Meniscal Injury: II. Management

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Abstract

Meniscal repair is a viable alternative to resection in many clinical situations. Repair techniques traditionally have utilized a variety of suture methods, including inside-out and outside-in techniques. Bioabsorbable implants permit all-inside arthroscopic repairs. The success of meniscal repair depends on appropriate meniscal bed preparation and surgical technique and is also influenced by biologic factors such as tear rim width and associated ligamentous injury. Successful repair in >80% of cases has been reported in conjunction with anterior cruciate ligament reconstruction. Success rates are lower for isolated repairs. Complications related to repair include neurologic injury, postoperative loss of motion, recurrence of the tear, and infection. Meniscal allograft transplantation may provide a treatment option when meniscus salvage is not possible or when a previous total meniscectomy has been done.

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Repair of the meniscus has become more feasible because of improved arthroscopic equipment and the development of advanced surgical techniques. The rationale for repair is based on the importance of the meniscus in load bearing, shock absorption, and stress distribution across the knee. Many surgeons have developed meniscal repair techniques with the intention of achieving long-term patient benefits. In some settings, however, resection is still required and is the appropriate treatment.

Resection

Total Meniscectomy

Although infrequent today, total meniscectomy was previously a commonly performed procedure. It was initially regarded as a benign procedure, and early reports on the results of this technique were considered excellent. However, in 1948, Fairbank[1] described the potential damaging effects of total meniscectomy. As long-term results have become available, this procedure has fallen out of favor.[2,3]

Partial Meniscectomy

To avoid the sequelae of total meniscectomy, partial resection of the meniscus is advocated when repair is not feasible. Metcalf et al[4] have provided general guidelines for arthroscopic resection that apply to most resectable meniscal lesions: (1) All mobile fragments that can be pulled past the inner margin of the meniscus into the center of the joint should be removed. (2) The remaining meniscal rim should be smoothed to remove any sudden changes in contour that might lead to further tearing. (3) A perfectly smooth rim is not necessary. Repeat arthroscopy has shown rim remodeling and smoothing at 6 to 9 months. (4) The probe should be used repeatedly to gain information about the mobility and texture of the remaining rim. (5) The meniscocapsular junction and the peripheral meniscal rim should be protected. This maintains meniscal stability and is vital in preserving the load transmission properties of the meniscus. (6) To optimize efficiency, both manual and motorized resection instruments should be used. Manual instruments allow for more controlled resection, while motorized instruments remove loose debris and smooth frayed fragments. (7) In uncertain situations, more rather than less intact meniscal rim should be left to avoid segmental resection, which essentially results in a total meniscectomy. Using these guide-

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lines, most tears not amenable to repair can be carefully contoured to preserve viable meniscal tissue (Fig. 1).

Much of the early literature compared partial meniscectomy with total meniscectomy. Northmore-Ball et al[5] found a marked difference in results comparing arthroscopic partial meniscectomy with open total meniscectomy (90% versus 68% good and excellent results, respectively). Other studies have demonstrated similar results.

Many of the studies of arthroscopic partial meniscectomy reported 80% to 90% satisfactory clinical results with, however, only short-term follow-up (<2 years). Return of joint function and a decrease in pain were common outcome measures. The major advantages over both open partial and total meniscectomy included decreased hospitalization, shorter recovery time, and a reduction in patient care costs.

However, a number of long-term studies have questioned whether partial meniscectomy is, in fact, a benign procedure. Fauno and Nielsen[6] showed that osteoarthritic radiographic changes occurred in 53% of knees that underwent partial meniscectomy compared with 27% of the untreated contralateral knees at 8-year follow-up. Similarly, Rangger et al[7] evaluated patients who had undergone arthroscopic partial meniscectomies at an average of 4 years and found increased radiographic changes of osteoarthritis in 38% of the patients who had undergone partial medial meniscectomy and 24% of the patients who had undergone partial lateral meniscectomy. However, they noted that these changes did not necessarily correlate with subjective postoperative results because 86% to 91% of patients had good or excellent clinical outcomes. Schimmer et al[8] reported 91.7% good or excellent results at 4 years; this rate dropped to 78.1% at 12 years. The factor with the greatest impact on long-term outcome was whether associated articular cartilage damage was observed during meniscectomy. Only 62% of patients with articular cartilage damage at the time of meniscectomy had a good or excellent result at final follow-up compared with 94.8% of patients with no articular cartilage damage. Other studies evaluating meniscectomy in older patients (age >40 years) have confirmed that articular cartilage damage seen at the time of meniscectomy is a major factor associated with poor long-term outcomes.

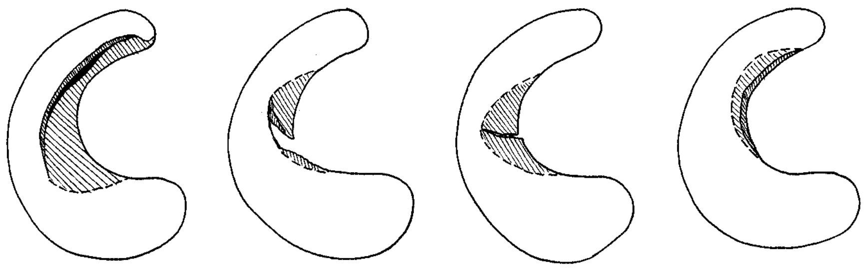


Figure 1 Principles of partial meniscectomy (shaded areas) for different types of meniscal tears. Balancing the meniscal resection with a vertical longitudinal tear **(A)**, an oblique tear **(B)**, a transverse radial tear **(C)**, and a horizontal tear **(D)**. (Adapted with permission from Newman AP, Daniels AU, Burks RT: Principles and decision making in meniscal surgery. *Arthroscopy* 1993;9:33-51.)

Burks et al[9] reported both clinical and radiographic results of patients with a nearly 15-year follow-up after partial meniscectomy. Patients who underwent concomitant anterior cruciate ligament (ACL) procedures at the time of meniscectomy were excluded from the study. The authors reported an 88% good or excellent clinical outcome and minimal degenerative radiographic changes compared with the untreated knee. Patients with ACL deficiency at the time of partial meniscectomy did notably worse than patients with an intact ACL in regard to both radiographic changes and clinical outcome.

Meniscal Cysts

The meniscus adjacent to a meniscal cyst may be torn and require excision. Cysts may rupture during meniscus débridement or may be entered by probing from within or by inserting the shaver or a rasp into the cyst to decompress it (Fig. 2). Metcalf et al[4] suggested that cysts usually do not recur if the underlying meniscal lesion is addressed, thus eliminating the need for open cyst excision. In certain instances, partial resection does not result in decompression of the cyst. Inserting an 18-gauge needle percutaneously through the cyst and into the joint will identify its exact position within the meniscus. Once located, more aggressive probing of the meniscus in this location often will decompress the cyst. If the cyst cannot be decompressed through arthroscopic means, open excision should be considered. The results of arthroscopic meniscal cyst treatment are reported as 90% to 100% good results without recurrence.[10,11]

Repair

Nonfixation Healing Enhancement

The healing of expectantly treated meniscal tears may be improved

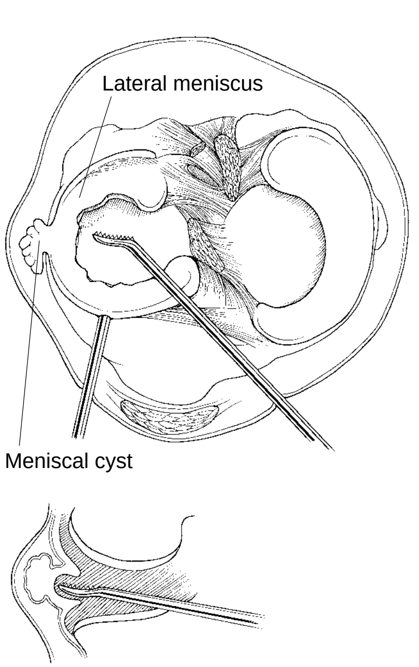


Figure 2 Arthroscopic decompression of a meniscal cyst with a rasp after resection of the underlying meniscal tear. (Adapted with permission from Patel D, Parisien JS: The torn lateral meniscus, in Parisien JS [ed]: *Arthroscopic Surgery*. New York, NY: McGraw-Hill, 1988, pp 111-123.)

through neovascularization techniques applied around the meniscal tear. Techniques such as synovial abrasion and meniscal trephination have been described to enhance healing.[12] Abrasion of the synovial fringe on both the femoral and tibial surfaces of the meniscus is by far the most widely accepted clinical method for stimulation of meniscal healing when formal repair is not considered necessary. Synovial abrasion is intended to produce a vascular pannus that will migrate into the meniscal tear and help produce a reparative response.

Vascular access channels have been shown in animals to allow proliferation of fibrovascular scar from the channel into the tear site.[13] These channels are not used extensively in clinical situations, however, because they are thought to disrupt the predominantly circumferential orientation of collagen fibers of the meniscus. This disruption may potentially weaken the meniscus as well as interfere with biomechanical function. As an alternative, trephination of the meniscus is a modification of this technique in which a series of horizontally oriented holes is made using a spinal needle or small trephine through the peripheral aspect of the meniscus. In one study in which multiple trephinations were used to treat incomplete meniscal tears in the peripheral and middle third of the meniscus, a 90% success rate was reported.[14]

Meniscal Bed Preparation

When formal repair is to be undertaken, the meniscal bed must be prepared before fixation devices are placed across the tear. Careful evaluation of the tear and determination of repairability are followed by tear preparation. A small shaver (3.5 mm) is often helpful in débriding the loose edges of large tears. This small size allows maneuverability within the joint with less risk of chondral damage. In large, bucket handle tears, the peripheral rim can be débrided with the shaver and then further roughened using a meniscal rasp. Rasping of the synovial fringe is helpful in achieving synovial bleeding and pannus formation. As tears extend into the avascular zones, trephination of the peripheral rim with a spinal needle should be considered, and for complex tears with avascular extension, the addition of exogenous fibrin clot may be beneficial.[5]

Open Repair

Annandale[15] is credited with the first successful meniscal repair, in 1885. However, meniscus salvage and repair did not gain popularity until the mid to late 1970s. These early repairs were done using open techniques, often in conjunction with open collateral ligament repairs. Popularized by DeHaven[16] and Wirth[17] as an early alternative to complete meniscectomy, open repair is most useful in peripheral tears. In the setting of either multiple ligament injuries (which may require open collateral ligament repair or reconstruction) or tibial plateau fracture, open meniscal repair is often necessary. Direct suturing of a peripheral tear with either absorbable or nonabsorbable sutures may be the most effective means of treating these injuries. The rate of repair success is high, likely because of the acuteness of the injury, the peripheral nature of the tear, and the associated hemarthrosis. In the setting of isolated meniscal tears or tears with associated ACL injuries, many surgeons have used arthroscopic techniques. However, advocates of open repair would suggest that many of these tears could have been addressed through open techniques and that the incisions for open repair are not substantially different from those used with the inside-out arthroscopic technique. Additionally, some authors think that meniscus preparation and suture fixation are more readily achieved with an open technique.

Arthroscopic Repair

Arthroscopy allows for the evaluation and treatment of meniscal tears previously not amenable to open repair. Modifications of suture techniques are numerous and were the first techniques to take advantage of the improved visualization provided by the arthroscope. The three basic suture techniques are inside-out, outside-in, and all-inside. Other arthroscopic repairs using bioabsorbable implants and suture anchors are also available.

Inside-Out Technique

Henning[18] popularized this technique in the early 1980s, and for many surgeons it remains the method of choice for the treatment of most meniscal tears. The inside-out technique utilizes double-armed sutures with long flexible needles positioned with arthroscopically directed cannulas. A medial or lateral incision is required to retrieve suture needles as they exit the joint capsule. Proper positioning of incisions and appropriate dissection down to the capsule are necessary to minimize the risk of neurovascular injury. Advantages of this technique include its ability to treat nearly all types of tears and the excellent fixation it affords, which are aided by the visualization possible arthroscopically. Disadvantages include the potential risks to neurovascular structures and the need for accessory incisions.

On the lateral side of the knee, the peroneal nerve is at greatest risk for injury; however, the popliteal artery, popliteal vein, and tibial nerve are also at risk. For this reason, absolute certainty of needle position is required. The lateral incision is centered on the joint line and is placed just posterior to the lateral collateral ligament (Fig. 3). Dissection is made with the knee at 90° of flexion. The interval between the biceps femoris tendon and the iliotibial band is opened and the biceps tendon is retracted posteriorly. This serves to protect the peroneal nerve. The lateral collateral ligament is palpable just anterior to this interval. To see the needles as they exit the capsule, the lateral gastrocnemius muscle fascia must be identified and split so that the muscle fibers can be swept off the joint capsule. This is most easily accomplished by identifying the gastrocnemius muscle fascia distally and working superiorly. Once the muscle is elevated from the capsule, a speculum retractor is placed deep to protect the neurovascular bundle (Fig. 4).

The structure most commonly injured on the medial side of the knee during a meniscal repair is one of the branches of the saphenous nerve.[19] Injury can result in localized numbness or a neuroma with associated pain. For this reason, sutures placed medially should be tied directly onto the capsule under direct visualization, following careful dissection down to the capsule. The medial incision is approximately 3 to 4 cm in length, starts above the level of the joint line, and is extended distally (Fig. 5). The infrapatellar branch of the saphenous nerve has a fairly consistent course approximately 1 cm proximal to the joint line. During placement of the incision, the surgeon should take great care to avoid injuring the saphenous nerve, which is usually just below the subcutaneous fat on the sartorial fascia. The approach should be made with the knee at 90° of flexion. This position moves the sartorius muscle and the saphenous nerve posteriorly. The sartorius fascia is opened in line with the skin incision, and an easily identifiable plane is developed between the sartorius

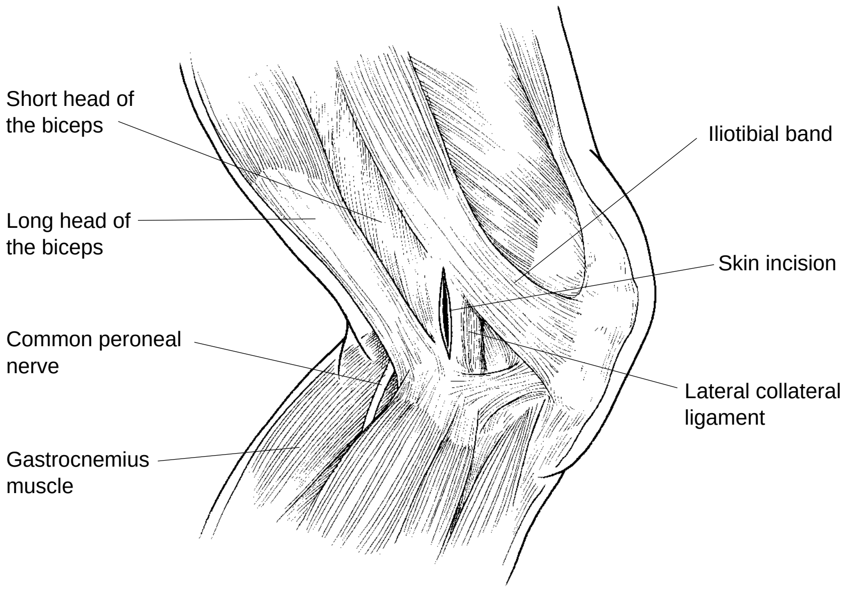


Figure 3 Gross anatomy of the lateral aspect of the knee. For the inside-out technique, the interval between the biceps and the iliotibial band is opened, with dissection carried out behind the lateral collateral ligament. (Adapted with permission from Bach BR Jr, Jewell BF, Bush-Joseph C: Surgical approaches for medial and lateral meniscal repair. *Techniques in Orthopedics* 1993;8:120-128.)

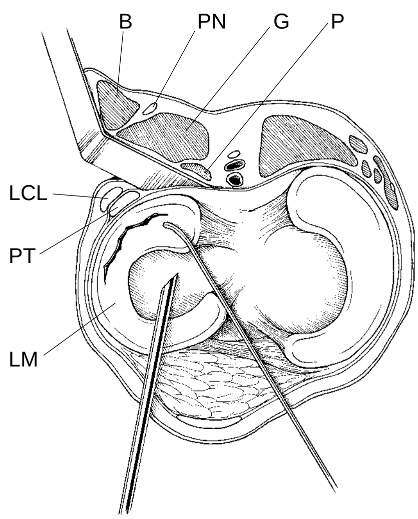


Figure 4 The dissection for a lateral meniscus repair for the inside-out technique requires retraction of the biceps tendon and lateral gastrocnemius muscle to protect the peroneal nerve. The arthroscope is placed in the ipsilateral portal and the cannula in the contralateral portal to minimize risk to the neurovascular structures. (B = biceps, PN = peroneal nerve, G = lateral gastrocnemius, P = plantaris, LCL = lateral collateral ligament, PT = popliteal tendon, LM = lateral meniscus.)

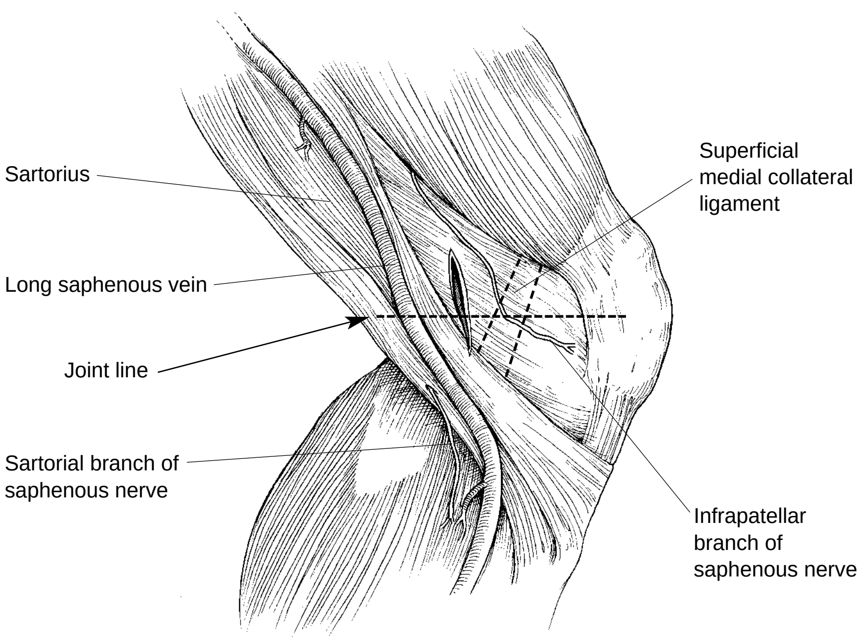


Figure 5 Gross anatomy of the medial aspect of the knee. Note the infrapatellar branch of the saphenous nerve. (Adapted with permission from Bach BR Jr, Jewell BF, Bush-Joseph C: Surgical approaches for medial and lateral meniscal repair. *Techniques in Orthopedics* 1993;8:120-128.)

and the capsule of the knee. A speculum retractor is placed into the space (Fig. 6), and the needles can be visualized as they pass through the capsule exiting distal to the joint line.

After the appropriate incision and dissection have been made and the meniscal bed has been prepared, curved cannulas are brought into the knee through the portal opposite the tear. For medial repairs, the knee is held in 10° to 20° of flexion with a valgus stress applied. For lateral tears, the knee is placed in 50° to 80° of flexion with a varus moment. Needles are advanced in 0.5-cm increments and are collected as they perforate the joint capsule. Sutures should be spaced evenly in 2- to 3-mm increments and, if possible, placed in a vertical mattress orientation (Fig. 7). This orientation has superior repair strength compared with horizontal sutures.[20] Multiple sutures are placed both superior and inferior to the meniscus before tying the ends under direct visualization over the capsule. Either absorbable or nonabsorbable 2-0 sutures may be used; studies show mixed results as to which is more efficacious.

Outside-In Technique

This technique was developed in an attempt to decrease the risk to neurovascular structures associated with the inside-out technique. It involves the passage of an 18-gauge spinal needle across the tear from outside to inside the joint.[21] A 0 polydioxanone suture is then passed into the joint through the needle and brought out through an anterior portal, where a knot is tied in the suture. This knot is then pulled back into the joint against the meniscus to hold it in a reduced position. The free ends of adjacent sutures are tied over the joint capsule through small incisions cleared of soft tissue through blunt dissection. A modification of this technique is to use parallel needles with a suture passed through one and a wire snare through the other to retrieve the free end of the suture (Fig. 8). The ends are once again tied over the capsule through small skin incisions.

The outside-in technique is most readily applicable to tears involving the anterior and middle thirds of the meniscus. With middle and posterior tears, this technique may put neurovascular structures at risk. These tears require a formal incision and an approach as described for the inside-out technique if needles are to be passed safely and at the correct orientations.

All-Inside Technique

The all-inside technique is indicated for unstable vertical longitudinal tears of the peripheral posterior horns of the menisci. Tears anterior to the posterior one third of the meniscus are not amenable to this technique. The all-inside technique

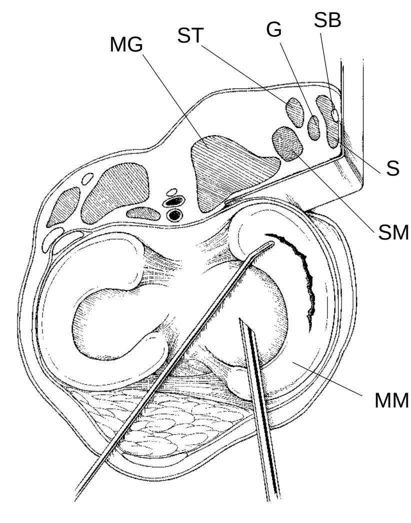
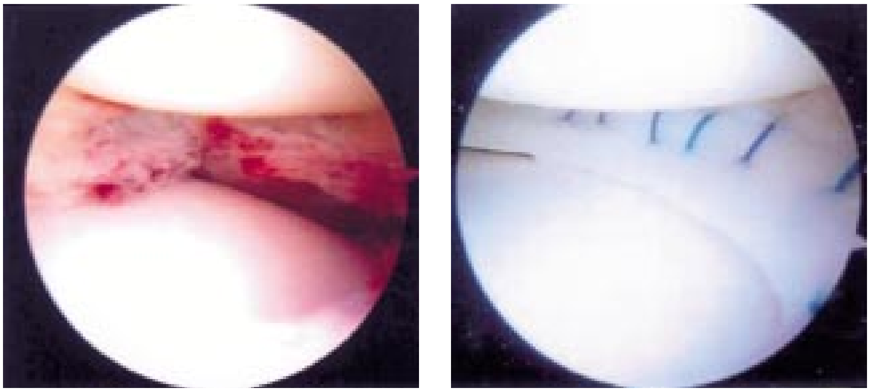


Figure 6 The medial meniscal repair dissection for the inside-out technique requires retraction of the sartorius to prevent injury to the saphenous nerve (MG = medial gastrocnemius, ST = semitendinosis, G = gracilis, SB = sartorial branch of saphenous nerve, S = sartorius gastrocnemius, SM = semimembranosus, MM = medial meniscus).



A B

Figure 7 **A,** Lateral meniscus tear in the red/red zone with the inner portion retracted medially. **B,** Repair of the tear using the inside-out technique with multiple vertical mattress sutures.

necessitates specialized setup and equipment, including the placement of a 70° arthroscope into the posteromedial or posterolateral portion of the knee, the creation of posteromedial or posterolateral working portals, and the use of curved cannulated suture-passing hooks. Suture placement is done through the accessory posterior portal, and visualization is achieved with the 70° arthroscope placed through the notch into the posterior aspect of the knee. Arthroscopic knot-tying techniques are used to approximate the meniscal tissue.

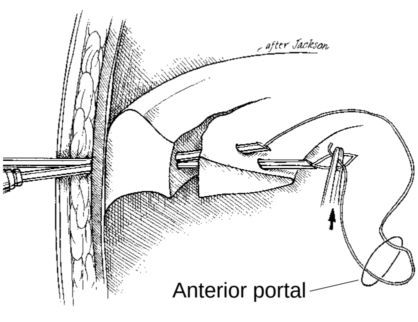


Figure 8 Outside-in technique with parallel needles placed through the meniscus. A wire snare is used to retrieve the sutures (arrow). (Adapted with permission from Johnson LL: Meniscus repair: The outside-in technique, in Jackson DW [ed]: *Reconstructive Knee Surgery*. New York, NY: Raven, 1995, pp 51-68.)

Nonsuture Techniques

As biomaterial technology has improved, sutureless meniscus fixation devices have been developed that obviate the need for additional incisions. The Meniscus Arrow (Bionx Implants, Bluebell, PA) is made of self-reinforced poly-L-lactic acid. Its barbed design, originally intended for the treatment of bucket handle tears, allows for compression of vertical longitudinal tears. Early clinical studies utilizing this device demonstrated good clinical efficacy. Biomechanical testing of peripheral vertical tears demonstrated that fixation strength using this device was not as secure as with vertical sutures ($P < 0.001$).[22] Use of an automatic insertion device (the Meniscus Arrow Crossbow inserter; Bionx Implants) has demonstrated improved fixation.

Numerous other sutureless implants have been designed for all-inside fixation of meniscal tears. Initial controlled clinical studies have shown their equivalent efficacy, but additional studies are necessary.[23]

Hybrid Suture Technique

An additional all-inside technique has been described by Barrett et al.[24] This technique utilizes a specially designed suture anchor (T-Fix suture bar, Smith & Nephew, Memphis, TN) that is placed through the meniscus. A suture is fixed to a nonbiodegradable bar that anchors itself against the peripheral rim of the meniscus. Sutures from adjacent anchors are tied arthroscopically using intra-articular knot-tying techniques. This repair can be accomplished without the need for accessory posteromedial or posterolateral incisions. It can be used in a variety of tear patterns but is most efficacious in the treatment of vertical longitudinal tears.

Results of Repair

In analyzing the results of meniscal repair, a number of factors must be considered. First, the criteria for a successful result must be clearly identified. A variety of means have been used to evaluate success, including second-look arthroscopy, double-contrast arthrography, clinical evaluation with the absence of symptoms referable to a meniscal problem, and, more recently, magnetic resonance imaging. Meniscal repair "success" rates therefore vary depending on the criteria selected to evaluate surgical outcome. Second, the presence or absence of associated ligamentous injury, most commonly ACL injury, must be defined. Patients who undergo meniscal repair concurrently with ACL reconstruction constitute a different subset of patients than do those who require isolated meniscal repair. The reasons for this are likely multifactorial, including the acuteness of injury to an often previously normal meniscus in the setting of ACL injury, and the hemarthrosis that occurs as a result of ACL reconstruction, which likely influences the healing environment of the knee. Third, short-term results may underestimate failure rates. At minimum, a 2-year follow-up is required to fully assess results.

Rubman et al[25] evaluated arthroscopic meniscal tears extending into the avascular zone. Of 198 tears that were repaired, 80% (159) were thought to be asymptomatic for tibiofemoral symptoms at follow-up. In the 20% (39) that required second-look arthroscopy for tibiofemoral symptoms, only 2 menisci were healed, 13 were partially healed, and 24 had failed. Within the whole group of 177 patients, 91 meniscal repairs were evaluated arthroscopically: 23 (25%) were classified as completely healed, 35 (38%) as partially healed, and 33 (36%) as failed. Only 24 of the patients with failures (73%) had symptoms referable to the tibiofemoral joint. In this study, lateral meniscus tears fared better, and a trend was seen toward improved results with meniscal repair done within 10 weeks of injury. The authors concluded that the benefits of repair justify this procedure despite a 20% rate of revision surgery and a 36% rate of failure in those evaluated arthroscopically. They suggested that the benefits of a potentially functional meniscus outweigh the risks of revision surgery and recommended that repair be done for tears that extended into the avascular portions of the meniscus. Table 1 outlines the results of other studies.

A review of the literature makes it apparent that isolated meniscal repairs have a lower success rate than do repairs done in conjunction with ACL reconstruction. Additionally, meniscal tears with rim widths of <3 mm, those resulting from acute injuries, and those involving the lateral meniscus seem to have a greater potential for healing.

Rehabilitation

Rehabilitation after meniscal repair remains controversial.[12,25] Because the majority of meniscal repairs are done in conjunction with ACL reconstruction, rehabilitation protocols for meniscal repair have followed the trends of early range of motion and weight bearing common to ACL rehabilitation.[34] Some

Table 1
Results of Meniscal Repairs

Study	No. of Repairs	Follow-up	Status of ACL	Criteria	Results	Positive (+) and Negative (–) Influences
Eggli et al[26]	54	7.5 yr (average)	Stable	Clinical ± MRI	73% success	(+) Acute injury <8 wk, age <30 yr, tear length <2.5 cm (–) Rim width >3 mm, absorbable sutures
Albrecht-Olsen and Bak[27]	27	3 yr (median)	Stable	Clinical	63% success	—
Miller[28]	79	3.25 yr (mean)	Stable and recon	Arthroscopy or arthrogram	84% healed (stable), 93% healed (recon)	(–) Failed ACL
Morgan et al[29]	74	8.5 mo (average)	Injured in most	Arthroscopy	65% healed (completely), 19% healed (incompletely), 16% failed	(+) Stable knees and ACL-recon knees (–) Unstable knee not recon
Cannon and Vittori[30]	90	≤10 mo (mean)	Stable (22), recon (68)	Arthroscopy or arthrogram	50% healed (stable), 93% healed (recon)	(+) Lateral meniscus, small rim width
Buseck and Noyes[31]	66	1 yr (average)	Recon	Arthroscopy	80% healed (completely), 14% healed (partially), 6% failed	(+) Repairs in outer 1/3 rim width = 98% healing
Tenuta and Arciero[32]	54	11 mo (average)	Stable (14), recon (40)	Arthroscopy	57% healed (stable), 90% healed (recon)	(+) Age <30 yr, early repair (–) Rim width >4 mm
Johnson et al[33]	38	10 yr 9 mo (average)	Stable	Clinical	76% success	(–) Increased rim

Recon = reconstructed.

authors suggest that meniscal repair done in conjunction with ACL reconstruction does not necessitate alteration in rehabilitation protocol; others modify the program. Restriction of hyperflexion after meniscal repair and either partial weight bearing or weight bearing with a brace locked in extension are common modifications of ACL rehabilitation protocols associated with meniscal repair. When done in isolation, meniscal repair rehabilitation has traditionally been relatively conservative, with protected weight bearing and restrictions on range of motion being common.

Complications

Complications of meniscal repair are similar to those of other arthroscopic knee surgeries and include infection, deep vein thrombosis, postoperative stiffness, pain, and hemarthrosis. Complications specific to the procedure are failure of meniscal healing with a need for repeat arthroscopy, injury to either the saphenous nerve during medial meniscus repair or the peroneal nerve during lateral meniscus repair, and loss of motion after repair (Table 2).

Shelbourne and Johnson[37] reported a 25% incidence of motion problems when meniscal repair and ACL reconstruction were done in patients with a locked bucket handle tear in a chronic ACL-deficient knee. Meniscal repair done concurrently with ACL reconstruction in this setting does appear to increase the risk for motion problems; however, the necessity of a staged repair remains controversial.

Meniscal Reconstruction

Meniscal allograft transplantation, first done by Milachowski et al,[38] has been investigated with preclinical studies in animals and cadavers as well as in clinical studies. Meniscal transplantation has been carried out in a variety of animal models in an effort to prove the viability of the procedure. Arnoczky et al[39] did 14 medial meniscus cryopreserved allograft transplants in adult dogs. The allografts retained their normal gross appearance and healed to the capsule by fibrovascular scar. At 3 months, histologic and autoradiographic examination revealed cellular distribution and metabolic activity comparable to those of controls.

Jackson et al[40] used a goat model to compare autograft, fresh allografts, and cryopreserved allograft medial meniscus transplants. At 6 months, the implanted menisci appeared histologically to differ little from the menisci of controls, with nearly normal peripheral vascularity. There were reduced numbers of cells in the central portions of the menisci, and biochemical analysis showed increased water content with decreased proteoglycan content.

Recent studies using fresh-frozen menisci demonstrated decreased cellularity early on but with progressive remodeling over 6 to 8 months. A study of cryopreserved versus deep-frozen transplants in goats found no notable differences between the two, with nearly complete remodeling at 6 and 12 months.[41] These findings are in agreement with a recent DNA analysis done on a cryopreserved meniscal transplant in a human recipient 1 year after transplantation.[42] The DNA profile of the meniscal allograft was 95% identical to that of the human recipient 1 year after transplantation, indicating nearly complete repopulation by host cells.

Studies of the biomechanical consequences of meniscal transplantation have demonstrated improved contact areas and decreased contact pressures after lateral meniscus allograft replacement in cadaveric models, provided that both the anterior and the posterior horns of the menisci are secured.[43] When the anterior and posterior horn attachments are released, the contact pressures are equal to those resulting from total meniscectomy. When one horn is released, some beneficial effect is seen; however, this effect is less than that seen when both horns are secure.

Table 2
Complications From Meniscal Repairs

Study	No. of Repairs	Types of Repair	Complications	Comments
Small[19]	3,034	Variety	Overall, 2.5%; saphenous nerve, 1.0%; peroneal nerve, 0.2%; vascular injury, 0.1%	Retrospective survey
Small[35]	257	Inside-out and outside-in	Overall, 1.2%; saphenous nerve, 0.4%	Prospective monthly questionnaire
Austin and Sherman[36]	101	Inside-out and outside-in	Overall, 18% (with ACL, 20%; isolated, 14%); arthrofibrosis, 6%; saphenous nerve, 7%	10% arthrofibrosis when with ACL

Indications for Transplantation

The indications for meniscal transplantation continue to change as clinical experience increases. At present, the ideal indication is the patient who has previously undergone a total or near-total meniscectomy and has joint line pain, early chondral changes, normal anatomic alignment, and a stable knee (or one that can be reconstructed). In this setting, meniscal transplantation may decrease pain and possibly prevent progressive degeneration of the articular cartilage. In patients with anatomic malalignment, a corrective osteotomy is thought to be important to normalize the joint forces on the meniscal allograft.

In patients with ligamentous instability who have had a total meniscectomy, concurrent ACL reconstruction with allograft meniscal transplantation may be reasonable in an effort to prevent long-term degenerative joint disease and improve joint stability. In patients with advanced degenerative joint disease, meniscal transplantation has a poor outcome and is not indicated.[44] The role of meniscal transplantation in young asymptomatic patients who have undergone a total meniscectomy is controversial. At present, the ability to prevent long-term degenerative joint disease with meniscal allograft transplantation is unproven, and therefore only symptomatic patients are thought to be appropriate candidates. Further clinical studies in this patient population are needed.

Surgical Considerations

Key factors in considering meniscal transplantation are graft selection, graft sizing, and choice of surgical technique.

Graft Selection

Fresh, fresh-frozen, and cryopreserved grafts are commonly used. Fresh grafts have been evaluated by Garrett[45] and show promising results. However, the logistical difficulties in the routine use of fresh grafts make them impractical for widespread use. Fresh-frozen and cryopreserved grafts allow more flexibility in graft handling and in the timing of surgeries. Whether future clinical results will document that cryopreservation is superior to fresh-frozen allograft transplantation remains to be seen. The additional cost of cryopreservation grafts over fresh-frozen grafts will need to be justified with improved clinical outcomes.

Graft Sizing

A variety of techniques can be used to match donor and recipient with regard to graft size. For optimal outcome, the transplanted meniscus should vary less than 5% in size from the recipient's original meniscus. Studies evaluating the use of computed tomography, magnetic resonance imaging (MRI), and plain radiography for the sizing of meniscal allografts have reported conflicting data. Shaffer et al[44] compared MRI and plain radiographs for determining graft size. MRI was accurate to within 5 mm of width and length measurements in 83% of cases, and plain radiographs were accurate in 79% of cases.

Surgical Techniques

Open techniques, open techniques with collateral ligament detachment, and arthroscopic-assisted techniques have been described for meniscal transplantation. Interestingly, ultimate success of the procedure is more likely influenced by patient selection, appropriate graft sizing, accurate graft placement, and secure graft fixation than by insertion technique. Fixation of the meniscal graft has been described with soft-tissue fixation alone or in conjunction with bone plug or bone bridge fixation. The importance of secure meniscal horn fixation has resulted in development of several techniques. Bone plugs placed into bone tunnels (Fig. 9), or a bone bridge between the anterior and posterior horns placed into a bony

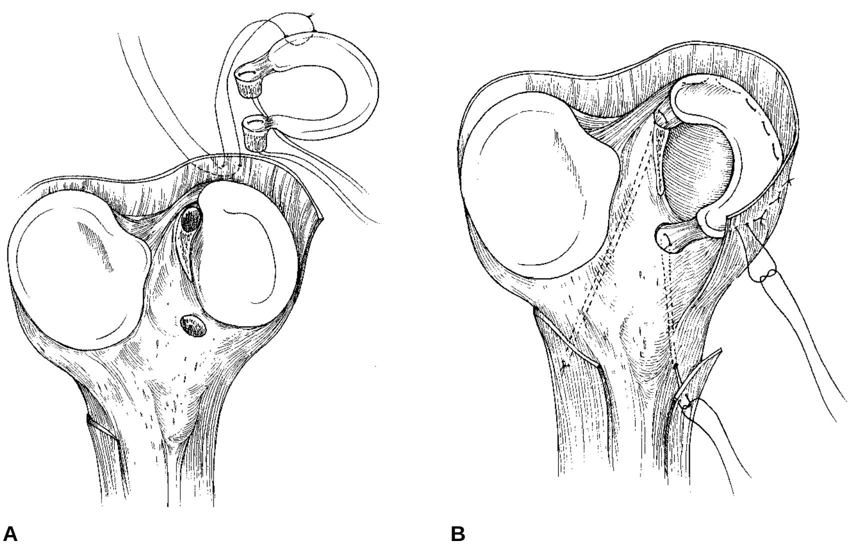


Figure 9 **A,** Allograft meniscal bone plugs are used to anchor the medial meniscus. **B,** Allograft bone plugs in place, secured with transosseous sutures. (Adapted with permission from Goble EM, Kane SM, Wilcox TR, Doucette SA: Meniscal allografts, in McGinty JB, Caspari RB, Jackson RW, Poehling GG [eds]: *Operative Arthroscopy*, ed 2. Philadelphia, PA: Lippincott-Raven, 1996, pp 317-331.)

trough, have both been done in an effort to provide secure fixation, recreate hoop stress within the meniscus when loaded, and prevent meniscus extrusion. New instrumentation that allows for secure, sutureless fixation of bone bridges using a "keyhole" technique may prove to be efficacious.

Results

Allograft meniscal transplantation success rates are difficult to quantify because of the varied criteria for success that have been used. These criteria include graft incorporation, decrease in preoperative symptoms, graft retention, evidence of radiographic progression of degenerative joint disease, and a normal appearance on MRI.

Published results to date often include patient populations with a variety of complex knee problems, making clinical evaluation difficult. In a series of 43 patients followed for between 2 and 7 years, only 7 had an isolated meniscal transplantation; 24 had concurrent ACL reconstructions; and 13 also had an osteotomy (one procedure was bilateral).[45] Fresh menisci were used in 16 cases and cryopreserved menisci in 27. Twenty-eight cases had a second-look arthroscopy; 15 were clinically "silent" and were not reexamined. Successful healing of the meniscal rim was achieved in 20 of 28 without meniscal shrinkage or degeneration. Unfavorable results were seen in patients with grade IV articular changes.

In another series of 23 patients who underwent cryopreserved meniscal transplantation, 20 had satisfactory results and 3 were failures, necessitating graft removal at 12, 20, and 24 months (follow-up, 2 to 5 years).[46] Failures were thought to be caused by uncorrected malalignment of the limb.

Cameron and Saha[47] used 67 fresh-frozen, irradiated meniscal allografts in 63 patients. Eighty-seven percent of knees had a good or excellent result using a modified Lysholm rating scale. The authors did 34 osteotomies in this series and felt that limb alignment was important for long-term success.

Noyes[48] reported on a series of 96 fresh-frozen, irradiated meniscal allograft transplants in 82 patients. Based on MRI and arthroscopic evaluations, 22% healed, 34% partially healed, and 44% failed. These poor results likely reflect the fact that many patients had advanced osteoarthritis at the time of transplantation. On MRI, normal knees had a 70% healing rate, with 30% partially healing; when severe arthrosis was present, 50% of the grafts failed and 50% partially healed.

Others have presented favorable results with transplantation done in the presence of minimal arthrosis and normal alignment. Pain relief and improved knee function were predictable in these settings. For this reason, meniscal allograft transplantation remains a potential option for patients with previous irreparable meniscal damage or those who have undergone total meniscectomy. However, further long-term studies are needed to fully evaluate this procedure.

Summary

When feasible, meniscal repair should be done in an attempt to maintain meniscal integrity and prevent long-term degenerative changes that occur after meniscectomy. When meniscal repair cannot be done or is contraindicated, partial meniscectomy may be considered, with the goal of retaining as much viable meniscal tissue as possible. When severe injury makes the meniscus irreparable and total meniscectomy is required, meniscal transplantation can be considered if symptoms referable to the meniscectomized joint are present.

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