Meniscal Repair

PART I: BASIC SCIENCE, INDICATIONS FOR REPAIR, AND OPEN REPAIR

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Meniscal repair is not a new concept; the first known repair was performed more than a century ago by Annandale in Edinburgh, Scotland. Despite this report, this procedure attracted little or no attention, and clinical management was directed toward excision since the meniscus was believed to be of little importance to knee function and to be incapable of healing. Classic laboratory research by King in the 1930’s documented that meniscal lesions that communicate with the peripheral blood supply do indeed heal, but this report also went virtually unnoticed, possibly because of the general acceptance at that time of total meniscectomy for the treatment of meniscal tears. Despite Fairbank’s warning, in 1948, that degenerative changes can follow meniscectomy, it was not until several studies* in the 1960’s and 1970’s more completely documented the disappointing long-term results following meniscectomy that this approach began to be seriously questioned. During the same period, several laboratory studies helped to clarify the functional importance of menisci in force transmission, stability, and shock absorption. These factors have collectively led to the emergence of a more conservative clinical approach to the management of meniscal tears over the past two decades. Appropriate treatment now may include the leaving of certain tears alone; partial meniscectomy; and, in selected patients, meniscal repair. This paper will summarize current basic-science information, the indications for repair, both open and arthroscopic repair techniques, and the results of meniscal repair.

Basic Science of the Meniscus

The menisci are C-shaped disks of fibrocartilage interposed between the condyles of the femur and tibia. Although they were once described as the functionless remains of leg muscle, it has been realized that the menisci are integral components in the complex biomechanics of the knee joint. This has resulted in a renewed interest in the basic science of the meniscus in terms of its structure, physiology, and function.

Gross Anatomy

The menisci of the knee joints serve as extensions of the tibia to deepen the articular surfaces in the region of the tibial plateau and thus to accommodate better the condyles of the femur. The peripheral border of each meniscus is thick, convex, and attached to the inside of the joint capsule; the opposite border tapers to a thin, free edge. The proximal surfaces of the menisci are concave and in contact with the condyles of the femur; the distal surfaces are flat and they rest on the head of the tibia (Fig. 1).

The medial meniscus is somewhat semicircular. It is approximately 3.5 centimeters long and considerably wider posteriorly than it is anteriorly. The anterior horn of the medial meniscus is attached to the tibial plateau in the area of the anterior intercondylar fossa, in front of the anterior cruciate ligament (Fig. 2). The posterior fibers of the anterior horn attachment merge with the transverse ligament, which connects the anterior horns of the medial and lateral menisci. The posterior horn of the medial meniscus is firmly attached to the posterior intercondylar fossa of the tibia between the attachments of the lateral meniscus and the posterior cruciate ligament. The periphery of the medial meniscus is attached to the joint capsule throughout its length. The tibial portion of the capsular attachment is often referred to as the coronary ligament. At its mid-point, the medial meniscus is more firmly attached to the femur and tibia through a thickening in the joint capsule known as the deep medial collateral ligament.

The lateral meniscus is almost circular, and it covers a larger portion of the articular surface of the tibia than does the medial meniscus; it is approximately the same width from front to back (Fig. 2). The anterior horn of the lateral meniscus is attached to the tibia, in front of...
Frontal section of the medial compartment of a knee, showing the articulation of the menisci with the condyles of the femur and tibia. (Reprinted, with permission, from: Warren, R.; Arnoczky, S. P.; and Wickiewicz, T. L.: Anatomy of the knee. In The Lower Extremity and Spine in Sports Medicine, p. 686. Edited by J. A. Nicholas and E. B. Hershman. St. Louis, C. V. Mosby, 1986.)

the intercondylar eminence and behind the anterior extent of the attachment of the anterior cruciate ligament. The posterior horn of the lateral meniscus is attached behind the intercondylar eminence of the tibia, in front of the posterior end of the medial meniscus. While there is no attachment of the lateral meniscus to the fibular collateral ligament, there is a loose peripheral attachment to the joint capsule except in the region of the popliteus tendon.

Several ligaments run from the posterior horn of the lateral meniscus to the medial femoral condyle, either just in front of or behind the origin of the posterior cruciate ligament. These are known as the anterior meniscofemoral ligament (the ligament of Humphrey) and
the posterior meniscofemoral ligament (the ligament of Wrisberg)55.

Ultrastructure and Biochemistry

Histologically, the meniscus is fibrocartilaginous tissue composed, primarily, of an interlacing network of collagen fibers interposed with cells. The extracellular matrix consists of proteoglycan molecules as well as glycoproteins.

The extracellular matrix of the meniscus is composed primarily of collagen (60 to 70 per cent of the dry weight)122. It is mainly (90 per cent) type-I collagen, although types II, III, V, and VI have been identified within the meniscus122. The circumferential orientation of these collagen fibers appears to be directly related to the function of the meniscus. In a classic study of the orientation of the collagen fibers within the menisci, it was noted that, although the principal orientation of the
collagen fibers is circumferential, a few small, radially disposed fibers appear on both the femoral and the tibial surfaces of the menisci as well as within the substance of the tissue. It has been theorized that these radial fibers provide structural rigidity and help to resist longitudinal splitting of the menisci, which could result from undue compression (Fig. 3). Subsequent light and electron microscopic examinations of the menisci revealed three different collagen-framework layers: a superficial layer composed of a network of fine fibrils woven into a mesh-like matrix; a surface layer just beneath the superficial layer composed, in part, of irregularly aligned collagen bundles; and a middle layer in which the collagen fibers are larger and coarser and are oriented in a parallel, circumferential direction. It is this middle layer that allows the meniscus to resist tensile forces and to function as a transmitter of load across the knee joint.

Function

The function of the menisci has been inferred clinically from the degenerative changes that accompany their removal. Fairbank described radiographic changes following meniscectomy that included narrowing of the joint space, flattening of the femoral condyle, and the formation of osteophytes (Fig. 5). These changes were attributed to the loss of the weight-bearing function of the meniscus. More sophisticated biomechanical studies have demonstrated that at least 50 per cent of the compressive load of the knee joint is transmitted through the meniscus in extension and that approximately 85 per cent of the load is transmitted in 90 degrees of flexion.

In the meniscectomized knee, the contact area is reduced approximately 50 per cent. This greatly increases the load per unit area and results in damage and degeneration of the articular cartilage (Fig. 6). Partial meniscectomy has also been shown to increase contact pressures greatly. In an experimental study, resection of as little as 15 to 34 per cent of the meniscus increased contact pressures by more than 350 per cent. Thus, even partial meniscectomy does not appear to be a benign procedure.

Another proposed function of the meniscus is shock absorption. An examination of the compressive load-deformation response of normal and meniscectomized knees has suggested that the viscoelastic menisci may function to attenuate the intermittent shock waves generated by impulse-loading of the knee during gait. Studies have shown that the shock-absorbing capacity of normal knees is about 20 per cent higher than that of knees that have been treated with a meniscectomy. Since the inability of a joint system to absorb shock has been implicated in the development of osteoarthrosis, the meniscus appears to play an important role in the maintenance of the health of the knee joint.

In addition to their role in load transmission and shock absorption, the menisci are thought to contribute to knee-joint stability. While meniscectomy alone may not seriously decrease joint stability, studies have shown that performance of the procedure in association with insufficiency of the anterior cruciate ligament increases the anterior laxity of the knee.

Because the menisci serve to increase the congruity between the condyles of the femur and the tibia, they contribute to over-all joint conformity. It has been suggested that this function is also synergistic with the lubrication of the articular surfaces of the joint. While this hypothesis has never been proved, it suggests another important function of the menisci.

Finally, it has been suggested that the menisci are proprioceptive structures providing a feedback mechanism for joint-position sense. This has been inferred from the observation of type-I and type-II nerve-endings in the anterior and posterior horns of the menisci.

In summary, the proposed functions of the menisci include load-bearing, shock absorption, provision of joint stability, lubrication, and proprioception. Loss of the meniscus, in part or in total, greatly alters these functions and predisposes the knee joint to degenerative changes.
Vascular Anatomy

The menisci of the knee are relatively avascular structures; the limited peripheral blood supply originates predominantly from the lateral and medial geniculate arteries (both inferior and superior). Branches from these vessels give rise to a perimeniscal capillary plexus within the synovial and capsular tissues of the knee joint. This plexus is an arborizing network of vessels that supplies the peripheral border of the meniscus throughout its attachment to the joint capsule (Fig. 7). These perimeniscal vessels are oriented in a predominantly circumferential pattern, with radial branches directed toward the center of the joint. Anatomical studies have shown that the degree of vascular penetration is 10 to 30 percent of the width of the medial meniscus and 10 to 25 percent of the width of the lateral meniscus.

The middle geniculate artery, along with a few terminal branches of the medial and lateral geniculate arteries, also supplies vessels to the meniscus through the vascular synovial covering of the anterior and posterior horn attachments. These synovial vessels penetrate the horn attachments and give rise to endoligamentous vessels that enter the meniscal horns for a short distance and end in terminal capillary loops. A small reflection of vascular synovial tissue is also present throughout the peripheral attachment of the medial and lateral menisci on both the femoral and the tibial articular surfaces. (An exception is the posterolateral portion of the lateral meniscus adjacent to the area of the popliteus tendon.) This synovial fringe extends for a short distance (one to three millimeters) over the articular surfaces of the menisci and contains small, terminally looped vessels. While this vascular synovial tissue adheres intimately to the articular surfaces of the menisci, it does not contribute vessels into the meniscal tissue.

Healing

Experimental studies of the vascular response of the meniscus to injury have demonstrated that the peripheral meniscal blood supply is capable of producing a
reparative response (exudation, organization, vascularization, cellular proliferation, and remodeling) similar to that observed in other connective tissues. Following injury within the peripheral vascular zone of the meniscus, there is formation of a fibrin clot that is rich in inflammatory cells. Vessels from the perimeniscal capillary plexus proliferate into this fibrin scaffold and are accompanied by the proliferation of undifferentiated mesenchymal cells. Eventually, the lesion is filled with a cellular, fibrovascular scar tissue that glues the wound edges together and appears continuous with normal adjacent meniscal fibrocartilage. Vessels from the perimeniscal capillary plexus and a proliferative vascular pannus from the synovial fringe penetrate the fibrous scar to support this healing response. Experimental studies have shown that lesions within the vascular portion of the meniscus are completely healed by a fibrovascular scar by ten weeks (Fig. 8). Modulation of this scar tissue into normal-appearing fibrocartilage, however, requires several months. The strength of this repair tissue as a function of time has not been delineated, and further study is needed to document its material properties.

The ability of meniscal lesions to heal has provided the rationale for the repair of peripheral meniscal injuries, and several reports have demonstrated excellent results following primary repair of these injuries. Postoperative examination of these peripheral repairs has revealed a process of repair similar to that noted in experimental models.

In the examination of injured menisci for potential repair, lesions are often classified by the location of the tear relative to the blood supply of the meniscus and by the vascular appearance of the peripheral and central surfaces of the tear. The so-called red-red tear (peripheral capsular detachment) has a functional blood supply on the capsular and meniscal sides of the lesion and obviously has the best prognosis for healing. The red-white tear (in the meniscal rim through the peripheral vascular zone) has an active peripheral blood supply, while the central (inner) surface of the lesion is devoid of functioning vessels. Theoretically, this lesion should have sufficient vascularity to heal by the aforementioned fibrovascular proliferation. The white-white tear (completely in the avascular zone) is without a blood supply and theoretically cannot heal.

While meniscal repair has generally been limited to the peripheral vascular area of the meniscus (red-red and red-white tears), many lesions occur in the central, avascular portion of the meniscus (white-white tears). Experimental and clinical observations have shown that these lesions are incapable of healing and have thereby provided the rationale for partial meniscectomy. In an effort to extend the level of the repair into these avascular areas, techniques that provide vascularity to white-white tears have been developed. These techniques include vascular access channels and synovial abrasion.

The concept of vascular access channels stems from the fact that lesions connected to the peripheral vascularity of the meniscus heal by the aforementioned process. Experimental studies have shown that connection of a lesion in the avascular portion of the meniscus to the peripheral blood supply via a vascular access channel can result in healing of the lesion. However, because
the creation of a large-enough access channel may disrupt the normal peripheral architecture of the meniscus, other methods for the stimulation of vascular ingrowth have been proposed. The technique of synovial abrasion involves the stimulation of the synovial fringe on both the femoral and the tibial surfaces of the meniscus. This is intended to produce a vascular pannus that will migrate into the lesion and, it is hoped, support a reparative response. An experimental study has demonstrated that, in addition to the described methods for provision of vascular access, an exogenous fibrin clot placed in a stable lesion in the avascular portion of the meniscus can support a reparative response similar to that seen in the vascular area. The clot provides a potent chemotactic and mitogenic stimulus as well as a scaffold on which the cellular response is supported. This technique may allow the repair of avascular lesions anywhere in the meniscus or optimize the repair of lesions in areas of marginal vascularity. Clinical studies are currently under way to determine the applicability of this repair technique.

On the basis of these basic-science investigations, operative repair has been widely accepted as the treatment of choice for certain meniscal lesions. This acceptance has led to the development of a number of operative techniques with which to accomplish this goal.

**Indications for Repair versus Excision**

The choice between repair and excision of a specific meniscal lesion is simplified by separation of the lesions that are definitely repairable from those that are questionably repairable. Tears known to be definitely repairable are traumatic, are within the vascular zone of the meniscus, and have caused minimum damage to the meniscal body fragment. These are most commonly vertical-longitudinal, peripheral, or nearly peripheral tears of one centimeter in length or longer.

Tears that should be considered questionably suitable for repair are those in the avascular zone or in an area where the vascularity is in doubt. When repair of such tears is attempted, it is important to add healing-enhancement techniques such as rasping of the superior and inferior synovial fringes and the insertion of a fibrin clot. Tears that are not suitable for repair include those involving moderate or severe damage of the meniscus and complete radial tears. Even if successful repair and healing of those tears could be achieved, there is no evidence that the menisci would be capable of biomechanical function.

Preoperative information can alert both the surgeon and the patient that a meniscal tear is potentially repairable. Patients with a repairable meniscus are typically young (twelve to forty-five years old, with the average age being twenty-one years old) and active (approximately 80 per cent have an acute or chronic tear of the anterior cruciate ligament). Both medial and lateral menisci can be suitable for repair; over the years, the repair ratio of one of us (K. E. DeH.) has been three medial to two lateral. Preoperative diagnostic studies can also be helpful. Double-contrast arthrography is useful for the assessment of chronic lesions involving the medial meniscus. A vertical tear near the meniscosynovial junction with minimum staining of the meniscus indicates a high suitability for repair. However, extensive staining of the meniscus probably indicates that damage is severe and that the meniscus would most likely not be suitable for repair. More recently, the resolution and reliability of magnetic resonance imaging have improved, and, where available, this modality has largely supplanted arthrography for the evaluation of meniscal tears. When clearly positive, magnetic resonance-imaging studies are almost always reliable, but many false-negative findings continue to be encountered, particularly regarding tears of the meniscosynovial junction.

Regardless of the amount of preoperative information that indicates that a meniscal tear is repairable, the final decision is made on the basis of arthroscopic assessment. This requires careful evaluation with use of a probe from anterior approaches to determine the exact type, location, and extent of the tear as well as the degree of damage to the meniscus. Even in tight knees, it is possible to visualize the inferior surfaces of both the medial and the lateral menisci out to the meniscosynovial junction. It is also usually (but not always) possible to see the superior surface of the lateral meniscus all of the way to the meniscosynovial junction, from an anterior approach, except in unusually lax knees. Therefore, it is recommended that posterior visualization be carried out when necessary for the lateral meniscus and routinely for the medial meniscus, either by placement of an arthroscope, angled 70 degrees, through the intercondylar notch and into the posteromedial or posterolateral compartment, or by viewing through a posterior portal.

The other critical step in the arthroscopic determination of repairability is the assessment of vascularity at the site of the tear. The pneumatic tourniquet should not be inflated during the arthroscopic examination since the presence of bleeding at the site of the tear is a crucial factor. In subacute and chronic lesions, the presence of vascular granulation tissue at the site of the tear is also indicative of vascularity. It is important to note, however, that the absence of observable bleeding at the site of the tear should not rule out the possibility of repair because the distention pressure of the arthroscopic irrigation-fluid system can be sufficient to close down the small capillary circulation. Under these circumstances, when bleeding or vascularity is not seen, a clinical judgment regarding whether or not to perform a repair must be based on the location of the tear relative to the meniscosynovial junction. Vascular injection
studies have indicated that a tear within three millimeters of the meniscosynovial junction is considered to be within the vascular zone of the meniscus, even when no bleeding is observed. If the tear is five millimeters or more from the meniscosynovial junction, it can be considered to be avascular unless there is direct evidence of vascularity (active bleeding or granulation tissue). The vascularity of tears three to five millimeters from the meniscosynovial junction is variable, and if repair is elected, enhancement of healing with insertion of a fibrin clot should be considered.

Open Meniscal Repair

**Indications**

The primary indication for open meniscal repair is a peripheral or nearly peripheral tear (within one to two millimeters of the meniscosynovial junction) of the posterior one-third of the medial or lateral meniscus. The length of the tear is also an important factor, since short tears (less than seven millimeters) usually do not need to be repaired, as they frequently heal spontaneously or are asymptomatic even if they persist. Most tears that are repaired are considerably more than one centimeter long. Ideally, there should be little or no damage to the meniscal body. When there is considerable damage to the body fragment, effective function would be doubtful even if successful healing were to occur.

Open repair of a meniscosynovial tear that extends from the posterior third of the meniscus into the middle or even anterior third requires such extensive exposure that these tears are better handled by arthroscopic techniques. While unusual, peripheral tears confined to the anterior third of either meniscus are also suitable for open repair. It is important to recognize that it is difficult, if not impossible, to perform a satisfactory open repair of any tear that is not within one or two millimeters of the meniscosynovial junction, and that arthroscopic repair techniques are preferable for those lesions. It should also be noted that approximately 80 per cent of repairable menisci are found in knees with an acute or chronic tear of the anterior cruciate ligament, and management decisions need to be linked to considerations of how this ligament is to be treated. If the anterior cruciate ligament is to be reconstructed, the sutures for the meniscal repair are not tied until the end of the reconstruction, so as to prevent damage to the meniscal repair from the motion and stability testing carried out during the ligament reconstruction.

Since all repairs of meniscal tears can be done with arthroscopy, one can question why any tears should be repaired with an open procedure if one is skilled in arthroscopic repair techniques. I (K. E. DeH.) continue to prefer the open technique whenever appropriate because of the ease of preparation of the meniscal rim and capsular bed, because of the ability to place vertically oriented sutures, and because the completed repair has been consistently more anatomical than the arthroscopic repair in my experience. Accordingly, there is at least the theoretical concern that arthroscopic repair of these tears might not be as reliable as the open technique has proved to be for me over the past sixteen years. However, the all-inside technique that will be described by Cannon and Morgan in Part II of this paper may prove to allow the same type of repair, with comparable results, to be carried out with arthroscopic rather than open means.

Another factor to consider is that the morbidity associated with meniscal repair is primarily related to the protection needed for both initial healing and maturation, which is the same regardless of the type of technique utilized. This constraint tends to negate some of the usual advantages of arthroscopic procedures (decreased morbidity and an earlier return to function). In addition, I (K. E. DeH.) always use posterior skin incisions to retract and protect neurovascular structures while performing arthroscopic repair (essentially the same incisions as those used for open repair), which means that there is no substantial difference between the cosmetic results of open and arthroscopic repairs. However, there obviously is a difference between the cosmetic results of the all-inside approach and an open repair, and if the all-inside technique proves to be as reliable as an open repair, it may emerge as the preferred alternative.

**Technique**

The open technique of one of us (K. E. DeH.) has been previously reported. Once it has been documented arthroscopically that open repair is suitable, one can proceed directly to the repair procedure. With current approaches to asepsis for arthroscopes and video equipment, reprepping and redraping are no longer recommended. Prophylactic antibiotics are used routinely. If there is no history of allergy, one gram of a cephalosporin is given intravenously before administration of anesthesia, and a second gram is administered intravenously after deflation of the tourniquet. When there is a history of allergy to penicillin or cephalosporins, 600 milligrams of clindamycin is administered intravenously before administration of anesthesia and after deflation of the tourniquet. Five hundred milligrams of vancomycin is sometimes slowly administered intravenously before administration of anesthesia, when there is a history of allergy. The knee is flexed 90 degrees and the pneumatic tourniquet is inflated.

**Medial Meniscal Repair (Posterior)**

A five to six-centimeter vertical postero-medial skin incision is centered at the level of the joint line and carried through the deep fascia to expose the postero-medial aspect of the capsule. An oblique capsular incision is made just posterior to the posterior border of the medial collateral ligament to expose the posterior meniscal tear. The peripheral rim of the meniscus is debrided of any unstable tags of meniscal tissue and...
freshened with a curet or a rasp. The capsular bed is also carefully prepared and freshened to ensure vascularity all along the capsular surface of the repair. It is not necessary or desirable to excise any intact and stable meniscal tissue that is still attached to the capsular bed.

Double-armed sutures (with a smaller needle on one end) are used to place vertical sutures that anatomically reapproximate the capsular bed back to the complete height of the meniscal rim. The smaller needle is passed from below upward through the meniscal rim, and the larger needle is passed from below upward through the corresponding portion of the capsular bed (Figs. 9-A and 9-B). Sutures are placed three to four millimeters apart, and as many as necessary are used to complete the repair (Figs. 9-C and 9-D). Absorbable or non-absorbable sutures may be utilized, and they can be tied inside or outside the capsule. I (K. E. DeH.) prefer to use small (4-0) absorbable suture and to tie the knots inside the capsule. Others\(^*\)\(^{2} \) have preferred heavier, non-absorbable suture placed through the capsule and tied outside the capsule. Heavier (2-0) suture is used to repair the capsule securely back to the meniscal rim at the site of the capsular incision, and plicating sutures are utilized to complete the capsular repair proximal to the joint line. If a ligamentous procedure is being carried out simultaneously, the sutures for the meniscal repair are tagged to be tied later, after the ligamentous procedure has been completed.

**Lateral Meniscal Repair (Posterior)**

The exposure and technique for the lateral meniscus (Figs. 10-A through 10-E) are somewhat different and

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*FIG. 9-A*

Figs. 9-A through 9-D: The technique of medial meniscal repair. (Reprinted, with permission, from: DeHaven, K. E.; Black, K. P.; and Griffiths, H. J.: Open meniscus repair. Technique and two to nine year results. Am. J. Sports Med., 17: 789, 1989.)

Figs. 9-A and 9-B: After the vertical capsular incision has been made, the meniscal rim is sutured to its detached synovial bed, with the use of vertically placed absorbable 4-0 mattress sutures. A double-armed suture is used. First, the small needle is passed from the inferior to the superior surface of the meniscus, and then the larger needle is passed from below up through the capsular bed.

*FIG. 9-B*

*FIG. 9-C*

Individual sutures are placed three to four millimeters apart and tied intracapsularly. As many sutures as necessary are used to achieve a strong repair.
slightly more difficult than those for the medial meniscus because of the differences in anatomy and the necessity to work around the popliteus tendon. A five to six-centimeter posterolateral vertical skin incision is made parallel to the posterior border of the fibular head. The iliotibial band is split in line with its fibers at the level of the joint line and retracted to expose the underlying capsule. An oblique posterolateral capsular incision is made parallel to the posterior border of the popliteus tendon to expose the lateral meniscal tear. The meniscal rim and capsular bed are prepared in a fashion similar to that described for the medial meniscus, and the same type of vertically oriented repair sutures are placed.

Since there is less space in which to work without damaging the popliteus tendon, the technique for placement of the sutures is different for the lateral meniscus. A small (4-0) absorbable suture with a small needle is utilized. First, the suture is passed from above downward through the meniscal rim and then it is passed

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**Fig. 10-A**

Figs. 10-A through 10-E: The technique of lateral meniscal repair. (Reprinted, with permission, from: DeHaven, K. E.; Black, K. P.; and Griffiths, H. J.: Open meniscus repair. Technique and two to nine year results. Am. J. Sports Med., 17: 790-791, 1989.)

**Fig. 10-A:** The vertical skin incision is made just posterior to the fibular collateral ligament, and the iliotibial band is split in line with its fibers at the level of the joint line and retracted.

**Fig. 10-B:** The iliotibial band has been split in line with its fibers and retracted, and the capsule has been opened vertically just posterior to the popliteus tendon. This drawing demonstrates normal anatomy at the junction of the popliteus and meniscal rim with a normal popliteus hiatus.

**Fig. 10-C**

A peripheral tear of the posterior horn of the lateral meniscus, which extends to the popliteus hiatus.

**Figs. 10-D and 10-E:** The suture is passed first from superior to inferior through the meniscus, then through the strong fibers that run from the medial belly of the popliteus to the lateral meniscus, and then through the synovial bed.
from below upward through the capsular bed (two separate passes). It is helpful to use a nerve-hook or a comparable retractor to pull posteriorly on the capsular bed and popliteus tendon complex, in order to make sufficient room to pass the sutures. The first pass through the capsular side of the repair includes the deeper and strong (but relatively avascular) layer, and the second pass is through the more superficial (but vascular) synovial membrane. Frequently, only two or three sutures are required to complete the repair around to the posterior border of the popliteus tendon, re-establishing the normal posterior border of the popliteus hiatus. The repair sutures are tied inside the capsule, and the capsular incision is closed carefully with plicating sutures similar to the method described for the medial meniscus. Similarly, if the anterior cruciate ligament is being reconstructed during the same procedure, the sutures for the meniscal repair are tagged and tied later, after the ligamentous procedure has been completed. If the tear extends anterior to the popliteus tendon, the exposure required for open repair, anterior as well as posterior to the popliteus tendon, is quite extensive, and in this case arthroscopic repair is preferable.

**Aftercare**

It is important to provide a six-week period of maximum protection, to allow initial healing, and a subsequent six-month interval of protection from vigorous stresses (which can cause early failure), to allow for maturation of the healing collagen tissue. Since 1976, my (K. E. DeH.) aftercare program has become more liberal in terms of motion, but it remains conservative with regard to early weight-bearing. Minimum touch-down weight-bearing with crutches is recommended for the first six weeks. Others have employed early weight-bearing with the knee held in extension in a splint, without any apparent deleterious effect on healing rates. It appears that it is possible to have either early motion or early weight-bearing, but there is concern that the combination of the two could compromise the healing response.

For an isolated meniscal repair, a hinged knee splint is applied, with the hinges locked at 0 degrees for the first two weeks, and it is worn until the wounds have healed and the sutures are removed. Isometric quadriceps and hamstrings-setting exercises, as well as straight-leg-raising exercises, are initiated immediately. Limited motion between 30 and 70 degrees (with the hinges set for that range) is started after two weeks, and the splint is removed four weeks after the operation so that gentle stretching exercises can be added to increase the range of motion as tolerated. More vigorous stretching is initiated at six weeks, to regain any lost motion. At the same time, more strenuous strengthening exercises are begun. Weight-bearing is progressively increased, as tolerated, after six weeks, and use of crutches is normally discontinued seven to eight weeks postoperatively.

Low-impact and non-agility athletic activities are initiated three months after the operation if there is adequate motion and muscle strength and if there is no pain, tenderness, or effusion. These limited activities include bicycling, use of a Stair-Master, use of a rowing machine, swimming, and straight-line jogging. Full squats, hard running, and agility activities are not recommended until six months have passed, to allow maturation of the meniscal repair site. When meniscal repair is carried out in conjunction with reconstruction of a ligament (typically, the anterior cruciate ligament), the standard ligament-rehabilitation protocol is followed, except that weight-bearing is limited until after six weeks. Doing so has provided adequate protection for the meniscal repair.

**Results**

The intermediate results (average, five years) and long-term results (minimum, ten years) of these open repair techniques have been assessed previously. The survival rate for repaired menisci was 89 per cent at five years and 79 per cent at ten years or more. Both studies documented a higher failure rate in unstable knees (38 per cent at five years and 54 per cent at ten years). The long-term survival rate in stable knees and nearly stable knees (a difference of as much as 4.5 millimeters between the right and left knees under maximum manual stress) was 94 per cent. This should be considered a best-case scenario for meniscal repair since these tears were all very peripheral in location, the meniscal body had sustained minimum damage, and the knees were stable or only slightly unstable. Others have also reported favorable early and intermediate results of open repair techniques.

While it is reassuring to know that these repaired menisci heal and remain healed, the most important issue is how well they function. The five-year study revealed radiographic evidence of effective biomechanical function of knees that had had a successful meniscal repair, and the radiographic results of the long-term study are even more compelling. Radiographs were made, with the patient standing and the knee in extension and in 45 degrees of flexion, for the entire series. In 85 per cent of the knees in which the repair had been clinically successful, the involved compartment was radiographically normal, compared with only 43 per cent of the knees that had sustained a second tear and had been treated with a partial meniscectomy. This was a statistically significant difference ($p = 0.04$).

These results support the conclusion that not only are suitable meniscal tears repaired by these open techniques capable of healing, but also most remain healed over time (ten to thirteen years) in stable or nearly stable knees that demonstrate biomechanical function.
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