Avascular Necrosis, Osteoarthritis and Synovitis

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70.1 Avascular Necrosis

70.1.1 Indications

Avascular osteonecrosis mostly concerns young adults in full activity. Besides traumas, most of the aetiologies are corticosteroid therapy, drepanocytose and alcoholism. After avascular necrosis, the cancellous bone rebuilt itself rather promptly unlike the subchondral bone. The subchondral bone disappears faster than it is reformed. It becomes a sensitive junction between the subchondral bone and the cancellous bone, with less resistance and a weak point that can promote subchondral fractures. If MRI allows establishing a complete statement of the necrosis, CT scan can be more precise in detecting subchondral fracture and minimal femoral head deformities [26].

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The presence of a subchondral fracture is a turning point in avascular osteonecrosis and at this stage, no conservative treatment can be undertaken. Thus, conservative surgery should be performed before the apparition of a subchondral fracture, to prevent evolution towards collapse of the femoral head and to hip osteoarthritis in young adults [10].

70.1.2 Surgical Techniques

Epiphyseal drilling decompression is the conservative therapeutic gold standard of avascular osteonecrosis of the femoral head. The usual technique presents the inconvenience of only having indirect control of the surgery by the X-ray. Moreover it imposes to drill the entire femoral neck. Hip arthroscopy allows a direct and precise approach of the lesion.

With axial traction on an orthopaedic surgical table, the femoral head is palpated under arthroscopic vision and X-ray control to determine the necrotic zone [28]. A 3.2 mm Steinmann pin is used through the mid-anterior approach. It is positioned at the junction between the femoral head and the femoral neck, focused towards the necrotic epiphyseal nucleus and introduced slowly with the engine. Under X-ray and arthroscopic control, small 3.2 mm drilling holes are realized with divergent orientation passing through the sclerotic lesion [15].

In the case of a sclerotic or cystic lesion of the epiphyseal nucleus, it is necessary to obtain a com-

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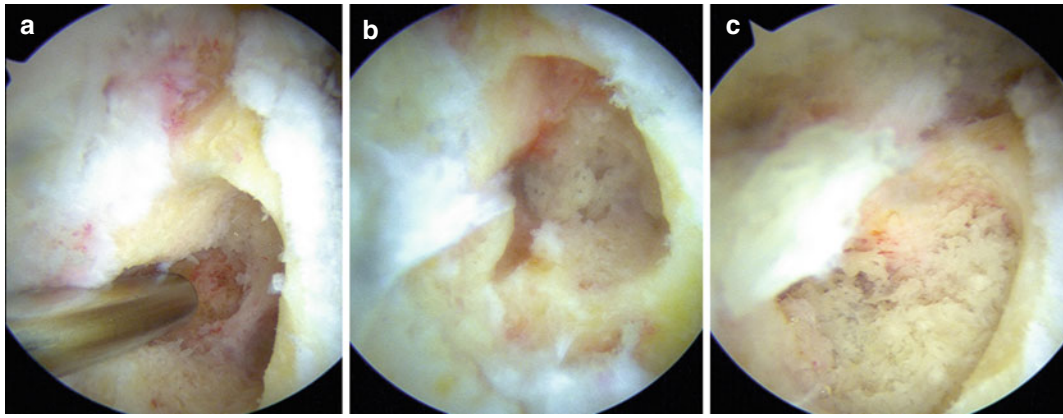

Fig. 70.1 Resection and grafting of necrotic bone of the head by drilling at the head-neck junction (neck on the left – femoral head cartilage on the right). (**a**) Shaver finishing to extract necrotic tissue. (**b**) Grafting the hole by fragmented autograft. (**c**) End of the procedure: the entire hole is grafted

plete resection of the necrotic tissues associated secondary to a bone autograft. To achieve it, a Kirschner wire is positioned in the lesion area from the junction of the femoral head and the femoral neck as explained previously. Using the Kirschner wire as a guide, an 8 mm hole is drilled through a 9 mm cannula. The pathologic area is then carefully drilled under X-ray control. The necrotic bone is resected with an adapted curette. Then, the bone autograft removed from the ipsilateral iliac bone is introduced by the cannula positioned at the entry of the cavity and carefully impacted [44] (Fig. 70.1).

The delay without support on the treated lower limb depends on the localization and the importance of the treated zone. Since most of avascular osteonecrosis are located at the anterosuperior area of the femoral head, which is undergoing the majority mechanical bearing stress, 45 days to 3 months of partial weight bearing is recommended.

70.1.3 Tips and Pearls

To obtain a good direction for the drilling, the installation of the patient is mostly important. It can be necessary to adjust hip flexion and hip rotation during surgery.

Before grafting the lesion, the arthroscope can be introduced in the drilled tunnel to check the absence of residual sclerotic tissues. The 70° scope is then very useful to obtain complete vision.

Cancellous bone autograft should be introduced in the cannula after fixing the cannula at the entry of the drilled tunnel in order not to spread bone around the hip.

70.1.4 Complications

Iatrogenic chondral lesion by overdrilling the femoral head is one of the specific complications. Special care should be done during this procedure and X-ray control is mandatory. Arthroscopic control must be used to monitor for chondral vibrations indicating that the drill in just under the subchondral bone. In this case, drilling must be stopped preventing chondral lesions.

Another specific complication is wire breakage that should be avoided by keeping the same direction between the wire and the drill.

70.1.5 Literature Overview

Rosenwasser et al. found 87 % of very good results by extra-articular conventional technique at 10 years follow-up [36].

From 1990 to 2000, Hernigou treated 534 illness hips presenting an early stage of femoral head osteonecrosis. He used a surgical technique associating extra-articular drilling and stem cell autograft [18]. At a mean follow-up of 13 years,

94 total hip replacements (THR) were realized. Among the remaining patients, Harris score increased from 70 in preoperative to 88 at the revision. On the MRI control, the osteonecrosis was healed in 69 hips. Among the remaining hips, the osteonecrosis area had decreased by half.

With the arthroscopic technique, Wang reports 60–85 % of very good results at 2 years follow-up according to the degree of the pathology [44].

70.1.6 Future Direction

An adjuvant treatment by stem cell autograft from bone marrow was proposed to increase the cure rate [18]. The transplant stem cells are taken from the iliac crest by aspiration through a trocar. Multiple punctures are necessary to obtain enough cells. Stem cells are then concentrated by filtration and centrifugation prior to injection.

An alternative of the stem cells is the treatment by platelet-rich plasma (PRP), whose interest in this indication remains theoretical to this day [15]. A prospective and randomized study recognized a better bone integration after the adjunction of PRP to bone allograft in opening wedge tibial osteotomy [3].

Regardless of the chosen adjuvant treatment, it is used by injection through the drilled holes in case of decompression of the epiphyseal nucleus. When there is a cancellous bone graft, part of the adjuvant treatment is injected and part is mixed with the graft a few minutes before grafting. Water irrigation should be stopped during the procedure.

70.2 Osteoarthritis

70.2.1 Indications

Since 1936, Smith-Peterson highlighted hip impingement as a cause of secondary osteoarthritis and treated his patients by acetabuloplasty [40]. Ganz et al. [11] and then Tanzer et al. [41] established the link between femoroacetabular impingement and arthritis. They established a causal link between the "pistol grip" head deformity, labral tears, pain and ostéoarthritis. In their study group of 125 hips with THA, the "pistol grip" deformation was systematically found [11, 41].

The Copenhagen study about osteoarthritis revealed the presence of a cam impingement in 17 % of the male population and in 4 % of the female population in a cohort of 4,151 patients [14]. This data has been recently confirmed concerning young asymptomatic adults [16, 35].

Even if the arthroscopic treatment of femoroacetabular impingement reveals excellent results, the presence of osteoarthritis at time of surgery remains a bad prognosis factor. Thus, a confirmed osteoarthritis is a contraindication to an arthroscopic treatment. However, some cases of starting osteoarthritis are likely to respond to this surgery.

The recommended indications are degenerative damage limited to less than or equal to grade 2 from Tönnis classification, induced by a femoroacetabular impingement, in young patients, with satisfactory acetabular cover. The radiological thickness of the joint space is important to take into consideration. The failure rate is 86 % at 40 months of follow-up for a joint space of less than 2 mm against 16 % with a thickness of more than 2 mm [39].

70.2.2 Surgical Techniques

Hip arthroscopy on pre-osteoarthritis is usually realized by the same surgical technique as the treatment of femoroacetabular impingement. Arthroscopic approaches remain the same, and treatment will aim to remove any cam or pincer effect and treat chondral and labral damage.

The specificities of hip arthroscopy in pre-osteoarthritis are linked to the presence of a fragile and degenerative labrum, sometimes calcified, and to the presence of advanced cartilage lesions. Femoral osteoplasty and acetabuloplasty are complicated by the presence of osteophytes, associated to osteoarthritis (Fig. 70.2). These osteophytes and capsular thickness can limit hip distraction making central compartment access difficult. In these cases, capsulotomy should be

enlarged in order to allow a complete resection of osteophytes and to obtain enough distraction for intra-articular procedures.

Regarding the labrum, despite a degenerative aspect, it is important to preserve it by anchor refixation. If repair is not possible, reconstruction should be discussed. Indeed, it has been shown that labral preservation or labral reconstruction is a better prognostic factor [7, 20, 21, 37]. The preservation or reconstruction of the labrum is especially important in cases of chondral lesions since it can stabilize a cartilage repair and reduce the mechanical stresses on this pathological cartilage.

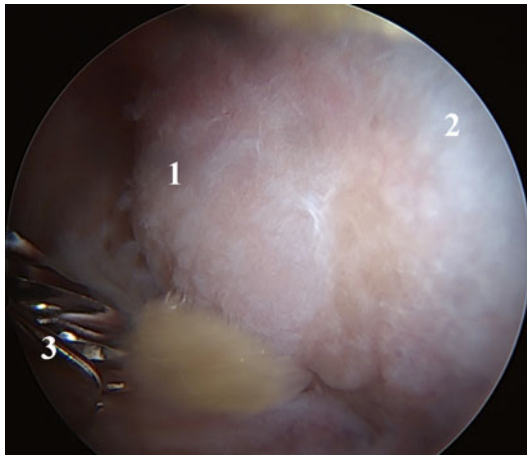

Fig. 70.2 Resection of osteophytes at the head-neck junction. Shaver finishing to extract necrotic tissue. *1* Osteophyte. *2* Head-neck junction. *3* Burr

Regarding chondral damages, they are usually described as focal lesions located on the anterior-superior edge of the acetabulum [31]. They must be debrided, being as conservative as possible. The goal is to fill the cartilage defect by the best filler available, in order to produce the best cartilage or fibrocartilage. This filling tissue allows the decrease of the pressure on the adjacent and healthy cartilage by 200 %, thus protecting it. The lesion either femoral or acetabular, the filling tissue to use will depend on the depth and the extent of the lesion, either it is femoral or acetabular:

- *Non-transfixing lesions*, with partial damage of the cartilage thickness (Outerbridge grade I–III), or isolated deep cracks (Fig. 70.3a) are usually treated by **cartilage debridement** (**chondroplasty**). Debridement is carefully made with a shaver or a basket punch (Fig. 70.3b). It may be made with a radio-frequency device, but if the result is more appealing, there is a risk of damage of the healthy peri-lesional chondrocytes by diffusion [25]. The debridement of unstable or small cartilage flaps must be undertaken in an economical way.
- In the presence of *stable transfixing lesions such as cartilage flap* (Fig 70.4), some surgical

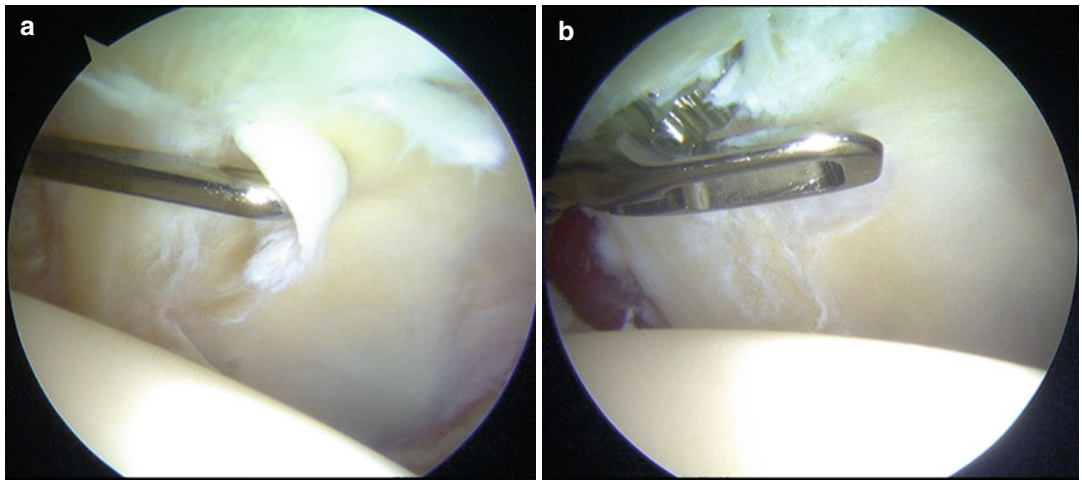

Fig. 70.3 (**a**) Isolated deep cracks at the anterosuperior border of the acetabulum. (**b**) Careful debridement of chondral cracks with a basket punch

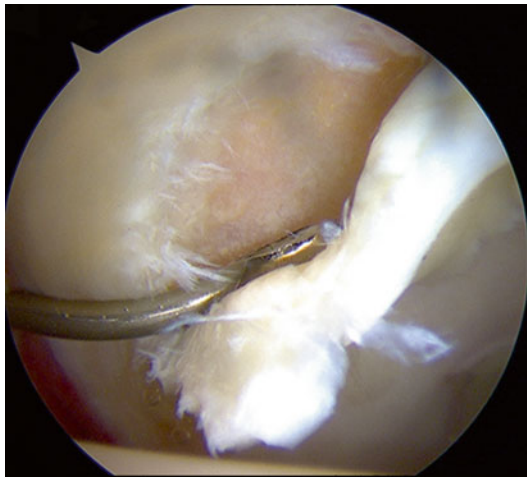

Fig. 70.4 Stable chondral flap at the superior border of the acetabulum

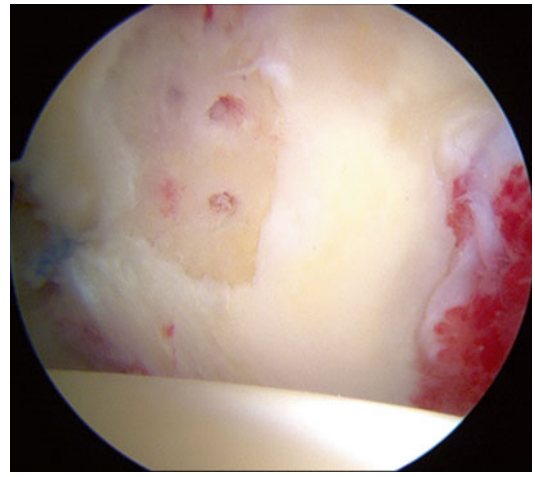

Fig. 70.5 Micro-fractures in the subchondral bone of a chondral defect at the anterosuperior margin of the acetabulum

teams suggest their conservation by repositioning after subchondral bone preparation [38, 43]. The preparation of the subchondral bone is performed according to the same principles as micro-fractures, while keeping the cartilage flap. After preparation, irrigation is stopped and the fluid removed from the hip. In a dry environment, fibrin glue is placed under the cartilage flap and pressure is applied for 2 min. This pressure is carried out by the balloon of a urinary catheter or by stopping the distraction on the orthopaedic table. The cartilage preservation is limited to treat large cartilage flaps with the entire cartilage thickness and with a healthy underlying bone [46]. If the flap is considered unstable or nonviable, excision is then the rule. We find ourselves in the situation of a cartilage defect.

- *Complete cartilage defects* (Outerbridge grade IV) should be treated depending on their extent after debridement: currently **micro-fracture** is the most used technique [34]. This technique is suitable for localized and circumscribed lesions *smaller than 2 cm* [2], with an intact subchondral bone. The indication can be extended to larger lesions, *up to 4 cm* [2], according to the patient's age (*higher*), weight (*lighter*), level of activities (*lower*) and the location of the lesion (*not a support area*) [32, 34, 46]. After debridement of the lesions until the subchondral bone, with regularization of its margins to be in healthy cartilage, it is essential to remove the calcified subchondral bone layer with a curette or a shaver. Holes ("micro-fractures") are then made in the subchondral bone, perpendicular to the bone surface and with a depth of 2–4 mm (Fig. 70.5). Since surgical approach during hip arthroscopy is not in the axis of the lesion, it is necessary to use specific square points, with different angulations (45–90°). The distance between each hole should be approximately 5 mm. Once the micro-fractures are performed, the irrigation pressure is lowered to check the appearance of bleeding from the holes.
- *Grade IV lesions of more than 2 cm²* in young patients are preferentially treated by **Autologous Matrix Induced Chondrogenesis** (**AMIC®**) [8, 23]. This technique begins with the realization of micro-fractures. The matrix, cut to the size of the defect, can then be introduced through an arthroscopic cannula. Its pore side is applied in contact with the prepared subchondral bone. Releasing the traction is sufficient to fix the matrix. Its attachment can however be improved by the application of biological glue.

If more than 4 cm² of grade IV chondral lesion, **Matrix Techniques with Autologous**

Chondrocyte Implantation (**MACI**) are often preferred to AMIC®. The technique is the same but needs a two-step surgery: first arthroscopic surgery to visualize the lesions and to harvest cartilage for planting. The second arthroscopic step is the application of the membrane supporting the chondrocytes harvested. The cost is significantly higher and to this day, their advantage is not proven.

All these filling techniques of cartilage defects lead to a fibrocartilage formation. However, some studies have shown that after a period of 2 years, fibrocartilage becomes real cartilage when using the AMIC® technique [30].

70.2.3 Tips and Pearls

The "central first" approach can be challenging to realize due to osteophytes and joint stiffness that can limit the joint distraction. Thus, it is sometimes necessary to start from the peripheral compartment, hip in flexion, to enter the joint. This "peripheral first" approach can also be difficult to realize by the presence of osteophytes. In these cases, we recommend the "extra-articular approach" technique described by F. Laude [42]: The affected limb is in a slight flexion without traction. The anterolateral portal is first placed at the level of the trochanter. The arthroscopic trocar is introduced under the fascia lata up to a contact with the femoral neck's capsule. While keeping the contact with the capsule, the 70° scope is introduced in the trocar. The anterior portal is then placed anterior to the facia lata and more distal. A fat-pad area (muscle-free zone) is present and removed with the shaver by the anterior portal. The capsule is exposed and with an electrocoagulation device it is incised as a "T" -shape from outside to inside. The labrum and cartilage surfaces are identified before exercising traction on the hip.

It is usually necessary to remove osteophytes first and realize a capsulotomy to be able to distract the hip and to free the instruments. Intraoperative X-ray will facilitate removing all the osteophytes.

At the end of the procedure, a dynamic testing is required to ensure the absence of residual impingement in abduction for superior cam and in deep flexion for anterior came.

70.2.4 Complications

Heterotopic ossification is the first complication in the cases of these stiff hips requiring high bone reaming, sometimes of inflammatory origin. It will be best avoided by a careful per operative joint washing, an early hip mobilization and the use of the NSAI drugs during the postoperative period.

Complications caused by the distraction device (perinea skin lesions, sensitive pelvic disorders…) are also more frequent in the case of joint stiffness due to the use of a stronger and longer distraction, linked to the difficulty and many intra-articular procedures (labrum and cartilage).

Finally, it is important to mention the risk of secondary displacement of the interposition matrix (*AMIC®/MACI*) used in cartilage reconstruction techniques [8]. This complication can be reduced by the use of biological glue.

70.2.5 Literature Overview

According to a recent systematic review of Domb et al. in 2015 [6], the risk of failure or the risk of osteoarthritis evolution is directly related to the importance of degenerative disorders with conversion to THA, ranging from 16 % to 52 % concerning Tönnis grade 2 or higher. Haviv and O'Donnell [17] described a rate of 16 % of THA conversion after 3 years, concerning 564 hip arthroscopies between 2002 and 2009 with cartilage disorders from 1 to 3 according to Tönnis rates. Larson [22] described a rate of 52 % THA conversion after 227 cases on higher grades than 2 after the same delay, between 2004 and 2008.

Excluding Tönnis grades 2 and higher, Palmer [33] showed 8 % conversion in 201 arthroscopies followed after 2–4 years. In a prospective study, at a minimum of 4 years follow-up, Gicquel [12] reported that the main prognostic factor was the preoperative osteoarthritis Tönnis grade: compared to Tönnis grade 0 hips, Tönnis grade 1 hips had lower WOMAC scores (77 vs. 88), lower satisfaction rates

(50 % versus 77 %), a higher rate of osteoarthritis progression (57 % versus 24 %) and a higher rate of arthroplasty (33.3 % versus 2.9 %).

In a study about the joint space narrowing on preoperative X-ray in 466 patients, Skendzel and Philippon [39] described that the conversion rate to THA is 86 % at 40 months when preoperative joint space is lower than 2 mm, against 16 % for a joint space of more than 2 mm.

70.2.6 Future Direction

Grade IV cartilage disorders treated by interposition of synthetic matrix (AMIC®) seem to provide at short and medium term encouraging results. The recent Italian study from Fontana and Girolamo [9] compares the treatment of hip chondral lesions by AMIC® (70 patients) to isolated micro-fractures (77 patients). They note an improvement up to 5 years from the surgery in the AMIC® group, while the micro-fracture group deteriorates after 1 year. No THA was required in the AMIC® group against 7.8 % in the micro-fracture group.

In the knee, McCarthy [30] realized a study comparing AMIC® versus autologous chondrocytes implantation (ACI) for the treatment of chondral defect. In systematic biopsies, realized at 18 months postoperatively, he found a significantly better quality of repaired tissue, with higher ICRS II score and higher hyaline cartilage formed, after AMIC® than ACI.

Labral reconstruction, often necessary in these degenerative hips, gives encouraging results compared to the labral resection. At 2 years follow-up, Domb [5] described greater results concerning labral reconstruction compared to segmental resection. Matsuda [29], comparing labral repair versus labral reconstruction with the gracilis tendon, confirms the interest of labral reconstruction.

70.3 Synovitis

70.3.1 Indication

Synovitis diagnosis should be considered when there is a mechanical, unilateral and progressive joint pain. It must also be discussed when patients complain of blockages or pseudo-blockages. X-rays can show subchondral cyst of the acetabular or the femoral head associated with a preserved joint space. It can also highlight intra-articular foreign calcified bodies.

MRI with gadolinium vascular injection is the best radiological imaging exam. It allows a diagnostic approach, a staging of the synovium and a screening of infra-radiological bone lesions.

Synovial chondromatosis is the most frequent synovial pathology. Multiple intra-articular foreign bodies characterize it but sometimes chondroid foreign bodies can be missed with MRI, because of radiological signal near the one with joint effusion. In this case, it is interesting to have a complete injected radiological assessment (arthro-CT or arthro-MRI) (Fig. 70.6). It will guide the arthroscopy surgery by the count of foreign bodies and by highlighting and localizing the pathological synovial membrane, which appears thickened and irregular.

In case of villonodular synovitis, the presence of hemosiderin deposition has a pathognomonic MRI aspect due to its particular ferromagnetic properties (Fig. 70.7).

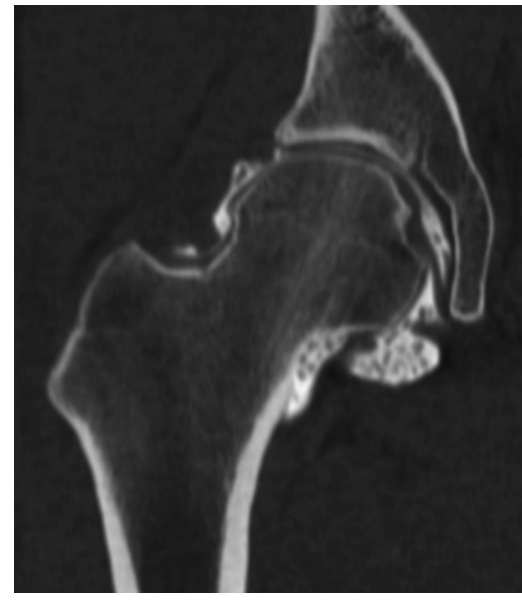

Fig. 70.6 Arthro-CT coronal view of chondromatosis in a right hip

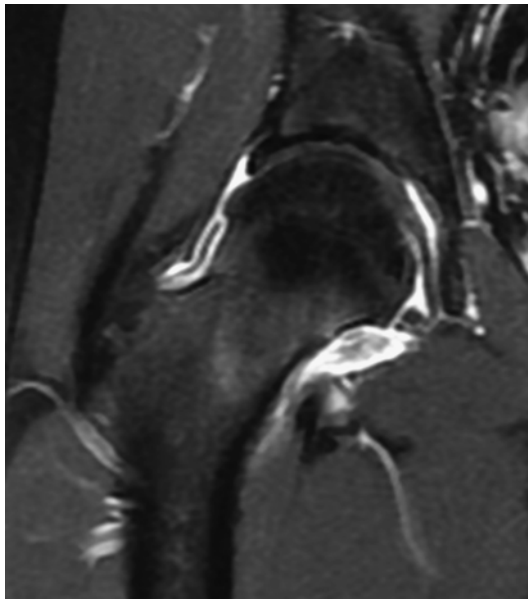

Fig. 70.7 MRI coronal view (T1-FS-gadolinium) of the right hip: pathognomonic hemosiderin deposition signal of a villonodular synovitis

Synovial pathologies were the first indications for hip arthroscopy. Arthroscopy will allow a macroscopic evaluation of the synovium and a diagnostic confirmation by histological biopsies. It will also allow the realization of the surgical treatment consisting in partial or subtotal synovectomy depending on the importance of the lesion and the removal of foreign bodies if needed. In the case of inflammatory rheumatism, the use of new biotherapies makes synovectomy under arthroscopy exceptional. Nevertheless, the endoscopic appearance of inflammatory arthritis should be well known. It is useful to practice a synovial biopsy whenever there is a suspicious appearance of the synovium.

70.3.2 Techniques

The articular exploration must be systematic to obtain a precise and complete diagnosis of the synovium.

The peripheral compartment is divided in four areas that must be described:

- The anterior zone
- The medial zone (inferior)
- The lateral zone (superior)
- The posterior zone

The anterior, medial and lateral zones are separated from proximal to distal by the orbicular ligament. The posterior compartment is very difficult to explore because it is a narrow space between the acetabular wall, covering the integrity of the posterior femoral head in hip extension, and a posterior capsular attachment that is more proximal on the femur than in the anterior space [4]. Furthermore, the flow of vessels crossing the supero-posterior edge of the neck makes the arthroscopic approaches of this area at risk of vascular injury.

The central compartment is composed by [4]:

- The articular surface of the acetabulum
- The acetabular fossa
- The ligamentum teres
- The articular surface of the femoral head

Areas covered by synovium are the integrity of the peripheral compartment and, for the central compartment, the acetabular fossa with the ligamentum teres.

Capsulotomy is realized as necessary. It will allow a better mobilization of surgical instruments to reach difficult areas and the removal of large foreign bodies if necessary. It is realized anteriorly in between portals, parallel to the acetabular edge. It can be extended to the lower anterior edge to reach the medial zone and to the upper and posterior edge to reach lateral zone. If needed, a vertical capsulotomy can be realized in the axis of the femoral neck, along the iliofemoral ligament. This capsulotomy will cut the orbicular ligament allowing a spectacular view and access to the anterior, medial and lateral areas (Fig. 70.8). To prevent the risk of bleeding in the context of inflammatory synovium, the capsulotomy is ideally performed with the thermocoagulation electrode.

After biopsies, the pathological synovium can be resected with a 4.5 mm or 5.5 mm shaver (Fig. 70.9) or with the thermocoagulation electrode, depending on the bleeding risk level. Curved shavers and adjustable angle electrodes help the surgical procedure. These two instruments are complementary to access most of the capsular recess.

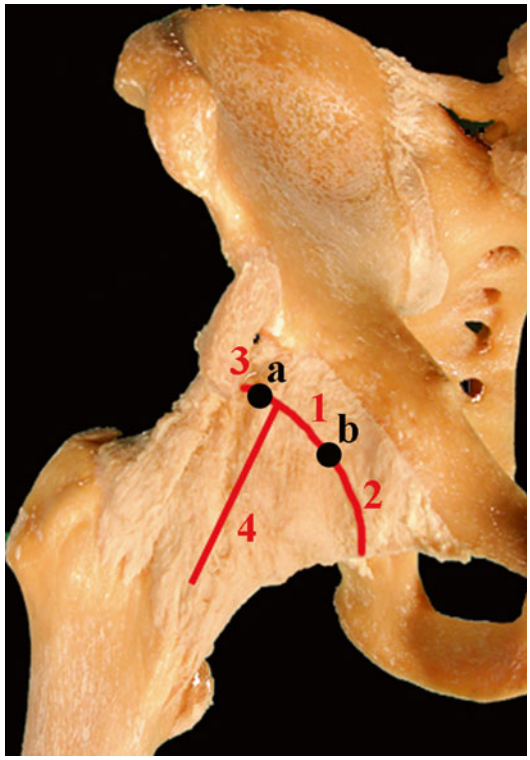

Fig. 70.8 Anterior view of a right hip and capsule: possibilities of capsulotomy extensions. (**a**) Capsular entry point of the anterolateral portal. (**b**) Capsular entry point of the mid-anterior portal. *1* In-between-portals capsulotomy, parallel to the acetabular edge. *2* Lower anterior edge capsulotomy to reach the medial zone. *3* Upper and posterior edge capsulotomy to reach lateral and posterolateral zone. *4* Vertical capsulotomy in the axis of the femoral neck, along the iliofemoral ligament, cutting the orbicular ligament

The central compartment is explored in extension, under traction of the lower limb. Internal rotation of the hip helps access to the anterior compartment, and external rotation helps access to the posterior compartment. Also, external rotation induces a tensioning of the ligamentum teres allowing visualizing all the synovium of the acetabular fossa. If synovectomy of this area is necessary, the curved instruments and different surgical approaches are essential.

70.3.3 Tips and Pearls

It is useful to use a 70° oblique optic as a periscope: according to its rotation, it will allow visualization of the femoral neck, the capsule, the orbicular ligament and capsular recesses.

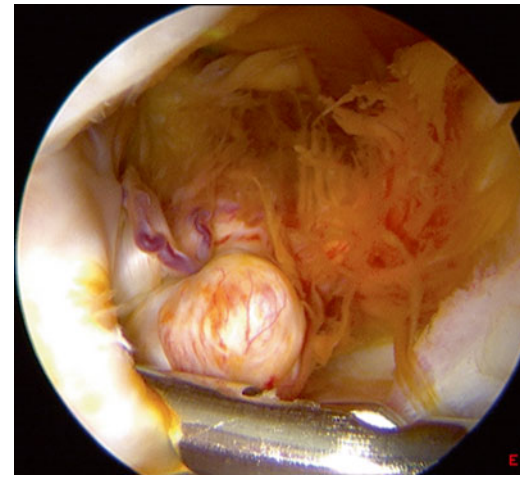

Fig. 70.9 Mechanical synovectomy with a 4.5 angulated shaver of the inferior recessus of the hip in the case of a villonodular synovitis

Capsulotomy is an important part of the procedure. It has to be adapted to the location and extension of the synovitis resection. If subtotal synovectomy is necessary, section of the orbicular ligament is recommended.

It is essential to master the different surgical arthroscopic approaches. They will be used depending on the area of the pathological synovial to reach. Some access requires switching optical and instrumental tracks.

Access to the entire central compartment will be facilitated by setting internal or external rotation of the limb.

70.3.4 Complication

The risk of bleeding in the context of inflammatory synovium exists. It is rarely a major complication but it can obscure the procedure. In this case, the pressure of the irrigation fluid should be higher in order to diminish bleeding and to help thermocoagulation of the vessels.

Extra-articular fluid extravasation is an unfrequent complication. Possible risk factors can be a prolonged operative time, a high pressure of the irrigation fluid, and an extended capsulotomy [19]. Those risk factors are mostly present in hip arthroscopy for synovectomy.

70.3.5 Literature Overview

The results of arthroscopic removal of chondroma or osteochondromas were analysed [2, 24, 27]. They are good and excellent in 48–57 % of cases according to the literature with a conversion to total hip replacement (THR) in 17 % at a mean follow-up of 6 years [2, 27]. Arthroscopy can be considered as the reference for the treatment of hip chondromatosis. However, the recurrence rate is high (16.2 % re-arthroscopy). Open surgery for synovectomy may have a lower recurrence rate but a greater morbidity with a higher conversion rate to THR.

Localized forms of villonodular synovitis (VNS) heal after removal of the nodule [1]. It should be realized under arthroscopy, with almost no risk of recurrence if resection is performed in healthy area with a large resection of the pedicle.

Concerning diffuse forms of VNS treated by arthroscopic synovectomy, each articular area must be methodically explored and cleaned to be as complete as possible. The main difficulty of a complete synovectomy under arthroscopy is to access the posterior compartment. This difficulty is increased by the presence of blood vessels tangential to the posterior capsule, with therefore a bleeding risk. We must therefore remember that arthroscopic synovectomy cannot be total. It is only justified by its lower aggressiveness in a disease where recidivism after surgery is frequent (up to 50 %), leading to osteoarthritis [1, 13]. To reduce the high risk of recurrence, synovectomy may be preceded and/or completed by a synoviorthesis (a few weeks before and/or 1–6 months after the surgery) [45].

References

1. Bouali H, Deppert EJ, Leventhal LJ, Reeves B, Pope T. Pigmented villonodular synovitis: a disease in evolution. J Rheumatol. 2004;31(8):1659–62.
2. Boyer T, Dorfmann H. Arthroscopy in primary synovial chondromatosis of the hip: description and outcome of treatment. J Bone Joint Surg Br. 2008;90(3):314–8.
3. Dallari D, et al. Enhanced tibial osteotomy healing with use of bone grafts supplemented with platelet gel or platelet gel and bone marrow stromal cells. J Bone Joint Surg Am. 2007;89(11):2413–20.
4. Dienst M, Godde S, Seil R, Hammer D, Kohn D. Hip arthroscopy without traction: in vivo anatomy of the peripheral hip joint cavity. Arthroscopy. 2001;17(9):924–31.
5. Domb BG, El Bitar YF, Stake CE, Trenga AP, Jackson TJ, Lindner D. Arthroscopic labral reconstruction is superior to segmental resection for irreparable labral tears in the hip: a matched-pair controlled study with minimum 2-year follow-up. Am J Sports Med. 2014;42(1):122–30.
6. Domb BG, Gui C, Lodhia P. How much arthritis is too much for hip arthroscopy: a systematic review. Arthroscopy. 2015;31(3):520–9.
7. Espinosa N, Rothenfluh DA, Beck M, Ganz R, Leunig M. Treatment of femoro-acetabular impingement: preliminary results of labral refixation. J Bone Joint Surg Am. 2006;88(5):925–35.
8. Fontana A. A novel technique for treating cartilage defects in the hip: a fully arthroscopic approach to using autologous matrix-induced chondrogenesis. Arthrosc Tech. 2012;1(1):e63–8.
9. Fontana A, de Girolamo L. Sustained five-year benefit of autologous matrix-induced chondrogenesis for femoral acetabular impingement-induced chondral lesions compared with microfracture treatment. Bone Joint J. 2015;97-B(5):628–35.
10. Fukushima W, Fujioka M, Kubo T, Tamakoshi A, Nagai M, Hirota Y. Nationwide epidemiologic survey of idiopathic osteonecrosis of the femoral head. Clin Orthop Relat Res. 2010;468(10):2715–24.
11. Ganz R, Parvizi J, Beck M, Leunig M, Notzli H, Siebenrock KA. Femoroacetabular impingement: a cause for osteoarthritis of the hip. Clin Orthop Relat Res. 2003;(417):112–20.
12. Gicquel T, Gedouin JE, Krantz N, May O, Gicquel P, Bonin N. Function and osteoarthritis progression after arthroscopic treatment of femoro-acetabular impingement: a prospective study after a mean follow-up of 4.6 (4.2–5.5) years. Orthop Traumatol Surg Res. 2014;100(6):651–6.
13. Gonzalez Della Valle A, Piccaluga F, Potter HG, Salvati EA, Pusso R. Pigmented villonodular synovitis of the hip: 2- to 23-year follow-up study. Clin Orthop Relat Res. 2001;459(7):187–99.
14. Gosvig KK, Jacobsen S, Sonne-Holm S, Gebuhr P. The prevalence of cam-type deformity of the hip joint: a survey of 4151 subjects of the Copenhagen Osteoarthritis Study. Acta Radiol. 2008;49(4):436–41.
15. Guadilla J, Fiz N, Andia I, Sanchez M. Arthroscopic management and platelet-rich plasma therapy for avascular necrosis of the hip. Knee Surg Sports Traumatol Arthrosc. 2012;20(2):393–8.
16. Hack K, Di Primio G, Rakhra K, Beaule PE. Prevalence of cam-type femoroacetabular impingement morphology in asymptomatic volunteers. J Bone Joint Surg Am. 2010;92(14):2436–44.
17. Haviv B, O'Donnell J. The incidence of total hip arthroplasty after hip arthroscopy in osteoarthritic

patients. Sports Med Arthrosc Rehabil Ther Technol. 2010;2:18.
18. Hernigou P, Poignard A, Zilber S, Rouard H. Cell therapy of hip osteonecrosis with autologous bone marrow grafting. Indian J Orthop. 2009;43(1):40–5.
19. Kocher MS, et al. Intra-abdominal fluid extravasation during hip arthroscopy: a survey of the MAHORN group. Arthroscopy. 2012;28(11):1654–1660 e2.
20. Krych AJ, Thompson M, Knutson Z, Scoon J, Coleman SH. Arthroscopic labral repair versus selective labral debridement in female patients with femoroacetabular impingement: a prospective randomized study. Arthroscopy. 2013;29(1):46–53.
21. Larson CM, Giveans MR, Stone RM. Arthroscopic debridement versus refixation of the acetabular labrum associated with femoroacetabular impingement: mean 3.5-year follow-up. Am J Sports Med. 2012;40(5):1015–21.
22. Larson CM, Giveans MR, Taylor M. Does arthroscopic FAI correction improve function with radiographic arthritis? Clin Orthop Relat Res. 2011;469(6):1667–76.
23. Leunig M, Tibor LM, Naal FD, Ganz R, Steinwachs MR. Surgical technique: second-generation bone marrow stimulation via surgical dislocation to treat hip cartilage lesions. Clin Orthop Relat Res. 2012; 470(12):3421–31.
24. Lim SJ, Chung HW, Choi YL, Moon YW, Seo JG, Park YS. Operative treatment of primary synovial osteochondromatosis of the hip. J Bone Joint Surg Am. 2006;88(11):2456–64.
25. Lu Y, Edwards 3rd RB, Nho S, Heiner JP, Cole BJ, Markel MD. Thermal chondroplasty with bipolar and monopolar radiofrequency energy: effect of treatment time on chondrocyte death and surface contouring. Arthroscopy. 2002;18(7):779–88.
26. Magid D, Fishman EK, Scott WW, Brooker AF, Arnold WP, Lennox DW, Siegelman SS. Femoral head avascular necrosis: CT assessment with multiplanar reconstruction. Radiology. 1985;157(3): 751–6.
27. Marchie A, Panuncialman I, McCarthy JC. Efficacy of hip arthroscopy in the management of synovial chondromatosis. Am J Sports Med. 2011;39(Suppl): 126S–31.
28. Marker DR, Seyler TM, McGrath MS, Delanois RE, Ulrich SD, Mont MA. Treatment of early stage osteonecrosis of the femoral head. J Bone Joint Surg Am. 2008;90 Suppl 4:175–87.
29. Matsuda DK, Burchette RJ. Arthroscopic hip labral reconstruction with a gracilis autograft versus labral refixation: 2-year minimum outcomes. Am J Sports Med. 2013;41(5):980–7.
30. McCarthy HS, Roberts S. A histological comparison of the repair tissue formed when using either Chondrogide((R)) or periosteum during autologous chondrocyte implantation. Osteoarthritis Cartilage. 2013;459(12):2048–57.
31. McCarthy JC, Noble PC, Schuck MR, Wright J, Lee J. The Otto E. Aufranc award: the role of labral lesions to development of early degenerative hip disease. Clin Orthop Relat Res. 2001;459(12):25–37.
32. McDonald JE, Herzog MM, Philippon MJ. Return to play after hip arthroscopy with microfracture in elite athletes. Arthroscopy. 2013;29(2):330–5.
33. Palmer DH, Ganesh V, Comfort T, Tatman P. Midterm outcomes in patients with cam femoroacetabular impingement treated arthroscopically. Arthroscopy. 2012;28(11):1671–81.
34. Philippon MJ, Schenker ML, Briggs KK, Maxwell RB. Can microfracture produce repair tissue in acetabular chondral defects? Arthroscopy. 2008;24(1):46–50.
35. Reichenbach S, et al. Prevalence of cam-type deformity on hip magnetic resonance imaging in young males: a cross-sectional study. Arthritis Care Res (Hoboken). 2010;62(9):1319–27.
36. Rosenwasser MP, Garino JP, Kiernan HA, Michelsen CB. Long term follow-up of thorough debridement and cancellous bone grafting of the femoral head for avascular necrosis. Clin Orthop Relat Res. 1994;452(9):17–27.
37. Schilders E, Dimitrakopoulou A, Bismil Q, Marchant P, Cooke C. Arthroscopic treatment of labral tears in femoroacetabular impingement: a comparative study of refixation and resection with a minimum two-year follow-up. J Bone Joint Surg Br. 2011;93(8):1027–32.
38. Sekiya JK, Martin RL, Lesniak BP. Arthroscopic repair of delaminated acetabular articular cartilage in femoroacetabular impingement. Orthopedics. 2009;32(9):744–50.
39. Skendzel JG, Philippon MJ, Briggs KK, Goljan P. The effect of joint space on midterm outcomes after arthroscopic hip surgery for femoroacetabular impingement. Am J Sports Med. 2014;42(5):1127–33.
40. Smith-Petersen MN. The classic: Treatment of malum coxae senilis, old slipped upper femoral epiphysis, intrapelvic protrusion of the acetabulum, and coxa plana by means of acetabuloplasty. 1936. Clin Orthop Relat Res. 2009;467(3):608–15.
41. Tanzer M, Noiseux N. Osseous abnormalities and early osteoarthritis: the role of hip impingement. Clin Orthop Relat Res. 2004;462(12):170–7.
42. Thaunat M, Murphy CG, Chatellard R, Sonnery-Cottet B, Graveleau N, Meyer A, Laude F. Capsulotomy first: a novel concept for hip arthroscopy. Arthrosc Tech. 2014;3(5):e599–603.
43. Tzaveas AP, Villar RN. Arthroscopic repair of acetabular chondral delamination with fibrin adhesive. Hip Int. 2010;20(1):115–9.
44. Wang BL, Sun W, Shi ZC, Zhang NF, Yue DB, Guo WS, Shi SH, Li ZR. Treatment of nontraumatic osteonecrosis of the femoral head using bone impaction grafting through a femoral neck window. Int Orthop. 2010;34(5):635–9.
45. Ward Sr WG, Boles CA, Ball JD, Cline MT. Diffuse pigmented villonodular synovitis: preliminary results with intralesional resection and p32 synoviorthesis. Clin Orthop Relat Res. 2007;454:186–91.
46. Yen YM, Kocher MS. Chondral lesions of the hip: microfracture and chondroplasty. Sports Med Arthrosc. 2010;18(2):83–9.