Meniscal Root Tears: Significance, Diagnosis, and Treatment

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Clinical Sports Medicine Update

Meniscal Root Tears

Significance, Diagnosis, and Treatment

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Meniscal root tears, less common than meniscal body tears and frequently unrecognized, are a subset of meniscal injuries that often result in significant knee joint disorders. The meniscus root attachment aids meniscal function by securing the meniscus in place and allowing for optimal shock-absorbing function in the knee. With root tears, meniscal extrusion often occurs, and the transmission of circumferential hoop stresses is impaired. This alters knee biomechanics and kinematics and significantly increases tibiofemoral contact pressure. In recent years, meniscal root tears, which by definition include direct avulsions off the tibial plateau or radial tears adjacent to the root itself, have attracted attention because of concerns that significant meniscal extrusion dramatically inhibits normal meniscal function, leading to a condition biomechanically similar to a total meniscectomy. Recent literature has highlighted the importance of early diagnosis and treatment; fortunately, these processes have been vastly improved by advances in magnetic resonance imaging and arthroscopy. This article presents a review of the clinically relevant anatomic, biomechanical, and functional descriptions of the meniscus root attachments, as well as current strategies for accurate diagnosis and treatment of common injuries to these meniscus root attachments.

Keywords: meniscus; meniscus root; medial meniscus; lateral meniscus; posterior root; anterior root; meniscal tear; meniscal repair

It has been increasingly recognized that the menisci, crescent-shaped fibrocartilaginous structures that provide tibiofemoral joint congruity, stabilization, shock absorption, and possibly proprioception, are essential for joint preservation.[17,35,37] Each meniscus is composed of an interlacing network of collagen fibers, proteoglycans, and glycoproteins specifically oriented to allow the conversion of tibiofemoral axial loads into hoop stresses during both knee extension and deep flexion.[17,37,56] Approximately 50% to 70% of total weight transmitted through either the medial or the lateral knee compartment is transmitted by each individual meniscus,[29] and such dissipation of axial loads is imperative for the viability and function of articular cartilage.[30,35,37] Injuries that involve detachment of the meniscus root attachments profoundly affect meniscal biomechanics and kinematics, leading to accelerated degenerative changes within the knee joint.[30,35,37,56,63,68] Therefore, it is imperative to accurately and concisely identify such lesions to guide treatment, surgical decision making, and prognosis.

For the menisci to function properly, the biomechanical integrity of each meniscus root on the tibial plateau must be maintained.[1,4] Injuries to the posterior meniscus root attachments, including root avulsions and full-length degenerative tears and radial tears adjacent to the root, have been linked to clinically significant medial meniscal extrusion, defined as displacement of the meniscus with respect to the margin of the tibial plateau.[42] Meniscal extrusion may dramatically impair hoop stress force transmission, leading to accelerated degenerative articular wear.[23,42] In fact, a biomechanical study has reported no difference between the peak tibiofemoral contact pressures after either a total medial meniscectomy or a posterior medial meniscal root tear.[4]

The clinical diagnosis of meniscal root tears remains challenging, but magnetic resonance imaging (MRI) and arthroscopy have improved the sensitivity and specificity for detection. Treatment of meniscal root tears, historically focused on partial meniscectomy, has recently evolved into a variety of repair strategies to restore meniscal function both biomechanically and clinically. Following is a review of the anatomy, function, and biomechanics of the meniscus root attachments, with additional pearls and current

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strategies for accurate diagnosis, surgical indications, and treatment of meniscal root avulsions.

ANATOMY OF THE MENISCUS ROOT ATTACHMENTS

The medial and lateral menisci are semilunar-shaped structures of fibrocartilage with 3 segments: an anterior horn/root, a body, and a posterior horn/root.[19,27] With the roots acting as an anchor to the bone for the menisci, the menisci function as shock absorbers by transmitting loads from the femur to the tibia through the stretching of circumferential collagen bundles in a radial direction, inducing the menisci to extrude toward the outside of the joint.[26,27,49,64]A tensile stress, commonly referred to as a "hoop stress," is then initiated to resist this extrusion.[26] The distribution of hoop stresses by the circumferential fibers helps to transmit relatively even axial loads across the joint surfaces, which prevents excessive loading and articular cartilage breakdown.[26,27,64]

The superior surfaces of both menisci are concave, allowing for articulation with the convex femoral condyles.[18,26] The inferior surfaces are relatively flat, which allows the menisci to effectively articulate with the relatively flat tibial plateaus.[18,26] The medial and lateral anterior roots both have relatively simple, planar insertions into the tibial plateau, while the medial and lateral posterior roots have complex, 3-dimensional insertions into the tibial plateau.[25,26] Knowledge of the specific anatomy of each meniscus root attachment site is important in guiding diagnosis and management (Figure 1).

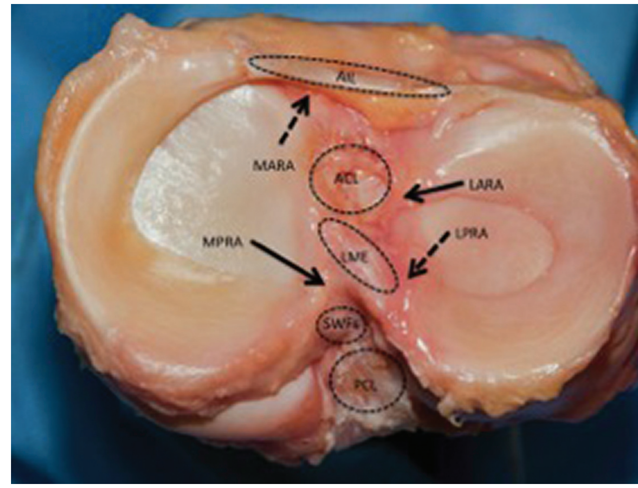

Figure 1. Photograph demonstrating the relationship of the 4 meniscus roots—medial meniscus anterior root attachment (MARA), lateral meniscus anterior root attachment (LARA), medial meniscus posterior root attachment (MPRA), and lateral meniscus posterior root attachment (LPRA)—in comparison with the anterior intermeniscal ligament (AIL), anterior cruciate ligament footprint (ACL), and posterior cruciate ligament footprint (PCL). The location of the accessory shiny white fibers (SWFs) is labeled in relation to the MPRA (lowermost solid arrow). The lateral meniscal expansion (LME) is also labeled in relation to the LPRA (lowermost dashed arrow).

Medial Meniscus Anterior Root

In the only known descriptions of quantitative relationships between the medial meniscus anterior root and other landmarks in the knee, Johnson et al[26] depicted the anterior root as inserting in line with the medial tibial eminence at an average of 7 mm anterior to the anterior cruciate ligament (ACL) tibial insertion, and Bhatia et al[8] reported that the center of the ACL was approximately 11.5 mm from the posterior aspect of the medial anterior root. The medial meniscus anterior root attachment has been reported to have the largest insertion site of any of the meniscus root attachments, with 2 studies reporting different areas: 61.4 and 139 mm^2.[26,36]

Berlet and Fowler[7] described 4 types of insertions for the medial meniscus anterior root. The first type, type I, inserted on the flat portion of the intercondylar region of the tibial plateau and occurred in 59% of knees. Type II presented in 24% of knees and inserted on the downward slope of the medial articular plateau to the anterior intercondylar area. Type III, which occurred in 15% of knees, was reported to insert on the anterior slope of the medial tibial plateau. Type IV was anchored only by the peripheral coronary ligament with no direct attachment to the tibial plateau and presented in 1 of the 34 knees (3%).[7] Others have also described similar variants as type IV and reported that 11% to 14% of knees presented with this condition.[48,51]

Berlet and Fowler[7] also described the anterior horn as associating with the ACL in 59% of knees. Other researchers have reported the anterior horn as connecting to the anterior intermeniscal ligament, also known as the transverse ligament, in approximately 70% of knees.[7,36,48,57] Nelson and LaPrade[48] reported that the anterior intermeniscal ligament traversed from the anterior horn of the medial meniscus to the anterior horn of the lateral meniscus in 46% of knees and from the anterior horn of the medial meniscus to the lateral aspect of the joint capsule anterior to the lateral meniscus in 26% of knees. The role of the anterior intermeniscal ligament is controversial. Poh et al[57] sectioned the anterior intermeniscal ligament and reported that the tibiofemoral contact mechanics of both the medial and lateral compartments were not significantly affected by sectioning. Considering this, the investigators reasoned that the individual tibial attachments of the anterior horns cause the menisci to distribute loads individually. Paci and colleagues[53] also sectioned the anterior intermeniscal ligament but did note a significant increase in peak contact pressures of the medial compartment of the knee. The authors reasoned that the anterior intermeniscal ligament may play an important stabilizing role in the knee as well and should be protected.

Medial Meniscus Posterior Root

Johannsen et al[25] qualitatively described the medial meniscus posterior root as posterior to the apex of the

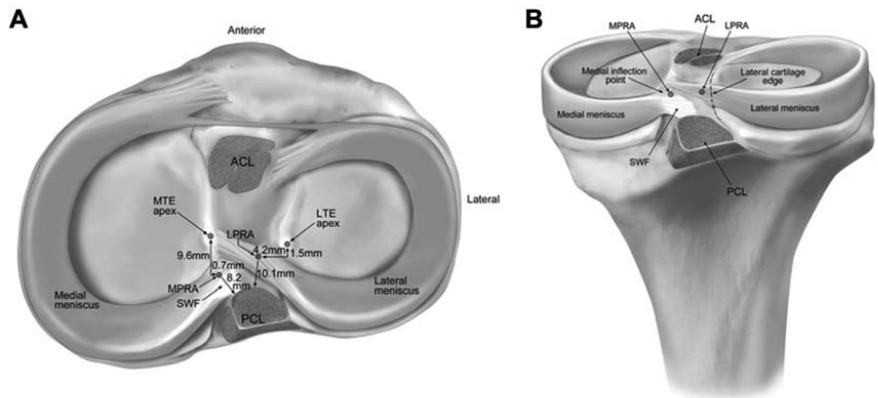

Figure 2. Pertinent anatomic relationships (right knee) as reported by Johannsen et al.[25] (A) Superior view and (B) posterior view. ACL, anterior cruciate ligament bundle attachments; LPRA, lateral meniscus posterior root attachment; LTE, lateral tibial eminence; MPRA, medial meniscus posterior root attachment; MTE, medial tibial eminence; PCL, posterior cruciate ligament bundle attachments; SWF, shiny white fibers of posterior horn of medial meniscus. (Reprinted with permission from Johannsen AM, Civitarese DM, Padalecki JR, Goldsmith MT, Wijdicks CA, LaPrade RF. Qualitative and quantitative anatomic analysis of the posterior root attachments of the medial and lateral menisci. *Am J Sports Med*. 2012;40(10):2342-2347.)

medial tibial plateau, lateral to the inflection point of articular cartilage of the medial tibial plateau, and anteromedial to the posterior cruciate ligament (PCL) tibial attachment point, which expanded on previous studies.[26,36,49] Johannsen et al[25] also elucidated specific quantitative landmarks of the medial meniscus posterior root attachment. They reported that the posterior root was approximately 9.6 mm posterior and 0.7 mm lateral to the apex of the medial tibial eminence. The root was also described as being 3.5 mm lateral to the medial tibial plateau articular cartilage inflection point and 8.2 mm anterior to the most superior PCL tibial attachment (Figure 2).

Anderson et al[5] first reported on the appearance of what the authors called the "shiny white fibers," a posterior-based sheet of supplemental fibers continuous with the main, dense posterior root attachment, distinct in visual appearance but not an entirely separate structure on the posterior horn of the medial meniscus (Figure 3). These diagonally oriented fibers were reportedly named after their brilliant white appearance during arthroscopy and were not considered part of the root attachment.[6,25] Johannsen et al[25] reported their attachment area to be 47.3 mm^2. Previous studies[26,36] have reported the insertion area of the entire posterior root as approximately 47 mm^2 and 80 mm^2. However, Johannsen et al[25] reported that the central, most dense root attachment averaged 30.4 mm, but when the size of the shiny white fibers was included, the total area of the shiny white fibers and posterior root averaged 77.7 mm^2. Therefore, while previous studies may have included the shiny white fibers in their root attachment area, these areas may not accurately describe the precise area of the posterior root that is currently repaired surgically.[25]

Lateral Meniscus Anterior Root

Johnson et al[26] qualitatively reported that the anterior root attached anterior to the lateral tibial eminence and

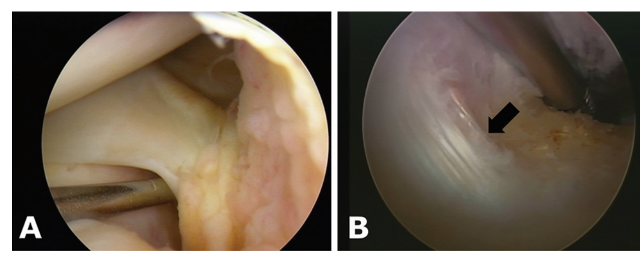

Figure 3. (A) Arthroscopic anatomy of the medial meniscus posterior root attachment with arthroscopic probe under root, left knee. (B) Note the shiny white fibers (arrow), a distinct landmark on the distal aspect of the posterior horn of the medial menisci (posterior cruciate ligament tibial attachment debrided, left knee). The shiny white fibers are a posterior-based sheet of supplemental fibers continuous with the main, dense posterior root attachment, distinct in visual appearance but not an entirely separate structure. The shiny white fibers are the most posterior fibers of the root, and there is no true plane or separation between them and the main root attachment. While previous studies may have included the shiny white fibers in their root attachment area, the precise area of the posterior root that is currently repaired surgically often does not include them.

adjacent to the insertion of the ACL. Zantop et al[74] reported that the anteromedial bundle of the ACL was an average of 5.2 mm medial and 2.7 mm posterior to the lateral anterior root, while the posterolateral bundle was an average of 11.2 mm posterior and 4.1 mm medial to the anterior root. Ziegler et al[75] reported that the center of the ACL was an average of 7.5 mm medial to the anterior root of the lateral meniscus center, 8.5 mm anteromedial to the posteromedial aspect of the anterior horn of the lateral meniscus, and 10.2 mm posteromedial to the anteromedial aspect of the anterior horn. Ziegler et al[75] also replicated earlier findings[26,36] and noted that the anterior horn of the lateral meniscus attached to the ACL bundles in all knees studied. Previous studies[26,36] reported that the lateral anterior root is smaller than its anterior medial meniscus root counterpart, with reported areas of 44.5 mm^2 and 93 mm^2.

Lateral Meniscus Posterior Root

Johannsen et al[25] qualitatively described the lateral posterior root as being posteromedial to the lateral tibial eminence apex, medial to the lateral articular cartilage edge, anterior to the PCL tibial attachment, and anterolateral to the medial meniscus posterior root attachment. This depiction expanded on previous studies.[26,36] These authors also quantitatively reported on the relationship between the posterior root and other landmarks in the knee. They reported that the distance between the lateral tibial eminence apex and the center of the lateral posterior root was approximately 5.3 mm. Also, the root was 4.2 mm medial and 1.5 mm posterior to the lateral tibial eminence, 4.3 mm medial to the lateral tibial plateau articular cartilage margin, 12.7 mm anterior to the most superior margin of the PCL tibial attachment, and 10.1 mm posterior to the posteromedial corner of the anterior root attachment of the lateral meniscus[25,75] (Figure 2). Ziegler et al[75] also reported that the posteromedial bundle of the ACL was 10.8 mm anterior to the posterior root.

Researchers first reported[26,39] that the posterior root attachment area was 28.5 mm^2 and 115 mm^2. Johannsen et al[25] later reported that the area averaged 39.2 mm^2, and the investigators theorized that the discrepancy between studies mostly related to the method of measurement, because they only measured the main fiber attachment area, as opposed to the central root plus supplemental fibers. These authors also first described the presence of an extension of the lateral meniscus attachment that was separated from the main root attachment. These supplemental fibers inserted on the lateral edge of the medial tibial eminence and were not considered part of the main fiber attachment area.[25,38]

EPIDEMIOLOGY AND PATHOGENESIS OF MENISCAL ROOT TEARS

Meniscal root tears have been reported to occur in both acute and chronic settings.[56] Acute tears have been reported in the setting of multiligamentous knee injuries or attributable to trauma resulting from hyperflexion or squatting.[35,55,56] The posterior horns of the medial and lateral menisci transmit more load than the anterior horns, especially at 90° of flexion.[18,73] The medial meniscus posterior root has the least mobility of all the meniscus roots, and studies have reported that this stress placed upon the posterior medial root results in it having the highest incidence of tears compared with the other roots.[27,52,70]

Medial Meniscus Posterior Root

The incidence of medial meniscal posterior root tears is more common than previously thought, with these tears presenting in about 10% to 21% of arthroscopic meniscal repairs or meniscectomies.[9,24,52] Actual prevalence may be even higher given a recently increasing wealth of knowledge about the diagnosis of root tears and the realization that MRI scans may miss approximately one-third of radial tears adjacent to the posterior root attachment of the medial meniscus.[9,52] Posterior root tears of the medial meniscus have been reported to have an incidence of about 3% along with multiligamentous tears.[10,33,35,55] Other studies have reported on risk factors for medial meniscal posterior root tears. Increased age, female sex, increased body mass index, and decreased sports activity levels have all been associated with a higher incidence of medial root tears.[9,24,52]

Lateral Meniscus Posterior Root

The lateral meniscus root has been reported to be approximately 2 times more mobile than the medial root, which has led to the hypothesis that the lateral meniscus has less of a role with stabilization of the knee, and consequently will encounter less stress, than the medial meniscus.[6,43,70] Therefore, the lateral posterior horn has been reported to be less affected by chronic ACL instability episodes than the medial posterior horn.[6,50] Brody et al[10] defined the meniscus root "as the last few millimeters of meniscal tissue angling down to the tibial plateau attachment in the intercondylar notch" for diagnosing root tears based on magnetic resonance appearance. Two studies using this MRI criterion reported a lateral meniscal posterior root tear in 8% and 9.8% of patients with ACL tears.[10,14] One study also reported an incidence of less than 1% for lateral root tears without a concomitant ACL tear.[14] The risk factors for lateral meniscal posterior root tears are relatively unknown. Researchers have reported that sports activity is involved in approximately 87% of lateral meniscal injuries, and Beldame et al[6] reported that 70% occurred with "pivot-contact" sports.[69]

Anterior Meniscus Roots

Little is known about the cause and incidence of tears of the anterior roots of the medial and lateral menisci. Thompson et al[70] reported that the anterior horns demonstrated more mobility than their posterior counterparts, and this may be why the anterior horns of the menisci are reported to undergo injury at a much lower incidence than the posterior horns.[6,64-66,70] Studies have reported that 11% of medial meniscal tears and 5% to 8% of lateral meniscal tears were located in any part of the anterior horn, without a specific reference of injury to the root attachments.[6,64] To date, case reports are the only available literature specifically describing anterior meniscal root tears, and these injuries were iatrogenic in nature or attributable to variant attachments of the anterior roots.[16,47,71]

BIOMECHANICAL AND KINETIC IMPLICATIONS

Few studies have investigated the biomechanical consequences of meniscal root injury. The recent literature has demonstrated that meniscal root tears, particularly posterior root avulsions of the medial meniscus, lead to deleterious alterations in tibiofemoral joint loading profiles.[4,45,54,62,67] Previous studies have suggested that the posterior root of the medial meniscus is essential for maintaining meniscal hoop tension and preventing meniscal extrusion.[20,31] In a landmark study, Allaire et al[4] reported that a posterior root tear of the medial meniscus resulted in a 25% increase in medial compartment peak contact pressure compared with the intact state—a similar loading profile as the total meniscectomized knee. However, when a posterior medial meniscal root repair was performed, the loading profile returned to normal.[4] Marzo and Gurske-DePerio[45] reported similar results, with medial posterior root avulsion significantly decreasing contact area and increasing peak contact pressures. Repair of the avulsion restored the loading profiles to the intact knee.[45] Similar effects after lateral meniscal root avulsions of the posterior root have been reported.[38,60] Root avulsion almost always resulted in significantly decreased tibiofemoral contact areas and increased mean and peak contact pressures, but while the mean and peak pressures were restored to those of the native knee after a transtibial pullout repair, these same studies reported that the contact areas were not always restored to those of the native knee.[38,60]

Further, recent literature has elucidated consequences of a meniscal root injury as it pertains to meniscal extrusion and knee kinematics. Hein et al[23] demonstrated that medial meniscal root avulsion results in significantly greater medial meniscal displacement and gap formation at the root avulsion site when compressive loads are applied to the knee. The authors concluded that this is the basis for which meniscal extrusion, a commonly encountered condition in degenerative knees, occurs.[23] It is possible that extrusion of the meniscus may be responsible for its functional failure in shock absorption.[56] Allaire et al[4] also demonstrated that meniscal root injury involving the posterior horn of the medial meniscus resulted in increased tibial external rotation and lateral translation. Such changes may ultimately increase the varus limb alignment commonly reported in patients with these injuries.[56] Root repair may avoid such changes by restoring kinematic profiles to the native state.[4,56]

Interestingly, while meniscal root repair has been heralded for its ability to restore tibiofemoral joint loading profiles to a more native pattern, evidence suggests that the margin of error is small when repairs are performed. Starke et al[67] elucidated this by demonstrating that a medial meniscal root repair placed nonanatomically just 3 mm medial or lateral significantly impairs the ability of the meniscus to convert axial tibiofemoral loads into hoop stresses.

DIAGNOSIS

Clinical Presentation

Proper diagnosis of meniscal root injury is critical for appropriate patient counseling and treatment decision making. Unfortunately, the clinical diagnosis is quite challenging because of the low likelihood that common signs and symptoms associated with meniscal body injury will manifest in patients with root tears. For example, patients with posterior root tears may report a history of joint line pain on the affected side, but mechanical symptoms such as locking, catching, or giving way are less likely to be present. Lee and coauthors,[40] in a review of 21 patients with posterior medial meniscal root tears, noted that only 14.3% and 9.5% of their patients complained of knee locking and giving way, respectively. Further, meniscal root injury is not typically associated with an inciting traumatic event. In one study, 68.9% of patients with medial meniscal root tears recalled a minor traumatic event, such as squatting, whereas others could not recall any specific event leading up to their injury.[31] In contrast, some patients may present with an acute onset of pain, with higher severity than experienced by patients with other types of meniscal tears.[31]

On physical examination, the most commonly encountered signs are posterior knee pain with deep flexion and joint line tenderness. Lee et al[40] noted that 66.7% and 61.9%, respectively, of their cohort of patients with posterior medial meniscal root tears presented with these findings. McMurray testing was positive in only 57.1% of patients and effusion was noted in only 14.3%.[40] Seil and colleagues[61] described a novel varus stress test that was useful in the clinical diagnosis of a medial meniscal posterior root avulsion. The authors performed the test with the patient fully relaxed and the knee in full extension. During varus stress testing, the anteromedial joint line was palpated and meniscal extrusion was reproduced. Extrusion disappeared when the knee was returned to normal alignment.[61] Although the authors did not objectively quantify the sensitivity or specificity based on results from a large series, they recommended it as a useful tool for diagnosis and clinical follow-up.[61]

Imaging

In the absence of highly sensitive and specific history and physical examination findings, MRI has become increasingly used to diagnose meniscal root tears. However, making an accurate diagnosis with MRI is often dependent on the quality of the imaging and the skill of the radiologist. In one study evaluating 67 patients with arthroscopically confirmed posterior medial meniscal root tears, a root tear could be demonstrated on preoperative MRI in only 72.9% of the patients, while the rest demonstrated degeneration and/or fluid accumulation at the posterior horn without a visible meniscal tear.[52] Others have reported significantly improved detection ability—up to 93.3% sensitivity, 100% specificity, and 100% positive predictive value—using a variety of magnetic resonance sequences and interpretation signs suggestive of root tears.[12,14,22]

Although frequently variable in sagittal cut views, the posterior medial meniscus root is visualized most easily in 2 consecutive coronal MRI images as a band of fibrocartilage anchoring the posterior horn to the tibial plateau.[35,42] T2-weighted sequences are generally considered to be the best images for visualization of tears given their

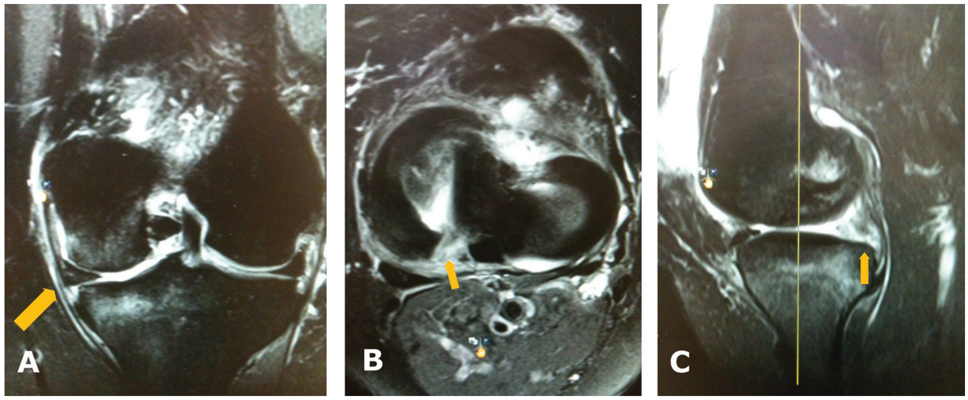

Figure 4. Visualization of meniscal root tears via magnetic resonance imaging. (A) Coronal T2-weighted section demonstrating medial meniscal extrusion (arrow) (left knee). (B) Axial image demonstrating high signal in region of meniscus root and posterior horn with a radial root tear (arrow) (right knee). (C) Sagittal image demonstrating ghost sign (arrow) (right knee).

maximum specificity and sensitivity values,[41] although some consider axial images to provide the highest sensitivity and specificity.[12] Given the difficulty of visualizing a frank tear because of the relatively small size of each meniscus root, the presence of meniscal extrusion has been described as a finding that highly correlates with the presence of a root tear.[11,44] Medial meniscal extrusion is defined as partial or total displacement of the meniscus from the tibial articular cartilage[39,42] (Figure 4). Studies have reported that >3 mm extrusion on midcoronal imaging is significantly associated with articular cartilage degeneration, severe meniscal degeneration, complex tear patterns, and tears involving the meniscus root.[13,42] Meniscal extrusion less than the 3-mm threshold was reportedly not associated with these findings.[13] Lerer et al[42] even purported that meniscal extrusion is a cause rather than a consequence of cartilage degeneration.[11] Although knees with medial meniscal extrusion are more likely to have a meniscal root tear, not all cases of meniscal extrusion are reflective of this. Magee[44] postulated that there may be a subset of patients in whom the meniscus root is stretched rather than torn, resulting in pathologic meniscal extrusion without a frank root tear.

Other important signs associated with root tears include the presence or absence of a ghost sign, which is the absence of an identifiable meniscus in the sagittal plane or high signal replacing the normal dark meniscal signal.[32,42,56] The MRI ghost sign is thought to represent a radial tear caught perfectly in line showing only a portion of the meniscus (Figure 4). Other signs for meniscal root lesions include a radial linear defect at the posterior bony insertion of the meniscus roots on axial imaging and vertical linear defects on coronal imaging[32] (Figure 4). Also, when treating patients with radial meniscal posterior tears, the clinician must differentiate true medial meniscal root tears from paracentral posterior horn radial tears to determine the appropriate treatment. The latter tears, because of a limited vascular supply in the paracentral posterior horn, have a far lower likelihood for side-to-side healing of repairs than do true meniscal root tears.[35] A summary of important pearls for the diagnosis of meniscal root tears on MRI is provided in Table 1. In the senior author's (R.F.L.) practice, it is commonly noted that patients present with ipsilateral tibiofemoral compartment bone marrow edema and insufficiency fractures in the presence of posterior horn meniscal root tears.[21]

Lateral meniscal root tears are also best visualized with standard magnetic resonance protocols. Typically, lateral meniscus roots are best seen on coronal and sagittal sequences that depict the posterior slope and apex of the lateral tibial eminence.[14] To date, however, the sensitivity and specificity for the detection of lateral root tears by MRI are unknown.

TREATMENT DECISION MAKING

The treatment of meniscal root tears can be broken down into 3 groups: (1) nonoperative, (2) partial meniscectomy, and (3) meniscal root repair. Historically, patients with root injuries have been treated with one of the first two options, and nonoperative management of these injuries may still be indicated in certain situations. For example, in patients who are poor surgical candidates (multiple comorbidities preventing surgical intervention, advanced age, or the presence of advanced degenerative joint disease), an initial trial of nonoperative management remains the treatment of choice. In these cases, initial surgical meniscectomy or repair is either not indicated or not possible. Surgical treatment of meniscal root tears is best reserved for patients with excellent chondral health and relatively acute meniscal root tears. Appropriate indications for surgical technique are imperative for success. An overview of treatment algorithm principles is depicted in Figure 5.

NONOPERATIVE TREATMENT

Although nonoperative management of root tears fails to restore native anatomy and function and may induce joint-space narrowing and arthritic changes over time,[63]

TABLE 1
Clinical Pearls for the Diagnosis and Treatment of Meniscal Root Tears[a]

Clinical Diagnosis	MRI Evaluation	Treatment
• Have suspicion in patients with posterior knee pain • Assess for effusion and painful flexion	• Assess for meniscal extrusion >3 mm at level of the MCL • Assess for ghost meniscal sign on sagittal MRI • Assess for vertical linear defects on coronal MRI • Differentiate true root tear from posterior horn radial tear • Determine status of cartilage • Assess for the presence of bony edema or insufficiency fractures of the ipsilateral tibiofemoral joint	• Intimate knowledge of root insertional anatomy is essential for restoration of meniscal function • Proper indications for surgical repair: young patients with traumatic tears and excellent chondral health • Proper tensioning of root repair • Proper anatomic placement of root repair on tibia

[a]MCL, medial collateral ligament; MRI, magnetic resonance imaging.

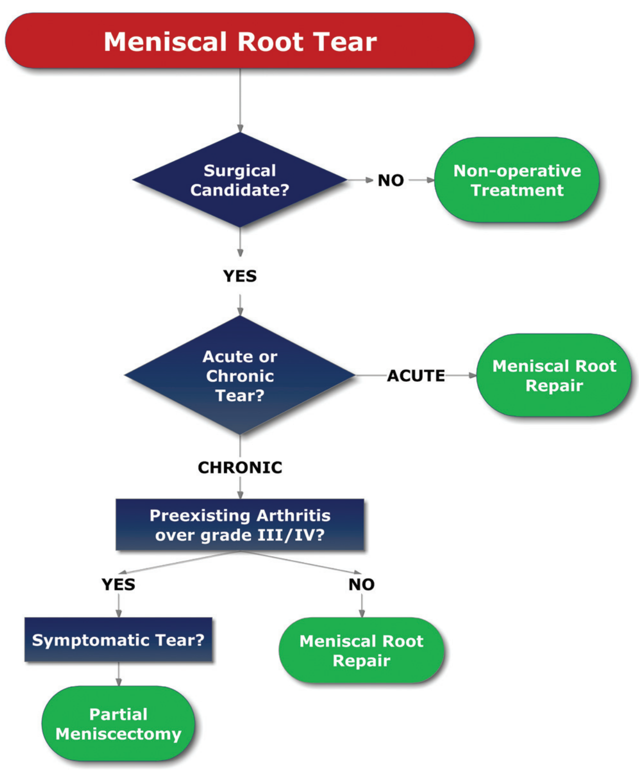

Figure 5. Treatment decision making for meniscal root tears. Appropriate indications for root repair are imperative for success with this procedure.

certain groups of patients may best be treated nonsurgically. Elderly patients, poor surgical candidates, or patients with advanced arthritis should attempt a period of nonoperative treatment before undergoing surgical intervention. Symptomatic treatment with anti-inflammatory medications (oral or topical), activity modification, and/or unloader bracing may alleviate joint pain associated with a root tear. In the case of advanced arthritis, intra-articular injections are a common form of nonoperative treatment to prolong or prevent the need for a total knee arthroplasty.

OPERATIVE TREATMENT

Meniscectomy

Surgical options for the treatment of meniscal root injuries include partial meniscectomy or repair. Historically, partial or complete meniscectomy has been performed for root tears or avulsions, often providing short-term symptomatic relief with unknown long-term consequences. However, a recent retrospective study of 58 patients with medial meniscal root tears who underwent either meniscectomy or repair reported that while both partial meniscectomy and repair significantly improve subjective outcome scores (Lysholm and International Knee Documentation Committee [IKDC] scores, $P < .05$), the repair group had more improvement and less progression of arthritic changes at a mean follow-up of 4 years.[32] Further, given that root tears biomechanically simulate a total meniscectomized state, there has been a recent trend toward repair over meniscectomy.[4,25] Nevertheless, for patients with chronic root tears and symptomatic grade 3 or 4 chondral lesions (ie, preexisting arthritis) who fail nonoperative treatment, or patients with partial root tears and a substantial portion of the footprint still intact (exact percentage or quantity of footprint yet to be determined), partial meniscectomy remains the preferred treatment option. Care should be taken to avoid debriding the entire footprint so that a partial tear is not converted into a complete tear, thereby creating a functionally meniscus-deficient knee. Advantages of partial meniscectomy over repair include decreased operative time, a less stringent postoperative rehabilitation protocol with no weightbearing restrictions, and faster return to activities and sports.

Meniscal Root Repair

For most other situations, repair of meniscal root injuries is indicated for both symptomatic relief and prevention of degenerative joint disease. Indications for meniscal repair over meniscectomy are constantly expanding. The main indications for meniscal repair currently include (1) acute, traumatic root tears in patients who have yet to develop osteoarthritis, with the goal of preventing arthritic changes in the future; and (2) chronic symptomatic root tears in young or middle-aged patients without significant preexisting arthritis.[35,56] More specifically, for lateral sided injuries, posterior root tears are often associated with ACL injuries, and the root should be repaired during concomitant ACL reconstruction. On the medial side, there are usually 2 injury patterns, acute and chronic. An acute medial root tear is often associated with a multiligamentous knee injury, specifically a complete tear of the MCL where the meniscocapsular ligaments are maintained but the meniscus is avulsed at the root.[55] In these situations, there is a clear indication for a root repair to prevent the development of arthritis. In contrast, chronic tears are often due to subtle, nonspecific injuries and have been reported to go on to rapid ipsilateral compartment cartilage degeneration if not properly diagnosed.[35,55] The physician must distinguish whether the tear is a result or a cause of arthritis, which is often a difficult task. If there is a significant amount of preexisting medial compartment arthritis with chronic changes on imaging, repair may not be indicated; however, if there are early chondral changes with evidence of a root tear and meniscal extrusion, meniscal repair would be indicated to attempt to prevent the progression of arthritis.

To date, repair techniques fall into 2 broad categories: transosseous suture repairs and suture anchor repairs. All of the reported techniques are performed arthroscopically to avoid open posterior dissections of the knee.[35] The following techniques have been described for posterior medial or lateral meniscal root tears only, and techniques for fixation of the anterior roots have yet to be established in the literature.

Transosseous Suture Repair

Over the past decade, several techniques have been described for fixation of both the medial and lateral posterior roots using transosseous sutures through the proximal tibia. For posterior horn medial meniscal root repair, Raustol et al[58] described an arthroscopic technique using an accessory posteromedial portal placed at a high angle to facilitate suture passage using 2 eyelet pins. The pins were passed through the medial root, creating a mattress stitch, and exited anterolaterally, where they were tied over a bone bridge. Kim et al[34] described passing 2 nonabsorbable sutures using a suture passer with a shuttle through the medial meniscus root, retrieving them through a 5-mm tibial bone tunnel drilled using an ACL guide, and tying them over a screw and washer anteromedially. Ahn et al[3] were the first to describe the use of a posterior transseptal portal to facilitate visualization of the root. In their technique, the ACL guide is placed through the posteromedial portal, the tunnel is drilled, and sutures are then passed and tied over a post. In a subsequent study, the authors elucidated the potential for a double-row technique to maximize fixation and healing.[2] Marzo and Kumar[46] also described a transosseous technique; however, they did not use posterior accessory portals, instead facilitating suture passage with a commercial suture passing device. They drilled a 7-mm tunnel using an ACL guide and tied their sutures over a washer. Finally, Nicholas et al[49] were the first to report a technique using a small intraosseous socket created with a retrograde reaming device (FlipCutter; Arthrex Inc, Naples, Florida, USA), thus removing only a minimal amount of tibial bone, which may be advantageous in the setting of concomitant cruciate reconstructions that require drilling of multiple bone tunnels.

The senior author's current preferred technique for fixation of a posterior horn meniscal root tear involves transosseous suture repair tied over a button on the anteromedial tibia (Figure 6). In addition to the 2 standard arthroscopy portals, an accessory posteromedial portal is placed to facilitate suture passage. For root avulsions, recently described arthroscopic landmarks are used for anatomic placement of the posterior root bone tunnels according to directional components referenced off the apices of the tibial eminences, as reported by Johannsen et al[25] and detailed in the anatomy section above. For radial root tears, fixation is performed in situ, based on the work of Padalecki et al,[54] who reported that an in situ pullout repair of radial tears restored joint mechanics (contact area and pressure) to the intact state. For a posterior horn medial root tear, the surgeon typically uses a curved suture passer through a cannula to insert a nitinol wire to shuttle 2 sutures that are passed via an accessory posteromedial portal; this is followed by creation of the bone tunnel at an anatomic location. The sutures are passed in an anterior-to-posterior configuration. The knee is cycled and the sutures are tied over a button on the anteromedial aspect of the proximal tibia (Figure 7).

Stitch Configuration

One recent area of interest involves the biomechanical properties of various suture techniques for transtibial pullout repair of posterior horn medial meniscal root tears. Kopf et al[37] first examined the properties of 3 commonly used meniscal root fixation techniques (2 simple stitches, modified Kessler stitch, and loop stitch) using 64 detached human meniscus roots in a cadaveric study. Regarding primary fixation strength, the modified Kessler stitch was the strongest technique, but none of the 3 tested suture fixation methods were able to restore the strength of the native roots, leading the authors to recommend a slow, conservative postoperative rehabilitation course after fixation.[37] More recently, Feucht et al[16] published a similar study examining suture strength in a biomechanical porcine model using 4 different techniques: 2 simple sutures, modified Mason-Allen, horizontal mattress, and 2 modified loop sutures. The investigators reported that the modified Mason-Allen technique provided the best biomechanical properties with regard to cyclic loading and load-to-failure testing, followed by the 2-simple-suture technique. The other 2 techniques had lower stiffness and higher

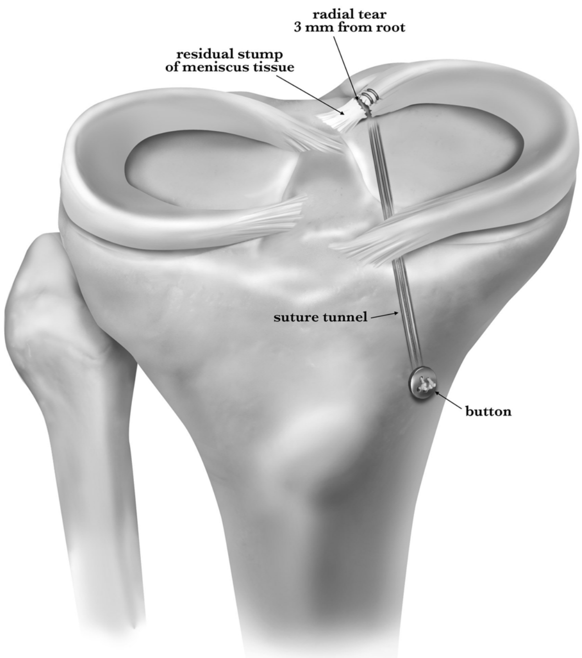

Figure 6. Preferred technique for fixation of a posterior horn medial meniscal root tear involves transosseous suture repair tied over a button on the anteromedial tibia. Proper tensioning and anatomic placement of the attachment are critical for healing and restoration of meniscal function. (Reprinted with permission from Padalecki JR, Jansson KS, Smith SD, et al. Biomechanical consequences of a complete radial tear adjacent to the medial meniscus posterior root attachment site: in-situ pullout repair restores derangement of joint mechanics. *Am J Sports Med*. 2014;42(3):699-707.

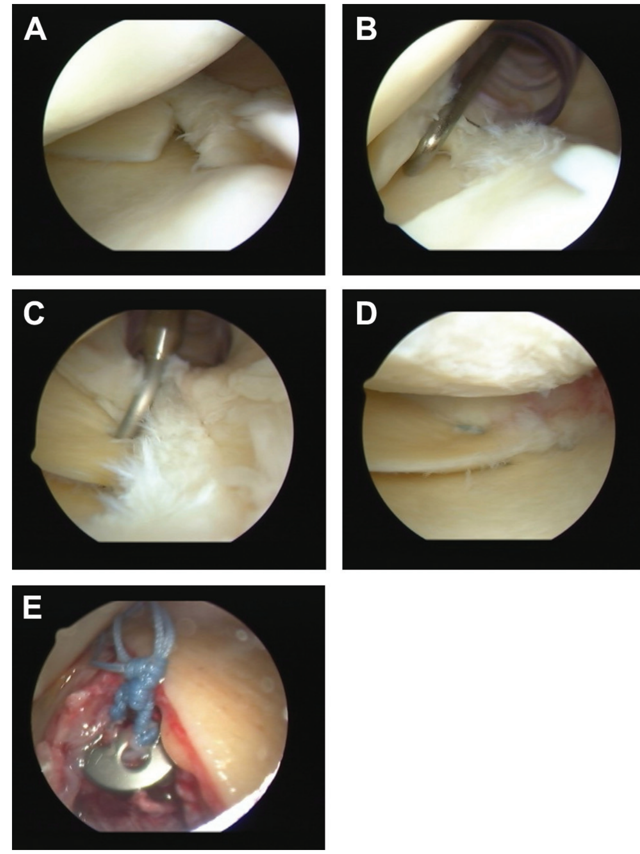

Figure 7. Steps taken during arthroscopic repair of the posterior medial meniscus radial root (left knee). (A) Radial root tear. (B) Probing of root tear through posteromedial knee portal cannula. (C) Placement of shuttle suture device through body of root tear. (D) Transosseous pullout repair of root tear. (E) Pullout sutures tied over a button on the anteromedial tibia.

displacement during cyclic loading. Regarding the optimal number of sutures used, Rosslenbroich et al[59] found that 2 sutures were better than 1 suture for posterior lateral meniscal root fixation, with elongation and stiffness similar to the intact state for the 2-suture group and significantly lower for the 1-suture group. Both the 1- and 2-suture groups, however, demonstrated lower ultimate failure loads compared with the intact group, again reinforcing a need for a conservative postoperative course after repair.

Suture Anchor Repair

The theoretical advantages of suture anchor repairs are that they avoid the need for tibial bone tunnels that could interfere with concomitant ligament reconstruction, and they avoid the need for distal fixation that places the sutures at risk for failure due to abrasion.[35] Arthroscopic fixation of meniscal root tears via use of a suture anchor technique was originally described by Engelsohn et al[15] using an accessory posteromedial portal. The repairs were then tensioned using standard arthroscopic knot tying techniques from the anteromedial portal. The authors reported that in ligamentously stable knees, a high posteromedial portal would be necessary to accomplish appropriate anchor placement.[15] Others have reported a similar technique for repair of posterior horn medial meniscal root tears, with placement of the high posteromedial portal approximately 4 cm proximal to the joint line and posterior to the medial femoral condyle, with insertion of a double-loaded metal suture anchor and suture passage using a suture hook and a shuttle suture.[28] The optimal location and orientation of suture anchor placement have yet to be identified in the literature.

POSTOPERATIVE MANAGEMENT

To date, there are no consensus guidelines for postoperative rehabilitation after meniscal repair. Most authors suggest full leg extension in either a long cylinder cast[32,40] or a knee immobilizer[56] for 2 weeks after repair, followed by passive range of motion from 0° to 30° for 2 weeks and a progressive increase of approximately 20° per week until full flexion is recovered.[56] Active flexion is typically allowed after the fourth week postoperatively in a controlled fashion from 0° to 90°, and flexion beyond 90° is avoided to prevent further stress on the repair construct. Isometric strengthening exercises for the quadriceps begin on postoperative day 1, and zero to partial weightbearing is allowed for the first 6 weeks, followed by an increase to full weightbearing by 2 months after surgery.

In contrast to a standard postoperative rehabilitation protocol for all meniscal repairs, the protocol used by the senior author is individualized to each patient. Each patient's protocol is based on the range of motion that is found to be stable intraoperatively by using the transosseous approach, and immediate passive motion is performed rather than immobilization in extension for 2 weeks. Intraoperatively, before tying the sutures over a button on the proximal tibia, the surgeon tensions the sutures, ranges the knee through a 90° arc of motion, and determines the tension placed on the meniscus via direct visualization and probing. For example, upon tension of the sutures before tying, if the knee can be flexed to 60° without putting tension on the repair, yet there is moderate tension at 90°, 60° is chosen for the maximum flexion angle for motion during the first 4 weeks of rehabilitation, followed by a slow, progressive increase in range of motion as tolerated over the next 4 weeks. An early emphasis is placed on edema control, isometric quadriceps exercises, and gentle passive knee range of motion starting on postoperative day 1. The patient is instructed to be nonweightbearing for the first 6 weeks, followed by a progressive increase in weightbearing, with full weightbearing typically achieved by 2 months. Return to full activities or sports is generally attempted at 5 to 6 months postoperatively, depending on other concomitant procedures.

CLINICAL OUTCOMES

Optimal treatment of meniscal root tears is still debatable. Recent clinical studies have attempted to compare clinical outcomes between nonoperative management, meniscectomy, and meniscal root repair. A summary of clinical results is provided in Table 2. Historically, partial meniscectomy was the treatment of choice for radial tears involving the meniscus root. However, a retrospective review by Ozkoc et al[52] of 70 posterior horn medial meniscal root tears treated with arthroscopic partial meniscectomy demonstrated that although mean Lysholm knee scores significantly improved, degenerative changes as defined by a Kellgren-Lawrence radiographic grade increased postoperatively at a mean follow-up of 4.7 years. The authors concluded that partial meniscectomy provides symptomatic relief in most cases of posterior medial meniscal root tears but does not arrest the progression of radiographically evident arthritis.[52] Lee and colleagues[39] recently performed a review of 102 knees with medial meniscal posterior horn tears to identify predictors of meniscal extrusion. The authors reported that tears in a radial orientation were more likely to have meniscal extrusion than nonradial tears. Increased amounts of meniscal extrusion, additionally, were associated with osteoarthritis severity.[39] Given the recent biomechanical evidence demonstrating the functional importance of the posterior meniscus root attachment in preventing a marked increase in tibiofemoral contact stress similar to total meniscectomy, such findings are expected.[4,45]

Clinical outcomes studies for medial meniscal root repairs suggest that when performed correctly, root repair may be a more effective long-term solution than partial meniscectomy because of improved clinical and radiographic results and a relatively high healing rate. In one of the largest clinical series comparing partial meniscectomy to root repair, Kim et al[32] evaluated 58 consecutive patients who underwent either a partial meniscectomy or a posterior medial meniscal root repair via a pullout suture technique with a mean follow-up of 48.5 months. Similar to Ozkoc et al,[52] Kim et al[32] reported a significant improvement in Lysholm and IKDC subjective knee scores in both the meniscectomy and repair group when compared with the preoperative state, but the repair group had better Lysholm and IKDC scores, less joint-space narrowing, and less progression of the Kellgren-Lawrence radiographic arthritis grade than the partial meniscectomy group. The repair group also had less meniscal extrusion postoperatively, and 93.3% had complete or partial healing of the meniscus. A second-look arthroscopy was performed in 14 patients in the repair group. Of this subgroup, 10 of the 14 patients had normal restoration of hoop tension. The authors concluded that arthroscopic pullout repair of a medial meniscal root tear provides better clinical and radiographic results long term than does partial meniscectomy and carries a higher possibility of complete healing and restoration of the meniscus's ability to convert axial loads into hoop stresses.[32] In a review of 21 consecutive knees with posterior root tears of the medial meniscus treated with an arthroscopic pullout suture repair at a mean follow-up of 31.8 months, Lee et al[40] demonstrated significant improvement in functional scores, with complete healing observed in all patients who underwent second-look arthroscopies. Radiographic progression of arthritis was observed in only 1 of 21 knees undergoing root repair.[40]

While arthroscopic repair of posterior medial meniscal root tears has demonstrated efficacy, the optimal surgical technique (pullout suture method vs suture anchor technique) has yet to be determined.[49] Root repair using the pullout suture technique has the inherent disadvantage of requiring a separate tibial tunnel but avoids the potential complication of loosening of the suture anchor. However, because the suture anchor technique involves using a knot pusher to place an arthroscopic knot directly on the meniscus root, more precise tensioning of the repair may potentially be achieved with this technique. Jung and colleagues[28] reported on the results of 13 patients with medial meniscal root tears that were treated with an all-inside repair using a suture anchor. One patient experienced loosening of the suture anchor at 8 months postoperatively and required arthroscopic removal. Kim and colleagues[31] performed a head-to-head comparison of functional and radiographic results of arthroscopic suture

TABLE 2
Summary of Results From Meniscal Root Repair Outcomes[a]

Study	Objective	Level of Evidence	No.	Duration of Follow-up	Methods	Key Findings	Conclusion
Ozkoc et al[52] 2008	Define clinical features of radial root tears and report the outcome of arthroscopic treatment.	Level 4, retrospective	67 patients (70 knees)	56.7 mo (range, 8-123 mo)	Patients with PHMM root tears were treated with partial meniscectomy. A retrospective review of postoperative MRI and surgical findings was conducted. Clinical results evaluated with Lysholm scores. Radiologic evaluation with KL grades.	Mean Lysholm score improved from 53 to 67 after arthroscopic partial meniscectomy. Preoperative KL grade of 2 (range, 0-3) increased significantly to 3 (range, 2-4).	Arthroscopic partial meniscectomy for tears of the PHMM generally improves symptoms but does not arrest the progression of radiographically demonstrated osteoarthritis.
Kim et al[32] 2011	Clinically, radiographically, and arthroscopically compare findings in patients with PHMM root tears treated with partial meniscectomy or root repair.	Level 3, retrospective comparison study	58 patients (28 meniscectomies, 30 repairs)	48.5 mo	58 consecutive patients with PHMM root tears underwent partial meniscectomy or pullout repair. Patients were evaluated by Lysholm and IKDC subjective knee scores, joint-space narrowing, and KL grade on simple radiographs; second-look arthroscopy performed in 14 patients with pullout repair.	Lysholm and IKDC scores improved in both groups ($P < .05$). The repair group had better Lysholm and IKDC scores and less joint-space narrowing and progression of KL grade than did the meniscectomy group ($P < .05$). In a subgroup analysis of the repair group, 28 (93.3%) showed complete or partial healing.	Arthroscopic pullout repair of a medial meniscal root tear gave significantly better clinical and radiologic results than partial meniscectomy, and sound healing with restoration of hoop tension of the meniscus was observed on MRI and second-look arthroscopy.
Lee et al[39] 2011	Determine the effect of a radial tear on degenerative PHMM tear extrusion and identify predictors of medial meniscal extrusion.	Level 4, retrospective	102 knees	—	Tears were classified as root (n = 17) and nonroot (n = 85) tears or as radial (n = 46) and nonradial (n = 56) tears. Multiple regression analysis was used to identify predictors of meniscal extrusion.	Extrusion was found to be associated with both the presence of a radial component and the preoperative KL grade.	Meniscal extrusion in osteoarthritic knees was associated with degenerative meniscal tear and osteoarthritis severity. Arthroscopic meniscal procedures, especially meniscal repair, should be cautiously considered in patients with meniscal extrusion.
Lee et al[40] 2009	Document the short-term clinical efficacy of arthroscopic pullout suture repair in treating posterior root tears of the medial meniscus.	Level 4, retrospective	20 consecutive patients (21 knees)	31.8 mo (range, 24-48 mo)	Patients were treated by arthroscopic pullout suture repair of PHMM root tears. Clinical results were evaluated by use of Lysholm knee and HSS scores and radiographic grade. Second-look arthroscopic findings for 10 knees were also analyzed.	KL radiographic grade increased by 1 grade in only 1 knee. On second-look arthroscopy, all repaired menisci had healed without additional chondral lesions. Preoperative HSS and Lysholm knee scores improved ($P < .0001$).	Arthroscopic pullout suture repair is an effective treatment for alleviating meniscal symptoms in patients with a symptomatic posterior root tear of the medial meniscus with degenerated articular cartilage of less than grade III. No discernible radiographic degenerative arthritic changes were found with the limited short-term follow-up.
Jung et al[28] 2012	Evaluate subjective and objective outcomes after repair of medial meniscal root tears.	Level 4, retrospective	13 patients	30.8 mo (range, 24-40 mo)	Patients with a PHMM root tear underwent all-inside repair using a suture anchor. Postoperative evaluation was performed using joint line tenderness, McMurray test, and follow-up MRI. Functional evaluations were performed using Tegner activity level and Lysholm knee score.	No patients had joint line tenderness, effusion, or positive McMurray test result postoperatively. Improvements in Tegner activity level and Lysholm score were statistically significant. Mean medial meniscal extrusion was 3.9 mm preoperatively and 3.5 mm postoperatively ($P > .05$).	This study demonstrated symptomatic improvement after meniscal root repair using a suture anchor. However, follow-up MRI scans did not show complete healing of all repaired root tears.

(continued)

TABLE 2
(continued)

Study	Objective	Level of Evidence	No.	Duration of Follow-up	Methods	Key Findings	Conclusion
Kim et al[31] 2011	Evaluate functional and radiographic results of arthroscopic suture anchor repair for PHMM root tears and compare with pullout suture repair.	Level 3, prospective	45 patients (22 in pullout suture group, 23 in suture anchor group)	25.9 mo (range, 24-27 mo)	For 2 groups of patients, the investigators compared IKDC criteria, KL grade, gap distance at PHMM root tear, structural healing, meniscal extrusion, and cartilage degeneration of the medial femoral condyle.	Both groups showed significant improvements in function and meniscal extrusion ($P < .05$) but did not show significant differences in KL grade or gap distance on MRI ($P > .05$). Complete structural healing was seen in 11 cases in the pullout suture group and 12 cases in the suture anchor group ($P > .05$).	Significant functional improvement was seen in both the suture anchor repair and pullout suture repair groups. Reduction of meniscal extrusion seems to be appropriate to preserve its protective role against progression of cartilage degeneration after complete healing.
Ahn et al[1] 2010	Evaluate effectiveness of all-inside repair of PHLM root full-thickness tears.	Level 4, retrospective	25 patients	18 mo (range, 12-48 mo)	Patients underwent all-inside repair of PHLM root tear with concomitant ACLR. Clinical and MRI outcomes were assessed postoperatively.	No postoperative effusion, joint-line tenderness, or positive McMurray provocation testing was observed. No statistically significant improvement in meniscal extrusion was observed in the coronal plane at 18-month follow-up MRI scans ($P = .096$); however, sagittal extrusion improved significantly ($P = .007$).	After repair of posterior lateral meniscal root tears, MRI showed that the displaced lateral meniscus was reduced, mainly in the sagittal plane.
Shelbourne et al[63] 2011	Evaluate long-term radiographic and subjective results of patients with PHLM root tears left in situ at the time of ACLR.	Level 3, cohort	33 patients	10.6 y	Patients who had isolated PHLM root tear and >5 y of objective and subjective follow-up were evaluated and compared with a matched control group without meniscal tears based on sex, chronicity of tear, age, and follow-up time. No repair of root tear performed. Patients were evaluated subjectively and objectively using the IKDC criteria.	The mean subjective total score was 84.6 ± 14 in the study group vs 90.5 ± 13 in the control group ($P = .09$). The measured amount of lateral joint-space narrowing compared with the other knee was 1.0 ± 1.6 mm in the study group vs 0 ± 1.1 mm in the controls ($P < .006$).	At a mean 10-y follow-up of posterior lateral meniscal root tears left in situ, mild lateral joint-space narrowing was measured without significant differences in subjective or objective scores compared with controls.

[a]ACLR, anterior cruciate ligament (ACL) reconstruction; HSS, Hospital for Special Surgery score; KL, Kellgren-Lawrence radiographic grade; IKDC, International Knee Documentation Committee subjective score; MRI, magnetic resonance imaging; PHLM, posterior horn lateral meniscus; PHMM, posterior horn medial meniscus.

anchor repair versus pullout suture repair in 51 patients with posterior medial meniscal root tears. The authors reported that both methods resulted in significantly improved functional scores.[31]

As noted above, the literature has demonstrated a clear benefit of surgically repairing posterior root tears of the medial meniscus. However, surgical repair of the posterior root of the lateral meniscus remains controversial. Some authors have reported a high degree of symptomatic improvement in posterior lateral meniscal root tears that were treated with repair at the time of concomitant ACL reconstruction (ACLR), whereas others have postulated that repair is unnecessary.[1,63] In a study of 27 patients treated with ACLR and posterior lateral meniscal root repair, Ahn et al[1] reported a significant improvement in postoperative meniscal extrusion, particularly in the sagittal plane, hypothesizing that repair may lead to improved joint health.

COMPLICATIONS

Meniscal root repairs are not without potential complications. The transosseous suture fixation technique has several unique disadvantages, including (1) the need for drilling bone tunnels that may potentially interfere with concomitant ligament reconstruction, (2) an increased risk for suture abrasion within the bony tunnel during knee motion before meniscal healing, and (3) an increased possibility of creep within the suture itself, decreasing the strength of the repair. For these reasons, anchor repair was developed. Unfortunately, complications of anchor repair include anchor pullout with subsequent failure of fixation, as well as technical difficulty associated with the procedure.[31]

Other notable complications, and perhaps the most prevalent, include retear of the root repair and progression of arthritis. The prevalence of these complications is unknown. Further, the surgeon must be aware of other common postoperative complications after knee surgery, including infection, arthrofibrosis, and deep vein thrombosis, especially in high-risk patients. Iatrogenic injury to the cruciate ligaments or posterior knee neurovascular structures is another potential complication, as noted by Vyas and Harner.[72]

In addition to the noted complications above, performing an arthroscopic meniscal root repair using either technique is a demanding procedure in a ligamentously intact knee. With an intact ACL and PCL, the insertion sites for the posterior horn of the medial and lateral menisci are not easily visualized. Properly identifying the footprints themselves, in addition to placing pullout sutures or anchors precisely in these footprints, can be difficult even for advanced arthroscopists. Further, debridement of the ruptured edges could potentially cause a loss of tissue substance and shorten the root, resulting in a nonanatomic repair. Multiple circumstances intraoperatively can prevent precise anatomic repair of root tears and induce loss of meniscal tension, either from failure to restore adequate tension intraoperatively or from a failure of fixation,[28,31] thereby increasing stress on surrounding cartilage and altering meniscal function at the site of repair.[67] Together, these effects may contribute to failure of the meniscal repair and progression of arthritis.

Recent studies on the quantitative anatomic landmarks of the meniscus roots have provided a better understanding of the appropriate location for an anatomic repair, but several variables have yet to be elucidated. The optimal repair technique, the strength and function of the native compared with surgically fixed roots, and long-term outcomes of available repair techniques for the posterior roots remain unknown. Similarly, a large gap in knowledge exists for the anterior roots, because few studies have attempted to define the quantitative and arthroscopically pertinent anatomy, biomechanical function, and optimal repair techniques for the anterior roots.

FUTURE DIRECTIONS

Management of patients with meniscal root lesions is a relatively new concept within orthopaedics, and the optimal treatment strategy is still evolving. The consequences of medial meniscal root tears are well established, particularly with regard to meniscal extrusion, tibiofemoral load alteration, and progression of arthritis.[35,55,56] Thus far, preliminary studies suggest a clear benefit for surgical repair over partial meniscectomy in select patients with acute traumatic tears to best preserve the inherent joint-protective function of the human meniscus.[32,56] Although much of the current body of work has helped refine surgical techniques and short-term outcomes, there is a clear need for longer term data investigating biomechanical consequences of root tears, surgical techniques, and outcomes of repair.

CONCLUSION

Tears of the posterior root attachment of the medial meniscus often lead to meniscal extrusion, a state in which tibiofemoral loads in the medial compartment are comparable with a total meniscectomized knee, a risk factor for rapid joint degeneration. Given the recently understood functional significance of the meniscus root attachments, accurate early diagnosis of root tears, especially in patients with minimal preexisting chondral disease, is paramount. Treatment for meniscal root tears historically was focused on partial meniscectomy, which has recently been found to induce an unacceptably high rate of arthritic progression postoperatively. Therefore, repair of meniscus root attachments has increased in popularity and, when done properly in select patients, demonstrates a high rate of healing as well as biomechanical and clinical efficacy in restoring the innate ability of the meniscus to dissipate axial tibiofemoral loads, thereby slowing or halting arthritic progression.[32,40,56]

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