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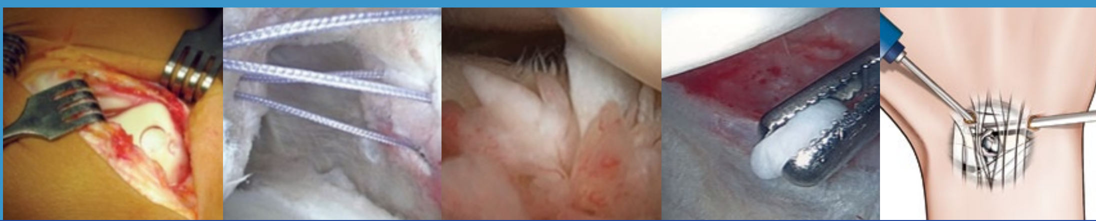

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11 Meniscal Repair: Indications, Techniques, and Outcome

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11.1 Introduction

"Nothing has changed so much in recent years of orthopaedics as the treatment algorithm of meniscus lesions" [77]. We moved from the "recommendation" during the 1970s to remove what was then considered a useless structure [73] to the current trend favoring preservation, repair, or even replacement of the menisci [77].

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Nevertheless, meniscectomy is still one of the most frequent orthopedic procedures [68] despite the latest results favor meniscal repair over partial meniscectomy concerning either clinical outcome or risk for osteoarthritis [57].

It is well known that different patterns of meniscus lesions have different clinical evolution and implications [48]. Recognizing the specificity of different meniscus tears is critical in order to determine the best choice for treatment. Several classification methods of meniscal lesions have been proposed over the years aiming to define the best course of action for treatment as well as prognosis and assessment of outcome [4]. The ISAKOS classification of meniscal tears provides sufficient interobserver reliability for decisive factors, which assist surgeons in the choice of the most adequate management, as well as collecting data from clinical trials designed to evaluate the outcomes [4]. This should be kept in mind once not all the prognostic factors rely on the division between acute and degenerative meniscal injuries.

Methods of repair can use all-inside, inside-out, or outside-in techniques, alone or in combination. Rasping, trephination, or augmentation with fibrin clot may assist in increasing the healing rate in properly selected cases including some degenerative meniscus tears [29]. Meniscal repair is not exclusive of acute traumatic tears, once some selected cases of degenerative injuries (including some horizontal cleavage tears) might also be considered as reparable [37]. Moreover, repair of degenerative meniscal root tears has also shown to provide favorable outcome [2].

Horizontal tears are frequently not traumatic and have a degenerative nature (even in younger patients) [72]. Vertical or longitudinal tears, bucket-handle tears, and radial tears usually (but not always) are associated with the traumatic group [61]. All these can be considered as possibly reparable depending on the classification, zone, and surgeon's experience. Flap tears are another type of meniscal tear which frequently arises after a traumatic event and is frequently irreparable. This type of lesion can also be observed in complex degenerative lesions.

Complex tear is a combination of other tears occurred in multiple planes. They appear more frequently in older patients and in the posterior horn. Generally the complex tears are non-repairable. Tears should be graded on the predominant tear pattern. Complex tears include two or more tear patterns. A tear appearing in the lateral meniscus that extends partially or completely in front of the popliteal hiatus should be graded as central to the popliteal hiatus.

Furthermore, a degenerative meniscus injury, previously asymptomatic, might change and become symptomatic after an acute traumatic event, thus representing a challenge for surgeons [10].

The possibility to repair a meniscal injury is multifactorial [12]; thus, several factors must be considered including age, activity level, tear pattern, chronicity of the tears, combined injuries (ACL injury), and healing potential/vascularization.

It is still somewhat debatable if an ACL injury associated with minor symptoms in patient involved in low-demand sports activities should undergo ACL repair. The diagnosis of a concomitant meniscal lesion represents an important argument favoring the surgical procedure.

Pujol and Beaufils have defended that the indications for surgical repair can be widened for the medial meniscus (increased risk of secondary meniscectomy if left alone), even for small stable lesions [63]. On the other hand, for the lateral meniscus with small stable lesions, "let the meniscus alone" can be the preferred approach given the low risk of subsequent meniscectomy [11]. An overall *odds ratio* of 3.50 for medial meniscal tears has been described when ACL surgery is performed more than 12 months after the ACL injury when compared to less than 12 months after ACL injury [74]. On the other hand, concerning lateral meniscus tears, minimal to no evidence was found as a risk factor, at least for the period of time comprised between ACL injury and reconstruction surgery [74].

These findings are somewhat in line with the recognized different roles of medial and lateral menisci within the knee joint.

There have been remarkable developments of suture techniques derived from improved biological and anatomical knowledge accompanied with advances in surgical techniques and medical devices [49].

This work aims to summarize the most frequent indications for meniscal repair and describe technical options as well as results and possible complications.

11.2 Indications for Meniscal Repair

According to recent advances in suture devices and surgical techniques, several injuries previously considered as irreparable are now potentially repairable (Table 11.1). Posterior capsular avulsions are considered out of the scope of this chapter and are dealt separately. Regardless of the used technique, vertical or horizontal mattress sutures are usually possible (Fig. 11.1). Vertical sutures have higher pullout resistance and are perpendicular to the circumferential fibers of the meniscus [70]. Both points of the suture can be put in the meniscus tissue or one in the capsule and another in the meniscus. Horizontal sutures are parallel to the same fibers.

11.2.1 Longitudinal and Bucket-Handle Tears

A vertical or longitudinal tear (Fig. 11.2) occurs in line with the circumferential fibers of the meniscus. If such tear reaches enough length, it is classified as a bucket-handle tear. The bucket-handle tear may be described as being attached anteriorly and posteriorly with high instability in the middle. It can progress and become detached at either end or transected in the middle thus creating unstable anterior and posterior flaps. A bucket-handle tear may displace into the intercondylar notch, where it may cause true locking of the knee joint.

The longitudinal tears, particularly those occurring closer to the peripheral vascular zones, have always been considered as the most direct indication for repair either by horizontal sutures, vertical sutures, or combinations of both [7, 56, 57].

Concerning bucket-handle tears, in case of a dislocated/unstable bucket handle, the first step will be to bluntly reduce the meniscus to its native site (using the hook probe or similar tool) [26].

If the meniscus is stable after reduction, the surgical procedure becomes easier, and the chances for successful repair are increased [1, 26].

11.2.2 Radial Tears

These are often related to trauma but sometimes have been also observed in degenerative meniscus. Radial tears can be complete or

Table 11.1 Injury types and possibility to repair

Injury types and possibility to repair	
Injury type	Potential for repair
Horizontal tear	Potentially repairable
Longitudinal tear	Repairable
Radial tear	Potentially repairable
Bucket-handle tear	Potentially repairable
Root tears	Potentially repairable
Oblique (flap or parrot beak) tears	Irreparable
Complex degenerative tears	Irreparable

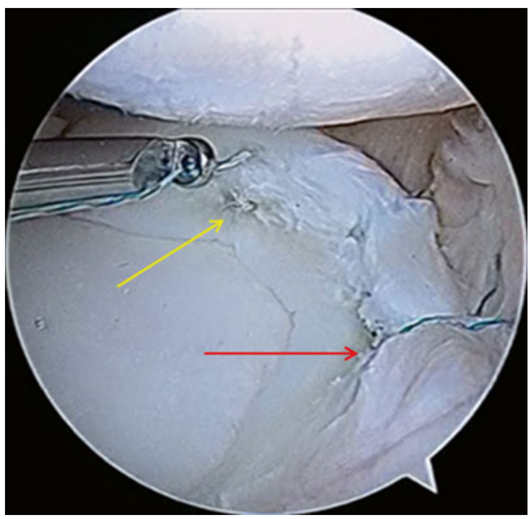

Fig. 11.1 Vertical (*red arrow*) and horizontal (*yellow arrow*) mattress sutures are visible

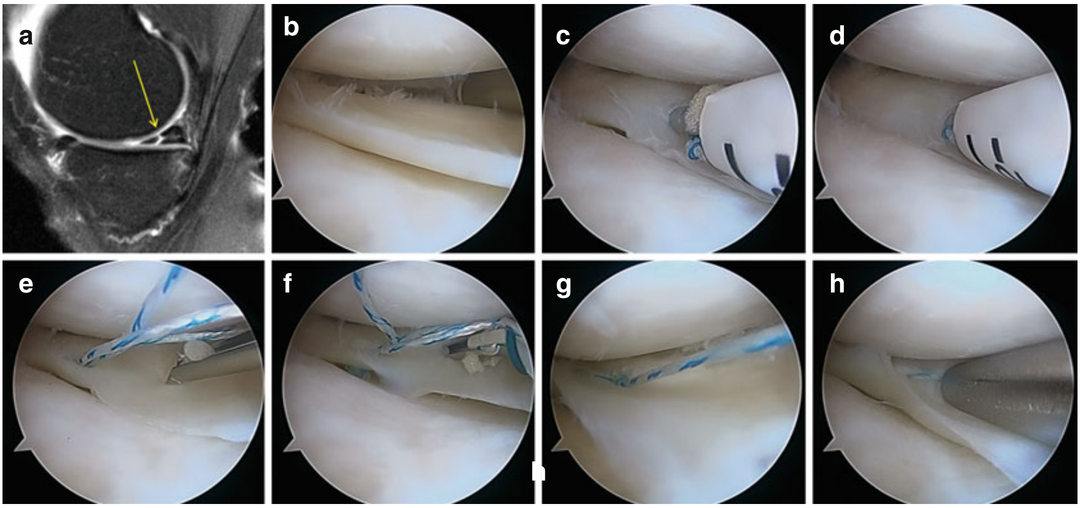

Fig. 11.2 MRI of longitudinal tear (**a**) and arthroscopic view (**b**); all-inside repair sequence with the first anchor introduction (**c**, **d**); the second anchor is deployed (**e**, **f**). The suture is finally tensioned by pulling the suture (**g**) and then by the use of a knot pusher (**h**)

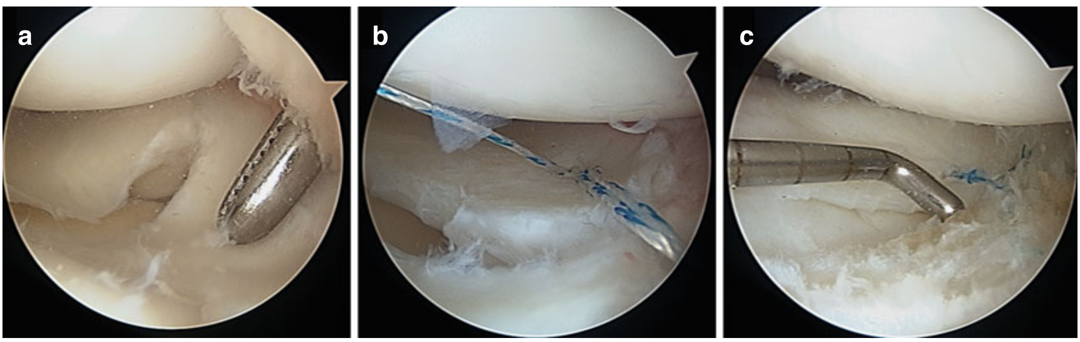

Fig. 11.3 Radial tear arthroscopic view (**a**) repaired by suture (**b**). Stability of the repair is confirmed by tensioning with the hook probe (**c**)

incomplete. They are oriented extending from the inner edge of the meniscus toward its periphery, where there might be some healing capacity (Fig. 11.3). Radial tears are in general defined as unstable [79]. They were generally considered as non-repairable because the circumferential hoop fibers are disrupted and the majority of the tear is avascular. However, repair of complete radial meniscal tears is a key to restoring the mechanical integrity necessary to maintain hoop tension in the meniscus. Repair of radial tears is currently considered a challenge and represents a difficult decision for the surgeon [49]. The major goal is to achieve a primary stable meniscal repair. This is considered crucial for providing a chance to efficiently heal meniscus [49]. Sometimes, the combination of sutures enhanced by fibrin clot has also allowed positive results for treatment of radial tears [37, 67].

11.2.3 Horizontal Cleavage Tears

In this type of tear, the superior and the inferior surfaces of the meniscus are divided (Fig. 11.4). It is typically a degenerative tear and most

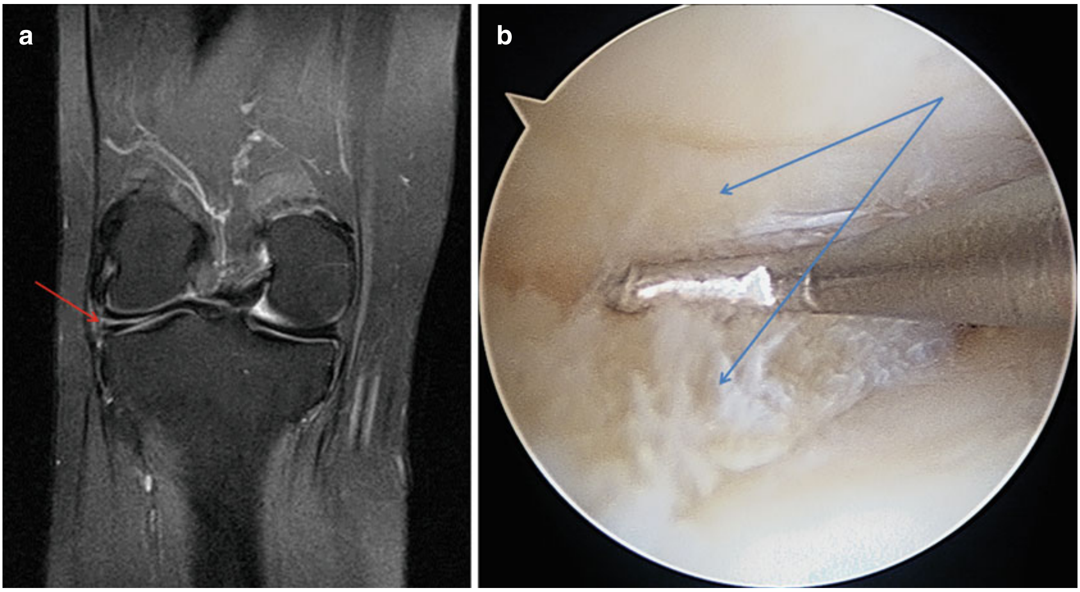

Fig. 11.4 Horizontal cleavage tear on MRI (**a**) and arthroscopic view (**b**) demonstrating the superior and inferior components of the tear (*blue arrows*)

frequently occur in older people. Symptomatic horizontal meniscal tears in young patients are a particular condition which often presents as an isolated severe meniscus lesion. A complete resection of such tear would subsequently result in a subtotal meniscectomy. Arthroscopic repair of such lesions is sometimes possible and has provided fair results [37]. A recent systematic review (level IV) concluded that horizontal cleavage tears show a comparable success rate to repairs of other types of meniscal tears [43].

Open meniscal repair of complex horizontal tears, even those extending into the avascular zone, have proven to be effective at midterm follow-up in young and active patients with a low rate of failure [64, 69].

11.2.4 Meniscal Root Tears (MRTs)

This type of meniscal tears is receiving increasing attention [13]. Most regularly, MRTs are degenerative in nature and must be differentiated from the rare true traumatic root tears. The traumatic root tears are frequently associated with an anterior cruciate ligament (ACL) tear, particularly on the posterior horn of the lateral meniscus.

They can be treated by tibial re-fixation, using a transtibial tunnel [2], if the remaining tissue is found to be adequate for repair.

The repair of root tears (Fig. 11.5) has been done by tibial tunnel [42] (namely, posterior horns) and all-inside techniques (more frequently on anterior horns) [55].

11.3 Techniques

Several techniques have been described and can be chosen according to the injury pattern, surgeon’s experience, and available resources (Table 11.2).

11.3.1 Inside-Out

Henning [33, 34] was the first to describe the inside-out technique of arthroscopic meniscal repair.

Inside-out techniques use specific long flexible needles connected to suture wire and zone-specific cannulas to pass sutures through the joint and across the tear (Figs. 11.6 and 11.7). A small posterior joint line incision is used to retrieve the sutures and tie them directly onto the capsule. The use of a posterior retractor is important in order to protect the posterior neurovascular structures when this technique is selected for posterior tears (Fig. 11.6).

11.3.2 Outside-In

The outside-in techniques have been described by Warren [78] and Morgan and Casscells [53]. This is a cheap method to provide sutures particularly to the body and anterior segments of menisci. Outside-in techniques involve passing sutures percutaneously through spinal needles at the level of joint line, across the meniscus tear, and then initially retrieving the sutures intra-articularly (Figs. 11.8 and 11.9).

Knots can then be tied on the intra-articular free ends of the suture. A small incision is then made at the joint line, where the protruding suture ends are retrieved and tied directly on the capsule.

More frequently, the sutures are pulled outside the skin using one of the needles as a suture passer. A small incision is made and both ends of the suture brought together subcutaneously and

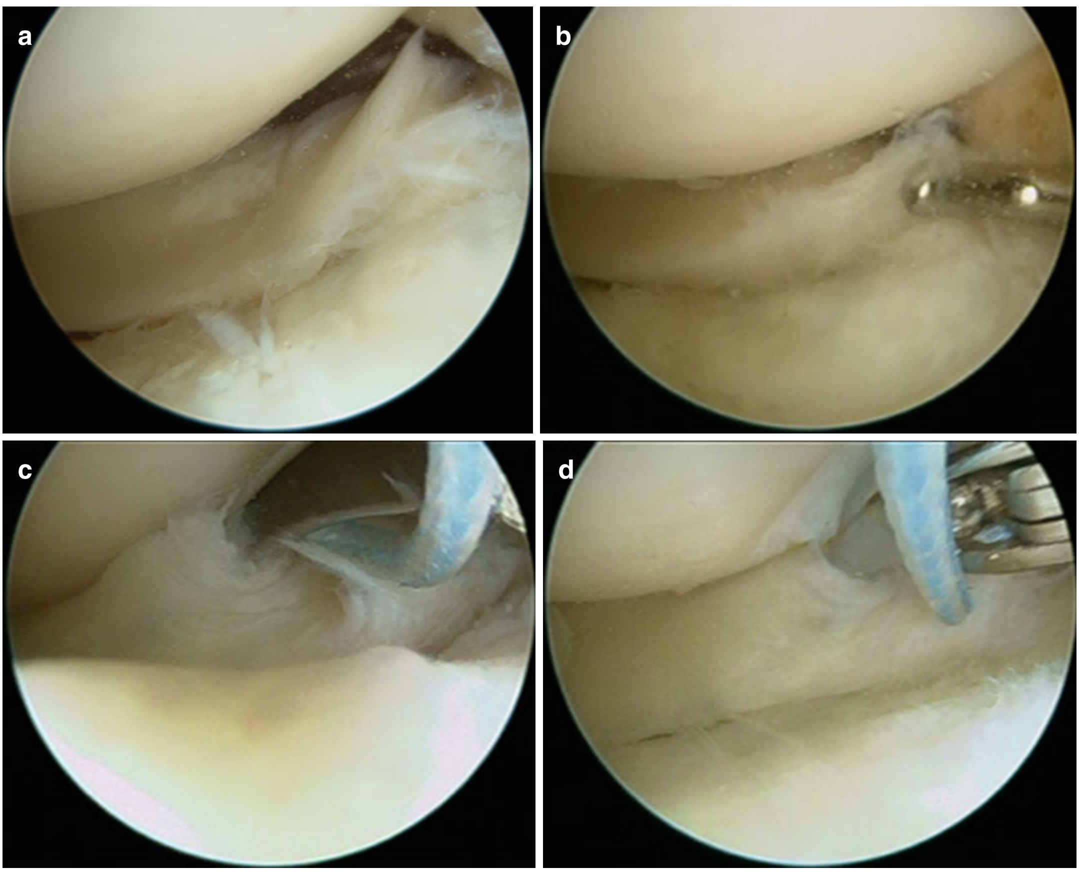

Fig. 11.5 Posterior root tear on arthroscopic view (**a**, **b**). Sutures are passed through the meniscus tissue by the use of shoulder instruments (**c**, **d**). After drilling a tunnel, the sutures are passed through and tensioned (**e**–**g**). Achieved stability is checked (**h**)

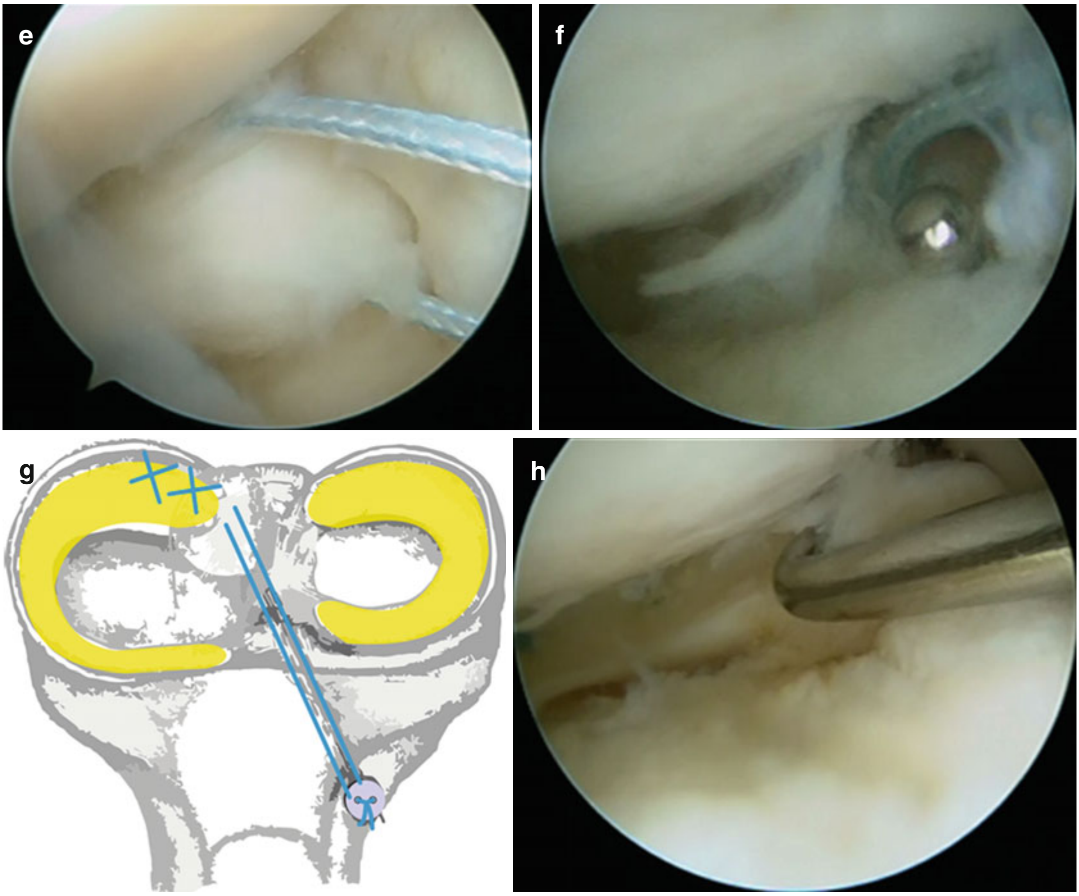

Fig. 11.5 (continued)

tied over the capsule. This avoids bulky knots inside the joint.

A potential disadvantage of the outside-in technique is difficulty in reducing the tear and opposing the edges while passing the sutures.

11.3.3 All-Inside Meniscus Repair

In recent years, there has been a huge development in all-inside techniques (Figs. 11.2 and 11.10) and related devices resulting in increased ease of use and reduced surgical times. Moreover such development also enabled to lower the iatrogenic risk to the neurovascular structures [32, 47]. Suture techniques exhibited biomechanical superiority over biodegradable flexible and rigid anchor devices for meniscus repair [18].

Several generations have been described.

Table 11.2 Repair techniques and most frequent indications

Repair techniques and most frequent indications	
Inside-out technique	Posterior horn tears
	Middle-third tears
	Bucket-handle tears
	Peripheral capsular tears
	Meniscal allograft
Outside-in technique	Anterior horn tears
	Middle-third tears
	Bucket-handle tears
	Peripheral capsular tears
	Radial tears
	Meniscal allograft
All-inside technique	Posterior horn tears
	Middle-third tears
	Bucket-handle tears
	Peripheral capsular tears
	Radial tears
	Meniscal allograft

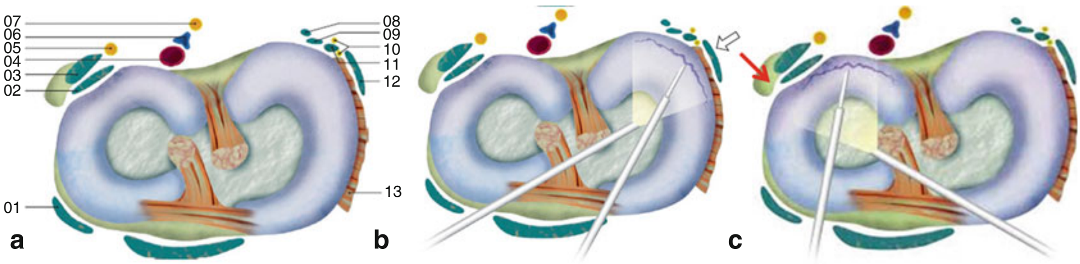

Fig. 11.6 Anatomical structures at risk during posterior horn of both meniscus repairs (**a**): *1* iliotibial band; *2* popliteus tendon; *3* biceps tendon; *4* popliteal artery; *5* peroneal nerve; *6* popliteal vein; *7* tibial nerve; *8* semitendinosus tendon; *9* semimembranosus tendon; *10* saphenous nerve; *11* gracilis tendon; *12* sartorius tendon; and *13* medial collateral ligament. (**b**) Structures at risk when repairing the medial meniscus (*white arrow* represents posteromedial approach). (**c**) Structures at risk when repairing the lateral meniscus (*red arrow* represents posterolateral approach) (From Katabi et al. [38])

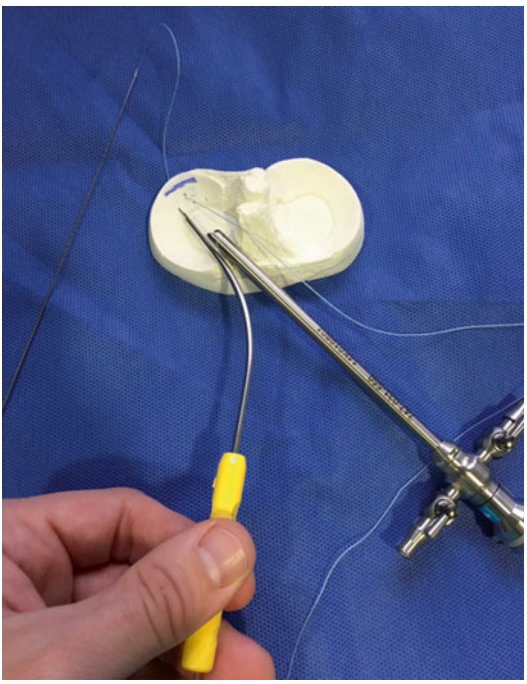

Fig. 11.7 Model representing inside-out suture by means of using a curved cannula and a system composed of two long needles connected by 2.0 suture

11.3.3.1 First-Generation All-Inside Repairs

The first generation of all-inside repairs was described in 1991 by Morgan [52] and required the use of curved suture hooks through accessory posterior portals to enable passing the sutures through the tear. Sutures were then retrieved and tied arthroscopically. The technique was technically demanding and had inherent considerable risk to the neurovascular structures at risk. It was consequently abandoned with the development of second-generation repairs.

11.3.3.2 Second Generation of All-Inside Meniscal Repairs

The second generation of all-inside meniscal repairs introduced the concept of technique-specific devices placed across the tear and anchored peripherally. The prototype of this generation was the T-Fix (Smith and Nephew, Andover, Massachusetts), which consisted of a polyethylene bar with an attached No. 2-0 braided polyester suture, deployed through a sharp needle or cannula in order to capture the peripheral meniscus or capsule. Adjacent sutures were then secured with arthroscopic knots pushed onto the meniscal surface.

This system enabled repair through the standard anterior arthroscopic portals without the need for accessory incisions and with lower risk to neurovascular structures.

However, the technical limitations of the device were the need for arthroscopic knots with potential chondral abrasion and the difficulty to tension the knots after placement.

Despite good early results, the acknowledgment of its limitations led to the development of third-generation devices [9, 24].

11.3.3.3 Third Generation of All-Inside Meniscal Repairs

The third generation consisted of an explosion of bioabsorbable meniscal repair devices, including arrows, screws [76], darts, and staples

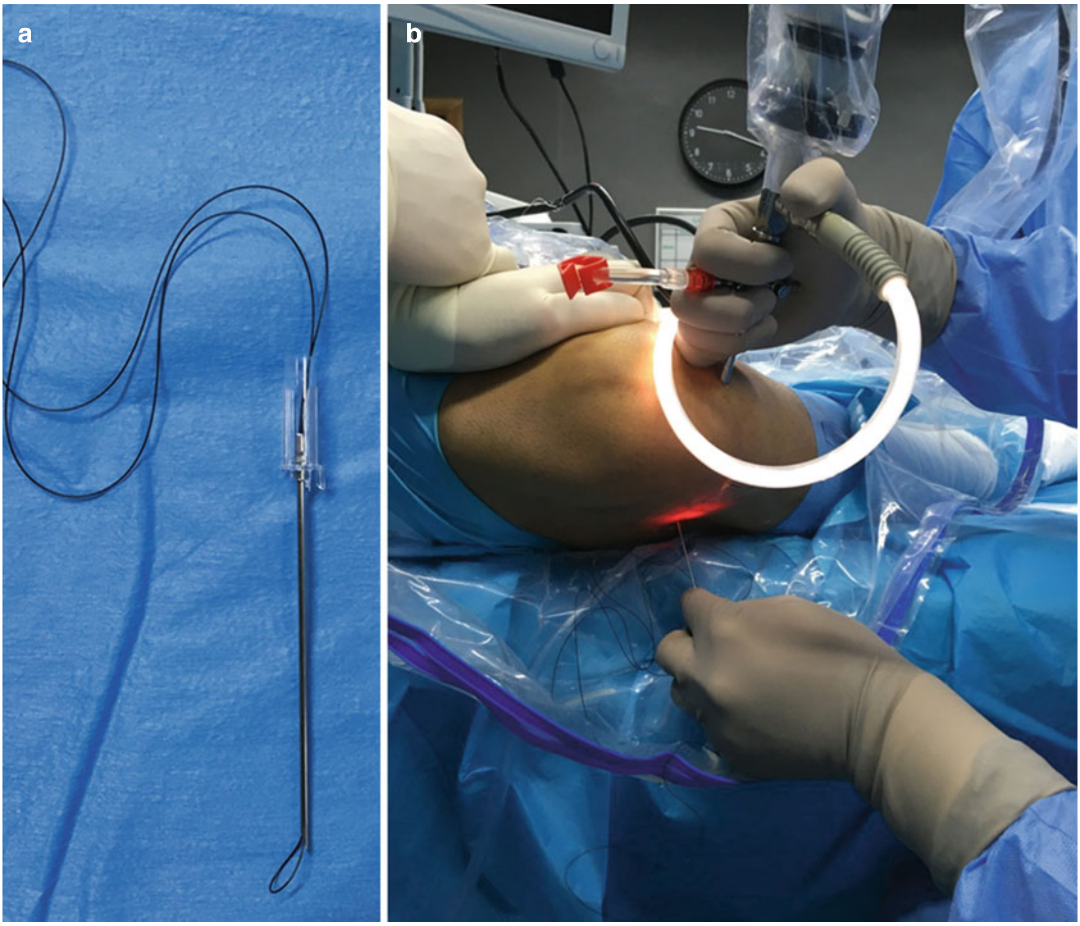

Fig. 11.8 Needle with nylon loop used to retrieve sutures for outside-in repair (**a**). Introduction from outside to the inside of the joint at the level of joint line by transillumination (**b**) and direct arthroscopic view

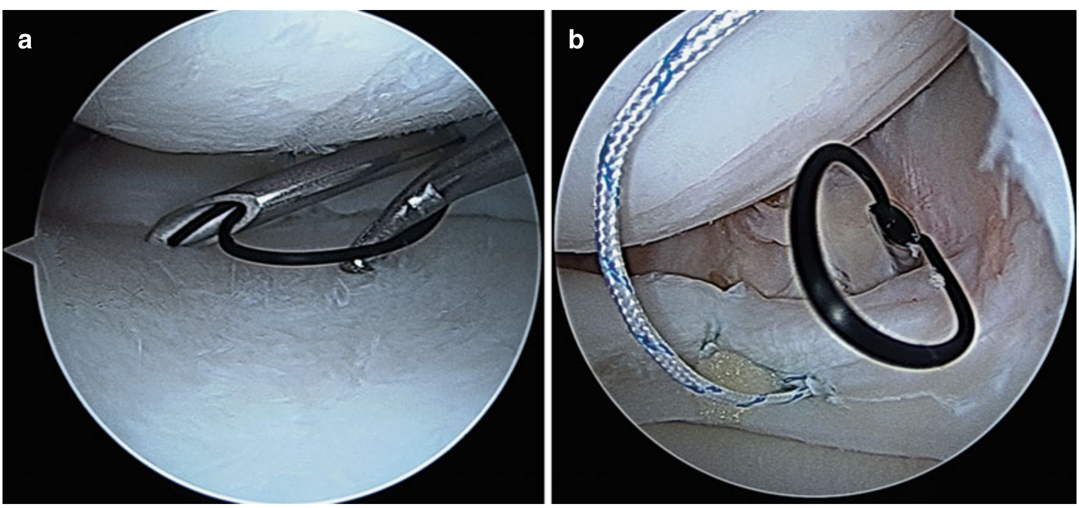

Fig. 11.9 Arthroscopic view of outside-in technique. The nylon loop (**a** and **b**) is used to bring the suture outside the joint percutaneously before final suture which requires a small stab skin incision

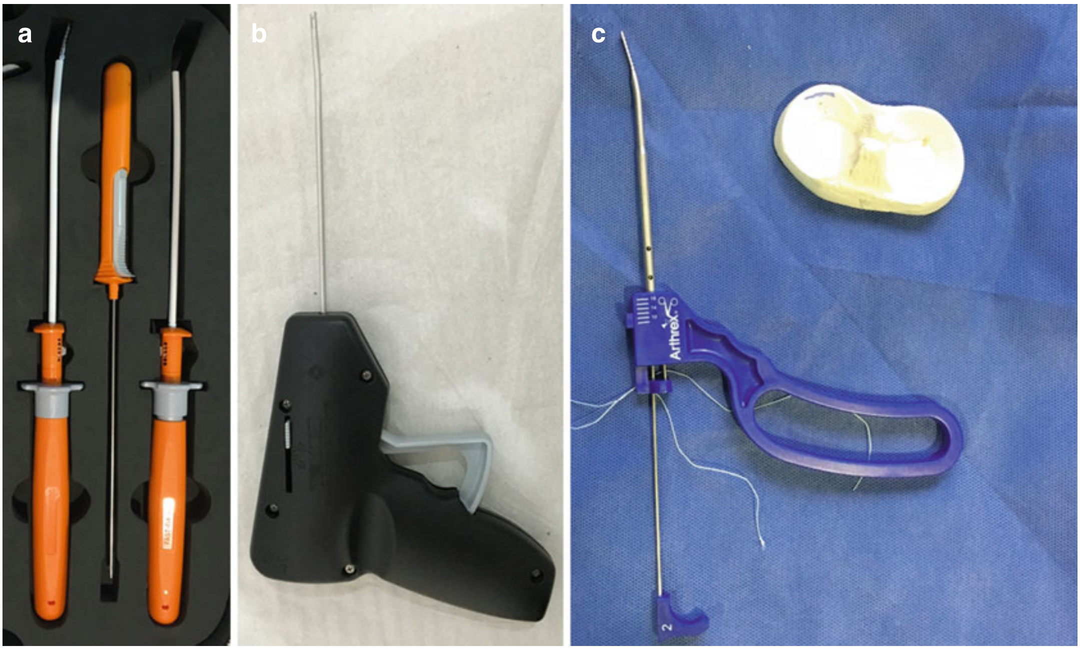

Fig. 11.10 Three common examples of all-inside devices: Fast-Fix® (Smith and Nephew) (**a**); MaxFire® (Biomet) (**b**); Meniscal Cinch® (Arthrex) (**c**)

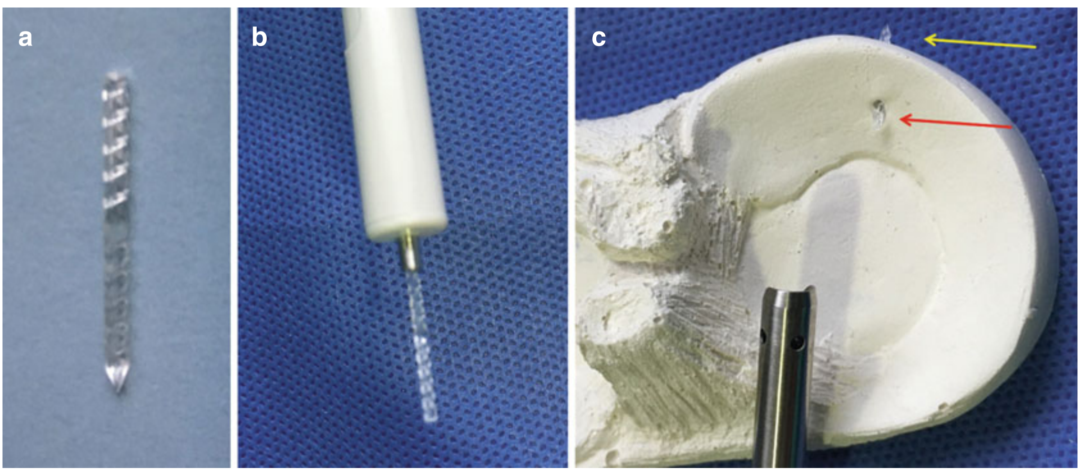

Fig. 11.11 Meniscal darts made of polylactic acid for meniscal repair (**a**). Introduction device (**b**) and final aspect of fixation on a rubber model (**c**). Notice that this hard structure has inherent risk for periarticular (*yellow arrow*) and/or chondral damage (*red arrow*)

(Fig. 11.11). Most of these devices were composed of the rigid poly-L-lactic acid (PLLA) which has been linked to some problems of erratic degradability. Despite some authors describing good results [3, 60], these devices were linked to higher failure rates [30, 44] and higher number of complications.

Numerous device-specific complications have also been reported, including synovitis, inflammatory reaction, cyst formation, device failure/migration, and chondral damage [44]. If these devices are placed too proud or if they loosen/migrate, significant chondral damage can result, often consisting of grooving of the adjacent femoral condyle. Given the deterioration of results and considerable prevalence of complications, the rigid third-generation devices have gradually lost popularity.

11.3.3.4 Fourth Generation of All-Inside Meniscal Repairs

The previously described limitations and complications, combined with the lack of adjustable tensioning, led to the development of the fourth and current generation of all-inside meniscal repair devices. These devices are flexible and suture based and have lower profile, and they allow for variable compression and retensioning across the meniscal tear. They are usually composed of suture combined with small anchors (serving as blocks) and a pre-tied slipknot [18]. Several devices exist according to different brands (e.g., Fast-Fix®, Smith and Nephew; Meniscal Cinch®, Arthrex; RapidLoc®, Depuy; Maxfire, Biomet®; Sequent®, Linvatec; etc.)

A depth-limiting sleeve on the inserter is used to avoid excessive penetrations of the needle with higher risk of iatrogenic complications (neurovascular structures) [51]. It may be precut to any desired length, and shorter length is usually required in the posterior horn of lateral meniscus [51]. The curved or straight inserter, with both anchors loaded, is introduced into the joint and advanced across the tear.

After deploying the first anchor, the needle inserter is withdrawn from the meniscus but kept inside the joint. The second anchor is advanced to the tip of the inserter, which is then advanced once more across the meniscus and arrayed. The anchors and the resultant suture bridge may provide a vertical or horizontal mattress configuration. The pre-tied slipknot is advanced with a push-pull technique to apply variable compression across the tear. The suture is then cut.

There are also other devices currently available.

The Meniscal Viper Repair System (Arthrex, Naples, FL) (Fig. 11.12) has been developed for repair of peripheral meniscal lesions located within 1–2 mm of the periphery [17]. For lesions located in zone 2 (within the central 50 %), careful assessment of their distance from the periph-

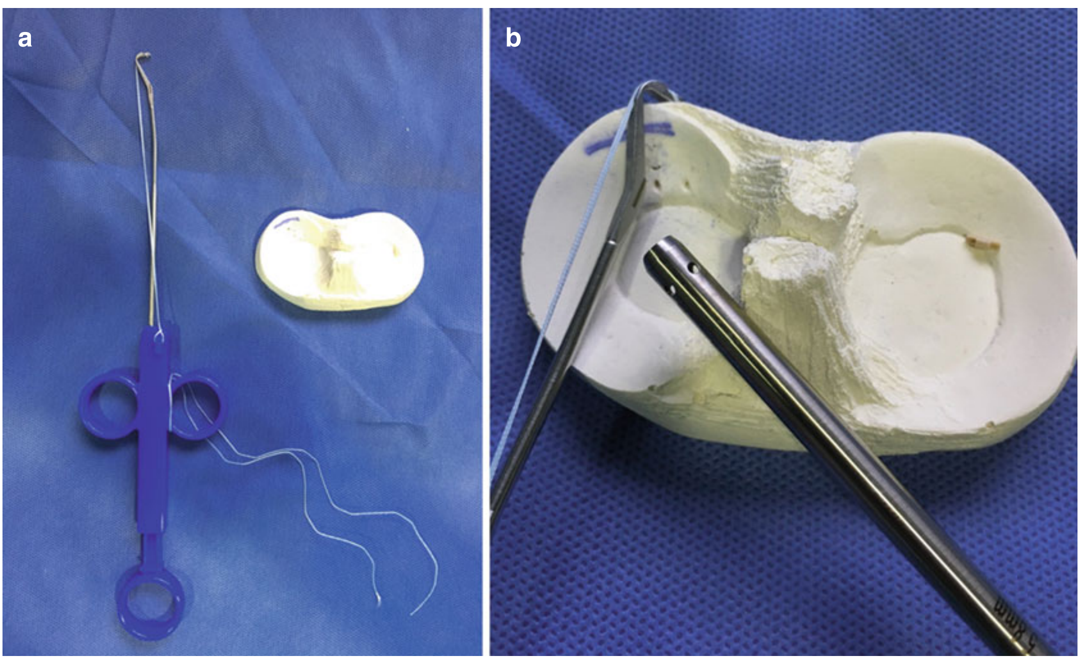

Fig. 11.12 The Meniscal Viper Repair System® (Arthrex, Naples, FL) has been developed for repair of peripheral meniscal lesions located within 1–2 mm of the periphery (**a**, **b**)

ery is recommended. For lesions located more than 3–4 mm away from the periphery, alternative repair systems or augmentation with other devices may be prudent.

This system provides all-inside, all- suture repair without using hard pieces (blocks) inside or in the periphery of the joint [17].

11.3.4 Biologic Augmentations

Other means of assisting the repair of avascular meniscal tears, including fibrin clot [6, 34], fibrin glue [39], meniscal rasping, growth factors [31], and cell-based therapies, have been attempted [59]. A method using a bioabsorbable conduit has been also tried to augment the healing of avascular meniscal tears in a dog model by improving vascularization [21]. Further attempts by biomaterials such as porous polyurethane [40], porcine small intestinal submucosa [22], fascia sheaths [41], collagen scaffolds, and growth factors have been reported with variable outcomes [58]. Tissue engineering and regenerative medicine strategies promise future possibilities, but this goal has not yet been completely achieved and requires ongoing research [58].

11.4 Results

According to the best available knowledge, the healing rate after meniscal repair is complete healing in 60 % of cases, 25 % of partial healing, and 15 % of failure [65]. On the other hand, partially or incompletely healed menisci are many times asymptomatic, at least in the short term [62, 64]. According to literature, the failure rate after arthroscopic meniscal repair ranges from 5 % to 43.5 % (mean, 15 %) [62]. The volume of subsequent meniscectomy after failed meniscal repair is not increased when compared with the volume of meniscectomy that would have been performed if an attempt of repair had not been performed at the first approach [62].

Arthroscopic meniscal repair provides long-term protective effects, even if the initial healing is incomplete [65].

It seems obvious that degenerative meniscal tears have inherently even more limited possibility for healing. However, it has been shown that repair horizontal cleavage tears might have favorable outcome in open or arthroscopic repair with a low rate of secondary meniscectomy [64].

Paxton et al. concerning radiographic changes observed that 78 % of meniscal repairs had no radiographic degenerative changes compared with 64 % of partial meniscectomies; one grade change or less was found in 97 % of meniscal repairs compared with 88 % of partial meniscectomies [57] (systematic review levels I–IV).

Another level III study concluded that meniscal repair for isolated traumatic meniscal tears provided significantly better results in long-term follow-up concerning prevention of osteoarthritis and sports activity recovery compared with partial meniscectomy [75]. No progression for arthritis was observed in 80.8 % after repair compared with 40.0 % after meniscectomy, and return to sports activity was 96.2 % after repair compared with 50 % after meniscectomy [75].

On level I–IV systematic review and meta-analysis, at minimum 5 years follow-up, mild (grade I) degenerative changes were reported in five studies and ranged from 8 % to 25 % [54]. Failure rate was reported from 22.3 % to 24.3 %, but these results do not reflect the experience with the most recent all-inside devices [54].

Some authors reported higher failure rates for medial meniscus repair comparing to lateral [45]. However, a more recent study could not identify significant differences comparing success or failure rate of medial comparing to lateral meniscus [57].

Moreover, despite traditionally it has been stated that meniscal repair combined to ACL reconstruction provides better outcome, this fact was not confirmed in a study at more than 5 years follow-up [45]. The failure rate was 22.7 % in the eight studies reporting on meniscal repairs in ACL-intact knees compared with 26.9 % in the three studies reporting on repairs in ACL-reconstructed knees [45].

On another recent (level IV) study, Pujol et al. have shown at a mean follow-up of 114 ± 10 months that 23 patients displayed no signs of osteoarthritis when compared to the noninjured knee, 6 patients had grade 1 osteoarthritis, and two had grade 2 [66].

The initial meniscal healing rate did not significantly influence clinical or imaging outcomes, and only 12.9 % of patients underwent subsequent meniscectomy [66].

Moreover, the risk for subsequent meniscectomy after meniscal repair is low (8.9 %), which also supports the fact that repairing a meniscus is a safe and effective procedure in the long term [46].

The risk for undergoing subsequent meniscectomies was decreased in patients undergoing a concomitant ACL reconstruction and in patients over 40 when compared to patients under 20 years old [46].

Moreover, it has been shown that the volume of subsequent meniscectomy after failed meniscal repair is not increased when compared with the volume of meniscectomy that would have been performed if not initially repaired [62].

For traumatic lateral meniscus tear approached during ACL reconstruction procedures [71] (level III), it seems plausible to provide the general recommendation to leave small (<1 cm) tears alone, repair large tears in vascular zone, and excise unstable tears in avascular zone [23] (level I).

The red-white (zone 2) (rim width 3 to <5 mm) of menisci has been considered the "gray" area for healing. A recent systematic review that addressed this topic could identify 767 repairs in zone 2 among a universe of 1,326 meniscus repairs [7] (systematic review levels I–IV). An acceptable midterm clinical healing rate was found for zone 2 meniscus repairs which might be connected to the development of surgical techniques and implants enabling more stable repairs. So, when indicated, repair in the zone 2 of menisci is possible and provides good results.

Another interesting topic is the combination of both approaches: combined meniscectomy and repair. Preserving as much tissue as possible through repair while resecting only what is considered irreparable, and a possible risk factor for mechanic problems or further aggravating the lesion. Limited related literature reports are available so far which impairs further conclusions.

The preservation of peripheral rim and the largest possible amount of meniscus tissue have positive implications in load transmission and contact area [5, 35, 66].

Ahn et al. [2] (level IV) described that in 6 of 78 cases, a partial medial meniscectomy in the avascular zone was performed, while the remaining tissue on the vascular zone was preserved by repair.

Another case reported described that after limited partial meniscectomy of unstable fragments of a radial tear while leaving alone the more peripheral part of the lesion in the vascular area resulted in self-healing (confirmed by second look arthroscopy) [28]. No evidence-based guidelines are possible, but the rationale for such approach can be discussed. The preservation of the meniscal rim is of paramount relevance in keeping the structure and biomechanical features. Moreover, if future replacement approaches are to be considered, preservation of meniscal rim is of critical relevance [14]. On the other hand, an unstable tear in the avascular zone, considered as irreparable, could be implicated in subsequent aggravation of the tear caused by repetitive motion in the site of injury. In such cases, it might be arguable that limited resection could help to preserve the meniscus and that the remaining tissue is still appropriate for repair. For practical purposes, it seems advisable (although debatable), in such cases, to first perform the repair and after stabilization of the meniscal tear remove the unstable part.

In general, the most recent meta-analysis concludes and reinforces that meniscal repairs have better long-term patient-reported outcomes and better activity levels than meniscectomy. Furthermore, meniscal repair had a lower failure rate than meniscectomy [80].

11.5 Complications

Arthroscopy meniscal repair shares some risks of complication which are common to any surgical procedure, namely, any arthroscopic procedure. These are considered out of the scope of this work, and herein we will focus on specific complications of meniscal repair.

11.5.1 Neurovascular and Soft Tissue Complications

Meniscal repair of the posterior horn of both medial and lateral menisci is associated with risk of iatrogenic damage to neurovascular structures given the local anatomy (Fig. 11.6) [38].

The popliteal artery and common peroneal nerve are at some degree of risk during repair of the posterior horn of lateral meniscus.

On the other hand, the saphenous nerve (mainly its infrapatellar branch) is at risk during repair of medial meniscus posterior horn. To our best knowledge, there are no reports of injury of popliteal vein or tibial nerve with currently available repair devices.

Popliteal artery injury (fistulas, pseudoaneurysm, or even laceration) is extremely rare but has been reported [15, 16, 34].

This has been reported with all techniques, including all-inside [20]. When inside-out technique is used, a posterolateral approach (Table 11.3) is recommended to control the exit of the needles and lower the risk for injury.

All-inside or inside-out needles placed in the posterior horn of lateral meniscus are very close to the peroneal nerve [36].

Neuropraxia of the saphenous nerve (and its infrapatellar branch) is the most common neural injury with some authors reporting 22 % of transient saphenous neuropraxia in inside-out techniques [8].

Espejo-Baena et al. recommend a medial incision with the knee around 70–90° of flexion to reach a "safe zone" located between the surface of the fascia cruris and the medial collateral ligament [25].

Other soft tissue injuries reported during meniscal repair include entrapment of popliteal tendon and iliotibial band (during lateral meniscus repair) [25, 50].

Table 11.3 Posteromedial and posterolateral approach for protection of structures during posterior horn repair

Posteromedial approach	Knee around 70–90°
	3–4 cm below joint line
	Bucket-handle tears
	"Safe zone" located between the fascia cruris and the medial collateral ligament
	Pass sutures around 20° flexion
Posterolateral approach	3–4 cm made with knee at 90° flexion
	Stay posterior to lateral collateral ligament and keep short head of biceps femoris posterior
	Retractor anterior to the lateral gastrocnemius head
	Pass sutures around 90° flexion

Entrapment of the saphenous vein, medial collateral ligament, sartorius, gracilis, and semimembranosus tendons have been observed during medial meniscus repair [19, 25].

11.5.2 Complications Related to Meniscal Implants and Repair Devices

Several rigid meniscal repair devices are made of polylactic acid or derivates. The structure and integrity of such polymers decrease with time, and fragments might become loose inside (Fig. 11.13) or outside the joint [27]. As abovementioned, such device-specific complications include synovitis, inflammatory reaction, cyst formation, device failure/migration, and chondral damage [44].

Concerning all-inside devices, mainly during the learning curve period, some related complications include intra-articular loosening of the implant, intra-articular deployment of the device, suture failure or cutting during tensioning, or bending of the device itself during application. These might result in meniscal and/or chondral damage [51].

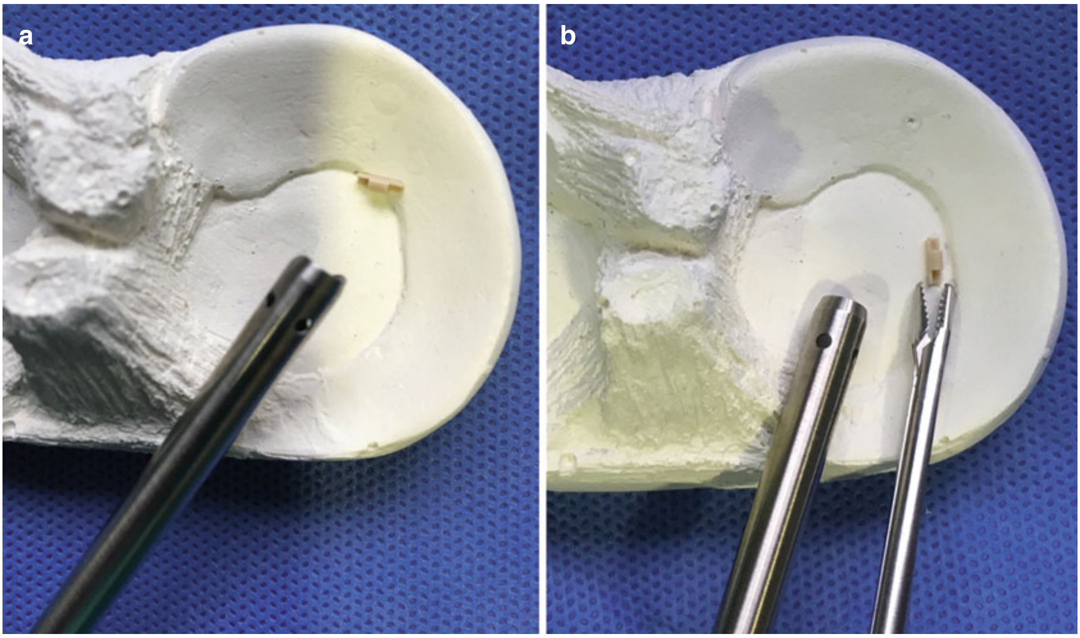

Fig. 11.13 Model demonstrating removal of a hard PEEK part of an all-inside device which can migrate intra-articularly (**a** and **b**)

Take-Home Message
Meniscal repair has proven to be effective, reproducible, and reliable if proper techniques and indications are respected. Some injuries previously considered as irreparable are currently found to be potentially reparable (e.g., horizontal cleavage tears, radial tears, root tears). There is a demanding learning curve for some techniques, and, in this sense, previous training and cadaver laboratory training courses are crucial. Preoperative planning relies on proper classification of tears, and, frequently, surgeons must be prepared with several repair options when dealing with some cases.

References

1. Ahn JH, Kim KI, Wang JH, Kyung BS, Seo MC, Lee SH. Arthroscopic repair of bucket-handle tears of the lateral meniscus. Knee Surg Sports Traumatol Arthrosc. 2015;23(1):205–10. doi:10.1007/s00167-013-2764-9.
2. Ahn JH, Wang JH, Yoo JC. Arthroscopic all-inside suture repair of medial meniscus lesion in anterior cruciate ligament – deficient knees: results of second-look arthroscopies in 39 cases. Arthroscopy. 2004;20(9):936–45. doi:10.1016/j.arthro.2004.06.038.
3. Albrecht-Olsen P, Kristensen G, Burgaard P, Joergensen U, Toerholm C. The arrow versus horizontal suture in arthroscopic meniscus repair. A prospective randomized study with arthroscopic evaluation. Knee Surg Sports Traumatol Arthrosc. 1999;7(5):268–73.
4. Anderson AF, Irrgang JJ, Dunn W, Beaufils P, Cohen M, Cole BJ, Coolican M, Ferretti M, Glenn Jr RE, Johnson R, Neyret P, Ochi M, Panarella L, Siebold R, Spindler KP, Ait Si Selmi T, Verdonk P, Verdonk R, Yasuda K, Kowalchuk DA. Interobserver reliability of the International Society of Arthroscopy, Knee Surgery and Orthopaedic Sports Medicine (ISAKOS) classification of meniscal tears. Am J Sports Med. 2011;39(5):926–32. doi:10.1177/0363546511400533.
5. Anderson L, Watts M, Shapter O, Logan M, Risebury M, Duffy D, Myers P. Repair of radial tears and posterior horn detachments of the lateral meniscus: minimum 2-year follow-up. Arthroscopy. 2010;26(12):1625–32. doi:10.1016/j.arthro.2010.07.020.
6. Arnoczky S, Warren R, Pivak J. Meniscal repair using an exogenous fibrin clot: an experimental study in dogs. J Bone Joint Surg Am. 1998;70:1209–17.
7. Barber-Westin SD, Noyes FR. Clinical healing rates of meniscus repairs of tears in the central-third (red-white)

zone. Arthroscopy. 2014;30(1):134–46. doi:10.1016/j.arthro.2013.10.003.
8. Barber FA. Meniscus repair: results of an arthroscopic technique. Arthroscopy. 1987;3(1):25–30.
9. Barrett GR, Treacy SH, Ruff CG. Preliminary results of the T-fix endoscopic meniscus repair technique in an anterior cruciate ligament reconstruction population. Arthroscopy. 1997;13(2):218–23.
10. Beaufils P, Englund M, Järvinen TLN, Pereira H, Pujol N. How to share guidelines in daily practice on meniscus repair, degenerate meniscal lesion, and meniscectomy. In: Zaffagnini S, Becker R, Kerkhoffs GMMJ, Espregueira-Mendes J, van Dijk CN, editors. ESSKA instructional course lecture book. Amsterdam: Springer; 2014. p. 97–112.
11. Beaufils P, Hulet C, Dhenain M, Nizard R, Nourissat G, Pujol N. Clinical practice guidelines for the management of meniscal lesions and isolated lesions of the anterior cruciate ligament of the knee in adults. Orthop Traumatol Surg Res: OTSR. 2009;95(6):437–42. doi:10.1016/j.otsr.2009.06.002.
12. Bernstein J. In brief: meniscal tears. Clin Orthop Relat Res. 2010;468(4):1190–2. doi:10.1007/s11999-010-1253-4.
13. Bhatia S, LaPrade CM, Ellman MB, LaPrade RF. Meniscal root tears: significance, diagnosis, and treatment. Am J Sports Med. 2014;42(12):3016–30. doi:10.1177/0363546514524162.
14. Bouyarmane H, Beaufils P, Pujol N, Bellemans J, Roberts S, Spalding T, Zaffagnini S, Marcacci M, Verdonk P, Womack M, Verdonk R. Polyurethane scaffold in lateral meniscus segmental defects: clinical outcomes at 24 months follow-up. Orthop Traumatol Surg Res: OTSR. 2014;100(1):153–7. doi:10.1016/j.otsr.2013.10.011.
15. Brasseur P, Sukkarieh F. Iatrogenic pseudo-aneurysm of the popliteal artery. Complication of arthroscopic meniscectomy. Apropos of a case. J Radiol. 1990;71(4):301–4.
16. Carlin RE, Papenhausen M, Farber MA, Ronningen E, Mauro MA, Marston WA, Keagy BA, Burnham SJ. Sural artery pseudoaneurysms after knee arthroscopy: treatment with transcatheter embolization. J Vasc Surg. 2001;33(1):170–3. doi:10.1067/mva.2001.110354.
17. Chang HC, Caborn DN, Nyland J, Burden R. Effect of lesion location on fixation strength of the meniscal viper repair system: an in vitro study using porcine menisci. Arthroscopy. 2006;22(4):394–9. doi:10.1016/j.arthro.2005.12.014.
18. Chang JH, Shen HC, Huang GS, Pan RY, Wu CF, Lee CH, Chen Q. A biomechanical comparison of all-inside meniscus repair techniques. J Surg Res. 2009;155(1):82–8. doi:10.1016/j.jss.2008.10.002.
19. Coen MJ, Caborn DN, Urban W, Nyland J, Johnson DL. An anatomic evaluation of T-Fix suture device placement for arthroscopic all-inside meniscal repair. Arthroscopy. 1999;15(3):275–80.
20. Cohen SB, Boyd L, Miller MD. Vascular risk associated with meniscal repair using Rapidloc versus FasT-Fix: comparison of two all-inside meniscal devices. J Knee Surg. 2007;20(3):235–40.
21. Cook JL, Fox DB. A novel bioabsorbable conduit augments healing of avascular meniscal tears in a dog model. Am J Sports Med. 2007;35(11):1877–87. doi:10.1177/0363546507304330. doi:0363546507304330 [pii].
22. Cook JL, Fox DB, Malaviya P, Tomlinson JL, Kuroki K, Cook CR, Kladakis S. Long-term outcome for large meniscal defects treated with small intestinal submucosa in a dog model. Am J Sports Med. 2006;34(1):32–42. doi:10.1177/0363546505278702. doi:0363546505278702 [pii].
23. Cox CL, Huston LJ, Dunn WR, Reinke EK, Nwosu SK, Parker RD, Wright RW, Kaeding CC, Marx RG, Amendola A, McCarty EC, Spindler KP. Are articular cartilage lesions and meniscus tears predictive of IKDC, KOOS, and Marx activity level outcomes after anterior cruciate ligament reconstruction? A 6-year multicenter cohort study. Am J Sports Med. 2014;42(5):1058–67. doi:10.1177/0363546514525910.
24. Escalas F, Quadras J, Caceres E, Benaddi J. T-Fix anchor sutures for arthroscopic meniscal repair. Knee Surg Sports Traumatol Arthrosc. 1997;5(2):72–6. doi:10.1007/s001670050029.
25. Espejo-Baena A, Golano P, Meschian S, Garcia-Herrera JM, Serrano Jimenez JM. Complications in medial meniscus suture: a cadaveric study. Knee Surg Sports Traumatol Arthrosc. 2007;15(6):811–6. doi:10.1007/s00167-006-0096-8.
26. Espejo-Reina A, Serrano-Fernandez JM, Martin-Castilla B, Estades-Rubio FJ, Briggs KK, Espejo-Baena A. Outcomes after repair of chronic bucket-handle tears of medial meniscus. Arthroscopy. 2014;30(4):492–6. doi:10.1016/j.arthro.2013.12.020.
27. Farng E, Sherman O. Meniscal repair devices: a clinical and biomechanical literature review. Arthroscopy. 2004;20(3):273–86. doi:10.1016/j.arthro.2003.11.035.
28. Foad A. Self-limited healing of a radial tear of the lateral meniscus. Knee Surg Sports Traumatol Arthrosc. 2012;20(5):933–6. doi:10.1007/s00167-011-1660-4.
29. Frizziero A, Ferrari R, Giannotti E, Ferroni C, Poli P, Masiero S. The meniscus tear. State of the art of rehabilitation protocols related to surgical procedures. Muscles Ligaments Tendons J. 2012;2(4):295–301.
30. Gifstad T, Grontvedt T, Drogset JO. Meniscal repair with biofix arrows: results after 4.7 years' follow-up. Am J Sports Med. 2007;35(1):71–4. doi:10.1177/0363546506293023.
31. Griffin JW, Hadeed MM, Werner BC, Diduch DR, Carson EW, Miller MD. Platelet-rich plasma in meniscal repair: does augmentation improve surgical outcomes? Clin Orthop Relat Res. 2015;473(5):1665–72. doi:10.1007/s11999-015-4170-8.
32. Haas AL, Schepsis AA, Hornstein J, Edgar CM. Meniscal repair using the FasT-Fix all-inside meniscal repair device. Arthroscopy. 2005;21(2):167–75. doi:10.1016/j.arthro.2004.10.012.

33. Henning CE. Arthroscopic repair of meniscus tears. Orthopedics. 1983;6(9):1130–2. doi:10.3928/0147-7447-19830901-08.
34. Henning CE, Lynch MA, Yearout KM, Vequist SW, Stallbaumer RJ, Decker KA. Arthroscopic meniscal repair using an exogenous fibrin clot. Clin Orthop Relat Res. 1990;252:64–72.
35. Hulet CH, Locker BG, Schiltz D, Texier A, Tallier E, Vielpeau CH. Arthroscopic medial meniscectomy on stable knees. J Bone Joint Surg. 2001;83(1):29–32.
36. Jurist KA, Greene 3rd PW, Shirkhoda A. Peroneal nerve dysfunction as a complication of lateral meniscus repair: a case report and anatomic dissection. Arthroscopy. 1989;5(2):141–7.
37. Kamimura T, Kimura M. Meniscal repair of degenerative horizontal cleavage tears using fibrin clots: clinical and arthroscopic outcomes in 10 cases. Orthop J Sports Med. 2014;2(11):2325967114555678.
38. Katabi N, Pujol N, Boisrenoult P. Meniscal repair: intra- and postoperative complications. In: Beaufils P, Verdonk R, editors. The meniscus. Berlin: Springer; 2010. p. 191–8.
39. Klompmaker J, Veth RP, Jansen HW, Nielsen HK, de Groot JH, Pennings AJ, Kuijer R. Meniscal repair by fibrocartilage in the dog: characterization of the repair tissue and the role of vascularity. Biomaterials. 1996;17(17):1685–91.
40. Kobayashi K, Fujimoto E, Deie M, Sumen Y, Ikuta Y, Ochi M. Regional differences in the healing potential of the meniscus-an organ culture model to eliminate the influence of microvasculature and the synovium. Knee. 2004;11(4):271–8. doi:10.1016/j.knee.2002.03.001.
41. Kobayashi Y, Yasuda K, Kondo E, Katsura T, Tanabe Y, Kimura M, Tohyama H. Implantation of autogenous meniscal fragments wrapped with a fascia sheath enhances fibrocartilage regeneration in vivo in a large harvest site defect. Am J Sports Med. 2010;38(4):740–8. doi:10.1177/0363546509350749. doi:0363546509350749 [pii].
42. Koenig JH, Ranawat AS, Umans HR, Difelice GS. Meniscal root tears: diagnosis and treatment. Arthroscopy. 2009;25(9):1025–32. doi:10.1016/j.arthro.2009.03.015.
43. Kurzweil PR, Lynch NM, Coleman S, Kearney B. Repair of horizontal meniscus tears: a systematic review. Arthroscopy. 2014;30(11):1513–9. doi:10.1016/j.arthro.2014.05.038.
44. Kurzweil PR, Tifford CD, Ignacio EM. Unsatisfactory clinical results of meniscal repair using the meniscus arrow. Arthroscopy. 2005;21(8):905. doi:10.1016/j.arthro.2005.06.002.
45. Logan M, Watts M, Owen J, Myers P. Meniscal repair in the elite athlete: results of 45 repairs with a minimum 5-year follow-up. Am J Sports Med. 2009;37(6):1131–4. doi:10.1177/0363546508330138.
46. Lyman S, Hidaka C, Valdez AS, Hetsroni I, Pan TJ, Do H, Dunn WR, Marx RG. Risk factors for meniscectomy after meniscal repair. Am J Sports Med. 2013;41(12):2772–8. doi:10.1177/0363546513503444.
47. Majeed H, Karuppiah S, Sigamoney KV, Geutjens G, Straw RG. All-inside meniscal repair surgery: factors affecting the outcome. J Orthop Traumatol: Off J Ital Soc Orthop Traumatol. 2015;16(3):245–9. doi:10.1007/s10195-015-0342-2.
48. Makris EA, Hadidi P, Athanasiou KA. The knee meniscus: structure-function, pathophysiology, current repair techniques, and prospects for regeneration. Biomaterials. 2011;32(30):7411–31. doi:10.1016/j.biomaterials.2011.06.037.
49. Matsubara H, Okazaki K, Izawa T, Tashiro Y, Matsuda S, Nishimura T, Nakanishi Y, Kawamura H, Iwamoto Y. New suture method for radial tears of the meniscus: biomechanical analysis of cross-suture and double horizontal suture techniques using cyclic load testing. Am J Sports Med. 2012;40(2):414–8. doi:10.1177/0363546511424395.
50. Miller MD, Blessey PB, Chhabra A, Kline AJ, Diduch DR. Meniscal repair with the Rapid Loc device: a cadaveric study. J Knee Surg. 2003;16(2):79–82.
51. Miller MD, Kline AJ, Gonzales J, Beach WR. Pitfalls associated with FasT-Fix meniscal repair. Arthroscopy. 2002;18(8):939–43.
52. Morgan CD. The “all-inside” meniscus repair. Arthroscopy. 1991;7(1):120–5.
53. Morgan CD, Casscells SW. Arthroscopic meniscus repair: a safe approach to the posterior horns. Arthroscopy. 1986;2(1):3–12.
54. Nepple JJ, Dunn WR, Wright RW. Meniscal repair outcomes at greater than five years: a systematic literature review and meta-analysis. J Bone Joint Surg Am. 2012;94(24):2222–7. doi:10.2106/JBJS.K.01584.
55. Osti L, Del Buono A, Maffulli N. Anterior medial meniscal root tears: a novel arthroscopic all inside repair. Transl Med UniSa. 2015;12:41–6.
56. Pasa L, Visna P. Suture of meniscus. Scr Med (Brno). 2005;78(3):135–50.
57. Paxton ES, Stock MV, Brophy RH. Meniscal repair versus partial meniscectomy: a systematic review comparing reoperation rates and clinical outcomes. Arthroscopy. 2011;27(9):1275–88. doi:10.1016/j.arthro.2011.03.088.
58. Pereira H, Frias AM, Oliveira JM, Espregueira-Mendes J, Reis RL. Tissue engineering and regenerative medicine strategies in meniscus lesions. Arthroscopy. 2011;27(12):1706–19. doi:10.1016/j.arthro.2011.08.283.
59. Peretti GM, Gill TJ, Xu JW, Randolph MA, Morse KR, Zaleske DJ. Cell-based therapy for meniscal repair: a large animal study. Am J Sports Med. 2004;32(1):146–58.
60. Petsche TS, Selesnick H, Rochman A. Arthroscopic meniscus repair with bioabsorbable arrows. Arthroscopy. 2002;18(3):246–53.
61. Poehling GG, Ruch DS, Chabon SJ. The landscape of meniscal injuries. Clin Sports Med. 1990;9(3):539–49.
62. Pujol N, Barbier O, Boisrenoult P, Beaufils P. Amount of meniscal resection after failed meniscal repair. Am J Sports Med. 2011;39(8):1648–52. doi:10.1177/0363546511402661.

63. Pujol N, Beaufils P. Healing results of meniscal tears left in situ during anterior cruciate ligament reconstruction: a review of clinical studies. Knee Surg Sports Traumatol Arthrosc. 2009;17(4):396–401. doi:10.1007/s00167-008-0711-y.
64. Pujol N, Bohu Y, Boisrenoult P, Macdes A, Beaufils P. Clinical outcomes of open meniscal repair of horizontal meniscal tears in young patients. Knee Surg Sports Traumatol Arthrosc. 2013;21(7):1530–3. doi:10.1007/s00167-012-2099-y.
65. Pujol N, Tardy N, Boisrenoult P, Beaufils P. Long-term outcomes of all-inside meniscal repair. Knee Surg Sports Traumatol Arthrosc. 2013. doi:10.1007/s00167-013-2553-5.
66. Pujol N, Tardy N, Boisrenoult P, Beaufils P. Long-term outcomes of all-inside meniscal repair. Knee Surg Sports Traumatol Arthrosc. 2015;23(1):219–24. doi:10.1007/s00167-013-2553-5.
67. Ra HJ, Ha JK, Jang SH, Lee DW, Kim JG. Arthroscopic inside-out repair of complete radial tears of the meniscus with a fibrin clot. Knee Surg Sports Traumatol Arthrosc. 2013;21(9):2126–30. doi:10.1007/s00167-012-2191-3.
68. Salata MJ, Gibbs AE, Sekiya JK. A systematic review of clinical outcomes in patients undergoing meniscectomy. Am J Sports Med. 2010;38(9):1907–16. doi:10.1177/0363546510370196.
69. Salle de Chou E, Pujol N, Rochcongar G, Cucurulo T, Potel JF, Dalmay F, Ehkirch FP, Laporte C, Le Henaff G, Seil R, Lutz C, Gunepin FX, Sonnery-Cottet B. Analysis of short and long-term results of horizontal meniscal tears in young adults. Orthop Traumatol Surg Res: OTSR. 2015;101(8 Suppl):S317–22. doi:10.1016/j.otsr.2015.09.009.
70. Seil R, Rupp S, Kohn DM. Cyclic testing of meniscal sutures. Arthroscopy. 2000;16(5):505–10. doi:10.1053/jars.2000.4379.
71. Shelbourne KD, Heinrich J. The long-term evaluation of lateral meniscus tears left in situ at the time of anterior cruciate ligament reconstruction. Arthroscopy. 2004;20(4):346–51. doi:10.1016/j.arthro.2004.01.029.
72. Smillie IS. The current pattern of the pathology of meniscus tears. Proc R Soc Med. 1968;61(1):44–5.
73. Smillie IS. Injuries of the knee joint. 4th ed. Edinburgh: Churcill Livingstone; 1972.
74. Snoeker BA, Bakker EW, Kegel CA, Lucas C. Risk factors for meniscal tears: a systematic review including meta-analysis. J Orthop Sports Phys Ther. 2013;43(6):352–67. doi:10.2519/jospt.2013.4295.
75. Stein T, Mehling AP, Welsch F, von Eisenhart-Rothe R, Jager A. Long-term outcome after arthroscopic meniscal repair versus arthroscopic partial meniscectomy for traumatic meniscal tears. Am J Sports Med. 2010;38(8):1542–8. doi:10.1177/0363546510364052.
76. Tsai AM, McAllister DR, Chow S, Young CR, Hame SL. Results of meniscal repair using a bioabsorbable screw. Arthroscopy. 2004;20(6):586–90.
77. Verdonk R. The meniscus: past, present and future. Knee Surg Sports Traumatol Arthrosc. 2011;19(2):145–6. doi:10.1007/s00167-010-1333-8.
78. Warren RF. Arthroscopic meniscus repair. Arthroscopy. 1985;1(3):170–2.
79. Weiss CB, Lundberg M, Hamberg P, DeHaven KE, Gillquist J. Non-operative treatment of meniscal tears. J Bone Joint Surg Am. 1989;71(6):811–22.
80. Xu C, Zhao J. A meta-analysis comparing meniscal repair with meniscectomy in the treatment of meniscal tears: the more meniscus, the better outcome? Knee Surg Sports Traumatol Arthrosc. 2015;23(1):164–70. doi:10.1007/s00167-013-2528-6.