Meniscal Repair

Abstract: The meniscus plays an important role in preventing osteoarthritis of the knee. Repair of a meniscal lesion should be strongly considered if the tear is peripheral and longitudinal, with concurrent anterior cruciate ligament reconstruction, and in younger patients. The probability of healing is decreased in complex or degenerative tears, central tears, and tears in unstable knees. Age or extension of the tear into the avascular area are not exclusion criteria. Numerous repair techniques are available, and suture repair seems to provide superior biomechanical stability. However, the clinical success rate does not correlate well with the mechanical strength of the repair technique. Biologic factors might be of greater importance to the success of meniscal repair than the surgical technique. Therefore, the decision on the most appropriate repair technique should not rely on biomechanical parameters alone. Contemporary all-inside repair systems have decreased the operating time and the level of surgical skill required. Despite the ease of use, there is a potential for complications because of the close proximity of vessels, nerves, and tendons, of which the surgeon should be aware. There is no clear consensus on postoperative rehabilitation. Weight bearing in extension would most likely not be crucial in typical longitudinal lesions. However, higher degrees of flexion, particularly with weight bearing, give rise to large excursions of the menisci and to shear motions, and should therefore be advised carefully. Long-term studies show a decline in success rates with time. Further studies are needed to clarify the factors relevant to the healing of the menisci. Tissue engineering techniques to enhance the healing in situ are promising but have not yet evolved to a practicable level. Key Words: Age—Growth factors—Healing—Meniscus—Rehabilitation—Repair technique.

Clinical evidence supports the hypothesis that meniscectomy leads to cartilage degeneration in men. Meniscectomy increases the risk of developing osteoarthritis (OA) of the knee significantly after more than 20 years. The extent of resection relates to the degree of radiologic OA. These arguments suggest that meniscal repair should lead to an improved clinical outcome compared with meniscectomy. However, the results found in the literature are equivocal. Some authors have reported fewer radiologic symptoms of OA in patients who had their meniscus repaired compared with patients who underwent meniscectomy. Others failed to prove a substantial clinical benefit to repairing a meniscus. A number of case series reported high rates of clinical success of meniscal repair, but investigations with a strong study design are rare. The available data indicate that meniscal repair cannot reliably prevent the progression of degenerative changes and clinical symptoms. A potential explanation is that both meniscal lesions and cartilage damage occur as different features of the same entity, which is not cured by repairing the meniscus. Indeed, there is evidence that meniscal pathology occurs not
only as a cause but also as a symptom of OA of the knee.\(^5\) It seems possible that the fate of a repaired meniscal lesion depends largely on its nature: namely, whether it is degenerative or traumatic in origin. Nonetheless, meniscectomy is an irreversible procedure. Neither replacement nor regeneration of the meniscus have yet evolved to a satisfactory level. It is therefore reasonable to prefer repairing the meniscus to removing it.

**BLOOD SUPPLY AND TEAR LOCATION**

In adults, only the peripheral 10% to 25% of the meniscus is vascularized (Fig 1).\(^6\) In normal tissue repair, local bleeding provides cellular elements and biochemical mediators that are essential for the repair response. It is therefore generally believed that it is the missing vascular supply that limits the healing capability of the central zones. However, it was shown in animal explant culture models that meniscal tissue is capable of a repair response in the absence of vascularity.\(^7\) In a clinical study of 198 meniscal repairs that extended into the avascular zone, 80% remained asymptomatic at follow-up.\(^8\) Kalliakmanis et al.\(^9\) did not find a significant difference between tears located in the red–red zone and tears in the red–white zone.\(^9\) Cannon and Vittori\(^10\) found a substantial drop in the healing rates if the rim width exceeded 4 mm in stable knees. Tears located mainly in the central zone have an inferior healing capability.\(^11\)

So far, it has not been established if the locally different healing response is solely a matter of the vascular supply. Mechanical stress, for instance, may influence the behavior of cells populating the meniscus. The chance of healing is increased if the tear either is located in the vascularized area or if access to blood elements is created. Therefore, most surgeons limit repair to lesions located in the Cooper zones\(^12\) 1 and 2 (Fig 2). Nevertheless, an extension of the tear into the avascular area is not an exclusion criterion. In select patients, such as young athletes, the chance of healing probably outweighs the potential risks of the procedure.\(^13\)

**Tear Pattern and Shape**

Meniscal lesions are generally more common in males.\(^14\) Metcalf and Barrett\(^15\) investigated tear patterns in a large number of patients with stable knees; 39% were peripheral tears (Cooper zone 1 or 2). The majority of tears occurred in the posterior horns, with 73% being isolated medial tears and 19% isolated lateral tears. Horizontal tears were most common in this study, followed by complex and flap tears. Longitudinal and bucket-handle tears were found in 19% of cases. In a similar study that investigated patients with an anterior cruciate ligament (ACL) rupture, the portion of lateral meniscal tears increased to 50% in acute cases.\(^16\) Again, most tears were located in the posterior horns. Peripheral tears (Cooper zones 1 and 2) were found in more than 60% of cases. The probability of encountering tears suitable for repair is substantially decreased in stable knees compared with ligament injured knees. If repaired, double longitudinal or complex tears have a higher probability for failure.\(^8\) Tears that involve only the posterior segment seem to have an inferior healing rate compared with lesions extending into the middle segments.\(^17\)
Horizontal cleavage tears are a frequent finding and may exist without clinical symptoms. There is little information on the significance of this type of tear. They can give rise to flap tears but are otherwise mechanically stable. It has not been clarified yet whether patients benefit from the repair of these tears. It appears questionable if sutures could neutralize the shear motion that is thought to be responsible for the development of these tears. If horizontal tears are encountered incidentally—during ACL surgery, for example—they might be left alone. At times, those tears are accompanied by meniscal cysts, which are thought to arise from the influx of joint fluid through meniscal tears. Partial meniscectomy is often carried out to drain the cyst. It has been suggested that aspiration of the cyst and closure of the tear with sutures could avoid the need for a meniscectomy.

Controversy exists concerning radial tears. They should be clearly distinguished between complete and partial radial tears. Empirically, partial radial tears often affect the central parts while the outer rim remains intact. This has important mechanical implications: in partial radial tears, the important circumferential fiber bundles are mostly intact and the function of the meniscus is retained. Further, those tears largely extend into the avascular area, which limits the chance of healing. Therefore, particularly in small radial tears, debridement of loose edges is usually sufficient. In cases of a complete trans-section, however, the effect can be similar to a complete meniscectomy. If left untreated, weight bearing would extrude the meniscus out of the joint space and most likely no functionally sufficient healing would occur. Although it has been found that lateral meniscal tears in conjunction with ACL tears seem to have good prognosis in general, some surgeons including the authors of this review, feel that it might be beneficial to approximate and secure the tear margins of a complete tear with sutures. In those cases, non-weight bearing exercise is warranted postoperatively because circumferential stress (so-called “hoop stress”) is induced in the meniscus with tibiofemoral loads, which would distract the tear margins.

The influence of the tear length on the failure rate is not entirely clear. Although some authors could not prove an association between the failure rate and the length of the tear, others found that failures occurred significantly earlier in larger tears. In one study, the healing rate was in excess of 90% if the length of the tear was less than 2 cm, whereas it was only 50% with tears larger than 4 cm.

### Medial Versus Lateral Lesions

In a series of 53 patients, no significant difference in the healing rate was found by means of computed tomographic arthrography for the medial and lateral meniscus. Cannon and Vittori found lateral menisci to have a better healing rate than medial menisci. Another investigation into ACL-reconstructed knees did not find different failure rates for lesions located in the Cooper zones 1 and 2 of either the medial or lateral meniscus. It is not entirely clear whether or not the healing potential in the medial and lateral meniscus are different. Yet the potential sequelae of meniscectomy are more serious in the lateral meniscus than in the medial. Therefore, in the decision-making process, it matters which of the menisci is affected.

### Influence of Age

It has been observed that meniscal tissue from patients over 40 years of age has a lesser cellularity and a decreased healing response than tissue from younger patients. Stratifying their patients into groups older and younger than 30 years and found retears to be more frequent in older patients. Bach et al. analyzed failures in a series of 300 meniscal repairs. The average time to failure was 34 months in this study. Older patients failed significantly later than patients younger than 30 years of age. Other investigators did not find a correlation between the revision rate and patient age in 113 cases of an inside repair using the Meniscus Arrow (Conmed Linvatec, Largo, FL). In a recent study, the results of meniscal repair in patients with reconstructed ACLs are reported, and in terms of failures, no difference was found between patients older or younger than 35 years of age. The rates of clinical success in repair procedures, which involve the avascular area, seem not to be worse in older patients (40 to 58 years) compared with the younger population. The outcome of repair in young patients is not generally favorable, as one might expect. By means of arthrography or magnetic resonance imaging, it was shown that healing of repaired tears remained incomplete in a high fraction of young patients, even in the absence of symptoms. The same negative prognostic factors as in older patients, such as a complex tear configuration, large distance to the periphery, or ligamentous instability, apply to the younger patients. Obviously, the clinical results in younger patients are in conflict with the better intrinsic healing capability that the basic science suggests. First, there are no randomized controlled studies in which the treatment
allocation is primarily based on patient age. Most investigators will consider the macroscopic appearance of the meniscus in their treatment decision and would not repair tears in grossly degenerated menisci. This results in a selection bias, which potentially obscures the influence of the patient’s age. Further, higher demands in sports and occupation in the young population might compromise the outcome despite a better intrinsic healing capability. The available data suggest that age is not a general contraindication to meniscal repair—it merely increases the likelihood of encountering a tear that is not suitable for repair.\(^\text{15}\)

**CHOICE OF THE REPAIR TECHNIQUE**

A central question for the surgeon is whether the healing response and long-term outcome depends on the technique that is used. Horizontal sutures usually yield a lower failure load because they lie in between the circumferential fiber bundles and are pulled through those as they are loaded.\(^\text{33}\) Vertical sutures are commonly considered the gold standard in regard to the strength, which was found to be in a range from about 60 N to more than 200 N, depending on the investigated model.\(^\text{34,35}\) In the case of vertical sutures, failure occurs mainly by rupture of the suture because the strong circumferential fiber bundles of the meniscus are contained within the suture loop. Here, the choice of the suture material determines the failure load.\(^\text{36}\) In general, vertical sutures are preferred to horizontal stitches; the techniques are very similar, but vertical sutures result in stiffer repairs. Variations, with the limbs of the suture crossing each other, further increase the failure load.\(^\text{37}\) Conventional suture techniques are afflicted with a relatively long operat-

### Table 1: Overview of Meniscal Repair Instruments and Implants

<table>
<thead>
<tr>
<th>Suture Repair Systems</th>
<th>Suture Rigid Implants</th>
<th>Rigid Implants</th>
</tr>
</thead>
<tbody>
<tr>
<td>● Inside-out (generic flexible needles and prebent cannulae)</td>
<td>● Meniscus Arrow (Conmed Linvatec)</td>
<td>Meniscus Arrow (Conmed Linvatec)</td>
</tr>
<tr>
<td>● Outside-in (generic intravenous cannulae)</td>
<td>● Meniscal Dart (Arthrex)</td>
<td>Meniscal Dart (Arthrex)</td>
</tr>
<tr>
<td>● All-inside (Meniscal Viper [Arthrex])</td>
<td>● BioStinger (Conmed Linvatec)</td>
<td>BioStinger (Conmed Linvatec)</td>
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<tr>
<td></td>
<td>● Meniscal Screw (Biom)</td>
<td>Meniscal Screw (Biom)</td>
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<td></td>
<td>● FasT-Fix (Smith &amp; Nephew Endoscopy)</td>
<td>FasT-Fix (Smith &amp; Nephew Endoscopy)</td>
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<td></td>
<td>● MaxFire (Biomet)</td>
<td>MaxFire (Biomet)</td>
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<td></td>
<td>● Meniscal Cinch (Arthrex)</td>
<td>Meniscal Cinch (Arthrex)</td>
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<td></td>
<td>● RapidLoc (DePuy Mitek)</td>
<td>RapidLoc (DePuy Mitek)</td>
</tr>
</tbody>
</table>

**FIGURE 3.** Bioreorbable implants. (A) Meniscus Arrow (Conmed Linvatec). (B) Meniscal Dart (Arthrex). (C) BioStinger (Conmed Linvatec).
ing does not necessarily cause clinical symptoms. Therefore, rates of so-called clinical healing do not exactly reflect the healing status in a structural sense. Further, the clinical success rates do not correspond closely to the magnitudes of the mechanical strength that is found for the different repair techniques (Table 2). The available data do not support the assumption that stronger repair techniques are accompanied by better outcomes. It must be acknowledged that mechanical testing is usually done in the axis of insertion, although it has not been shown conclusively that substantial distraction forces do occur on repaired lesions. Shear forces might be more relevant but are not addressed in most studies investigating the stability of repair systems.

The success rates for the Meniscus Arrow and conventional sutures seem to drop with time (Table 2). Because there are no long-term studies for the newer implants, the false impression might arise that those are more successful than sutures or the Arrow. It is possible that the same decline in the healing rate will take effect with a longer follow-up of those systems.

COMPLICATIONS AND PITFALLS OF MENISCAL REPAIR

Bleeding or pseudoaneurysms descending from popliteal vessels are described with arthroscopic meniscal surgery. But those reports almost exclusively pertain to the resection of the posterior horns, not meniscal repair. In a cadaver study, it was found that the lateral genicular artery is at risk of being penetrated by the needle with inside-out and outside-in sutures of the lateral meniscus (Fig 6). However, it has not yet been established whether a laceration of this vessel has detrimental effects on the healing meniscus.

Capture of branches of the peroneal nerve is possible when lateral meniscal lesions are sutured, but seems to be rather seldom. Proper use of retractors can largely avoid this complication. In the case of medial meniscal repair, the saphenous vein and nerve are at risk of being affected. Although transient neuro-
praxia was described in up to 22% of cases, permanent damage was found to occur in 0.4% to 1%. An anatomic study that investigated the placement of the T-Fix (Smith & Nephew Endoscopy) device showed that neurovascular structures seem not to be at risk of being pierced with the insertion cannula. In a more recent investigation, the authors found that the application cannula of a FasT-Fix device came within 3 mm of the popliteal artery under certain circumstances, whereas the RapidLoc (DePuy Mitek, Raynham, MA), with its shorter cannula, had a greater distance to that vessel. The use of the depth limiter that comes with the FasT-Fix is therefore recommended. However, Kalliakmanis et al. reported no neurovascular complications in a larger series of repairs using the T-Fix and FasT-Fix implants.

Table 2. Summary of Outcomes for Different Repair Techniques and Systems

<table>
<thead>
<tr>
<th>Author</th>
<th>No. of Cases</th>
<th>Follow-up Time (mo)</th>
<th>Concurrent ACLR</th>
<th>Effect of ACLR Arrow</th>
<th>Meniscal Screw</th>
<th>T-Fix</th>
<th>FasT-Fix</th>
<th>RapidLoc</th>
<th>BioStinger</th>
<th>Suture</th>
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<td>Albrecht-Olsen et al. 51</td>
<td>65</td>
<td>3</td>
<td>Some</td>
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<td>91</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>75</td>
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<td>50</td>
<td>6</td>
<td>Majority</td>
<td>None</td>
<td>—</td>
<td>—</td>
<td>82</td>
<td>—</td>
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<tr>
<td>Cannon and Vittori 10</td>
<td>90</td>
<td>7-10</td>
<td>Majority</td>
<td>Better</td>
<td>96</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>93 (50)</td>
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<tr>
<td>Kocabay et al. 57</td>
<td>55</td>
<td>10.3</td>
<td>Majority</td>
<td>—</td>
<td>—</td>
<td>81</td>
<td>—</td>
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<tr>
<td>Barret et al. 83</td>
<td>21</td>
<td>12</td>
<td>All</td>
<td>—</td>
<td>88</td>
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<tr>
<td>Marinescu et al. 88</td>
<td>68</td>
<td>12</td>
<td>Some</td>
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<td>Hüslein et al. 59</td>
<td>26</td>
<td>16.7</td>
<td>Some</td>
<td>88</td>
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<tr>
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<td>61</td>
<td>18</td>
<td>Majority</td>
<td>None</td>
<td>—</td>
<td>—</td>
<td>90.2</td>
<td>—</td>
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<td>—</td>
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<tr>
<td>Frosch et al. 76</td>
<td>40</td>
<td>18</td>
<td>Majority</td>
<td>Better</td>
<td>100 (82)</td>
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<td>Venkatachalam et al. 51</td>
<td>62</td>
<td>21</td>
<td>Some</td>
<td>Better</td>
<td>56</td>
<td>57</td>
<td>—</td>
<td>—</td>
<td>78</td>
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<tr>
<td>Petsche et al. 92</td>
<td>29</td>
<td>24</td>
<td>Majority</td>
<td>—</td>
<td>93</td>
<td>—</td>
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<tr>
<td>Haas et al. 93</td>
<td>42</td>
<td>24.3</td>
<td>Majority</td>
<td>Better</td>
<td>—</td>
<td>86</td>
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<td>26</td>
<td>24.5</td>
<td>Some</td>
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<tr>
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<td>265</td>
<td>24.5</td>
<td>All</td>
<td>—</td>
<td>89.4</td>
<td>92.4</td>
<td>86.3</td>
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<tr>
<td>Barber et al. 95</td>
<td>89</td>
<td>26.5</td>
<td>Majority</td>
<td>—</td>
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<td>91</td>
<td>100</td>
<td>—</td>
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<td>—</td>
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<td>125</td>
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<td>All</td>
<td>89</td>
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<td>Majority</td>
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<td>—</td>
<td>87.5</td>
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<tr>
<td>Ellermann et al. 100</td>
<td>105</td>
<td>33</td>
<td>Majority</td>
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<tr>
<td>Noyes and Barber-Westin 39</td>
<td>30</td>
<td>34</td>
<td>Majority</td>
<td>Better</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
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<tr>
<td>Quinby et al. 101</td>
<td>54</td>
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<td>All</td>
<td>—</td>
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<tr>
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<td>—</td>
<td>95</td>
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<td>Rubman et al. 8</td>
<td>198</td>
<td>42</td>
<td>Majority</td>
<td>—</td>
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<tr>
<td>Kurzweil et al. 103</td>
<td>60</td>
<td>54</td>
<td>Majority</td>
<td>72</td>
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<td>Kurosaka et al. 104</td>
<td>114</td>
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<td>Majority</td>
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<td>—</td>
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<td>Gifstad et al. 105</td>
<td>118</td>
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<td>Some</td>
<td>None</td>
<td>59</td>
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<tr>
<td>Koukoulas et al. 106</td>
<td>11</td>
<td>73</td>
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<td>—</td>
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<td>28</td>
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<td>52</td>
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<td>Majewski et al. 108</td>
<td>116</td>
<td>120</td>
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<td>—</td>
<td>—</td>
<td>76</td>
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</table>

NOTE. The criteria for success are heterogeneous. Most authors shown in Table 2 define failure as the need for repeat arthroscopy or symptoms of locking and catching. Table 2 is sorted by length of follow-up time, from the shortest amount of time at the top to the longest amount of time at the bottom. Whether or not the anterior cruciate ligament was reconstructed is given and, if applicable, the impact on the outcome. Numbers in parentheses give the outcome for the subgroup with unstable knees. It should be noted that there is a general trend of increasing failure rates with time. Meniscal repairs in anterior cruciate ligament–reconstructed knees have better results than repairs in primary stable knees or unstable knees.

Abbreviation: ACLR, anterior cruciate ligament reconstruction.
though the results are not as severe as lacerations of the nerves or vessels, increased postoperative pain may compromise and slow down rehabilitation.

Complications specific to solid repair devices are migration or breakage of the implant. Parts of the implants that surmount the surface of the meniscus can also wear down the cartilage in the contact zones and cause chronic synovitis. Although this has been addressed by changes in the design and resorption time of the implants, it seems that these problems are not fully eliminated.

ENHANCEMENT OF THE HEALING RESPONSE

Biologic factors might be of greater importance to the success of meniscal repair than the choice of the surgical technique. The healing potential apparently coincides with the vascular supply of the meniscal tissue. However, the local application of vascular endothelial growth factor did not lead to improved healing in a sheep model. Exogenous fibrin clots seem to improve the healing in animal models and in humans. It is postulated that the clot serves as a chemotactic and mitogenous stimulus. Some investigators succeeded in enhancing the healing of meniscal lesions with the application of mesenchymal stem cells. It is not clear whether this is a direct action of the progenitor cells or is rather mediated by secretion of certain stimulating factors. The behavior of meniscal fibrochondrocytes can be modulated when the cells are exposed to certain growth factors. The response to mitogenic stimuli, however, seems not to be necessarily the same for all regions. Human menisci are populated by cells of different phenotypes that might respond differently to extrinsic stimuli, as was reported by Verdonk et al.

There are study findings showing that trephination or rasping alone without suturing the meniscus might be a reasonable option in stable tears. Shelbourne and Heinrich and Shelbourne and Rask published clinical studies investigating the fate of stable lesions in the medial and lateral meniscus that were either left alone or treated by rasping and trephination in conjunction with an ACL reconstruction. They found that only a minor proportion of their patients required subsequent surgery for their meniscus. Fox et al. reported on a similar procedure with good or excellent results.
results in about 90% of cases. Zhang and Arnold and Zhang et al. have shown in animal studies that trephination enhances the healing capacity of lesions in the avascular zone with and without additional sutures.

INFLUENCE OF CONCURRENT INJURIES

An injury to the ACL is the most often described entity encountered together with a meniscus tear. While the classic description of the O’Donoghue triad comprises a lesion of the medial meniscus together with a rupture of the ACL and medial collateral ligament, Barber and Shelbourne and Nitz have pointed out that lesions of the lateral meniscus are much more common in acute injuries. In chronic ACL deficiency, the relation shifts toward the medial meniscus. It has been shown that an abnormal anteroposterior laxity increases the resultant forces in the medial meniscus. The meniscus becomes a secondary stabilizer, a purpose for which it is not primarily made.

Accumulated microdamage explains the increasing rates of medial meniscal lesions in the course of untreated ACL deficiency. Conclusively, meniscal repair should result in a better outcome if it is done in conjunction with a stabilization of the knee. There have been no randomized studies that have investigated the outcome of meniscal repair in relation to the ACL state. Usually, the anteroposterior instability will be regarded as the primary problem, and randomization in terms of the ACL reconstruction is not an option. Nevertheless, there are some studies that comprise subgroups of patients with either ligamentous intact, reconstructed, or unstable knees. In the majority of these studies, it seems that the outcome of a repair is better with concomitant reconstruction than in knees that remain unstable or even better than knees without ACL injury.

The fact that meniscal repair appears to be more successful in combination with an ACL reconstruction deserves some detailed reflection. The simplest explanation is that, with the stabilization of the knee, the inciting cause for the repeated microtrauma of the menisci is eliminated, or at least diminished. Moreover, marrow elements are introduced into the joint cavity with the ACL procedure that, as described earlier, are thought to modulate the healing response of meniscal fibrochondrocytes. Another potential explanation for a seemingly improved healing rate with concurrent ACL surgery is related to patient selection. It must be assumed that in the subgroup of patients with concomitant ACL reconstruction, the main reason for the procedure is instability, and that conclusively not only symptomatic but also clinically silent lesions of the meniscus are identified and repaired. However, in patients with stable knees, the cause for the meniscal repair usually is meniscal symptoms, such as locking or effusion. The possibility of a selection bias must therefore be considered.

REHABILITATION

Patients should be informed in advance that meniscal repair is usually accompanied by much longer periods of restricted motion and limitation of the knee function than after a meniscectomy. It has been shown that the reparability of meniscal tears can be predicted reasonably well by magnetic resonance imaging studies, which gives both the patient and surgeon the opportunity to be prepared in advance.

A generally valid rehabilitation algorithm has not been established. Rehabilitation plans need to be individually tailored and should take into consideration the nature of the tear, concurrent injuries and procedures, and the influence of specific exercises on the repaired tear (Table 3).

There are both mechanical and biologic effects associated with postoperative weight bearing and motion of the knee. In repaired bucket-handle lesions, weight bearing reduces the meniscus and stabilizes the tear. Flexion under tibiofemoral loads of the knee, however, leads to increasing compressive and shear loads in the posterior horn. It was reported that weight bearing flexion from full extension to 90° increases the pressure on the posterior horn by, roughly, a factor of 4. The menisci translate dorsally with knee flexion. This motion depends not only on the flexion angle but also on the weight bearing condition. The table below provides a postoperative rehabilitation program for a typical bucket-handle lesion.

| Table 3. Postoperative Rehabilitation Program for a Typical Bucket-Handle Lesion |
|-----------------------------------|-----------------------------------|-----------------------------------|
| **Early Phase**                   | **Intermediate Phase**            | **Late Phase**                    |
| • Ice and analgesics              | • Partial or full weight bearing  | • Regain full range of motion     |
| • Crutches as needed              | • Brace to limit motion           | • Strength training               |
| • Brace to limit                  | • Isometric strength training     | • Consider modification of        |
|       motion                     | • Aqua jogging                   |     activities if related to      |
| • Non–weight bearing motion      | • Continue brace                 |     development of tear           |
| (60° to 90°)                     | • No squats for 12+ wks          |                                  |

NOTE. Patients might need an individually tailored program.
nitude of the posterior femoral rollback, and necessarily the posteriorly directed translation of the menisci, is substantially increased in the weight-loaded knee compared with the unloaded state. Although this was not directly proven by the cited study, motion exercises of the knee without weight bearing might therefore be preferable during rehabilitation to limit the stress on the repair. Weight bearing in extension most likely does not pose a problem to repaired meniscal lesions. An exception to this is complete transections of circumferential fiber bundles of the meniscus, such as radial tears that comprise the whole cross-section or posterior root tears. In those cases, weight bearing would be deleterious because the hoop stress distracts the tear margins and healing is prevented. 81

Tibial rotation causes large excursions of the meniscus within the first 30° of flexion. 82 Terminal flexion is accompanied by a large dorsal translation of the condyles and causes increased compressive stress of the meniscus. 79,80 Therefore, deep squats and tibial rotation should be avoided for at least 12 weeks.

Although the magnitude of the posterior translation of the medial and lateral meniscus is different, no significant difference in the pressure that arises on the medial and lateral posterior horns was found by Becker et al. 79 at up to 90° of flexion. So far, it is not clear if medial and lateral meniscal repairs deserve different rehabilitation protocols. Most investigations about the biologic effects of immobilization found that it impaired the healing of repaired menisci. 83 Limited motion and weight bearing in full extension might have stimulating effects on the healing response. 84

There have been some clinical investigations regarding the effect of a more aggressive rehabilitation of meniscal repair patients. Barber and Click 46 and Barber 85 did not find any evidence that an accelerated program compromises the result of the repair. Similarly, Mariani et al. 86 failed to show deleterious effects when patients with concomitant ACL surgery were subjected to an accelerated rehabilitation program. However, the design and case number of those studies do not allow one to infer in general that restrictions after meniscal repair are not necessary.

CONCLUSIONS

Meniscal preservation has gained a high level of awareness in the recent years. The surgeon must consider the nature of the tear in his decision of whether or not to repair or resect. The prognosis of a meniscal repair is better if it is possible to identify and treat an underlying problem like an ACL deficiency. Contemporary all-inside repair systems have significantly decreased the level of technical skills required for a successful repair. There is currently no scientifically substantiated reason to believe that the choice of a particular repair technique would improve the outcome. It has not been shown thus far that a high failure load is associated with better clinical results.

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