Surgical management of osteochondritis dissecans of the knee

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Osteochondritis (OCD) of the knee is a pathology of the joint cartilage and underlying subchondral bone. OCD in skeletally immature patients is designated as juvenile OCD. Its preferred location is the lateral aspect of the medial femoral condyle. These types of lesions are generally classified based on their radiographic [1,2], MRI [3,4], and arthroscopic appearances [5,6]. The risk of progression is predicted primarily by the age of onset [7] and stability of the lesion [8,9].

The goal of treatment, in addition to pain relief, is to reconstitute the subchondral bone and prevent articular surface degeneration, ultimately preventing early secondary arthritis, especially in patients which a loose osteochondral fragment.

Surgical management of OCD may be considered after conservative treatment has failed. These modalities depend on the patient's symptoms and skeletal maturity, as well as the characteristics of the lesion (nature, location, size, and stability). Nevertheless, surgical management remains controversial without any real consensus on the matter. Nonetheless, different therapeutic options will be discussed, and a management algorithm based on the results in the literature will be suggest.

If surgical management of an osteochondral lesions is considered, associated favoring mechanical factors, such as axial deformities of the lower limbs, especially frequently encountered in more severe cases, must also be addressed.

I – Surgical techniques

1. Arthroscopic exploration and assessment

Surgical management in patients presenting with OCD begins with an arthroscopic exploration of the knee, including inspection and testing of the osteochondral lesion with a hook. The lesion is thus characterized based on its appearance, size, and stability, allowing to either confirm or adjust the considered surgical technique [6] (figure 1).

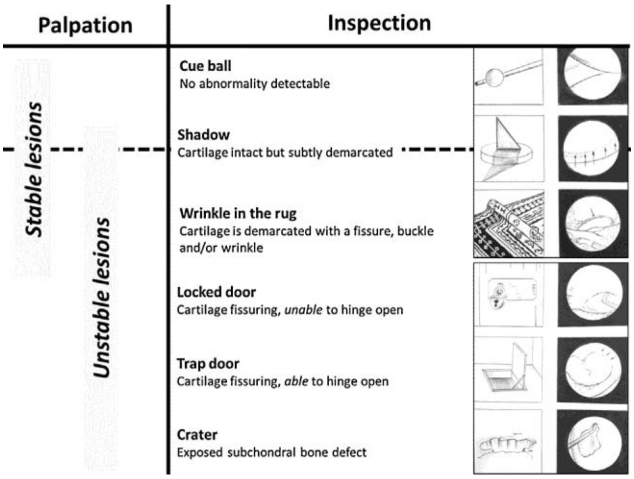


Figure 1: Arthroscopic classification of osteochondral lesions of the knee.

Furthermore, certain arthroscopic appearances may correspond to both a stable and unstable lesion on MRI. As a result, considering the progress made in the field of magnetic resonance imaging, especially its ability to diagnose early lesions and its high sensitivity in evaluating signs of secondary instability [10], in cases where MRI and arthroscopy confer conflicting results, the surgical strategy should preferentially be based on the appearance on MRI.

The patients and their families should be informed of the possibility of such discordant findings during arthroscopic exploration compared to preoperative imaging, with a possible intraoperative change in surgical strategy and technique. These possibilities should be anticipated, and the appropriate instruments and materials should be readily available. In the case where a more severe lesion than previously thought is encountered and a change in surgical technique is required, the surgeon should not hesitate to delay the surgical reconstruction if the required tools are lacking until the appropriate instruments are available.

2. Microfractures

The surgical creation of microfractures in the treatment of OCD is considered as the standard surgical technique by many authors. It is less frequently used in France, where the perforation (Pridie) technique is more common.

The principle of this techniques is to mobilize the subchondral mesenchymal stem cells which colonize a post traumatic blood clot by punching a hole around the osteochondral lesion via a direct transchondral approach. This technique generally undertaken by an arthroscopic approach. After debridement of the lesion and removal of the calcified plaque (Tidemark), a hole is made through the residual cartilaginous tissue using a fine awl or an angulated punch, at 3 to 4mm intervals. The areas where the microfractures were created must be checked for bleeding at the end of the intervention [11].

The healing process is achieved through a relatively quick formation of fibrocartilaginous tissue ensuring the fusion of the osteochondral lesion. However, these fibrocartilaginous formations seem to lose stability over the long term, with progressive degradation taking place [12].

3. Autologous matrix-induced chondrogenesis

Autologous matrix-induced chondrogenesis is an evolution of the previously described surgical technique and consists of enclosing the clot induced by the microfractures by trapping it in a protective membrane. This membrane is generally fashioned out of periosteum or collagen (e.g. Chondro-gide®) that is either glued or sutured over the osteochondral loss of substance [13]. This membrane plays the role of a matrix securing the proteoglycans in place and inducing chondrogenic differentiation.

Early studies were very promising, with other authors later questioning the real efficacy of this technique [14].

4. Drilling

The drilling technique is much more frequently used in France compared to the microfractures technique. Pridie introduced the essential principles of drilling the exposed subchondral bone with the aim of achieving fibrocartilaginous healing, even before Smillie developed the drilling technique for osteochondritis dissecans [15].

This surgical technique is indicated after failure of conservative treatment of a stable lesion with a preserved cartilaginous surface.

The objective of this technique is to permeabilize the area of sclerotic bone surrounding the osteochondral lesion in order to induce bony healing through a local secretion of growth factors, revascularization of the osteochondral area, and migration and proliferation of osteochondral cells. This consists of perforating the floor of the lesion, either through a trans-chondral approach through the joint cartilage, or by a retroarticular approach. Both provide similar clinical and radiographic results (95% after 15 months of follow-up in patients between 10 and 16 years old) [16].

4.a. Trans-chondral drilling

Trans-chondral drilling is performed on stable lesions via knee arthroscopy, even though it was initially described by Smillie via open arthrotomy [15]. The osteochondral lesion is drilled by a retrograde approach directly through the cartilaginous surface by using fine K-wires (1.2mm) at a depth of 15 to 20mm (figure 2).

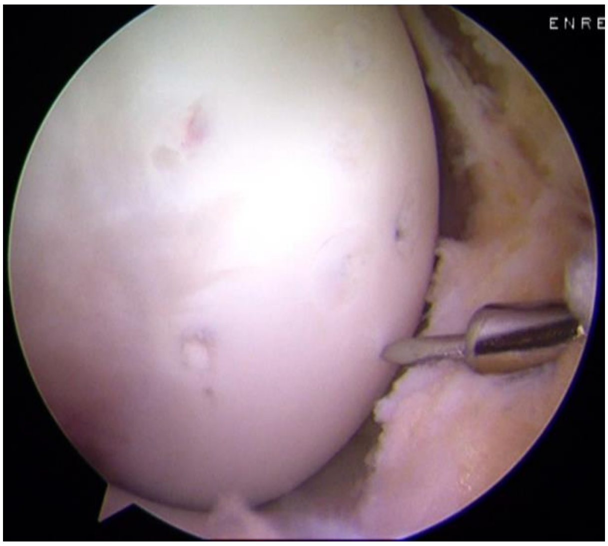


Figure 2: Arthroscopic view of trans-chondral drilling to treat stable osteochondritis dissecans.

Afterwards, a 1-month period of strict bed rest with complete unloading of the limb is imperative. Results are generally satisfactory, with younger subjects showing better results.

4.b. Retroarticular drilling

Retroarticular drilling implies the use of fluoroscopy. This technique respects the cartilaginous surface as well as the physis by utilizing a retrolesionnal and transepiphyseal approach. The K-wires are introduced under fluoroscopic guidance through the femoral condyle, on both anteroposterior and lateral images, until reaching the cartilage. A maximal number of perforations must be performed, covering the entire surface of the lesion [17,18] (figure 3).

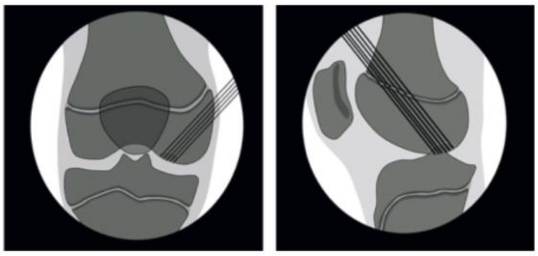


Figure 3: *Depiction of the fluoroscopic anteroposterior and lateral views of the retroarticular perforations technique.*

5. Fixation of an osteochondral fragment

When MRI confirms the unstable nature of an osteochondral fragment, fixation of said fragment is the preferred method, and is ideally undertaken via fluoroscopic guidance. However, in order to achieve proper fixation, a sufficiently large fragment is required.

The bed of the osteochondral fragment is first debrided and prepared, then perforated by K-wires as previously described. If the lesion is too deep relative to the thickness of the loose fragment thereby leaving a dead space after restoring the fragment, a cancellous bone graft from either the iliac crest of the proximal tibial metaphysis should be used.

In sum, the fragment is restored and maintained in place by a thin temporary K-wire. Osteosynthesis is then realized by 1 or 2, ideally cannulated, or even doubly threaded, screws. The head of the screws must be countersunk within the cartilaginous surface in order to avoid any local retractions any friction between tibial plateau and the screw head (figure 4).

Figure 4: *Fixation of an unstable osteochondral fragment. a: fixation by 1 metallic screw. b: absorbable "low-profile" SmartNail® ConMed® implants presenting alternatives to screws.*

Both standard and absorbable screws may be used. In fact, metallic screws present the inconvenience of causing artefacts on a future MRI and are frequently the source of significant local friction, thus requiring revision surgery for the removal of the screw [5]. As such, absorbable screws essentially made out of two materials are preferred: polyglycolic acid (PGA) and Polylactic acid (PLA). The former has the advantage of being relatively fast absorbing (around 3 months) but generates a significant amount of local inflammation [19], whereas the latter has a slower absorption time (up to 6 years) which may lead to similar complications as non-absorbable screws [20].

Another alternative is an association of the 2 polymers. These implants are not screws, but rather jagged nails which avoid cut-out and allow compression of the fragment with a shallow head (low profile) [21] (figure 4).

The outcomes of fragment fixation are globally satisfactory in children with better results than in adults [22].

6. Autologous osteochondral graft

The principle of autologous osteochondral grafting consists of packing the prepared defect zone with osseous tissue covered by a cartilaginous surface. The graft is harvested from a non-weight-bearing area in order to limit morbidity at the donor site.

The graft may consist of a single osteochondral block: this technique is limited in terms of grafting surface, since morbidity increases with the size of the harvested area and with the incongruency of the shape of the grafting area relative to that of the bone graft (radius of the curve). This technique is indicated in less extensive lesions.

Alternatives consist of grafting one or multiple cylinders (mosaic) allowing to globally model the shape of the grafting volume while playing on the lengths of different implanted grafts (plasty).

6.1. Mosaicplasty

This technique of osteochondral grafting allows the reconstruction of surfaces presenting a relatively extended loss of substance. Initially attempted by Matsusue in 1988 [23], it was later developed by Hangody in the early 1990s, who based their findings on experimental animal studies and backed by a large number of case series with good global outcomes (around 90% depending on the series and outcome criteria) [24,25]. Outcomes are generally better in younger subjects [26].

In fact, histological studies of grafted areas show that, 10 weeks after grafting, 60 to 70% of the grafted surface is formed by hyaline cartilage and 30 to 40% fibrocartilage. Similar results have been found in studies on humans who were biopsied 5 years after grafting.

Mosaicplasty presents, compared to autologous chondrocyte grafting – its modern alternative – the advantages of being easy-to-use since it does not require cellular cultures (and the means that this imposes), and being undertaken as a single event.

Objectives:

The objectives of mosaicplasty include:

- After debridement and preparation, completely fill the volume of the osteochondral lesion until reaching a healthy bony bed. The bony part of the graft must be in contact with the healthy bone.
- The surface of the grafted cartilage must constitute 70% of the surface of the defect (80% for some authors).
- Respect the physis which is deep to the lesion site. Figure 5 illustrates the procedure.

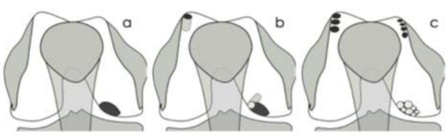


Figure 5 : *Illustration of an autologous osteochondral graft by mosaicplasty. a: initial lesion. b: harvesting of the first graft and preparation of the grafting area. c: final grafting with 7 grafts harvested from both edges of the trochlea.*

Approach:

Mosaicplasty is undertaken either via open arthrotomy (medial or lateral parapatellar approach depending on the location of the lesion) or by arthroscopy, depending on the surgeon's experience with arthroscopy, the accessibility of the osteochondral lesion, and the available instruments.

Materials and instruments:

Specific instruments are required, including drill bits for the preparation of the grafting site (with possibly an adjustable depth stop) of different diameters (2, 7 and 8mm), chisels for graft harvesting with diameters in accordance with those of the preparation drill bits, an adapted bone impactor, and a tube with a depth gage for the easy positioning of the grafts.

Donor sites:

The harvesting areas include, in descending order of preference, the edges of the femoral trochlea, preferably the medial side (especially superomedial), then lateral, and finally the periphery of the femoral intercondylar notch [27]. Some surgeons prefer harvesting from the edge of the contralateral femoral condyle in order to identify the origins of any possible future pain [28].

The lateral edge of the trochlea allows harvesting of larger grafts (up to 3 grafts of 10 to 11mm each), a more delicate procedure on the medial side (grafts of 7 to 8mm each) and at the intercondylar notch (grafts of 6mm each).

Note that the areas of bone and cartilage loss secondary to the harvesting of the grafts may bleed and may be responsible for a postoperative hematoma. As a result, some authors suggest packing these defects with, for example, collagen gauzes which allow, in addition to their powerful hemostatic abilities, proper reconstitution of a fibrocartilaginous surface [29].

Preparation of the grafting site:

Preparation consists of debriding any fibrous tissue and questionable edges around the lesion area using a shaver and/or a curette until reaching healthy cartilaginous edges that are regular and perpendicular to the subchondral bone. The depth of the lesion is debrided using a curette or a burr until arriving at healthy bone. Although contact with healthy tissue, either cartilaginous or bony, is essential for the graft to take properly, graft harvesting is nevertheless realized with moderation in order to avoid unnecessary damage.

The grafting area which will be receiving the cylindrical grafts is prepared with a drill bit, the diameter of which corresponds to the diameter of the cylinders. The required drilling depth should be previously set on the drill bit. Preparation of the osteochondral lesion must be done in a perfectly perpendicular fashion which implies a very precise and delicate positioning of the drill bit. The different cylinders should be either spaced at intervals of 1mm, or in contact with one another. This implies meticulous placement of the drill bit in order to achieve perfectly parallel tubes.

In practice, the grafting area is drilled after the osteochondral grafts have been harvested in order to ensure compatibility of size (height of graft and depth of the grafting area), a process which is easier to control while drilling rather than harvesting.

Size and amount of graft:

The sizes of the grafts depend on the depth of the osteochondral lesion, the defect that must be filled, and the distance to the physis (which must be respected). Practically, the graft often has a length of around 15 to 25mm. The diameters of the grafts depend on both the size and shape of the defect and surgeon preference. Nevertheless, recent publications tend toward harvesting larger grafts, which present with the advantage of increased stability, generating less fibrous interposition between the fragments, providing a wider cartilaginous surface, and minimizing the risk of causing a fracture of the donor site. An alternative would be to harvest cylinders of varying diameters in order to optimize it to the shape of the lesion (>80%). The number of grafts required should be determined at the beginning of the intervention after the osteochondral lesion has been evaluated by comparing its surface to bone impactors of different diameter.

Graft harvesting:

Specific instruments are required, including drill bits of different diameters (2, 7 and 8mm) for the preparation of the grafting site (with possibly an adjustable depth stop), chisels for graft harvesting with diameters in accordance with those of the preparation drill bits, an adapted bone impactor, and a tube for easy positioning of the graft with a depth gage.

Harvesting is undergone with dedicated tubular chisels. Care must be taken to properly place the chisels perpendicularly to the articular surface (figure 6).

Figure 6 : *Illustration of the arthroscopic view of the chisel during graft harvesting placed perpendicular to the lateral edges (a) of the trochlea far from the patellar tendon (b). Note the gradations (arrow) on the chisel for gaging the length of the graft.*

The chisel is then slowly advanced as to avoid excessively heating the surrounding tissues. Once the proper depth is reached, determined beforehand on the chisel, the graft is detached from its base by repetitive varus-valgus movements around the axis of the chisel. Care must be taken during this process in order to avoid fracturing the harvesting site.

A distance of 3mm should be respected between the different fragments.

Implantation of the graft:

Various methods exist depending on whether a non-press-fit effect (cylinders at the grafting area are slightly dilated at the surface by using a slightly conic dilator, in order to allow a non-traumatic implantation) or a press-fit effect (cylinders of 1mm smaller diameter than the bone graft) is desired. Animal studies have shown that a press-fit effect is preferable for graft taking and is thus recommended by many authors [30].

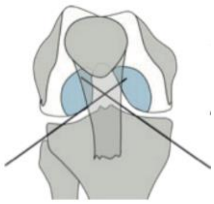
The graft is introduced through a tubular introducer of proper diameter and is then implanted with a bone impactor passed through the introducer, thus pushing the graft to the far end of the defect area. The graft must be introduced until the cartilaginous surface becomes level with the contiguous healthy or grafted cartilage (ideally, the height would be assessed using the bone impactor).

The cartilaginous surfaces must invariably be level with each other. In fact, it was previously established that a step off of 2mm or more would lead to involution of the cartilaginous layer [31]. As a result, it is important to harvest the grafts perfectly perpendicular to the articular surface, since a mere angulation of 10° while harvesting a 10mm diameter graft leads to a height difference of 1mm between the opposing edges.

Specifics of arthroscopy:

This technique is reserved for surgeons with experience in arthroscopy due to its high level of difficulty. These difficulties are essentially twofold:

- Location of the lesion which must allow perpendicular access (figure 7).



- Size of the lesion as it is more difficult to pack a lesion superior to 2cm (a maximum of 6 cylinders).

Patient positioning must allow knee flexion up to 120°. Entry points are more central than usual since the lesions are often centered around the intercondylar notch (figure 7). A needle can be used to determine the ideal entry point allowing for perpendicular access to the grafting surface. If necessary, multiple entry points may be created. Contrarily, in order to decrease the number of required grafts, a single, large fragment may be used to fill the defect (figure 8).

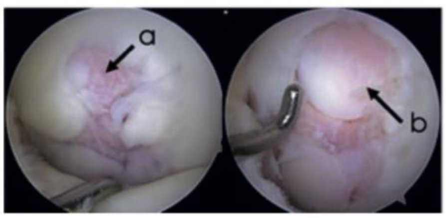


Figure 8: *Arthroscopic view of an osteochondral lesion (a) treated by osteochondral grafting using the mosaicplasty technique with a single, 10mm-wide graft (b).*

All the instruments, including the drill bit, dilator, and chisel are graduated in order to assess the depth of the lesion on the instruments (figure 6).

The remainder of the procedure is undertaken according to the same principles as in open procedures.

Postoperative management:

The limb must be unloaded for an average of 6 weeks depending on the different authors (4 to 8 weeks), followed by progressive weight bearing. The knee is immediately mobilized in flexion and extension, at first only passively.

Complications:

The primary reported complications include postoperative hematomas, deep infections, deep vein thrombosis (adults), and rare, essentially painful, degenerative lesions around the donor site (3%) [32].

6.2. Massive osteochondral allograft

This relatively old technique consists of using a fresh or frozen osteochondral allograft for voluminous losses of tissue and is more commonly used as a salvage procedure in adults.

6.3. Chondrocyte culture

These techniques consist of grafting the previously prepared lesion using autologous chondrocytes which have been harvested during a prior surgery and have been placed in a culture medium in vitro for over 2 to 3 weeks [33]. First-generation grafts entailed autologous harvested chondrocytes, cultivated and amplified in a cellular culture medium, placed in the grafting area under a patch of periosteum removed from the tibia which is then sutured or glued to the healthy edges. Long-term results are good in patients with osteochondritis, with a hyaline-like tissue filling the gaps, as confirmed by histology [34]. Nevertheless, its superiority to mosaicplasty was questionable and a certain number of complications were reported, related especially to the periosteal patch (calcifications, ossifications, avulsions, leakage) [35,36].

As such, in second-generation grafts, the patch was replaced by synthetic, protein or polysaccharide membranes, a technique known as autogenous matrix induced chondrogenesis (AMIC). These membranes contain interactive capacities with the grafted chondrocytes, favoring graft taking.

Finally, third-generation grafts consist of placing the chondrocytes in a culture medium in an implantable biological matrix, favorable for the promotion of cellular proliferation, conservation of phenotypical characteristics, and synthesis of extracellular matrix, all of which for a moderate cost [37]. In deeper lesions, multiple layers may be required, a technique known as a “sandwich graft” (if depth of the defect >8mm). These third-generation grafts, such as those utilizing hyaluronic acid, are still being evaluated [38].

II- The special case of osteochondral lesions of the patella

Osteochondral lesions of the patella are less frequently encountered and are treated with the same surgical techniques and therapeutic indications as was previously discussed, with the only exception that an open approach is preferred due to difficulties in accessibility by arthroscopy (figure 9) [39].

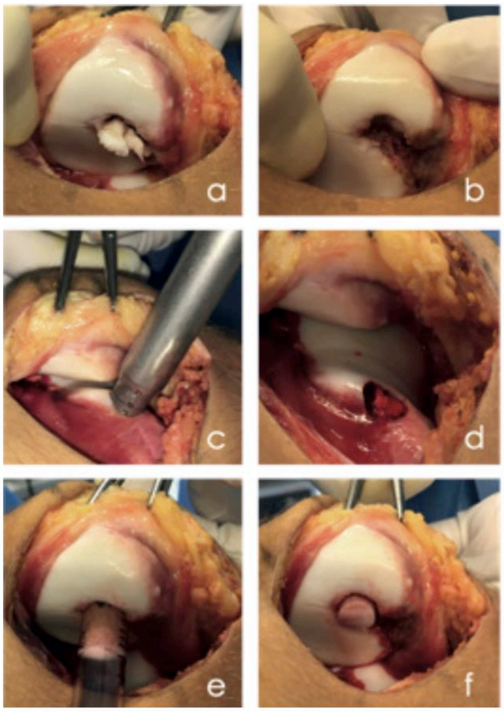


Figure 9: *Treatment of osteochondritis dissecans of the patella by mosaicplasty by arthrotomy.*
a: unstable and eroded lesion. b: preparation of the lesion area to receive the graft. c: graft harvesting from the lateral edge of the trochlea with a gradated cylindrical chisel. d: appearance of the harvesting site after removal of the graft. e: insertion of the graft into the lesion. f: appearance at the end of the intervention with the osteochondral graft in place.

III- Indications

An algorithm, based on the patient’s age (major prognostic factor) and appearance of the lesion on MRI and arthroscopy (stability), as was proposed by Accadbled et al., with a modified version being later proposed based on the works on Carey and the American Association of Orthopedic Surgery (figure 10) [40].

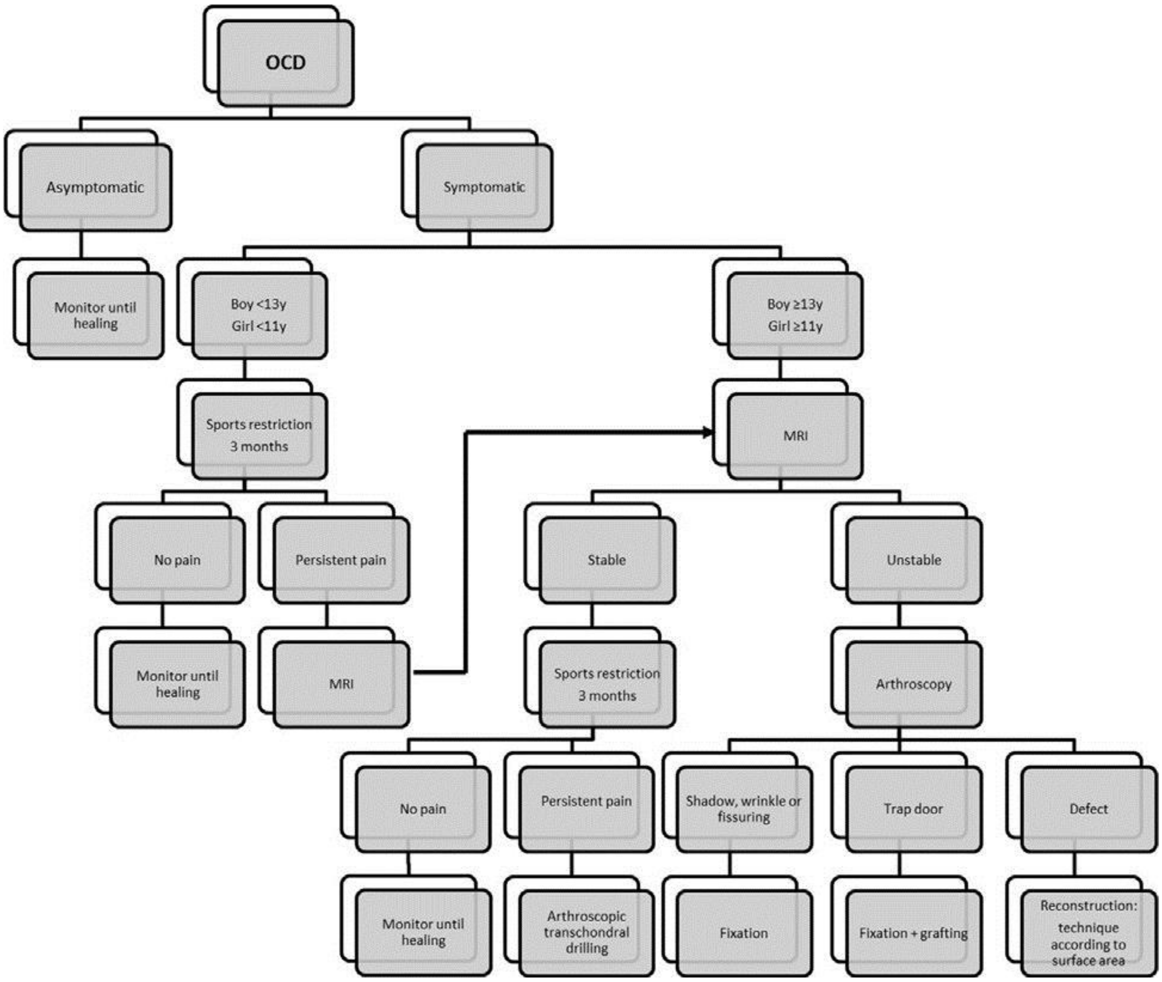


Figure 10: Treatment algorithm for osteochondritis dissecans of the knee according to Accadbled et al. [6].

It is to note that, if there is discordance on the stability of the lesion between MRI and arthroscopy, MRI is privileged for the final decision (MRI signs are encountered earlier in the disease process).

IV- Conclusions

When operative treatment of osteochondritis dissecans is indicated, it must be preceded by an MRI. Most often, surgery is approached via arthroscopy allowing to firstly complete a macroscopic evaluation of the lesions, and to secondly treat the lesion by drilling the stable lesions (based on MRI and/or arthroscopy), or either fixing or grafting unstable lesions.

As for the clinical and radiographic outcomes of treatment, both drilling and mosaicplasty have shown good results and are relatively simple to achieve by surgeons experienced in arthroscopy.

Other solutions including autologous chondrocyte or matrix grafts are promising, even though they may be more difficult to achieve.

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