LECTURES

Thirty years of arthroscopic meniscal suture: What’s left to be done?

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Introduction

The first arthroscopic meniscal suture was performed in 1976 by Ikeuchi, a student of Watanabe, who was one of the fathers of arthroscopic surgery; and the subsequent 3 decades have shown meniscal repair to be effective over the medium and long term in 70 to 80% of cases. Despite these excellent results, meniscal repair represents, on an annual basis, no more than 2% of meniscal surgery as a whole, according to the data reported by Charrois et al.[1] to the 2008 congress of the French Arthroscopy Society (SFA). Given that the SFA’s “educational impact” is fairly strong in France, the situation may be presumed to be much the same if not worse in the other European countries. On the other hand, monitoring SFA meetings on meniscal pathology reveals an increase in the frequency of repair operations in certain series, from 0% in 1980 to 25% in 2003. Fundamental change in practice would thus seem to follow the timescale of succeeding generations of surgeons. The figures also suggest that meniscal repair enjoys considerable potential for the years to come. Specific lesion types are becoming better known — and we shall give a few examples below — while at the same time surgical techniques are getting simpler. The trend is to less invasive surgery, with improved safety and greater technical precision. The 1980s and 1990s saw the initial clarification of the anatomobiological mechanisms of meniscal tissue healing, and at the present time, there is a new interest in the surrounding biological environment. This may yet come to resemble the current vogue for cartilage repair and the prospect of “biological surgery”.

Indications

Indications for meniscal repair may be distinguished in terms of associated lesions, and notably of knee ligament status and lesion morphology. It is agreed that meniscal repair should “ideally” be carried out in young patients (< 40 years) free of associated degenerative lesion, for vertical lesions in the peripheral third of the meniscus (red-red zone), preferably associated to anterior cruciate ligament (ACL) reconstruction. The various clinical situations for which meniscal repair may be indicated are detailed below.

Meniscal lesions on unstable knee

In acute knee sprain, most meniscal lesions associated with ACL tearing seem to be lateral, while medial meniscus (MM) lesions tend to be more frequently associated with chronic instability. This difference in evolution between medial and lateral meniscus (LM) lesions is due to biomechanical and kinematic factors. In anterior laxity, the MM has been shown to act as a secondary stabilizer of the knee [2], with a

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significant increase in posterior horn stress [3]. It is this stabilizing role that accounts for the increased rate of MM lesions in unstable knees [4,5]. They are to be found in the posterior horn, mainly at the periphery or even at the peripheral capsule attachment. They are not always immediately obvious and need to be specifically looked for — either directly, by inspecting the posterior compartment, or indirectly when posterior horn instability is detected by the hook palpator. The LM, in contrast, is more mobile and plays little part in stabilization [2,6]. It is under less stress than the MM in chronic laxity, and therefore, few if any additional LM lesions appear over time. In terms of knee kinematics, the posterior horn of the MM is compressed between the tibial plate and the femoral condyle during maximal flexion, whereas in the LM, it subluxates posteriorly to the tibial plate [7], thereby undergoing greater shear stress, mainly affecting the body segment, which is more rarely involved than the posterior horn in unstable knees (25% vs 75% of lesions, respectively [8]). Consequently, it would seem that certain LM lesions associated with severe knee sprain and ACL tearing may be left in situ [9], as they are capable of spontaneous cicatrization [10,11]. The same is not the case for the medial femorotibial compartment. Pierre et al. [12], analyzing the onset of meniscal lesions secondary to ACL reconstruction with abstention from operating on the initial meniscus lesion, found secondary lesions occurring in the MM while LM lesions remained asymptomatic, in agreement with earlier reports by Beaufils et al. [13], Fitzgibbons and Shelbourne [14] and Zemanovic et al. [15]. At the same time, many studies have reported a secondary increase in the number of MM lesions in chronic anterior instability in both adults [4,5,16] and children [17,18]. These findings were recently corroborated by reports to the SFA’s 2008 LM congress. The rate of MM lesions was shown to increase with increasing accident-to-surgery interval following ACL tear, whereas that of LM and bi-meniscal lesions remained stable over time after the initial sprain [19]. It is therefore recommended that medial meniscal lesions associated with ACL tear should be stabilized [9], and particularly any vertical lesion exceeding 10 mm in length, with associated ligament stabilization.

Beldame [8], in a series of 1000 ACL reconstructions with varying accident-to-surgery intervals, found 43% isolated ACL tears, 29% with associated medial meniscal lesion, 18% with associated lateral meniscal lesion and 10% with associated bimenisal lesion. Posterior horn lesions principally involved the peripheral two-thirds of the meniscus, with a majority of potentially repairable vertical lesions. Even so, in a series of 300 LM lesions, meniscectomy was performed in 52% of cases, compared to abstention (20%) or repair (28%) in 48%. A non-negligible factor determining treatment option was the accident-to-surgery interval, with conservative attitudes prevailing more when patients were operated on early after the initial accident (abstention/repair in 77% of patients treated within 8 weeks vs 42% after 1 year or more). Associated lateral meniscectomy is known to worsen the clinical results of ACL reconstruction [20–23], with onset of pain and swelling. In parallel to this change in surgical practice, there has been found to be an increase over time in the rate of grade ≤ 2 chondral lesions when associated with meniscal lesion, in agreement with the data of Murrell et al. [24]. These secondary lesions, whether chondral or meniscal, argue for rapid anatomic correction of traumatic lesions of the knee.

In recent years, the typology of LM lesions associated with ACL tear has been refined, notably by Ahn et al., although the type of lesion in which surgical stabilization is indicated remains to be defined [25,26]. Moreover, the indications for meniscal repair have been extended to radial lesions, in which only a few years ago, it seemed impossible [27]. Although rare, these lesions are in future worth attempting to repair, as meniscectomy creates a predisposition to lateral meniscal extrusion [28,29], functionally equivalent to total meniscectomy.

**Meniscal lesions on stable knee**

Meniscal lesions on stable knee differ significantly according to age at onset. The large study by Metcalf and Barrett [30] confirmed the pattern found in the literature in general for meniscus lesion morphology: analyzing some 1500 meniscal lesions on stable knee, they found peripheral lesions to be slightly more frequent in patients over the age of 40, and a greater number of complex, degenerative and horizontal lesions in this age group; in contrast, potentially repairable lesions (flaps, bucket-handles and vertical lesions) as well as radial lesions were more frequent in the under-40s. They also reported differences between the medial and lateral menisci: 98% of MM lesions involved the posterior horn while the anterior horn was almost never affected, whereas in LM lesions, the body and posterior horn showed equal involvement and the anterior horn was affected in a quarter of cases. The 2008 SFA LM congress reported similar distributions. With regard to therapeutic attitude, meniscus capital was conserved in 33% of cases, with 21% suture, 10% combined meniscectomy and repair and 2% abstention [31].

**LM posterior horn instability**

A specific subcategory is that of LM posterior horn instability (Fig. 1). These lesions are rare and are mainly found in teenage and young patients. They are to be borne in mind in case of painful knee locking with no immediately obvious structural lesion on arthroscopy. In such cases, meniscal instability should be checked by hook palpator. Posterior horn luxation beyond the femoral condyle equator is to be considered pathological. Such instability may be associated with a posterior horn flap masking the initial cause of the lesion. The literature on this subject is not abundant. Simonian et al. [32] described the specific anatomy of the posterior LM attachment, with popolemeniscal fibers and their MRI aspect. George and Wall [33] reported the case of a 9-year-old patient presenting with symptomatic instability of the posterior horn of the LM, repaired by inside-out suture. A similar case was reported by Garofalo et al. [34] in a 19-year-old soccer player.

**Horizontal LM delamination**

Repair surgery for horizontal LM delamination frequently encounters an associated meniscal cyst (Fig. 2). Surgery is required in case of pain associated either to the joint lesion or to the LM cyst. Cyst symptomatology ranges from unsightly tumefaction to peroneal nerve compression. As symptoms are mild and failure is possible, not all LM cysts
Thirty years of arthroscopic meniscal suture: What’s left to be done?

Figure 1 Example of painful instability of the posterior horn of the left lateral meniscus. A 15-year-old soccer player consulted for recurrent painful knee lock in flexion. Clinical examination suggested a meniscal lesion, although MRI found an apparently normal meniscotibial attachment (A: arrow). Knee arthroscopy found a normal meniscus structure (B), but with the possibility of the posterior LM horn luxating in the joint (C). D: Meniscocapsular repair could be performed using the Arthrex Meniscal Viper (MV), adapted for the purpose by enabling a kind of spatula to hook behind the capsule (arrow). LM: lateral meniscus; LC: lateral condyle.

should immediately be treated. We shall not attempt here to deal with the full range of LM cysts, but rather focus on the associated horizontal lesions, which almost always involve the body segment and often extend to either the posterior or the anterior horn or both. The two superficial meniscal layers are often more or less intact while the conjunctive layer has been destroyed. An innovative attitude has therefore recently developed, seeking to conserve as much meniscal capital as possible [35]. After intra- or extra-articular debridement of the cyst and degenerate meniscal tissue, the remaining two layers of meniscal tissue can be repaired by inside-out suture. Although we are unable to report medium to long-term results, initial findings in our series encourage us to continue with this technique.

Discoid meniscus

This section will seek not to deal exhaustively with the problems posed by discoid meniscus, but rather to provide an update on recent developments in knowledge (Fig. 3). It is now well established that symptomatology triggered by discoid meniscus is absolutely not to be managed by total meniscectomy. Most authors currently recommend partial meniscectomy in the affected area and restoring a normal meniscal form (saucerization). Recent studies have shown most pathological discoid menisci to be associated with peripheral instability due to an absence of meniscocapsular attachment. This is found in 28 to 77% of cases ([36], and [37], respectively) and is more frequent in complete discoid meniscus and in the anterior horn (47—53%) than in the posterior horn (39%) or body segment (11%) [36,37].

Meniscus root lesions

Meniscal root lesions were first described in the early 1990s by Berg and Pagnani et al. [38,39], then forgotten about,
Figure 3  Example of discoid meniscus in a 12-year-old girl (left knee). She presented with flexion contracture and painful crepitation on clinical examination. Examination under anesthesia found a false pivot shift. Arthroscopy found an intact discoid meniscus, detached in the anterior horn. Meniscocapsular repair was performed, using the Conmed-Linvatec Spectrum II with PDS-0 sutures. At 12 months postoperatively, the knee was symptom-free and had recovered normal function.

only to be ’rediscovered’ recently. They consist in either bony or ligamentary avulsion of the posterior horn meniscotibial insertion. Bone avulsion would seem to be the same pathological entity as the previously described meniscal ossicles [40–42]. The posterior detachment robs the meniscus of all biomechanical capacity, resulting in an increase in pressure and reduction in tibiofemoral bearing surface equivalent to total meniscectomy [28,43]. In young patients, the lesion is traumatic, occurring on a stable knee, and can be managed either by anchorage [44] or by transtibial tunneling [25,43,45–48]. Partial meniscectomy, as initially recommended by Pagnani et al., incurs a risk of rapid degeneration. Apart from such purely traumatic lesions in young patients, a series of 67 radial meniscus root lesions in stable knees in older patients (mean age, 56 years) was recently reported by Ozkoc et al. [49]; unlike in the lesions previously discussed, partial meniscectomy was performed here to prevent locking symptoms in these menisci that had probably already lost any biomechanical function. Most medial detachments have been reported in stable knees. Engelsohn et al. [45] described posteromedial meniscal root detachment in severe knee trauma with associated multi-ligament lesions (Figs. 4–6).

These medial lesions are to be distinguished from LM root lesions, which are usually associated with ACL tear, in which their incidence is estimated at almost 7%. Two attempts at classification have been made to date. West et al. [50] distinguish three types of lesion:

• type I comprising root avulsion;
• type II radial lesions less than 1 cm from the root;
• type III complex lesions with radial and vertical components.

Ahn et al. [25,26] distinguish three types of lesion in acute sprain:

• the first is a complex T-shaped lesion associating a radial and a vertical component, equivalent to West’s type III;
• the second is a vertical lesion extending from the root on one side to beyond the popliteal hiatus on the other;
• the third is a radial lesion splitting the meniscal root in two.

This third type, equivalent to West’s type II, is often associated with a meniscofemoral ligament of Humphrey, which is the only ligament stabilization element remaining in the posterior horn. According to Brody et al. [29], the presence of a meniscofemoral ligament correlates with reduced meniscal extrusion, indicating conservation of the meniscus’s buffer function in these cases; even so, Ahn et al. [25,26] advocate suturing these lesions when acute, and this could easily be combined with ACL plasty and notably with tibial tunnels for posterolateral bundle reconstruction in double bundle plasty very close to the posterior insertion of the LM.
Surgical techniques

Stimulating the surrounding meniscal and synovial tissue

After arthroscopic visualization, repositioning of any bucket-handle and hook palpator assessment of lesion stability and healing potential, the 1st step in meniscus repair consists in stimulating the surrounding meniscal and synovial tissue using a shaver or dedicated rasp. Especially in long-standing lesions, it is essential to refresh the scar tissue, which tends to be fairly bradytrophic and vascularized only in the peripheral third. This refreshment triggers the biological processes of tissue repair [51]. Other authors have stressed the importance of refreshing the synovial membrane, to be performed on the tibial and femoral side of the meniscus [52]. Several experimental studies have demonstrated the positive impact on meniscal lesions of vascular input via the synovial membrane [53–55]. Kimura et al. [56] showed that meniscus healing can be obtained in humans even in a non-vascularized (white-white) zone by suturing a free synovial membrane flap into the lesion.

Piercing vascular input channels

Several authors have also described the so-called ‘‘needling’’ technique, which consists in piercing vascular input channels from the base to the avascular center of the meniscus, using an 18G needle. Although Zhang et al. [57] demonstrated the effectiveness of the technique in an animal model, there is little scientific evidence for it from a clinical point of view, apart from one study by Fox et al. [58].

Suturing an autologous venous blood clot

The third ‘‘biological’’ option presently available consists in suturing an autologous venous blood clot into the meniscal lesion in order to supply the growth factors needed for...
Meniscal repair decision tree according to zone of involvement (white/white, white/red, red/red).

Outside-in technique
This consists in percutaneous suture by needle, and can be applied in the anterior horn and body segment. After passing from within to outside the joint, the wires are sutured to the knee capsule. This is a simple and low-cost technique.

Inside-out technique
A few years ago, this was still the most widespread meniscal repair technique. It is suitable for posterior horn lesions, and uses long cannulae to pass long needles through the meniscal tissue. Exiting the needles from the joint requires a posterolateral or posteromedial approach. A wire attached to the long needle is sutured to the extra-articular part of the capsule. The technique requires an additional approach, increasing the risk of iatrogenic damage to the saphena nerve posteromedially and the peroneal nerve posterolaterally and to the main vasculonervous structures in the center of the popliteal space.

All-inside suture technique
Here again, two types of technique are to be distinguished.

For meniscosynovial lesions (Fig. 8) of the capsular attachment of posterior horns that are hard to repair by other techniques, meniscal suture may be performed using a curved "corkscrew" inserter with a posterolateral or posteromedial arthroscopic approach. The wires are sutured using a knot pusher. A Spectrum II suture passer (Conmed Linvatec) can be used, but other firms also manufacture dedicated instruments. The method was developed from one of the earliest meniscal repair techniques, described by Morgan in 1991. It is difficult to perform, as it requires an additional posterior approach and the surgeon needs to be proficient in arthroscopic knot techniques.

The second purely articular technique was developed by Arthrex Inc., with a dedicated instrument called the "Meniscal Viper". Here again, the wires are sutured using a knot pusher. It is especially useful for LM lesions facing the politibone hiatus. In the medial femorotibial compartment, the size of the instrument often requires superficial medial collateral ligament release by percutaneous microincision using a needle; this provides 2 to 3 mm greater joint opening [72] and avoids condyle cartilage lesions.

Meniscal implants
For the last 15 or so years, a range of meniscal implants have been developed, mostly made in biodegradable material. There are anchors, screws and small arrows to be inserted in the meniscal tissue at the lesion site. These techniques are

<table>
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<th>Table 1 Review of main meniscal repair methods.</th>
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<td><strong>Suture</strong></td>
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<td>Inside-out (flexible needles and cannulae)</td>
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<td>Outside-in (standard i.v. needles)</td>
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<td>Meniscal Viper (Arthrex)</td>
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<td>Spectrum II (Conmed-Linvatec)a</td>
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a System developed for shoulder surgery, but adapted to very peripheral meniscosynovial lesion suture (Cooper and Warren, zone 0; Cooper et al. [124]).
Intended for longitudinal lesions in the peripheral third of the meniscus, and especially in the posterior horn. Although they are all poorer than classical meniscal suture in their biomechanical performance, some have proved comparable in terms of clinical result. They were very popular at the turn of the century, but are now giving way to hybrid techniques.

Hybrid techniques

Hybrid techniques combine implants and suture (Table 1). They are quick and relatively easy to perform in simple longitudinal lesions, and are currently very popular despite their cost and the fact that the implants are not always biodegradable. This raises the risk of the implant becoming a free body in the joint in case of detachment, causing subcutaneous or intra-articular irritation (complications).

Results

In reporting meniscal repair results, it is important to distinguish anatomic and clinical recovery rates. The anatomical assessment criteria were introduced by Henning in 1983 [73]. He defined three categories of healing: complete, incomplete and absent. This method of assessment is the most precise, but unfortunately can only be made after invasive diagnosis such as by control arthroscopy or arthrosan or arthro-MRI imaging, with the result that only a few studies have adopted this means of classifying their results. Fig. 9 presents them according to three clinical categories: unstable knee, stable knee and repair associated to ACL plasty. Healing rates vary greatly with clinical context, as can be seen at a glance from this graph. Clinical recovery criteria concern pain, associated or not with intra-articular effusion, and tend to overestimate healing as compared to anatomic criteria, due to clinically silent cases of partial healing [74–76]. Meniscal repair healing rates vary from 50 to 91% [77], and depend on lesion type, associated ligament plasty, knee stability and alignment, and accident-to-surgery interval. Recently, Pujol et al. [78] showed that repair restricted to the posterior horn healed less well than lesions extending to the body and anterior horn; they further reported that healing involved a narrowing of the meniscus, probably due to shortening caused by cicatrization.

Medium-to-long-term results are analyzed on the following three criteria: recurrence rate, X-ray signs of osteoarthritis, and joint function. Recurrence ranges from 7 to 36% (mean, 21%) at 7.5 to 12.9 years’ FU after primary surgery (Fig. 10). Incidence is maximal during the first 3 years following repair. Iterative tearing is more frequent in case of persisting knee instability, which is why it is no longer recommended to repair menisci on unstable knees. The sole exception is early surgery after severe sprain for a meniscal lesion causing mechanical problems such as luxated bucket-handle. In these inflammatory acute phases, a 2-step approach is recommended, with meniscal repair followed by stabilization by ACL plasty remote from the inflammatory phase (i.e., some 6 weeks later). It is noteworthy that the same is very far from being the case with multi-ligament lesions, in which 1-step repair of all affected structures is recommended. X-ray signs of osteoarthritis were found to be more frequent in cases of re-tear than where meniscal repair was effective: 57% vs 15% for DeHaven et al. [79], and 57% vs 13% for Rockborn and Messner [80], and Rockborn and Gillquist [81]. There seems to be a lower risk of osteoarthritis on X-ray in case of meniscal healing.
after suture than after partial meniscectomy; normal knee function was recovered in 76 to 91% of patients.

These findings seem to show that in absence of re-tearing, repaired menisci can recover long-term biomechanical and clinical function, although more long-term studies are needed for a definitive assessment of the benefit provided by meniscal repair.

Prognostic factors

- Meniscal repair associated to ACL plasty: this association provides the best results in meniscal repair, even on strict anatomic criteria [75], with success rates exceeding 75% in most reports. Fig. 9 shows a success rate of between 50% and 75% for meniscal repair on stable knee, while repair on unstable knee without associated stabilization appears much less effective [79]. Several factors can be identified in the better results found with meniscal repair associated to ACL plasty: apart from more favorable biological conditions, with blood effusion supplying the growth factors needed for meniscal healing [52,76], there is also a selection bias: the lesions are traumatic and not necessarily symptomatic, whereas repair on stable knees concerns menisci that are presumably symptomatic and usually represent the sole intra-articular lesion (degenerative meniscus);

- Peripheral lesion location: Cannon and Vittori [75] and Rubman et al. [82] found peripheral lesions to have greater healing potential, confirming the initial anatomic work by Arnoczky which showed meniscal vascularization to be confined to the periphery of the meniscus;
Thirty years of arthroscopic meniscal suture: What’s left to be done? S93

which can cause cartilage abrasion in the femoral condyles (Galaud B, personal communication). Other implants include articular irritation and require secondary ablation surgery blocked behind the meniscus may cause intra- or peri-lesions have been observed [108—113]. Nor are hybrid subcutaneous tissue, synovial irritation, prolonged intra-

Complications

Small [97,98] estimated the complications rate for meniscal repair by suture at 2.6%. The most frequent complications are related to saphena nerve lesions in the posteromedial approach in the inside-out repair technique. In series in which this issue was analyzed, frequency ranged from isolated cases to 12.9% in medial meniscal repair [99—104]. Lesions in the main branch of the saphena nerve induce paresthesia or pain in the nerve territory on the medial side of the limb. They are generally due to compression caused by the retractor or the suture equipment. The infrapatellar branch of the saphena nerve leaves the main nerve trunk in the distal part of the posteromedial approach, and extends laterally and distally. Compression or sectioning of this fine nerve network induces hypoplasia or paresthesia of a territory the size of the palm of the hand below the patella. Such lesions often resolve within 6 months; neurolysis is rarely required.

Jurist et al. [105] and Anderson and LaPrade [106] reported peroneal nerve lesion secondary to LM suture. Other authors have reported medial meniscal cysts following suture [101,107].

Several complications have been reported following use of biodegradable implants. Broken implant migration in subcutaneous tissue, synovial irritation, prolonged intra-articular effusion and sometimes very severe cartilage lesions have been observed [108—113]. Nor are hybrid implants problem-free. A non-resorbable transverse bar blocked behind the meniscus may cause intra- or peri-articular irritation and require secondary ablation surgery (Galaud B, personal communication). Other implants include a kind of cap lying on the femoral surface of the meniscus, which can cause cartilage abrasion in the femoral condyles [114,115].

Rehabilitation

The big short-term disadvantage of meniscal repair compared to meniscectomy is obviously the long period of postoperative rehabilitation. In certain types of lesion, MRI can help predict whether repair is to be preferred over resection (Thoreux et al. [116]), which may be useful for patient information.

At the present time, there is no universally consensal validated program of rehabilitation. Programs vary according to the type and location of the lesion and associated lesions. The biomechanical effects (lesion site reduction, compression and stabilization) of weight-bearing are also to be taken into [117], although mobility under weight-bearing must not be overdone as it could impose undue traction and shearing stress, hindering healing. Compression forces on the posterior meniscal horn increase in flexion, and in maximum flexion the meniscus shifts posteriorly, with the LM slipping behind the tibial plate and the MM being compressed between tibial plate and femur [118,119]. These differences between medial and LM are well known from anatomic studies and imaging, but the biomechanics has not been determined to the point where rehab programs adapted to each meniscus can be designed. At the present time, stress is thought to increase 10-fold in flexion exceeding 90° and to be less in unloaded than in weight-bearing knees. Many authors therefore recommend weight-bearing with the knee locked in extension in a brace for a period of around 6 weeks. Except in rare radial or root lesion repairs, weight-bearing in extension avoids harmful stress in the repair site. At the same time, it is recommended to restrict passive flexion to 90° during this period and to avoid all active flexion and any flexion movement exceeding 90°. Tien et al. [120] showed that the MM is very mobile in rotation in the first 30° of flexion, so that rotation movement should also be avoided during the first postoperative weeks. Pivot, and especially pivot-contact, activity as well as squat exercises involving maximum flexion of the knee under weight-bearing are not to be resumed for 4 to 6 months.

Several studies have analyzed the effects of more aggressive rehabilitation programs. Barber and Click [121,122] and Mariani et al. [123] found no harmful effects of what they call ‘‘aggressive rehabilitation’’ on meniscal repair outcome. It should, however, be borne in mind that most studies were of repair associated to ACL plasty and that their evidence value is limited by the number of cases included and the composition of the studies.

References


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Thirty years of arthroscopic meniscal suture: What’s left to be done? S95


