

Meniscal repair

Overview

- Meniscal tear is the most common injury to the knee that necessitates surgery [1].
- The medial meniscus is torn approximately three times more often than the lateral meniscus [1].
- Lateral meniscus tears occur more commonly with acute ACL tears [1].
- There is an increased rate of osteoarthritis in knees after meniscal tears and meniscectomy, particularly on the lateral side [1].
- Traumatic meniscal tears are common in young patients with sports-related injuries [1].
- Degenerative tears usually occur in older patients and can have an insidious onset [1].
- Meniscal tears can be classified according to location in relation to the vascular supply, position (anterior, middle, posterior third, root), and appearance and orientation [1].
- A meniscal root tear is defined as a radial tear or avulsion of the meniscal root from the tibial plateau [1].
- A meniscal root tear completely disrupts the circumferential fibers of the meniscus [1].
- Biomechanically, a meniscal root tear results in a loss of hoop stresses and an increase in contact forces [1].
- A meniscal root tear is functionally equivalent to a total meniscectomy [1].
- Lateral root tears are associated with ACL tears [1].
- Medial root tears are associated with chondral injuries [1].
- Acute root tears should be repaired whenever possible [1].
- Indications for repair of degenerative root tears continue to evolve [1].
- The vascular supply of the meniscus is a primary determinant of healing potential [1].
- Tears in the peripheral third have the highest potential for healing [1].
- In the absence of intermittent swelling, catching, and locking, meniscal tears—particularly degenerative tears—may be treated conservatively [1].
- Younger patients with acute tears, patients with tears causing mechanical symptoms, and patients with symptoms that fail to improve with conservative measures may benefit from operative treatment [1].
- Acute meniscal root tears should be repaired early; the treatment of chronic tears is more controversial [1].

- Tears that are not amenable to repair—excluding those that do not necessitate any treatment (e.g., partial-thickness tears, those <5 to 10 mm in length, and those that cannot be displaced >1 to 2 mm)—are best treated with partial meniscectomy [1].
- In general, complex, degenerative, and central/radial tears are treated with resection of a minimal amount of normal meniscus [1].
- Partial meniscectomy increases peak stresses in the affected compartment [1].
- General indications for meniscal repair include a tear between 1 and 4 cm [1].
- General indications for meniscal repair include a vertical tear [1].
- General indications for meniscal repair include a red-red tear [1].
- General indications for meniscal repair include a meniscal root tear [1].
- General indications for meniscal repair include a patient younger than 40 years [1].
- Concomitant ACL reconstruction may extend the indications for meniscal repair because results are typically better [1].
- Augmentation techniques (fibrin clot, platelet-rich plasma clot, vascular access channels, synovial rasping) may extend the indications for meniscal repair [1].
- Four techniques are commonly used for meniscal repair: open, “outside-in,” “inside-out,” and “all-inside” [1].
- Newer techniques for all-inside repairs are popular because of their ease of use [1].
- The latest generation of “all-inside” devices allows tensioning of the construct [1].
- The gold standard for meniscal repair remains the inside-out technique with vertical mattress sutures [1].
- It is essential that the saphenous nerve branches (anterior to both the semitendinosus and gracilis muscles and posterior to the inferior border of the sartorius muscle) be protected during medial repairs [1].
- It is essential that the peroneal nerve (posterior to the biceps femoris) be protected during lateral repairs [1].
- Rehabilitation following meniscus repair should involve avoidance of knee flexion beyond 90 degrees [1].
- The level of allowed weight bearing following meniscus repair is controversial [1].
- In several studies, 80% to 90% success rates with meniscal repairs have been reported [1].
- Success of meniscal repair depends on location, type of tear, and chronicity [1].
- The results of meniscal repair are best with acute peripheral tears in young patients undergoing concurrent ACL reconstruction [1].
- The success rate is 90% when meniscal repair is performed in conjunction with an ACL reconstruction [1].
- The success rate is 60% when meniscal repair is performed in a knee with an intact ACL [1].
- The success rate is 30% when meniscal repair is performed in a knee with a deficient ACL [1].

Anatomy & Pathophysiology

GROSS ANATOMY

- The menisci are wedge-shaped fibrocartilaginous structures situated between the femoral condyles and tibial plateaus [19].
- The menisci have a triangular cross section [21].
- The medial meniscus is semicircular, or C-shaped, and covers 50% to 60% of the medial tibial plateau surface [19].
- The medial meniscus covers 64% of the condyle surface and is 10 mm wide and 3 to 5 mm thick [21].
- The lateral meniscus is more circular in shape than the medial meniscus, with equally sized anterior and posterior horns [19].
- The lateral meniscus covers 84% of the condylar surface; it is 12 to 13 mm wide and 3 to 5 mm thick [21].
- The medial meniscus is attached to the deep medial collateral ligament fibers and joint capsule, limiting its mobility [19].
- The lateral meniscus has less continuous attachment to the capsule than the medial meniscus, conferring more mobility [19].
- The popliteomeniscal fascicles extend from the lateral meniscus to the posterior capsule, creating the popliteal hiatus as the popliteus tendon becomes intra-articular [19].
- The menisiofemoral ligaments connect the posterior horn of the lateral meniscus to the medial femoral condyle [19].
- The anterior menisiofemoral ligament of Humphrey courses anterior to the posterior cruciate ligament [19].
- The posterior menisiofemoral ligament of Wrisberg courses posterior to the posterior cruciate ligament [19].
- The transverse intermeniscal ligament is the most common connection between the medial and lateral menisci, present in 60% to 94% of knees [19].

HISTOLOGY & BIOCHEMISTRY

- The extracellular matrix of the meniscus primarily comprises type I collagen with smaller amounts of types II, III, V, and VI collagen [19].
- Proteoglycans such as aggrecan are present in the meniscal extracellular matrix [19].
- Water comprises 65% to 75% of the meniscal volume [19].
- Type I collagen is most abundant in the superficial zones of the menisci to provide tensile strength [19].
- Larger concentrations of proteoglycans and water are found in the deeper zones and provide compressive strength [19].
- Fibrochondrocytes are the predominant meniscal cell type and produce the extracellular matrix [19].

CQ HAND + UPPER LIMB

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VASCULAR SUPPLY & ZONES

- The vascular supply of the menisci comes from the superior, middle, and inferior geniculate arteries [19].
- The peripheral 10% to 30% of the meniscus is well vascularized by synovial and capsular branches [19].
- The anterior and posterior root attachments are well vascularized by synovial branches [19].
- The outer third of the meniscus is called the red/red zone and is well vascularized [19].
- The middle third of the meniscus is called the red/white zone and is at the border of the vascularized and avascular zones [19].
- The inner third of the meniscus is called the white/white zone and is devoid of a vascular supply [19].
- At birth, 50% of the meniscus is vascularized, whereas only 10% to 25% is vascularized in the adult [21].
- The vascularity of the meniscus decreases with advancing age [4].
- The location of a meniscal tear relative to vascular zones helps guide treatment because healing potential increases with vascularity [19].

BIOMECHANICS

- In knee extension, as much as 50% of the load is absorbed by the meniscus [19].
- The percentage of load-sharing by the meniscus increases to 90% at 90° of knee flexion [19].
- Beyond 90° of flexion, most of the force is transmitted to the posterior horns of the menisci [21].
- The lateral meniscus provides more biomechanical protection to the joint than the medial meniscus [21].
- When the meniscus is removed completely, articular cartilage contact stress increases by two to three times that experienced when the meniscus is intact [21].
- Removal of the inner third of the meniscus results in a 10% reduction in contact area and a 65% increase in contact stress on the articular cartilage [21].
- Medial meniscus root tears result in peak articular cartilage contact pressure similar to that seen after a complete meniscectomy [21].
- A vertical tear of the medial meniscus causes increased contact area and maximum contact pressure in both the lateral and medial compartments of the knee [21].
- A radial tear of the medial meniscus that extends from the inner rim to the peripheral third but preserves the peripheral third has not been found to change maximum contact pressure and contact area in the knee [21].
- A radial tear involving 90% of the medial meniscus results in a posterocentral shift in peak-pressure location [21].

TEAR PATHOPHYSIOLOGY

- Meniscal tears are classified according to location in relation to vascular supply, position, and appearance and orientation [1].
- Longitudinal tears most commonly occur as a result of trauma to a reasonably normal meniscus [3].
- Longitudinal tears are oriented parallel to the edge of the meniscus [3].

CQ HAND + UPPER LIMB

- A bucket-handle tear occurs when the inner fragment of a complete longitudinal tear displaces over into the intercondylar notch [3].
- Horizontal tears tend to be more common in older patients and occur from shear, dividing the superior and inferior surfaces of the meniscus [3].
- Radial tears are vertically oriented, extending from the inner edge of the meniscus toward its periphery [3].
- Complex tears may contain elements of longitudinal, horizontal, oblique, and radial tears and are more common in chronic meniscal lesions or older degenerative menisci [3].
- A meniscal root tear results in a loss of hoop stresses and an increase in contact forces [1].
- The discoid meniscus is a congenital anomaly that is almost always lateral and extremely rare to find medially [12].
- The central area of a discoid meniscus is partially or completely filled in and may lack normal attachments to the surrounding capsule, distal femur, and proximal tibia [12].
- The histopathology of the discoid meniscus shows a disorganization of the circumferential collagen network at a molecular level [12].
- Structural abnormalities in the discoid meniscus compromise its ability to withstand normal stresses and predispose it to tears [12].

HEALING BIOLOGY

- After injury within the peripheral vascular zone, a fibrin clot rich in inflammatory cells forms [27].
- Vessels from the perimeniscal capillary plexus proliferate throughout the fibrin scaffold accompanied by proliferations of differentiated mesenchymal cells [27].
- The lesion is eventually filled with cellular fibrovascular scar tissue that glues the wound edges together and appears continuous with adjacent normal meniscal fibrocartilage [27].
- Complete radial lesions of the meniscus are completely healed with a young fibrocartilaginous scar by 10 weeks in animal studies [27].
- Several months are required for maturation to fibrocartilage that appears normal [27].
- For a meniscus to regenerate to any extent, the entire structure must be resected to expose the vascular synovial tissue or the excision must extend to the peripheral vasculature [27].
- Subtotal excisions of the meniscus within the avascular central half do not show any regeneration potential [27].

Classification

TEAR MORPHOLOGY AND ETIOLOGY

- The O'Connor classification of meniscal tears includes longitudinal, horizontal, oblique, radial, and variations such as flap, complex, and degenerative tears [3].

- Longitudinal tears are typically vertically oriented and result from trauma to a reasonably normal meniscus [3].
- Longitudinal tears may extend completely or partially through the thickness of the meniscus [3].
- A complete longitudinal tear oriented parallel to the meniscal edge can produce a displaceable inner fragment [3].
- A displaceable inner fragment that moves into the intercondylar notch is referred to as a bucket-handle tear [3].
- A longitudinal tear near the meniscocapsular attachment is referred to as a peripheral tear [3].
- Peripheral vertical tears in zone I are termed red-red tears, while tears between zone I and II are termed red-white tears [3].
- Red-red and red-white tears are located in the vascularized portion of the meniscus [3].
- Horizontal tears are more common in older patients and occur due to shear forces that divide the superior and inferior surfaces of the meniscus [3].
- Horizontal cleavage planes are most commonly seen in the posterior half of the medial meniscus or the midsegment of the lateral meniscus [3].
- Many flap tears and complex tears originate with a horizontal cleavage component [3].
- Oblique tears are full-thickness tears running obliquely from the inner edge of the meniscus into its body [3].
- An oblique tear with a posterior base is referred to as a posterior oblique tear [3].
- An oblique tear with a base in the anterior horn is referred to as an anterior oblique tear [3].
- Radial tears can be complete or incomplete depending on the extent of involvement [3].
- The pathogenesis of radial tears is similar to that of oblique tears [3].
- Flap tears are similar to oblique tears but usually contain a horizontal cleavage element rather than being purely vertical [3].
- Flap tears are classified as superior or inferior based on where the flap is based on the meniscal surface [3].
- Complex tears may contain elements of longitudinal, radial, oblique, and horizontal tear types [3].
- Complex tears are more common in chronic meniscal lesions or older degenerative menisci [3].
- Complex tears are generally caused by chronic, long-standing altered mechanics of the meniscus [3].
- Degenerative tears often refer to complex tears presenting with marked irregularity and complex tearing within the meniscus [3].
- Degenerative tears are most often seen in older patients [3].
- The most common type of meniscal tear is the longitudinal tear, usually involving the posterior segment of either the medial or lateral meniscus [16].
- Transverse, radial, or oblique tears more commonly involve the lateral meniscus than the medial meniscus [16].
- Radial tears tend to occur at the junction of the anterior and middle thirds of the meniscus [16].

- Radial tears result from forces that separate the anterior and posterior segments of the meniscus, stretching the inner concave border [16].
- The lateral meniscus is more circular with a shorter radius, making its inner free edge more easily torn radially than the medial counterpart [16].
- Radial tears can also result from degenerative changes within the meniscus or from cystic changes at the periphery that reduce meniscal mobility [16].
- Cysts of the menisci are nine times more common on the lateral side than on the medial side [16].
- The most common cause of meniscal cysts is trauma that produces degeneration and secondary mucinous and cystic changes in the meniscal periphery [16].
- Discoid menisci are vulnerable to compression and rotary stresses due to hypermobility and tissue bulk between articular surfaces [16].
- Degeneration and tears may develop within discoid menisci [16].

SPECIFIC TEAR PATTERNS AND ASSOCIATIONS

- The posterior root tear is a type of radial tear located at the posterior root attachment of the meniscus [16].
- The ramp lesion is a form of longitudinal tear located at the meniscocapsular junction or meniscotibial attachment [16].
- Posterior root tears and ramp lesions are thought to lead to increased anterior instability in ACL-deficient knees [16].
- Posterior root tears are associated with increased contact forces and early arthritis [16].
- Meniscal tears can be complete or incomplete [16].
- Most meniscal tears involve the inferior rather than the superior surface of the meniscus [16].
- Small tears limited to the posterior horn cause pain, recurrent swelling, and a feeling of instability but are not capable of producing locking [16].
- Extensive longitudinal tears can cause mechanical locking if the central portion of the meniscus is displaced into the intercondylar notch [16].
- Mechanical locking from longitudinal tears occurs when a pedunculated fragment of the bucket-handle fragment becomes detached [16].
- Before the extensive use of arthroscopy, medial meniscal tears were approximately five to seven times more common than lateral meniscal tears [16].
- With increased use of arthroscopy allowing thorough inspection of both menisci, medial and lateral meniscal tears are believed to occur with almost equal frequency [16].
- Complex tears may follow degeneration or repeated traumatic episodes [16].
- The diagnosis of discoid meniscus is often made incidentally on MRI or at the time of arthroscopy [16].
- Discoid menisci may not produce significant symptoms until derangement of the meniscus occurs [16].

Clinical Presentation

HISTORY

- Meniscal tears are unusual in patients younger than 10 years [8].
- Most meniscal tears in adolescents and young adults occur with a twisting injury or with a change in direction [8].
- Middle-aged and older adults can sustain meniscal tears from squatting or falling [8].
- With an acute meniscal tear, an effusion often develops several hours after injury [8].
- Swelling from an acute meniscal tear differs from an anterior cruciate ligament (ACL) injury, in which swelling develops rapidly within the first few hours [8].
- Patients with meniscal injuries localize pain to the joint line or posterior knee [8].
- Patients with meniscal injuries may describe mechanical symptoms of locking or catching [8].
- Chronic meniscal tears demonstrate intermittent effusions, often with mechanical symptoms [8].
- Patients with a traumatic meniscal tear may report pain onset during a twisting mechanism or during deep knee flexion [22].
- Occasionally, an audible or palpable popping is reported with a traumatic meniscal tear [22].
- Approximately one-half to two-thirds of patients with a meniscal tear report knee swelling [22].
- Mechanical symptoms such as catching or frank locking have been reported in 12% to 69% of patients with meniscal tears [22].
- Mechanical symptoms such as catching or frank locking may suggest an unstable meniscal tear [22].

PHYSICAL EXAMINATION

- Small joint effusions and joint line tenderness with palpation are common findings with meniscal tears [8].
- Manipulative maneuvers, including the McMurray and Apley tests, may produce a palpable or audible click with localized tenderness [8].
- The McMurray and Apley tests are not specific for meniscal pathology [8].
- In the Thessaly test, the patient flexes the knee to 20° while standing on the affected extremity and twists in internal and external rotation [8].
- The Thessaly test often reproduces pain in patients with a meniscal tear [8].
- Range of motion is typically normal in patients with meniscal tears [8].
- Longitudinal bucket-handle tears may block full extension of the knee joint [8].
- Patients may report tightness in flexion if an effusion is present [8].
- Palpation of the joint line may elicit tenderness at the location of a meniscal tear [22].
- Posterior horn tears are most prevalent, making the posterior joint line a common location for tenderness [22].

- The meniscus-specific McMurray, Apley, and Thessaly tests should be interpreted for pain as well as mechanical signs [22].
- In a patient with an isolated meniscal tear, joint line tenderness was found to be an accurate test in 81% to 90% of patients [22].
- In a patient with an isolated meniscal tear, the McMurray test was accurate in 57% to 77% of patients [22].
- In a patient with an isolated meniscal tear, the Thessaly test was accurate in 61% to 80% of patients [22].
- In patients with associated ligamentous or chondral injury, the McMurray, Apley, and Thessaly tests lose specificity for meniscal pathology [22].

IMAGING

- Standard knee radiographs should be obtained to evaluate for bone injuries or abnormalities [8].
- A weight-bearing radiograph is necessary to evaluate for osteoarthritis [8].
- A right-to-left difference of at least 2 mm on weight-bearing radiographs represents a significant difference that will be verified by articular cartilage chondrosis at the time of arthroscopy [8].
- MRI remains the noninvasive diagnostic procedure of choice for confirming meniscal pathology [8].
- In grade III MRI classification of meniscal tears, increased signal intensity reaches the articular surface of the meniscus [8].
- MRI has demonstrated a high negative predictive value for meniscal tears [8].
- A well-performed MRI of a knee with no meniscal pathology will rarely demonstrate a tear [8].
- Radiographic evaluation of a patient with knee pain should begin with weight-bearing radiographs including AP in full extension, lateral, and PA 45° flexion (Rosenberg) views in addition to a Merchant view of the patellofemoral joint [22].
- The presence of osteoarthritis on radiographs suggests a degenerative meniscal tear [22].
- Avulsion fractures or tibial plateau fractures can be associated with an acute meniscal tear [22].
- A high proportion of surgical split-depressed lateral plateau fractures (> 2 mm of depression) also have peripheral longitudinal meniscal tears warranting repair [22].
- Meniscal tears can be well evaluated with T2-weighted and proton density-weighted MRI sequences [22].
- Magnetic resonance arthrography may be considered to assess for suspected meniscus tear in the setting of prior meniscectomy or meniscus repair [22].
- With high-field strength MRI and appropriate pulse sequences, magnetic resonance arthrography is less commonly required [22].
- The criteria for MRI diagnosis of a meniscal tear include increased signal intensity extending to an articular surface from within the normally low-signal meniscal substance [22].
- The criteria for MRI diagnosis of a meniscal tear include distortion of the shape or size of the meniscus, which signifies missing meniscal tissue [22].
- The criteria for MRI diagnosis of a meniscal tear include a displaced meniscal fragment [22].

- The sensitivity and specificity of 1.5-Tesla (T) and 3.0-T MRI diagnosis of medial meniscal tears, as confirmed with arthroscopy, were found to be 93% to 96% and 88% to 90%, respectively [22].
- MRI was less sensitive (77% to 82%) but more specific (98% to 99%) for lateral meniscal tears [22].
- A study of 3.0-T MRI for detecting posterior meniscal root tears found sensitivity of 77% and specificity of 73% [22].
- The decreased accuracy of MRI for diagnosing root tears may be attributable in part to the radial orientation of many posterior root tears, making them more difficult to visualize on MRI [22].
- To be considered a relevant finding, a tear seen on MRI should correspond to the patient's history and clinical examination findings [22].

DIAGNOSTIC ACCURACY AND DIFFERENTIAL DIAGNOSIS

- Several large studies have demonstrated the accuracy of the clinical diagnosis of meniscal tears to be 70% to 75% [8].
- The differential diagnosis for meniscal tears includes intra-articular diagnoses such as osteochondritis dissecans, medial patella plica, patellofemoral pain syndromes, loose bodies, pigmented villonodular synovitis, inflammatory arthropathies, and osteonecrosis [8].
- The differential diagnosis for meniscal tears includes extra-articular diagnoses such as collateral ligament injuries, slipped capital femoral epiphysis, bone or soft-tissue tumors, osteomyelitis, synovial cyst, pes or medial collateral ligament bursitis, injury, complex regional pain syndrome, lumbar radiculopathy, iliotibial band friction, and stress fracture [8].
- Meniscal injury is identified on MRI in 31% of asymptomatic athletes [7].
- Meniscal injury is identified on MRI in 91% of patients with knee osteoarthritis [7].
- In nonarthritic knees, focal joint line tenderness, effusion, and positive meniscal signs on physical examination may indicate meniscal pathology as a symptomatic source worthy of surgical intervention [7].
- In the presence of osteoarthritis, mechanical symptoms such as locking or catching in combination with unstable meniscal tears on MRI warrant intervention [7].
- Débridement of stable meniscal tears in the presence of osteoarthritis is unlikely to provide lasting relief [7].

Investigations

HISTORY AND CLINICAL PRESENTATION

PHYSICAL EXAMINATION

- The accuracy of the clinical diagnosis of meniscal tears has been demonstrated to be 70% to 75% in several large studies [8].

IMAGING

- Weight-bearing radiographs for osteoarthritis evaluation may include a weight-bearing AP or 45° PA flexion view [8].

DIFFERENTIAL DIAGNOSIS

- The differential diagnosis for meniscal tears includes intra-articular and extra-articular diagnoses [8].
- Possible intra-articular diagnoses include osteochondritis dissecans, medial patella plica, patellofemoral pain syndromes, loose bodies, pigmented villonodular synovitis, inflammatory arthropathies, and osteonecrosis [8].
- Possible extra-articular diagnoses include collateral ligament injuries, slipped capital femoral epiphysis, bone or soft-tissue tumors, osteomyelitis, synovial cyst, pes or medial collateral ligament bursitis, injury, complex regional pain syndrome, lumbar radiculopathy, iliotibial band friction, and stress fracture [8].

Treatment

NON-OPERATIVE MANAGEMENT

- Nonsurgical management is a consideration for stable peripheral tears shorter than 5 to 10 mm in length [6].
- Nonsurgical management is a consideration for some degenerative tears that do not cause mechanical symptoms [6].
- Nonsurgical management is a consideration for tears in the setting of substantial osteoarthritis (Kellgren-Lawrence grade 3 or 4) [6].
- Tear types commonly managed nonsurgically include stable longitudinal tears less than 10 mm in length with less than 3 to 5 mm of displacement [4].
- Tear types commonly managed nonsurgically include degenerative tears associated with significant osteoarthritis [4].
- Tear types commonly managed nonsurgically include short (<3 mm in length) radial tears [4].
- Tear types commonly managed nonsurgically include stable partial tears [4].
- Nonsurgical management can include ice, NSAIDs, or physical therapy for range of motion and general strengthening of the lower extremities [4].
- In pediatric patients, partial thickness tears comprising less than 50% of the total meniscal thickness may be suitable for nonsurgical management [17].
- In pediatric patients, an attempt at nonsurgical treatment may be made for small (<1 cm), stable, longitudinal tears in the peripheral red-red zone [17].
- In pediatric patients, short (<10 mm) vertical peripheral tears often heal sufficiently to resolve symptoms [5].

PARTIAL MENISCECTOMY

- Arthroscopic partial meniscectomy is indicated for radial, oblique, flap, horizontal cleavage, and complex tears [4].
- Arthroscopic partial meniscectomy is indicated for tears located in the white-white avascular zone [4].
- Irreparable unstable tears causing mechanical symptoms (locked knee) can be treated with partial meniscectomy [6].
- Tears in the avascular zone, such as radial or flap tears, can be treated with partial meniscectomy [6].
- Degenerative tears without substantial osteoarthritis can be treated with partial meniscectomy [6].
- The goal of arthroscopic partial meniscectomy is to débride degenerative or torn meniscal tissue, leaving a stable contoured rim and preserving as much tissue as possible [4].
- Peak contact articular cartilage stresses increase proportionally to the amount of meniscus removed [4].
- Clinical studies with long-term follow-up of partial meniscectomy found an increase in osteoarthritic changes within the affected compartment [6].
- Partial meniscectomy for the management of radial tears that were within 1 cm of the posterior horn insertion led to progression of osteoarthritis in 35% of patients at a mean 77-month follow-up [6].
- At 5- to 7-year follow-up of 46 patients, one-third had progression of Kellgren-Lawrence grade 0 to 2 osteoarthritis to grade 3 or 4 osteoarthritis after partial meniscectomy [6].
- Only 56% of patients reported pain improvement after partial meniscectomy [6].
- Factors that predict better long-term function following arthroscopic partial meniscectomy include age younger than 40 years, normal lower extremity alignment, minimal arthritic changes noted at the time of arthroscopy, and a single fragment tear [4].
- Studies have demonstrated greater than 80% satisfactory function at minimum 5-year follow-up after arthroscopic partial meniscectomy [4].
- Degenerative changes and a decrease in function occur more quickly in patients who have undergone arthroscopic lateral meniscectomy [4].
- In pediatric patients, tears deemed irreparable by virtue of poor tissue quality, poor vascular supply, or some combination of factors are best treated by partial meniscectomy [17].

MENISCAL REPAIR: INDICATIONS

- Tear types appropriate for repair include vertical longitudinal tears in the vascular zone of the meniscus [4].
- Tear types appropriate for repair include displaced bucket-handle tears that remain in good condition once they are reduced [4].
- Relative contraindications for meniscal repair include advanced degenerative articular cartilage damage [4].
- Relative contraindications for meniscal repair include complex tears [4].
- Relative contraindications for meniscal repair include poor meniscal tissue quality [4].
- Relative contraindications for meniscal repair include ACL deficiency [4].

- Augmentation techniques (fibrin clot, platelet-rich plasma clot, vascular access channels, synovial rasping) may extend the indications for repair [1].
- In pediatric patients, indications for meniscal repair include long (>10 mm) tears in the periphery without irreparable damage to the body of the meniscus [5].
- In pediatric patients, tear patterns generally considered amenable to repair include longitudinal, vertical, and bucket-handle tear morphologies [17].
- In pediatric patients, attempts are typically made to repair radial tears, especially if the tear extends to the periphery of the meniscus [17].
- In pediatric patients, oblique and horizontal tear configurations are less amenable to repair [17].
- In pediatric patients, meniscal tears that are complex in nature, with extensive tissue maceration or degeneration, may be irreparable [17].
- Acute meniscal root tears should be repaired early [1].
- The treatment of chronic meniscal root tears is more controversial [1].

MENISCAL REPAIR: TECHNIQUES

- Open repair usually is reserved for peripheral tears in the posterior horn approached through a capsular incision [4].
- Arthroscopic inside-out repairs are performed using absorbable or nonabsorbable sutures placed using zone-appropriate cannulas; the sutures are retrieved and tied through a small capsular incision [4].
- The arthroscopic outside-in technique usually is reserved for anterior horn tears [4].
- The arthroscopic outside-in technique involves placing a suture through a needle placed across the tear, retrieved and tied outside the knee through an arthroscopic portal, with the knot pulled into the knee to reduce the tear when tied over the capsule [4].
- Arthroscopic all-inside repairs involve absorbable stents or sutures tied to stents placed through arthroscopic portals [4].
- All-inside repairs may offer reduced neurovascular risk [4].
- Mechanical studies have demonstrated that no all-inside device improves on the load to failure of vertically placed inside-out sutures [4].
- In pediatric patients, viable methods of meniscal repair include all-inside, inside-out, and outside-in techniques [17].
- In pediatric patients, anterior horn tears are typically repaired in an outside-in fashion with monofilament suture [17].
- In pediatric patients, tears of the body and posterior horn may be repaired with an all-inside fixation system or an inside-out technique with the sutures tied just outside the joint capsule [17].
- It is generally recommended to avoid an all-inside repair technique in younger children because the smaller distances from the meniscal anchors placed through the joint capsule and the popliteus neurovascular bundle may put the bundle at increased risk for direct injury [17].

- Preparation of the meniscus and capsule by mechanically abrading the tissue on either side of the planned repair with a rasp or shaver is considered to be an important step in all meniscal repair procedures [17].
- Young patients with isolated meniscal tears that are chronic in nature may benefit from techniques intended to optimize the vascularity of the repair, such as trephination, injection of autologous blood clots, and microfracture of the notch at the level of the posterior cruciate ligament [17].
- For open medial meniscal repair, interrupted sutures of Mersilene or other nonabsorbable surgical suture material are placed every 3 to 4 mm [10].
- In open medial meniscal repair, each suture should be oriented vertically rather than horizontally to achieve maximal purchase on the meniscus [10].
- In open medial meniscal repair, the edges of the tear and parameniscal synovial tissue are abraded with a small rasp to evoke an increased inflammatory healing response [10].
- For open lateral meniscal repair, the posterior horn of the lateral meniscus is exposed through a posterolateral capsular incision above the popliteal tendon [10].
- Lateral meniscal tears are more difficult to repair than medial meniscal tears due to the coursing of the popliteal tendon through a hiatus in the periphery of the lateral meniscus [10].
- Radial tears that extend to the capsule may be repaired in young patients with otherwise healthy menisci using synovial rasping followed by longitudinal repair [28].
- Unstable root tears of the posterior horn of the medial or lateral meniscus may be repaired to a freshened posterior bony bed using an anterior cruciate ligament guide to drill from the anterolateral tibia to the base of the root footprint [28].
- The repair of unstable root tears may also be accomplished using a 2.7 suture anchor placed through a high posteromedial portal [28].
- Root tears of the lateral meniscus may do well by rasping and allowing them to heal in situ [28].

MENISCAL REPAIR: OUTCOMES AND COMPLICATIONS

- Clinical success rates for all meniscal repair techniques in stable knees range from 70% to 95% [4].
- Second-look arthroscopy has shown lower rates of success for meniscal repair, ranging from 45% to 91% [4].
- Ligamentously unstable knees decrease the success rate of meniscal repair to 30% to 70% [4].
- Meniscal repair success is greater than 90% when performed in conjunction with an ACL reconstruction [4].
- The success rate of meniscal repair is 90% when performed in conjunction with an ACL reconstruction [1].
- The success rate of meniscal repair is 60% when performed in a knee with an intact ACL [1].
- The success rate of meniscal repair is 30% when performed in a knee with a deficient ACL [1].
- Complications of meniscal repair include failure to heal the tear, knee stiffness, and potential damage to the articular surface from mechanical devices used to repair the tear [4].
- In a systematic review of management for traumatic meniscal tears, short-term revision surgery rates were higher after meniscal repair than after meniscectomy (16.5% versus 1.4%) [6].

- In a systematic review of management for traumatic meniscal tears, long-term revision surgery rates were higher after meniscal repair than after meniscectomy (20.7% versus 3.9%) [6].
- There were no plain radiographic degenerative changes in 78% of knees after meniscal repair, compared with 64% of knees after meniscectomy [6].
- Nearly 80% of patients with arthroscopic meniscal repair had no osteoarthritis progression compared with only 40% of patients with meniscectomy at 8- to 10-year follow-up [6].
- Approximately 96% of the patients who underwent arthroscopic meniscal repair returned to their preinjury level of sports activity compared with only half of those who underwent a partial meniscectomy [6].
- At 4-year follow-up, patients who underwent repair of a medial meniscal root tear had less progression of osteoarthritis and better clinical scores than those who underwent partial medial meniscectomy [6].
- The risk for symptomatic osteoarthritis progression following meniscal repair is 25% to 50% lower than that following arthroscopic partial meniscectomy [6].
- The risk for symptomatic osteoarthritis progression following meniscal repair remains approximately twice as high as the general population [6].
- Preservation of the integrity of the articular cartilage on quantitative MRI has been associated with healed meniscal repairs [6].
- Concomitant ACL reconstruction positively correlated with healing [6].
- Age younger than 30 years trended toward a positive correlation with healing [6].
- Tears longer than 2 cm are negatively associated with healing rates [6].
- Smoking is negatively associated with healing rates [6].
- The failure and revision surgery rate was found to be higher for medial than lateral meniscal repairs at short-term and medium-term follow-up [6].
- In pediatric patients, 3- to 5-year outcomes of meniscal repair are generally good [5].
- In pediatric patients, it is likely that tears extending more than 3 mm from the periphery will have a good intermediate outcome [5].

REHABILITATION

- In pediatric patients, a majority of meniscus repairs are treated with restricted weight bearing for 6 weeks [5].
- In pediatric patients, vertical and posterior tears may be amenable to early weight bearing [5].
- If an open meniscal repair is not combined with another procedure and the tear is small and stable, immediate range of motion from 0 to 90 degrees is permitted [10].
- If an open meniscal repair is not combined with another procedure and the tear is small and stable, touch-down weight bearing is permitted immediately [10].
- If an open meniscal repair is not combined with another procedure and the tear is small and stable, full weight bearing is permitted at 6 weeks [10].

- If an open meniscal repair is not combined with another procedure and the tear is small and stable, no sports are allowed for 3 months [10].
- If an open meniscal repair is not combined with other procedures but the tear is sufficiently large to allow displacement into the joint, the knee is placed in a hinged brace locked in full extension for 3 to 4 weeks [10].
- If an open meniscal repair is not combined with other procedures but the tear is sufficiently large to allow displacement into the joint, only touch-down weight bearing with crutches is permitted for the first 4 weeks [10].
- If an open meniscal repair is not combined with other procedures but the tear is sufficiently large to allow displacement into the joint, motion from 0 to 90 degrees is begun at 4 weeks [10].
- If an open meniscal repair is not combined with other procedures but the tear is sufficiently large to allow displacement into the joint, weight bearing to 50% is reached at 6 weeks [10].

MENISCAL TRANSPLANTATION

- Meniscal allograft transplantation has been reserved for the patient who remains symptomatic in activities of daily living after partial or total meniscectomy or who develops recurrent pain after partial or total meniscectomy [4].
- Meniscal allograft transplantation is usually reserved for patients who are skeletally mature but younger than 50 years [4].
- Contraindications for meniscal allograft transplantation include uncorrected lower extremity malalignment [4].
- Contraindications for meniscal allograft transplantation include uncorrected ligamentous instability [4].
- Contraindications for meniscal allograft transplantation include inflammatory arthritis [4].
- Contraindications for meniscal allograft transplantation include significant chondral changes in the treated compartment [4].
- Return to strenuous sports is generally not recommended after meniscal allograft transplantation [4].
- Subjective improvement in tibiofemoral pain and increased activity levels are seen after meniscal transplant [4].
- A long-term benefit for preventing the progression of osteoarthritis has not been established for meniscal allograft transplantation [4].
- Grafts have performed better when placed with a bone block or plug [4].
- Preservation of at least some peripheral rim is important to prevent peripheral extrusion after meniscal transplant [4].
- Meniscal allograft transplant is being performed as a salvage option for children and adolescents with symptomatic meniscus-deficient knees [17].
- Short-term and midterm outcomes of meniscal allograft transplantation in children and adolescents show improvements in patient-reported knee function [17].

Complications

NERVE INJURY

- Saphenous nerve branches must be protected during medial meniscal repairs [1].
- The peroneal nerve must be protected during lateral meniscal repairs [1].
- Safe zones and trajectories for all-inside meniscus repairs have been established to avoid injury to the posterior neurovascular bundle and peroneal nerve [5].

OSTEOARTHRITIS PROGRESSION

- Partial meniscectomy for radial tears within 1 cm of the posterior horn insertion led to progression of osteoarthritis in 35% of patients at a mean 77-month follow-up [6].
- At 5- to 7-year follow-up of 46 patients, one-third had progression of Kellgren-Lawrence grade 0 to 2 osteoarthritis to grade 3 or 4 osteoarthritis following partial meniscectomy [6].
- The relative risk of osteoarthritis after undergoing total meniscectomy is 14.0 [7].
- Total meniscectomy is associated with 4% cartilage loss per year [7].
- The extent of subsequent joint degeneration is directly proportional to the amount of meniscal tissue removed [7].

REVISION SURGERY AND FAILURE RATES

- Short-term revision surgery rates were higher after meniscal repair (16.5%) than after meniscectomy (1.4%) [6].
- Long-term revision surgery rates were higher after meniscal repair (20.7%) than after meniscectomy (3.9%) [6].
- The benefit of meniscal repair is balanced with an increased risk of revision surgery after meniscal repair (20.7%) as compared with partial meniscectomy (3.9%) [7].
- Overall failure rate (conversion to total knee arthroplasty) for meniscal allograft transplantation ranges from 10% to 29% in long-term follow-up [7].

HEALING FACTORS

REHABILITATION CONSTRAINTS

- A majority of pediatric meniscus repairs are treated with restricted weight bearing for 6 weeks [5].
- Vertical and posterior meniscal tears may be amenable to early weight bearing in pediatric patients [5].

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