REVIEW ARTICLE

Arthroscopic treatment of femoroacetabular impingement: Technical review

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KEYWORDS
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Summary The objectives of surgical treatment of femoroacetabular impingement are to improve the symptoms and to prevent or slow the progression of osteoarthritis by improving joint clearance between the acetabular rim and the femoral neck. Arthroscopic correction of bone abnormalities and treatment of articular lesions requires the use of techniques that provide good access to the peripheral and central compartments of the hip joint. Various patient positions and portal placements have been suggested. The sequence used to access the two compartments may differ according to the option chosen. Entering the central compartment first is the most popular technique for arthroscopic hip joint access and requires joint distraction under fluoroscopic monitoring. Accessing the peripheral compartment first can be achieved without distraction and does not always require fluoroscopic guidance. Regardless of the sequence, capsulotomy greatly facilitates the therapeutic procedures that are common to all approaches. Osteoplasties are conducted after careful pre-operative planning based on various visual or fluoroscopic landmarks. Several options are available for treating articular cartilage and labral lesions.
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Introduction

The research conducted by Ganz et al. [1] has provided valuable information on femoroacetabular impingement (FAI) and its place among mechanical hip disorders inducing early osteoarthritis. Improved understanding of the pathogenic mechanisms involved has enabled the development in adults of effective surgical procedures designed to alleviate the symptoms and to prevent the progression of osteoarthritic changes [2,3]. In the past, surgical hip dislocation was considered the standard of treatment for correcting the causal bony abnormalities and managing the secondary articular lesions [2,4]. Less invasive techniques such as hip arthroscopy were developed subsequently based on the same principles. The first results validating arthroscopic FAI treatment were reported in 2004 by Sadri, who studied arthroscopic correction of bone abnormalities during traction via an original intra-osseous juxta-articular pin distractor, comparatively to conventional open surgery with dislocation [5]. In 2005, Sampson described an arthroscopic osteoplasty technique based on a more conventional

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approach with a standard traction table [6]. This technique involving conventional portals and hip distraction rapidly gained popularity [7,8]. Another method consists in primary access to the hip compartment that can be penetrated without traction. Capsulotomy is then performed before the application of traction [9].

Here, we describe the various options available for patient installation and hip exposure. Some of the techniques are common to all options. We describe their key features and specificities.

Background information

Arthroscopic hip anatomy

Since the description by Dorfmann and Boyer [10], the hip is usually viewed as comprising two separate compartments. The peripheral compartment (PC) can be accessed without traction. It includes the intra-capsular region of the neck and the lateral portion of the femoral head located lateral to the free margin of the labrum. The synovial membrane lines the capsule and the circumferential zona orbicularis. At the femoral neck, the synovial membrane forms several folds, of which the most noticeable is the medial synovial fold (or pectineo-foveal fold) at the anterior-inferior border of the neck. The lateral synovial fold adheres to the superior and lateral aspect of the neck and marks the boundary between the lateral and posterior spaces [11]. Access to this narrow area is more difficult, and this fold is less conspicuous. It is important, however, as it marks the passage through the capsule of the terminal medial circumflex femoral artery that gives off the superior retinacular vessels for the femoral head. The ilio-femoral compartment, commonly referred to as the central compartment (CC), is a virtual space between the acetabular and femoral joint surfaces. Access to the CC requires traction to separate the femur from the pelvis, thus exposing the medial aspect of the labrum, the semi-lunar cartilage surfaces, and the synovial membrane lining the acetabular fossa. The upper part of the femoral head in the weight-bearing area and the ligament of the head of the femur (ligamentum teres) can also be accessed in the CC.

Preoperative assessment

The diagnosis of FAI can be established based on the physical findings, standard radiographs, and axial lateral radiograph [1], which can be obtained through various projections [12]. The radiographic findings indicate whether the impingement mechanism is cam, pincer, or mixed. Knowledge of the mechanism helps to plan the osteoplasty procedure [12,13]. Second-line imaging studies (MR- or CT-arthrogram) (Fig. 1) with radial views may show femoral head asphericity that was not detectable by standard radiography [14]. Dynamic fluoroscopic imaging of the femoral neck at the beginning of surgery may provide additional information on the femoral abnormalities. Preliminary templates of the extent and depth of the osteoplasties can be generated at this stage but are more accurate for the femur than for the acetabulum [12].

The final assessment of the intra-articular lesions is achieved by arthroscopic exploration. Given the pressure exerted by the femoral head, imaging studies may fail to visualise acetabular cartilage delamination or even labral tears. Therefore, the need for labral repair is usually determined only during the arthroscopic procedure.

Figure 1 Magnetic resonance arthrogram before surgery for cam femoroacetabular impingement secondary to slipped capital femoral epiphysis. Radial sections at 10° intervals. At the anterior part of the neck, (horizontal section plane), the α angle is normal (41°, middle image). At the antero-superior part of the neck (50° section plane), in contrast, the α angle is markedly increased (83°).

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Options for patient installation and arthroscopic hip access

Patient installation

Various installations may be used (Fig. 2). The choice depends on the surgeon’s preference or on the technical options chosen. The lateral decubitus position increases the prominence of the greater trochanter, which facilitates the creation of the peritrochanteric portals, most notably in obese patients. This position allows the use of various distraction options with or without a perineal post (Fig. 2B–D). Installation in the supine position is simpler. Counter-traction stabilises the pelvis on a large perineal foam pad that is positioned to shift the patient’s weight onto the ischial tuberosities, thereby decreasing the risk of perineal compression (Fig. 2A).

Arthroscopic portals and anatomic relationships

The creation of hip arthroscopy portals is demanding and may raise challenges for surgeons at the beginning of the learning curve. One difficulty is the considerable depth of the hip joint, which modifies the usual triangulation distances. Another is limitation of instrument mobility by the thick rigid capsule, which magnifies the adverse consequences of suboptimal instrument positioning. Moreover, care should be taken to avoid injuring the neighbouring blood vessels and nerves.

Figure 2  Patient positions. A. Supine position with a perineal post. Courtesy of Boyer. B. Lateral decubitus position with a perineal post. Reprinted with permission from Simpson et al. [23]. C. Lateral decubitus position lateral with a buttock support. D. Lateral decubitus position with invasive distraction. Reprinted with permission from Gédouin et al. [12].

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Several studies have reviewed the standard hip arthroscopy portals described before [10,15] and shortly after [16] the introduction of arthroscopic FAI treatment. These portals can be divided into three categories based on their anatomical location: peritrochanteric portals, anterolateral portals (anterior to the peritrochanteric portals), and anterior portals (Fig. 3).

Byrd et al. [17] studied the anatomical relationships between the peritrochanteric portals [18], anterior portal [19], and neighbouring vessels and nerves. The anterior peritrochanteric portal is at the antero-superior corner of the greater trochanter. This portal is usually preferred for primary CC access, as it is furthest from the vessels and nerves (Figs. 3 and 4). The line tangent to the posterior border of the greater trochanter is the posterior boundary of the safe zone. The sciatic nerve runs posterior to this line. The posterior peritrochanteric portal is created on this line, with the hip in extension and neutral or slight external rotation to keep the sciatic nerve at a distance. The anterior portal is located at the intersection of the vertical line through the anterior superior iliac spine (ASIS) with the horizontal line through the tip of the greater trochanter. Its use is controversial, as it is near the lateral femoral cutaneous nerve (LFCN), a sensory nerve characterised by frequent anatomical variations. Byrd et al. [17] reported that the anterior portal must cross through the belly of the sartorius to ensure that it remains medial to the femoral branch, which is the most medial branch of the LFCN. Moving this portal to a safe distance from the femoral vasculo-nervous bundle would increase proximity with the LFCN. The gluteal branch of the LFCN is not at risk, since it courses more laterally and superiorly. In contrast, the femoral branch is closer, along the edge of the sartorius muscle, and may cross the outer edge of the tensor fascia lata muscle (TFL) [20]. The muscles are difficult to identify by palpation, a factor that further compromises the safety of the anterior portal. Therefore, the portal should be kept at a distance laterally from the anterior edge of the TFL. This goal can be achieved by using the portal described by Dorfmann and Boyer [21], which is located in the middle of the antero-lateral zone (Fig. 3) and runs down to the peripheral compartment [10]. In this region, our practice is to locate the portal more distally and laterally (portal 2, Fig. 3). This portal serves chiefly for the instruments and is similar to the mid-anterior portal described by Robertson et al. [16]. It crosses through the TFL then passes either through the interval between the gluteus minimus and rectus femoris or through the lateral fibres of the rectus femoris, entering the joint capsule. The ascending branch of the lateral circumflex femoral artery is the closest neurovascular structure to this portal. We create our first and main portal at, or slightly anterior to, the tip of the greater trochanter (portal 1, Fig. 3), through the iliotibial band then the gluteus medius and finally the capsule towards the PC. A third portal located in the superior antero-lateral region (Portal 3, Fig. 3) may be used occasionally. This portal provides the best angle of attack for approaching the antero-superior acetabular rim. Proximally, it should remain near the top of the acetabulum to prevent injury to the gluteal branch of the LFCN or terminal branches of the superior gluteal nerve.

In the past, the peritrochanteric portals combined with the anterior portal were used to access the CC and the

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**Figure 3** Skin entry sites for the main hip arthroplasty portals. From posterior to anterior, the posterior peritrochanteric portal (PP) and the anterior peritrochanteric portal (AP). Between these two portals, the supero-trochanteric portal (portal 1) provides access to the peripheral compartment and has the same entry site as the middle peritrochanteric portal (*). The anterior-lateral portal (AL), portal 2, and portal 3 travel through the fascia lata in the antero-lateral region. The anterior portal (A) crosses through the sartorius muscle.

**Figure 4** Anatomic relationships between portals 1 and 2 and the neighbouring blood vessels and nerves. The sciatic nerve runs behind the portals. Anterior to the portals, note the division of the lateral femoral cutaneous nerve into two branches: a horizontal gluteal branch that travels posteriorly and a femoral branch that courses downwards. Anterior to this nerve are the femoral nerve then the femoral artery.

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antero-lateral portals to access the PC. Practices evolved, however, with the development of arthroscopic FAI treatment, which required increasingly complex procedures including a capsulotomy. Instrument mobility was improved by the capsulotomy, allowing a decrease in the number of portals. Two skin incisions (portals 1 and 2, Figs. 3 and 4), each smaller than 1 cm, may suffice to provide access to both hip compartments and to carry out all the arthroscopic procedures needed for FAI treatment.

Technical options and procedures

The main difference among available techniques is the sequence of hip compartment access, which governs the choice of portals. Overall, all procedures (osteoplasty and treatment of articular cartilage and labral lesions) have the same technical requirements, regardless of the option chosen.

Primary access to the central compartment

This is the most commonly used technique in all hip disorders, for historical reasons. The patient is in the lateral decubitus or supine position. A traction vector facilitating hip distraction has been suggested by Byrd et al. [22]. The hip is in abduction and internal rotation, with no flexion or extension, to prevent excessive stretching of the sciatic nerve. However, some authors advocate up to 20° of flexion to relax the ilio-femoral ligaments and facilitate distraction [7,8,15]. Philippon et al. [7] apply adduction and maximum internal rotation under traction. Spinal anaesthesia with an efficient motor block may be used. When general anaesthesia is performed, complete muscular relaxation should be obtained by administering a neuromuscular blocking agent. Traction is then applied until distraction is sufficient to allow the introduction of at least one cannulated needle. This manoeuvre is designed to break the vacuum seal, which is often visible fluoroscopically as a crescent-shaped lucency (Fig. 5). Proper needle positioning is critical. The needle should be located in the lower half of the joint line to avoid piercing the labrum, and the bevel should face downwards to ensure that it will slip on the femoral head cartilage in case of contact. Strong resistance to needle advancement may indicate that the labrum has been pierced, in which case needle position must be corrected [23].

Breaking the vacuum seal of the hip joint may provide enough space for introduction of the capsule dilators and arthroscope. However, additional traction may be required. When visualization of the CC is satisfactory, the second portal is created under arthroscopic control. If the first peritrochanteric portal is in an excessively anterior position, the second portal is generally placed more posteriorly, to provide sufficient distance for proper visualisation of the zone to be treated. Some authors advocate the use of a third, peritrochanteric [8] or anterior portal [22]. Philippon et al. [7] advocate the use of only two portals: a first peritrochanteric portal in a mid- or superior-trochanteric position and an anterior portal. In every case, the arthroscopic portal must be located at a sufficient distance from the instrument portal to allow proper visualisation and palpation of the CC. The lesions can then be assessed. If the lesion is limited and located in a favourable position relative to the portals, simple local debridement may be sufficient, with no capsulotomy. In most cases, however, instrument mobility is inadequate to provide full access to the lesion, requiring as-needed capsulotomy. Capsulotomy is fairly easy to perform using an arthroscopic blade, a radiofrequency probe, or a shaver. Partial capsulectomy is then performed to improve exposure when acetabuloplasty with or without labral refixation is indicated.

When femoroplasty is needed, the PC must be accessed. Lateral extension of the capsulotomy may allow direct passage from the CC to the PC via the same portals. Otherwise, one or two specific additional portals are created, in most cases by using one of the existing cutaneous entry sites. Access to the PC is achieved with no traction and with the hip flexed to ensure maximal opening of the anterior intra-capular space.

Sampson suggested a technical variant [6] for PC access consisting in lateral-to-medial capsulotomy with the arthroscope placed outside the capsule at the femoral head-neck junction. This technique requires the creation of a visualization space at the expense of the muscle fibres in contact with the capsule.

Primary CC access requires that traction be applied before the portals are created. The traction is decreased only once the capsulotomy has been performed. When the intra-articular space is sufficient, access is fairly easy, although fluoroscopic control is not sufficient to eliminate all risk of iatrogenic injury to the labrum or articular cartilage. Performing the capsulotomy through an extra-capsular portal has been advocated to improve the safety of CC access [24]. This technique, which involves greater injury to the surrounding muscle fibres, may be useful when hip distraction seems inadequate despite a strong traction force.

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The potential complications related to strong and prolonged pressure on the perineal post can be avoided by using an invasive distractor (Da Rold Medical\textsuperscript{TM}, Solothurn, Switzerland) (Fig. 2D)\textsuperscript{[5,9,25]}. Advantages include improved traction torque due to direct anchoring at closely spaced sites in the juxta-articular bone segments; improved femoral head exposure and therefore easier treatment of zones that are usually difficult to access; and reduced anxiety about minimising the operating time during the learning curve. However, placement of this device is technically challenging at first and therefore increases the operating time. Furthermore, passage of the anchoring pins through the muscles may result in additional postoperative pain.

Primary access to the peripheral compartment

Primary PC access with the patient supine was first popularized by Dorfman and Boyer\textsuperscript{[10]}, chiefly for the treatment of synovial membrane disorders. Dienst et al.\textsuperscript{[26]} developed a variant to improve the safety of secondary CC access. Under direct vision via the PC, a flexible metal (nitinol) guide wire is inserted under the medial aspect of the labrum. Fluoroscopy is used to verify that adequate hip distraction has been achieved. The arthroscope, previously withdrawn during traction, is reintroduced through the anterior portal into the CC. The other portals, located more posteriorly, are then created under arthroscopic control.

We started to perform arthroscopic FAI treatment in 2004, using primary CC access, first with an orthopaedic table and a perineal post then with an invasive distractor. We introduced a number of technical changes, both to decrease the complexity of the procedure and to minimise the risk of perineal complications. Since 2007, we have been using a modular orthopaedic table (Maquet, Rastatt, Germany) that allows patient positioning on a pelvic support with no perineal post (Fig. 2C). The counter-traction is less direct and the risk of pelvic tilt is greater. To decrease the traction force needed to achieve hip distraction, we perform the capsulotomy before applying traction, via primary PC access\textsuperscript{[9]}. The capsulotomy allows direct passage from the PC to the CC via the same portals. This step may raise challenges, particularly when the capsular incision is too small near the top of the acetabulum. However, it allows safe CC access under direct vision and decreases the traction force needed. If direct access from one compartment to the other appears too difficult, particularly at the beginning of the learning curve, secondary CC access can be achieved using conventional techniques, i.e., a separate capsular approach under fluoroscopic guidance or the variant described by Dienst et al.\textsuperscript{[26]}. This sequence for accessing the hip compartments, chiefly developed in France, is feasible with all patient positioning techniques\textsuperscript{[12]}. With practice, the use of an image amplifier may become unnecessary.

Management of femoroacetabular impingement

We will review the treatment procedures that are universally agreed on and their specific technical features when they are performed via our usual approach. Regardless of the type of FAI (cam, pincer, or mixed), a capsular incision must be made, and the chronology of access to the two compartments is always the same.

Operating room and equipment

General anaesthesia is performed. The patient is maintained in lateral decubitus on the orthopaedic table by posts in the posterior lumbosacral and anterior chest positions. The counter-traction post is placed flat on the contralateral ischial tuberosity without putting pressure on the perineum (Fig. 2C). The operative hip is flexed at 45° to open up the anterior subcapsular space. The hip is placed in neutral or slight external rotation to expose the anterior femoral neck. To this end, the knee is held on a U-shaped support secured to the traction bar. The conventional boot is reinforced by non-adhesive traction tape (Tensoplast\textsuperscript{TM}, Hamburg, Germany) wound up to the distal third of the thigh to minimise loss of traction in the more distal joints (Fig. 2C). The skin below the floating ribs is cleansed and painted with antiseptic according to standard procedures. A vertical isolation drape (Hartmann, Heidenheim, Germany) intended for traumatology is draped horizontally so that the adherent surface generously covers the incision zones. This drape covers the entire traction table, as well as the fluoroscopy arm placed over and towards the patient’s head. The operator and surgical assistant stand behind the patient, facing the arthroscopy column located above the fluoroscopy screen (Fig. 6).

Standard basic instruments are used. The only procedure-specific instruments are two cannulated needles for conveying flexible nitinol guide wires for the dilating obturators. Needles and guide wires of various lengths and diameters are available on the market. Depending on the procedures performed, we use one or two rigid slotted metal cannulas (Smith & Nephew, Andover, MA, USA), a microfracture awl, and a palpating hook. Similar to most other teams, we use a 70° optical system that improves visualisation of the ceiling of the central compartment, i.e., of the upper part of the acetabulum and medial aspect of the labrum, thereby facilitating visual control when creating the approaches or capsulotomy. Familiarisation with this visualisation angle is acquired rapidly. The arthroscope is of standard length. Sizes

Figure 6 Operating theatre layout.

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are also standard for the synovial resector blades (5 mm in diameter) and powered burrs (oval, 4 mm in diameter), which are identical to those used for other joints (Arthrex, Karlsfeld the French version, Germany). A smaller-diameter (4.2 mm) angled knife can be helpful to access the tighter anterior or antero-inferior portion of the joint. A hooked radiofrequency probe is used for the capsulotomy and, to a lesser degree, for haemostasis. An arthropump is used with bags of heated saline to limit the drop in body temperature. A suture kit comprising a bit and drill guide, an arthroscopic knife, a suture passer, a knot manipulator, and a suture cutter is also required in the event of labrum refixation.

Access to the peripheral compartment

The position of the primary portal is determined by palpation, the reference point being the tip of the greater trochanter or a point slightly anterior to this landmark (portal 1, Fig. 3). The needle is directed in a straight line towards the head until contact with the bone. Then, the needle trajectory is changed in small steps to a downwards and anterior direction until it slips over the anterior rim of the neck into the anterior chamber. Fluoroscopy can be used to check needle position. A nitinol guide wire is introduced through the needle until contact with the antero-inferior capsule produces elastic resistance. A dilating obturator is inserted over the guide wire taking care to follow the same trajectory. The capsule is thick at this point and can easily twist small-diameter guide wires. If abnormal resistance is met when piercing the capsule, suspect a kink in the guide wire, which can lead to breakage. Once the obturator is in the PC, the arthroscope sheath or a dedicated metallic cannula is slipped over it, the obturator is removed, and the arthroscope is introduced. At this stage, mobility of the arthroscope is very limited. The arthroscope must be rotated to visualise the lateral part of the head and lateral aspect of the labrum medially and the neck under the overhanging capsule and synovial membrane laterally. The instrument portal (portal 2, Fig. 3) is positioned 7 to 10 cm anterior and distal to the arthroscope portal (portal 1). The needle is directed to the arthroscope tip and pierces the capsule under arthroscopic guidance (Figs. 7 and 8). At the beginning of the learning curve, excessive convergence due to concern about an exaggerated anterior trajectory may occur. The obturator is easier to introduce, as the capsule is thinner at this location. A second sheath or cannula is placed in this portal (Fig. 9) and the arthroscope is moved from portal 1 to portal 2. A short slotted cannula on an obturator is introduced into portal 1 then used to insert the hooked radiofrequency probe, after which the cannula is removed.

Capsulotomy

The first step is a short oblique incision from anterior to posterior and from medial to lateral to broaden the capsule entry site. This incision considerably facilitates mobilisation of the radiofrequency probe. Next, a proximal arc-shaped incision is performed along the labrum from anterior to posterior to the tip of the femoral head, i.e., from about 3:00 to 12:00 o’clock in the right hip (Figs. 10 and 11). The incision is then continued laterally along the axis of the neck,

Figure 7 Creation of the instrumental portal (portal 2) using a cannulated needle under visual control via the arthroscope introduced through portal 1 into the peripheral compartment.

Figure 8 Arthroscopic view corresponding to Fig. 7 (right hip). The nitinol guide wire is visible emerging from the needle.

in an L shape, to portal 1 (Fig. 12). If the capsulotomy must be extended posteriorly, then the proximal incision should be prolonged posteriorly, along the labrum, to produce a T-shaped incision (Supplementary data, Video 1).

Femoroplasty

If the femoral head is aspherical (cam or mixed FAI), femoroplasty is started at this stage (Fig. 13A, B). Several landmarks can help to determine the medial boundary of the osteoplasty. The transition from the healthy femoral head cartilage, which is perfectly smooth, to the uneven and sometimes ulcerated crust of cartilage at the junction

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of the head with the bulging neck may be clearly visible. This transition is usually located along the line marking the fused growth cartilage (Fig. 14A, B). As no perfectly reliable visual landmarks are available, using the radiofrequency probe to mark the transition under fluoroscopic visualisation may be helpful (Fig. 14C, D). The osteoplasty procedure can then be started under visual guidance via the arthroscope left in portal 2, with the burr introduced through portal 1. If the capsule hinders visualisation, a shaver can be used for limited as-needed capsulectomy. Capsulectomy may cause bleeding, which decreases visibility. Haemostasis using the radiofrequency probe is not always easily achieved. The risk of bleeding can be decreased by injecting a saline or lidocaine solution containing adrenaline around the capsule at the beginning of the procedure [24]. Experienced operators may be able to perform this step without a working cannula, as the capsulectomy considerably facilitates the introduction of the instruments. The femoroplasty is continued by returning the arthroscope to portal 1 and the burr to portal 2. We prefer barrel-shaped or cylindrical burrs, whose contact surface area is greater. The depth of the resection is guided by the pre-operative radiological findings and intra-operative direct (and if needed fluoroscopic) visualisation. The upper and posterior boundaries of burr application are classically determined by the emergence of the terminal medial circumflex or superior retinacular vessels [2,27]. In practice, these boundaries cannot be accessed

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with the hip flexed and no traction. In this position, only the anterior part and, sometimes, the inferior part, of the head-neck junction are treated. Inferiorly, the extent of the resection depends on pre-operative templating and on the intra-operative appearance by direct vision or fluoroscopy; in any case, the resection should not extend beyond the medial synovial fold. Laterally, the burled-down area should merge gently into the femoral neck cortex (Supplementary data, Video 2).

At this stage, the femoroplasty is often incomplete, as a result of inadequate access to the superior portion of the head-neck junction. This portion is treated after the procedure conducted in the CC. The traction is decreased by one-third and the hip placed in extension and slight internal rotation to improve exposure of the superior part of the head. In this position, the posterior capsular flap is slightly anterior to the apex of the head and protects the superior retinacular vessels. In some cases, to correct deformities extending superiorly, we have applied the burr beyond the usual zone, up to the apex of the head-neck junction (at 12:00 o’clock), without visualising the blood vessels, a variant that had no adverse effects. Although some terminal arterial branches may be compromised in this region [28], the common trunk, located in a more lateral position, remains protected by the capsule, which must be preserved at this site (Supplementary data, Video 3).

Access to the central compartment

A neuromuscular blocking agent is given a few minutes before applying traction. The hip is placed in extension and neutral rotation, and the U-shaped support is lowered. Traction is applied by the scrub nurse, who starts by grasping the leg under the drapes. This manoeuvre may provide sufficient distraction to allow access to the central compartment. If the joint does not open up sufficiently, the traction force is increased by using the distractor’s traction handle. This step is performed under arthroscopic control via portal 1 (Fig. 12). The joint may remain tight despite a high traction force. Furthermore, the capsule is put under tension, which may displace the arthroscopic anteriorly. Both problems require prolongation of the proximal capsulotomy incision upwards and, if needed, slightly posteriorly, using the radiofrequency probe introduced via portal 1 (Supplementary data, Video 4).

Exploration of the central compartment

With a 70° arthroscope and the increased mobility provided by the capsulotomy, the entire surface of the semilunar cartilage and the medial aspect of the labrum are visible via portal 1. The femoral head ligament is best visualised via portal 2. The typical cartilage lesions produced by FAI consist in delamination located in the antero-superior acetabular quadrant. Posterior secondary contrecoup lesions of the cartilage are inconsistently found and appear as erosions or ulcers. The femoral head cartilage is very often normal. The arthroscopic hook is used to detect open laminated lesions such as a mobile flap or a blister that creates a wave effect under the hook. Opposite these lesions, the labrum should be examined for a detached zone, with uneven or bruised edges, which must be differentiated from a normal recess. The depth and extent of the lesion should be assessed, as well as the size and trophicity of the body of the labrum.

Acetabuloplasty

Acetabuloplasty is required in patients with pincer or mixed FAI. Planning is more challenging than with femoroplasty. The size of the burled-down area, both in length (along the acetabular rim) and in depth (which medialises the acetabular rim) depends on the degree of antero-superior impingement.
bony coverage. Except in the event of acetabular protrusion, the pincer effect is related, by definition, to acetabular retroversion [1]. The cross-over sign on the anteroposterior radiograph does not always indicate excessive acetabular coverage [13]. In contrast to hip dysplasia, no angle values defining over coverage have been validated. In an earlier study, we defined acetabular over coverage as retroversion combined with an anterior and/or lateral centre-edge angle greater or equal to 30° [12]. Provided the intra-operative findings are consistent with the radiological data, acetabuloplasty can be performed by estimating that 1 mm of bone resection results in about 1° of correction and by taking care not to decrease the angle below 25° [12].

**Figure 14** Femoroplasty. A. Clearly visible boundary (arrows) between the healthy cartilage covering the head and the ulcerated cartilage on the bulge at the head-neck junction that is taken as the medial osteoplasty boundary (right hip, arthroscopic view through portal 1). B. Same hip and same view after femoroplasty. C. The radiofrequency probe is used to mark the medial boundary of the osteoplasty. Here, the boundary is less clearly visible (arthroscopic view through portal 2, left hip). D. The femoroplasty can be started via portal 1 and is performed along the medial mark.

**Treatment of the joint lesions**

**Cartilage lesions**

Cartilage flaps are usually removed using a shaver or punch. Microfractures may be created in the exposed subchondral bone after curetting. However, a challenge to the creation of microfractures is the often tangential orientation of the awl shaft, particularly when the surface to be treated is in a markedly lateral and superior location. The tip of the awl may slip instead of perforating the surface. A technique suggested to circumvent this problem consists in making transfixing holes from lateral to medial using a small-diameter drill bit and a ligamentoplasty aiming device [29]. When large pieces of cartilage are detached,
re-implantation using biological glue has been suggested [28]. This method is criticised, however, since cartilage tissue has no potential for healing. Implantation of a synthetic matrix to replace the torn cartilage has also been suggested [23].

**Labral lesions**

Labral tears usually develop at the insertion of the labrum. If the tear is deep and the body of the labrum is spared, suturing to re-implant the labrum can be considered. Otherwise, debridement or partial resection of the damaged zone is performed, usually with the shaver.

The most widely used labral repair method starts with further detaching the labrum using an arthroscopic knife, in order to create a bucket handle cleavage (Fig. 15) allowing introduction of the burr between the labrum and the acetabular rim (Fig. 16). The bony rim is either simply burred down to bleeding bone or resected when acetabuloplasty is in order. This step is facilitated by the use of an ancillary instrumental portal (portal 3) to allow orientation of the instruments closer to the plane perpendicular to the acetabular rim. In this orientation, the largest surface of the burr is in contact with the bone (Fig. 16).

We use non-absorbable sutures with absorbable intra-osseous anchors (Bioraptor® 2.9, Smith & Nephew, Andover, MA, USA). The drill hole should be located near the cartilage to ensure continuity with the medial aspect of the labrum, thus optimally restoring the seal function of the labrum. An upwards direction of the drill hole minimises the risk of cartilage surface damage and is easier to achieve using portal 2. The sutures are placed from anterior to posterior under visual control via portal 1. Two or three anchors are usually necessary, depending on the size of the lesion. First, the most anteriorly placed anchor is inserted by positioning the drill guide and inserter under the labrum, in order to optimise visual control. The other anchors are introduced above the labrum, which is displaced downwards towards the femoral head, to control proper positioning and avoid excessively lateral suture placement. The slipknots are lowered using a knot manipulator and positioned on the lateral aspect of the labrum. The sutures are usually looped around the body of the labrum (Fig. 17A, B) using a Reverdin-type suture passer (Supplementary data, Video 5). This is the simplest technique but has the disadvantage of changing the labrum cross-section shape from a triangle to a circle. If the labrum is wide, passage of the suture through the labrum may be preferable but requires an additional step with a suture-passing device normally used for rotator cuff repair. This method is more effective in restoring normal labrum shape and function (Fig. 18).

**Dynamic testing**

A dynamic impingement test is performed once the complementary femoroplasty procedure is completed. Traction is released and the foot freed. The hip is placed in the position associated with impingement, i.e., flexion, adduction, and internal rotation. The surgical assistant performs this manoeuvre in a stepwise fashion, holding the leg at various degrees of flexion and internal rotation. Visual control is via portal 1 or 2 depending on soft tissue interposition in the field of view. The burr is left in the instrumental portal and serves to retract the capsule in order to improve visibility, as well as to perform additional bony resection as required.

Dynamic testing is not always informative, and fluoroscopic assistance may be useful in this situation. The use of fluoroscopy is strongly recommended at the beginning of the...
Prevention of complications, and postoperative care

Technical improvements have decreased the all-cause complication rate of hip arthroplasty to a very low level. Complications may be more common after arthroplasty for FAI, since the procedure involves the bone and is sufficiently complex to require a longer operating time [12,31]. The risk of injury to the lateral femoral cutaneous nerve is non-negligible and may be chiefly related to the use of the anterior portal [12]. The other neurological and perineal complications can be avoided by limiting traction duration and force and by using appropriate supports [9,12]. Heterotopic ossification is a usually benign complication that can be avoided by adjunctive indomethacin therapy.

Capsulotomy and stability

The joint capsule plays a key role in hip stability [32]. In our experience, we have had no instances of instability after arthroscopic treatment for FAI, despite the capsulotomy and, in some cases, a limited capsulectomy. In addition, in the few patients who required revision arthroscopy or arthroplasty, the capsule consistently appeared fully healed, i.e., continuous and thick (Fig. 19A, B).

Therefore, we suggest that, in this indication at least, suturing the capsule at the end of the procedure is unnecessary, although other authors disagree [33].

Postoperative care

We do not use drains. Postoperative pain is mild and we do not perform complementary regional anaesthesia. However, at the end of the procedure, we inject a diluted delayed-action local anaesthetic into the PC. The patients are discharged on the second postoperative day. Forearm crutches are used for walking during three to five weeks. The importance of weight-bearing protection depends on the intensity of the pain and on the nature of the

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Figure 17  Suture-refixation of the labrum (left hip). The suture is looped around the labrum (A) and fixation is performed (B).

Figure 18  Types of labral suture, cross-sectional view. Passage through the labrum preserves the triangular shape of the labral cartilage. Below, the usual loop method of labral suture. In both cases, the knot is positioned at the dorsal aspect of the labrum.

Operating time

The operating time decreases as experience increases. As indicative information, our mean traction time is 25 minutes (from 10 minutes for simple debridement to 50 minutes in some cases of acetabuloplasty with suture of the labrum). The mean time needed for exposure and femoroplasty is 30 minutes. Thus, the mean total operating time is 55 minutes (40 to 80 minutes).

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procedure. After major femoroplasty, caution mandates partial protection from weight-bearing for four weeks followed by a gradual transition to full weight-bearing over one or two weeks. During this period, home exercises consisting in flexion of the hip along the leg axis, with no rotation, promote optimal healing of the capsule. These hip cycling movements are important as they may contribute to the development of capsular adhesions [34]. We have encountered a single case of capsular adhesions in a patient who required revision surgery and had an adhesion between the capsule and the free edge of the labrum (Fig. 19B).

A few physical therapy sessions may be prescribed at the end of the sixth postoperative week. Later on, depending on the features in each individual case, sporting activities can be resumed gradually, giving preference to low-impact activities.

Conclusions

Regardless of the technical approach, the quality requirements are the same for all therapeutic procedures. There is a learning curve and, consequently, cases should be selected to ensure that the operator gradually achieves expertise in overcoming the various technical challenges. With experience, the procedure becomes simpler but remains technically demanding.

Several unresolved issues persist regarding the pre- and postoperative evaluation of bony dysmorphisms and the extent of corrective procedures. The optimal management of labral and cartilage lesions also remain unclear. In the future, technical advances in fields such as 3D dynamic imaging and biomaterials should provide at least partial answers.

Disclosure of interest

The author declares that he has no conflicts of interest concerning this article.

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Appendix A. Supplementary data

Supplementary data (Videos 1–5) associated with this article can be found, in the online version, at doi:10.1016/j.otsr.2012.06.001.

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