

Meniscal Ramp Lesions and Root Tears: A Review of the Current Literature

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Abstract: The importance of the menisci in providing joint stability and their role in load transmission within the knee are well understood. A growing body of literature has emerged on 2 distinct injury patterns to these crucial anatomic structures, ramp lesions and root tears. Ramp lesions may be characterized as tears at the posterior meniscocapsular junction, while root tears involve bony or soft tissue avulsion of the meniscal insertions at the anterior or posterior intercondylar regions. In this 2-part review, we present an overview of the current available literature on ramp lesions and meniscal root tears, summarizing the unique anatomic considerations, etiology, biomechanics, management decisions, clinical outcomes pertinent to these very distinct injuries.

Key Words: meniscus, ramp lesion, root tear, anatomy, biomechanics, repair

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RAMP LESIONS

Introduction

Meniscus tears at the posterior meniscocapsular junction and posterior meniscotibial ligament were first characterized by Strobel, who coined the term *ramp lesion* to characterize these unique injuries.¹ Since their introduction, ramp lesions have become increasingly recognized, with a reported incidence of 9% to 42% in the setting of a concomitant anterior cruciate ligament (ACL) injury.^{2–5} Several mechanisms have been described in the development of a ramp lesion. A combined valgus moment at the knee, internal rotation of the tibia, and axial loading results in strain of the posteromedial capsule.⁶ Direct entrapment of the medial meniscocapsular junction may also occur during anterior tibial translation at the time of an ACL injury. Simultaneous contraction of the semimembranosus tendon, which shares a close anatomic relationship to the deep posteromedial structures of the knee, may contribute to this proposed injury pattern.⁷

Anatomy

The medial meniscus is a fibrocartilage structure anchored to the tibial plateau by anterior and posterior root attachments, as well as meniscotibial ligaments.⁸ While important for normal knee kinematics, the stability conferred by these structures comes at the cost of reduced mobility and increased susceptibility to injury during deep flexion and rotational movements. It is within this context that most ramp lesions arise.

Vieira et al⁹ presented evidence that ramp lesions occur within a spectrum of posteromedial instability, rather than in isolation. DePhillipo et al¹⁰ suggested a dynamic role of the semimembranosus muscle-tendon complex, which is firmly attached to the posterior horn of the medial meniscus (PHMM) in 86% of cases. Upon arthroscopic dissection and subsequent loading of the semimembranosus tendon attachment, posterior translation of the PHMM and stretching of the meniscocapsular region was noted. Biomechanical studies have further demonstrated that increased anterior tibial translation and external rotation are increased in the setting of a posterior meniscocapsular injury.^{11,12} In fact, simultaneous repair of meniscocapsular lesions with ACL reconstruction has been shown restore greater rotational stability compared with ACL reconstruction alone.¹²

Thaunat et al¹³ developed a classification for ramp lesions based on tear pattern. Type 1 lesions involve the meniscocapsular junction. Type 2 lesions are partial superior meniscal tears within the red-red zone, type 3 lesions are partial inferior tears, and type 4 lesions are complete. Type 5 lesions are double vertical tears. Anterior subluxation of the medial meniscus may be seen in type 1 and type 4 lesions during arthroscopic examination.

Risk Factors and Associated Injuries

Evidence suggests that risk factors for ramp lesions may be multifold, stemming from mechanism of injury to inherent patient characteristics. Balazs et al⁵ demonstrated an association with a contact injury mechanism [odds ratio (OR) 1.8] and concurrent lateral meniscus tear (OR 1.7). No associations with demographics or other radiographic variables were identified. Liu et al⁵ reported that the prevalence of ramp lesions increases logarithmically for the first 2 years after an ACL injury, and is more common in male patients less than 30 years of age. In a prospective cohort of 224 patients undergoing ACL reconstruction, patients were 2.98 times more likely to have a ramp lesion if the ACL injury was caused by direct contact, and 8.71 times more likely if the ACL injury was complete.¹⁴

Medial posterior tibial slope is defined as the angle between the line perpendicular to the tibial longitudinal axis and the line tangent to the medial tibial plateau, with evidence suggesting a correlation between increasing slope and the incidence of secondary PHMM lesions in the setting of noncontact ACL injuries.¹⁵ Medial meniscal slope is an analogous principle that uses a line tangent to the superior anterior and posterior meniscal borders instead of the tibial plateau. Song et al¹⁶ performed a matched-cohort analysis of 53 patients undergoing ACL reconstruction with arthroscopically verified ramp lesions, and found a statistically higher mean medial meniscal slope compared with a control group without ramp lesions (3.5 vs. 2.0 degrees). Interestingly, no significant association between medial posterior tibial slope and ramp lesions were identified in their study.

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Bone marrow edema of the posteromedial tibial plateau (PMTTP) has been suggested to be an independent risk factor for the presence of a ramp lesion. Kumar et al¹⁷ reported a sensitivity of PMTP edema of 66.3% for ramp lesions, and when present, PMTP edema was significantly more likely to indicate a ramp lesion than a meniscal body tear (OR 3.3). These findings are further supported by recent cross-sectional study of 275 patients undergoing ACL reconstruction, with and without concomitant ramp lesions, in which PMTP contusions were significantly more common in patients with ramp lesions compared with those without (OR 4.20).⁴ Additional cited risk factors in this study included steeper medial tibial and meniscal slopes (OR 1.29 and 1.46, respectively), and varus alignment > 3 degrees (OR 2.34).

Perhaps unsurprisingly, the most widely studied associated injury of posterior medial meniscus lesions is that of an ACL tear. The reported rate of concomitant ACL and meniscocapsular injuries ranges from 9% to 42%. In a review of 575 meniscal tears associated with ACL injuries, Smith and Barrett¹⁸ found that 75% of those involving the medial meniscus occurred in the peripheral posterior horn. Biomechanical evidence of the interplay between these structures was demonstrated in Papageorgiou et al¹⁹ classic study, which showed that sectioning of the ACL doubles forces experienced by the medial meniscus in response to anterior tibial translation. Likewise, in situ forces on the ACL graft increased 33% to 50% following medial meniscectomy. In cadavers with intact menisci, native forces on the medial meniscus were re-established following ACL reconstruction.

Evaluation and Imaging

Evaluation for a meniscus tear begins with a thorough patient history and physical examination; however, detection of a ramp lesion remains a diagnostic challenge. The Finochietto²⁰ sign was first described in 1935 in patients with posterior meniscal pathology, and was recently demonstrated to correlate with ramp lesions as well. The examination is performed with the patient supine and the knee flexed to 90 degrees. The examiner applies an anterior load with their forearm to the patient's calf, while holding down the patient's foot with their contralateral hand.²¹ The examination is positive when visible snapping occurs as a result of anterior subluxation of the tibia underneath the femoral condyles. Suspicion of a ramp lesion should also be heightened during examination of an ACL-deficient knee. Mouton et al²² reported a higher prevalence of grade 3 pivot shift examinations under anesthesia (47% vs. 24%) in patients with arthroscopically confirmed ramp lesions during ACL reconstruction.

Magnetic resonance imaging (MRI) is a generally a reliable diagnostic modality, although its sensitivity in detecting ramp lesions varies in the literature. The presence of a thin fluid signal interposed between the PHMM and adjacent capsule is usually indicative of this injury (Fig. 1).²⁴ Hatayama et al²⁵ reported a significantly lower sensitivity for ramp lesions (71.7%) than that of meniscal body tears (94.3%), without statistically significant differences when using a 3-Tesla magnet versus a 1.5-Tesla magnet. Kim et al⁴ reported sensitivity and specificity of MRI findings to be 85.3% and 78.3%, respectively. However, MRI failed to identify all lesions in a series of 11 patients who underwent subsequent arthroscopy, with confirmed findings.² The authors presumed that knee extension at the time of imaging, which reduces meniscocapsular separation, accounted



FIGURE 1. Sagittal T2 magnetic resonance image of the medial compartment of a right knee demonstrating subtle separation in the posteromedial meniscocapsular junction consistent with a ramp lesion (yellow arrow).²³ [full color online](#)

for the discrepancy. A recent meta-analysis of MRI findings in 9 studies (883 patients undergoing ACL reconstruction) demonstrated 71% sensitivity and 94% specificity for detection of ramp lesions.²⁶ High-resolution MRI and appropriate knee position, with thorough assessment at the time of arthroscopy were recommended.

Management

A systematic algorithm for the management of ramp lesions remains difficult to define. Much of this difficulty may be attributed to the diagnostic challenges in identifying these lesions. In a cross-sectional study surveying 36 orthopedic sports medicine fellowship directors, 22% reported that MRI was “rarely” accurate in diagnosing ramp lesions, while 44% indicated that MRI was “often” accurate.²⁷ During arthroscopic examination, these injuries are often overlooked. Sonnery-Cottet et al²⁸ demonstrated that only 23% of ramp lesions were detected using a standard anterior portal, while an additional 17% required probing of the tear through a posteromedial portal. In series of 50 patients with ramp lesions, sequential arthroscopic exploration resulted in 52% of lesions being missed by standard viewing through the anterolateral portal and advancement through the intercondylar notch with a 30 degree arthroscope, with remain lesions found after exchanging for a 70 degree arthroscope (Fig. 2).²⁹ However, no further lesions were found with the addition of a posteromedial portal. As such, when clinical suspicion is high, routine inspection of the posteromedial meniscocapsular junction using a modified Gillquist view and 70 degree arthroscope, with an accessory portal as needed, can help identify otherwise “hidden” lesions.

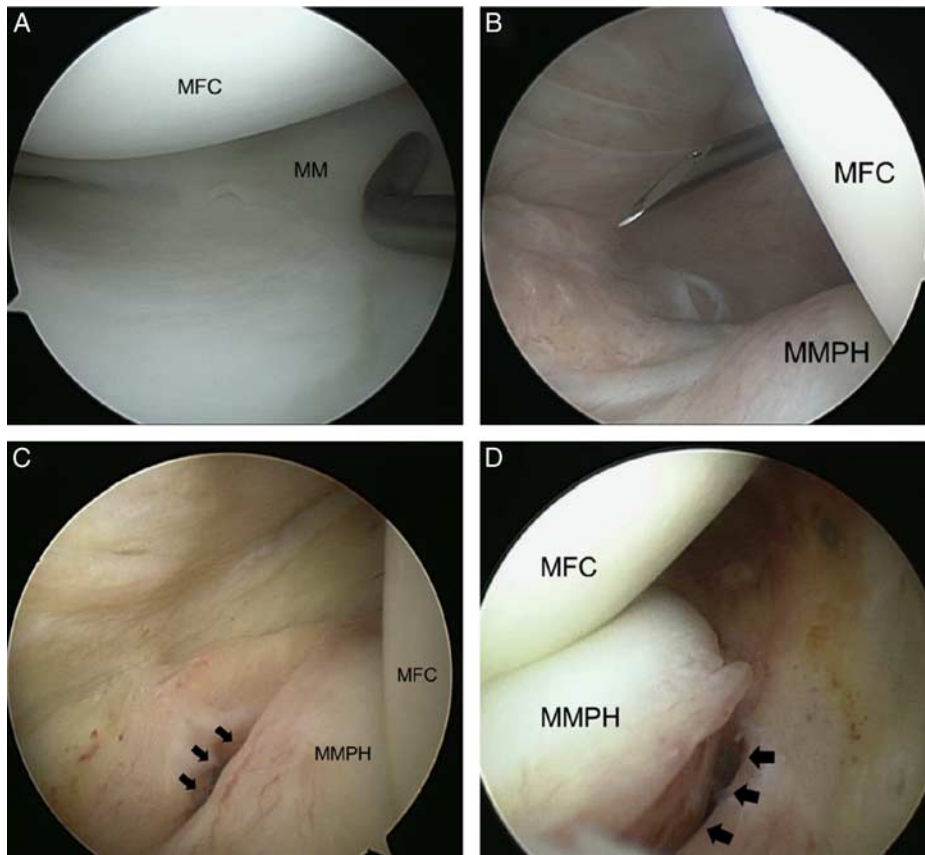


FIGURE 2. A, Arthroscopic finding from the anterolateral portal with valgus position cannot show the meniscocapsular junction area of the posterior horn in the medial meniscus (MM) due to the medial femoral condyle (MFC) in the right knee. B, A 30 degree arthroscope inserted from the anterolateral portal to the posterior compartment did not verify a lesion at the posterior horn of the medial meniscus (MMPH). C, After changing to a 70 degree arthroscope, tears in the posterior horn of the medial meniscus at the meniscocapsular junction were seen. D, Arthroscopic finding from a 30 degree arthroscope inserted from the posteromedial portal to the posterior compartment confirms tears at the meniscocapsular junction (arrows).²⁹ full color online

Localization of meniscal lesions to the red-red, or vascularized zone of the meniscus yields improved healing potential compared with more central regions, and several authors have demonstrated that small, stable tears in this region may heal uneventfully with conservative management.³⁰⁻³² This notion may be particularly true in the setting of an ACL reconstruction, which portends to a favorable healing environment.³³ Conversely, it may be reasoned that a hypermobile meniscus detached at its meniscocapsular interface, especially in the setting of chronic ACL deficiency, has lower healing potential. Long-term evidence evaluating the natural history of ramp lesions remains unavailable.

Operative Techniques and Outcomes

Once the decision to repair a ramp lesion has been made, several arthroscopic techniques may be utilized. The inside-out technique allows for direct visualization of the posterior capsule and saphenous neurovascular bundle, and allows for versatility in suture placement. With the knee flexed at 90 degrees, a 4 cm vertical incision placed one third above and two third below the joint line just posterior to the tibial plateau is made. The sartorius fascia is incised in-line with its fibers and the medial head of gastrocnemius is reflected from the posterior capsule. A retractor is then placed into a triangular interval between the capsule anteriorly, gastrocnemius

posteriorly, and direct arm of the semimembranosus inferiorly to protect the posterior neurovascular structures.³⁴ Cannulas are used to guide meniscal needles. Vertical mattress suture arrangements at both the superior and inferior surfaces of the posterior meniscocapsular junction are recommended. If the medial compartment is tight, a pie crust technique in which an 18-G needle is used to create multiple puncture sites and partially release the medial collateral ligament, may aid in visualization.³⁵ Disadvantages of the inside-out repair include the technically demanding nature of the procedure, and the morbidities associated with an additional incision.

The outside-in technique for repair of posterior meniscal structures utilizes a 5 mm percutaneous incision.³⁶ Sutures are placed through spinal needles and tied over the joint capsule. Morgan and Casscells reported excellent results in 98.6% of patients at 18-month follow-up. The authors stated this technique avoids the risk to posterior neurovascular structures posed by the “blind” exit of meniscal needles encountered during the inside-out technique. However, unlike repair of anteriorly based meniscal tears, a theoretical disadvantage of this technique in the posterior meniscocapsular junction is the inability to achieve a repair configuration tensioned orthogonally to the tear orientation.

All-inside repair techniques of meniscal lesions have gained increasing popularity, given their relative ease,

reduced neurovascular risk compared with the inside-out technique, and advantage of fewer incisions. Negrin et al³⁷ described repair of a ramp lesion by reduction of the capsule of the posteromedial recess to the medial meniscus with an arthroscopic grasper through a posteromedial portal, followed by fixation with an all-inside suture device through the anteromedial portal. Alternatively a suture hook can be used through a posteromedial portal, capturing both capsule and meniscus in a single pass.³⁸ Li et al³⁹ reported 14-month average follow-up in 23 patients with ramp lesions treated with an all-inside technique, and noted an improvement in Lysholm scores from 64.4 ± 4.52 preoperatively to 91.2 ± 4.6 postoperatively.

In general, surgical repair of ramp lesions has been shown to provide a high rate of meniscal healing. In a case series of 132 patients who underwent all-inside repairs using a suture hook device through a posteromedial portal, 9 patients (6.8%) had failure of the repair.³⁸ Mean follow-up was 27 months, and 5/9 failures were resultant of a newly formed tear anterior to the initial tear. The average International Knee Documentation Committee (IKDC) rose from 63.8 preoperatively to 85.7 at final follow-up. Similarly, Gulenc et al⁴⁰ showed a mean increase in Lysholm score from 64.4 to 82.5 in 15 patients who underwent surgical repair of a RAMP lesion. Liu et al⁴¹ suggested that stable ramp lesions, as confirmed by lack of excessive anterior translation of the posterior horn during arthroscopy, may be amenable to abrasion and trephination alone. In their randomized controlled trial of 91 patients, no significant difference in healing was noted on follow-up MRI between stable ramp lesions treated with repair versus abrasion and trephination alone.

ROOT TEARS

Introduction

Meniscal root tears (MRTs) may be characterized as avulsions of the meniscal insertions at the anterior or posterior tibial intercondylar regions. Weaver first described this injury pattern in 1935 based on plain radiographs, in which a meniscal ossicle was visualized.⁴² Following improvements in diagnostic imaging capabilities, isolated soft tissue injury to the meniscal root on MRI was described by Pagnani et al.⁴³ Since then, the functionality of the meniscus root in securing the meniscus to the tibial plateau, and the detrimental biomechanical consequences of their detachment have been well described.^{5,44,45} Increased awareness of MRTs and their unique injury patterns have led to a growing understanding of meniscal roots in the preservation of normal knee kinematics. Recent reports on outcomes following surgical repair of MRTs have demonstrated the importance of meniscal preservation in preventing accelerated degenerative changes within the knee.^{3,46,47} Modern techniques utilize arthroscopic approaches aimed at repairing lesions using suture anchors or transosseous pull-out sutures.

Anatomy

The medial and lateral menisci are semilunar-shaped fibrocartilage structures, anchored to the tibia via their anterior and posterior root attachments.⁴⁸ These attachments allow the menisci to transmit loads through stretching of circumferential collagen bundles, subsequently initiating even distribution of hoop stresses across the joint surfaces.⁴⁹ Knowledge of the anatomic variations of each of the 4

meniscal roots is essential in guiding management of meniscus injuries.

The anterior roots have a planar insertion pattern. The medial meniscus anterior root has the largest cross-sectional area of any root attachments, and inserts in line with the medial tibial eminence, 7 mm anterior to the ACL footprint.³ Berlet and Fowler⁵⁰ described 4 insertion types. Type I inserts on the flat portion of the intercondylar region of the tibial plateau. Type II inserts on the downward slope of the medial articular plateau. Type III inserts on the anterior slope of the medial tibial plateau. Type 4 has no direct attachment to the plateau, and is anchored only by the peripheral coronary ligament. Conversely, the lateral meniscus anterior root is attached to the lateral tibial eminence and to the ACL.⁵¹

In contrast to the anterior root attachments, the medial and lateral posterior meniscal roots have a more complex insertion pattern (Fig. 3). The medial meniscus posterior root is 9.6 mm posterior and 0.7 mm lateral to the medial tibial eminence, 3.5 mm lateral to the medial tibial plateau articular margin, and 8.2 mm anterior to the posterior cruciate ligament (PCL) tibial attachment.⁷ Its insertion is anteromedial to the PCL tibial attachment site.⁵³ Meanwhile, the center of the lateral meniscus posterior root inserts 5.3 mm posteromedial to the lateral tibial eminence, 4.3 mm medial to the lateral articular cartilage edge, 12.7 mm anterior to the PCL tibial attachment, and 10.1 mm posterior to the posteromedial corner of the lateral meniscus anterior root attachment.⁵²

Biomechanics

Significant changes in contact pressure and knee joint kinematics may present following MRTs. In a cadaveric study, Harner et al⁴⁷ demonstrated that a posterior root tear of the medial meniscus causes a 25% increase in peak contact pressures compared with intact menisci. Interestingly, the authors reported that total medial meniscectomy performed in knees with medial meniscus posterior root tears (MMPRTs) did not further increase medial compartment pressures, but did further increase lateral compartment pressures by 13%. Marzo and Gurske-DePerio⁵⁴ reported similar conclusions with regards to medial compartment loading profiles, with an increase in peak contact pressures from 3841 to 5084 kPa following meniscal root avulsion, and a decrease in contact area from 594 to 474 mm². Following root repair with transosseous tunnels, restoration of contact pressures and contact area were restored to native levels. Lateral meniscal root avulsions have also been reported to affect contact profiles. Schillhammer et al⁵⁵ demonstrated in a cadaveric model a significant increase in tibiofemoral contact pressure from 2.8 to 4.2 MPa, with subsequent transtibial tunnel repair of the lesion reducing pressure to 2.9 MPa.

Given the essential role the meniscus root has in maintaining circumferential hoop tension and preventing medial displacement, meniscal extrusion in the setting of a root tear has been an increasingly studied topic. In fact, medial MRTs have been suggested to be the basis for meniscal extrusion. Hein et al⁵⁶ demonstrated increased medial meniscal displacement of 3.28 mm on mechanical loading compared with 1.60 mm in the native knee, with restoration to 1.46 mm upon surgical repair. In a review of MRI studies in 42 patients with posterior root tears (22 medial and 20 lateral), meniscal extrusion was present in 18 medial MRT patients and 1 lateral MRT patient.⁵⁷ The

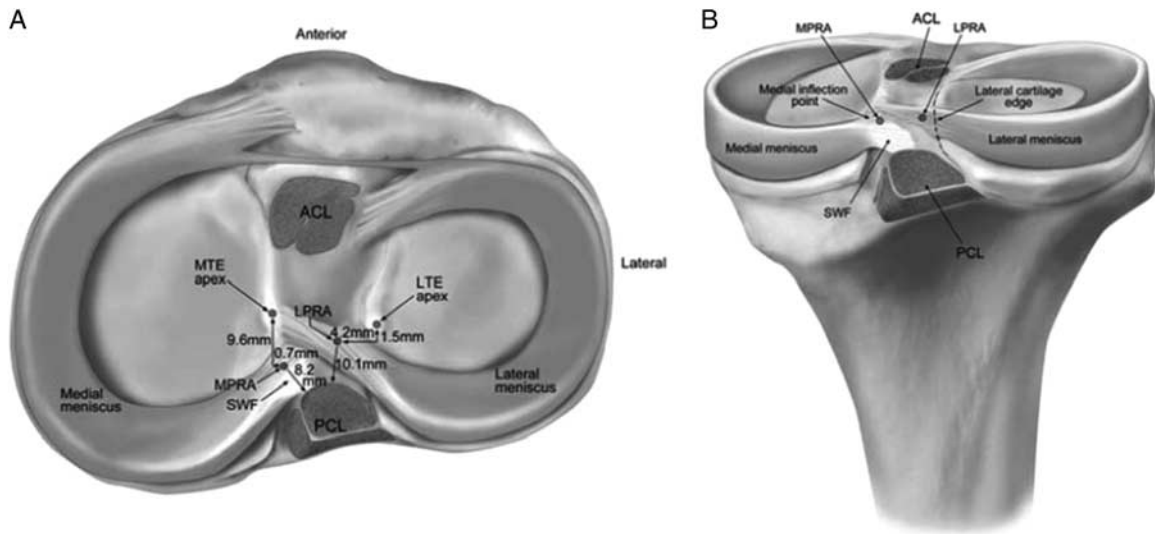


FIGURE 3. Pertinent anatomic relationships as reported by Johannsen et al⁵² images are of the right knee. A, Superior view. B, Posterior view. ACL indicates anterior cruciate ligament bundle attachments; LPR, lateral meniscus posterior root attachment; LPE, lateral tibial eminence; MPRA, medial meniscus posterior root attachment; MTE, medial tibial eminence; PCL, posterior cruciate ligament attachments; SWF, shiny white fibers of posterior horn of medial meniscus.

mean extent of extrusion was 4.2 mm in medial MRT group, and 0.9 mm in the lateral MRT group.

Etiology and Classification

The etiology of MRTs has recently become more defined, with age and history of trauma having been cited as associated risk factors for medial and lateral tears, respectively. Medial root tears are generally more chronic in nature.⁵⁸ In a retrospective review by Koo et al,⁵⁷ patients with medial MRTs were significantly older than patients with lateral MRTs (52 vs. 30 y of age). Furthermore, as the medial meniscus posterior root has the least mobility of all meniscus roots, the resulting increases in stress during axial or radial loading confers the highest incidence of tears in comparison with all other roots.² Several additional intrinsic and extrinsic risk factors for medial MRTs are similar to those which predispose to osteoarthritis, and include female sex, increased body mass index (BMI), greater varus mechanical axis, and lower sports activity level.⁵⁹

Meanwhile, lateral MRTs more frequently occur in conjunction with acute ligamentous injuries, such as in the setting of ACL rupture, where translation and impaction of the posterolateral meniscus on the tibial plateau occurs during a traumatic pivot shift. Another proposed mechanism is acute trauma with the knee in a hyperflexed position, such as squatting.⁶⁰ Brody et al⁶¹ demonstrated a 9.8% incidence of lateral posterior MRTs when an ACL tear was present. A complementary report by De Smet et al⁶² showed an incidence of <1% for lateral root tears in the absence of concomitant ACL tear. Finally, root tears may be cause iatrogenically, as in the disruption of the anterior root and horn of the lateral meniscus during drilling of the tibial tunnel for an ACL reconstruction.⁶³

LaPrade et al⁶⁴ developed a classification system of MRTs based on tear morphology as seen in a consecutive series of arthroscopic cases (Fig. 4). Type 1 tears are partial stable root tears. Type 2 tears involve complete radial tears within 9 mm of the bony root attachment. Type 3 is a bucket-handle tear with complete root detachment. Type 4

is a complex oblique tear extending into the root attachment. Type 5 is a bony avulsion fracture of the root attachment. A more recent study by Kim et al⁶⁵ specifically classified MMPRTs based on the tear gap. Type 1 is an incomplete root tear, while types 2 to 5 are complete root tears (type 2, no gap or overlapped; type 3, gap of 1 to 3 mm; type 4, gap of 4 to 6 mm; type 5, gap of 7 mm). The authors stated the increased utility of their system in predicting the resultant chondral pathology arising from the degenerative injury pattern of MMPRTs.

Diagnosis

The clinical diagnosis of a MRT can be challenging as no single examination finding is specific for the meniscus root. In fact, many of the signs and symptoms associated with meniscal body tears are absent with root tears such as locking, catching, or a positive McMurray test. Patients may report a sudden onset of pain after a minor twisting event or after deep knee flexion such as squatting or rising from a deep-seated position. The most common findings of MRTs include joint line tenderness, pain on deep knee flexion, and recurrent effusions.⁶⁶ MRTs can be classified into 2 broad categories to include traumatic tears and degenerative tears. Traumatic root tears typically occur in the young, active patient, occur on the lateral side, and may be associated with ligamentous injuries. Degenerative root tears usually occur in older patients, occur on the medial side, and are often associated with a low-energy mechanism.⁶⁷ A comprehensive history, physical examination, and orthogonal weight-bearing radiographs should be obtained to assess for potential root pathology and to rule out osseous abnormalities. Full-length, standing radiographs should be considered to evaluate for malalignment. However, MRI is the diagnostic study of choice for MRTs due to the absence of specific findings on history, physical examination, and plain radiographs.⁶⁸ T2-weighted sequence provides the best assessment for root injuries.⁶⁸ MRI findings indicative of a meniscus root injury include the following 4 signs: (1) a radial tear in the root visualized

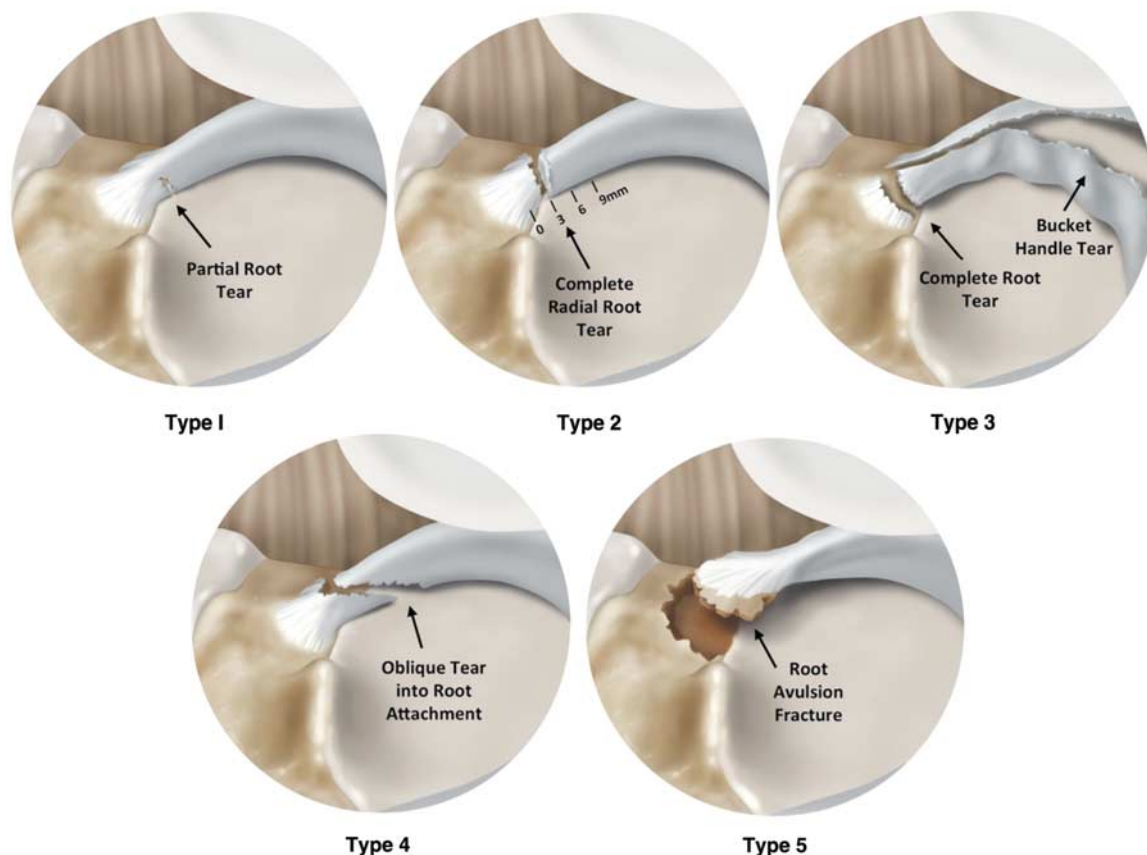


FIGURE 4. Illustrations of the meniscal root tear classification system based on tear morphology (example is of right knee medial meniscal posterior root tear). Type 1, partial stable root tear. Type 2 is a complete radial tear within 9 mm from the bony root attachment. Type 3 is a bucket-handle tear with complete root detachment. Type 4 is a complex oblique or longitudinal tear with complete root detachment. Type 5 is a bony avulsion fracture of the root attachment.⁶⁴ full color online

on axial imaging, (2) a vertical linear defect in the root (truncation sign) on coronal imaging, (3) increased signal in the root (ghost sign) on sagittal imaging, and (4) meniscal extrusion >3 mm outside the tibial plateau on coronal imaging (Fig. 5).⁶⁷ LaPrade et al⁶⁹ determined that MRI had a sensitivity of 77% and specificity of 73% for detecting MRTs. The sensitivity was 82% and specificity was 80% for medial root tears and 60% and 90% respectively for lateral root tears. Other authors have reported higher percentages for detecting root tears on MRI.^{62,70} However, Cinque et al⁷¹ reported that only 33% of root tears were identified preoperatively on MRI by fellowship-trained musculoskeletal radiologists.

Surgical Technique for Arthroscopic Meniscal Root Repair

Two primary techniques are used for meniscus root repair. The end state goal for each technique is to restore the anatomic attachment site of the meniscus root back to bone which converts axial loads from weight-bearing into hoop stresses. Standard arthroscopic portals are created with the knee at 90 degrees. The transtibial pullout technique (authors' preferred technique) uses an ACL tibial drill guide with the guide tip placed at the anatomic root attachment site.⁷² For medial root repairs, it may be helpful to debride part of the medial tibial spine and the lateral aspect of the medial femoral condyle inside the

notch to improve placement and visualization of the tibial guide at the anatomic footprint. For lateral root repairs, it is helpful to place the knee in the figure 4 position to facilitate guide placement and visualization. A retrocutting drill that measures 6 mm when deployed is drilled from the anteromedial tibia and enters the knee at the root attachment site and a 5 to 7 mm deep socket is retro drilled. A #2 passing suture is passed up the tibial tunnel and shuttled out the camera portal in the anterior knee (Fig. 6). Using the portal from the ipsilateral side of the MRT, a self-capturing knee passing device shuttles 2 or 3 0 permanent sutures with a loop on 1 end through the torn meniscal root tissue creating a cinch loop construct (Fig. 7). The suture ends are then shuttled down the tibial tunnel using the #2 passing suture and tied over a button on the anteromedial face of the tibia in 30 degrees of knee flexion (Fig. 8). Other methods of tibial fixation include a screw and washer or a suture anchor type of device. It is often helpful to place a cannula on the side of the root repair to minimize soft tissue bridges. The second technique is performed using a suture anchor through an accessory posteromedial or posterolateral portal which facilitates anchor placement and suture passage near the root attachment.⁷³ Accessory portals should be placed more proximal than usual to create a safe trajectory for anchor placement into the tibia. After anchor placement, a suture lasso can be used to pass the permanent sutures through the torn meniscal root

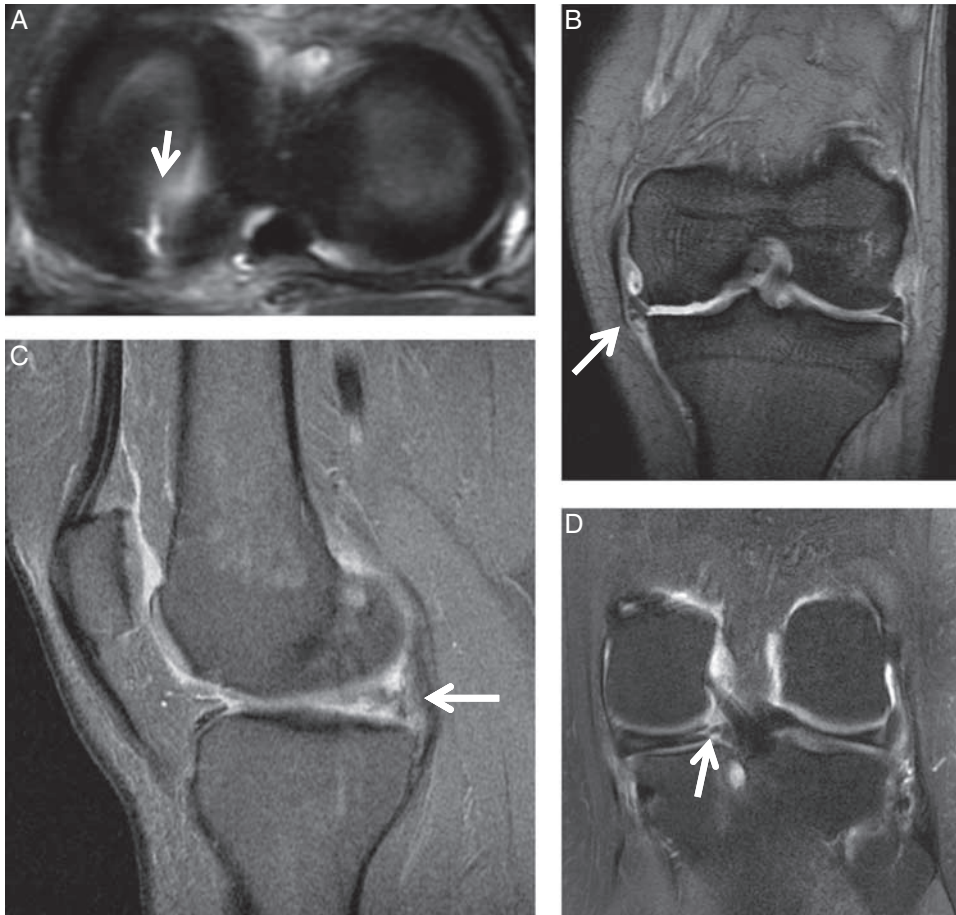


FIGURE 5. Magnetic resonance imaging findings suggestive of meniscus root injury include radial tear in the root (A), meniscal extrusion outside of the tibial plateau (B), increased signal/absent meniscus (ghost sign) (C), and vertical linear defect in the root (truncation sign) (D). Arrows point to described pathology.

tissue from the accessory portal. Alternatively, a rotator cuff-type suture passing device can be used from an anterior portal similar to the first technique described. After

suture passage, an arthroscopic knot is tied in 30 degrees of knee flexion with the knot posterior to avoid damage to the cartilage.



FIGURE 6. Tibial tunnel drilled and #2 passing suture placed up tibial tunnel.



FIGURE 7. Two 0 permanent sutures placed in a cinch loop construct.

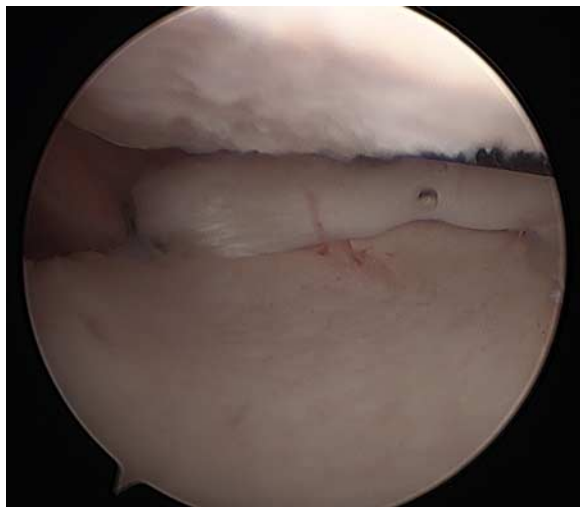


FIGURE 8. Meniscal root reduced and tied in 30 degrees of flexion over a button on anterior tibial cortex. [full color online](#)

Postoperative Rehabilitation

The authors prefer to keep patients toe-touch weight-bearing and 0 to 90 degrees for 6 weeks postoperatively in a brace. After 6 weeks, the brace is discontinued and full weight-bearing and motion are progressively achieved. Loading the knee past 90 degrees of flexion does not begin until at least 4 months after surgery. Most patients are cleared to return to full activities around 6 months postoperatively.

Outcomes

Recent literature on outcomes following meniscal root repair has been supportive of surgical intervention for maintained function and prevention of arthritis. Griffith et al⁷⁴ published a case report on repair of a posterior root avulsion fracture of the medial meniscus in a 16-year-old female, utilizing a transosseous technique with sutures tied over a button. At 3-year follow-up the patient had normal knee function without pain or instability. In a retrospective comparative study of 20 patients who underwent partial meniscectomy versus 37 patients who underwent pullout repair for MMPRTs, repair resulted in better clinical and radiographic outcomes at 5-year follow-up.⁷⁵ Patients who underwent repair had higher increases in Lysholm (32.0 vs. 11.8 points) and IKDC (33.7 vs. 11.3 points) scores, showed less progression in joint space narrowing and Kellgren-Lawrence grade, and had a lower conversion rate to total knee arthroplasty (35% vs. 0%). These findings were confirmed in recent meta-analysis comparing repair versus partial meniscectomy for MMRTs.⁷⁶

While clinical outcomes of MMRTs have generally been favorable, several studies have demonstrated significant rates of incomplete healing.^{73,77,78} Jung and colleagues assessed clinical outcomes in a case series of 13 patients who underwent all-inside repair of MMPRTs at average 30.8-month follow-up. The authors reported improvement of mean Lysholm scores (69.1 preoperatively to 90.3 postoperatively); however, follow-up MRI in 10 patients demonstrated complete healing in only 50% of cases. Lee et al⁷⁷ demonstrated significant improvement in Hospital for Special Surgery and Lysholm scores (61.1 to 93.8 and 57.0 to 93.1, respectively) at 2-year

follow-up in 21 patients who underwent arthroscopic pullout suture repair of MMPRT. However, healing rate on second-look arthroscopy was only 47.6%.

Several risk factors for poor prognosis following MMPRT repair have been reported. In a case series of 51 patients with MMPRTs who underwent the arthroscopic pullout technique, Moon et al⁷⁹ reported Outerbridge grade 3 or 4 chondral lesions and varus alignment of >5 degrees to be independent risk factors of inferior clinical outcomes, as measured by visual analog scale for pain and other validated functional scores. In a comparison of arthroscopic suture anchor versus pullout suture repair techniques for MMPRT, Kim et al⁸⁰ demonstrated no significant differences in gap distance, structural healing, or meniscal extrusion between techniques on 2-year postoperative MRI. However, all patients with incomplete meniscal healing had progression of arthritic changes based on Kellgren-Lawrence grade. In a recent study comparing the postoperative medial meniscus extrusion ratio (MMER) in patients who underwent the pullout technique, significantly higher progression of radiographic osteoarthritis was found in patients with increased MMER versus those with maintained MMER.⁸¹ Repair of the MRT within 13 weeks of symptom onset was suggested to be preventative for progression of meniscal extrusion. Brophy et al⁸² demonstrated an association between BMI > 35 kg/m² and rate of subsequent surgery following repair of MMPRTs (25% vs. 0% in patients with BMI < 35 kg/m², $P=0.049$). In their series, BMI > 35 kg/m² was also associated with a significantly higher incidence of clinical osteoarthritis (75 vs. 28.6%, $P=0.035$).

Outcomes following lateral MRTs remain limited. In a retrospective review of 141 root tears, 30 of which were lateral MRTs, Krych et al⁸³ reported significantly increased IKDC (89.5 vs. 80.4, $P=0.02$) and Tegner scores (6.5 vs. 5.1, $P<0.05$) following repair of LMRTs versus MMRTs. The authors attributed the better outcomes in the LMRT group to patient characteristics, as these injuries occurred in younger male patients with lower BMI, less cartilage degeneration, and less extrusion on MRI than their medial MRT counterparts. Shelbourne et al⁴⁶ matched 33 patients with isolated LMPRTs left in situ with an uninjured control group based on sex, tear chronicity, age, and follow-up period, and found no statistically significant differences in IKDC score at 10-year follow-up. However, joint space narrowing was greater in the study group versus the control group (1.0 ± 1.6 vs. 0 ± 1.1 mm, $P<0.05$). Further research is needed to elucidate outcomes in this patient population.

Summary

Meniscal ramp lesions and MRTs are distinct injury patterns with key differences in etiology and management. While they remain under-recognized entities, their clinical significance must not be underestimated. Biomechanical evidence has demonstrated the importance of the posterior meniscocapsular junction in maintaining translational and rotational stability in ACL-deficient knees, and of the meniscal roots in the maintenance of normal pressure kinematics. While surgical repair of unstable ramp lesions and root tears yields favorable patient-reported outcome measures, incomplete healing and meniscal extrusion following root repair are risk factors for progression of osteoarthritic changes.

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