



# Modern treatment of meniscal tears

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- The complex ultrastructure of the meniscus determines its vital functions for the knee, the lower extremity, and the body.
- The most recent concise, reliable, and valid classification system for meniscal tears is the International Society of Arthroscopy, Knee Surgery and Orthopaedic Sports Medicine (ISAKOS) Classification, which takes into account the subsequent parameters: tear depth, tear pattern, tear length, tear location/rim width, radial location, location according to the popliteal hiatus, and quality of the meniscal tissue.
- It is the orthopaedic surgeon's responsibility to combine clinical information, radiological images, and clinical experience in an effort to individualize management of meniscal tears, taking into account factors related to the patient and lesion.
- Surgeons should strive not to operate in most cases, but to protect, repair or reconstruct, in order to prevent early development of osteoarthritis by restoring the native structure, function, and biomechanics of the meniscus.
- Currently, there are three main methods of modern surgical management of meniscus tears: arthroscopic partial meniscectomy; meniscal repair with or without augmentation techniques; and meniscal reconstruction. Meniscus surgery has come a long way from the old slogan, "If it is torn, take it out!" to the currently accepted slogan, "Save the meniscus!" which has guided evolving modern treatment methods for meniscal tears. This last slogan will probably constitute the basis for newer alternative biological treatment methods in the future.

**Keywords:** knee injury; meniscus tears; investigation; treatment

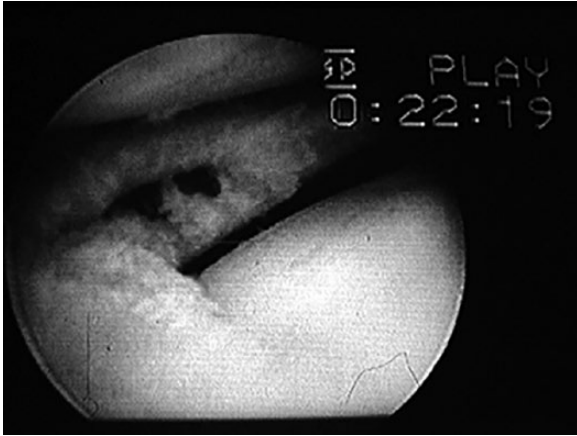
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## Introduction

Meniscal tears are the most frequently encountered and treated injuries in the knee joint, with a bimodal age distribution in young, active sports people and in elderly people, and with a relatively high annual cost.<sup>1-3</sup> Similarly, meniscal tear surgery is among the most commonly performed procedures in orthopaedic surgery.

There are two menisci, which are medial (U-shaped) and lateral (S-shaped) semilunar shaped, hydrated, biphasic fibrocartilaginous soft-tissue structures in the medial and lateral tibiofemoral compartments of the knee joint, respectively. They are not solely a separate structure; they are a part of the 'meniscus-meniscal ligament complex' together with the surrounding ligamentous structures (menisco-tibial, menisco-femoral, menisco-patellar, intermeniscal ligaments) and bony attachments as anterior and posterior roots.<sup>4</sup> Although the meniscus is totally vascularized at birth, its vascularity is limited to only the peripheral 10% to 30% zone in adulthood (Fig. 1).<sup>5,6</sup> The morphology of this load-bearing complex structure, which contains radial fibrils centrally, circumferential fibrils peripherally and perforating fibres, determines its vital functions: load bearing, joint stability, joint congruity, increasing joint contact area, decreasing joint contact stresses, protection of articular cartilage, shock absorption, lubrication, limitation of extreme movement and proprioception.<sup>7-9</sup> The structural degeneration or deterioration of the menisci due to senescence, trauma or surgery eventually leads to osteoarthritis of the knee joint, independent of meniscus morphology.<sup>10-16</sup>

The risk factors for meniscal tears were summarized in a recent systematic review.<sup>17</sup> In this study, on the one hand, advanced age (> 60 years), male gender, work-related kneeling, squatting and climbing stairs (> 30 flights) were found as risk factors for degenerative tears with strong supporting evidence. On the other hand, daily sitting more than two hours was found to reduce the risk for degenerative tears with strong evidence. Moreover, for



**Fig. 1.** Arthroscopic view illustrating meniscal vascularity. Note the bleeding from the peripheral part of the lateral meniscus after partial meniscectomy.

acute traumatic tears, playing soccer and rugby and waiting more than 12 months between anterior cruciate ligament (ACL) injury and reconstruction were found to be important risk factors with strong evidence.

## Clinical evaluation

History taking, which may give important diagnostic clues for experienced surgeons, must be the first step in clinical evaluation for meniscal tears. Patients may have the following complaints: pain, subacute swelling, hearing or sensation of a ‘pop’ during injury, and mechanical symptoms such as popping, limitation of range of movement, catching, locking, etc. It should also be noted that the type and severity of meniscal tears do not correlate with the patient’s symptoms.<sup>18</sup>

Physical examination should be performed systematically, beginning from the evaluation of lower extremity alignment to the evaluation of ligamentous and soft tissues. Although special provocative signs for meniscal tears (McMurray, Apley test, ‘Bounce’ test, Thessaly test and especially joint line tenderness, etc.) are present, their accuracy, specificity and sensitivity are highly variable and questionable.<sup>19,20</sup> It should be kept in mind that these above-mentioned mechanical symptoms and physical findings may also be found secondary to articular cartilage or ligamentous injuries. Although an experienced surgeon may suspect meniscal tears following a careful history and physical examination, radiographic and arthroscopic evaluations should be made to confirm the diagnosis. Moreover, radiographic evaluation is performed for malalignment, concomitant bony pathology, presence of arthritic changes, etc. MRI and arthroscopy are still the benchmark non-invasive and invasive methods for the evaluation of meniscal tears, respectively.<sup>21-23</sup>

## Classification

Meniscal tears can be classified according to the tear patterns, aetiology and MRI. However, the most recent concise, reliable and valid classification system for meniscal tears is the International Society of Arthroscopy, Knee Surgery and Orthopaedic Sports Medicine classification, which takes into account the following parameters: tear depth, tear pattern, tear length, tear location/rim width, radial location, location according to the popliteal hiatus, and quality of the meniscal tissue.<sup>24</sup> The main limitations of this classification are reported as the absence of oblique tears, root ligament injuries, lesions of discoid variants and the evaluation of previously operated menisci.<sup>22</sup> The most common meniscal tears in active young people and in the elderly are traumatic longitudinal-vertical and degenerative tears respectively. The most common side and site for tears are the medial meniscus and the posterior horn of the menisci.<sup>25</sup>

## Management strategies

The vital functions of the meniscus and the development of osteoarthritis reported after its resection, has forced orthopaedic surgeons to protect as much as possible, to repair or to reconstruct the meniscus. The management decision to use non-operative or operative methods should take into consideration factors related to patients (age, expectations, activity level, lifestyle, general health status, etc.) and lesions (location, type, aetiology, tissue quality, associated lesions, etc.). It is the orthopaedic surgeon’s responsibility to combine clinical information, radiological images and clinical experience in an effort to tailor the correct management in an individualized way, according to the factors related to the patient and the lesion.<sup>26</sup>

### Non-operative management

Non-operative management is useful for the initial treatment for acute knee trauma and as a first-line treatment method in degenerative meniscal tears. In the former situation, the ‘PRICE’ (protection, rest, ice, compression, elevation) protocol is applied. In the latter case, non-operative management (anti-inflammatory and analgesic medications, quadriceps strengthening, activity modification, unloader bracing and intra-articular injections, etc.) rather than surgical methods should be tried for at least three to six months, if the mechanical symptoms do not dominate the clinical picture.<sup>27-29</sup> If the patient’s symptoms persist thereafter, the surgical alternatives, which are summarized below, are available.

### Operative management

Currently, there are three main methods for the surgical management of meniscus tears: meniscectomy, meniscal

repair, and meniscal reconstruction. In a recent meta-analysis, it was emphasized that there was a deficiency of high-level evidence to guide the surgical management of meniscal tears.<sup>30</sup>

#### *Meniscectomy (open versus arthroscopic, total versus partial)*

Meniscectomy can be performed totally or partially, open or arthroscopically. The first arthroscopic meniscectomy was believed to be performed by the ‘father’ of arthroscopy, Masaki Watanabe.<sup>26</sup> In the current era, total meniscectomy is almost never performed or advised as a primary procedure in meniscal lesions. This is due to its detrimental effects, most importantly development of early osteoarthritis and unsuccessful long-term clinical results.<sup>10,11</sup> Interestingly, although the rate of total knee arthroplasty due to symptomatic osteoarthritis of the knee after open total meniscectomy in adolescence was found to have increased comparatively in a prospective longitudinal 40-year follow-up study, it should also be noted that not all the patients had undergone surgery.<sup>31</sup> Currently in the modern treatment of meniscal tears, neither open nor arthroscopic total meniscectomy are advised to be performed primarily in most cases.

Partial meniscectomy can be performed in an open or more frequently arthroscopic fashion. It is indicated in patients who have radial tears in the white-white zone and degenerative meniscal tears – which are considered as the precursor lesion of early stage osteoarthritis – with mechanical symptoms and refractory to at least 3-6 months of non-surgical management, and if meniscal repair is not possible due to factors related to the patient or lesion. Arthroscopic partial meniscectomy (APM) is the most frequently performed surgical procedure for the treatment of meniscal tears (Fig. 2).<sup>32,33</sup> The three main reasons are the rapid speed of the procedure, low morbidity, and good short-term results.<sup>34</sup> The details of the modern surgical techniques on APM for the above-mentioned commonly-described patterns of meniscal tears were recently described in detail.<sup>35</sup> The short-term clinical results were found to be highly successful, but a high rate of progression to osteoarthritis at long term was also demonstrated.<sup>36</sup> Moreover, even with degenerative and traumatic meniscal tears, recent, relatively high LoE studies have found low to moderate evidence regarding the absence of long-term comparative clinical benefit between APM and non-operative or sham treatments.<sup>37-41</sup> In symptomatic, degenerative root tears of the medial meniscus, APM was found to provide no benefit at all, with female gender, increased body mass index and meniscal extrusion as bad prognostic factors.<sup>42</sup>

Currently, due to the above-mentioned reasons and clinical results, APM should be the last resort for most meniscal tears, even degenerative meniscal lesions, and should be limited as far as possible. It may be applicable in

carefully selected patients, who have persistent mechanical symptoms from degenerative tears, symptomatic complex tears with a damaged meniscus and non-repairable tears in middle-aged patients with non-symptomatic ACL injury for traumatic tears.<sup>27</sup> According to the current algorithm of the 2016 ESSKA Meniscus Consensus Project, the messages regarding APM were as follows:

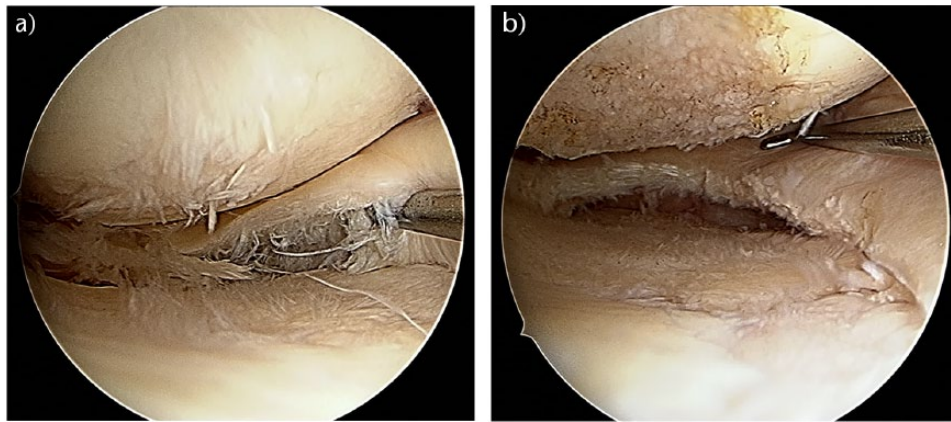
1. APM should not be considered as the first-line treatment choice;
2. APM should only be proposed after a proper standardized imaging protocol;
3. APM can be proposed after three months of persistent pain/mechanical symptoms or earlier in cases with considerable mechanical symptoms;
4. No APM should be proposed with advanced osteoarthritis on Schuss view.<sup>43</sup>

#### *Meniscal repair*

Meniscal repair can be performed open or arthroscopically. Meniscal repair was initially performed by Annandale and DeHaven.<sup>44-46</sup> After this milestone in the history of meniscus surgery, the first arthroscopic repair was performed by Ikeuchi.<sup>26</sup> The era of meniscal preservation was based on three pillars: repair of the torn meniscus whenever reasonable; non-surgical treatment of asymptomatic meniscal pathologies despite a meniscal tear according to MRI; and partial meniscectomy and resection of as much as necessary and as little as possible.<sup>34</sup> In this regard, the most amenable tears to be repaired are acute, traumatic tears within the peripheral well-vascularized red-red zone which are longitudinal-vertical in orientation.<sup>15</sup> In traumatic tears, the first choice is repair or non-removal.<sup>27</sup> Extended indications for meniscal repair were recommended for the subsequent clinical entities: horizontal cleavage tears in young athletes, root tears, ramp lesions, radial tears and tears in the red-white zone.<sup>47-52</sup>

Open repair may be still useful, especially for posterior meniscal tears with a very tight medial compartment, if percutaneous release of medial collateral ligament does not provide enough visualization of the compartment.<sup>21</sup> Although successful clinical results were reported with open repair, there has been increasing evolution from open to arthroscopic repair and currently the latter predominates for meniscal tears.<sup>53</sup>

At present, there are three main techniques for meniscal repair: inside-out, outside-in, all-inside. Among them the strongest repair has been accepted as the inside-out technique, which was first described by Henning.<sup>54,55</sup> In this technique, the tear is fixed by placement and fixation of the passing sutures from the intra-articular region with the use of special cannulae to a safe extracapsular area over the capsule with a posterolateral or posteromedial incision. For the posteriorly-placed tears, an open



**Fig. 2.** Arthroscopic view of a degenerative medial meniscus posterior horn tear, unresponsive to non-operative management (a). After arthroscopic partial meniscectomy (b).

technique with the use of special retractors is used in order to protect the neurovascular structures. The benchmark currently remains an inside-out vertical mattress suture repair.<sup>56</sup> Successful clinical results have been reported with inside-out meniscal repair.<sup>57,58</sup>

Outside-in techniques were described by Warren and Levy and Morgan and Casscells.<sup>59,60</sup> In this less frequently used technique, passing sutures were passed through the previously passed two spinal needles from the meniscal rim to the meniscal body across the meniscal tear. The two ends of the passing sutures were tied onto the capsule, under direct vision. The improper apposition of the ends of the meniscal tear is an important disadvantage of this technique.

The all-inside technique with the use of a suture hook device was first described by Morgan.<sup>61</sup> Thereafter an absorbable polylactic acid tack implant was introduced by Albrecht-Olsen et al.<sup>62</sup> Various polylactic acid-based implants have also been used: arrows, screws and staples, but due to implant-induced synovitis and cartilage damage etc., the use of these implants has fallen out of clinical practice.<sup>63</sup> The flexible, suture-based devices have become more popular since 2006 (Fig. 3).<sup>64</sup> The pull-out strength of the all-inside suture-based devices was found to be similar to traditional mattress sutures.<sup>65,66</sup> This technique has been an increasingly used method for most meniscal tears due to its advantages: avoidance of opening accessory portals and additional incisions, easy applicability, use of bio-absorbable implants and relatively less risk for injury to posterior neurovascular structures. However, its use is limited to anteriorly placed meniscal tears.

As a result, in a recent systematic review by Fillingham et al,<sup>63</sup> two important conclusions were reported. First, the quality of evidence comparing inside-out and all-inside meniscal repair remained low, with a majority of the literature being evidence level 4 studies. Secondly, there were no significant differences in terms of

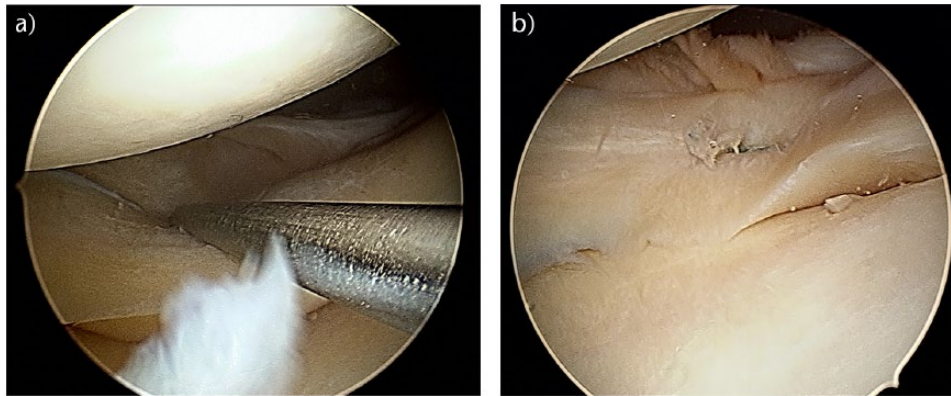
anatomical and clinical failure rates, functional outcome scores and complication rates. In a meta-analysis, it was concluded that although meniscal repairs had a higher re-operation rate than meniscectomy, they result in a better long-term functional outcome, better activity level and lower failure rate.<sup>67</sup> Moreover, meniscal repair was found to be more cost-effective than meniscectomy.<sup>68</sup> Although the advantages of meniscal repair outweigh those of meniscectomy, interestingly, APM is still more frequently performed. This may be due to the fact that repair is technically more demanding, more time-consuming, needs longer rehabilitation time and is more expensive.<sup>34</sup>

In order to enhance healing after meniscal repair, a variety of augmentation techniques and biological products have been introduced: needling, trephination, platelet-rich plasma, bone marrow aspirate, hyaluronan-collagen scaffold, fibrin clot, fibrin glue, mesenchymal stem cells, growth factors, etc.<sup>69-73</sup> Except for needling and trephination, the evolving significant potential for biological augmentation and tissue engineering strategies in the enhancement of meniscal repair and reconstruction still requires high level of evidence comparative studies in order to be translated clinically to be put forward as the optimal method of treatment.<sup>27,74,75</sup>

#### *Meniscal reconstruction*

Meniscal reconstruction techniques, which are used to replace the partially or totally resected meniscus in symptomatic patients unresponsive to conservative management, mainly consist of two main procedures: meniscal scaffolds and meniscal allograft transplantation (MAT). Although saving meniscal tissue is the ideal management method, partial or total meniscal resection are also used, especially in irreparable meniscal lesions or by inexperienced surgeons for meniscal repair. In the latter cases, meniscal reconstruction is a last chance to fill the defect after





**Fig. 3.** Arthroscopic view of acute, traumatic, longitudinal-vertical tear of the lateral meniscus posterior horn (a). ‘All-inside’ horizontal suture of the lateral meniscal tear (b).

meniscectomy in patients who are unresponsive to other treatments. They have been relatively rarely performed compared with previously discussed procedures.

The main aims of meniscal reconstruction procedures are to place safely a functional meniscus that is anatomically and structurally similar to the native meniscus, to restore the knee and lower extremity biomechanics, to improve joint function, to relieve pain and eventually to prevent or delay the degenerative process in the knee joint.

#### Meniscal scaffolds

Highly porous, cell-free and biodegradable meniscal scaffolds are used to fill the defect in the previously partially-resected meniscus and to develop the meniscal tissue by allowing migration and growth of vascular channels and precursor cells into the scaffold.<sup>76-78</sup>

In clinical practice, there are two main types of meniscal scaffolds: the Collagen Meniscus Implant (CMI) and polyurethane-based scaffold.<sup>79-81</sup> The indications and surgical techniques are similar for these two implants. These procedures can be performed arthroscopically, as described previously.<sup>78</sup> Regarding clinical efficacy, good mid-term and long-term clinical outcomes of polyurethane-based scaffolds and CMI were recently reported.<sup>82-85</sup> Currently, it is concluded that the mid-term survival rate of scaffolds is favourable compared with meniscal repair, but unfavourable compared with MAT.<sup>82</sup> In conclusion, the chondroprotective effects of these implants are still controversial, and long-term higher level of evidence comparative studies are required to clarify the clinical efficacy of these implants.

#### MAT

MAT procedure is not actually a new concept. The interposition arthroplasty with autogenic fat pad was first reported at the beginning of the 1900s.<sup>26</sup> Since the more recent performance of MAT by Wirth in the 1980s, the MAT

procedure has evolved to be what it is now; an increasingly performed, safe, reliable and highly specialized knee procedure, rather than an experimental or investigational surgery in patients whose meniscus is lost for any reason, and who have refractory persistent symptoms.<sup>86-89</sup>

The current indications for MAT were summarized according to the recommendations of consensus statements developed from the 2015 International Meniscus Reconstruction Experts Forum, which were based on current evidence from clinical results following MAT: uni-compartmental pain in the presence of total or partial ‘functional’ meniscectomy; as a concomitant procedure to revision ACL reconstruction to aid in joint stability when meniscus deficiency is believed to be a contributing factor to failure; or as a concomitant procedure with articular cartilage repair in a meniscus-deficient compartment.<sup>90</sup>

Currently, the MAT can be performed as an open procedure or arthroscopically in carefully selected patients by experienced surgeons. The malalignment, instability and limb length inequality of the patients must be corrected beforehand or concomitantly. Among four storage methods of meniscal allografts (fresh viable, fresh-frozen, cryopreserved and lyophilized), fresh viable and fresh-frozen allograft are recommended.<sup>90,91</sup> The optimal-sized allograft, according to the MRI or radiological knee films of the patient, can be fixed with or without bone plugs or block. In order to obtain conclusive results regarding the relative technical and clinical superiority, the relevant literature requires comparative studies with higher LoE, involving higher numbers of patients and longer follow-up periods.

### Management of special lesions

#### Root tears and ramp lesions

Lateral and medial menisci are attached to the tibial plateau anteriorly and posteriorly via meniscal root

ligaments. Their tear was firstly described by Pagnani.<sup>92</sup> Although tears of meniscal roots are relatively less common than meniscal body tears, their biomechanical and clinical impact is more significant in terms of stability and shock absorption functions.<sup>93</sup> Their injuries are frequently underestimated and unrecognized by inexperienced, or sometimes experienced, surgeons. A high index of suspicion is necessary for diagnosis. The pathognomonic signs are found on MRI: ‘ghost’ signs (absence of posterior root on sagittal images) and meniscal extrusion.<sup>94</sup> Three specific lesions related especially to posterior meniscal roots are present: root avulsion injuries, radial tears and degenerative changes.<sup>95</sup> Meniscal extrusion, which is also present with posterior root tears, impairs the stability and biomechanical functions of the menisci.<sup>96</sup> Although the management of these lesions is relatively new, a current algorithm was suggested by Bhatia et al:<sup>52</sup> non-operative treatments (anti-inflammatory medication, activity modification, unloader bracing and intra-articular chondroprotective injections, etc.) for improper surgical candidates; meniscal root repair for acute tears and chronic tears without pre-existing arthritis; and partial meniscectomy for chronic and symptomatic tears with pre-existing arthritis. Regarding meniscal repair, the subsequently described techniques at present are: transosseous pull-out suture, suture anchor and side-to-side repairs.<sup>95,97,98</sup>

Ramp lesions, which are longitudinal peripheral lesions of the posterior medial meniscus or meniscocapsular junction, previously called ‘hidden lesions’, mostly associated with ACL tears, form a relatively new terminology after the systematic arthroscopic exploration of the knee joint.<sup>50,99</sup> Although their diagnosis requires a high index of suspicion, posteromedial tibial bone bruising was found to be an important secondary MRI finding of ramp lesions.<sup>100</sup> They were also classified by Thauinat et al.<sup>51</sup> The treatment alternatives were reported as non-operative, inside-out repair and all-inside repair.<sup>50,51</sup>

Currently, the optimal management and technique regarding meniscal repair in root tears and ramp lesions is still evolving and remains debatable and controversial.<sup>50-52,101</sup>

### Discoid meniscus tears

Since the first observation and description of discoid meniscus, which was more frequently seen laterally than medially, it is established that it is more prone to tearing than a normal meniscus.<sup>102</sup> The current management depends mostly on the symptomatology of the patient. Asymptomatic discoid meniscus is classically treated conservatively. If the patient is symptomatic, the preferred method is APM (saucerization) with preservation of the stable peripheral rim, which has seen successful clinical results.<sup>102</sup>

## Conclusions

The enthusiastic evolution of meniscus surgery has seen a great change from interest in repair in the 1800s to total resection in the 1970s, and finally to protection, or reconstruction if resected, from the 1990s to the present day.<sup>103</sup> The rapid developments in cell biology and tissue engineering will advance new alternative biological methods in the treatment of meniscal tears in the future. Finally, meniscus surgery has come a long way from the old slogan ‘if it is torn, take it out!’, to the currently accepted ‘Save the meniscus!’, which now guides the evolving modern treatment methods for meniscal tears. ‘Save the meniscus!’ is the slogan which will probably constitute the basis for newer alternative biological treatment methods in the future.

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