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Review article

Meniscal pathology in children and adolescents

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ABSTRACT

The menisci play a key role in knee biomechanics and long-term cartilage protection. Preserving the meniscus is thus a major functional consideration in children and adolescents. In normal menisci, lesions are traumatic in origin. They are often vertical, in the posterior segment, associated with anterior cruciate ligament tear. In abnormal menisci, lesions are much more specific to children, occurring atraumatically, mainly in discoid menisci. Clinical signs of traumatic meniscal lesion are minimal, and associated ligament involvement should be systematically screened for. In contrast, clinical findings are rich and specific in discoid malformative pathology, sometimes showing the typical "clunk" sign highly suggestive of a detachment. The complementary examination of choice is MRI. In children more than in adults, lesions need screening for in apparently normal menisci. This particularly concerns ramp lesions of the medial meniscus. It is important also to be aware of false signs, and notably linear hypersignal of vascular origin in the posterior segment of the medial meniscus. MRI is essential in determining type of tear and guiding surgery in discoid meniscal pathology. Indications for meniscal repair in children are maximal, even in lesions extending into the white zone, and the risk of failure needs to be assumed. All meniscal suture techniques – all-inside, in-out and out-in – need to be acquired. Meniscectomy, even partial, should be exceptional. Treatment of symptomatic discoid meniscus usually involves minimal central meniscoplasty and suture of the discovered lesion. Results of meniscal repair in children are generally very satisfactory, whatever the type or site of lesion. Vertical suture is to be preferred; suture failure is often only partial. In all, optimal treatment of meniscal pathology in children and adolescents requires perfect knowledge of pediatric specificities and above all mastery of repair techniques to restore meniscal tissue as fully as possible so as to conserve future knee function.

1. Introduction

The analysis, diagnosis and treatment of meniscal lesions in children and adolescents have greatly progressed over the last 15 years. The ultimate objective, even more than in adults, is to conserve or restore optimal meniscal capital to protect the knee against osteoarthritis. The present article thus aims to address 5 questions, and to highlight the recent progress.

What meniscal lesions are encountered in children and adolescents? Are any specific?

We shall present the 2 main categories of meniscal lesion: traumatic in normal meniscus, and atraumatic in malformed meniscus, the latter being fairly specific to children:

- what is the importance of meniscal examination in children? Meniscal examination is primordial, although sensitivity is poor in traumatic cases; it is much more contributive for diagnosis of discoid meniscus with lesion;
- what precautions should be taken in screening for meniscal lesions on MRI? MRI can be misleading, with false negatives that need to be unmasked, and false positives that need to be recognized;
- meniscal repair in children: for what lesions and with what techniques? The vast majority of meniscal lesions can be repaired in children and adolescents. All meniscal suture techniques need to be mastered, and will be detailed below;
- what functional and objective results can be expected of meniscal repair? Results are very good in children, in both normal and discoid menisci.

2. What meniscal lesions are encountered in children and adolescents?

In children, 2 groups of meniscal pathology are distinguished according to "normal" or "abnormal" structure:

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- normal meniscus: lesions are usually traumatic and equivalent to those seen in adults. Stable and unstable knee are to be distinguished: repair is effective only in stable or stabilized knee;
- abnormal meniscus: malformative lesions, usually without any trauma, concern discoid meniscus and hypermobile meniscus.

2.1. Normal meniscus

The incidence of lesions in normal meniscus is poorly known, but is constantly increasing due to ever more intense sport activity in ever younger patients, and to improved paraclinical diagnosis on MRI [1,2]. In more than 80% of cases, injury follows trauma in high-intensity sport [2].

Three criteria are relevant: type of lesion, meniscal vascularization around the lesion, and knee stability.

The same types of lesion are found as in adults, but in different proportions [3] (Fig. 1). Vertical lesions are those most often encountered in children, and up to 80% are in stable knees [4]. They respect the longitudinal organization of collagen and their postoperative healing potential is thus better [5]. Vertical lesions in unstable knee can progress forward in the meniscus, forming a bucket-handle tear. In the posterior segment of the medial meniscus, the most peripheral wall lesions are known as “ramp” lesions. These are of various types, ranging from true parietal red-zone lesion to meniscosynovial detachment of the posterior meniscotibial ligament [6].

Horizontal lesions consist in delamination parallel to the joint surface. They are rare in children, and often with no obvious associated trauma; origin is rather microtraumatic. They may induce lateral meniscal cyst just forward of the lateral collateral ligament (LCL), which is easy to palpate with the knee in flexion [7]. Meniscal cysts are not degenerative, as is the case in adults.

Radial fissures are rare in children and confined to the middle or anterior segment following trauma in hyperextension. In unstable knee, they are mainly posterior and are among the lesions of the posterior meniscal root [8]. They involve radial lesion of the meniscal horn, or else root avulsion [9], “cutting” the meniscus in two transversally; this leads to meniscal extrusion: i.e., non-functional or phantom meniscus.

Complex lesions associate several types, and show no specificities in children.

In neonates, the peripheral two-thirds of the meniscus is vascularized. With growth, after the age of 12 years, the meniscus becomes less vascularized as in adults, only in the peripheral third [10]. Thus, in children, indications for repair extend to the central third, in the white-white zone [11].

Anterior collateral ligament (ACL) tear is associated with meniscal lesions, whether medial or lateral, in 47-61% of cases [1,3]. It basically consists in posterior longitudinal vertical fissures. Chronic instability induces secondary meniscal lesions, especially in the medial meniscus, or aggravates pre-existing lesions [1,12,13]. Thus, knee stability has to be taken into account in children in managing meniscal lesions; the knee must be stable or else stabilized. The ACL and posterior segment of the medial meniscus work synergistically to promote stability. According to some authors, complementary anterolateral plasty associated to ACL reconstruction can protect the meniscal repair [14].

2.2. Abnormal meniscus

Abnormality is morphologic or structural. The most frequent pathology is discoid meniscus, with the meniscus shaped like a disc rather than a crescent. In some rare cases, a posterior attachment defect may induce “hypermobile” lateral meniscus.

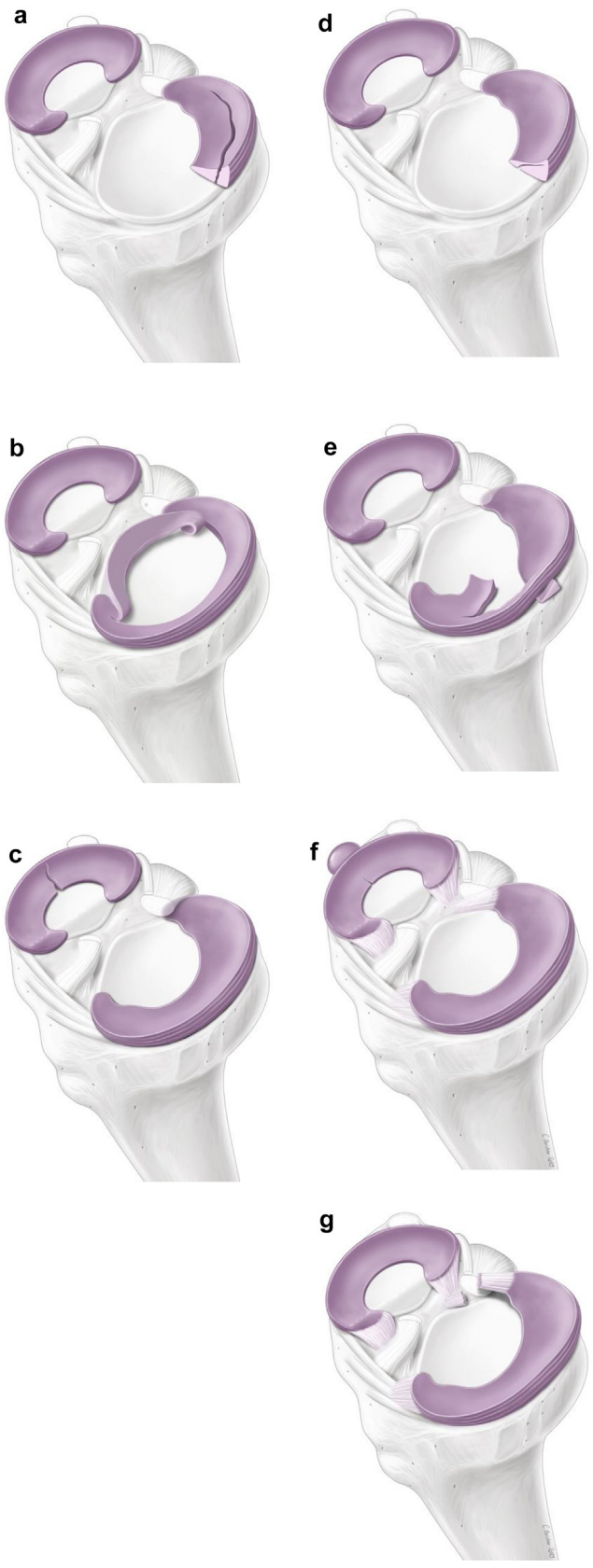

Fig. 1. Lesions in normal meniscus: a: longitudinal vertical lesion; b: bucket-handle vertical lesion; c: radial fissure; d: longitudinal fissure; e: complex fissure; f: meniscal cyst; g: root lesion.

Fig. 2. Discoid meniscus: Ahn's MRI classification: a: no-shift type; b: anterocentral shift type; c: posterocentral shift type; d: central shift type.

2.2.1. Discoid meniscus

Discoid meniscus is a congenital pathology mainly concerning the lateral meniscus, although some medial cases have been reported. Prevalence is 0.4-16.6% in Asian populations [15,16]. It is bilateral in 5-20% of cases. Lateral femoral condyle osteochondritis is associated in 15% of cases. Abnormal collagen structure,

associated Wrisberg ligament abnormality (thicker and with more superior attachment) and diminished vascularization render the meniscus fragile and impair healing. The mechanical theory of permanent friction of discoid meniscus between femoral condyle and tibial plateau explains progressive lesion onset.

Ahn described 2 classifications: one functional, on MRI [17], and one descriptive, on arthroscopy [18], to locate the tear and plan meniscoplasty-suture.

The MRI classification does not aim to describe the type of lesion, but shows the resulting meniscal displacement. There are 4 types (Fig. 2):

- no shift type: no apparent meniscal lesion;
- anterocentral shift type: meniscus dislocated forward, with phantom posterior segment aspect;
- posterocentral shift type: meniscus dislocated backward;
- central shift type: meniscus dislocated inward.

The arthroscopic classification comprises 3 types of tear starting from the popliteal hiatus (Fig. 3):

- MC-A (meniscocapsular junction, anterior horn) type: parietal tear forward of the popliteal hiatus up to the anterior segment of the meniscus, which may be dislocated backward in knee flexion;
- MC-P (meniscocapsular junction, posterior horn) type: parietal tear behind the popliteal hiatus; the meniscus may be dislocated forward in extension;
- posterolateral corner loss type: lesion in the meniscus at the popliteal hiatus, with basically medial dislocation.

The 2 classifications show perfect correlation: MRI posterocentral shift type lesions correspond to MC-A type, anterocentral and central shift types to posterolateral corner loss type, and no-shift type to MC-P type.

2.2.2. Hypermobile meniscus

Hypermobile meniscus is rare, with just some case reports (Fig. 4). The posterior segment of the lateral meniscus has normal morphology but is hypermobile, causing blockage in forced flexion. It probably involves an insertional defect in the posterior segment of the lateral meniscus, although the exact origin is obscure [19].

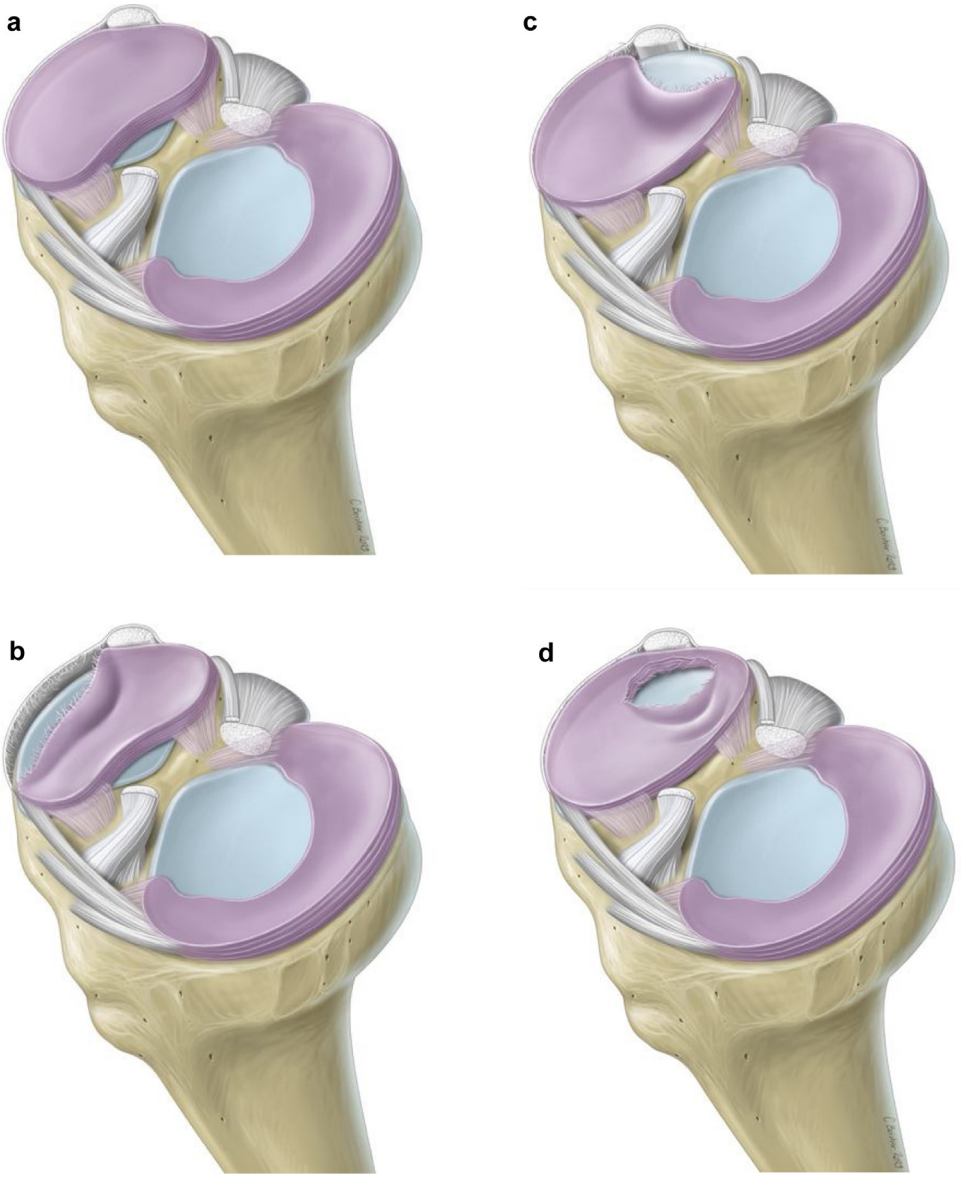

Fig. 3. Discoid meniscus: Ahn's arthroscopic classification: a: lateral discoid meniscus without tear; b: MC-A type tear; c: MC-P type tear; d: posterolateral corner loss type tear.

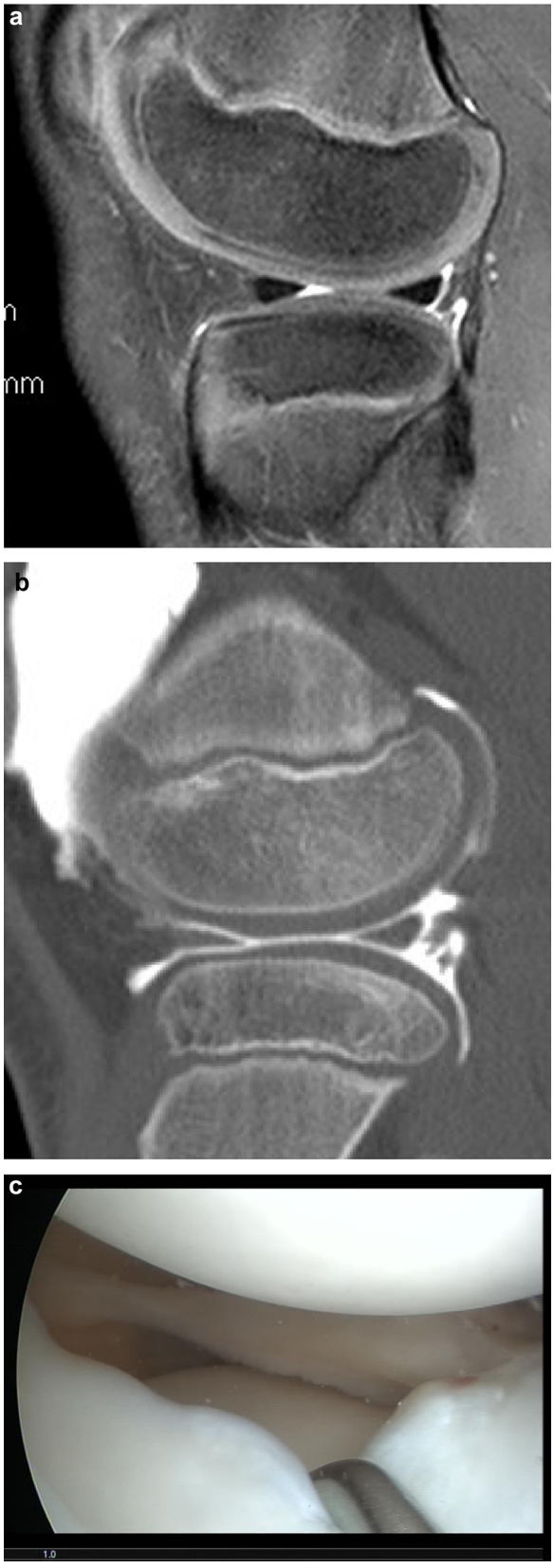

Fig. 4. Hypermobile meniscus: a: MRI; b: CT-arthrography; c: arthroscopy.

3. What is the importance of meniscal examination in children?

3.1. Lesions in normal meniscus

Lesions in normal meniscus are usually secondary to sport trauma with knee in torsion, causing hemarthrosis. They are rare in under-10 year-olds. They may be isolated or, more often, associated with knee instability.

Functional signs are classical: pain, and sensation of blockage. Unlike in adults, objective clinical signs of isolated traumatic meniscal lesion are poor in children. The grinding test, Appley test or MacMurray test are specific, but with much poorer sensitivity than in adults. Thus, MRI is needed for suspected meniscal lesion in case of post-traumatic pain at a joint line, especially if post-traumatic hemarthrosis is detected. Knee flexion contracture suggests bucket handle lesion, but caution is needed as bucket-handle can be asymptomatic in children. If palpation in flexion finds painful swelling just forward of the LCL, meniscal cyst should be suspected.

Interview should seek any unexplored history of trauma or episodes of the knee giving way some time after a trauma. Comparative ligament testing should be undertaken. In case of ACL tear on clinical examination, MRI is mandatory, not so much to confirm the tear as to screen for associated asymptomatic meniscal lesion.

3.2. Lesions in discoid meniscus

Lesions in discoid meniscus are not associated with trauma. Patients are often under 10 years of age. The more severe the abnormality, the earlier the onset of symptoms, often at 2 or 3 years of age. Onset of a lesion in discoid meniscus induces meniscal instability with characteristic cracking or clunking, bringing the parents to consult. The thicker the meniscus, the more audible and visible the cracking. Cracking is caused by meniscal tissue dislocation anterior to the condyle in posterior tear or behind the condyle in anterior tear. It disappears and gives way to flexion deficit if the meniscus remains dislocated posteriorly or to flexion contracture if dislocated anteriorly. As there is often laxity, flexion contracture may show only as loss of physiological recurvatum, whence the importance of examination in prone position with the lower leg off the table.

Sometimes there is simple non-specific pain at the lateral joint line. These are older patients (adolescents or young adults) with partial or less thick discoid meniscus and a horizontal cleavage and/or radial fissure without meniscal instability [20].

4. What precautions should be taken in screening for meniscal lesions on MRI?

Some situations in children call for caution in interpreting MRI.

4.1. False positives

MRI is the examination of choice for the meniscus but, in children, may underestimate lateral meniscal lesions and above all show false positives in the medial meniscus [21]. Horizontal hypersignal in the posterior segment is usually physiological, corresponding to extensive meniscal vascularization in children (Fig. 5). Absence of trauma and of hemarthrosis casts doubt on a diagnosis of meniscal lesion. Only Crues grade 3 hypersignal with linear

Fig. 5. Physiologic medial meniscus hypersignal.

extension to the joint surface can indicate true meniscal lesion [22]. Likewise, linear hypersignal in a discoid meniscus does not systematically indicate a lesion.

"Partial" discoid meniscus, or complete discoid meniscus without lesion, may be found on MRI. Discovery is serendipitous in the absence of signs of meniscal instability. No surgery, even preventive, should be performed in such cases.

4.2. False negatives

In ACL tear, ramp lesion should always be suspected but is difficult to demonstrate on MRI ("hidden lesion"). Physiological hypersignal in the posterior meniscosynovial fold can be a source of confusion (Fig. 6). Intraosseous tibial hypersignal should be screened for under the posterior segment of the medial meniscus: this is a reliable sing of ramp lesion [23].

MRI is normal in hypermobile lateral meniscus: at most, the popliteal hiatus looks a bit too wide. Recurrent blockage in flexion, however, is suggestive and MRI in flexion, when possible, orients diagnosis.

5. Meniscal repair in children: for what lesions and with what techniques?

5.1. Indications for meniscal repair in children

Even partial meniscectomy triggers osteoarthritic progression [24]. Meniscal lesions show greater healing capacity in children [25,26]. Apart from remodeled complex forms deemed irreparable on arthroscopy and palpation, all childhood meniscal lesions should be repaired, whether the meniscus is normal or discoid, whatever the type of lesion and even if it extends into the white-white zone. Treatment delay is not an argument for abstention [27]. The risk of suture failure should be assumed, and explained to the child and parents.

5.2. General principles of meniscal repair

Apart from in large meniscal cyst, repair is arthroscopic, with the classic 30° adult angle of view and diameter of 4.5 mm. Knee arthroscopy is feasible as of 3 to 4 years of age [28]. The optical and instrumental portals are inverted for optimal exploration and repair.

Lateral meniscus lesions are easy to access, with a wide work-space for arthroscopy. Lesions under the posterior segment of the medial meniscus can be difficult to access. In "tight" knee, medial collateral ligament (MCL) pie-crusting by needle [29] opens the medial joint line and provides a wider work-space for better quality repair without jeopardizing the joint cartilage. Ramp lesions get overlooked on classical anterior visualization and are not always seen on MRI either. They require systematic screening, introducing the arthroscope through the anterolateral portal into the groove between the medial condyle and the posterior cruciate ligament (PCL). In children, they are found in 23% of cases of ACL reconstruction [30].

Freshening is necessary ahead of repair, and poor freshening incurs a risk of failure [31]. An arthroscopic rasp or, if possible, a shaver or basket forceps are used; this may require an extra portal to be as tangential as possible to the lesion, especially in the posterior segment [32].

Fixation has to endure throughout the slow process of natural healing. Suturing uses non-absorbable UHMWPE (Ultra-High-Molecular-Weight PolyEthylene) or slow-absorption suture such as PDS® 2.0. The stitches should be as perpendicular as possible to

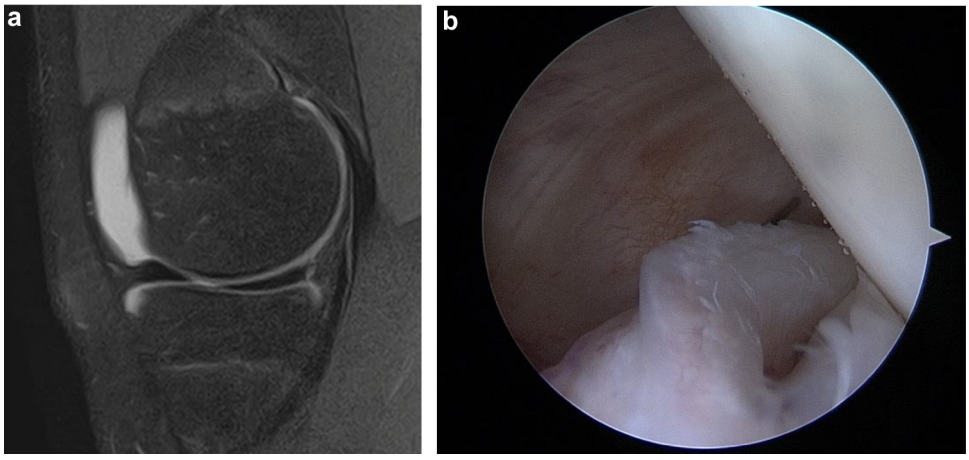

Fig. 6. Ramp lesion: a: MRI, sagittal slice through medial meniscus; b: corresponding arthroscopic view.

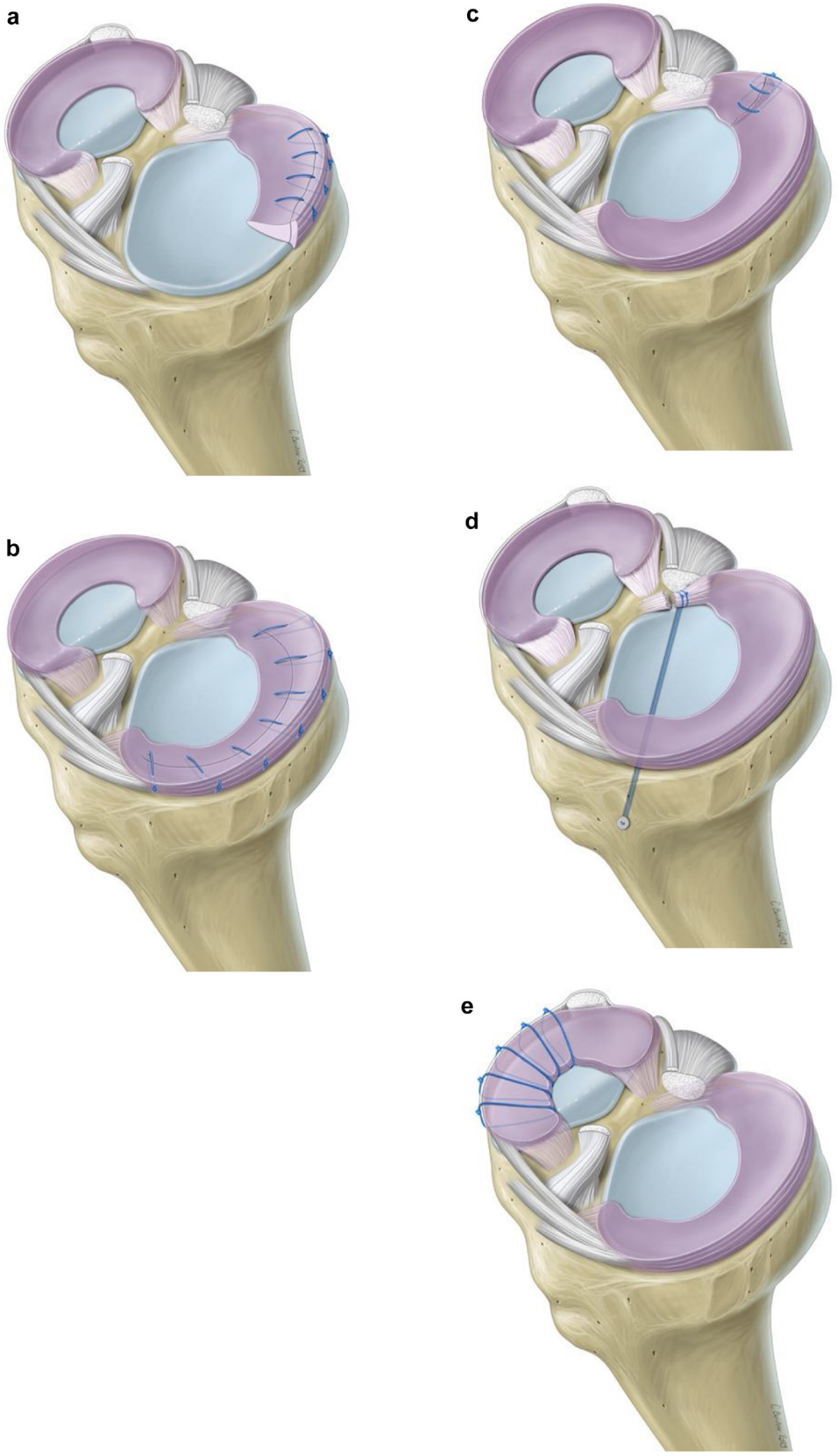

Fig. 7. Meniscal repair: principles according to lesion type: a: suture of vertical lesion; b: suture of vertical bucket-handle lesion; c: suture of radial posterior horn fissure; d: bone suture of root lesion; e: meniscoplasty-suture MC-A type discoid meniscus lesion.

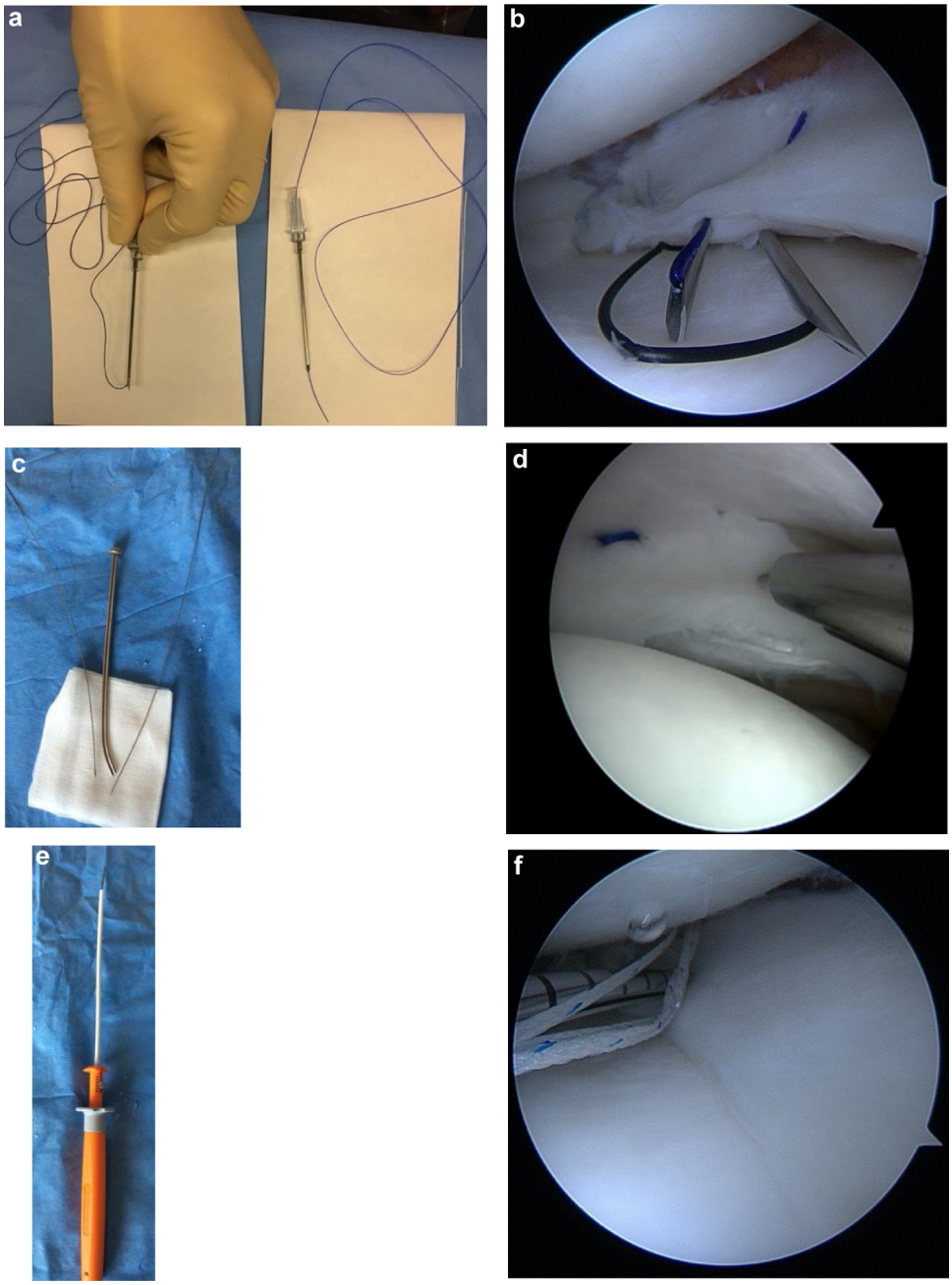

Fig. 8. Technical principles of meniscal repair: a: out-in: material; b: out-in: arthroscopic view; c: in-out: material; d: in-out: arthroscopic view; e: all-inside: example of device; f: all-inside: arthroscopic view.

the meniscus. Apart from in radial lesions, vertical sutures are preferred, having better mechanical fixation. They may sandwich the meniscus, especially in discoid pathology, with secondary meniscal remodeling (Fig. 7). They should not be over-tightened to limit the risk of secondary iatrogenic radial meniscal lesion. Intervals of 5-7 mm are reasonable and sufficient to achieve stable meniscus on palpation without risk of secondary ischemia [33].

The surgeon needs to master all suture techniques, to cope with all situations: in-out, out-in and all-inside (Fig. 8), depending on lesion location in the anteroposterior plane.

The out-in technique is used for lesions in the anterior half of the meniscus and ramp lesions of the medial meniscus. In anterior lesions, 2 needles are passed out-in, with PDS 2.0 suture in one and a relay suture of a different color in the other. Once inside the joint, the first suture is passed into a loop in the second. A knot is tied after a short anterior incision of a few millimeters. For ramp lesion, a cannulated curved hook is passed via an accessory posteromedial portal to successively hook the meniscotibial ligament then the detached meniscus so as to pass a suture.

The in-out technique is mainly used for lesions of the posterior segment to about halfway along the middle segment. A double-barrel straight needle pusher is brought up against the meniscus, guiding 2 long flexible eyed needles through the damaged meniscus. The needles are picked up at the back of the knee. The drawback is the need for a posteromedial or posterolateral counter-incision to pick up the sutures and make the knot without neurovascular risk.

The all-inside technique enables meniscal suture without supplementary incision, and is suited to lesions of the posterior segment and posterior half of the middle segment. Two small

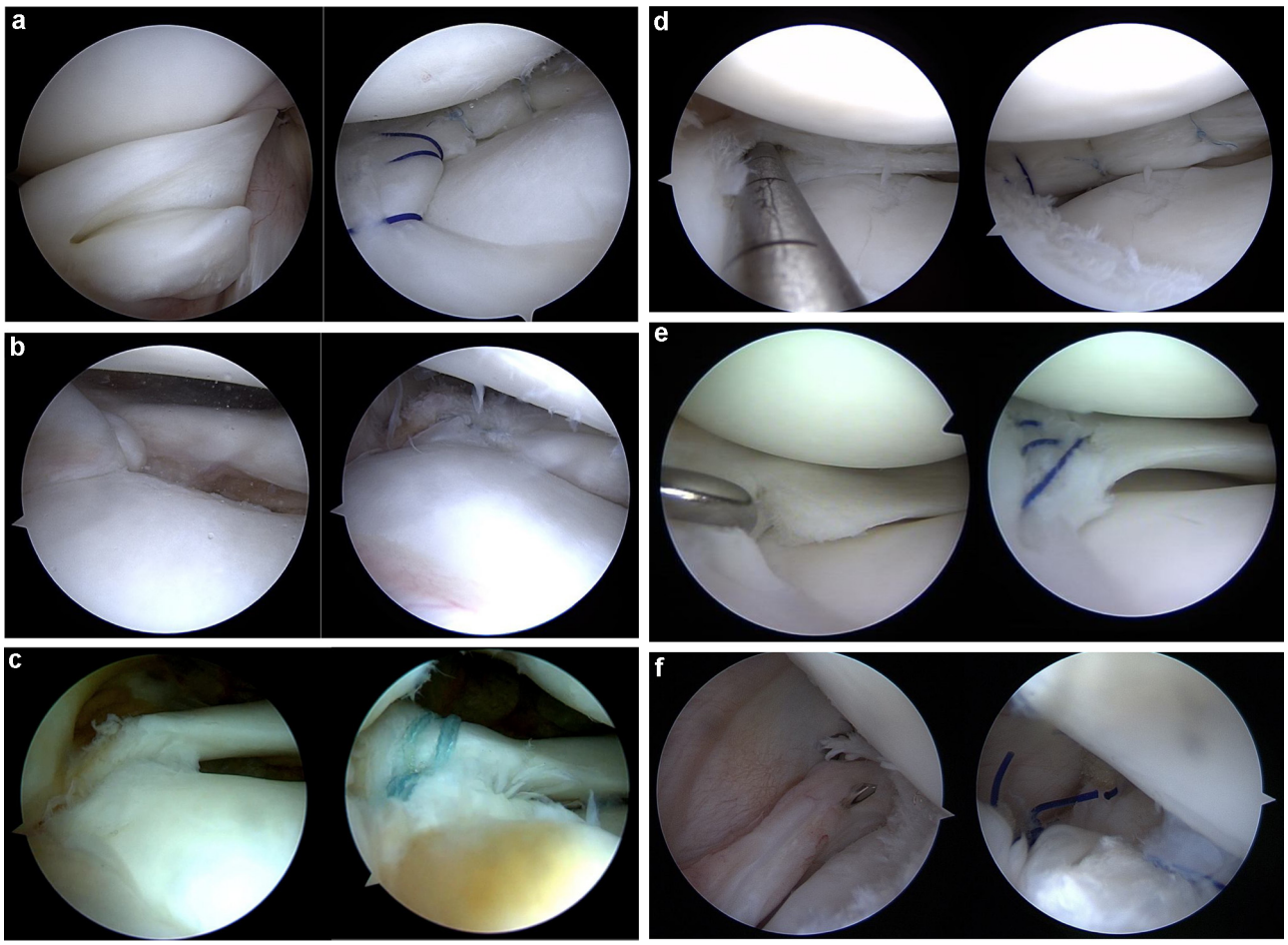

Fig. 9. Arthroscopic views of normal meniscus repair: a: medial meniscus bucket-handle lesion; b: direct suture for radial medial meniscus root lesion; c: bone suture for lateral meniscus root avulsion; d: suture for horizontal cleavage of medial meniscus; e suture of radial fissure of middle segment of lateral meniscus; f: posteromedial suture of ramp lesion.

implants, mounted on a needle and connected together by non-absorbable suture, are dropped one after the other on either side of the lesion and behind the capsule. Traction on the suture slides a pre-formed knot down against the meniscus; to avoid any "butter cutter" injury, a palpator should be pressed against the meniscus when pulling on the suture to bring down the knot. All-inside systems are simpler and quicker than the in-out technique, but are not free of complications: additional meniscal lesion, or intra-articular or subcutaneous implant migration. Neurovascular complications are rare, but all-inside suture of the posterior segment of the lateral meniscus on direct anterolateral route should be avoided and the anteromedial portal should be used instead, with a slightly oblique approach to the meniscus, avoiding noble structure.

5.3. Particularities of traumatic meniscus repair

Vertical lesions in the posterior segment are sutured in-out and/or all-inside (Fig. 9). There is often associated ACL tear, treated in the same step so as not to jeopardize meniscal healing. The sutures are vertical, with meniscal entry including the lesion and an entry point in the adjacent synovium. If possible, sub- and supra-meniscal stitches should alternate [33]. Extensive bucket-handle lesions can be difficult to reduce in the medial meniscus, especially when long-standing. They may be remodeled or associated with radial or horizontal lesions, which does not contraindicate repair. Debridement should be good quality, using an accessory medial portal if necessary to be in the right plane. In-out traction using a double-barrel suture pusher can facilitate reduction and positioning all-inside implants on either side. If the bucket-handle lesion extends forward beyond the middle of the middle segment, out-in suture is needed in order to be perfectly perpendicular to the meniscus.

Horizontal lesions concern the middle or the posterior segment. They are freshened then repaired using an out-in technique sandwiching the lesion. Meniscal cyst may be associated with middle segment cleavage; if it is large, excision via a lateral preligamentous portal may be necessary. Passing the palpator through the lesion in the cyst helps center the lateral capsule incision and repair by vertical suture including the meniscus and joint capsule.

Radial lesions concern the middle or anterior segment and are sutured by out-in horizontal stitches.

Meniscal root lesions are repaired to limit meniscal extrusion. In case of radial lesion conserving meniscal tissue at the root, all-inside horizontal suture reduces the lesion. In case of root detachment, transosseous suture using an arthroscopic tibial visor ensures reduction and stability [33].

No reliable studies demonstrated the interest of injecting platelet-rich plasma into the repaired lesion.

5.4. Particularities of discoid meniscus repair

The surgical principle consists in meniscoplasty-suture (Fig. 10). Meniscoplasty, or saucerization, limits recurrence risk by resecting the excess meniscus, which can be difficult if the meniscus is very

Fig. 10. Arthroscopic views of discoid meniscus meniscoplasty-suture: a: MC-P type; b: MC-A type; c: horizontal cleavage.

thick. A beaver knife can be useful at this stage. Good visualization of the lesion is important, to avoid resection in a "useful" zone. It can be difficult to know where to start. When MRI indicates posterior tear, surgery has to begin sufficiently anteriorly so as not to encounter the posterior lesion too soon. When the tear is anterior, the meniscus can put under traction and smoothed out using an out-in anterior suture, facilitating well-located saucerization. A horizontal cleavage may be encountered, and should be freshened and repaired.

The quantity of meniscus that needs to be removed is hard to determine. Removing too much amounts to partial meniscectomy; removing too little incurs risk of recurrence. The natural tendency is to remove too much. A depth of about 1 cm of meniscal tissue needs to be conserved, using the palpator measurer. It is advisable to alternate arthroscope and instrument regularly between the 2 portals, to avoid undue aggressiveness in the middle segment and to be able to assess the final result.

The meniscal suture has no specificities: stitches are mainly vertical, sandwiching the meniscus to optimize solidity. It can be difficult to close an anterior tear without seeming to exert excessive traction on the posterior segment. Sufficient debridement in the middle segment should be performed, using arthroscopic scissors, to avoid this effect.

5.5. Meniscal substitutes

Using substitutes is not exactly repair, and should be considered in case of pain in the knee without signs of osteoarthritis after subtotal meniscectomy. Indications in children are very rare; symptoms appear in older adolescents and young adults. There have been no strictly pediatric studies of results with meniscal substitutes.

6. What functional and objective results can be expected of meniscal repair?

6.1. Postoperative instructions and resumption of activities

There is no consensus on postoperative course and return to sport. Strict immobilization is unnecessary mechanically, but can help avoid pain in under-10 year-olds, especially after surgery on discoid meniscus. Depending on the author, weight-bearing is authorized immediately, or partially for 1 month [20]: all depends on the type of lesion and quality of suture. It seems logical to postpone weight-bearing for 3 or 4 weeks in radial lesions; but weight-bearing should be authorized after stable repair of a vertical lesion [34]. Flexion may be restricted for the first month after repair of a posterior lesion, so as to avoid straining the sutures.

There is no consensus on the need for rehabilitation. It may be useful after discoid meniscus surgery, where the multiplicity of sutures can cause pain.

Resumption of activities is progressive. What is indispensable is to have a dry and pain-free knee. Non-weight-bearing activities are resumed first, at 4-6 weeks. Running should be delayed for 3-4 months. Pivot and pivot-contact sport can be resumed at

4-6 months, 6 months being the average healing time after meniscal repair.

6.2. Objective results

There are no non-invasive tests to check meniscal healing; absence of symptoms is not necessarily proof of healing. MRI some time after repair shows residual scar images that are hard to interpret. Only CT-arthrography, which is invasive and irradiating, can demonstrate meniscal sealing and thus probably reliable healing; in practice, this may be considered ahead of revision surgery in case of repair with poor clinical progression.

Meniscal suture provides long-term joint cartilage protection even when healing is less than perfect with persistent MRI signal abnormality [35]. Repair results are very good in children and adolescents – better than in adults [5,27,36]. Regarding type of lesion, complex horizontal radial lesions have poorer healing potential (18–65%) than vertical lesions (80%) [37,38]. Likewise, sutured vertical bucket-handle lesions are at greater risk of recurrence than vertical in-situ lesions [39]. In children, even lesions extending into the white-white zone have good results after repair.

Failure risk is highest during the first year [39]. In case of poor clinical or functional progression (residual pain), revision surgery may be necessary. In 50% of cases, failure is only partial, confirming the interest of undertaking primary repair [40]. The residual lesion is usually resected, but iterative suture can be tried, especially in extensive lesions such as bucket-handle or parietal lesion. In recurrence with unstable operated knee, ACL graft efficacy must be evaluated.

Functional results of surgery on discoid meniscus are very good [18,20]. Recurrent cracking is rare. The medium-term benefit of meniscoplasty-suture compared to meniscectomy s obvious: less pain and fewer secondary cartilage lesions. Long-term protection against osteoarthritis is unproven, but is probably as good as in repair of normal meniscus.

7. Conclusion

Meniscal lesions in children and adolescents are frequent and require repair. There are traumatic lesions in over-10 year-olds, with hemarthrosis. There are discoid meniscus lesions in under-10 year-olds that are painful or show characteristic clinical signs. All traumatic lesions in children can be repaired, even when complex, long-standing or involving the white-white zone. In discoid meniscus, surgery generally consists in saucerization associated to suture. Meniscal repair globally provides very good results in children and adolescents. It presupposes mastery of all arthroscopic techniques. A risk of failure has to be assumed in children, and this needs to be clearly explained to and understood by the family.

Disclosure of interest

The author declares that he has no competing interest.

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Author contributions

Not applicable.

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