum		
Pincer	Circumferential, protrusio acetabuli	Rim trim [29], possible labral reconstruction
Retroversion	Severe acetabular retroversion – Retroversion index [37] >30% – Significantly reduced posterior coverage [13, 38] – Positive ischial spine sign [39]	Anteverting PAO [30, 40] Offset correction
Other		
Extra-articular impingement	Severe heterotopic ossifications	Pre-op irradiation, open resection
	Severe sub-spine impingement	Open resection of spine, reattachment of rectus tendon
	Ischiofemoral impingement	Proximal femoral derotation, lesser trochanter osteotomy
	Trochanter major impingement	Relative neck lengthening, distalization trochanter major
Labrum and cartilage lesions	Severe labrum lesions	Open reconstruction
	Severe cartilage lesions	Osteochondral transplantations, membrane
	Acetabular cysts	Débridement and autograft
	Focal femoral head necrosis	Débridement, trapdoor autologous bone grafting
Revision	Excessive resection	Bone graft, PAO
	Malpositioning of acetabular fragment	Rim trim, revision PAO

SHD surgical hip dislocation, *SCFE* slipped capital femoral epiphysis, *SA* Southwick angle, *LCPD* Legg-Calvé-Perthes disease, *PAO* periacetabular osteotomy. Radiographic reference values from Tannast et al. [41]

7.4 Results and Review of the Literature

The overall long-term results of open surgical treatment of FAI are favorable. Steppacher et al. [27] reported on 72 patients after a mean follow-up of 11 years (range, 10–13 years). Eighty percent of patients had a good clinical result without progression of osteoarthritis nor conversion to total hip arthroplasty. The most common reason for subsequent surgery was trochanteric screw removal (31%) or treatment of intra-articular adhesions (6%). Only few studies specifically report the results after open surgical treatment of FAI in athletes. Naal et al. [42] reported on 22 professional male athletes after open treatment of cam- or mixed-type impingement. At a mean follow-up 3.8 years, 82% were satisfied with their hip surgery and 86% with their sports ability. All but one patient (96%) were able to resume their sports and continue professional careers. In a follow-up study on 126 female and male patients who were regularly active in sport [43], 85% remained active at a mean follow-up of 5 years. 60% stated that their sports ability had improved after surgery. 19% however indicated a deterioration. Novais et al. [44] reported on 24 competitive adolescent athletes with a mean age of 15.5 years (range, 11–19). At a mean follow-up of 22 months after open surgery for FAI, 21 patients (88%) were able to return to play, and 19 (90%) returned to play at a level that was equivalent to or greater than their level of play during the 12 months before the operation. The median time to return to play was 7 months. Three patients were unable to return to play for reasons unrelated to the hip.

Several studies compare the results of open and arthroscopic treatment of FAI. In a systematic review, Botser et al. [45] analyzed the outcomes of 1409 patients' (1462) hips at a mean follow-up of 27 months. Mean age was 32.7 years (range, 11–68 years). Complications occurred in 1.7% of the patients treated with arthroscopy (heterotopic ossifications 1.1%, transient neuropraxia of LFCN and pudendal nerve 0.4%). Complications of open surgery were mainly due to heterotopic ossifications (3.2%) or related to the fixation of the greater trochanter (5.5%). Both approaches led to comparable and consistent improvements in patient outcomes. Because of a wide variety of subjective hip questionnaires however, direct comparisons were difficult. Reiman et al. [46] performed a systematic review of FAI surgical outcome studies specifically in athletes. Of the 35 included studies (1634 athletes/1828 hips), open procedures were used in only 3 studies. Athletes returned to sport at an average of 7 months after surgery. The overall return to sport rate was similar between open and arthroscopic treatment (89% vs. 91%, respectively). However, the pooled rate of return to sport at pre-injury level after open surgery was 83%, which was significantly better than after hip arthroscopy (74%).

7.5 Conclusion

While hip arthroscopy has become the generally accepted treatment method for simple FAI, surgical hip dislocation remains a safe and reliable treatment for complex impingement cases in athletes with excellent long-term results. The comparatively higher rate of subsequent surgeries is primarily related to intra-articular adhesions or pain over the greater trochanter due to the screws. Return to sport is comparable after open and arthroscopic surgery, with 90% of patients return to sports activities in the short to mid-term follow-up.

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8 Arthroscopic Management of Femoroacetabular Impingement in Athletes

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8.1 Introduction

Injuries around the hip account for 3.1–8.4% of all sports-related injuries [1, 2]. The athlete presenting with hip and groin pain remains a diagnostic dilemma, which often leads to frustration between the patient and healthcare providers. The difficulty with groin-related symptoms stems from the fact that a wide variety of conditions involving multiple organ systems can often refer pain to the hip and surrounding structures. The musculoskeletal etiologies of groin pain in athletes, such as sports hernias, adductor strains, osteitis pubis, and flexor tendinopathy, have all been areas of expanding research [3]. A recent systematic review reported that the most common causes for groin pain in the young athlete were femoroacetabular impingement (FAI) (32%), athletic pubalgia (24%), and adductor-related pathology (12%) [4]. Thus, it is important for clinicians and therapists to be diligent when managing athletes with hip- and groin-related symptoms in order to prevent delays in accurate diagnosis and ensure that care is directed appropriately.

The 2016 Warwick Agreement [5] introduced the term "FAI syndrome" to reflect the central role of patient symptomatology in the disorder. To establish diagnosis and help indicate patients for surgery, a triad of appropriate symptoms, positive physical exam signs, and imaging findings should all be present. Patients typically present with motion-related pain that is usually localized to the groin, although pain

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may also be felt in the lower back, buttock, and lateral thigh [6]. The diagnosis of FAI syndrome does not depend on a single clinical sign; many have been described and are used in clinical practice. The most commonly used hip impingement test, flexion adduction internal rotation (FADIR), has only moderate sensitivity and specificity with variability in reported values [7]. There is often a limited range of hip motion, typically restricted internal rotation in flexion. It is essential to perform a complete neurological exam of the lumbar spine [8] and assess the abdominal musculature for inguinal hernias and athletic pubalgia [9]. Radiographic assessment is best achieved initially with plain radiographs. A systematic review of 68 studies of fair-quality evidence (5125 patients) found that the anterior-posterior pelvis and orthogonal radiographs of the femoral neck (cross-table lateral or Dunn view) were the most commonly obtained views [10]. The authors found that the most commonly reported measure of cam-type impingement was the alpha angle (66%), whereas for pincer-type impingement, the crossover sign (48%) was most reported. Where further assessment of hip morphology and associated cartilage and labral lesions is desired, cross-sectional imaging is appropriate. Limited images of the distal femoral condyles allow assessment of femoral version, while 3D reformatting of CT or radial MRI allows assessment of focal morphological abnormalities [11, 12]. Lastly, pain relief following an image-guided local anesthetic injection can support a diagnosis of FAI syndrome. Importantly, a negative response to an intra-articular hip injection has been shown to predict a higher likelihood of having a negative result from FAI surgery [13].

FAI is a commonly reported cause of pain and disability in the young athletic population [14–16]. The repetitive axial loading and increased hip mobility required during sporting activities can cause abnormal collision (or impingement) in the athlete with cam and/or pincer morphologies. The impact of vigorous sporting activities on a developing physis has been appreciated for other joints, in particular the proximal humerus of Little League baseball players [17] and the distal radius of young gymnasts [18]. Similarly, repetitive torsion on the proximal femoral physis during periods of skeletal growth and maturation may incite the formation of a cam morphology from subclinical physical injury. A prospective cohort study that followed a group of young elite level soccer players found that the prevalence of a cam morphology (alpha >60°) increased from 2.1% to 17.7% after patients had reached skeletal maturity ($p = 0.002$) [19]. Furthermore, there was no significant increase in the prevalence or magnitude of the cam morphology after closure of the proximal femoral physis. A systematic review and meta-analysis by Nepple et al. found that male high-level athletes were 1.9–8.0 times more likely to develop a cam morphology than male counterparts without prior exposure to intensive sporting activities [14]. Several other studies have suggested that exposure to high-impact athletic sports at a young age is a risk factor for cam morphology development [20–22].

Open hip dislocation has long been the standard surgical treatment for FAI. However, technical advances have enabled much of the FAI pathology to be addressed with arthroscopic surgery. Systematic reviews comparing hip arthroscopy and open surgical dislocation have suggested that both approaches have comparable short-term efficacy but that arthroscopic procedures have decreased risks of major complications [23, 24]. Despite the increasing evidence supporting the arthroscopic management of FAI, some controversy remains with respect to patient selection, surgical indications, and intraoperative techniques. The indications for surgery are patient and surgeon dependent; however, the senior author uses a combination of a history of groin-dominant pain (minimum 3 months), a positive clinical exam (FADIR test), X-ray, and MRI radiographic findings of FAI morphology with associated damage and temporary relief from an intra-articular hip injection to determine candidacy for surgery. CT scan imaging is reserved for revision settings or patients with complex deformities. The purpose of this chapter will be to review the arthroscopic management of FAI in the athlete using an evidence-based approach to each of the associated pathologies.

8.2 Articular Cartilage Damage in the Athlete with FAI

Discrete, full-thickness cartilage lesions of the femoral head and acetabulum can cause pain and disability and can occur from a variety of impingement-type mechanisms [25]. Unrecognized FAI can have long-term sequelae as several prospective cohort studies have reported that cam morphology is associated with an increased risk of developing osteoarthritis (OA) [26–30]. A retrospective study of 338 patients undergoing hip arthroscopy found that an alpha angle >50° on a frog-leg lateral radiograph was an independent risk factor for having grade 3 or 4 acetabular chondromalacia [31]. Similarly, a longitudinal cohort of 1003 women (mean age 54.2, range 44–67 years) who had pelvic radiographs taken at baseline and at 20-year follow-up found that cam morphology (alpha >65°) was significantly associated with the development of radiographic OA. Furthermore, each incremental increase in alpha angle by 1° above 65° was associated with an increased risk of 5% (OR 1.05 [95% CI 1.01–1.09]) for radiographic OA and 4% (OR 1.04 [95% CI 1.00–1.08]) of having a total hip replacement [32].

The epidemiological studies on the relationship between cam-type impingement and intra-articular hip damage in young athletes are limited. A study by Reichenbach et al. showed that cam morphology was associated with decreased cartilage thickness in an asymptomatic young population of male army recruits [33]. Wyles et al. prospectively compared 26 adolescent hips (age range 12–18 years) having limited internal hip rotation <10°, with a control group of 26 age and sex matched hips having internal hip rotation of >10° [34]. After 5-year follow-up, 27% of the group with limited internal rotation showed mild signs of OA, as compared to 0% of the hips in the control group. The presence of a cam morphology was the largest predictor of developing degenerative changes at 5 years (RR, 2.5; 95% CI, 1.1–6.0; $p = 0.039$). However, not all patients with cam-type impingement will progress to arthritis. Thus, a better understanding of the genetic, environmental, and biomechanical factors, including the role of pincer-type impingement, is needed to help predict risk of future degenerative disease of the hip.

Hip arthroscopy starts with diagnostic examination of the central compartment. Dynamic assessment of the hip joint intraoperatively can be used to confirm areas of impingement and assess the corresponding zones of injury to the articular cartilage and labral tissue. Chondral damage is typically found in the anterosuperior quadrant of the acetabulum corresponding to the weight-bearing area of the hip joint [35, 36]. A cross-sectional study of 1502 arthroscopic hip surgeries found that higher amounts of acetabular chondral damage were significantly associated with male sex, advanced age, chondrolabral detachment (Seldes type 1), and posterior extension of the labral tear [37].

Cartilage defects have a limited capacity to heal without surgical intervention [38]. Although still largely experimental with limited high-quality evidence, multiple arthroscopic techniques have been developed to restore areas of damaged articular cartilage in the hip. Areas of chondral flaps and delamination that appear relatively healthy on arthroscopic inspection may be salvageable using cartilage preservation techniques. Although clinical results are limited, authors have described techniques to repair areas of subchondral delamination using sutures [39] or fibrin adhesive material [40]. The newest generation of techniques includes matrix-induced autologous chondrocyte implantation (MACI), which is a procedure whereby areas of healthy, non-weight-bearing cartilage are first harvested from the patient's own tissue. The autologous chondrocytes are then extracted and cultivated in vitro on a biodegradable collagen scaffold. Once the cells have matured, a second operation is performed to fill the areas of focal cartilage damage in the affected hip. While research is limited, Fontana et al. compared the effectiveness of simple chondral debridement to arthroscopic MACI for management of hip cartilage defects in 30 patients with Outerbridge grade 3 and 4 lesions (size of defect >2 cm^2) [41]. The authors reported better clinical outcomes with MACI than with simple chondroplasty with an average Harris hip scores (HHS) of 87.4 and 56.3, respectively ($p < 0.05$), at final follow-up (mean 74 months).

The most commonly studied and accepted treatment method of focal chondral lesions remains microfracture or bone marrow stimulation. The indications of this treatment modality in the hip (focal, contained lesion, <4 cm^2 in size) [42, 43] have been extrapolated from original literature on the knee. The principles of the microfracture technique are the same in the hip joint. First, the chondral defect is debrided to establish a contained lesion with vertical walls. Higher-angled awls are used to perforate the subchondral bone (2–4 mm depth and spaced 3–5 mm apart), allowing bone marrow cells to fill the area promoting the formation of fibrocartilage. This technique has been shown to be relatively inexpensive and can produce reliable results. The largest clinical study on microfracture in the hip remains a case series by Byrd and Jones who treated 200 patients (45% athletes) with FAI [44]. The authors showed 85% good or excellent results in 28% of patients (58 hips) who underwent microfracture for treatment of grade 4 chondral defects. However, this study was limited by short-term results with average follow-up of only 16 months (range 12–24 months). More recently, it has been shown that 79% of elite athletes who have undergone microfracture of the femoral head and/or the acetabulum for full-thickness chondral defects were able return to play at the same athletic capacity within 1 year of surgery [45]. Studies reporting sport-specific performance outcomes can often provide more meaningful information to athletes, than simply the rate of return to sport. A study of 17 professional hockey players looking at performance-based outcomes following arthroscopic microfracture for full-thickness chondral lesions in patients with FAI showed no differences in games played, ice time, points, save percentage, and shots against goal (in goalies) compared to pre-injury statistics [46].

8.3 Pincer-Type FAI in the Athlete

Arthroscopic rim trimming is most commonly performed to correct pincer-type impingement due to cranial retroversion of the acetabulum. Some authors have recommended that the lateral center-edge angle (LCEA) should not be corrected to less than 20° [47]. Philippon et al. correlated the amount of rim resection with changes to the LCEA on anteroposterior (AP) radiographs. The authors determined that 1 mm of bone resection resulted in a 2.4° decrease of the LCEA and that each additional millimeter of bone resection resulted in a 0.6° decrease of the LCEA [48]. Although the LCEA is a useful guide, there are several limitations with the use of LCEA to quantify rim resection. The LCEA can only measure the superolateral aspect of the acetabulum and cannot be used to detect corrections of the anterior wall, which is commonly altered with arthroscopic rim trimming. Moreover, the AP pelvis view does not account for pelvic tilt and rotation, which can affect the LCEA and the presence of a crossover sign [49–51]. Furthermore, the LCEA can underestimate the anterior acetabular overcoverage and may lead to errors in bone resection when used as criteria to judge rim trimming using fluoroscopy. To address some of these limitations, Gross et al. developed the anterior wall angle (AWA), anterior rim angle (ARA), and anterior margin ratio (AMR) as added radiographic parameters to help assess pincer correction [52]. In a cohort of 72 asymptomatic patients (44 females) with anteroposterior pelvic radiographs, the mean ARA was 88.91° ± 8.06°, the mean AWA was 34.89° ± 8.09°, and the mean AMR was 0.49 ± 0.15 [53]. While the authors recommended using these values as a guideline for limits on resection of the anterior rim of the acetabulum, this study is limited by a small population sample, and the clinical significance remains to be tested.

Although pincer resection is commonly performed in arthroscopic hip surgery, emerging evidence suggests that excessive rim resection can result in abnormal hip contact pressures. A recent biomechanical study of non-dysplastic, human cadaveric hemipelvis found that resecting more than 4–6 mm of the acetabular rim during arthroscopic hip surgery can lead to a threefold increase in joint contact pressures [54]. This study suggests that excessive rim resection may ultimately predispose to early joint degeneration. Thus, a judicious approach to pincer correction is needed when contemplating rim resection. Furthermore, recognition of those athletes with subtle signs of borderline acetabular dysplasia is needed to avoid secondary risk of iatrogenic structural hip instability. A cross-sectional study of female collegiate athletes found that 21% (26/126) of hips had acetabular dysplasia (LCEA <20°), and 46% (58/126) of hips had borderline dysplasia (LCEA ≥20° and ≤25°) [55]. Acetabular dysplasia has also been found to be more common among hockey goalies (29%) than among position hockey players (15%) with the average CT-measured LCEA being 27.6° ± 5.3 vs 30.0° ± 5.4, respectively ($p = 0.04$) [56]. This is in comparison to the largest cross-sectional study assessing hip joint morphology which found a much lower prevalence of acetabular dysplasia in the general population (3.9% of 3620 hips) [57].

Patients with global retroversion and overcoverage of the acetabulum have historically been treated with open surgery that involves osteotomies of the proximal femur and acetabulum. While low-level evidence has emerged to support arthroscopy in these scenarios [58], the long-term data and return to sport outcomes have not been defined.

8.4 Arthroscopic Approach to Labral Tears in FAI

The prevalence of labral tears in athletes presenting with hip and groin pain has been reported to be 22% [59]. The labrum appears to have several important functions in the hip joint; these include joint stability, load dissipation, proprioception, synovial fluid regulation, and maintenance of the suction seal. Ferguson et al. showed that the labrum acts to preserve a synovial fluid seal, which maintains hydrostatic pressure in the hip joint [60]. When the labrum is removed, the pressure gradient is interrupted due to a loss of intra-articular fluid leading to abnormal joint contact pressure [61]. Historical descriptions of acetabuloplasty involved detaching the labrum to expose the acetabular rim [47, 62]. More recently, technical refinements have allowed for preservation of chondrolabral junction during arthroscopic rim trimming. A retrospective study of 50 high school and college athletes with a mean follow-up of 34 months found that arthroscopic labral takedown and reattachment was associated with lower clinical outcomes compared to labral repair with chondrolabral preservation [63]. However, indications for labral takedown in this study included advanced chondrolabral pathology, and thus the outcomes may be influenced by the level of chondral damage rather than the surgical approach. A systematic review on the surgical management of labral tears in FAI found significantly better clinical outcomes (five of six studies) with labral repair compared to debridement alone [64]. However, in select cases labral debridement is still a reasonable option for segmental irreparable damage. Current labral repair techniques involve suture anchors using looped or pieced labral passage (base stitch repair). While there is theoretical concern that a looped stitch can abrade the cartilage of the femoral head or cause eversion of the labrum with disruption of the normal fluid seal, prospective registry data comparing suture repair configurations have shown no influence on clinical outcomes [65].

The patient with an irreparable labral tear presents a difficult clinical challenge. To address labral deficiency, an arthroscopic approach with an autologous iliotibial band graft can be performed [66]. Indications for labral reconstruction have been largely based on expert opinion: a hypotrophic labrum (width less than 3 mm) and/or complex irreparable labral tears [67]. A retrospective case series of 21 elite athletes who underwent an arthroscopic iliotibial band labral reconstruction was analyzed. The rate of return to play was 85.7% (18/21), with 81% (17/21) returning to a similar level of play at an average follow-up of 41 months (20–74 months) [68]. While these preliminary results are promising, this was an observational study of only male athletes participating in limited subset of sports. Studies of longer-term follow-up are needed to determine outcomes for both male and female athletes participating in a variety of sports with more repetitive, cutting-type movements.

8.4.1 The Authors Preferred Technique for Rim Resection and Labral Repair

The anterolateral portal is used as the viewing portal for rim resection in the central compartment. We favor the use of a mid-anterior portal which is more lateral and distal to the conventional anterior portal. We feel that this improves the trajectory for instrumentation of the labrum and acetabular rim and increases the margin of safety from the lateral femoral cutaneous nerve [69]. A radio-frequency ablation device is used to clear the extracapsular rim and expose the area of the pincer. The labral attachment at the chondrolabral junction is preserved whenever possible. However, formal detachment and re-fixation may be required for cases of global overcoverage, in which significant resection of the acetabular rim is required. Although we try to minimize the size of the interportal capsulotomy, it can be extended posteriorly to the piriformis tendon or anteriorly to the psoas tendon depending on the extent and location of pathology encountered. Rim resection is performed with a 5.5 mm round burr placed in the mid-anterior portal with the goal of correcting anterosuperior pincer-type impingement caused by cranial retroversion. Fluoroscopy is used to identify the starting point for resection, which is typically just inferior to the location of the crossover sign (Fig. 8.1a). The amount of

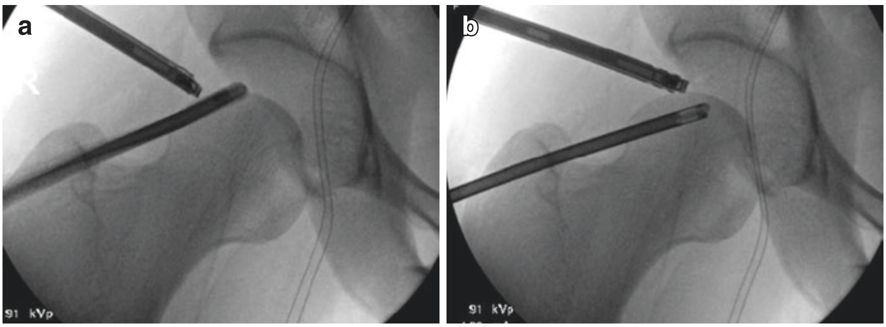

Fig. 8.1 (**a**) Anteroposterior (AP) fluoroscopic view of the right hip showing a crossover sign and prominent ischial spine indicating focal pincer and acetabular retroversion. (**b**) Post-anterosuperior rim resection demonstrating the elimination of the crossover sign

bony resection should be sufficient to remove portions of the rim that extend beyond the chondrolabral junction (eliminating the crossover sign) and to restore the LCEA to 25–40° on fluoroscopic imaging (Fig. 8.1b).

Once adequate rim resection is complete, labral re-fixation is performed to repair labral pathology (Fig. 8.2a). Preparation of the labrum may be completed using a motorized shaver to remove any frayed portions of irreparable labral tissue. Anchors should be placed with a distal-proximal trajectory to avoid intra-articular penetration. Fluoroscopy is used to confirm that the drill is superior to the acetabular sourcil. Suture anchors placed too far from the articular surface risk everting the labrum. Conversely, suture anchors placed too close to the articular surface risk violating the joint. To avoid iatrogenic cartilage damage, the ideal anchor placement should be approximately 2.3–2.6 mm from the rim [70]. The use of a curved drill guide delivery system has also been shown to provide a safer angle of anchor insertion and distance from subchondral bone at the 1, 2, and 3 o'clock positions during drilling [71]. Although we do not routinely use a distal anterolateral accessory (DALA) portal, it can be a useful adjunct to ensure safe anchor placement [72]. However, the risk of psoas tunnel perforation during anterior anchor placement can be a potential concern with using the DALA portal [73]. Direct visualization of the articular surface is recommended during drilling and anchor placement to confirm that the articular cartilage is not penetrated. The number of anchors used is dependent on the extent of the labral tear. We prefer to use labral base fixation stitches when possible. Looped stitches, however, may be necessary for repairing hypertrophic labra with intra-substance damage or in situations where formal labral detachment is needed (Fig. 8.2b). The sutures are then tied using standard arthroscopic knot-tying techniques.

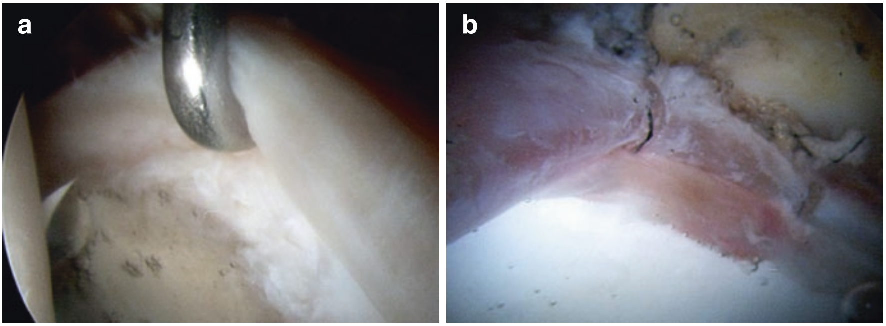

Fig. 8.2 (**a**) Arthroscopic view of the left hip with a probe showing chondrolabral separation and chondromalacia at the anterosuperior zone of the acetabulum. (**b**) Right hip showing labral re-fixation using two anchors with looped stitch technique at the anterosuperior zone of the acetabulum. Erythema is seen within the labrum and adjacent articular cartilage

8.5 Sub-spine Impingement in Athletes

Repetitive muscular contraction of the rectus femoris has been associated with acute avulsions of the anterior inferior iliac spine (AIIS) in both soccer and American football players [74]. Avulsion injuries typically occur in adolescents as a result of an eccentric contraction of the rectus femoris with hip extension and knee flexion during a kicking movement or with a sudden forceful contraction while decelerating after sprinting [74–76]. However, these forces do not always result in acute avulsion injuries and instead may cause subclinical avulsions or traction apophysitis leading to AIIS hypertrophy with extension toward the anterior acetabular margin [77, 78]. This in turn may cause extra-articular AIIS impingement, a condition called sub-spine impingement that was initially described by Pan et al. [78]. Larson et al. subsequently recognized sub-spine impingement in a series of three patients found to have abnormal caudal extension of the AIIS [79]. Following this, a classification system for AIIS morphology was reported by Hetsroni et al. who demonstrated pain with straight terminal hip flexion, where the femoral neck collides with the hypertrophied AIIS [80]. Intraoperative assessment is frequently associated with focal chondrolabral pathology adjacent to the prominent AIIS (zone 2, anterior-superior acetabulum [81]). However, it remains unclear whether labral tears are due to the sub-spine impingement alone or concomitant FAI [82].

Due to the broad origin of the rectus femoris (direct head) at the AIIS, hip flexion weakness following sub-spine decompression can occur and become especially apparent in kicking athletes. Devitt et al. reported avulsion of the direct head of the rectus femoris due to a hyperextension injury of the hip following arthroscopic resection of sub-spine impingement in a 23-year-old professional Australian Football League player [83]. Hapa et al. performed a cadaveric study to define the rectus femoris origin [84]. They noted a consistent bare area, devoid of rectus femoris tendon at the anterior and inferomedial aspect of the AIIS. The authors also reported on 163 patients undergoing arthroscopic treatment of FAI associated with sub-spine impingement [84]. They found significant clinical improvements postoperatively at a mean follow-up of 11.1 ± 4.1 months. Importantly, none of the patients developed hip flexion weakness or rectus femoris avulsions following decompression limited to the AIIS bare area. A retrospective review comparing 26 soccer players (34 hips) and 87 non-kicking athletes (115) hips showed that 84% of soccer players demonstrated some abnormality of the AIIS extending to (type II, 52%) or below the anterior acetabular rim (type III, 32%), compared with 52% non-kicking athletes ($p < 0.001$). Despite displaying significant AIIS hypertrophy, the soccer group reported postoperative outcome scores consistent with scores of the non-kicking control group ($p < 0.001$) at a mean follow-up of 35 months (range 24–57 months) [85]. The authors noted fewer interportal capsular closures performed among soccer players. This may relate to the fact that extensive debridement of the sub-spine often results in removal of the proximal portion of the capsule, limiting the ability to perform a capsular repair. Despite this, the study suggests that with consistent recognition of sub-spine impingement and appropriate decompression without jeopardizing the rectus femoris insertion, kicking athletes with this problem may expect favorable outcomes.

8.6 Cam-Type Impingement in the Athlete

One of the major goals of FAI surgery is to alleviate the abnormal biomechanical conflict between the femoral head-neck junction and acetabular rim caused by cam-type impingement. The clinical diagnosis of symptomatic cam-type impingement is made using a combination of patient history, focused physical examination, radiographic assessment, and pain relief following an intra-articular hip injection. At the time of surgery, systematic examination of the central compartment of the hip is first performed to identify pathologic changes associated with cam impingement, as discussed in the previous section of this chapter. Next, an examination of the peripheral compartment of the hip is performed according to the Sect. 8.4.1.

With the arthroscope in the anterolateral portal, the distal anterolateral accessory (DALA) portal is created using the Seldinger technique [86], and a T-capsulotomy is completed to facilitate multiplanar deformity correction of the cam morphology. The location of the T-capsulotomy is determined using fluoroscopic guidance ensuring adequate access to both the anterior and lateral portions of the cam morphology. The T-capsulotomy extends from the femoral head-neck junction to the intertrochanteric line, incising the iliofemoral ligament between the gluteus minimus and iliocapsularis muscles. Care is taken to not extend the T-capsulotomy beyond the zona orbicularis. The area of cam impingement is visualized at the anterolateral femoral head-neck junction (Fig. 8.3a). In the setting of chronic impingement, full-thickness cartilage lesions are often noted with additional osteophyte formation. The extent of the cam morphology is appreciated with dynamic examination of hip motion at the femoroacetabular interface. Preoperative planning is critical as significant variability in magnitude and location of the cam morphology can exist between patients. This was supported by a case series of 44 butterfly-style hockey goalies compared to a matched group of 26 hockey position players. The authors showed that the maximum alpha angle was significantly higher in goalies (80.9° vs 68.6°; $p < 0.0001$), and the cam morphology was located in a more lateral head-neck position (1 vs 1:45 o'clock; $p < 0.0001$) compared to position players [56]. Thus, the surgery (the location and amount of cam resection) should be tailored to the presenting pathology.

Appropriate resections based on intraoperative fluoroscopic imaging can help to avoid inadequate or overzealous resection, which could result in residual impingement or iatrogenic fracture and/or loss of the labral seal, respectively. A study of 50 consecutive hips (48 patients) comparing fluoroscopic images to radial reformatted CT using a 3-D software program showed that specific fluoroscopic views allowed for evaluation of the medial and lateral femoral head-neck junction (extension views) and anterior and posterior head-neck junction (flexion views) [87] (Fig. 8.4a–d). The results demonstrated reproducibly to characterize the topography of the cam morphology

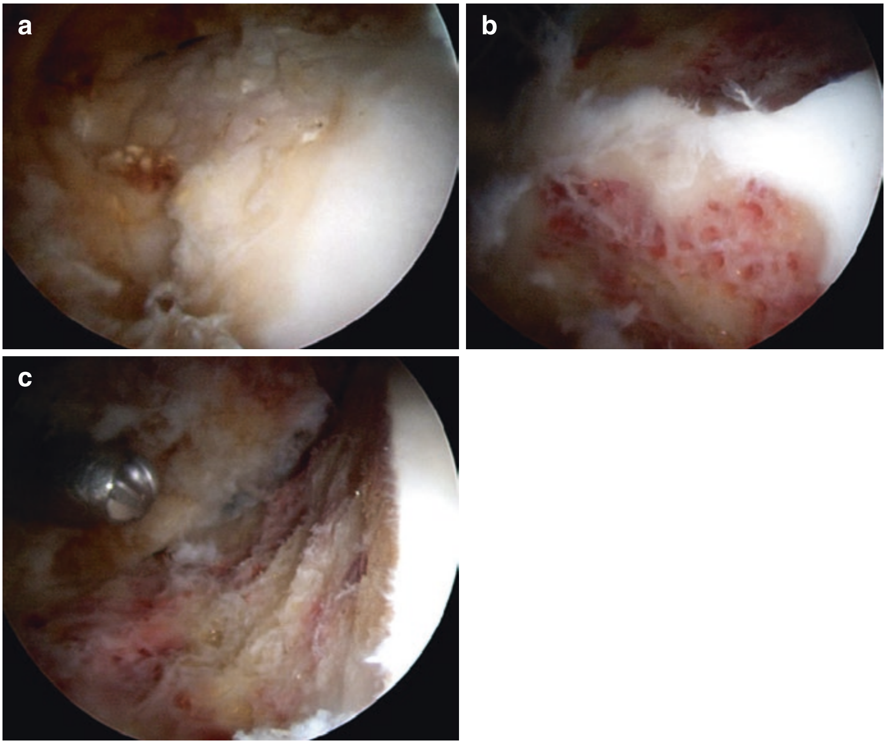

Fig. 8.3 Arthroscopic view of the peripheral compartment of the right hip. (**a**) Anterolateral cam lesion. (**b**) A section of the cam morphology remains between the resected anterior and lateral portions of the cam. (**c**) Final view showing complete cam resection

from the 11:45 to the 2:45 o'clock positions, which covers the areas of the maximum alpha angles that are most commonly seen. The AP internal rotation view is also able to localize cam morphologies that are posterior to the 12:00 o'clock position with is the region most commonly missed during arthroscopic resection [88].

Fluoroscopic guidance results in the transmission of ionizing irradiation to the patient and entire operating room staff. Although recent studies have demonstrated that fluoroscopy-assisted hip arthroscopy entails safe levels of radiation [89, 90], there remains a particular concern for both the younger population undergoing FAI surgery and the operating room personnel with cumulative career exposure. Therefore, a systematic approach, with knowledge of the deformity location and the respective fluoroscopic views that require attention, is important to minimize the radiation dosage.

Once the region of the cam morphology has been adequately defined, surgical resection of the lesion can proceed to restore the normal head-neck offset of the proximal femur (Fig. 8.3b, c). Starting at the level of the physeal scar, a 5-mm round burr is used to transform the convexity of the lesion into a concave surface. The depth and width of the resection are determined by the native anatomy (i.e.,

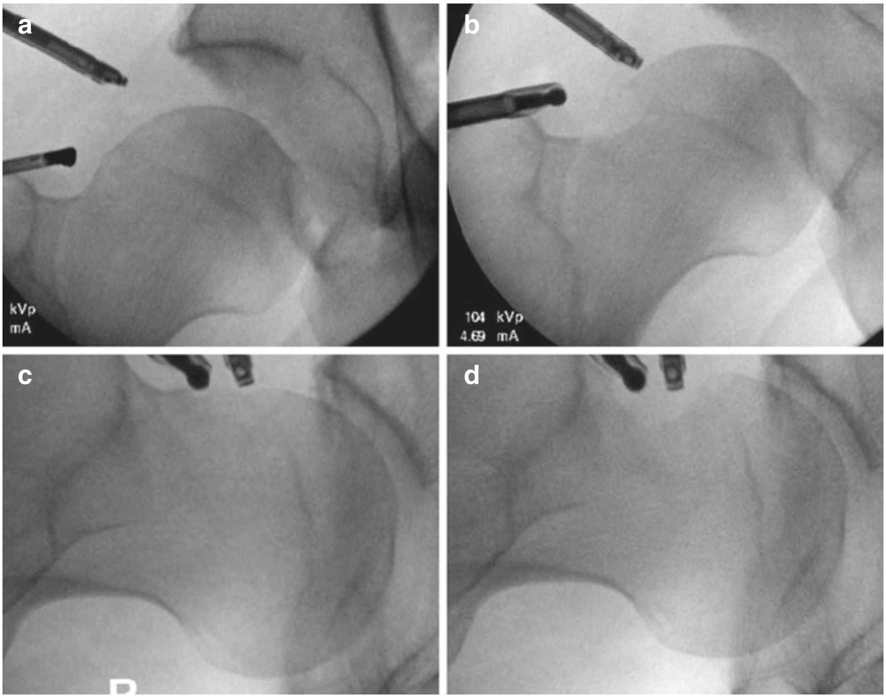

Fig. 8.4 Patient example of visualization and correction of the cam morphology with fluoroscopic views of the right hip. (**a**) AP internal rotation image demonstrating the lateral extent of the cam morphology. (**b**) Post-resection AP internal rotation image. (**c**) Flexion 40° external rotation image showing the anterior extent of the cam morphology. (**d**) Post-resection flexion 40° external rotation image

retinacular vessels) and the amount of surface area of impingement. Generally, the resection is 5–7 mm deep and 8–12 mm wide [91]. The resection is performed along the anterior femoral head-neck junction from inferior (6-o'clock position) to superior (12-o'clock position). The amount of bone to resect during FAI surgery is debatable. Neumann et al. advocated for an alpha angle restoration of 43° post-osteochondroplasty to ensure impingement-free motion of 20–25° in internal rotation at 90° of hip flexion [92]. However, the amount of resection must be approached cautiously, as over-resection may both predispose to iatrogenic femoral neck fracture and compromise the ability to maintain a labral seal with hip flexion [93]. Resection of the cam morphology to a maximum of 30% of the femoral neck diameter is the current accepted parameter, being mindful that additional factors such as older age and lower bone quality (osteopenia or history of osteoporosis) further limit resection. A systematic review reported improved patient outcomes with a postoperative alpha angle restored to less than 55° [94]. However, a cohort study examining 3-D CT navigation for FAI correction suggested that the alpha angle does not in fact correlate with outcomes [95]. Brunner et al. found no statistical differences in non-arthritic hip scores, visual analogue scale (VAS) pain scores, and hip motion in patients that did not achieve an alpha angle correction <50° or mean difference of 20° from pre- and postoperative values. However, with relatively small sample sizes, it is unknown whether this study was sufficiently powered to make definitive conclusions. Ultimately, which ever strategy the surgeon uses, a reliable and systematic approach is needed to ensure adequate resection given that incomplete cam resection is the most commonly cited reason for revision arthroscopic hip surgery [96]. This finding was further supported by a systematic review that found cam-type impingement (37.2%), either unaddressed or inadequately addressed, was more commonly the cause for revision when compared with pincer-type impingement (26.4%) [97]. In a cohort of 79 patients (85 hips) with a mean age of 29.5 years who underwent arthroscopic revision FAI correction found that 90% of cases demonstrated residual cam-type femoral morphology with inadequate head-neck offset, most commonly at the superoposterior/lateral location [88].

In summary, our approach is to resect sufficient bone to achieve an alpha angle correction of 55° or less or to obtain a 20° difference from the preoperative measurement. We then confirm impingement-free range of motion intraoperatively with rotation of the hip. Following resection, we will consider inserting a prophylactic 7.3 mm screw to prevent femoral neck fracture in cases of relative osteopenia.

8.7 Arthroscopic Capsular Management in FAI

Arthroscopic hip capsular management in FAI is controversial. After all central and peripheral compartment work has been performed, the capsulotomy can be either left open, partially repaired, or completely repaired. Historically, capsular management consisted of capsulotomy or capsulectomy. Early outcome studies reported good short-term results with these techniques [98, 99]. More recently, several authors have reported cases of instability after hip arthroscopic surgery for FAI, including frank hip dislocation [100, 101]. Determining if instability after arthroscopic hip surgery is iatrogenic (i.e., from excessive capsulotomy or capsulectomy) versus traumatic or is a result of generalized ligamentous laxity is difficult to conclude. There remains limited evidence for how capsular repair contributes to outcomes after arthroscopic surgery for FAI. A retrospective case series of 51 recreational and competitive runners with FAI treated with capsular plication reported a return to running rate of 94% at a mean of 8.5 months after hip arthroscopy [102]. A retrospective comparative study showed that patients undergoing primary arthroscopic hip surgery for FAI experienced superior clinical outcomes and lower revision rates with complete capsular closure as opposed to partial capsular closure (mean follow-up 29.9 months) [103].

The presence of increased mobility needed for flexibility sports is important to appreciate when managing FAI. Flexibility athletes (dance, cheer, figure skating, gymnastics) are often female, may have a mild amount of dysplasia and/or soft-tissue laxity, and subject their hips to supraphysiological motions [104, 105].

Athletes participating in flexibility sports often depend on physiologic joint hypermobility, and thus capsular tightening procedures may be detrimental to their ability to return to sport. Although our understanding of the role of the hip capsule for maintaining joint stability has evolved, a recent systematic review found no consistent indications for routine versus selective capsular closure [106]. The technical details on strategies pertaining to capsular management will be the focus of another chapter of this book.

8.8 Outcomes of Arthroscopic Management of FAI in Athletes

Multiple case series have reported high rates of return to sport following arthroscopic management of FAI in the athlete. A systematic review of a total of 418 athletes treated surgically for FAI reported that the rate of return to sport and the rate of return to pre-injury level of sport were 92% and 88%, respectively [107]. Factors influencing the rate of return to sport include both the type of sport and level of competition, as well as the severity of pre-existing damage to the hip joint [108]. Previous studies have indicated that professional athletes demonstrate a higher return to sport rate than recreational athletes. A retrospective case-control study of 74 patients found that athletes undergoing FAI correction and labral preservation did better than non-athletes in terms of patient-reported outcomes at 24 months after surgery [109]. A prospective study that compared 40 professional athletes (PA) to 40 recreational athletes (RA) (mean age, 35.7 years) following hip arthroscopy for FAI showed that the mean time to resume sporting activities was 5.4 months, which was lower for PA (4.2 months) as compared with RA (6.8 months). Eighty-two percent (66 patients) (PA = 88% versus RA = 73%) returned to their pre-injury level of sport within 1 year of surgery [110]. A similar trend was identified by Byrd and Jones who examined a cohort of 200 patients with FAI undergoing hip arthroscopy and reported a 95% return to sport rate for professional athletes compared with an 85% return for intercollegiate athletes [111]. A higher return to sport rate was also identified by Nho et al. who reported an 83% return for professionals compared with just 59% for intercollegiate athletes at a minimum 1-year follow-up [112]. However, it is important to appreciate that professional athletes are conditioned to play through pain and have different incentives to return to sport than amateur athletes. Thus, patient-reported outcomes and rates of return to sport in professional athletes need to be interpreted with caution. The time to return to sport following arthroscopic hip surgery is variable in the literature. When polling 27 high-volume arthroscopic hip surgeons, Domb et al. reported return-to-sport recommendations ranged between 6 and 24 weeks [108]. In general, the timing of return to sport appears to be dependent on the population studied, the surgical procedure, and the type of postoperative rehabilitation.

Since the passing of Title IX in 1972, the percentage of female athletes participating in high-level sporting activities has seen a sharp increase. In the United States, 42% of high school participants and 43% of collegiate athletes in competitive sports are female [113]. As the female athletic population has increased globally, the number of female patients presenting with FAI syndrome has also risen [114]. Studies have shown that there is a difference in the type of FAI morphology seen between sexes, with male patients exhibiting a higher prevalence of cam-type FAI and female patients showing more pincer-type FAI [55, 57, 115, 116]. Female athletes tend to have more generalized ligamentous laxity and participate in sporting activities that require flexibility such as gymnastics, dancing, and ballet. Thus, the female population may also be more susceptible to symptoms associated with instability.

Limited data is available on the gender-based differences in terms of the rate of return to pre-injury level of sport after arthroscopic hip surgery. A retrospective cohort study of 98 elite athletes (49 female) who underwent arthroscopic hip surgery showed that 84.2% of female athletes and 83.3% of male athletes were able to return to the same level of competition at a mean of 8.3 ± 3.0 and 8.8 ± 2.9 months, respectively [117]. Female athletes had more pincer-type FAI ($p = 0.0004$) and instability ($p < 0.0001$). Conversely, male athletes were diagnosed more commonly with combined FAI ($p < 0.0001$), demonstrated greater acetabular chondral damage ($p = 0.0004$), and more often required microfracture ($p = 0.0014$). Female athletes competed more frequently in flexibility (4/38, 11%; $p = 0.047$) and endurance (9/38, 24%) sports, while male athletes participated in more cutting (14/42, 33%) and contact (6/42, 14%) sports.

FAI is generally managed non-operatively before surgical treatment is considered, and the timing of non-operative management is variable. In a study of 525 patients, Aprato et al. reported significantly higher 1-, 2-, and 3-year postoperative clinical outcomes for patients with symptoms for less than 6 months [118]. The investigators proposed that patients who have delayed surgery are at increased risk for the developing high-grade chondral lesions. This finding was supported by Claßen et al. who demonstrated a positive relationship between chondral lesions and duration of symptoms before surgery [119]. In a case series of 60 professional hockey players that assessed predictors of career longevity following hip arthroscopy for FAI found that players who played <5 years after arthroscopy had a significantly longer duration of symptoms before surgery than compared with those who played ≥5 years (20.2 vs 9.3 months, respectively) [120]. Thus, improved surveillance and communication with frontline primary care physicians are needed to prevent unnecessary delays in diagnosis of FAI that may negatively impact postoperative outcomes and the rate of return to pre-injury level of sport.

8.9 Conclusion

Although there is convincing evidence that participation in high-impact activities during skeletal growth is a risk factor for cam morphology, not all patients who acquire this deformity will develop symptoms of FAI. Future research is needed to better understand the genetic, environmental, and biomechanical factors that cause subpopulations with various types and magnitudes of FAI morphology to develop pain and limitation in physical activity.

Over the past decade, the ability to perform arthroscopic acetabuloplasty, labral re-fixation, and articular cartilage restoration has likely had a positive effect on the outcomes of cam decompression. It has clearly been shown that incomplete treatment of all the associated pathologies, especially treating labral tears without addressing the FAI pathology, results in potential recurrence of symptoms. Contemporary results of arthroscopic procedures for FAI in the athletic population are emerging with early positive reports. However, longer-term studies that continue refine indications and techniques will enable improved clinical decision-making.

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Conflicts of Interest None

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9 Arthroscopic Management of Chondral and Labral Injuries

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9.1 Chondral Pathology

9.1.1 Athlete Selection

Chondral hip pathology in athletes is recognized as a source of hip pain that can occur acutely from traumatic subluxation or dislocation or can present as a result of mechanical wear in the setting of dysplasia and femoroacetabular impingement (FAI) [1–3]. Although the true prevalence of chondral defects of the hip in the athletic population is unknown, chondral lesions are associated with other hip conditions such as labral tears, loose bodies, hip instability, or abnormal acetabular coverage (i.e., pincer-type FAI or hip dysplasia). Furthermore, longer duration of symptoms (>2 years) is associated with higher-grade lesions [4].

In a recent review of hip arthroscopy in professional US athletes, the procedures comprised osteoplasty in 22.9%, debridement in 9.3%, loose body excisions in 7.9%, and microfracture in 5.7% of athletes [5]. In light of these co-existing conditions, it is difficult to assess the actual impact of cartilage damage in the global health of an athlete's hip. However, there is general consensus that full-thickness cartilage lesions are likely to progress in size and lead to further joint degeneration, ultimately impacting player performance and overall activity. With this in mind, cartilage lesions in the hip warrant careful consideration and management.

The majority of athletes who present with hip pain will more frequently have some sort of FAI variant and/or labral pathology. While certain clinical exam findings are helpful to identify these pathologies, exam findings for chondral pathology are largely

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non-specific. However, if an athlete can recall an inciting event to their hip pain, such as direct contact to hip from forced abduction-external rotation or adduction-internal rotation, it may suggest an acute subluxation of the hip, which should raise suspicion for a chondral injury. Despite limited diagnostic value for chondral pathology, a thorough clinical exam and plain film radiographic parameters should be assessed to determine other underlying hip pathologies that should be addressed [6].

Preoperative assessment with MRI and MRA is helpful to determine location and severity of chondral lesion to help with diagnosis and surgical planning. Chondral lesions are more frequently located in the acetabulum (70–90%), especially the anterior-superior and posterior quadrants of the acetabulum (3–9 o'clock position), and less often in the superior aspect of the femoral head [6]. If a lesion is suspected outside of a weight-bearing portion of the hip, it is important to confirm pathology in other structures such as the labrum and ligamentum teres. In a systematic review, Smith et al. calculated a sensitivity and specificity of 59% and 94% for MRI and sensitivity and specificity of 62% and 86% for MRA in overall detection of chondral lesions. These numbers varied slightly based on acetabular and femoral lesions, but ultimately the authors concluded that the diagnostic accuracy of MRI is superior to that of MRA in the detection of chondral lesions [7]. At our institution, the use of non-contrast 3-T MRI with standard orthogonal fields of view, axial, coronal, and sagittal, complemented by fat-suppressed T2 imaging to optimize subchondral bone edema capture is utilized. Despite improvement in advanced imaging technology, diagnostic hip arthroscopy remains the gold standard for determining chondral lesion size and severity. Thus, surgeons should be prepared to adapt their surgical plan if the intraoperative findings do not match the preoperative MRI.

Conservative management of chondral lesions includes NSAIDs, physical therapy, and intra-articular injections. Although little data exists on the benefit of these interventions, we recommend a 12-week trial of non-operative therapy prior to surgical intervention.

9.1.2 Arthroscopic Treatment: Chondral Lesions

9.1.2.1 Surgical Technique

For arthroscopic management of hip chondral lesions, the patient is positioned supine in a traction table as previously described [8]. Preferred portals include the anterolateral (AL) and modified anterior portals (MAP) (Fig. 9.1) [9]. During initial diagnostic arthroscopy [10], chondral lesions are identified, and appropriate intervention is subsequently planned. Portal placement will vary based on the location of the chondral lesion (Table 9.1)

Although multiple options exist to address chondral pathology, current indications for chondral preservation techniques about the hip remain unclear, and many have been extrapolated from accepted principles used for knee chondral pathology and are therefore not hip-specific [6, 11]. For instance, one of the most common indications for hip arthroscopy is the cam-type FAI, which often presents with concomitant

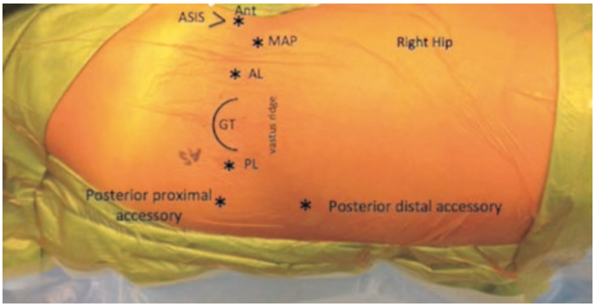

Fig. 9.1 Clinical picture depicting common portals utilized for hip arthroscopy and anatomic relationships

Table 9.1 Preferred instrumentation portal based on location of chondral lesion

Portal	Location of lesion
Anterior/modified anterior	Anterior central compartment
Anterolateral	Superior central compartment
Posterolateral	Posterior central compartment

acetabular chondral defects and differs substantially from the pathomechanics of chondral lesions observed in the knee [6, 12]. Despite great advancements in technique and orthobiologics, there remains a great degree of variability in the literature supporting specific modalities to address chondral lesions in the hip.

9.1.2.2 Chondroplasty

Arthroscopic chondroplasty is the most common technique utilized for the management of chondral lesions in the hip [6]. Chondral flaps with remaining articular cartilage and low-grade chondral defects (Outerbridge grades I–III) are generally treated with chondroplasty alone. However, there are no current guidelines for surgeons to determine when the size or location of the lesion may warrant more involved procedures. Chondroplasty can be performed with mechanical shavers or thermal chondroplasty with radiofrequency energy (RFE). Proponents of thermal chondroplasty propose that stabilization of focal lesions with a plasma layer of conductive fluid provides better cartilage smoothness and stiffness compared to the use of a mechanical shaver [13]. In contrast, others have reported that RFE is associated with potential chondrocyte death and should be used with caution [14, 15]. A direct comparison of RFE versus mechanical chondroplasty by Barber et al. demonstrated no significant differences on MRI assessment of subchondral damage (i.e., avascular necrosis) of the hip at 12 months following either modality in the management of high-grade chondral lesions (Outerbridge grade III) [16]. We recommend limited use of RFE in managing chondral hip pathology due to risk of thermal necrosis of healthy tissue.

9.1.2.3 Microfracture

Microfracture techniques have been extensively described both in general population and elite athletes [17, 18] (Fig. 9.2). Current indications for microfracture in the hip have evolved from what originally were taken from the knee literature (Outerbridge grades III and IV, lesion size <400 mm^2) [19]. Reported indications for hip microfracture include full-thickness loss of articular cartilage, Outerbridge grades III and IV, lesions in weight-bearing areas or in area of contact between femoral head and acetabulum, focal and contained lesions measuring less than 200–400 mm^2 in size, and unstable lesions with intact subchondral bone [2, 12, 20–24]. However, microfracture has been reported on lesions ranging from 20 to 750 mm^2, and although some authors argue that microfracture should not be limited to smaller lesions (<400 mm^2), we recommend that large chondral lesions (>400 mm^2) are likely to benefit from augmentation with chondral allograft or autograft [6, 19].

Reports describing the quality of the repair tissue in the hip during second-look hip arthroscopy have demonstrated that at an average 20-month follow-up, 93.1% of patients had a 75–100% fill of the defect with good repair quality [23, 25]. Limited histological analysis of these patients demonstrated primarily fibrocartilage with randomly arranged collagen fiber bundles throughout the extracellular matrix.

Technical Pearls: Debridement and Microfracture for Hip Chondral Lesions

- Chondral lesion edges should be stable.
- Subchondral plate should be lightly decalcified with curettage.
- The microfracture perforations should be 2–4 mm apart to prevent combining the holes.
- Is the setting of a chondral lesion adjacent to a torn labrum, it is important to repair the labrum first to create a stable margin and contained defect.

Fig. 9.2 Nonanatomic arthroscopic image demonstrating microfracture technique for management of high-grade acetabular chondromalacia. Note the spacing between microfracture perforations (2–4 mm)

9.1.2.4 Outcomes

Few studies in the literature have reported on outcomes following hip arthroscopy for chondral lesions in professional athletes. Singh et al. reported a 100% return to play rate on Australian football players with full-thickness, discrete (<300 m^2) acetabular chondral lesions located at the chondrolabral junction [26]. McDonald et al. demonstrated a return to play rate of 77% following hip arthroscopy with or without microfracture [2]. Athletes who underwent microfracture for discrete, Outerbridge grade IV chondral lesions had similar postoperative scores and return to play rates when compared to those who did not require microfracture. Interestingly, the average age of those athletes who did not return was 31.6 years compared with 29.9 years for those who did return. Although this small difference did not reach statistical significance, the authors argue that 1.7 years may be noteworthy in an athlete's career. Similar findings were reported in a retrospective review by Schallmo et al., with a return to play rate of 69.2% after microfracture compared to 85.5% without microfracture, which was not statistically significant ($p = 0.121$). The authors also noted that players who returned were younger (28.5 ± 4.0 vs 31.3 ± 4.3 $p < 0.001$) and played fewer years prior to surgery (7.4 ± 4.6 vs 10.0 ± 5.9, $p = 0.004$) [5]. Team physicians should encourage players to seek medical evaluation early after symptoms present to potentially minimize the risk of chondral lesion progression.

As previously mentioned, chondral lesions are commonly associated with FAI. Philippon et al. reported 47% ($n = 21/45$) of professional athletes with FAI had an associated grade IV acetabular chondral defect, while 38% ($n = 17/45$) had at least a grade I–III acetabular chondral lesion [27]. In this same cohort, 7% ($n = 3/45$) had a grade IV femoral head chondral lesion, and 24% ($n = 11/45$) had at least a grade I–III femoral chondral lesion. High-grade lesions were more often treated with microfracture and low-grade lesions with chondroplasty. The authors reported a return to play rate of 96%. At 1.6 years after hip arthroscopy, 78% remained active at a professional level. Although encouraging, it is difficult to assess the impact of either chondroplasty or microfracture on the management of chondral lesions in this patient population that required varying types of intervention, including treatment for FAI and labral tears [27].

9.1.2.5 Future Directions in Management of Chondral Lesions in the Hip

Microfracture augmented with platelet-rich plasma-infused micronized allograft cartilage has recently been implemented as an alternative to microfracture alone for the management of high-grade chondral lesions during hip arthroscopy [28]. From a technical standpoint, it is important that any additional intra-articular pathology is addressed before allograft placement, with special care to ensure that the margins around the defect are adequate to hold the marrow clot and graft (Fig. 9.3a–c).

Other techniques described for chondral lesions include autologous chondrocyte transplantation (ACT) [29, 30], fibrin adhesive [31, 32], and retrograde osteochondral autologous transplantation [33]. There are limited reports in the literature for their use, and none have been reported on athletes. To date, there are no studies comparing the indications or clinical outcomes between different techniques

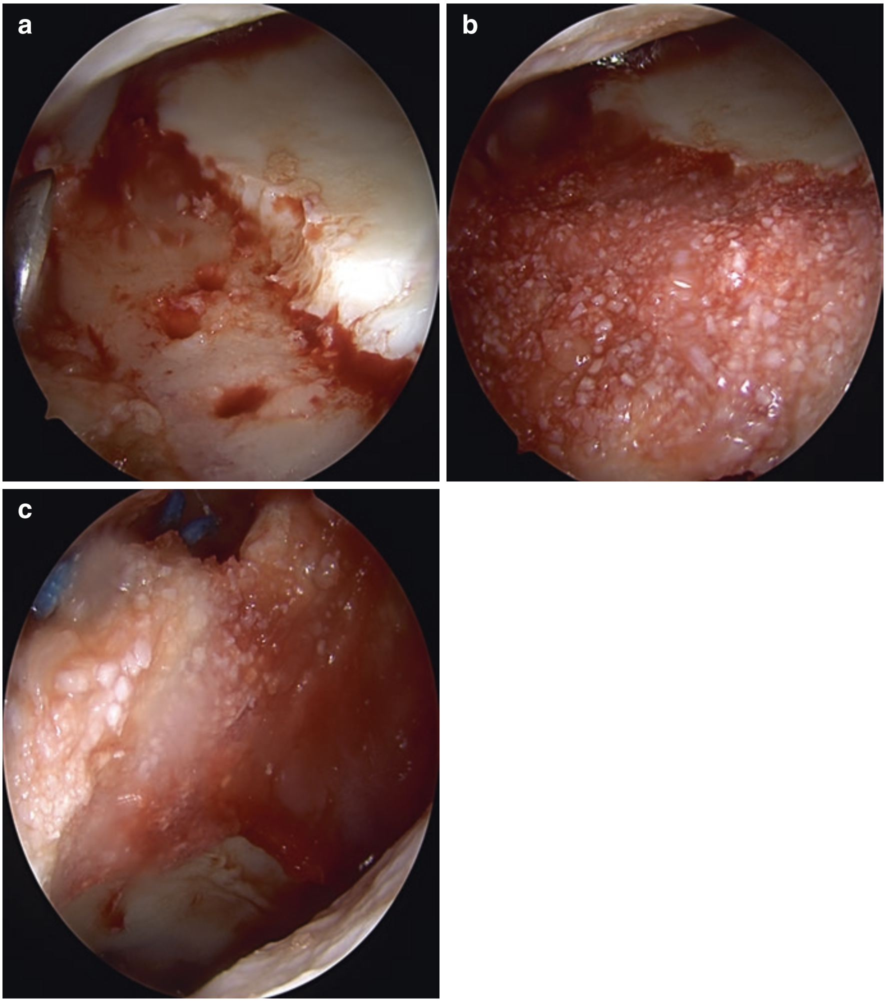

Fig. 9.3 Arthroscopic images demonstrating management of acetabular high-grade chondral lesion with (**a**) microfracture (nonanatomic view) and [**b** (nonanatomic view) and **c** (anatomic view)] micronized cartilage allograft. Note associated labral repair to create stable rim around defect

targeting chondral lesions. In a systematic review by Marquez-Lara et al., the authors demonstrated that on average, lesion size was significantly larger in ACT-treated patients compared with those who underwent microfracture (357.3 ± 96.0; range, 180–600 mm^2 vs 149.5 ± 20.7 mm^2; range, 20–378; $P = 0.020$). All techniques were associated with improved postoperative patient-reported outcomes; however, no differences were found between techniques at an average of 28.8 months. Although there is a growing body of literature in the management of complex chondral lesions in the hip, the majority of what is known about the management of chondral pathology stems from the knee literature [6]. Further understanding of hip chondral pathology and continued advancement in hip arthroscopic techniques and instrumentation will ultimately help develop hip-specific indications for treatment of chondral lesions.

9.2 Labral Tears

9.2.1 Athlete Selection

The prevalence of labral tears in professional athletes varies in published literature. Narvani et al. reported a 22% prevalence of labral tear in athletes complaining of groin pain [34]. In contrast, Silvis et al. reported a prevalence of 56% in asymptomatic hockey players [35]. Although the clinical significance of labral tears is only partially understood in athletes, biomechanical hip research suggests that an intact labrum helps optimize hip joint stability by increasing the overall acetabular depth by 21% and contact surface area by 28% [36, 37]. Given the physical stresses observed in the hips of elite athletes, the presence of an intact labrum is critical to player performance; consequently, labral repair is frequently performed in athletes undergoing hip arthroscopy [5]. More specifically, Schallmo et al. reported that since 1999, labral repair was the most common procedure (73.1%) performed in professional US athletes undergoing hip arthroscopy [5].

The clinical presentation of athletes with labral tears is variable, and a high level of suspicion is warranted to prevent delay in diagnosis and treatment. Groin pain is the most common complaint, which worsens with activity. Other symptoms, including night pain and the sensation of the hip giving way with running, are associated with labral tears [38]. In addition to an athlete's history, a thorough physical exam will further help elucidate the presence of symptomatic labral pathology. The anterior flexion-adduction-internal rotation (FADIR) impingement test is performed with the affected hip flexed to 90° with passive adduction and internal rotation of the hip (Fig. 9.4). The FADIR test has a sensitivity that ranges between 59% and 100% and specificity of 43% [34, 38, 39]. When testing for the less common posterior labral tears, the leg is positioned in extension, abduction, and external rotation (EABER test) (Fig. 9.5) [40].

Since 1999, plain radiographs and advanced imaging, such as magnetic resonance imaging (MRI) and magnetic resonance arthrogram (MRA) have experienced significant advancements in image quality, thereby, playing a critical role in identifying and characterizing a wide variety of hip pathologies. Plain radiographs allow surgeons to assess the hip morphology. Multiple views should be obtained including anteroposterior, cross-table lateral, Dunn, frog-leg lateral, and false-profile views [41]. Both MRI and MRA are useful in identifying labral tears; however, Smith et al. demonstrated that MRA is superior to MRI for detection of labral tears with sensitivity and specificity of 87% and 64% for MRA compared to 66% and 79% for MRI, respectively [7]. More recently, the emergence of 3-T MRI has allowed the ability to obtain highly accurate imaging (sensitivity 97.7%, specificity 100%) for the evaluation of intra-articular hip pathology without the need for contrast [42–44].

Fig. 9.4 Picture depicting flexion-adduction-internal rotation (FADIR) test to assess superior and anterior labral tears. The test is positive when the pain symptoms are reproduced with the maneuver

Fig. 9.5 Picture depicting the extension-abduction-external rotation (EABER) test to assess posterior labral tears

As mentioned above, we use a dedicated hip non-contrasted 3-T MRI with standard orthogonal fields of view, axial, coronal, and sagittal, complemented by fat-suppressed T2 imaging to optimize subchondral bone edema capture.

If a labral tear is suspected and clinical symptoms are mild with less than 3- to 6-month duration, non-operative management is an option. Conventional treatment includes nonsteroidal anti-inflammatory drugs (NSAIDs), intra-articular hip injections, and physical therapy. To our knowledge, there are no studies demonstrating a long-term benefit of conservative treatment for athletes with labral tears, and comparative studies between operative and non-operative management have demonstrated greater improvement following hip arthroscopy in non-athlete population [25]. However, early intervention may play a beneficial role in athletes. Philippon et al. demonstrated that hockey players with labral tears who underwent arthroscopic treatment within 1 year from the time of injury returned to sports earlier than patients who had surgery more than 1 year after injury [45]. Further studies are warranted to determine the benefit of conservative management for symptomatic labral tears versus early surgical intervention in athletes.

Most athletic hip labral tears are addressed through the anterolateral and modified anterior portals, which can be identified under fluoroscopic guidance or anatomic landmarks. Surgical options include labral debridement, repair, and reconstruction. Conserving the labrum (i.e., repair or reconstruction) results in better outcomes compared to resection [46–48]. In a meta-analysis of outcomes after partial labral resection with an average 2.5-year follow-up, patients demonstrated resolution of mechanical symptoms, a 31–40% improvement in the modified Harris hip score with reduction in hip pain seen in 91% of patients [49]. Biomechanically, Greaves et al. demonstrated that chondral stress is lower with an intact or repaired labrum, compared to labral insufficiency (tear or resection) [50]. As such, whenever possible, labrum refixation should be attempted. During debridement, it is important to try to preserve the capsular blood supply to the labrum and avoid resection at the capsular-labrum junction to optimize healing potential for tears near the capsular surface [35, 51, 52]. Unstable flaps should be removed to address potential mechanical impingement. At the end of debridement, the labrum stability should be tested. If deemed unstable, such as from a detached peripheral midsubstance tear, repair should be performed [53]. Occasionally, the labrum is calcified or significantly degenerated; in which case, repair or reattachment is not feasible. In those cases, a partial or total resection or segmental reconstruction is indicated (Fig. 9.6) [54, 55].

9.2.2 Arthroscpic Treatment of Labral Treatment: Repair

9.2.2.1 Surgical Technique

Once the labrum is determined to be amenable for repair, the labrum is mobilized from the acetabulum (Fig. 9.7a) with care not to further damage its fibers. This allows the surgeon to perform the necessary acetabular rim preparation or acetabuloplasty (Fig. 9.7b). Preoperative center-edge angle should be taken into consideration to avoid over-resection. Refixation of the labrum can be performed utilizing multiple described techniques [56–59]. Knot-tying may present a steeper learning curve during hip arthroscopy compared to knotless tying; however, a randomized controlled trial failed to demonstrate superiority of one repair technique over the other [57]. Jackson et al. compared an anatomic labral base repair (LBR) and circumferential suture. Both demonstrated positive outcomes; however, the authors suggest that the knotless suture anchor technique is easier and more reproducible

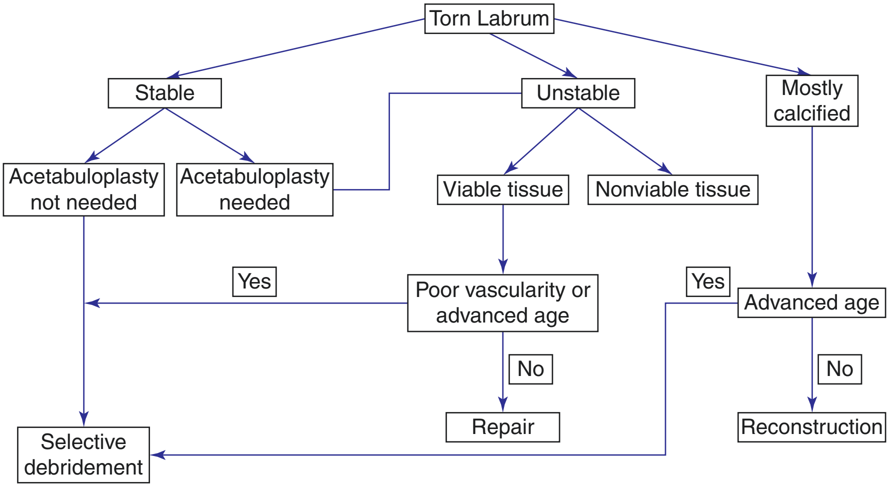

Fig. 9.6 Algorithm for management of labral tear (Adapted from Domb, Benjamin G., Hartigan, David E., Perets, Itay. Decision Making for Labral Treatment in the Hip: Repair Versus Débridement Versus Reconstruction. J Am Orthopaedic Surg. 2017, 25:3. p e53-e62)

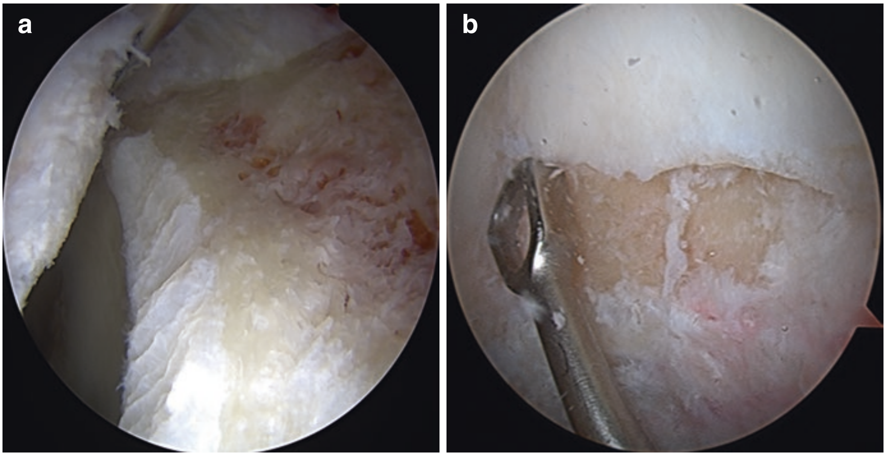

Fig. 9.7 Intraoperative arthroscopic image demonstrating (**a**) labrum peeled off acetabular rim and (**b**) scraping of acetabular rim in preparation of labral repair

for arthroscopic labral repairs [60]. Some of the stated advantages included shorter operative time and better tensioning control and handling of labral position during the repair. Other described techniques for labral repair include the looped or pierced techniques [58]. We recommend a combination of loop and pierced technique to balance the repair (Fig. 9.8a–d). A suture through the labrum will tend to invert the labrum, while a loop suture will tend to evert the labrum. Lastly, if utilizing a knot-tying technique, the knot must be placed on the capsular side to ensure that it does

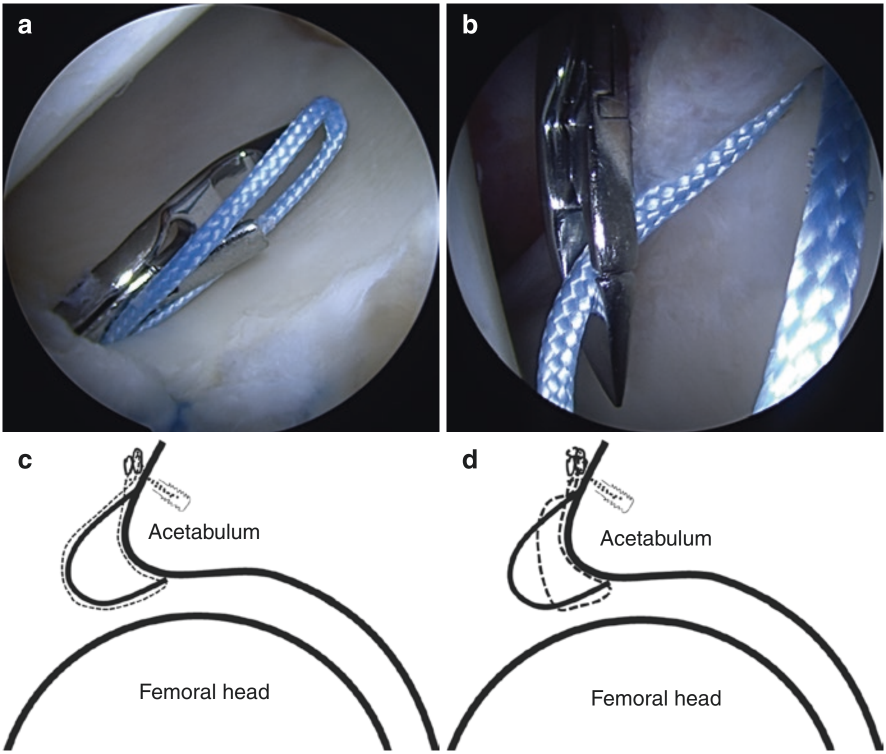

Fig. 9.8 Intraoperative arthroscopic image demonstrating labral repair utilizing a (**a**) penetrating suture retriever to pierce the suture through chondrolabral junction and (**b**) following with a loop over the labrum. Illustrations depicting an anatomic labral base repair technique passing the suture through the chondrolabral junction and either (**c**) around the labrum or (**d**) pierced through the labrum to achieve fixation. Alternating these two techniques helps eliminate bunching while securing the suction seal

not contact the adjacent articular cartilage (Fig. 9.9a, b). Regardless of the technique, surgeons should be aware of the acetabular rim angle to optimize suture fixation and minimize the risk of articular cartilage penetration [61]. The rim angle is defined as two straight lines of fixed length that start at the acetabular rim and touch the subchondral bone margin on one side and the outer cortex on the acetabulum on the other side. The acetabular rim angle is smallest at the 3 o'clock position; therefore, extra care must be taken when drilling or inserting anchors at this position. In addition, it is critical to prevent the labrum from pulling away from its native position during tensioning, in order to avoid causing disruption of the suction seal. After the repair is complete, traction is released, and the hip is ranged to assess labral stability and areas of impingement that may need to be addressed (Fig. 9.10).

There is a recent surge in the use of biologically augmented repairs for multiple orthopedic interventions. Current data is limited to retrospective reviews with small sample sizes, which makes it difficult to determine its efficacy and safety. During

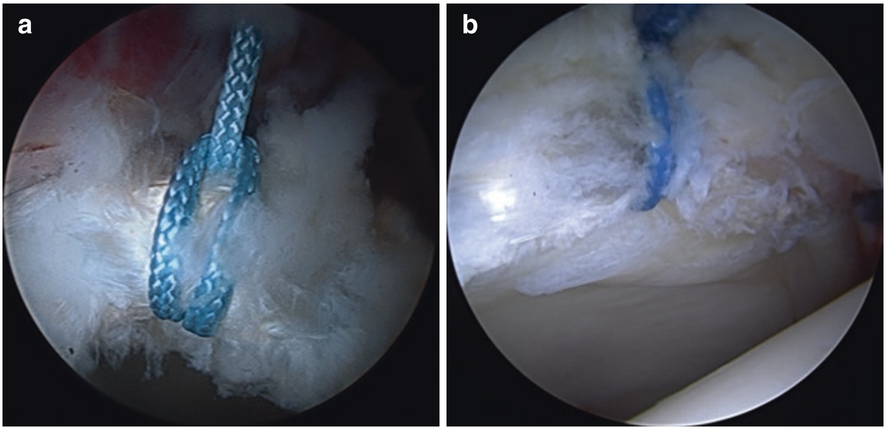

Fig. 9.9 Intraoperative arthroscopic image demonstrating (**a**) the knot is placed on the capsular side of the labrum and (**b**) final construct of labral repair prior to releasing traction assuring knots are not in contact with the articular surface

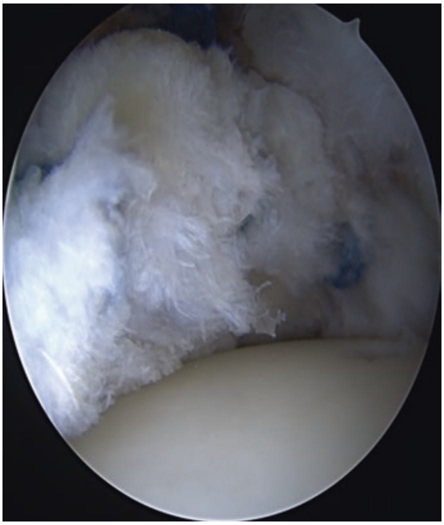

Fig. 9.10 Intraoperative arthroscopic image of final labral repair after release of traction. Note repaired labrum creating stable margin around femoral head without evidence of impingement

labral repair, the addition of platelet-rich plasma (PRP) to labral repair failed to demonstrate any significant clinical improvement [62]. As such, further research is warranted to better characterize the potential benefits of orthobiologics during hip arthroscopy.

9.2.2.2 Outcomes

There is limited data in the published literature comparing different treatment options for labral injuries, particularly in athletes. Menge et al. reported 10-year outcome data following hip arthroscopy for femoroacetabular impingement (FAI) comparing labral debridement versus repair [63]. Among patients with >2 mm of joint space, the median hip survival time was 3.2 years (minimum, 0.1 year) after labral debridement and 3.1 years (minimum, 0.5 year) after labral repair. Among patients who required acetabular microfracture, the median survival time was 3.1 years (minimum, 0.1 year) after labral debridement and 5.1 years (minimum, 0.5 year) after labral repair. The authors concluded that hip arthroscopy for FAI with either labral debridement or repair resulted in significant improvements in patient-reported outcomes and satisfaction. However, labral debridement was found to be associated with a significantly higher risk of progression to total hip arthroplasty compared with labral repair when the analysis was controlled for microfracture. The authors concluded that significant contributors to a lower rate of hip survival were older age, need for microfracture of the acetabulum, and a joint space of <2 mm [63]. Domb et al. reported 5-year outcomes following labral base repair (LBR) and demonstrated significant improvement in patient-reported outcomes, including mHHS (increase from 64.4 ± 13.8 to 85.3 ± 17.7 ($P < 0.001$), NAHS (increase from 63.7 ± 17.0 to 87.0 ± 14.7 ($P < 0.001$), and HOS-SSS (increase from 47.1 ± 23.2 to 76.5 ± 25.9 ($P < 0.001$) [64]. In this cohort, 9.4% of patients required subsequent total hip arthroplasty, and 17.2% required revision hip arthroscopy, all of which had intact labral repair, but symptomatic nonabsorbable sutures. Further research is warranted to determine if similar techniques and outcomes can be applied to elite athletes who present with symptomatic labral tears.

In a study of 45 professional athletes with FAI, 42 athletes (93%) returned to professional play following hip arthroscopy [27]. The remaining three players (1 football player, 1 hockey player, and 1 baseball player) had diffuse osteoarthritis at the time of primary arthroscopy. Five athletes (11%) required revision hip arthroscopy. Three underwent lysis of adhesions, and two had symptomatic treatment of extensive osteoarthritis. All of the patients who underwent revision surgery for lysis of adhesions returned to professional play, and the two with extensive osteoarthritis did not return to play. Thirty-five of the 45 athletes (78%) remained active at the professional level at an average of 1.6 years after hip arthroscopy [27].

Mohan et al. reported 2-year outcomes in young athletes (age range 13–23 years) following hip arthroscopy with labral repair and demonstrated a high rate of return (92%; 46/50) after hip arthroscopy while performing activities at near preinjury levels. The authors noted that arthroscopic labral repair with chondrolabral preservation, which reflected less severe chondrolabral pathology, performed better than labral repair with surgical takedown and reattachment [65].

As previously mentioned, labral tears are often associated with other hip pathologies including FAI and chondral defects, which often warrant addressing both soft tissue and bony and cartilage pathologies during hip arthroscopy [27]. The most common form of FAI is a mixed cam and pincer pathology characterized by structural abnormalities along the anterior femoral neck and anterior-superior acetabular rim resulting in chondrolabral impingement, particularly during flexion and internal rotation movements. In the series of 45 professional athletes (majority hockey players $n = 24$) with FAI reported by Philippon et al. [27], all athletes had associated labral tears. Twenty-five patients (56%) underwent either labral repair or refixation following rim trimming with suture anchors (average 1.3 anchors per patient, range 1–3). Labral repair was performed with suture anchors to repair detached labral tears or to refix the labrum following iatrogenic detachment for complete resection of pincer lesions. The previously described technique involved placement of the anchors high on the acetabular rim in the area of detachment [59]. Typically, one bioabsorbable anchor (BioRaptor, Smith+Nephew, Andover, MA, USA) was placed at the 12 o'clock acetabular position, and re-enforcement was placed either anteriorly or posteriorly in this area as needed. One limb of suture (Ultrabraid, Smith+Nephew, Andover, MA, USA) was passed between the labral tissue and the rim and was retrieved through the substance of the labral tissue. In cases of marginal labral tissue or in patients with highly degenerative, friable tissue, the suture was passed around the labral tissue. Standard arthroscopic knots fixed the repair to the rim. For midsubstance labral tears, a suture passer looped a 0-Vicryl around the torn tissue to approximate the edges of the midsubstance split.

9.2.3 Arthroscopic Labral Treatment: Reconstruction

9.2.3.1 Surgical Technique

When indicated, labral reconstruction offers good to excellent clinical outcomes [54, 66, 67]. However, it should be approached cautiously compared to repair or refixation. For instance, labral reconstruction reproduces 66% of the normal distractive stability of a native hip [68]. Furthermore, hip stability may be further compromised due to the greater rim resection and capsular disruption required for reconstruction compared to labral repair [69]. Finally, patients who require revision surgery following labral reconstruction may have limited hip preservation options, potentially resulting in young patients requiring total hip arthroplasty.

To prepare the autograft, a longitudinal incision is made over the greater trochanter, and a rectangular graft is harvested from the iliotibial band. Ideally, the tissue removed is 30–40 mm in width and 30% greater than the measured size of the defect in length. The graft is tubularized with absorbable sutures and introduced through the mid-anterior portal. A side-to-side anastomosis with the native labral stump is created. Additional anchors are placed at 5–8 mm intervals until the graft is secured to the acetabular rim (Fig. 9.11a–d). Traction is released and the hip taken through a dynamic range of motion examination to confirm that the labral graft is anatomic and the reconstructed labral seal is re-established [55].

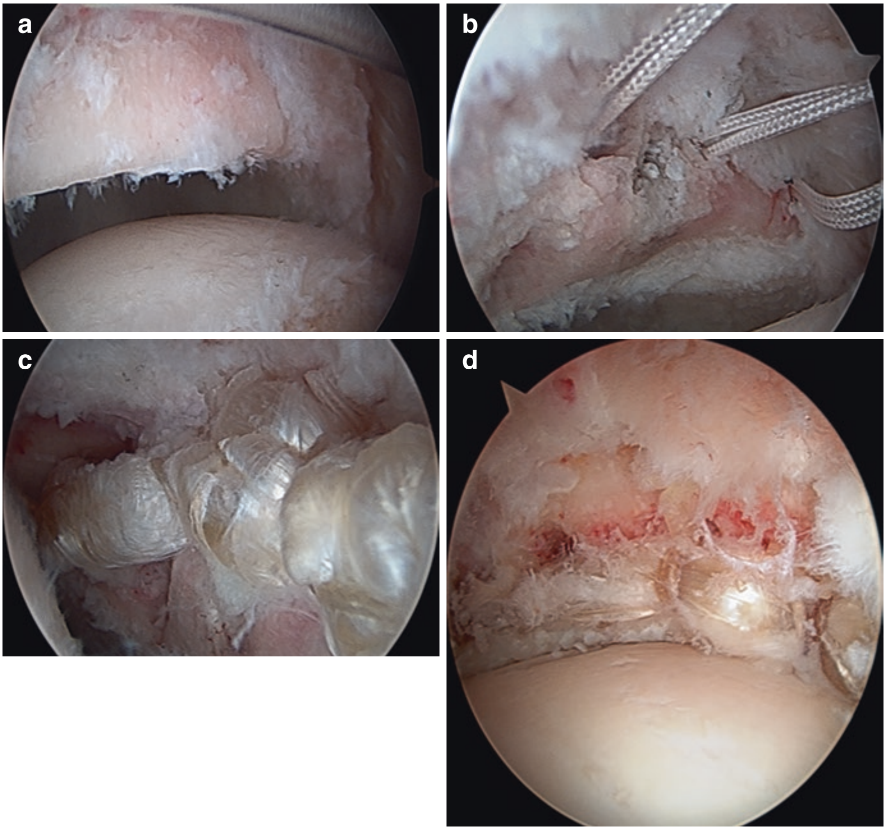

Fig. 9.11 Intraoperative arthroscopic image demonstrating (**a**) irreparable of anterior-superior labral tear. (**b**) Suture anchors are spaced at each hour interval, and then (**c**) the tubularized autograft is secured to the acetabular rim. (**d**) Traction is then released to confirm congruence of labrum to femoral head and assure no impingement

Technical Pearls: Labral Repair and Reconstruction

- Anchor management is critical for a good repair. The goal is to achieve one anchor per hour on the clock face.
- Suture placement around or through the labrum should be based on tissue quality.
- Labrum should be repaired anatomically. Avoid advancing the repair onto the acetabular face or everting the tissue.
- Knotted repairs should be placed on the capsular side of labrum.
- Capsular-labrum junction should be preserved whenever possible for optimal blood flow.
- During labral reconstruction, meticulous graft preparation will increase working time within joint.

9.2.3.2 Outcomes

Labral reconstructions in athletes are reserved for the management of irreparable labral tears or revision surgery after a failed labral repair (Table 9.2) [66, 70, 71]. However, more recently, labral reconstruction has been proposed as an alternative to primary labral repair [67, 72]. White et al. demonstrated a significantly lower failure rate following labral reconstruction compared to repair in patients who underwent bilateral hip arthroscopy (0% vs 29%). Although his comparative findings were encouraging, he reported a failure rate of 31% at 2 years, which is significantly higher than other reports in the published literature for primary labral repair [58, 63, 73]. While further research is warranted to clarify the indications and outcomes for labral reconstructions in athletes, publications on surgical techniques and graft options for labral reconstruction have continued to emerge (Table 9.3) [66, 67, 74–82]. Further, tendon allograft for labral reconstruction has shown to demonstrate early vascularization without evidence of necrosis at 8 weeks [81].

Although the published data is limited, labral reconstruction has demonstrated encouraging short- to midterm outcomes, with an average survivorship of 56 months with iliotibial band autograft; however, 24% of patients in the study eventually required total hip arthroplasty [75]. Furthermore, other clinical studies have demonstrated superior outcomes with labral reconstruction compared to debridement for the management of irreparable labral tears [71, 83]. Scanliato et al. recently

Table 9.2 Indications for labral repair versus reconstruction

• Repair – Translational instability and linear stability of labral rim cartilage – Subchondral bone quality supports suture anchor placement – Patient compliance with rehabilitation program
• Reconstruction – History of failed labral debridement/resection – Failed revision labral repair – Primary labral reconstruction in compliant patient with irreparable labrum and good chondral surface condition

Table 9.3 Graft options for acetabular labral reconstructions

• Autograft – Iliotibial band autografting – Quad tendon – Gracilis – Autologous capsule or indirect head of rectus tendon – Fascia lata
• Allograft – Iliotibial band – Peroneus brevis – Fascia lata – Semitendinosus – Gracilis

demonstrated comparable outcomes between labral repair and reconstruction, despite less favorable patient characteristics and worse hip pathology in the reconstruction group [66]. The labral reconstruction group was older (43.4 ± 10.7 vs 29.5 ± 11.0, $p = 0.01$) and more often required acetabular chondroplasty (88.9% vs 55.4%, $p = 0.01$) and synovectomy (60.3% vs 39.4%, $p = 0.01$). Despite these differences, there were no differences in the weighted analysis in postoperative patient-reported outcomes. At an average of 2 years, failure rate was 5% for the repair cohort and 8% for the reconstruction group ($p = 0.45$).

Labral reconstruction in elite athletes is limited to those patients in whom the labrum is found to be diminutive and inadequate for repair. An irreparable tear is one that completely disrupts the longitudinal fibers, thus leaving little functional tissue to repair. Reconstruction was also indicated if the labrum was hypotrophic, generally less than 5 mm in width [84].

Boykin et al. reported on 21 male elite athletes following labral reconstruction with iliotibial band allograft [55]. The authors reported a return to play rate of 85.7%, and all but one successfully returned to their previous level of play or better. Of the three who did not return to professional sports, two patients progressed to arthroplasty at 23 and 24 months, and one subsequently retired. With an average of 41.4-month follow-up, two patients required revision surgery for capsulolabral adhesions, who demonstrated good integration of the graft after the revision.

9.3 Postoperative Management: Rehabilitation and Return to Play

Postoperative protocols following hip arthroscopy are relatively standard and vary based on the type of procedure [85–89]. While there is no consensus, we use thromboprophylaxis in athletes undergoing hip arthroscopy. Our current protocol treats low-risk athletes (no history of DVT or clotting disorder) for 2 weeks post-surgery and high-risk athletes (history of DVT or clotting disorder) for 4 weeks post-surgery. In general, patients are limited to 10–20 lbs (20–30% of body weight) of flat foot weight-bearing for 3 weeks (6–8 weeks with concomitant microfracture) and progressed to weight-bearing as tolerated at week 4 [55]. To protect the iliofemoral ligament, an internal rotation night boot or bolster is worn for 10–14 days post-surgery. Further, to encourage a gradual return to activities of daily living, we utilize a daytime hip brace limiting range of motion, especially flexion, extension, and abduction, for 21 days.

One of common reasons for revision arthroscopy is postoperative capsular adhesions [84]. To prevent adhesion formation, hip flexor sparing physical therapy exercises should be started within 3–5 days after surgery. When available, we recommend continuous passive motion that is initiated on postoperative day 1 for 8 h/day, which should be continued for 2–8 weeks, the latter if microfracture is performed [55]. Active hip flexion is often limited for 3 weeks to prevent hip flexor tendonitis. Early rehabilitation is focused on gaining motion, strengthening the gluteus medius, rebalancing the hip musculature, and establishing a normal gait pattern.

General consensus regarding when players should return to full competitive activity ranges between 12 and 24 weeks [27, 72]. However, time to return is likely to vary based on the sport. Schallmo et al. reported on athletes from the four major US professional sports who underwent hip arthroscopy and demonstrated that Major League Baseball (MLB), the National Basketball Association (NBA), and the National Football League (NFL) players returned at an average of 222–243 days (31.7–34.7 weeks), while players from the National Hockey League (NHL) returned at 177 days (25.3 weeks) [5]. Although some reports appear to clear players at earlier times, the authors suggest that surgeons are likely to clear players based on pain and function, while "professional game play" data may represent the time needed for a player to reach a high level of performance.

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10 Hip Instability in the Athlete

Amit Nathani and Marc Safran

10.1 Introduction

The etiology of hip pain is often elusive. While the injuries associated with macro-instability of the hip following significant trauma have been well documented, the concept of more subtle instability patterns has only recently been described. Generally, hip instability is defined as extraphysiologic hip motion that causes pain with or without symptoms of hip joint unsteadiness [1]. In contrast to gross instability of the hip, microinstability is more poorly defined, has a far less dramatic clinical presentation, and lacks standardized objective evaluative criteria. The proposed pathomechanism (Fig. 10.1) of microinstability begins with subtle anatomic abnormalities in the presence of repetitive hip rotation and axial loading. This pattern of microinstability has been observed in athletes who participate in sports such as gymnastics, golf, martial arts, tennis, ballet, skating, football, and baseball [1, 2]. Alternatively, microinstability can result from inherent ligamentous laxity (i.e., Ehlers-Danlos or other hypermobility syndromes) and/or periarticular muscle weakness. Regardless of the etiology, microinstability leads to supraphysiologic motion of the femoral head relative to the acetabulum. This resultant increase in motion can lead to damage to the native labrum, now recognized as an important hip stabilizer, injury or attenuation to the capsuloligamentous complex (CLC) of the

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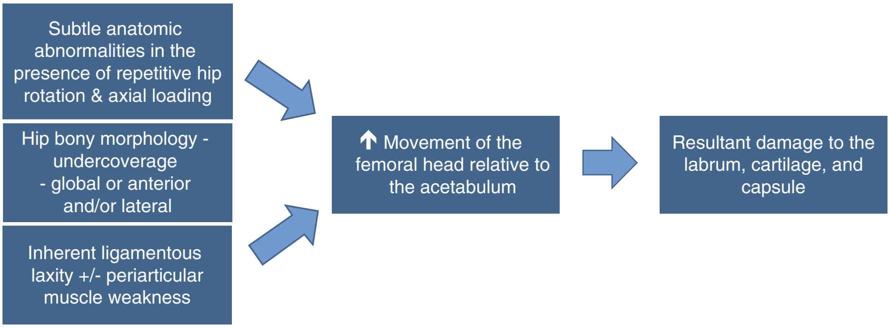

Fig. 10.1 Pathomechanics of hip microinstability

hip, or bony and chondral injury. Similar to other etiologies of labral-chondral injury, this raises significant concerns for the development of early hip degeneration and its associated morbidities.

10.2 Anatomy

The relative contributions of the bone and soft-tissue structures contribute to normal hip joint stability (Fig. 10.2). Traditionally, the hip has been considered highly constrained, relying heavily on assumed concentric bony congruence between the femoral head and acetabulum as the primary contributor to stability in all directions. More recent anatomic studies utilizing gross anatomic, imaging and finite element analysis have demonstrated more incongruence and asphericity than was previously assumed, suggesting that the role of soft-tissue structures to hip joint stability may previously have been underestimated or overlooked [3, 4]. Even under physiologic loads, dynamic MRI studies show there can be as much as 2–5 mm of translation of the hip joint center and flattening and widening of the weight-bearing surface [4, 5]. More specifically, Safran et al. demonstrated in a cadaveric model the center of the femoral head moves 3.4 mm in the medial-lateral plane, 1.5 mm in the anteroposterior plane, and 1.5 mm in the proximal-distal plane relative to the center of the acetabulum as the hip is taken through terminal motion [4]. The hip center likely translates even further during supraphysiologic motion. A recent motion capture study of 11 professional ballet dancers with morphologically normal hips showed that 4 typical ballet movements (développéá la seconde, grandé cart facial, grandé cart latéral, grand plié) caused hip center subluxation of up to 6.35 mm [6]. Recent studies have attempted to quantify the importance of the labrum, capsule, and ligamentous structures to joint stability, particularly as the hip moves through physiologic and supraphysiologic motion. It is clear that the interplay of bone and soft-tissue restraints to hip instability is complex, similar to other less congruous joints in the body like the shoulder, where microinstability is a well-established concept and damage to the bony and soft-tissue restraints is an accepted cause.

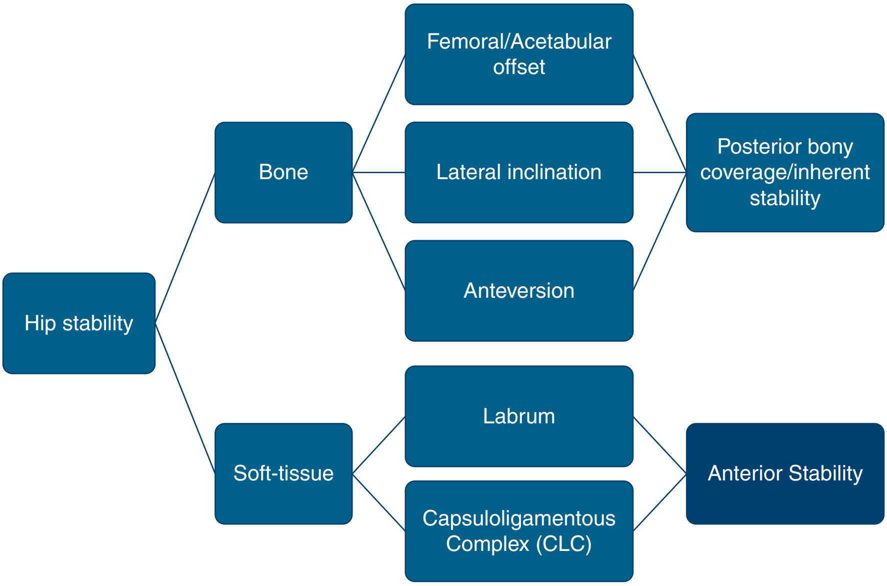

Fig. 10.2 The relative contributions of bone and soft-tissue structures to normal hip joint stability

10.2.1 Bone

Native bony morphology of the acetabulum and proximal femur contributes significantly to inherent hip joint stability, particularly in the posterior plane. The quasi-hemispherical shape of the acetabulum covers approximately 170° of the femoral head [7]. In normal individuals, the acetabulum is oriented in the pelvis in an anteverted position, with about 15–20° of anterior tilt and roughly 45° of lateral tilt, while the proximal femur is superiorly inclined on average nearly 130° (neck-shaft angle) and in about 10° of anteversion [8]. Overall, the combination of femoral and acetabular offset, anteversion, and lateral inclination results in greater posterior bony coverage. The inherent stability provided by posterior bony constraint afforded by the bony anatomy explains the ability for relative increased hip flexion and abduction compared to hip adduction and extension in normal individuals. As a consequence of inherent posterior stability, stability in the anterior plane relies more heavily on soft-tissue restraints, particularly when the hip is in positions of extension, adduction, and external rotation.

10.2.2 Ligamentum Teres

The role of the ligamentum teres in hip stability is controversial. The pyramidal structure takes origin from the transverse acetabular ligament and posterior inferior acetabular fossa and inserts onto the femoral head at the fovea capitis [1]. This non-capsular ligament tightens in a position of flexion, adduction, and external rotation and therefore has been hypothesized to potentially add to posterior hip stability [9, 10]. Traumatic rupture has been identified and treated as a source of hip pain, but the exact contribution of the ligamentum teres to hip stability remains poorly defined [11].

10.2.3 Labrum

As the field of hip arthroscopy advanced from its infancy to current state of the art, the importance of the labrum to hip joint stresses and stability became appreciated. Early arthroscopic procedures focused on labral resection to improve mechanical symptoms associated with tearing, while current practice emphasizes and supports labral preservation (repair/reconstruction) when possible [12–15]. The labrum is in circumferential continuity with the bony acetabular rim, measuring approximately 3–8 mm in width, increasing the acetabular surface area by roughly 25% and the acetabular volume by approximately 20% [16]. The tissue characteristics and increased surface area function to distribute joint stresses during loading. Additionally, the labrum functions to maintain negative intra-articular pressure by forming a suction seal between the central and peripheral compartments. Crawford and colleagues showed 60% less force was required to distract the hip in the presence of a labral tear, demonstrating its importance to native hip stability [16–20].

10.2.4 Capsuloligamentous Complex (CLC)

The capsuloligamentous complex of the hip joint plays an important role in hip stability. Approximately 60% of the hip capsule is comprised of and reinforced by named ligaments, which represent discreet capsular thickenings. The circular zona orbicularis wraps around the femoral neck at the narrowest point of the capsule [21]. It can be visualized intra-articularly as a band of tissue encircling the femoral neck and has been shown to be an important restraint to femoral head distraction in the axial plane [22]. Three longitudinal capsular ligaments—the iliofemoral ligament (ILFL), pubofemoral ligament (PFL), and ischiofemoral ligament (ISFL)—form a helical structure around the femoral head and attach onto the acetabulum just proximal to the labrum (Fig. 10.3). The ILFL is the strongest of the longitudinal ligaments and forms an inverted Y position with a single proximal attachment at the base of the anterior inferior iliac spine and two distal attachments. The medial arm runs to the level of the lesser trochanter, while the lateral arm inserts on the anterior prominence of the greater trochanter. The ILFL limits external rotation with the hip in flexion and limits both internal and external rotation with the hip in extension [23, 24]. Additionally, Myers showed that anterior femoral head translation is primarily limited by the ILFL, with the labrum acting as a secondary restraint [25]. The PFL functions as a sling, originating on the anterior acetabular rim and wrapping posteroinferiorly around the femoral head. Its distal insertion blends with the medial arm of the ILFL and distal ISFL. It similarly limits external rotation with the hip in extension. The ISFL originates on the ischial acetabular margin and runs superolaterally to the base of the greater trochanter, serving two functions: limiting internal

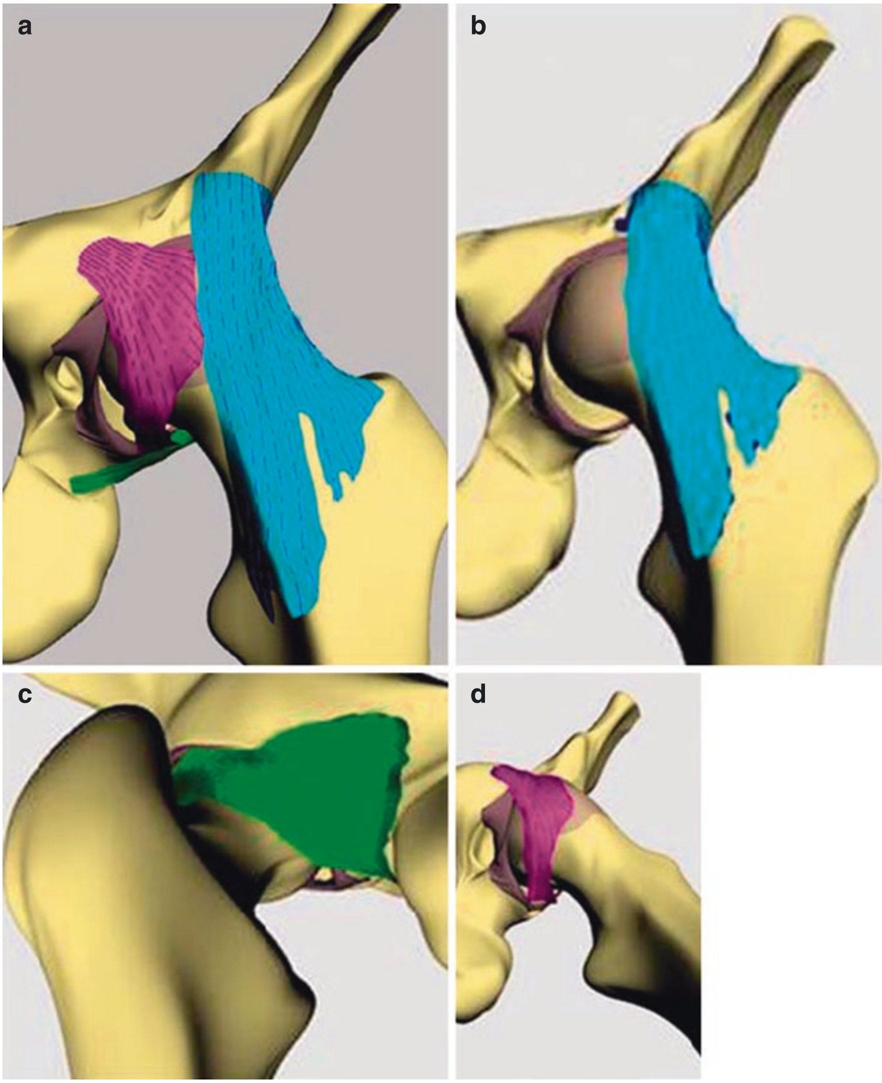

Fig. 10.3 The capsuloligamentous complex (CLC) of the hip joint. (**a**) The helical structure of the CLC, (**b**) ILFL, (**c**) PFL, (**d**) ISFL. Reprinted with permission of [59]

rotation in both hip flexion and extension as well as limiting posterior femoral head translation. The combination of the ILFL, PFL, ISFL, and zona orbicularis forms the so-called hip "screw-home" mechanism. In the potentially unstable position of hip extension, the CLC twists, tightens, and compresses the femoral head into the acetabulum. During flexion, adduction, and internal rotation, the CLC untwists and loosens, providing less soft-tissue constraint in the more inherently stable position [24]. Attenuation of the CLC due to underlying collagen disease, repetitive microtrauma during supraphysiologic motion, or iatrogenic injury has serious implications to hip stability.

10.2.5 Dynamic Stabilizing Factors

Several dynamic factors contribute to hip stability including adhesion-cohesion, negative intra-articular pressure, and periarticular muscle contraction. Seventeen muscles cross the hip joint and during contraction increase joint reactive forces and thus hip stability, by compressing the femoral head into the acetabulum. Anterior femoral head translation is also additionally resisted by the anatomic location of the iliopsoas musculotendinous unit.

10.3 Etiology

The etiology of hip microinstability is diverse, but can generally be divided into six categories: (1) bony abnormalities, (2) connective tissue disorders, (3) post-traumatic, (4) idiopathic, (5) repetitive microtrauma (athletics), and (6) iatrogenic (Fig. 10.4). Bony abnormalities such as acetabular dysplasia and, more recently, certain patterns of FAI can predispose to microinstability. A spectrum of anatomic changes are typical in developmental dysplasia of the hip (DDH), including a shallow acetabulum with lack of anterolateral coverage, increased acetabular tilt, and increased femoral and acetabular anteversion. In mild cases, this type of morphology predisposes to anterior microinstability while in severe cases can lead to hip subluxation and even frank dislocation [26]. The aforementioned soft-tissues responsible for anterior stability see increased stress, with subsequent labral and CLC damage over time [27]. In FAI, both Cam- and Pincer-type morphologies can lead to microinstability. Impingement of a CAM deformity against the acetabular rim during terminal motion can lever the head out of the socket (Fig. 10.5). While

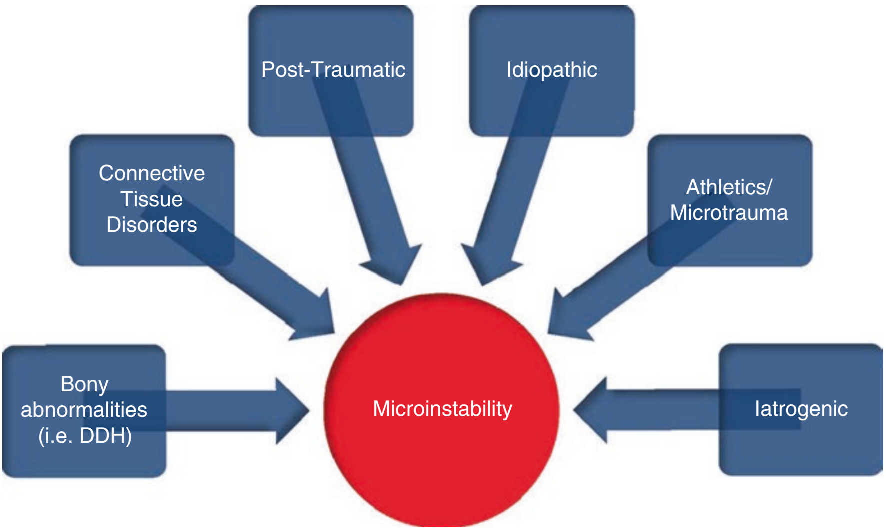

Fig. 10.4 Etiology of hip microinstability

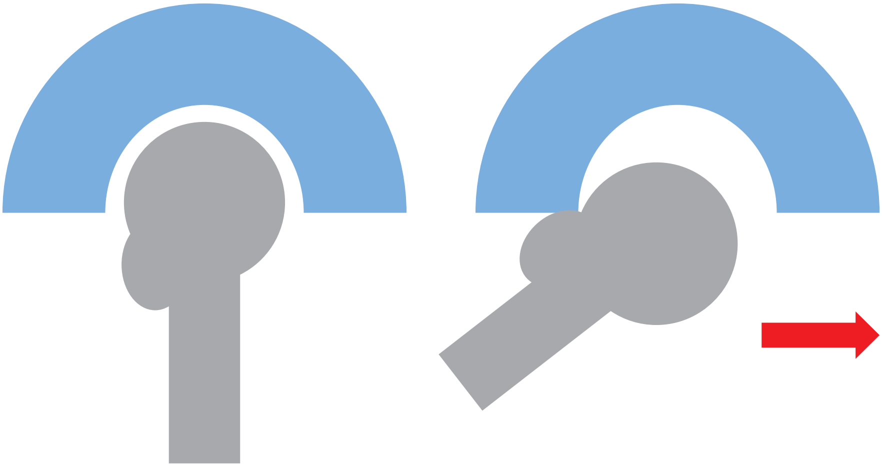

Fig. 10.5 FAI (Cam lesion) showing mechanism of microinstability

dysplasia is commonly thought of as a problem stemming from “undercoverage” of the femoral head, a Pincer-type deformity or “overcovered” head from deformities such as coxa profunda or severe acetabular retroversion can similarly lead to symptomatic posterior instability through a common lever-type mechanism. A recent systematic review showed high rates of FAI morphologic characteristics (74% CAM, 64% Pincer) in patients with symptomatic hip microinstability [28]. While the quality of literature included only Level III and Level IV research, three of the four included studies utilized real-time visualization (dynamic confirmation) of FAI-induced hip subluxation.

The second category of hip microinstability stems from underlying connective tissue disease such as Ehlers-Danlos syndrome, Marfan’s syndrome, Down’s syndrome, or other hypermobility syndromes. Regardless of the etiology, these disorders typically present with a spectrum from extreme to subtle joint laxity. The CLC and other soft tissues typically are attenuated, allowing for microinstability in hip positions less reliant on inherent bony stability.

Post-traumatic microinstability of the hip can occur following a high-energy mechanism (MVA) or sports injury [29]. While frank dislocation and macroinstability are well-described events in the trauma literature, post-traumatic microinstability is less clearly defined. Generally speaking, hip subluxation/dislocation events are considered stable when they occur in the absence of an associated fracture. While immediate surgical stabilization is often not necessary, residual laxity of the hip joint can occur due to soft-tissue injury to the ILFL, ligamentum teres, and chondral-labral surfaces. Often, instability in this acute setting is only observed during fluoroscopic examinations under anesthesia.

Idiopathic microinstability represents a subset of patients without a clear etiology. Often, these patients present with several possible contributing factors, including mild acetabular dysplasia not meeting radiographic criteria, subclinical ligamentous laxity (Beighton 4–5), or subtle FAI morphology [1].

While an athlete is subject to microinstability from any etiology, microtrauma represents a specific subset of patients in which the repetitive motion of sport causes underlying soft-tissue damage or attenuation leading to instability. This pattern of microinstability has been observed at the extremes of motion in sports that require repetitive hip rotation and axial loading, such as dance, golf, and gymnastics [1]. Often, subclinical laxity is advantageous for the athlete, allowing supraphysiologic hip motion; however it can also place them at higher risk for hip injury and instability. Impingement and hip subluxation are observed frequently in ballet movements, even in morphologically normal hips. Charbonnier et al. showed that four specific ballet movements were associated with a high frequency of impingement and hip subluxation. Furthermore, the locations of impingement correlated with radiologically diagnosed damaged zones in the labrum [6, 30].

Iatrogenic hip microinstability is an evolving and controversial topic. Catastrophic failure (dislocation) following hip arthroscopy has been reported in the literature several times; however given variable arthroscopic techniques for capsular management, identifying and generalizing the etiology is challenging [31–33]. Some have postulated that partial division of the ILFL during routine hip arthroscopy without repair may be the cause of hip subluxation due to increased femoral head translation in neutral flexion-extension and rotation [25, 34, 35]. During routine arthroscopy, the anterior and anterolateral portals are often connected (interportal capsulotomy). The interportal capsulotomy cuts the ILFL by necessity, and by extending the capsulotomy distally in a “T” fashion, more of the ILFL is divided [21]. Several biomechanical studies have investigated the consequence of ILFL division and have shown increased hip external rotation and distraction as more of the ligament is sectioned [36, 37]. Recently, Frank and colleagues showed improved outcomes after hip arthroscopic surgery in patients undergoing T-capsulotomy with complete repair versus partial repair (T-capsulotomy repaired and interportal capsulotomy left open) [38].

10.4 Diagnosis

In the absence of significant bony abnormalities or underlying connective tissue disease, the diagnosis of hip microinstability can be challenging. In contrast to macroinstability of the hip, microinstability is more poorly defined and lacks standardized objective evaluative criteria. Often, the presentation is quite subtle, and the treating clinician must have a strong clinical suspicion based on history, physical examination, and imaging. Ultimately, examination under anesthesia and other intraoperative findings can help confirm the diagnosis.

10.4.1 History

Pain is the primary complaint of patients with hip microinstability, though less commonly apprehension or a sense of giving way is also reported. Exacerbating factors, such as axial loading, rotation, and other sport-specific activities, can give the examiner clues to the underlying diagnosis. Most patients do not report a specific trauma or inciting event, instead describing an insidious onset with gradually worsening discomfort. It is very important to elicit any previous hip injuries or previous surgical procedures. Iatrogenic instability is becoming a more commonly recognized etiology. In patients requiring revision hip arthroscopy, McCormick and colleagues reported 78% had radiographic evidence of capsular and ILFL defects on magnetic resonance arthrography [39]. Another study by Philippon et al. similarly showed that one in three patients undergoing revision hip arthroscopy required capsulorrhaphy at the time of revision, suggesting undiagnosed hip microinstability as a potential cause for revision [40].

10.4.2 Physical Examination

A thorough physical exam is crucial in the diagnosis of suspected hip microinstability. Intra-articular pain is typically described as groin, buttock, thigh, or in the classic C-distribution. It is important to rule out other sources of pain that can be referred to the hip from common dermatomal/myotomal origins and thus confused with hip pain, including those from the lumbar spine, abdomen, and knee. Palpation, strength, and range of motion testing should be a part of every hip examination, as well as a general screening for ligamentous laxity using the Beighton scoring system. More specific laxity testing for the hip is observation of internal or external rotation of the hip greater than 60° in either direction and hip flexion greater than 150° and/or observation that if the leg is placed in a figure-of-four position, the knee joint line falls to less than 3 in. from the examination table.

The goal of diagnosing hip microinstability is to reproduce pain or apprehension the patient feels utilizing a specific set of provocative testing. Six specific maneuvers have been described to evaluate hip stability: (1) hyperextension anterior apprehension test, (2) abduction-extension-external rotation test, (3) prone external rotation test, (4) log roll test, (5) axial distraction test, and (6) posterior apprehension test. Hoppe et al. recently published on the diagnostic accuracy of the first three of the aforementioned tests and showed a sensitivity of 71% and specificity of 85% for the hyperextension anterior apprehension test, a sensitivity of 81% and specificity of 89% for the abduction-extension-external rotation test, and a sensitivity of 33% and specificity of 98% for the prone external rotation test. When all three tests were positive, the likelihood of intraoperative confirmation of hip microinstability was 95% [41]. Those three tests are described in Fig. 10.6. The log roll test is performed while the patient is supine and the knee is in extension. The examiner first fully internally rotates the foot, then removes their hand, and allows the foot to passively fall back into external rotation. Asymmetric external rotation compared to the contralateral side suggests anterior hip laxity (especially if the foot-table angle <20°). The axial distraction test is similarly performed in a supine position with the knee of the examiner abutting the ischium of the extremity being examined. The hip and knee are flexed to about 30° while an axial force is placed on the hip. Any sense of hip "toggling" or reproduction of apprehension or pain is considered a positive

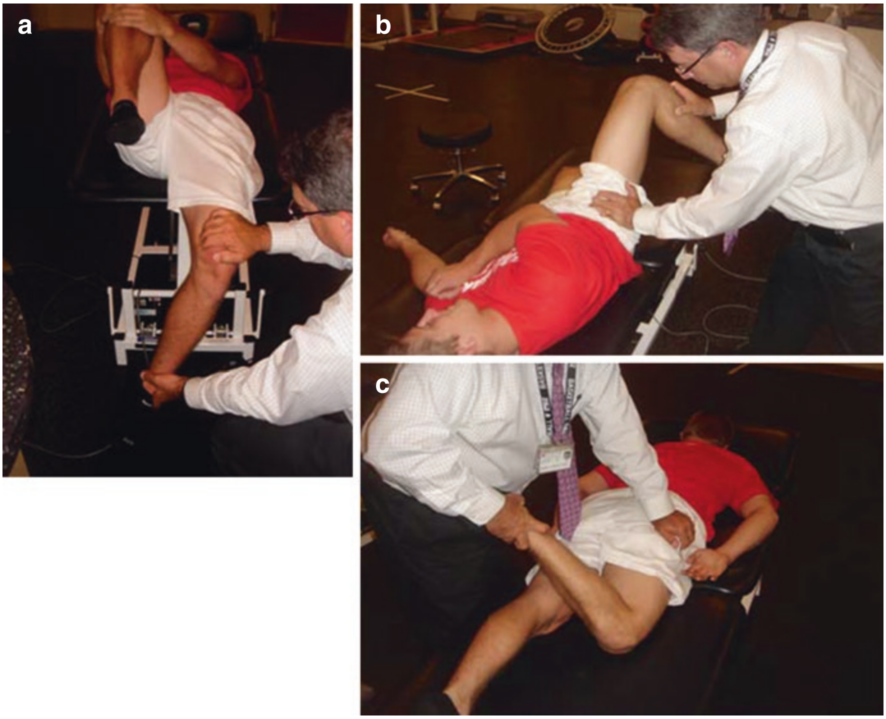

Fig. 10.6 Provocative maneuvers for hip instability: (**a**) anterior apprehension test, (**b**) abduction-extension-external rotation test, (**c**) prone external rotation test

result. The posterior apprehension test is also performed in a supine position. The examiner flexes the patient's hip to 90° while also adducting and internally rotating the hip and placing a posteriorly directed force on the knee. Any sense of pain or apprehension is considered a positive result.

10.4.3 Imaging

Imaging begins with high-quality plain radiographs, including a supine AP pelvis, lateral radiograph (cross-table or Dunn view), and false-profile views. X-rays should be scrutinized for degenerative changes, trauma, prior surgery, FAI, and morphological clues about the shape and orientation of the proximal femur and acetabulum. A lateral center-edge angle of less than 20–25° on the AP pelvis and on the false-profile view is highly suggestive of acetabular dysplasia, as does an acetabular roof inclination (Tonnis angle) of greater than 10° upsloping. Acetabular version is important to assess as it is associated with hip pathology, with anteversion correlated with DDH and retroversion related to Pincer-type FAI. However, assessing version on an AP radiograph relies upon the relationship between the anterior and posterior walls, but cannot capture the volume (quantitative) of the socket, which is often abnormal in cases of dysplasia or global overcoverage [42]. While normal version lies between 12 and 20° of anteversion, this parameter changes with both pelvic tilt (increased tilt reduces version) and changes in the supine to standing position (pelvic tilt decreases in the standing position) [43, 44]. A crossover sign, posterior wall sign, and ischial spine sign are qualitative indicators of acetabular version. On an AP radiograph, when the contour of the anterior wall lies lateral to the corresponding point of the posterior wall, the presence of retroversion or focal anterosuperior overcoverage is present. The sensitivity and specificity of the crossover sign are 96% and 95%, respectively [45]. The posterior wall sign is seen when the posterior wall of the acetabulum lies medial to the center of the femoral head, indicated acetabular retroversion or global acetabular dysplasia [46]. If the posterior wall sign is present, but the crossover sign is absent, this denotes a so-called “low-volume” acetabulum without version abnormalities [47]. The ischial spine sign is seen on an AP radiograph when the ischial spine lies medial to the iliopectineal line [48]. When all three (crossover, posterior wall, and ischial spine) signs are present, the acetabulum is globally retroverted [47, 49]. More recently, Safran and Packer described the “cliff sign”—a radiographic finding where there is a steep drop-off of the lateral femoral head-neck junction and its strong correlation to microinstability. On an AP pelvic XR, a perfect circle is created around the center of the femoral head. If the lateral femoral head does not completely fill the perfect circle, a positive “cliff sign” was denoted (Fig. 10.7). In their study of 96 patients, 74% of those with a positive cliff sign had microinstability, while only 7% with microinstability did not demonstrate a cliff sign (unpublished, presented at ISAKOS 2017). Given the

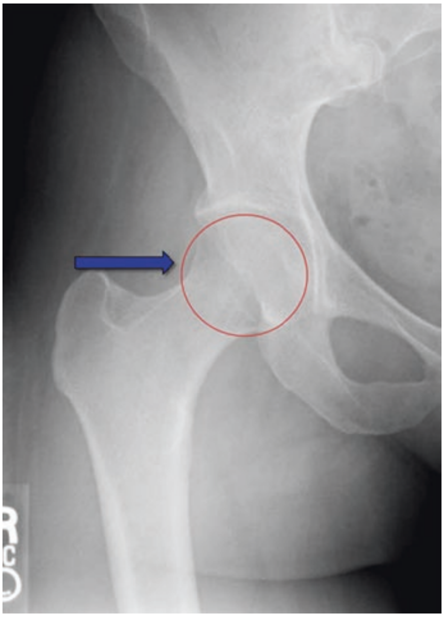

Fig. 10.7 “Cliff” sign

difficulty in diagnosis, another study recently reported an additional radiographic parameter associated with hip instability in borderline dysplasia patients. Wyatt and colleagues described the FEAR (femoral-epiphyseal acetabular roof) index—formed by two lines that connect the acetabular roof inclination and the femoral head physeal scar. This angle, when positive (acetabular roof inclination steeper than physeal scar), was associated with instability [50].

MRI is often utilized in cases of intra-articular hip pain to evaluate the soft-tissue structures, including the chondral surfaces, labrum, and capsule. Magnetic resonance arthrogram (MRA) can be even more useful in the work-up of suspected hip microinstability, as the gadolinium dye distends the hip capsule. McCormick et al. utilized MRA and showed a high prevalence of capsular defects following hip arthroscopy [39]. Magerkurth and colleagues retrospectively reviewed preoperative MRAs and noted that hip joint laxity was associated with a widened hip joint recess of >5 mm and a thinned lateral capsule <3 mm adjacent to the zona orbicularis [51].

Ultimately, the patient's intraoperative findings provide confirmation of the diagnosis of hip microinstability, beginning before the arthroscope is even introduced. The ease of distractibility is a very reliable indicator of instability. Often, body weight traction alone provides significant distraction. After removal of negative intra-articular pressure, traction is released, and the hip joint is reassessed fluoroscopically and often will show a femoral head that remains incompletely reduced or lateralized relative to the acetabulum (Fig. 10.8a, b). Intraoperative findings consistent with microinstability are direct anterior or direct lateral labral injury compared with the classic anterolateral labral damage commonly associated with FAI [52]. Other frequent findings include adjacent chondral wear that is typically shallow (1–3 mm) and worn rather than delaminated, central femoral head chondral injury, and tearing and hypertrophy of the ligamentum teres.

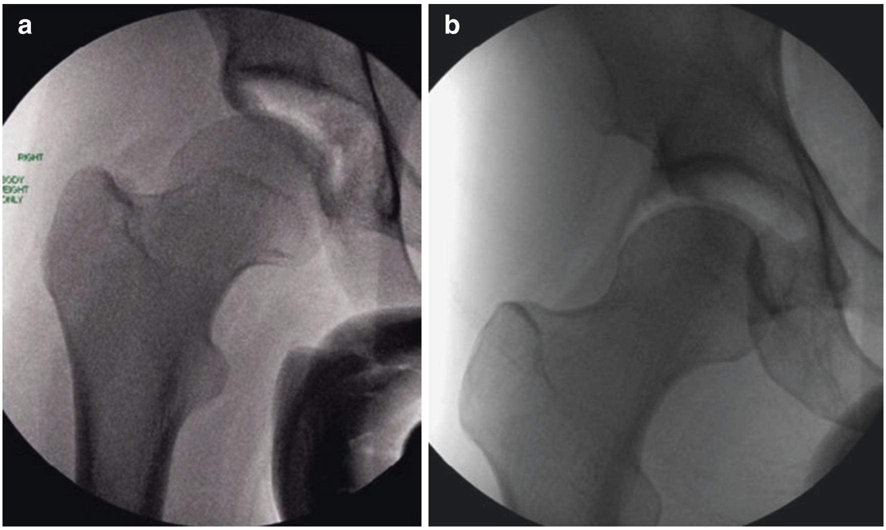

Fig. 10.8 Intra-operative fluoroscopy of (**a**) hip distracted only using body weight to remove gross traction and (**b**) after removal of negative intra-articular pressure and traction, the hip is incompletely reduced

10.5 Treatment

The treatment of hip microinstability is controversial and not yet well defined. It is becoming more accepted as a cause of hip disability in the athlete, but management algorithms backed by long-term data are nonexistent. Instead, at this time there is a reliance upon some of the pioneers and experts of the field who treat this entity more commonly. Parallels are drawn from the shoulder instability literature, and typically non-operative management is attempted first. Conservative care focuses on modifiable factors, including activity modification, anti-inflammatories, and especially periarticular hip muscle (dynamic) and core strengthening. While there is no literature to date documenting or comparing operative and non-operative treatment, it is the author's (M.S.) experience that a percentage of patients do improve with therapy alone and are able to return to regular activities. However, a significant number of patients do require surgical intervention.

Surgical treatment should focus on the underlying etiology for instability. In the case of severe bony abnormalities (dysplasia, acetabular retroversion), redirectional osteotomies should be considered. In the absence of significant bony abnormalities, the focus of treatment is on the soft tissues responsible for secondary stability, including the labrum and CLC. Both open and arthroscopic techniques to reduce capsular volume have been described, but comparative studies are lacking [53–55]. As hip arthroscopy technique has advanced, arthroscopic management is the primary method of addressing hip microinstability. During treatment of microinstability, the treating surgeon should address associated intra-articular pathology, including labral repair when possible, and consideration for labral reconstruction when non-salvageable, as the labrum is an important hip stabilizer [56]. Arthroscopic capsular repair or plication is recommended for patients with capsular redundancy, symptomatic capsular laxity, and any patient with underlying connective tissue disorder or generalized ligamentous laxity undergoing arthroscopic treatment for any other reason (FAI, labral tear, chondral injury). Philippon reported on the use of arthroscopic thermal capsulorrhaphy in 12 patients with hip instability [7]. While he reported no complications and good results, concern over possible thermal capsular necrosis and chondrolysis, as seen in the shoulder, has led to the development of alternative procedures. Arthroscopic suture capsular plication is a technically demanding procedure, but several authors have no reported good results with a variety of techniques. Larson and colleagues showed 90% good to excellent results in 16 hips of patients with Ehlers-Danlos syndrome with suture capsular plication [57]. Domb et al. published on a series of patients with hip microinstability and borderline hip dysplasia. His technique involved shifting the inferior capsule proximally (shortening the ILFL) and showed favorable results at 2 years post-op; however patients in this cohort lost approximately 10° of hip external rotation [58]. Most recently, Kalisvaart and Safran reported on 31 consecutive patients treated for microinstability of the hip with labral surgery and suture capsular plication. In their series, all patients were women, 71% did not have dysplasia, 29% had mild dysplasia (CEA 18–24°), and no bony work was done. Their technique utilized suture plication through the capsular "bare area" between the ILFL anteriorly and the ISFL posteriorly (Fig. 10.9). All patients had improvement in symptoms, with 100% return to sport in the athletes treated and without significant loss of motion.

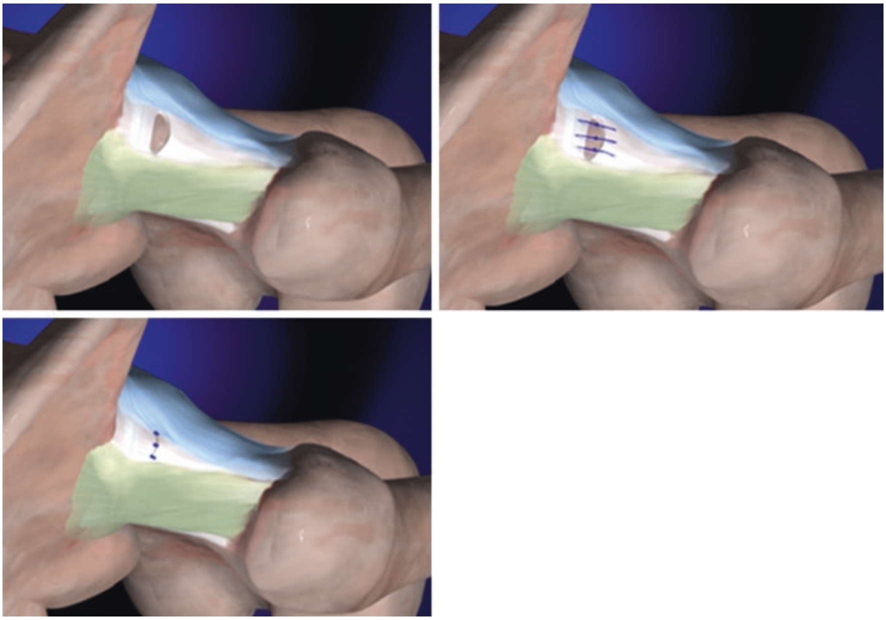

Fig. 10.9 Arthroscopic capsular plication technique

10.6 Summary

Hip microinstability is an emerging concept that is gaining acceptance as a cause for hip disability. While there are many etiologies, in the absence of significant bony abnormalities or underlying connective tissue disorders, athletes with repetitive motion can cause microtrauma or attenuation to the secondary stabilizers of the hip (labrum and CLC). Specific sports with rotation and axial hip loading are at higher risk, as well as athletes that attain supraphysiologic motion despite normal bony morphology. Microinstability is a difficult diagnosis as it lacks standardized evaluative criteria. Its clinical presentation is less dramatic than macroinstability; thus the treating clinician should have a high index of suspicion. Several well-described provocative maneuvers help identify instability reliably, but confirmation of the diagnosis is an intraoperative finding. Once identified, both nonsurgical and surgical management can be effective. If conservative management fails, arthroscopic capsular plication techniques have shown promising short- and midterm outcomes.

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Special Issues Related to Hip Pain in the Adolescent Athlete

11

Marc J. Philippon and Karen K. Briggs

11.1 Introduction

In the past 10 years, the understanding of femoroacetabular impingement (FAI) and the associated intra-articular injuries has drastically increased. This has led to improved diagnosis and treatment. Initially, less attention was paid to FAI in the pediatric and adolescent population. Hip disease, including FAI, can cause significant disability in young patients and may lead to early onset of degenerative joint disease. Addressing FAI early is critical since total hip replacement is not a therapeutic option in adolescents. In addition, young patients commonly have a high activity level and a longer life span for which the hip joint needs to function.

Femoroacetabular impingement (FAI) is associated with injury to the acetabular labrum and articular cartilage which leads to osteoarthritis [1–3]. Causes of FAI in younger patients have been reported, including sports-related joint overloading, developmental dysplasia of the hip or other congenital hip conditions, slipped capital femoral epiphysis (SCFE), and Legg-Calve-Perthes disease [4–9]. Participation in sports which include repetitive hip flexion combined with rotational movements has also been associated with increased risk of FAI pathology [10–15]. In young patients who participate in vigorous sporting activities where the hip is overloaded, cam-type FAI has been attributed to a developmental process causing irregular bony growth around the femoral head physis (Fig. 11.1) due to repetitive trauma [14]. This developmental theory of cam-type FAI is supported by multiple studies which show an increase in alpha angle (a measure of the cam lesion), with increasing age in young athletic patients [13, 16]. With more adolescents participating in higher levels of sports, the possibility of FAI in a pediatric patient cannot be ignored.

Acetabular dysplasia (femoral head under-coverage) and/or hip microinstability (femoral micromotion against the acetabulum) often coexists with FAI in adolescent

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Fig. 11.1 Three-T MRI sagittal view showing irregular bony growth (arrow) around the femoral head physis in a young hockey player

athletes. Dysplastic patients have the choice to have hip arthroscopy prior to a periacetabular osteotomy (PAO). The last procedure improves the acetabular coverage of the femur. Although PAO is a major surgical procedure, many times these patients see improvement in symptoms and can return to sports activities. Borderline or mild dysplasia can cause damage to ligaments, the hip capsule, and the labrum. These patients often present with signs and symptoms of hip microinstability (pain despite therapy, positive dial test, or pain with other maneuvers on physical examination), but it is still unclear whether microinstability is the result of dysplasia or FAI or a combination of both. If hip microinstability remains undiagnosed, and therefore untreated, then hip structural damage will continue as the patient continues to participate.

11.2 Special Issues Related to Examination

When obtaining the medical history, the adolescent should be allowed to describe his or her symptoms in detail. Apart from pain, hip clicking, catching, or popping is sometimes present. The last should raise the suspicion of hip microinstability or the presence of loose body inside the joint. If the patient has a history of hip dislocation, slipped capital femoral epiphysis, Legg-Calve-Perthes disease, dysplasia, coxa vara, juvenile rheumatoid arthritis, or chondrolysis, further exploration is necessary [9]. The condition of the femoral head can be evaluated using MRI or bone scan to assess for avascular necrosis. AVN must be ruled out in adolescents with hip pain who have been treated with corticosteroids in the past. Hip dislocations in adolescents require immediate treatment and often present following reduction [17]. Careful evaluation, including computed tomography, should be obtained in athletes with previous hip dislocations.

In examining the adolescent hip, it may difficult for the patient to describe the characteristics of pain (timing, location, radiation, etc.) with accuracy. Parents or legal guardians can be helpful during the diagnostic process. However, adolescents should be given the chance to spend some individual time with the physician. It is important to determine the movement which provokes hip pain, especially if the patient is involved in a sport which places excessive stress on the hip or included hip "at-risk" positioning (deep flexion, flexion-adduction, extension-abduction or rotation, etc.). "At-risk" movements bring the cam lesion and the pincer lesion into conflict, while the labrum and the adjacent acetabular cartilage can be injured. An abnormal biomechanical sequence is generated in the joint which increases the risk of damage. Sports with "at-risk" movements include ballet, ice hockey, baseball, football, and soccer to name a few. When FAI symptoms arise, they prevent the athletes from participating in their sport and eventually even with daily activities.

In adolescent female athletes, metabolic and hormonal factors should be considered. The female triad was defined by the American College of Sports Medicine as the interrelatedness of energy availability, menstrual function, and bone mineral density [18]. Low energy availability associated with the female triad may also be related to eating disorders in females. A previous study reported associations among eating disorders, bone mass density, and musculoskeletal injuries [19–23]. There is a higher prevalence of menstrual irregularity in the athletic population which has been estimated between 20% and 54% in high school athletes [20]. Based on our experience, adolescent females with hip injuries are more difficult to treat than the males. While it is unclear what contributes to this, adolescent females are slower to recover and more likely to need revision surgery in the senior author's practice. In the young female athlete with amenorrhea and decreased estrogen levels, this may increase the risk for femoral neck fractures following performance of osteoplasty during hip arthroscopy. Several studies have shown that menstrual irregularity is associated with exercise-related leg pain, musculoskeletal injuries, and stress fractures [19–23]. All these factors should be considered in evaluating the female adolescent athlete with hip injury.

A study by Newman et al. showed that adolescents who have more than one revision arthroscopic hip surgery have inferior outcomes [24]. While all revision patients in the study showed a significant improvement in outcomes, their final outcome scores were lower when compared to a group of primary arthroscopies in adolescents. If a patient does have previous surgeries, it is necessary to obtain a copy of the prior surgery report. This is also important when viewing the MRI to determine if any damage exists from the previous surgery or if this is a new injury. The patient's history of medications, including hormone replacement therapy, growth factors, birth control, and supplements, should be reviewed.

A complete physical examination includes evaluation of the soft tissues and bones. The patient must be assessed for athletic pubalgia or possibility soft tissue tumors. Pain in the pubic symphysis should be further evaluated on the AP pelvic radiograph. It is critical to have the parent or other adult in the room during the entire examination. The examination may result in palpation close to the genital area, which may cause discomfort to the adolescent. Care should be taken to provide adequate information, so the patient and parent understand the process of the examination and suspected diagnosis.

The possibility of bilateral hip pathology should be considered especially in adolescents who are involved in a sport that has high risk of hip pathology, such as hockey. Although the focus is on the symptomatic hip, the exam should include bilateral assessment and evaluation of the hip range of motion. Gait evaluation should focus on antalgic gait, Trendelenburg gait, and others. Specialized tests will be completed including the anterior impingement test, performed with the hip in 90° of flexion and then adducted and internally rotated, which is usually positive in hips with FAI. The FABER test, measuring the distance of the lateral knee to the exam table when the limb is in flexion-abduction-external rotation, is positive with a difference of more than 4 cm between the two sides, and the dial test evaluates hip laxity and may be particularly useful in those patients with signs and symptoms of hip instability. The presence of generalized joint hyperlaxity should raise suspicion of hip microinstability.

11.3 Special Issues Related to Imaging

Critical issues in imaging include assessing the physeal status in the proximal femur and assessing the bony morphology. It is important to limit the radiation exposure in the young patient. In patients with suspected FAI pathology, radiographic evaluation should include the anteroposterior (AP) pelvic, false profile, and 45° Dunn view. The AP pelvic image is used to evaluate the lateral center-edge angle, Sharp's angle, acetabular coverage, and joint space. The Dunn view, taken in the supine position with the leg in 45° of flexion and 20° of abduction, assesses the alpha angle. Pincer impingement is diagnosed if this view shows coxa profunda, protrusio acetabuli, crossover sign, or posterior wall sign. The last two are also indicative for acetabular retroversion. The anatomy and position of the symphysis pubis can be evaluated. In case of severe dysplastic changes on radiographs, a three-dimensional computed tomography (CT) can be ordered. Differences may occur between genders, with larger cam lesions in males [25].

Magnetic resonance imaging (MRI) assesses labral tears, chondral lesions, alpha angle, femoral version, and the surrounding soft tissue (Fig. 11.2). Femoral anteversion has been correlated with larger labral tears and limitations in internal and external

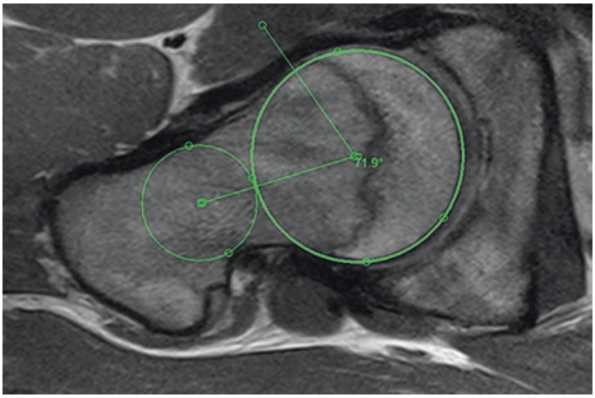

Fig. 11.2 Alpha angle measurement on axial view of 3-T MRI

rotation and can be accurately measured with MRI [26, 27]. A recent study showed that the interrater and intrarater reliability and repeatability for the femoral version measured on MRI were equal to CT, which avoids the exposure to additional radiation [27]. MRI can be an ideal tool to evaluate the state of the femoral physis in these patients due to its cartilaginous nature. MRI should also be reviewed for soft tissue injuries surrounding the hip.

11.4 Special Issues Related to Treatment

Initial treatment for FAI in all patients is a minimum of 6 weeks of conservative therapy, including oral analgesics, physical therapy, and activity modification [28]. Local injections are often useful. In patients with clinical and radiographic evidence of FAI which persist despite conservative treatment, hip arthroscopy is indicated. The indications for hip arthroscopy in adolescents do not differ significantly from the adult population.

Excellent outcomes have been reported following hip arthroscopy for FAI in adolescents [16, 28–33]. Under fluoroscopic guidance, traction is applied with the leg in slight abduction until 10 mm of distraction is achieved on fluoroscopy, which provides enough space to maneuver within the joint while avoiding iatrogenic chondral damage [34]. The use of intraoperative fluoroscopy must be minimal in adolescents since radiation exposure increases the risk of future malignancy. The mid-anterior and anterolateral portal are established first, followed by an interportal capsulotomy approximately 2.5 cm in length. Diagnostic arthroscopy is performed to evaluate for chondral damage or other bone lesions, labral tears (Fig. 11.3), ligamentum teres pathology, and capsular lesions. If a pincer lesion is present, rim trimming is accomplished with an arthroscopic burr. When addressing the cam lesion, damage to the physis must be avoided during hip arthroscopy at the risk of causing growth disturbances. Closure of the physis is initiated between the ages of 16 and 18, and fusion can occur between 17 and 20 years of age [35, 36]. In cases of a cam-type FAI in which the lesion does not communicate with an open physis, it is safe to perform osteoplasty for decompression. If the cam lesion interferes with an open physis, a staged procedure is recommended, with the osteoplasty of the cam lesion addressed at a second arthroscopy after the physis is closed (Fig. 11.4).

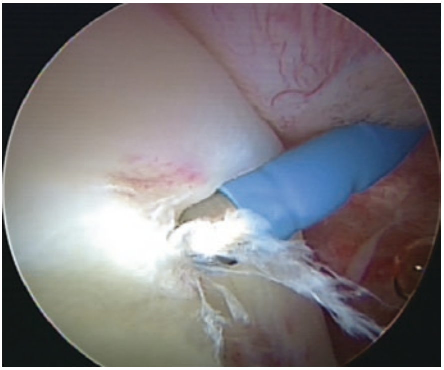

Fig. 11.3 Damaged labrum seen on diagnostic arthroscopy. Labrum is torn at base with an unstable chondrolabral junction

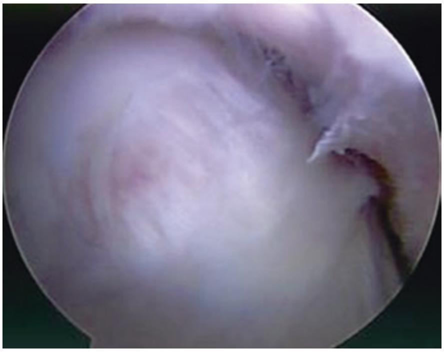

Fig. 11.4 At arthroscopy, the physis can be seen on femoral neck. Identifying this area is important so it can be avoided to prevent physis damage

Labral tears are repaired with suture anchors, with the size based on the anatomic region. The torn labrum is debrided of unhealthy tissue and reattached to the acetabular rim with suture anchors. Chondral lesions can be treated with chondroplasty to stabilize the lesion, rim trimming to reduce its size, or, for Outerbridge grade IV full-thickness damage, microfracture. A dynamic intraoperative exam in which the hip is taken through its full range of motion while the labral seal is under direct vision is used to ensure complete decompression of the impingement [37] and ensure that the labral seal is restored. The capsulotomy is closed with the hip in 45° of flexion and internal rotation. If preoperative exam indicated laxity, the capsule can be plicated to alleviate symptoms. This is executed with the hip in deeper flexion and with more capsular tissue incorporated into the closing sutures. Other adjunct procedures, such as release of the iliopsoas or trochanteric bursectomy, can be performed when symptoms are present.

Postoperatively, patients wear a brace limiting external rotation and abduction and are kept foot-flat weight bearing for 2–3 weeks. If microfractures are performed during surgery, the weight bearing restriction period is extended to 8 weeks. Patients use a stationary bike without resistance and a continuous passive motion machine beginning on the day of surgery. Passive motion is encouraged early in the rehabilitation process, as it has been shown to reduce the formation of adhesions [38]. Rehabilitation progresses from regaining range of motion to gentle strengthening and, eventually, to functional activities [39]. Young female patients may experience difficulty immediately after surgery and recover more slowly. Extra care should be taken with these patients to increase their confidence in recovery and rehabilitation and monitor their nutrition.

11.5 Complications

The adolescent skeleton continues to grow as the patient recovers from surgery. SCFE, AVN at a later stage, joint infection, and premature physeal closure are some of the complications seen primarily in pediatric patients who undergo hip arthroscopy. Transient perineal neurapraxia, heterotopic ossification, and deep vein thrombosis are rare.

The rate of revision hip arthroscopy in adolescents has been reported between 0% and 15% [32]. Causes of revisions include non-addressed FAI, recurrent FAI, and adhesions. Development of postoperative adhesions is common in young female patients. In the study by Newman et al., all hips had adhesions at revision. This may be due to hormonal changes; however, this has not been studied. Adhesions usually occur at the site of the labral repair in proximity to the capsule. Willimon et al. reported that the addition of hip circumduction to the rehabilitation protocol decreased the prevalence of revision arthroscopy due to adhesions [38].

11.6 Outcomes

Outcomes following hip arthroscopy in the young athlete have been widely reported [16, 28–33]. In a study of 60 patients between 11 and 16 years of age, there were excellent clinical outcomes at 2–5 years following hip arthroscopy [16]. It is important to note that none of these patients had center-edge angle under 25°. In addition, the alpha angle was positively associated with age, and females had lower modified Harris hip score and a higher rate of revision arthroscopies. Byrd et al. reported on 104 adolescent patients at a minimum of 2 years following hip arthroscopy [29]. There were 97% of patients improved, and 94% had good to excellent results. Several other studies have reported similar outcomes following hip arthroscopy in adolescent patients. Newman et al. reported improvement in adolescents undergoing revision hip arthroscopy; however, when compared to primary hip arthroscopies in adolescents, final outcome scores were lower [24].

11.7 Preventing Injuries

With the rise in hip injuries in young patients, research is focusing on preventing these injuries. In addition, research showing a connection between FAI and osteoarthritis has led to concerns over FAI in adolescents. Various hypotheses on the development of cam lesions have raised concern over youth participation in sports. Theories include damage to the open femoral physis of the adolescent athlete in competitive sports leads to early cam development. In addition, when an athlete specializes in a sport, certain movements are performed more frequently, which leads to more damage. In a recent consensus, the following recommendations were made for young athletes involved in early sports specialization [40]:

- Children who participate in more hours/week than their age, for more than 16 h/week in intense training, and who are specialized in sport activities should be closely monitored for indicators of burnout, overuse injury, or potential decrements in performance due to overtraining.
- All youth can benefit from periodized strength and conditioning to help them prepare for the demands of competitive sport participation.

- Youth who specialize in a single sport should plan periods of isolated and focused integrative neuromusculature training to enhance diverse motor skill development and reduce injury risk factors.

One area of research that may protect adolescents involved in sports is to determine their risk through screening programs. Preparticipation Physical Evaluation (PPE) has been used in other joints to determine risk of injury during athletics. We have developed a screening protocol that consists of range of motion, impingement test, and FABER distance test. A study on asymptomatic youth hockey players showed that FAI and labral tears were already prevalent at a young age [13]. Additionally, the older and more experienced players had, on average, more physical exam findings, higher alpha angles, and more extensive labral and chondral damage on imaging than younger players [13]. A related study showed that certain moments in the ice skating stride placed the hip at particularly high risk for impingement lesions to cause damage [41]. If the motion causing the increased stress on the physis can be identified, then programs can be developed to decrease this risk. For example, limiting squatting during critical growth periods may slow the development of the cam deformity. In addition, when patients do develop symptoms, treatment should not be delayed. Studies have shown that delayed treatment can lead to increased cartilage damage [42].

11.8 Conclusion

Adolescents can be challenging cases when treating hip injuries. However, with an excellent history and clinical exam, most challenges can be addressed. Providing the patient and their parent with a detailed plan will allow the adolescent to recover and return to their activity of choice. Parents and children should be educated to possible complications and risk of revision arthroscopy. It is critical to diagnose and treat hip pathologies in the adolescent hip to avoid early onset of osteoarthritis.

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12 Hip Dysplasia in Athletes

Soshi Uchida, Dean K. Matsuda, and Akinori Sakai

12.1 Introduction

Hip dysplasia is one of the most common causes of hip pain in athletes in the Asian population [1]. Athletes with hip dysplasia typically present with groin and lateral hip pain which is associated with intra-articular pathology. Numerous studies have demonstrated that anterosuperior and superolateral shallow acetabulum can cause repetitive overload resulting in labral tearing, cartilage damage, and occasional rim

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Each author certifies that he or she has no commercial associations (e.g., consultancies, stock ownership, equity interest, patent/licensing arrangements, etc.) that might pose a conflict of interest in connection with the submitted article. Informed consent has been obtained from the patient. The patient approved the use of her data for the publication of this manuscript.

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stress fracture with predisposition to premature osteoarthritis. In addition, chronic fatigue overload of the periarticular musculotendinous structures including gluteus maximus, gluteus medius, IT band, rectus femoris, and iliopsoas tendon snapping issues may cause similar groin and/or lateral hip pain in athletes with dysplasia. Hip dysplasia has been better defined as being closely linked with hypermobile sports activities such as rhythmic gymnastics, figure skating, and ballet [2], where extremes of hip motion confer an advantage. Another study has shown that throwing athletes (baseball players) also have hip dysplasia in 7.9% and borderline hip dysplasia in 15.9% [3]. Emerging studies report cam deformities often coexist with DDH [4, 5].

12.2 Radiographic Evaluation

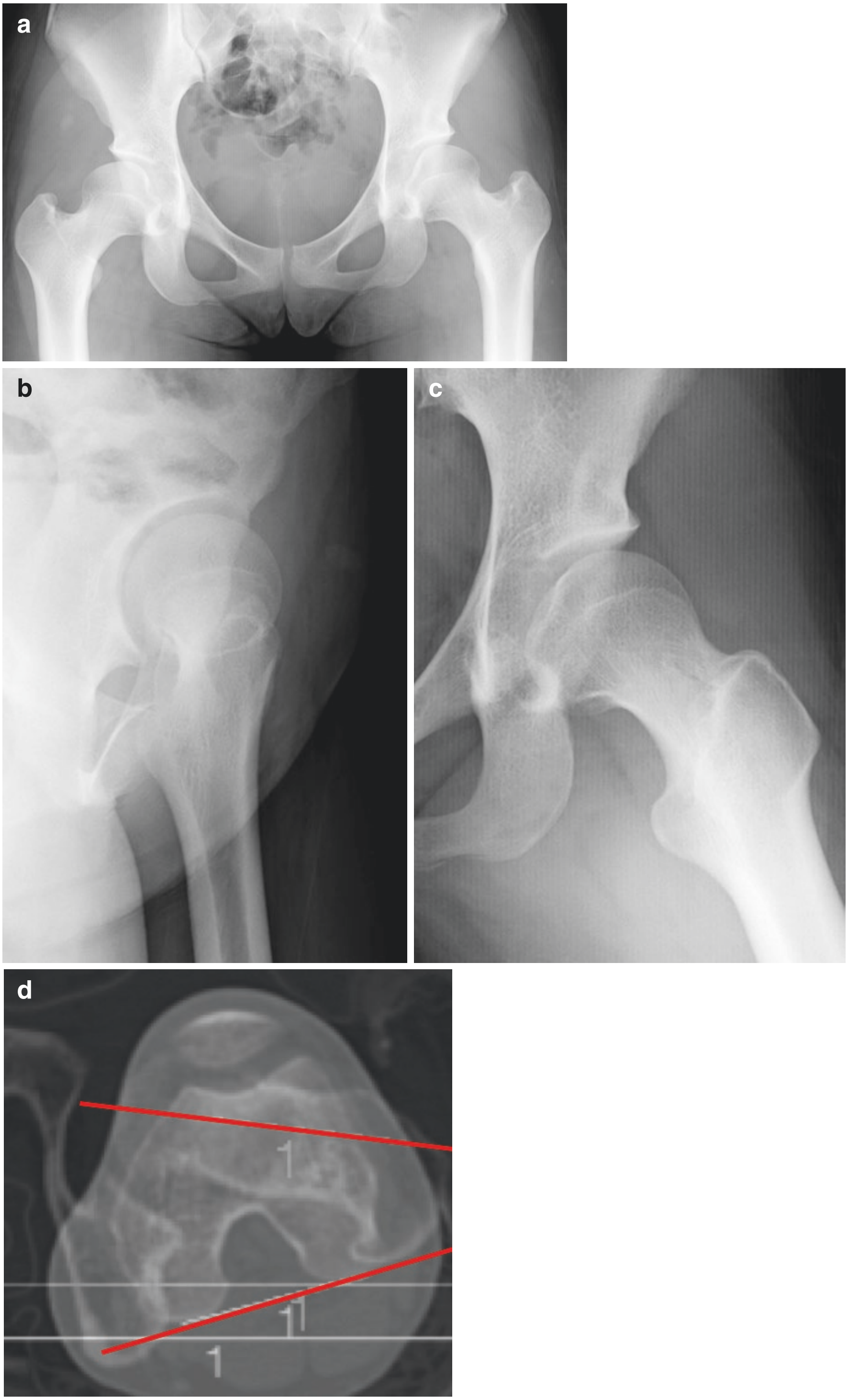
Plain radiographs are widely available, enabling two-dimensional visualization of the bony morphology of the pelvis, acetabulum, and proximal femur. Proper radiographs aid surgical decision-making in joint-preservation surgery including hip arthroscopy or endoscopic shelf acetabuloplasty.

Anterior posterior pelvis view in supine and standing position should be performed. Lateral center edge angle, Tonnis angle, femoral neck-shaft angle, joint spacing, and Shenton's line can be assessed [6] (Fig. 12.1a).

False profile view of Lequesne is performed to evaluate the anterior acetabular coverage or anterosuperior subluxation of the femoral head which is of particular relevance in DDH [7]. Vertical center anterior (VCA) angle should be measured (Fig. 12.1b). Modified Dunn view is performed to evaluate cam deformity at femoral head-neck junction which is frequently associated with DDH (Fig. 12.1c).

Preoperative three-dimensional imaging via CT and, more recently, magnetic resonance imaging (MRI) scanning can significantly enhance morphologic evaluation of the femoral head-neck junction, acetabular coverage, acetabular version, and femoral version. Additional cuts through the distal femoral condyles relative to the femoral neck enable measurement of femoral anteversion [8] (Fig. 12.1d). Femoral anteversion is correlated with acetabular anteversion in DDH patients with anterior and globally shallow socket [9]. Increased femoral anteversion may be associated with osteoarthritis [10].

Fig. 12.1 Preoperative imaging. A 20-year-old female rhythmic gymnast with developmental dysplasia of the hip presented to us with a 6-month history of left hip pain. (**a**) Diagnostic preoperative pelvic AP radiograph shows DDH. The center edge angle is 11°, and the sharp angle is 49°. (**b**) Preoperative false profile view also shows anterior shallowness of the acetabulum. The vertical-center-anterior (VCA) angle is 10°. (**c**) A modified Dunn view showing aspherical shape of the femoral head and alpha angle is 89 suggesting cam lesion. (**d**) A computed tomography of the femoral neck overlapped with additional cut of the distal femur showing femoral version is 16°


a
b
c
d

12.3 Role of Hip Arthroscopic Labral Preservation

Previous studies have established hip arthroscopy as a beneficial procedure for treating borderline and mild DDH; however, the recent literature reports higher reoperation and conversion total hip arthroplasty rates compared with more consistently successful outcomes from femoroacetabular impingement (FAI). Recent research by the senior author concluded that hip arthroscopy should not be performed for DDH when patients have a broken Shenton's line, a femoral neck-shaft angle >140°, and LCEA <19°. Some recent studies have shown that patients with borderline DDH (BDDH) respond favorably to arthroscopic labral preservation and capsular repair or plication surgery, plus femoroplasty if coexistent cam FAI is present [11]. Furthermore, another study by the senior author advises against performing hip arthroscopy for BDDH when patients have a broken Shenton's line, age older than 42 years, VCEA <13°, acetabular inclination >17°, and/or severe cartilage damage at the time of the surgery [12]. Despite several reports looking at the effectiveness of various surgical procedures to address hip dysplasia in general, this book chapter focuses on its treatment in athletes.

12.4 Periacetabular Osteotomy for Athletes with Hip Dysplasia

Periacetabular osteotomy (PAO) and rotational acetabular osteotomy are established beneficial procedures for the treatment of patient with DDH, especially moderate to severe DDH. There are two studies looking at the clinical outcomes and return to activity after PAO. Van Bergayk and Garbuz, in a series of 26 patients undergoing PAO, reported that 19 of 22 patients were able to participate in sports following PAO and the mean sports activity score improved from 1.9 to 4.4 with a very high mean satisfaction rating of 89.7 [13]. Recently, Ettinger et al. in a series of 77 patients undergoing PAO reported the mean UCLA-AS score significantly improved from 4.8 preoperatively to 7.7 [14]. Bogunovic et al. reported a series of 36 patients (39 hips) treated with PAO with 72% return to increased or the same activity level and 97% rate of satisfaction, with 11% incidence of residual hip pain limiting activity [15]. Heyworth et al. reported 46 athletes (36 females) with DDH with 80% return to play (37 of 46) at a median of 9 months after surgery [16].

However, high-demand athletes with DDH appear to be suboptimal candidates for these conventional open approaches due to prolonged postoperative rehabilitation and unestablished ability to return to sports.

12.5 Operative Procedure

Uchida et al. recently devise a new surgical technique of endoscopic shelf acetabuloplasty with arthroscopic chondrolabral and capsular reparable surgery to better access and address the anterolateral bony acetabular deficiency of DDH [17].

Endoscopic shelf acetabuloplasty is a new strategy, which concurrently addresses labral, capsular, and bony pathology in an arthroscopic manner. The procedure provides promising clinical outcomes and return to sports-related activity for mild dysplasia associated with intra-articular pathologies including labral tears and rim stress fracture [1].

12.5.1 Operative Technique

Supine hip arthroscopy is performed on a traction table under general anesthesia. Anterolateral, mid-anterior, and proximal mid-anterior portals (ALP, MAP, and PMAP) are created. Interportal capsulotomy is performed. Intra-articular pathologies including acetabular chondrolabral damage and femoral head chondral damage are assessed and documented (Fig. 12.2a). Microfracture chondroplasty is performed if ICRS grade III or IV chondral defects are present. Next, unstable labral tears are addressed with suture anchor fixation following conservative rim freshening using a motorized burr to create a bleeding bone surface. Labral repair is performed using bioabsorbable suture anchors (OsteoRaptor, Smith & Nephew, Andover, MA) with knots tied on the capsular side of the labrum (Fig. 12.2b). Arthroscopic dynamic examination is performed to assess for cam impingement. When necessary, cam osteochondroplasty using a motorized round burr is performed (Fig. 12.2c). Following cam impingement evaluation and reshaping, shoelace capsular closure is performed using Ultratape (Smith & Nephew, Andover, MA) with the hip at 40° of flexion via the MAP and PMAP (Fig. 12.2d) [18].

Endoscopic shelf acetabuloplasty is then performed as described previously [1, 17]. A 30-degree arthroscope is positioned into the extracapsular space under the fluoroscopic guidance. After identifying the straight head and reflected head of the rectus femoris and debriding the latter with a shaver and radiofrequency ablator, two parallel 2.4-mm guidewires are introduced using the drill guide through the MAP, along the anterior acetabular rim adjacent to the capsule (Fig. 12.2e). The slot is enlarged with the use of 10-mm osteotome to measure approximately 5–6 mm in height, 25 mm in width, and at least 20 mm in depth (Fig. 12.2f). The optimum width and depth are confirmed using a custom-made dilator. Autologous tricortical bone graft (tricortical) is harvested from the ipsilateral iliac crest (Fig. 12.2g). Two 1.5-mm Kirschner wires are introduced in 1.8-mm-diameter drill holes, helping to control the graft position during endoscopic insertion into the aforementioned anterolateral periacetabular slot (Fig. 12.2g). Finally, the free bone graft is secured into the appropriate position, with cortical surface facing the femoral head in intimate contact with the intervening capsule, using a press-fit technique with a cannulated bone tamp (Smith & Nephew, Japan) (Fig. 12.2h). An additional cortical bone graft is inserted under endoscopic guidance above the new shelf and fixated with a hydroxyapatite PLLA screw and washer to support shelf graft (Fig. 12.2i).

Postoperative X-ray showed improved coverage of acetabulum, and 3DCT showed proper position of the shelf graft (Fig. 12.3).

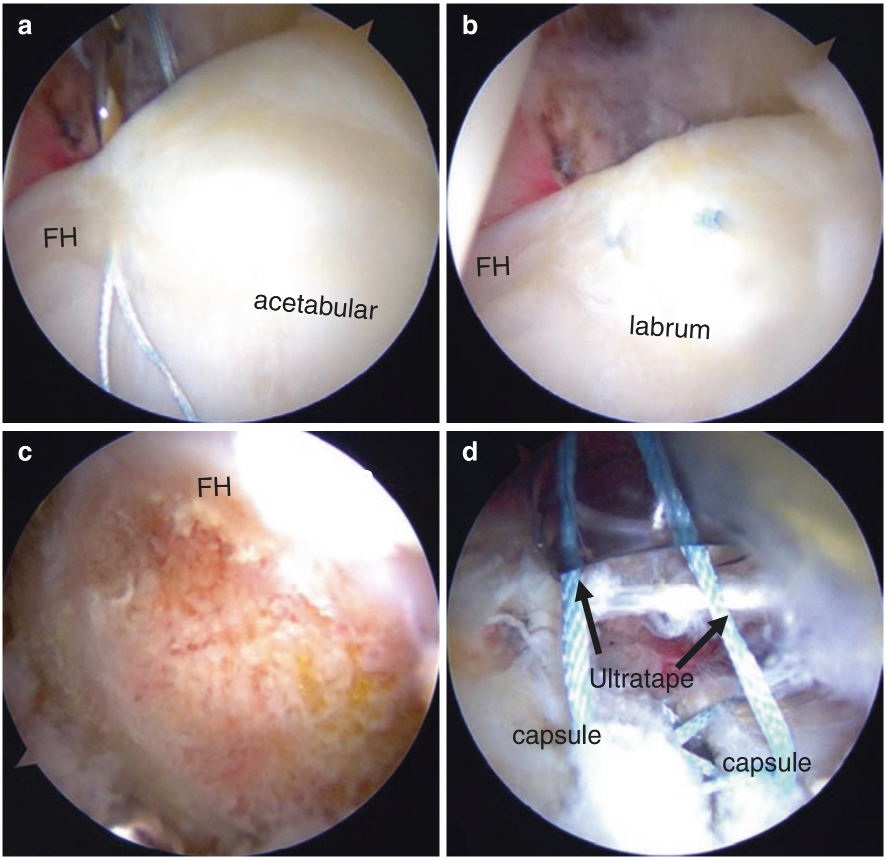


Fig. 12.2 Endoscopic shelf acetabuloplasty. (**a**) Supine arthroscopic view from the anterolateral portal (ALP) showing an anterior superior labral tear. (**b**) Labral repair with suture anchor is visualized from the ALP. (**c**) Arthroscopic view from the mid-anterior portal (MAP) showing cam osteoplasty. (**d**) Shoelace capsular closure using Ultratape via the mid-anterior portal (MAP) and the proximal mid-anterior portal (PMAP) viewing from the ALP. (**e**) Two 2.4-mm guidewires were introduced through the MAP under fluoroscopy. (**f**) Osteotome was utilized to make the shelf slot along with 2.4-mm guidewires. (**g**) Free bone graft harvested from ipsilateral iliac crest, with two parallel 1.5-mm Kirschner wires. (**h**) The free bone autograft was inserted into the slot through the guidewires with press-fit fixation. (**i**) An additional cortical bone graft is inserted above the new shelf and fixed with hydroxyapatite PLLA screw and washer to support shelf graft under endoscopic guidance

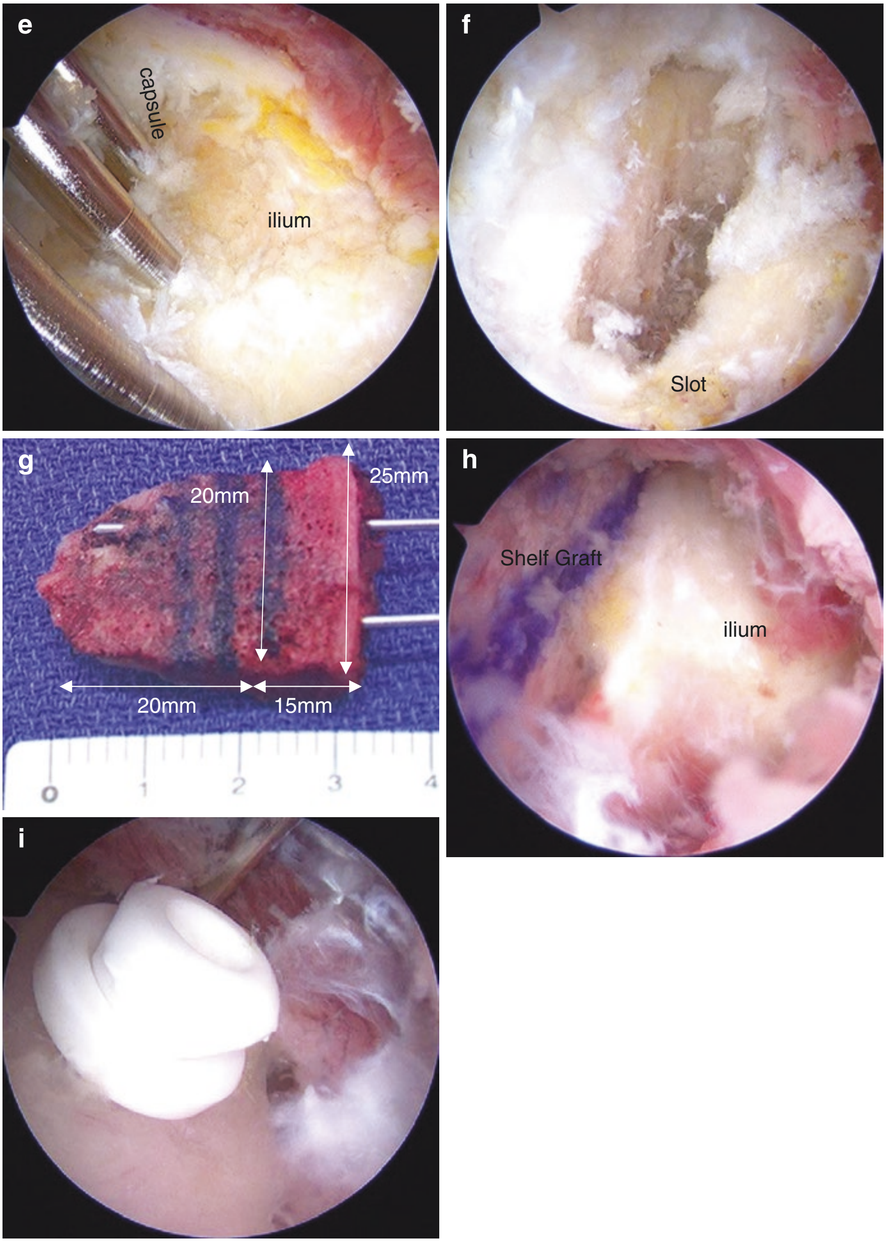


Fig. 12.2 (continued)

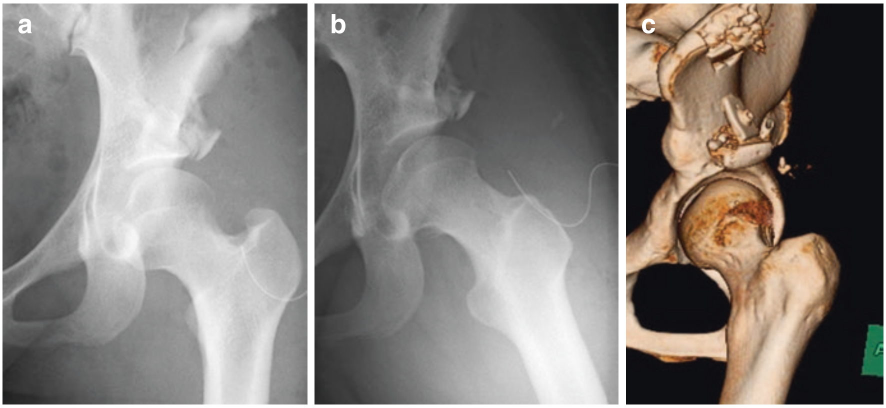


Fig. 12.3 (**a**) Pelvic AP radiograph showing improved coverage of the acetabulum with a shelf graft just after surgery. LCE angle was 41°. (**b**) A modified Dunn view showing improved coverage of the acetabulum with a shelf graft and improved femoral head-neck offset just after surgery. (**c**) 3DCT showing proper position of shelf graft

12.6 Postoperative Rehabilitation

Patients are instructed to use flatfoot weight-bearing for the first 3 weeks. If microfracture is performed, weight-bearing limitations are extended to 6–8 weeks. Patients are placed in a brace (Philippon hip brace; Bledsoe) for 2–3 weeks to protect the hip and limit flexion (0–120°), abduction (0–45°), and rotation (external rotation 0°). Gentle passive range of motion (ROM) exercise is initiated during the first week, under supervision of a physiotherapist. Circumduction is performed at 70° of hip flexion and neutral hip flexion for the first 2 weeks. Then, continuous passive motion (CPM) is used to prevent adhesive capsulitis by applying 0–90° of hip flexion for up to 4 h a day, for 2 weeks.

During Phase II (weeks 6–12), patients improve their mobility, trunk stability, and proprioceptive activity. Endurance strengthening is commenced only after ROM is maximized, and good stability in gait and movement is demonstrated.

Patients are allowed to progress to Phase III (weeks 12–16) once passive ROM is symmetric and pain-free with a normal gait pattern. Aerobic conditioning is advanced using elliptical machine with a goal of 30 min of continuous exercise at a low to moderate intensity.

Patients are allowed to progress to physical activity only if passive ROM is symmetric and pain-free, with a normal gait pattern. The goal of Phase IV prepares patients for return to play or work. Gentle sports-specific or work agility exercise is initiated [Spencer-Gardner, 2014 #1598].

12.7 Outcomes of Shelf

Uchida et al. described in a series of 32 active patients undergoing endoscopic shelf acetabuloplasty combined with labral repair that the mean PRO scores (modified Harris hip score, nonarthritic hip score, and iHot) significantly improved from preoperatively to postoperatively.

They demonstrated 90% RTP with a mean period of 9 months; UCLA activity score also significantly improved [1].

Recent technical notes have shown that endoscopic shelf acetabuloplasty can address DDH athletes with large acetabular bone cyst as well as rim stress fracture [19, 20].

12.8 Take-Home Message

Preoperative patient evaluation and planning is paramount for successful treatment.

Patient history, examination, and imaging studies are necessary to elucidate existing pathology and offer the best treatment option.

Patient expectations should not be neglected.

Educate your patients about their disease and discuss the importance of compliance with the postoperative rehabilitation.

12.9 Conclusion

Athletes with BDDH may be reasonable candidates for hip arthroscopy including labral preservation, capsular repair/plication, and femoroplasty in cases of coexistent cam FAI, but the recent addition of endoscopic shelf acetabuloplasty extends the minimally invasive approach to athletes with mild to moderate DDH.

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Complications Related to the Arthroscopic Treatment of the Femoroacetabular Impingement

13

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The recognition of a variety of hip pathologies such as femoroacetabular impingement as a potential precursor to hip osteoarthritis has led to the development of hip preservation surgery. Improvements in technique and instrumentation continue to increase the number of cases performed worldwide. However, there is a significant learning curve associated with hip arthroscopy. Although the rate of complications is low (7.5%), it is largely related to the learning curve. Fortunately, most of these complications are transient and do not affect the patients in long term. Although some complications may be life-threatening, most of them can be avoidable applying preventive measures such as careful preoperative plan will reduce the risk of complications and failures, and learning curve plays an important role.

13.1 Introduction

With the increase of arthroscopic procedures around the hip for the treatment of a variety of disorders including femoroacetabular impingement (FAI) and many other articular and periarticular pathologies [1, 2], more literature regarding outcomes and complications associated with hip arthroscopy can be found. Previous studies, primarily from high-volume hip arthroscopists, report that the complication rate varies from 1.34 to 15% [3–10]. However, Truntzer reviewed an insurance company database and found the rates of major and minor complications within a 1-year postoperative period were 1.74% and 4.22%, respectively, significantly higher major

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complication rate than otherwise reported by high-volume surgeons [9]. A subsequent comparative evaluation comparing complications from high-volume specialists and general databases demonstrates a 1.3 times increase relative risk of major complications following hip arthroscopies performed by non-high-volume centers. Particularly, there was a significantly higher rate of femoral neck fractures, hip dislocations, and reoperations in the database studies, suggesting again that experience plays a significant role in hip complications [10]. Further supporting this is the work by Mehta, who demonstrated that the risk for further surgery following hip arthroscopy decreased with surgeons' experience. Those authors, looking at a statewide database, found that surgeons who performed between 98 and 388 hip arthroscopies had a 13.8% risk of reoperation within 5 years, as compared with surgeons who performed 389–518 hip arthroscopies (10.1%), and the least need for reoperations were patients whose surgeons performed more than 518 hip arthroscopies, at 2.6% [11].

Iatrogenic chondrolabral injury [12] and neuropraxia usually temporary [13] secondary to traction are frequently mentioned in relation to hip arthroscopy and are directly related to the learning curve and can be preventable.

The reoperation rate was 6.3%, and the most common indication for reoperation was incomplete reshaping of impingement deformities and conversion to total hip arthroplasty, which is, in general, considered failure of the procedure rather than a complication even though the need for total hip replacement may be directly related to a complication.

13.2 Iatrogenic Chondrolabral Injury

Iatrogenic injury to the labrum or articular cartilage may occur during initial portal placement from spinal needle entry, dilation, cannula placement, or capsulotomy, especially those hips with global over-coverage with limited intra-articular space despite traction. To avoid this, surgeons should access the intra-articular space from the periphery in order to check that the labrum and the articular cartilage have not been damaged [14] (Figs. 13.1 and 13.2).

Although various studies have shown that iatrogenic labral punctures have no significant effect on short-term clinical outcome, this must be always considered undesirable, and every effort should be made to avoid labral penetration during hip arthroscopy [14] (Fig. 13.3).

Patient positioning is the first step in hip arthroscopy, and careful positioning will allow us to achieve sufficient traction to separate the femoral head from the acetabulum and provide good amount of space to access the central compartment of the hip diminishing the risk of articular cartilage injury.

The safety of portal placement is related directly with learning curve. Arthroscopic access to the hip is achieved using specially designed cannulated instruments and techniques. The anterolateral portal is established once traction is applied; usually a 17-gauge spinal needle is navigated into the joint with fluoroscopy-guided technique. Even though the anterolateral portal is at the center of the safe zone, it has the highest risk of iatrogenic injury to the intra-articular structures because it is done blindly, without direct arthroscopic vision, and guided only by fluoroscopy. A 70° arthroscope

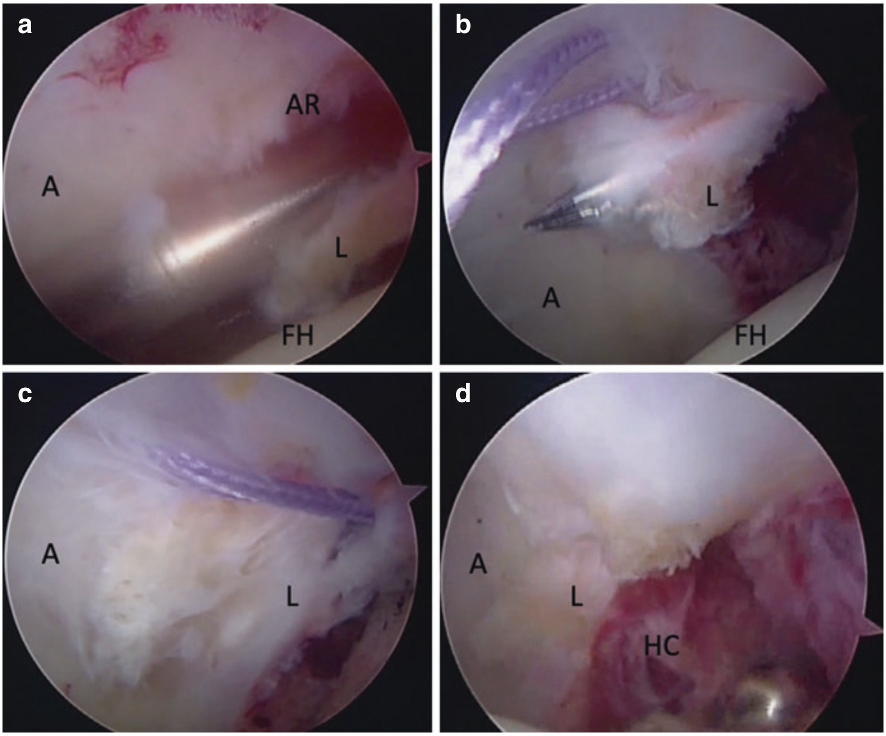

Fig. 13.1 Intra-articular image in a right hip showing a labrum piercing detachment. (**a**) A cannula is observed between the acetabular rim (AR) and the labrum which was accidentally detached with the cannula. The acetabulum (A) is at the top of the photograph and the femoral head (FH) at the bottom. (**b**) After management of a pincer deformity, a suture anchor was used for labral reattachment. A suture was passed through the detachment, and the labrum (L) is being pierced to retrieve the suture for the repair. (**c**) The suture is observed in position before knot tying. (**d**) In the final picture of the labral repair, hip capsule (HC) is observed behind the labrum

is used to directly visualize the anterior portal placement. Once both portals are established, the arthroscope is switched back to the anterolateral portal, and capsulotomy is made. This step requires precision to avoid labral and chondral injury [15]. During labral repair or reconstruction, the surgeon must be aware that the non-anatomical placement of the suture anchor can compromise the function of the repaired labrum as well as increases the risk to damage the intra-articular cartilage surface. The use of different portals to provide better angle of anchor insertions may decrease the incidence of intra-articular penetration during arthroscopic labral repair [16].

13.3 Instrument Breakage

Broken instruments can result in loose foreign bodies that can cause severe damage to the surrounding structures. Hip anatomy makes manipulation of the arthroscope and instruments difficult. A review of 1054 consecutive hip arthroscopies

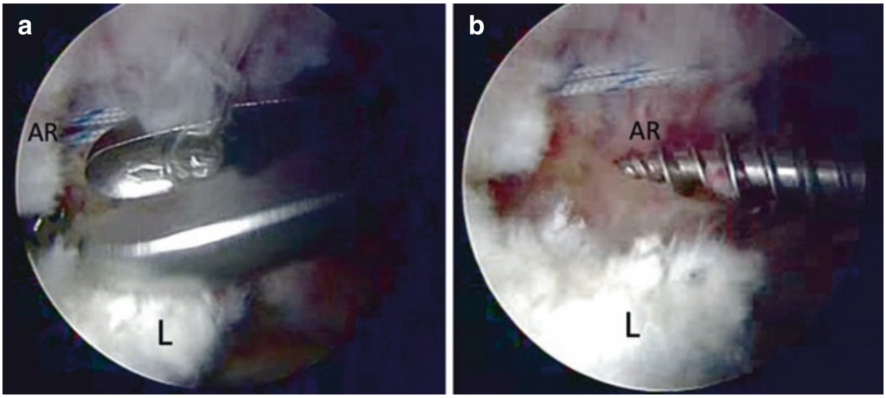

Fig. 13.2 (**a**) Intra-articular position of a metal anchor (to the left), the acetabular rim (AR), and sutures from a new anchor during revision are observed proximal to the metal anchor. The labrum is at the bottom (L). (**b**) Metal anchor is retrieved

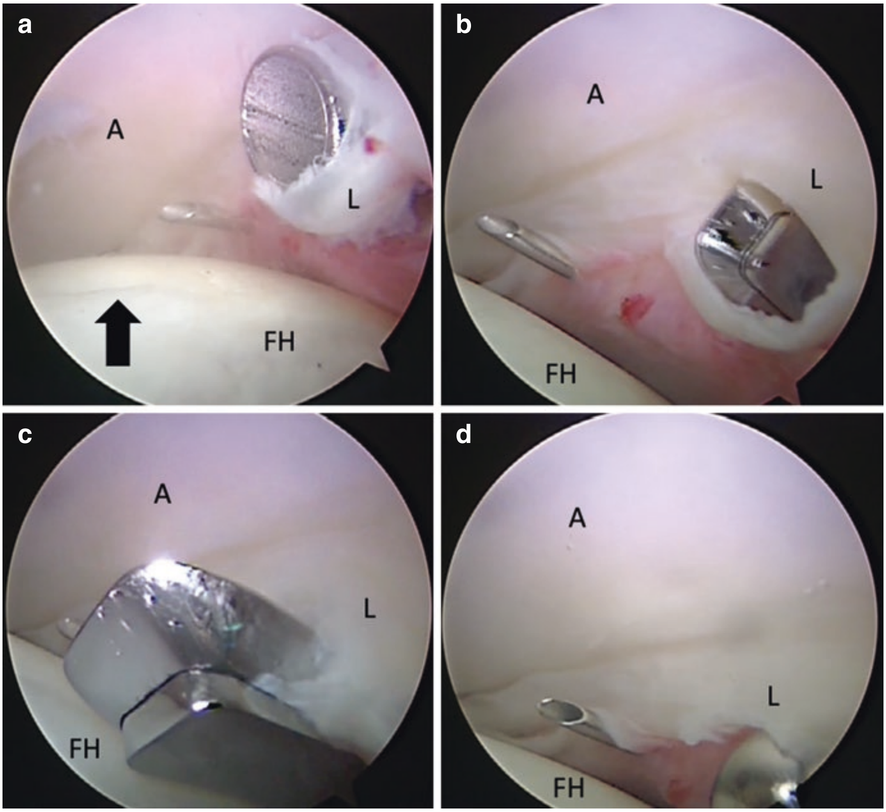

Fig. 13.3 Labral piercing at the free margin of the labrum. (**a**) A cannula is observed piercing the labrum (L) close to its free margin. The acetabulum (A) is at the top, and the femoral head is at the bottom. The black arrow points to a needle mark on the femoral head (FH). (**b**, **c**) A basket forceps was used to remodel the tear. (**d**) Final image of the remodeled tear. Intra-articular image in the right hip showing a labrum piercing

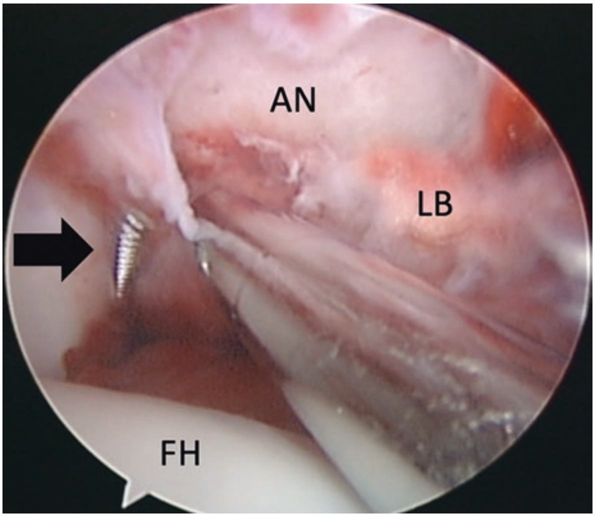

Fig. 13.4 Arthroscopic image in the right hip. During loose body (LB) retrieval, a grasper broke inside the joint. The black arrow points to the fragment of the grasper at the acetabular notch (AN). Femoral head is at the bottom (FH)

by Clarke et al. included only 2 instances of instrument breakage [17]. Seijas et al. in a recent publication found five cases where surgical instruments broke [18]. Previously Sampson identified three cases of instrument breakage in a 1000-patient series [19]. Although these studies did not discuss or evaluate the cause for instrument breakage, surgeons should always handle arthroscopic instruments delicately, ensuring that the nitinol guide wire is retracted carefully during cannula insertion; as well, surgeons always must inspect them for signs of breakage or abnormal wear before and after introducing them into the joint (Fig. 13.4).

13.4 Iatrogenic Hip Instability

Hip joint stability relies on a highly congruent osseous anatomy, the acetabular labrum, the ligamentum teres, and the hip capsule. Intraoperative compromise of these structures can result in instability, pain, and functional limitations [20].

Although hip instability following arthroscopy is reported to be approximately 0.07% [21], it is important to be aware of the catastrophic consequences. Multiple cadaveric biomechanical studies have demonstrated that iliofemoral ligament sectioning results in increased external rotation, extension, and anterior translation [22–24].

In those patients with ligamentous laxity preoperatively, the peripheral compartment should not be accessed through the central compartment through capsulotomy to minimize capsular dissection, or the capsule should be repaired following the procedure. Senior author has developed an arthroscopic technique preserving the iliofemoral ligament performing a portal enlargement, reducing the necessity of capsular treatment after the procedure [25]. Matsuda in 2009 [26] presented a case report of an iatrogenic anterior hip dislocation following an arthroscopic procedure. Over-resection of the acetabular rim may result in bony instability, with a lateral center-edge angle <25°. Rim recession should be avoided in patients who have a lateral center-edge angle of 20° or less. Bony instability is a devastating complication, which is very difficult to address, and the patient may require further surgical complex procedures to improve symptoms and avoid dislocations [27–30].

13.5 Neurovascular Injury

The hip joint is surrounded by several neurovascular structures: the lateral femoral cutaneous nerve, the femoral neurovascular bundle, and the sciatic nerve and gluteal vessels [31] (Fig. 13.5).

In hip arthroscopy, the incidence of nerve damage is 1%, with transient neuropraxia accounting for nearly all cases. The most commonly reported affected nerve is the pudendal, and probably related to direct pressure from the perineal post, followed by the lateral femoral cutaneous nerve, sciatic nerve, common peroneal nerve, and femoral nerve [32] (Fig. 13.6). Although the traction weight has been directly correlated with sciatic nerve dysfunction and injury, total traction time effect remains unclear [33]. To avoid neural injuries, it is important to create an adequate padding of the perineal post; as well, careful portal establishment is mandatory [19] (Fig. 13.7).

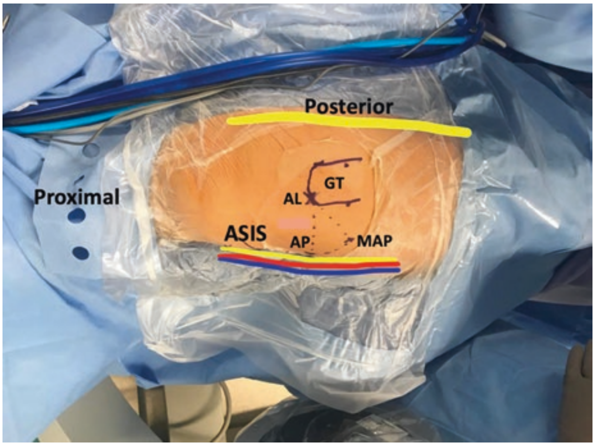

Fig. 13.5 Topographic anatomy of a left hip during hip arthroscopy in the lateral position. The greater trochanter (GT) and the anterior superior iliac spine (ASIS) are outlined. No portals are placed posterior to the GT to protect the sciatic nerve. No portals are placed medial to the ASIS to protect the femoral neurovascular bundle. The anterolateral portal (AL) is at the corner of the GT. The direct anterior portal (AP) is at the intersection of a line coming from the GT and a line coming to the ASIS. At this point branches of the lateral femoral cutaneous nerve are present and may be pierced. At the tip of an equilateral triangle with its base between AL and AP is the mid-anterior portal (MAP)

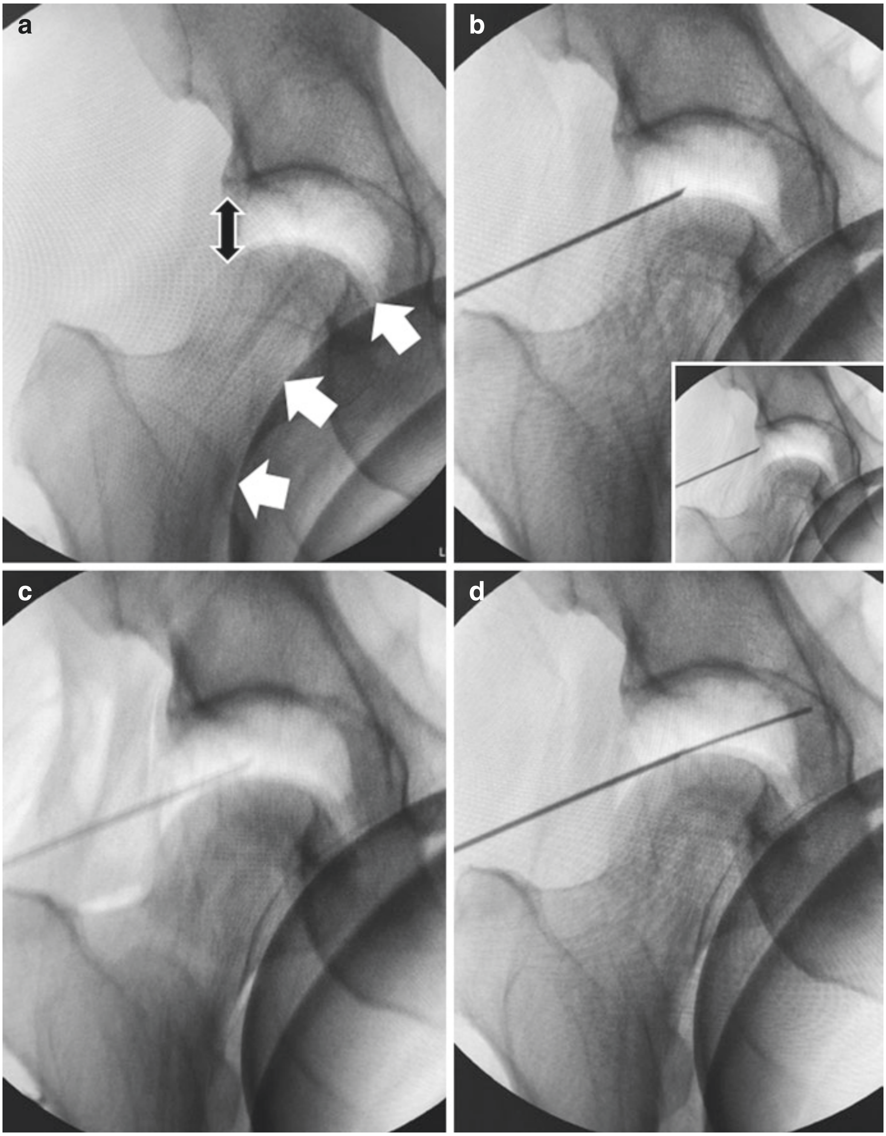

Fig. 13.6 Fluoroscope images of a right hip with traction during hip arthroscopy. (**a**) A separation of at least 10 mm is obtained between the lateral rim and the femoral head (black arrow). The white arrows demonstrate the perineal post resting on the patient thigh. (**b**) A needle is introduced to the anterolateral portal into the hip joint. The needle is placed as close as possible to the femoral head with the blunt side on the femoral head (bottom right: if the needle is placed close to the rim, the labrum may be pierced). (**c**) The capsule is distended by injecting air, and the space between the femoral head and the rim increases without further traction. (**d**) The needle must rest on the head as a sign is not piercing the labrum

Fig. 13.7 (**a**) Clinical photograph showing a patient positioned in the right lateral decubitus for left hip arthroscopy. Compression points are well padded on the non-operative leg. An extra-large perineal post is positioned against the patient thigh without compression of the patient genitalia. (**b**) The patient positioned must allow for traction release and dynamic assessment of hip motion. Note that extra padding of the foot as it is fixed on the traction device

The most common vascular structures at risk for injury anteriorly are the femoral artery, the ascending branch of the lateral femoral circumflex artery, and the superior gluteal artery, and majority of these injuries are related with incorrect portal placement [34].

13.6 Heterotopic Ossification

Heterotopic ossification (HO) after hip arthroscopy may complicate the postoperative outcome and can be a cause for revision arthroscopy [35].

Although the incidence and severity of heterotopic ossification may be multifactorial, the use of nonsteroidal anti-inflammatory drugs (NSAIDs) and/or low-dose radiation therapy is effective prophylaxis [36]. Previous authors have proposed that HO after hip arthroscopy may result from periosteal remnants or seeding of osteogenic marrow into the surrounding tissue after bone remodeling for the treatment of

FAI [37]. Bedi et al. previously demonstrated a decrease in HO formation with naproxen plus indomethacin compared with naproxen alone in a larger cohort. They found that the incidence of HO was 1.8% in the naproxen-plus-indomethacin group and 8.3% in the naproxen-only group. Beckmann et al. [37] found a 25% incidence of HO in patients not receiving naproxen, compared with incidence of 0–44% on previous studies [25, 38].

13.7 Incomplete Reshaping

Incomplete reshaping of FAI has been shown to be a common cause of revision hip arthroscopy. Philippon et al. [39] found on a retrospective review that 95% of their revision cases had residual FAI and 97.2% had radiographic signs of residual FAI. Heyworth et al. [40] on a previous study found that 79% of the cases had unaddressed or undertreated bony impingement lesions. Over-resection of a cam deformity may disrupt the labrum seal against the over-resected area. A major concern in this context is the risk of femoral neck fractures due to weakening of the bone. Wijdicks et al. [41] performed a biomechanical evaluation of iatrogenic femoral cortical notching and risk of femoral neck fracture. They concluded that 4.0-mm and 6.0-mm cortical notching significantly decreased the ultimate load and energy to failure compared with intact femoral bone. Mardones et al. [42] performed a cadaveric study, and they found that resection of up to 30% of the anterolateral head-neck junction did not significantly alter the load-bearing capacity of the proximal part of the femur. Domb et al. [43] found that the rates of conversion to THA were higher in the over-resection group compared with the under-resection group.

13.8 Deep Vein Thrombosis

Given the increase of hip arthroscopies worldwide, all patients undergoing hip arthroscopies must be assessed for risk factors and stratified for development of venous thromboembolic events (VTE). Those patients with an elevated risk for developing VTE such as inherited prothrombotic conditions, metabolic or cardiovascular disturbances, oral contraceptive use, malignancy, or obesity, or history of prior VTE, should be given pharmacologic prophylaxis. Salvo et al. [44] published that the rate of symptomatic deep vein thrombosis (DVT) after hip arthroscopy can be 3.7%. Alaia et al. [45] published recently an incidence of 1.4% of symptomatic DVT and zero asymptomatic DVT. Mohtadi et al. [46] in a prospective study demonstrate an incidence of deep venous thromboembolism of 4.3%. Haldane et al. [47] after a systematic review concluded that the low incidence of VTE events suggests that routinely prophylaxis may not be necessary in low-risk patients undergoing hip arthroscopy; however, the true rate may be underreported, and future research is needed to determine which prophylaxis strategy is best reducing the incidence of this potentially morbid complication.

13.9 Abdominal Compartment Syndrome

The most catastrophic complication related with hip arthroscopy is intra-abdominal or retroperitoneal fluid extravasation that may lead to abdominal compartment syndrome, cardiac arrest, and death [48–51]. One of the first cases reported by Bartlett et al. [51] was a patient who underwent to hip arthroscopy after acetabular fracture for removal of intra-articular fragments. Sampson has reported an incidence of 1%. In total 20 cases have been reported in the literature, and hypotension appears to be a cardinal sign for increased abdominal pressure, and both careful monitoring by the anesthesiologist and regular abdominal checks by the orthopedic surgeon should occur throughout the procedure. Significant risk factors are higher arthroscopic fluid pump pressure, iliopsoas tenotomy, and operative time [52, 53]. Thus, keeping intra-articular pressure as low as possible, performing the surgery as efficiently as possible without compromising quality, frequently monitoring the abdomen and peak ventilatory inspiratory pressure, and performing iliopsoas releases, when indicated, at the conclusion of the case might help to minimize the risk for this complication.

13.10 Avascular Necrosis of the Femoral Head

Avascular necrosis of the femoral head (AVN) following hip arthroscopy has been reported with several case reports in the literature. Many factors have been described as a possible cause of iatrogenic AVN such as increased distraction time, partial capsulectomy, and injury to the lateral epiphyseal branch of the medial femoral circumflex artery (MFCA) which is critical for the vascularity of the femoral head [54–56]. When femoral osteochondroplasty for cam deformity is considered, the lateral synovial fold is a reliable landmark that can be used to identify the branches of the MFCA [25] (Fig. 13.8).

13.11 Conclusions

Most complications of hip arthroscopy are minor or transient, but serious complications can occur, and surgeons must be aware of them. Currently, different preventive measures have been described in order to reduce these complications and make hip arthroscopy a safe surgical procedure. Thus, experienced and appropriate trained surgeons on hip arthroscopy procedures are needed in order to obtain successful outcomes. We also believe that the adequate patient selection plays a critical role.

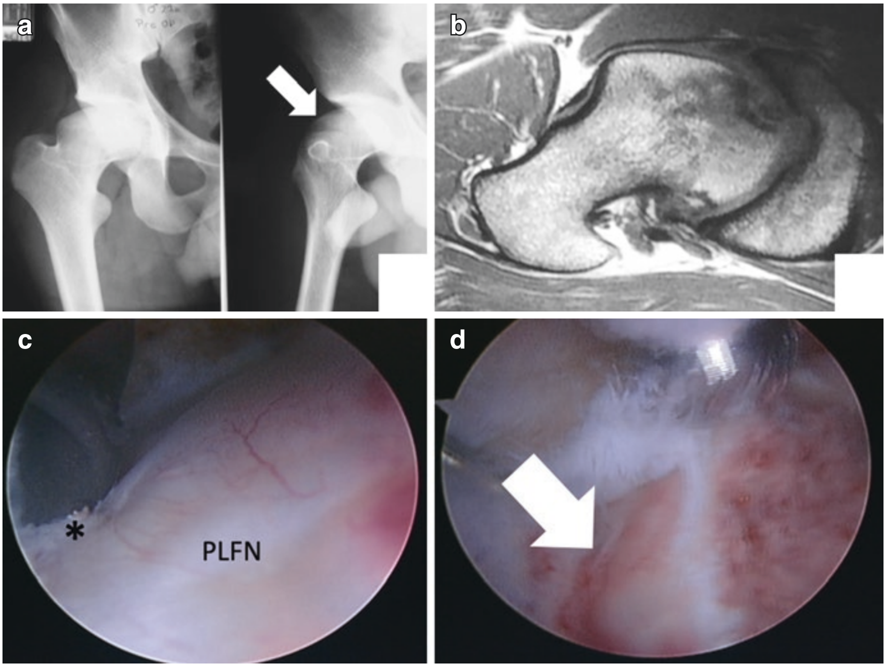

Fig. 13.8 Severe CAM deformity in a right hip. (**a**) The white arrow demonstrates a posterior extension of the CAM deformity. (**b**) Corresponding MR image showing the size of the deformity. (**c**) Endoscopic image of the posterior synovial fold (*) and blood vessels going into the posterior lateral femoral neck (PLFN). (**d**) CAM remodeling with the right visualization of the vascularity to prevent injury (white arrow)

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Hip Arthroscopy: What Are the Limitations

14

John O'Donnell

As the indications for arthroscopic hip surgery increase at such a fast rate, with new areas, such as surgery of the deep gluteal space, developing rapidly, it is tempting to claim that the only limitation to hip arthroscopy is the imagination of the surgeon. Whilst that is certainly partly true, there are other limitations still!

The various limitations can be grouped under the following headings—surgeon, equipment, patient (pathology, biological issues, bone issues), and cost, and we will consider each in turn.

14.1 Surgeon Limitations

Hip arthroscopy is not easy, and an ability to perform arthroscopic surgery of another joint, such as the knee, does not automatically bestow the same ability to perform hip arthroscopy. It has been estimated that it takes at least 30–100 hip arthroscopies to gain proficiency. Konan et al. [1] found that the number of complications decreased after 30 cases and the operating time decreased up until 100 cases. Of course, the number of cases it takes to become proficient will vary from one surgeon to another, and a general proficiency does not mean that new arthroscopic hip procedures will not also have to be learned. Alvand et al. [2] concluded that, with respect to knee and shoulder arthroscopy, some individuals were unable to achieve competence in basic arthroscopic tasks despite sustained practice. It seems reasonable to extrapolate this finding to hip arthroscopy also.

In order to minimise the number of operations it takes to become fully proficient, and, of course, to minimise the risk of doing harm to patients whilst

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gaining surgical skill and experience, proper training and mentoring is critically important. It is also important for surgeons to be aware that just because they have watched an expert perform an operation and make it look easy, it does not follow they will be immediately able to do the same operation with the same outcome.

14.2 Equipment Limitations

In the early days of hip arthroscopy, all operations were difficult. It was very difficult to correctly place and maintain portals, for example, using only standard knee and shoulder instrumentation, but the introduction of needles and guide wires, along with cannulated instruments, transformed this part of the operation.

Similarly, curved and articulated instruments have greatly improved the ability to access all areas of the joint, and curved drill guides, drills, and anchor introducers have improved our ability to accurately place anchors for labral repair and reconstruction.

The constant evolution and improvements of instruments and surgical techniques are the main reasons that today's limitations are likely to simply become tomorrow's every day, easily dealt with, problems.

14.3 Patient Factors

General patient factors which limit hip arthroscopy may include such things as bleeding disorders and skin conditions which predispose to infection, for example, but the most frequently encountered general patient limitation is obesity, which is an increasing problem. In more extreme cases, it can be difficult to locate the hip, and movement of instruments within the hip can be severely compromised, or the instruments may not even be long enough to reach the necessary areas within the hip. In this situation use of a longer (30+ cm) cystoscope may be necessary in order to reach the hip joint.

In addition, there are important factors related to the psychology of the patient and the expectations of the patient. It is critically important that the patient does not enter into surgery with expectations which cannot possibly be met.

14.3.1 Specific Pathologies

Specific patient factors relate to the pathologies present, and there are three major groups of pathologies which remain significant limitations for hip arthroscopy. These are severe general pincer impingement, chondral loss and osteoarthritis, and acetabular dysplasia and other bony deformities.

Severe general pincer impingement, such as coxa protrusio, may make it impossible to distract the hip with traction (Fig. 14.1).

Fig. 14.1 A case of severe protrusio, where hip distraction is likely to be very difficult or impossible

14.3.1.1 Global Overcoverage

Although it is possible to approach the hip from the peripheral compartment and excise rim bone from outside-in, many surgeons are not familiar or practised at this approach and not comfortable using it for difficult cases. Access to the more posterior and postern-inferior parts of the acetabular rim is similarly unfamiliar to most surgeons. Many may prefer to use an open rather than an arthroscopic approach to deal with these cases. There are case reports by expert surgeons showing excellent outcomes for arthroscopic rim resection in this situation [3], so it is certainly possible but probably beyond the abilities of most surgeons.

14.3.1.2 Osteoarthritis

Arthroscopic treatment for patients with moderate or severe hip joint arthritis has been shown to have significantly poorer outcomes than for patients with minimal or no arthritis. As a result, arthroscopic hip surgery is generally thought to be contraindicated in the presence of arthritis. It is always a little difficult to define "how much arthritis is too much?", but the most commonly accepted measurement for making the determination is when the measured joint space at any point of the joint is <2 mm [4] on a standard radiograph (Fig. 14.2). However, there may be an exception to this rule. In some areas of the world, patients with arthritis of the hip are being treated with stem cells. There are few reported results and no high-quality evidence to support this treatment. However, patients having stem cell treatment to try to regrow articular cartilage, or even just to relieve pain, may possibly do better if any impinging osteophytes are removed and any intra-articular pathology which is amenable is treated arthroscopically.

14.3.1.3 Articular Cartilage Defects

Treatment of lesser articular cartilage injuries also presents a limitation to arthroscopic treatment as there is still no reliable way to treat areas of full-thickness

Fig. 14.2 A case of osteoarthritis, where the joint space is less than 2 mm

articular cartilage loss and regrow normal articular cartilage. Reliable fibrocartilage healing is usually possible with smaller lesions (less than 2 square centimetres) when treated with microfracture. Larger lesions up to 3–4 square centimetres may be treated with microfracture and supplemental gel (chitosan) or membrane coverage or by autologous cartilage grafting, but the long-term outcomes of these treatments remain unknown.

14.3.1.4 Dysplasia

Arthroscopic surgery for acetabular dysplasia remains a controversial area. It is generally accepted that moderate or severe dysplasia requires a periacetabular osteotomy (PAO). However, some cases with milder dysplasia and a CE angle of >18° have been reported following arthroscopic treatment [5], including labral repair, ligamentum teres (LT) debridement, and capsule plication, but the reported results are very short term at around 2 years. Excellent outcomes following PAO have been reported at 10 and 20 years [6], so we must be extremely cautious in accepting claims that arthroscopic results can be as good as open surgery in even mild cases of dysplasia. At least 10-year follow-up will be required to see if these claims are true. At this early stage, treatment of hip dysplasia should be considered to be beyond arthroscopic surgery for any but the mildest cases or when PAO is not thought to be indicated.

As well as acetabular dysplasia, many bony deformities involving the hip still require open surgery to perform corrective osteotomies. Examples include head reduction osteotomy to reshape a deformed post-Perthes femoral head deformity, severe femoral version deformities, and a prominent high greater trochanter. However, as has happened in many other areas, including arthroplasty, there is an ongoing progression to minimise the "invasiveness" of these procedures. Already we have seen PAO become a progressively smaller procedure, and techniques involving arthroscopic assistance have been reported. It seems certain that such progress will continue and arthroscopically assisted and all arthroscopic techniques will be developed to deal with these problems in the future.

14.4 Cost Factors

In several countries around the world, there have been efforts by governments and third-party payers to restrict healthcare costs by severely restricting the use of hip arthroscopy, as this is seen to be an area of health spending which is expanding rapidly. Of course, these payers tend to focus on immediate surgical equipment costs which are typically greater for arthroscopic surgery than open surgery, but once other costs such as operating room time, time off work, etc. are taken into account, arthroscopic surgery is found to be more cost-effective than either open surgery or conservative treatment.

As justification for these restrictions, there have been claims that there is no evidence for the benefit of arthroscopic treatments. Obviously, these claims are not true as there are great many outcome studies which have been published. However, it is true that most of these published studies are of low-level (Level 4) evidence. Several randomised control trials (RCTs) are currently underway and will, over the next 12 months, provide the Level 1 evidence which has been demanded.

14.5 Conclusions

There are still limitations in our abilities to treat all hip joint preserving procedures arthroscopically. These limitations may result from limitations in the ability of the surgeon, from inadequate equipment, from limitations in our abilities to treat some pathologies, or from cost pressures and government regulation. Over time, no doubt all of these limitations will be overcome. As newer techniques and procedures are developed, it is likely that new limitations will arise, but solutions will be found for them also.

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15 Rehabilitation Following Hip Arthroscopy: Takla-O'Donnell Protocol (TOP) for Physical Therapy

Amir Takla

15.1 Introduction

Hip arthroscopy involves assessment and treatment for several intra- and extra-articular pathologies of the hip and therefore is helpful to be able to differentiate between them [1]. The intra-articular pathologies, for example, include labral tears, chondral lesions, ligamentum teres tears, and femoroacetabular impingement (FAI) to name but a few [2].

Clinical examination is not entirely reliable, and it can be difficult to identify which specific structure is injured. Examination of the hip can be complicated due to its deep architecture/soft tissue envelope, as well as by the relatively common incidence of referred pain from the lumbosacral spine, intra-abdominal or abdominal wall problems and occasionally from genitourinary tract [3, 4].

Physiotherapy rehabilitation should be tailored to the specific pathology and or the surgical intervention. Preoperative rehabilitation for patients with hip joint osteoarthritis undergoing hip joint replacement has been shown to be effective [5–7].

Griffin [5] reported the use of gentle, repetitive hip internal rotation range of motion exercises early in the rehabilitation process to prevent adhesions of the joint capsule and subsequent loss of motion.

Philippon et al. [8] described a postoperative protocol for patient that started range of motion exercises of the surgical hip within 4 h after surgery with neutral rotation. The authors argued that rotation precaution was necessary for approximately 18–21 days and straight-leg raising was prohibited for 4 weeks. The rehabilitation was guided toward early aquatic, proprioception, and strengthening exercises.

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Kinnaman and Mabrey [9] also described a protocol consisting of physical therapy or self-guided exercises program. The exercises vary from isometric/isokinetic to open kinetic chain exercises.

Finally, many programs have been described but none tested until the recent FAIR trail [11]. The FAIR trail examined a specifically designed protocol for patients following hip arthroscopic surgery. In short, the patients undergoing this program performed significantly better than control patients in the short to medium term following the surgery, therefore facilitating early return to activities or daily living and recreational sport.

15.2 Assessment of the Hip Joint Should Include Three Elements

Firstly, a detailed subjective examination focusing on specific area of pain [23, 24, 25], as well as possible referred symptoms arising from the lumbar spine and sacroiliac joint, should be obtained [3, 12–14]. The subjective exam should include identification of aggravating activities of daily living (ADL) such as dressing, putting on your shoes and/or socks, ascending or descending stairs, sitting, and running and postures including crossing legs, driving, squatting, and rising from squatted or kneeling positions. Secondly, physical examination should be performed, focusing on range of motion [15, 16]. Thirdly, a neuromotor assessment focused on proprioceptive control and the ability of the patient to execute the skill of motion must be completed [5, 17]. These three components will be the framework for the rehabilitation journey.

15.3 Preoperative

Physiotherapy intervention initially focuses on explanations regarding activities to be avoided to prevent further aggravation of symptoms [10, 18]. These often include activities such as running, twisting, squatting, and lunging. Care must be taken regarding posture, particularly when sitting and getting into and out of a car. Significant time is spent explaining to individuals the anatomy of the hip, particularly the structure and function of deep hip muscles that provide dynamic stability for the hip during gait and function. This is critical for the client to understand what they can do to facilitate their recovery especially when it comes to assessing return to function. If they understand their individual anatomy, they can then assess if they are able to return to certain activity or not, for example, return to work and manual activity [10].

Quadratus femoris (QF), obturator internus (OI), and gemelli (G) are the major deep hip rotators (DHR) [19]. These muscles have a short lever arm and are therefore able to act as deep stabilizers [20]. This is an important factor in providing dynamic hip stability throughout the range of motion of the hip. The QF is a flat, quadrilateral muscle. Located on the posterior side of the hip joint, it is a strong lateral rotator and adductor of the thigh but also acts to stabilize the femoral head in the acetabulum. There is a paucity of literature published on the role of the deep hip stabilizers and their role pre- and post-hip arthroscopy.

15.4 Assessment of Deep Hip Rotators (DHR)

Bennell et al. [17] reported DHR contraction is assessed with the individual in the prone lying position [10]. The hip should be slightly abducted, with the knee flexed to 90 degrees. The patient is asked to externally rotate the thigh, while the physiotherapist assesses by palpation whether the DHR contraction is present, weak, or absent. In equivocal cases, real-time ultrasound can be used to assess for the presence of a contraction. The use of real-time ultrasound can be useful in providing feedback to facilitate QF contraction especially if duration of symptoms has been prolonged resulting in pain inhibition and/or atrophy.

The glutei, hamstrings, and adductor muscles should not be excessively recruited during this assessment. Isolated contraction of the DHR especially QF should be practiced preoperatively (Fig. 15.1).

Once an isolated contraction of the DHR is achieved (without global activity within the glutei), the individual is progressed to four-point kneeling with the addition of hip internal and external rotation (see Fig. 15.2). Simultaneous contraction of QF with either internal or external rotation should help provide stability of the femoral head in the acetabulum. This is an essential step of the pre- and postoperative pathway and should be well rehearsed.

With athletes, they should be trained to cycle with a high seat (to avoid the hip flexion beyond 90°) to maintain physical fitness and endurance.

15.5 Outline for Physical Therapy Manual Treatment/ Progression Summary

Further loading will involve sports-specific training including jogging, sprinting, and change of direction.

15.6 Postoperative

The Takla-O'Donnell Protocol has three principle goals: firstly, returning to normal activities of daily living with a pain-free range of motion while protecting healing tissue; secondly, resumption of loading with functional strength and endurance; and finally, a prevention strategy that will protect the hip from any further injury.

The protocol is designed to guide physiotherapists in achieving "core hip stability following hip arthroscopy followed by global strengthening." This model is based on controlling the motion of the hip initially, gradual global muscular strengthening followed by endurance loading.

Level 1 – Deep hip rotators lying face-down

Starting position

Lie on your stomach with your knees apart.

Bend your knees so that they are at 90 degrees.

Place the sole of the foot on your non-operated leg against the inner surface of your ankle on your operated side.

Exercise

Keeping your thigh on bed, gently press the ankle on your operated side against the sole of the other foot.

Relax hamstrings. Relax buttock muscles. Breathe.

Place your fingers on the bony part of your bottom called the ischial tuberosity. Then move your fingers 2cm out then 2cm up.

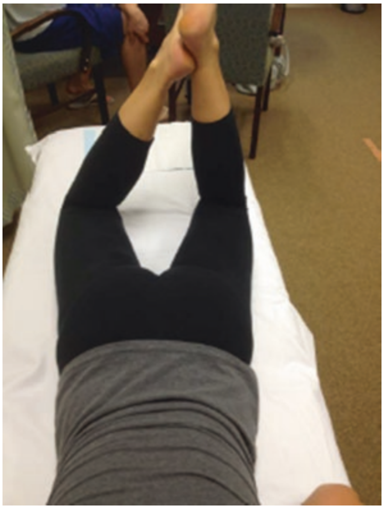
Feel a gentle contraction of QF muscle underneath your fingers. Hold for 3 seconds then relax for 2 seconds (approximately 12 repetitions in one minute)

Dosage

Pre surgery: 1 minute, at least 6 times per day
After surgery: 1 minute, 3-4 times per day

Indicators for progression

When able to do 12 contractions in one minute with good technique



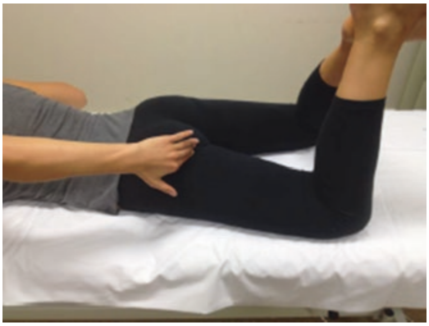


Fig. 15.1 DHR/QF retraining in prone. Reproduced with permission: Bennell KL, O'Donnell JM, Takla A, et al. Efficacy of physiotherapy rehabilitation program for individuals undergoing arthroscopic management of femoroacetabular impingement—the FAIR trial: a randomized controlled trial protocol. BMC musculoskeletal disorders 2014;15:58.doi:https://doi.org/10.1186/1471-2474-15-18

Level 2 – Deep hip rotators on all fours

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<u>Starting position</u>

4 point kneeling with the lower back in a neutral position.

<u>Exercise</u>

Relax hamstrings. Relax buttock muscles. Breathe.

Place your fingers on the bony part of your bottom called the ischial tuberosity. Move your fingers 2cm out then 2cm up.

Feel a gentle contraction of QF muscle underneath your fingers. Hold for 3 seconds then relax for 2 seconds.

It may help to think of pulling your thigh up towards your pelvis.

<u>Dosage</u>

Pre surgery: 1 minute, at least 5 times per day

After surgery: 1 minute, 3-4 times per day

<u>Indicators for progression</u>

When able to do 12 contractions in one minute with good technique

<u>Variations:</u>

If shoulder pain or fatigue are a problem, support your chest on the seat of a chair

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Fig. 15.2 Prone QF retraining at the Pre-op stage

The therapist will need to consider healing times for different structures. Stracciolini et al. [12] reported bones healing from 6 to 18 weeks and, also, ligaments taking even longer with a range of 3–12 months.

15.7 Phase 1

15.7.1 1–14 Days Postoperatively

15.7.1.1 Analgesia

We encourage all patients to maintain pain control with paracetamol and nonsteroidal anti-inflammatory medication for the initial 4 weeks [7, 8]. These medical recommendations have been developed by Prof. John O'Donnell.

With good pain control, individuals are encouraged to activate DHR focusing on QF. This also helps to avoid developing a Trendelenburg gait.

15.7.1.2 Range of Motion

Hip ROM activities are introduced and can be guided based on the healing properties of the involved tissues (comparative healing rates of bone, labral tissue, capsule-ligamentous structures, and cartilage) [5, 12]. The patient is educated about the need for regular yet controlled ROM activity to prevent the formation of adhesions especially following labral repairs.

15.7.1.3 Gait

Maintenance of a normal gait pattern is critical in providing appropriate loading of the hip joint to avoid compensatory gait patterns that may place excessive loading of the healing tissue [5, 21, 24]. To assist with gait retraining and to promote early ambulation, the hydrotherapy pool should be initiated once wound healing is achieved. This should be initiated 10–14 days postoperatively (wound must be healed for initiation of hydrotherapy).

15.7.1.4 Soft Tissue Work (STW)

Soft tissue work (deep muscle massage) should be commenced simultaneously, and attention should be focused on the psoas, rectus femoris (RF), tensor fascia latae (TFL), adductors, and the glutei. Lumbar spine mobility should also be monitored to ensure extra load is not placed on the spine. Please refer to table 15.1 for Physiotherapy manual techniques and guidelines.

15.7.1.5 Precautions

The following tasks should be avoided for the first 2 weeks (as per pre-operative education program):

1. Hip flexion beyond 90° during activities of daily living, for example, putting on shoes and socks. This will minimize soft tissue impingement/irritation especially of the healing joint capsule.
2. Sitting in deep and or low chairs. Patient can be provided with a pillow to sit on to avoid excessive hip flexion.
3. Prolonged standing, pivoting, and twisting particularly while getting in and out of a car, negotiating public transport, and returning to work.

Table 15.1 The physiotherapy intervention

	Aim	Description	Time frames	Dosage
Manual therapy				
Mandatory technique				
Trigger point massage of rec femoris, add, TFL/glut medius/ glut minimus and pactineus muscles and fascia	Address soft tissue restrictions with aim of reducing pain and improving hip range of movement	Sustained pressure trigger point release with muscle on stretch. In general, mobilise restrictions laterally to the line of tension of muscle being treated	Sessions 2–7	30–60 s per trigger point
Optional technique				
Lumbar spine mobilisation, if indicated by lumbar spine physiotherapy assessment	Improve mobility and pain-free movement of lumbar spine for better hip function	Unilateral postero-anterior accessory glides. grades III or IV	Sessions 3–7	3–5 sets of 30–60 s
Home exercises (see online Supplementary Material 15.1)				
Deep hip rotator muscle retraining	Optimise hip neuromuscular control and improve dynamic stability of the hip	Seven stages progressing through prone, four-point-kneel and dynamic standing positions, with and without resistance	Pre-op to session 7	1 min, 3–6 times per day
Anterior hip stretch	Assist in regaining full hip extension range of movement	Supine in modified Thomas Test position with affected leg over side of bed. Hip is extended until a stretch is felt at front of hip	Sessions 2–4	5 min daily
Hip flexion/ extension in four-point kneel—'pendulum' exercise	Prevent adhesions, especially in those with labral repair	Four-point kneel with gentle pendular swing of affected leg into hip flexion and extension as far as comfortable	Sessions 2–5	1 min daily
Posterior capsule stretch	Assist in regaining full hip range of movement	Lying on unaffected side with affected Hip as close to 90° flexion as comfortable and affected leg over bed side	Sessions 3–7 (sessions 4–7 if MF)	3 × 30 s
Gym/aquatic programme				
Stationary cycling	Improve hip range of motion	Upright bike with high seat to avoid hip flexion past 90°. Initially 15 min at mod intensity	Session 2 onwards (session 3 if MF)	2× weekly

(continued)

Table 15.1 (continued)

	Aim	Description	Time frames	Dosage
Walking in pool	Maintain cardiovascular fitness and improve hip range of motion	Walking at cheat depth, forwards, straight lines only. Ten minutes for FOC or labral repair, 5 min for MF or ligamantum teres repair	Session two onwards (session three if MF)	2× weekly
Swimming	Maintain/regain cardiovascular fitness	No kicking until 6–8 weeks postsurgery, 500 m^{-1} km	Session 2 onwards (session 3 if MF)	2× weekly
Cross trainer	Maintain/regain cardiovascular fitness	Initially 5 mins at moderate intensity	Session 2 onwards (session 3 if microfracture)	2× weekly
Squats, lunges, leg press, leg extensions, hamstring curls	To improve lower limb strength and function	Three sets of 10 repetitions, working at 'moderately hard' on modified rating of perceived exertion	Session 6 onwards	2× weekly
Functional programme				
Jogging	Maintain/regain cardiovascular fitness	Jogging on running track or grass, with affected leg to the outside of the track, that is, anticlockwise for the right hip. One lap of oval should be approximately 400 m	Session 4 onwards (FOC only) session 5 others	3× weekly 6 laps in first week, 8 in second, 10 in third week (up to 4 km)
Acceleration/ change of direction drills	Improve lower limb strength and function	Zig-zag jogging	Session 5 onwards (FOC only) session 6 others	Dependent on sport goals and surgical procedure
Sports-specific drills (see online Supplementary Material 15.2)	Improve lower limb strength and function	Examples: foot drills/ serving practice (tennis); comer hit-outs/tackling drills (grass, hockey); kicking/marking drills (Australian rules football)	Session 4 onwards (FOC only) session 6–7 others	Dependent on sport goals and surgical procedure

Reproduced with permission Bennell et al. [17]
FOC femoral osteochrondroplasty, *MF* microfracture, *TFL* tensor fasciae latae

15.8 Phase 2

15.8.1 Weeks 3–6 Postoperatively

15.8.1.1 Progressing the Deep Hip Rotator Stability Program

Attention should now be turned to the DHR in the prone position, four-point kneeling and with resistance band (Figs. 15.3, 15.4, 15.5a, b, and 15.6a, b).

Level 3 – Deep hip rotators on hands and knees with hip external rotation (twisting foot inwards)

Starting position

4 point kneeling with the lower back in a neutral position.

The operated leg should be parallel to the opposite side, in a relaxed position (ie not twisted inward or outward)

Exercise

Activate QF muscle, and then gently rotate the foot on the operated leg inwards. Aim for your foot to be above your calf on your non-operated side at the end of the movement.

Slowly return to the starting position.

Continue to hold the QF contraction whilst performing a total of 5 repetitions of the movement. Rest for 3 seconds then repeat, continuing for one minute.

Dosage

One minute, 3-4 times per day

Indicators for progression

When able to perform exercise for one minute maintaining good technique and with no pain.

Starting position

External rotation, twisting thigh to foot inwards

Fig. 15.3 DHR/QF retraining in four-point kneeling external rotation

Level 4 – Deep hip rotators in 4-point-kneeling with hip internal rotation (twisting foot outwards)

Starting position

4 point kneeling with the lower back in a neutral position.

The operated leg should be parallel to the opposite side, in a relaxed position (ie not twisted inward or outward)

Relax hamstrings. Relax gluteals. Continue to breathe throughout the exercise.

Exercise

Activate QF muscle on the operated side. Keep the muscle tightened while you gently rotate the foot on the operated leg outwards. Take the foot as far as you can go comfortably.

Slowly return to the starting position.

Continue to hold the QF contraction whilst performing a total of 5 repetitions of the movement. Rest for 3 seconds then repeat, continuing for one minute.

Dosage

5 reps then rest, repeat for one minute

Indicators for progression

When able to perform exercise for one minute maintaining good technique and with no pain.

Starting position

Internal rotation, twisting thigh to take foot outwards

Fig. 15.4 DHR/QF retraining in four-point kneeling into internal rotation

Level 5, Exercise 1 – Hip external rotation on hands and knees with resistance band (Theraband®)

Starting position

Kneel on all fours with your lower back in a neutral position.

Your operated leg should be parallel to the opposite leg, in a relaxed position (ie not twisted inward or outward).

Place resistance band around your ankle on your operated side as shown.

Exercise

Activate the QF muscle on your operated side. Gently twist your teg to take your foot on the operated side inwards against the pull of the elastic band. Aim for your foot to be above your calf on your non-operated side at the end of the movement.

Slowly return to the starting position, carefully controlling the speed of the movement.

Rest for 3 seconds then repeat, continuing this process for one minute.

Dosage

One minute, 3-4 times per day

Indicators for progression

Able to perform exercise for one minute pain-free; able to maintain good technique, with smooth, controlled movement

External rotation – starting position

External rotation exercise

Resistance band:

NONE YELLOW RED GREEN

Fig. 15.5 (**a**) DHR/QF retaining in four-point kneeling into external rotation with resistance band. (**b**) DHR/QF retaining in four-point kneeling internal rotation with resistance band

Level 5, Exercise 2 – Hip internal rotation on hands and knees with resistance band (Theraband®)

<table>
<tr>
<td>
<u>Starting position</u>
Kneel on all fours with your lower back in a neutral position.
Your operated leg should be parallel to the opposite leg, in a relaxed position (ie not twisted inward or outward).
Place resistance band around your ankle on your operated side as shown.
<u>Exercise</u>
Activate the QF muscle on your operated side. Keep the muscle tightened. Gently twist your teg to take your foot outwards, away from your other leg, against the pull of the elastic band. Take your foot as far as you can go comfortably.
Slowly return to the starting position, carefully controlling the speed of the movement.
Rest for 3 seconds then repeat, continuing this process for one minute.
<u>Dosage</u>
One minute, 3-4 times per day
<u>Indicators for progression</u>
Able to perform exercise for one minute pain-free; able to maintain good technique, with smooth, controlled movement
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Internal rotation exercise
Resistance band:
NONE YELLOW RED GREEN
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Fig. 15.5 (continued)

Level 6, Exercise 1 – Hip external rotation with resistance (Theraband®) and abduction with belt on hands and knees

Starting position

Kneel on all fours with your lower back in a neutral position and your knees about two fist-widths apart.

Place a Pilates belt or resistance band around both your thighs and a resistance band around your ankle on your operated side as shown.

Exercise

Keep your knee on the bed. Tighten the muscle at the side of your hip by pushing your operated side against the belt (as though trying to take your knees apart).

Al the same time, activate the QF muscle on your operated side. Gently twist your leg to take your foot inwards against the pull of the elastic band. Aim for your foot to be above your calf on your non-operated side at the end of the movement.

Slowly return to the starting position, carefully controlling the speed of the movement.

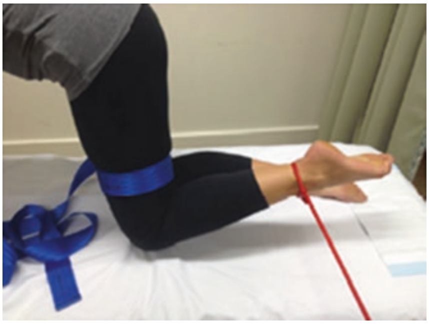
Rest for 3 seconds then repeat, continuing this process for one minute.

Dosage

One minute, 3-4 times per day

Indicators for progression

Able to perform exercise for one minute pain-free; able to maintain good technique, with smooth, controlled movement.



External rotation – Red Theraband® resisting twisting movement and blue Pilates belt providing resistance to thigh movement

To be done in conjunction with Level 6, Exercise 2 (internal rotation)

Resistance band:

NONE YELLOW RED GREEN

Fig. 15.6 (**a**) External rotation – Red Theraband resisting twisting movement and blue Pilates belt providing resistance to thigh movement. (**b**) Internal rotation – Red Theraband resisting twisting movement and blue Theraband providing resistance to thigh movement

Level 6, Exercise 2 – Hip internal rotation with resistance (Theraband®) and abduction with belt in 4-point-kneeling

Starting position

Kneel on all fours with your lower back in a neutral position and your knees comfortably apart.

Place a Pilates belt or resistance band around both your thighs and a resistance band around your ankle on your operated side as shown.

Exercise

Keep your knee on the floor. Tighten the muscle at the side of your hip by pushing your operated side against the belt (as though trying to take your knees apart).

Activate the QF muscle on your operated side. Gently twist your leg to take your foot cutwards, away from your other leg. against the pull of the elastic band. Take your foot as far as you can go comfortably.

Slowly return to the starting position, carefully controlling the speed of the movement.

Rest for 3 seconds then repeat, continuing this process for one minute.

Dosage

One minute, 3-4 times per day

Indicators for progression

Able to perform exercise for one minute pain-free; able to maintain good technique, with smooth, controlled movement.

Internal rotation – Red Theraband® resisting twisting movement and blue Theraband® providing resistance to thigh movement

To be done in conjunction with Level 6, Exercise 1 (external rotation)

Resistance band:

NONE YELLOW RED GREEN

Fig. 15.6 (continued)

Fig. 15.7 Cycling high seat—ensure hip under 90°

Cycling should be commenced with a high seat setup to ensure hip flexion is kept below 90° (Fig. 15.7).

15.8.1.2 Recruitment of the Gluteal Muscles and Proprioceptive Training

Proprioceptive training should be initiated at this stage to promote dynamic stability and to prevent further injury [5, 22, 23]. In particular, single leg with forward reach stance. This should be practiced with the eyes open and closed (Fig. 15.8—"The Arabesque").

Recruitment of the gluteal muscles is performed in weight bearing with a belt (Fig. 15.9). The individual is instructed to activate QF initially, followed by an isometric contraction of the hip abductors (resistance provided by belt). The purpose of this exercise is to encourage the individual to locally stabilize the hip, while glutei muscles contract to contribute to limb motion.

15.8.1.3 Hydrotherapy

Deep water running should be commenced at this stage and provides an opportunity to progress toward running without the gravity effect.

Level 7, Exercise 1 – Arabesque

Starting position Standing with feet shoulder width apart. **Exercise** Tence the QF muscle on your operated side. Lean your chest forward and take your arms out to the sides as you lift the non-operated side behind you. Hold the position for 3 seconds. Bring your non-operated leg down to take a step forward. Step forward on to your operated side and repeat. **Dosage** Do as many repetitions as you are able to with good technique and no pain. Aim to do 26 repetitions in a row. You may break this up in the initial stages, for example 5 arabesques, 5 times per day. **Indicators for progression** Able to complete 26 repetitions in a row with good technique, and no pain.	

Fig. 15.8 The Arabesque

15.8.1.4 Precautions

The following tasks should be avoided for up to 6 weeks:

1. Repetitive hip joint flexion mobilization beyond 90° particularly following labral repair.
2. Aggressive compressive forms of loading such as running on hard surfaces, squats, lunges, skipping, and mini-trampoline. Griffin [5] reported that the explosive character of compressive forces generated by certain specific physical and sports activities may need to be curtailed or modified with substitutions that the joint can tolerate during healing.

15.9 Phase 3

15.9.1 7–12 Weeks: Sports-Specific Training—SST

15.9.1.1 Global Muscular Strengthening

Unilateral loading should be practiced with emphasis on obtaining QF control and improving global muscular support (Fig. 15.10).

Level 7, Exercise 2 – Duck Walk

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Starting position

Have your feet shoulder-width apart.

Place a Pilates belt (or other belt) around your thighs, just above your knees. It is best to use a belt rather than exercise band for this exercise.

Do a ¼ squat, so that your knees are bent to around 30 degrees.

Your knees should be over your big toes.

Place your fingers on your QF muscle to check for/improve contraction.

Exercise

Keep your ¼ squat position as you walk forward 10 metres.

Keep your QF tense during the exercise.

Dosage

Do one walk of 10 metres, 10 times per day.

Indicators for progression

Able to complete 10 metre walk, with good technique, and no pain.

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Fig. 15.9 Pilates belt, QF retraining with visual feedback. Reproduced with permission: Bennell KL, O'Donnell JM, Takla A, et al. Efficacy of physiotherapy rehabilitation program for individuals undergoing arthroscopic management of femoroacetabular impingement—the FAIR trial: a randomized controlled trial protocol. BMC musculoskeletal disorders 2014;15:58.doi:https://doi.org/10.1186/1471-2474-15-18

Fig. 15.10 Unilateral Qf loading with gluteal contraction for global movement

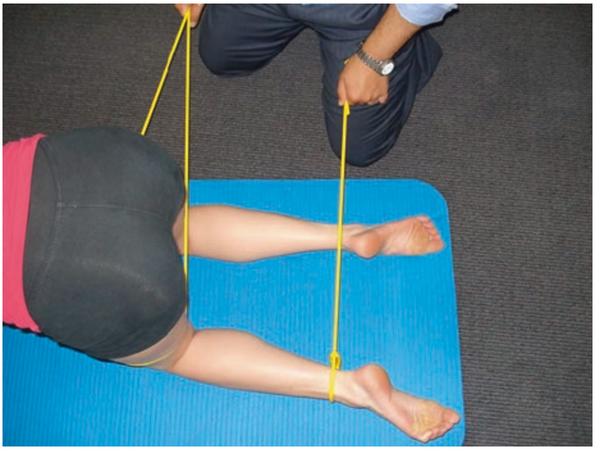

Fig. 15.11 DHR with co-contraction of hip abductors at 90° hip flexion

DHR loading with co-contraction of gluteus medius and minimus in varying degrees of hip flexion-extension ranges of motion should be developed. This should promote hip stability and promote skill execution (Fig. 15.11).

15.9.1.2 Spinal Stability Program

Core spinal stability should be encouraged in the preoperative phase. Barker et al. [11] reported that this facilitates a stable base for global muscles to work on. This should help promote coordinated limb movement.

15.9.1.3 Impact Loading

Running, jumping (Fig. 15.12), figure of eight drills, and skills-based exercises should be commenced. Particular attention should be directed toward DHR endurance during these tasks. As described earlier, real-time ultrasound could be utilized for feedback in standing, single leg stance, and associated movements.

Once the individual has returned to sports-specific training, they are educated about the importance of regular exercises to maintain and improve their recovery [5, 10]. The individuals' compliance and adherence to local stabilization training, skill development, and limb strengthening are necessary for performance and injury prevention (supplementary Table 15.1 provides examples for return to sport protocols). Finally, isokinetic testing provides an estimate of total strength production by a group of agonists and can be useful during the strengthening phase as an objective measure as well as a treatment modality.

Fig. 15.12 Jumping retraining drills

15.10 Summary

Hip arthroscopic assessment and treatment of femoroacetabular impingement have progressed in recent years. Physiotherapists need to be aware of variation in intra- and extra-articular pathologies within the hip, and rehabilitation needs to be tailored accordingly. In particular, rehabilitation should initially focus on local muscle systems for stability (deep hip rotators) followed by global muscular strengthening and endurance. This process will allow the individual to stabilize the hip joint, while global muscles absorb shock during limb function and loading.

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Future of Hip Arthroscopy in the Management of the Athlete's Hip

16

Richard Villar

Tell the future? By what right do we feel we can do so? Indeed, by what right is this a task I have been given?

If the predictions of hip arthroscopy that I offered in the late 1980s and early 1990s are to be considered, by now hip replacement would have disappeared, and hip arthroscopic surgery would have taken over, while anterior cruciate ligament reconstruction would have vanished, and the ligamentum teres would be our staple diet. Hip arthroscopy would have come away from the hands of the specialist and into the generalist's armamentarium. I was only partially correct.

16.1 How to Tell the Future

Telling the future has long been mankind's fascination. For example, Michel de Nostredame (1503–1566), otherwise known as Nostradamus [1] and a sixteenth-century French physician, astrologer and prophet, had insights that have been credited with predicting the French Revolution in 1789, the Hiroshima bomb in 1945, the death of Princess Diana in 1997 and even 9/11. "Two steel birds will fall from the sky on the Metropolis, the sky will burn at forty-five degrees latitude", he was said to have written [2]. New York City is at latitude 40.7128°N [3]. Nostradamus is an example of postcognition, not precognition. We fit events to his statements; we bend reality to suit what we convince ourselves he said. Even that presumes the translation of his versed Middle French [4] is accurate. The scientific equivalent is creating a hypothesis once a researcher knows the results.

Looking back is easy; looking forward is hard. Many [5–7] have tried to work out ways of determining what might happen in the future, as Dalkey wrote in 1968,

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"the notion that the future is hidden—that prediction is the realm of seers, necromancers, and other unsavoury types—is part of our cultural heritage" [8]. How good it would be to identify what was coming next.

16.2 Surgeons Are Driven by Patients

As surgeons, we are driven by the patient and can only operate on those who walk through our door. Recently, an internationally recognised charity said to me that in one of their frontline hospitals, surgeons were seeing the place as a form of surgical playground. They were undertaking procedures of which the charity had never heard. The same can perhaps be said for hip preservation, more specifically hip arthroscopy. There was once a view that the operation had been created for the benefit of the surgeon, not the patient. But the fact is that the procedure was created for a need. Hip replacement may be a wonderful operation but is a confession of failure. It is a salvage operation when all else has failed. By what right do we offer a patient a hip replacement when we know it has a finite life? Surely, we must do anything we can to avoid it? That is why hip preservation is so important.

16.3 Keep the Hip Joint Natural

To me, the hip preservation surgeon's duty is clear. It is to keep the hip joint natural, untouched by matters artificial. My first prediction, therefore, is that this aim will continue. Hip preservation surgeons will persist in trying to avoid hip replacement, however much the designs change, as joint replacement manufacturers attempt to improve an arthroplasty's longevity.

16.4 Sport Is Changing, Too

Changes in sport will also steer us in the appropriate direction, as sport is transforming before our eyes. In the last 100 years, training science has taken only 1 second off the time it takes to complete a 100-m sprint, but 53 min from the time it takes to finish a marathon. Sprint times have reduced by 10% and marathon times by 30% [9]. It seems clear that the pathologies the hip preservation surgeon will see will tend more towards the chronic, overuse, endurance injury than the unpredictable, acute event. Degeneration perhaps, and how to minimise its risk, will become more dominant as the decades pass.

Should anyone doubt that the management of degeneration will be a feature of the hip preservation practitioner who deals with the modern-day athlete, consider the mean age of Olympic athlete over time. There has been a generally upward trend [10]. This is well shown by the mean age of finalist in the single sculls, which increased from 24 to 31 years between 1976 and 2012. Japan put forward a 71-year-old competitor for the 2012 Olympics, in the sport of equestrian dressage [11].

16.5 Our Genes

Our genotype is clearly important. China already screens out youth divers at the age of 5 years if their elbows cannot touch above their head. There are known gene variations that are associated with superathleticism, such as ACTN3 carried by so many Olympic sprinters and weightlifters, EpoR that increases the red blood cell count, ACE that permits mountaineers to climb 8000-m peaks without oxygen, or SCN9A that can block the pathways of pain and permit athletes to play through their injuries. There are also TNC and COL5A1 that decree whether or not a body is susceptible to tendon and ligament injury and LRP5 that might theoretically be associated with unbreakable bones.

Clustered *R*egularly *I*nterspaced *S*hort *P*alindromic *R*epeats (CRISPR) is now widely discussed and the technology patented. This is a family of DNA sequences in bacteria that contain small pieces of DNA from viruses that have attacked bacteria. These are key as a bacterial defence mechanism and form the basis of CRISPR/Cas9 technology that can change genes within an organism [12].

It is no surprise to read the words of Raymond McCauley from Singularity University, "Genetic engineering techniques are now cheap and widespread enough that any knowledgeable individual can order every material they need off the Internet and download the software to do their own experiments on themselves. Everyone in citizen science and the biohacker community has stories of being contacted by trainers, coaches, and athletes. There is absolutely no way to regulate it, and if you tried to it would be like stemming the tide with a fork" [13].

It seems clear that in future sports will diverge, not so much man versus robots, but natural versus enhanced athletes. Someday, the stigma associated with self-optimisation in sport must surely disappear, once the ability to improve one's own genetic make-up becomes accepted. Who thought that cannabis would be legalised? Yet for some this is now the new normal. Or, prohibition in the USA from 1920 to 1933 [14]? Societies change, peoples adapt, and mankind adjusts. What may be unheard of now can be tomorrow's reality, which will unquestionably influence the role of a hip preservation surgeon. Unless we adapt, by tomorrow we will be outdated. I sometimes wonder if, some decades down the line, there will be a role for surgeons, as we presently understand them, at all.

16.6 Managing Osteoarthritis

Assuming hip preservation surgeons continue to be needed for many decades to come, how do I see their role changing and for the athlete in particular? Certainly, there will be a need to address the problems of established hip degeneration, not just prevention. As yet none of us can say that we can delay or prevent osteoarthritis. We are able to say that we can help its symptoms, albeit to a greater or lesser degree, depending on the severity of the disease. The worse the degeneration, the worse the result [15].

At what point, therefore, is it worthwhile trying a hip arthroscopic procedure and at what point is it deemed pointless? The hip preservation surgeon has not been helped by various government-led healthcare systems that have taken it upon themselves to decide when an operation is worthwhile and when it is not. This approach is wrong. The validity of a procedure is a matter for patients and doctors and has nothing to do with politicians; however they might justify their involvement. For example, what is wrong in a patient accepting a 50% chance of symptomatic success after hip arthroscopic debridement for degenerative change, as long as all has been made clear beforehand? If that is a patient's desire, then so be it. The hip arthroscopic management of osteoarthritis, irrespective of the naysayers, is certainly an area for the future.

16.7 Hip Arthroscopy Is Not for All

There is now a widespread acknowledgement that hip arthroscopic surgery is for the technically adept. It is not a procedure that all can master [16], so education is key [17]. The critical number appears to be 30 [18], although at a personal level, I am uncertain I would agree with such a low number. However, what seems clear is that once a procedure is properly learned and once it has become a way of life, acquired skills will not be lost even after a 6-month break [19]. So, I expect education in hip arthroscopic surgery to develop further, for courses to veer away from the general and focus more on specific techniques—capsular closure, plication, labral grafting, the deep gluteal space, the periarticular structures, and ligamentum reconstruction. I would also expect a formal hip arthroscopic curriculum to one day appear. This necessity is made all the more essential thanks to the increased number of candidates undertaking hip arthroscopic surgery. Once there was a mere handful. Today there are multiple thousands of orthopaedic surgeons familiar with hip arthroscopic surgery, although in practice a small number (6.5%) of high-volume hip arthroscopists undertake 34.6% of procedures [20]. The recent arrival of needle arthroscopy will most likely cause these numbers to rise further [21].

There has been a worry, too, as to whether hip arthroscopic surgery might interfere with an athlete's future participation in sport. It appears not, certainly for American football. Work has shown that athletes with a history of hip arthroscopic surgery were not at risk for diminished participation when compared with other athletes during their first season in the National Football League [22]. There are now plenty of athletes worldwide who have represented their nations after hip arthroscopic surgery and have returned home bearing medals [23].

16.8 Bioinspired Biomaterials

Hip arthroscopy has yet to fully enter the field of joint replacement, its role presently in this field being to manage the largely soft-tissue problems that arthroplasty surgeons find hard to handle should a joint replacement become painful, but where investigations are normal or inappropriate [24].

Yet there are times when it is essential to implant artificial materials arthroscopically. For example, anchors, screws, sutures, studs, tape, or even a matrix to encourage soft-tissue regeneration. Some of these items are metallic, some are not. Although the field of bioinspired biomaterials has previously been more applicable to joint replacement, one can also see a developing role in hip arthroscopy. Anything implanted should create as little reaction as possible, as with reduced reaction comes longevity, less chance of adhesions and the potential for longer-term success [25]. Implanted biomaterials should mimic, as closely as possible, the tissue they are replacing. The first generation of biomaterials imitated the gross composition and mechanical properties of the tissue to be replaced. However, this did not precisely mimic the complexities of the true environment. Work is now underway to resolve this with the engineering of biomimetic [26], bioinspired and bioactive biomaterials that might offer control over cellular functions, interact positively with the host and actively contribute to tissue regeneration in vivo [27].

16.9 Proteomics

Proteomics, the large-scale study of proteins, was a term coined in 1997 as a combination of the words "protein" and "genome" [28]. Proteomics is different to genomics, possibly more complicated, as an organism's genome is more or less constant, but the proteome differs from cell to cell and from time to time [29]. In clinical practice the possible benefits of proteomics might be in the development of drugs that are tailor-made for a specific disease and/or patient. For example, if a certain protein is implicated in a disease, drugs can be designed to interact with the protein. This is a clear threat to the hip preservation surgeon.

16.10 Immunotherapy

Immunotherapy is also on the rise, the treatment of disease by modifying an immune response [30]. One key target for this is osteoarthritis. With the increasing interest in endurance activities, the widespread acceptance that sport can continue well beyond retirement age, it is more than certain that the hip preservation practitioner of the future will be involved in the management of degenerative change. Biological evidence now suggests that immune-mediated inflammation, involving T and B lymphocytes as well as activated macrophages, are critical parts in the development of inflammation as osteoarthritis progresses. Activated immune cells—immunotherapy—could be specifically targeted for intervention in the OA process [31]. There is much taking place around us that might disrupt surgical practice. No longer is hip preservation surgery at the cutting edge.

16.11 Tissue Engineering

Tissue engineering is the use of a combination of cells, engineering and materials to replace biological tissues [32] and involves the use of a tissue scaffold for a medical purpose. It is now increasingly used by hip preservation surgeons and is of real interest to the athlete community. Mosaicplasty and autologous chondrocyte transplantation, labral grafting using tissue-engineered scaffolds, grafting of the ligamentum teres and, right now, the employment of regenerative medicine are examples of this [33]. Cellular therapies are being explored, where pluripotent cells, for example, stem cells, extracted from various sources such as bone marrow or adipose tissue are now being used regularly by hip preservation surgeons around the globe. Initial results show promise, certainly in terms of symptomatic improvement [34].

16.12 And the Future?

So, how does the future look for hip arthroscopy and the athlete? Rosy, I sense, but perhaps not long term. At present there is much evidence to suggest that athletes can return to top-level sport after the procedure, that it does not influence their selection and that as global interest in sport increases, so will the number of hip preservation operations required. But laboratory research is hot on the heels of the subspecialty and cannot be far off delivering therapies that do not require a surgeon for their implementation. One wonders if a chapter such as this, if written in 20 years' time, would be best done by a physician than a surgeon? I suspect it might, although only time can say.

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