Meniscus Repair
Considerations in Treatment and Update of Clinical Results

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The meniscus plays an important role in the function of the knee. Preservation of the meniscus is preferred if possible when considering treatment of a meniscus tear. A thorough understanding of the anatomy of the meniscus, the structure, the mechanics, and other factors of meniscal healing are critical when evaluating a torn meniscus for a reparative procedure. Many options for meniscus repair exist for the orthopaedist. Options such as open repair or arthroscopically-assisted inside-out techniques have long-term favorable results. The all-inside techniques are attractive because of the decrease in operative time and ease of the technique. Short-term results are positive for the all-inside technique; however, good long-term data on these techniques are lacking. Few well-designed prospective studies exist on any of the meniscus repair techniques. Future directions include the potential use of growth factors and gene therapy to augment meniscus repair.

When an individual presents to the physician with signs and symptoms of a meniscal tear, certain decisions need to be made regarding the treatment. Although some disorders of the meniscus can be treated nonoperatively, others require surgery. A few decades ago, the meniscus generally was thought to be unimportant to the function of the knee. Tears in the meniscus typically resulted in complete excision of the meniscus. Since then there has been an increasing awareness of the importance of the normal meniscus structure. The long-term consequences of a meniscectomy or even partial meniscectomy have been shown to be potentially deleterious to the joint surface.18,19,25,36,42,62,78 Tears in the vascularized portion of the meniscus have been shown to possess the potential to heal and be amenable to repair.

The concept of repairing the meniscus is not new. The first report of a meniscus repair was in 1885 by Annandale.6 Subsequently, there have been numerous studies and articles published on the treatment of meniscal tears, particularly since the advent of arthroscopy in the past 30 years.10,18,19,30,62,73,78,91 Techniques have evolved from open repairs to semiopen repairs to all arthroscopic repairs. Devices for repairing the meniscus also have evolved. The current options for fixing a meniscus are numerous and will continue to increase into the new millennium.

Meniscus Structure and Function
The menisci are semilunar shaped fibrocartilage structures on the medial and lateral sides
of the knee. Once thought of as vestigial structures, the menisci now are known to be integral components of knee function. They consist of approximately 75% Type I collagen. The collagen fibers lie mostly along the longitudinal axis, with oblique and radial fibers to enhance the structural integrity. The viscoelastic properties of the menisci allow compressive loads to be dissipated along circumferential fibers, thereby reducing the impact forces on the articular cartilage.

The blood supply to the menisci is important to understand. The peripheral 20% to 30% of the medial meniscus and the peripheral 10% to 25% of the lateral meniscus are vascular (Fig 1). Branches from the superior, inferior, and lateral geniculate arteries supply this vascular zone. The avascular zone of the menisci, which includes at least the inner ⅓ of each meniscus, is nourished by synovial fluid diffusion. The middle ⅓ zone may have some blood supply, yet it likely derives most of its nourishment from the synovial fluid. The vascular distribution has important clinical implications for meniscal repair surgery because healing is enhanced greatly in the vascular regions.

The menisci are not fixed on the tibia but actually have anteroposterior (AP) translation with knee motion. The lateral meniscus translates as much as 9 to 11 mm in the AP plane, whereas the medial meniscus is less mobile, translating only 2 to 5 mm. This relative lack of motion may be important clinically as a contributing factor to the increased incidence of meniscal tears on the medial side.

The primary function of the meniscus is to evenly distribute load across the knee. Forces across the knee may be as high as two to four times body weight during walking and as high as six to eight times body weight during running. When the meniscus is loaded in weight-bearing, the meniscal fibers elongate as they are pushed to the periphery. With the knee in extension, approximately 50% of the load is transmitted to the menisci. This is increased to almost 90% with the knee at 90° flexion. Most of the force is transmitted through the posterior horns with flexion past 90°.

The lateral meniscus has been shown to transmit a greater percentage of the load in the lateral compartment (approximately 70%), compared with the medial meniscus (approximately 50%). This suggests that patients who have lateral meniscectomy may be at higher risk for early subsequent joint degeneration. Medial meniscectomy decreases the contact surface area of the femoral condyle by 50% to 70% while doubling the stresses on the tibial plateau.

When meniscal integrity is compromised, abnormal articular contact stresses result, leading to increased wear of the articular cartilage and early degenerative changes. The more meniscal tissue that is excised, the greater the loss of contact surface area and the greater the increase in peak local contact stresses. The clinical importance of this initially was described by Fairbank as he found loss of articular cartilage, flattening of the femoral condyles and osteophytes in meniscectomized knees.

The menisci also play a role in knee stability. They deepen the socket of the tibia to better conform to the ovoid shape of the femoral condyles. Isolated medial or lateral meniscectomy does not result in significant increases in

Fig 1. A frontal section, 5-mm thick, of the medial knee compartment using the Spalteholz technique, shows vessels from the perimeniscal capillary plexus (PCP) penetrating the periphery of the medial meniscus (Magnification, ×3). F = femur, T = tibia (Reprinted with permission from Arnoczky SP, Warren RF: Microvasculature of the human meniscus. Am J Sports Med 10:91, 1982.)
AP translation. However, the menisci act as secondary stabilizers in the anterior cruciate ligament deficient knee. The posterior horn of the medial meniscus particularly is important for this function because it acts as a wedge to resist anterior translation.

Finally, the meniscus has a role in joint lubrication. During loading of the knee, when the meniscus is compressed, synovial fluid is driven into the articular cartilage. This form of lubrication significantly reduces the coefficient of friction in the knee.

**Healing of the Meniscus**

The peripheral meniscal blood supply is key to the healing of the meniscus. Numerous experimental and clinical studies have shown a peripheral blood supply that is capable of producing a healing response similar to that seen in other connective tissues. Initially, healing occurs by the formation of fibrovascular scar tissue. This tissue gradually matures to a fibrocartilage over several months. Most of the studies that have examined meniscal healing have focused on vertical and longitudinal tear types. However, these types of healed tears may not perform adequately from a biomechanics standpoint. Newman et al. found that despite gross and histologic healing in radial tears, the circumferential collagen fibers were not restored to their original length and, therefore, the ability to transmit load was not maintained.

**Evaluation and Decision Making in Treatment of a Meniscus Tear**

Numerous factors are involved in the determination of treatment of a meniscal tear. In assessing these factors one has to be cognizant of meniscal biomechanics including the role in load transmission and congruity of the knee, as discussed previously. Because of the importance of intact functional meniscus tissue, the first goal is to preserve as much of the viable tissue as is possible. Therefore, decisions on the type of treatment should reflect this.

Factors of the meniscal tear that must be taken into consideration include the location, length, tear pattern, and stability of the tear, and any damage to the integrity of the meniscus body. Other factors to consider are the patient’s age, presence of degenerative tissue (mucoid degeneration), concurrent intraarticular injuries, integrity of the anterior cruciate ligament, and chronicity of the tear.

When assessing the patient with a suspected meniscus tear, history and physical examination may assist in making the diagnosis of a tear, but the exact site and potential for repairability may not be determined clinically. Double contrast arthrography traditionally has been an excellent method for the evaluation of the medial meniscus. However, magnetic resonance imaging (MRI) has largely replaced arthrography as the imaging modality of choice for the meniscus because the accuracy has been shown to be greater than 90%. Magnetic resonance imaging is not routinely required for the diagnosis of all meniscal tears before arthroscopic surgery is done. Although most surgical decisions should be based on the physical examination and history, the MRI scan provides additional information that may prove important regarding the status of the ligaments and articular cartilage and the location of the meniscus tear. Despite the accuracy of MRI to detect a tear, there have not been any studies that show that an MRI scan can help predict the reparability of tears. Additionally, false-negative MRI studies often are encountered in most peripheral tears, which are best for repair. The characteristics of the tear can be assessed arthroscopically using traditional anterior lateral and medial portals. A posterior portal occasionally is necessary to observe the posterior horn of the medial meniscus. A probe is used to assist in the assessment of the tear.

**Suitability for Repair**

The location of the tear is critical because tears in the vascular zone of the meniscus are suitable for repair if the meniscal tissue is of adequate quality. Typically, this involves a tear in the peripheral ⅓ of the meniscus. Current tech-
Techniques have pushed the limits to allow some tears of the central and middle ⅓ zones to be repaired. If vascularity of the meniscus is seen with observable bleeding in the tear area, a repair should be considered. DeHaven considers tears in the peripheral 3 mm as vascular, those 5 mm or more from the periphery as avascular, and those between 3 and 5 mm as variable in vascularity. The area in the posterolateral aspect of the lateral meniscus around the popliteus tendon is a watershed area with relative hypovascularity even in the peripheral ⅓. In areas with marginal vascularization, abrasion of the meniscal tissue and/or a fibrin clot may be used to enhance healing of a repair. Van Trommel et al documented successful healing in five patients with radial tears in the hypovascular zone of the lateral meniscus using a fibrin clot.

The pattern, the length, and the stability of the tear all play important roles in decision-making. If the circumferential hoop fibers remain intact, there is a greater chance for healing than when they are disrupted, such as in a complete radial tear. Radial tears in general are less amenable to repair, although some complete tears do warrant attempts at repair, especially when the alternative is a subtotal meniscectomy. Short inner radial tears (≤ 5 mm) usually do not heal, but often can be left alone because they may be asymptomatic. Bucket handle tears that are complex with radial components, often seen in chronic cases, have more difficulty healing with repair than simple acute bucket handle tears. Radial tears at the posterior horn heal better than those in the middle part of the meniscus secondary to the vascularity in this region. Fitzgibbons and Shelbourne reported that posterior horn avulsions of the lateral meniscus may result in no clinical symptoms when left alone in conjunction with an anterior cruciate ligament reconstruction. Longitudinal (vertical) tears in the periphery are most amenable to repair. Some authors think that stable tears less than 1 cm in length can be left alone. Stable tears have been defined as those in which the central portion cannot be displaced more than 3 mm. Longitudinal tears that are stable and in the peripheral ⅓ often can be left alone, particularly if they are less than 5 mm in length. Partial thickness tears of various types, particularly longitudinal tears, usually can be left alone if they are less than 5 mm in length. Oblique and horizontal tears may have difficulty healing.

Repair of the meniscus has been shown to be more successful when done in conjunction with an anterior cruciate ligament reconstruction (62%–96% healing rate) versus no anterior cruciate ligament reconstruction (17%–62%). The reasons for this are likely the stability provided by the anterior cruciate ligament reconstruction and the favorable healing environment from the hemarthrosis incurred during anterior cruciate ligament reconstruction. As mentioned previously, Fitzgibbons and Shelbourne showed that numerous of lateral meniscal tears remain asymptomatic when left alone at the time of anterior cruciate ligament reconstruction. In a smaller series, Orfaly et al reported similar results.

Any significant injury to the meniscus body, such as a complex tear, numerous cleavage tears, change in the meniscal body contour, or degenerative tearing may render any repair effort futile. The problem with such injuries to the meniscus body is the structural integrity of the meniscus is damaged and the vascularity may be impaired. Additionally, degenerative tears are difficult to hold with meniscal repair material. Older individuals often have a degenerative component to their tears. The degenerative portion should be debrided and repair attempted depending on the type of tear and age of the individual. In addition to a meniscal tear, articular cartilage degeneration may be present in the older person. In this type of patient, a meniscal repair may be ill-advised. The chronicity of the tear also plays a role in the amount of degenerative change found and the complexity of the tear. Some authors have reported better healing in acute tears than in chronic tears. Although this may be true, there has not been conclusive evidence that a tear more than 2 or 3 months old will have impaired healing.
Repair Techniques and Review of the Literature

Types of repair include the time honored open repair and arthroscopic techniques of the inside-out and outside-in suture repairs and the all-inside techniques. Inside-out and outside-in repairs involve a mini-incision and securing the meniscus to capsule with suture. The all-inside technique entails many options including arthroscopic suture tying and numerous absorbable fixation devices with such names as arrow, fastener, dart, and staple.2,17,21,28,35,46,58

Open Repair

Open repair of meniscus tears has been shown to have successful long-term results.29,31,61,70 The technique consists of making a small incision similar to that made in an arthroscopic inside-out meniscus repair. The major difference is the capsule and synovium are incised in the open repair so that observation of the tear can be made (Fig 2). No prospective studies have been published from results using this technique. The open repair has been done successfully by the senior author (KED) since 1976. Long-term results published by DeHaven et al31 showed a survival rate of repaired menisci of 79% after 10 to 13 years. In this retrospective series of 33 open meniscus repairs, the menisci in stable knees performed best. Another retrospective series by Mullner et al61 documented a survival rate of repaired menisci at 91% after a mean followup of almost 13 years. Of 22 patients, only two had retears and these occurred in unstable knees. Magnetic resonance imaging also was done on all the patients and was found to be unreliable in assessing the healed nature of the meniscus because more than ½ of the menisci had at least a Grade III signal alteration. Rockborn and Gillquist70 compared results of 31 patients who had open repair with a matched group of healthy subjects. After a 13-year followup, 80% of patients had normal knee function for daily activities. The incidence of low-grade radiologic changes was similar between both groups.

Currently, the specific indications for the open repair technique are a posterior medial meniscus tear (within 2 mm of the meniscosynovial junction) encountered in a tight medial compartment. The visibility of the meniscus from an anterior portal is very difficult in the extremely tight knee and the all-inside technique with knot tying can be challenging.

Arthroscopic Inside-Out Repair

The inside-out meniscal repair technique involves fixation of a tear by placing sutures from inside the knee to a protected area on the outside of the joint capsule. The sutures are typically on long needles with either absorbable or nonabsorbable 2–0 sutures placed from anterior portals under arthroscopic observation. Cannula systems of various types are used to place the sutures at different angles and locations on the meniscus (Fig 3). The ability to achieve consistent perpendicular suture placement through the meniscal tear in the posterior horn gives this method an advantage over some of the other techniques. However, this also carries some risks. A neurovascular injury is possible while placing the needle from inside the joint to outside the joint. A posterior incision is required to place a retractor to protect the neurovascular structures when using this technique.

Fig 2. Open meniscus repair shows the small arthrotomy made with repair of the meniscus to the capsule with sutures. (Reprinted with permission from Miller M: Atlas of meniscal repair. Oper Tech Orthop 5:70–71, 1995.)
Inside-out repairs have yielded favorable results in numerous published reports. Almost all of the studies have been retrospective.21,40,45,60 The success rates of the studies based primarily on clinical results have ranged from 73% to 91%.13,15,18,33,47,48,66,77,83 These studies have examined only one technique without any comparison. In a comparison study, Hanks et al40 retrospectively reviewed open repairs versus arthroscopic inside-out repairs. After an average of 4.2 years, there was no statistical difference between the two groups in terms of failure rates (11% open versus 8.8% inside-out). Anterior cruciate ligament deficient knees had a higher failure rate.

Numerous studies have used more objective means to evaluate the healing of meniscus repairs rather than only clinical results. These studies used second-look arthroscopy to evaluate inside-out repairs.4,44,45,50,55,74,76,78,86 Horibe et al45 evaluated 132 meniscal repairs. Seventy-three percent of the menisci had complete healing. The other 17% had incomplete healing but only nine patients had symptoms related to the meniscus such as locking, swelling, or pain. Tenuta and Arciero44 evaluated 54 meniscal repairs with a second look. Sixty-five percent were healed completely, 16% had incomplete healing, and 19% did not heal. Repairs with a concomitant anterior cruciate ligament reconstruction had an increased healing rate (90%) versus repairs done for an isolated tear in an anterior cruciate ligament stable knee (57%). Rosenberg et al74 found 83% (24 of 29) meniscus repairs were healed at the time of the second look. Four of the five failed repairs occurred in anterior cruciate ligament deficient knees. Kimura et al50 evaluated 46 of 137 repairs with repeat arthroscopy and reported an 83% healing rate. Asahina et al11 examined 98 knees with repeat arthroscopy: 74% had complete healing, 13% had incomplete healing, and 12% had no evidence of healing. Decreased healing rates were observed in menisci repaired in the central 1/3 zone and those that had been locked or could be locked by probing at the time of repair.

Similar findings of decreased healing in the central zone of the meniscus were found by Rubman et al.76 They examined only patients with repairs involving the central avascular region of the meniscus. Ninety-one menisci were evaluated with repeat arthroscopy and only 25% had complete healing and 38% had incomplete healing.

Other studies have used a combination of either second look arthroscopy, arthrograms, or both. Van der Reis and Cannon86 reported their experience of 172 inside-out meniscal repairs. Either second look arthroscopy (131 repairs) or arthrograms (41 repairs) were done to evaluate healing. Satisfactory anatomic healing (> 50%) was evident in 70% of the repairs. However, when assessed clinically, 88% of the repairs had no symptoms and were deemed.
clinically healed. Scott et al\textsuperscript{78} prospectively examined 178 repairs with either arthroscopy or arthrography and found 61.8\% with evidence of healing, 16.9\% with incomplete healing, and 21.3\% with no healing. Cannon and Vittori\textsuperscript{24} found an overall 82\% success rate in healing. Meniscus repairs done in conjunction with anterior cruciate ligament reconstruction had an even better rate of healing at 93\%, whereas isolated repairs in anterior cruciate ligament stable knees were only 50\% successful.\textsuperscript{24} Miller\textsuperscript{55} also used either arthroscopy or arthrography to evaluate 47 patients and reported a success rate of 91\%.

In one of the few prospective studies, Alpar and Bilsel\textsuperscript{4} prospectively followed up patients with peripheral longitudinal tears of the posterior horn. At repeat arthroscopy, 96\% (48 of 50) of the repairs had healed. All 48 patients were symptom-free.

\textbf{Arthroscopic Outside-In Repair}

Outside-in meniscal repairs use spinal needles passed from outside of the joint to inside the joint under arthroscopic observation (Fig 4). The needles are passed through the meniscus rim and then through the meniscus body fragment. Suture material then is passed through the spinal needle. The suture is retrieved by one of two methods. One method uses a metal snare through another needle retrieving the suture. This suture then is tied outside the joint over the capsule. Alternatively, the suture is retrieved through the anterior portal. Knots then are tied on the end of the suture, which is pulled back into the joint, and traction of the knot against the meniscus body fragment reduces and holds the fragment. Individual sutures can be passed through the inferior or superior surfaces of the meniscus, and adjacent sutures are tied to each other over the capsule. This method is useful for tears in the anterior or body of the medial or lateral meniscus. This technique does not work for tears near the posterior horn. A theoretical advantage of this technique is the avoidance of placing the neurovascular structures at risk.

Excellent clinical results in 98.6\% of patients were reported by Morgan and Cassells\textsuperscript{59} in their examination and review of symptoms of patients who had outside-in meniscal repair. Their followup from 12 to 28 months of 70 patients included only one retear that occurred 2 months after the initial procedure. In a later, more extensive study, Morgan et al\textsuperscript{60} evaluated 74 outside-in meniscal repairs with second look arthroscopy (of 353 outside-in meniscus repairs). Sixty-five percent of these were healed completely, 16\% completely failed, and 19\% had incomplete healing. Ninety-two percent (11 of 12) of the failures involved the posterior medial meniscus. Rodeo and Seneviratne\textsuperscript{72} reported on the results at the Hospital for Special Surgery involving 90 patients using objective criteria such as MRI, computed tomography (CT) arthrography, or arthroscopy to assess outcome. Eighty-seven percent of the patients had successful outcomes as defined...
by no symptoms and complete or partial objective healing. The failure rate was higher in unstable knees (five of 13) versus stable knees (five of 33) and in those with medial repairs (11 of 72) versus lateral repairs (one of 18). In another study from the same institution, van Trommel et al also used objective criteria (MRI, arthrography, or arthroscopy) to assess healing. After an average of 15 months, complete healing occurred in 45% and partial healing in 32% of repairs. Poor healing with the outside-in technique was observed in patients with tears into the posterior horn of the medial meniscus.

Plasschaert et al retrospectively reviewed the healing rate, and reported a 74% survival at a mean followup of 3.5 years. Similar results were reported by Mariani et al with 77.3% clinically good results at an average followup of 28 months. Valen and Molster reported the least favorable results. They reported a cumulative survival rate of 50% at 5-year followup in 51 patients. However, as the authors noted, their indications for repair were extensive including attempts at repairing tears in the white-white zone.

**Arthroscopic All-Inside Repair**

Arthroscopic all-inside meniscal repair techniques recently have become popular because they seem to avoid many of the potential complications of other meniscal repair techniques and decrease operative time. This may be the most common meniscus repair technique today, yet it is one of the least documented. The popularity of this method has increased as numerous devices and techniques have been introduced.

In 1991 Morgan first described the all-inside arthroscopic meniscus repair technique. He described a posterior cannula and the use of a suture passer to pass monofilament absorbable suture through posterior horn meniscus tears. Arthroscopic knots then were tied to secure the tissue. The technique is effective, yet technically demanding. Subsequently, various devices have been developed to avoid any posterior incisions. The T-Fix anchor was introduced in the mid1990s. This was developed to allow secure fixation of the meniscus with complete arthroscopic observation. Any posterior incisions were avoided and placement of the anchor was deemed easy. The suture anchor consists of a suture fixed around the waist of a small nonbiodegradable bar, which is introduced across the tear site. A second anchor is placed near the first anchor. The two sutures then are tied. Arthroscopic knot tying skills are mandatory for this technique.

Results from use of the T-Fix have been favorable. Two short-term prospective studies have been published on the use of this device. Barrett et al followed up 20 patients with 21 meniscus repairs for a minimum of 1 year. All repairs were done in conjunction with an anterior cruciate ligament reconstruction. Four patients (19%) remained symptomatic and were considered to have failed clinical results. Three of these four patients had complex horizontal tears in the central 1⁄3 of the meniscus. Escalas et al followed up 20 patients for 6 months. Ninety percent of the group returned to their preoperative activity levels or better with resolution of symptoms. No complications were observed with the device.

Additional development of all-inside meniscus repair devices has brought forth bioabsorbable devices that eliminate any arthroscopic suture tying. Again, published reports on the clinical success of these devices are limited. Two published studies have reported the short-term results of the meniscus arrow. The arrow is a bioabsorbable device with barbs that are placed across a meniscal tear (Fig 5). Hurel et al retrospectively followed up 25 patients (26 repairs) for an average followup of 16 months. These patients had an all-inside repair using the absorbable Biofix arrow fixation device. Eighty-eight percent of the patients had good or excellent results. In two patients, soft tissue irritations appeared secondary to the arrow. A prospective randomized study by Albrecht-Olsen et al compared inside-out meniscal repair with meniscus repair using the arrow. The study included 68 patients. A second look arthroscopy was done on 65 patients (96%); however, the
followup was only 3 to 4 months. The two groups were well matched. Postoperative rehabilitation was identical for the two groups with nonweightbearing for 5 weeks. The operative time for the patients who received arrows (30.3 minutes) was half that of the operative time for patients who received sutures (59.8 minutes). At the second arthroscopy, 91% of the tears in the patients who received arrows had completely or partially healed compared with 75% in the patients who received sutures ($p = 0.11$). Two infections occurred in patients who received sutures whereas no infections occurred in the patients who received arrows.

Recently, numerous case reports documenting complications have been reported with use of the arrow device for meniscus repair. Several reports have described grooves or scuffs in the articular surface corresponding to the location of the arrow on the adjacent meniscus. Transient posterior knee pain also has been associated with the arrow implants. Breakage and migration of the implant has been described. Other reports have presented cases of the arrow causing a subcutaneous foreign body and a cystic hematoma.

The pullout strength of the arrow device has been studied in vitro. It has been shown to have approximately equivalent pull-out of one horizontal suture with $0$ Maxon and approximately $50\%$ the pull-out of a vertical suture of $2–0$ Ethibond.

**Rehabilitation After Repair**

There are many views on rehabilitation after meniscus repair. Traditionally, an individual with a meniscal tear has been treated with immobilization, no weightbearing, or both. DeHaven et al. published good results with this type of aftercare and currently recommend 2 weeks of immobilization with the knee in extension, for patients with isolated repairs. This is followed by limited motion ($10^\circ$–$80^\circ$) for 2 additional weeks, followed by unrestricted motion. A patient with a meniscal repair done in conjunction with an anterior cruciate ligament reconstruction is allowed immediate motion. Weightbearing is limited significantly until 6 weeks for patient with isolated repairs and patients with repairs done in conjunction with an anterior cruciate ligament reconstruction. DeHaven et al. think that the repair needs to be additionally protected from heavy stresses for at least 6 months after surgery. This includes refraining from agility drills, full-speed running, and full squats.

Other authors advocate a more accelerated rehabilitation program. Shelbourne et al. Barber, and Barber and Click reported good results with immediate range of motion.

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**Fig 5A–B.** (A) All-inside arthroscopic repair using the arrow technique is shown. (B) All-inside arthroscopic repair after placement of three arrows is shown. (Reproduced with permission of Bionx Implants, Blue Bell, PA.)
and weightbearing as tolerated after meniscal repair. These authors think that activity restrictions are unnecessary after repair of the meniscus. Return to full activity was reported at an average of 10 weeks in the study of Shelbourne et al\textsuperscript{80}; however, the percentage of patients who achieved full activity was not reported.

Concepts are continuing to evolve regarding rehabilitation after meniscal repair. Currently, there is not adequate prospective data supporting either the traditional conservative method of postoperative care after meniscal repair or accelerated rehabilitation. However, accelerated rehabilitation certainly is attractive, particularly to the athlete who would like to return to his or her sport early. The method of fixation and technique and the presence of anterior cruciate ligament reconstruction and postoperative rehabilitation must be considered to duplicate the reported results.\textsuperscript{14,15,80} Clearly, more prospective, especially prospective comparative or randomized studies are needed to make scientific judgments.

**Future Directions in Meniscal Repair**

Techniques and devices continue to be developed for the repair of the meniscus. Recent research in the laboratory is focusing more on the biology of healing and techniques to stimulate or augment that healing.\textsuperscript{20,71,81,90} Techniques such as trephination of meniscal tissue, rasping, and the use of a fibrin clot have been used to augment repair of the meniscus.\textsuperscript{10,73,78,87} Investigations have targeted growth factors and gene therapy to enhance healing of the meniscus.\textsuperscript{20,71,81,90} Various growth factors have been shown to stimulate meniscal cell migration and matrix synthesis. It may be possible that fibrin clot can be used as a carrier vehicle for growth factors or even cultured fibrochondrocytes. Tissue culture may be an avenue to grow the cells to augment and grow in the meniscal tear defect. Techniques of gene therapy have shown the ability to do in vitro transfer of genes into meniscus cells and then directly into meniscus tissue in vivo.\textsuperscript{38} With this technology, the possibility exists that genes could be transfected into meniscus cells, stimulating the production of various growth factor and matrix components. These growth factors could direct cell proliferation and cell matrix production in the healing meniscus.

Cell-based techniques will continue to evolve and likely will provide exciting options for the orthopaedist to consider when confronted with meniscus tears in the future. Advances in technology might allow bioabsorbable meniscus fixation implants to be impregnated with meniscal tissue stimulating (growth) factors. Other possibilities for meniscal repair might include the use of collagen bonding with something such as ultraviolet light or laser.

The treatment of a meniscus tear involves the consideration of multiple factors. Comprehension of the mechanics and anatomy of the meniscus are important in the decision making. The peripheral \(\frac{3}{4}\) of the meniscus is vascularized and most amenable to repair. Additionally, a meniscus repair done in conjunction with an anterior cruciate ligament reconstruction has been shown to have an increased rate of healing.\textsuperscript{5,23,41,64,75,79,92} Favorable long-term results regarding meniscus repair have been documented only in the open or arthroscopic inside-out technique. Outside-in and all-inside techniques are promising in the short-term results, but lack sufficient long-term results to be widely subscribed to. Many reports have documented some complications with the use of some of the bioabsorbable devices used in the all-inside repair technique.\textsuperscript{5,23,41,64,75,79,92} There remains some controversy regarding rehabilitation after meniscus repair. Some authors favor a conservative approach with minimal weightbearing and minimal motion whereas others advocate a more accelerated program consisting of early motion and weightbearing. Good results have been documented with both approaches.

Despite a continual advancement of techniques during the past 2 decades, there still are many questions that remain, particularly with newer techniques and with rehabilitation. Additional studies done in a prospective randomized fashion are recommended to elucidate these questions.
References


Clinical Orthopaedics and Related Research


