Meniscal Ramp Lesions: Anatomy, Epidemiology, Diagnosis, and Treatment

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ABSTRACT

Injuries to the medial meniscus meniscocapsular junction, also known as ramp lesions, are common in the setting of anterior cruciate ligament injuries with a prevalence of 9% to 42%. Anatomically, ramp lesions involve disruption of the posterior meniscocapsular junction and meniscotibial ligaments. Biomechanically, ramp lesions are associated with an increase in anterior tibial translation and internal and external tibial rotation in anterior cruciate ligament–deficient cadaveric knees. Magnetic resonance imaging is useful in evaluating the meniscocapsular junction. Irregularity or increased signal near the posterior meniscocapsular junction and/or signal change indicative of posterior medial tibial plateau edema can suggest these injuries are present before surgical intervention. The current benchmark for diagnosis is arthroscopic visualization of the posterior medial meniscocapsular junction viewed through the intercondylar notch. Once a ramp lesion is identified, stability should be assessed by arthroscopic probing to determine the degree of anterior displacement. Optimal treatment has been debated in the literature, especially for stable ramp lesions, although good outcomes have been shown with and without repair. Repair is warranted for those lesions that are unstable to probing. Unfortunately, only limited literature available to guide clinicians on the optimal rehabilitation for ramp lesions.

Meniscal tears are common in the setting of anterior cruciate ligament (ACL) tears, with a prevalence as high as 55% to 65%. Meniscal ramp lesions were initially described as a type of meniscal injury involving the peripheral meniscosynovial attachment of the posterior horn of the medial meniscus seen in conjunction with an ACL tear. Strobel et al coined the term ramp lesion to distinguish this injury from other types of posterior longitudinal meniscal tears because ramp lesions occur at the posterior periphery of the meniscal ramp on a sagittal MRI. More recently, in addition to the peripheral meniscocapsular junction, disruption of the meniscotibial ligaments is also noted. Injuries to this area are biomechanically relevant because they increase not only anterior tibial translation but also internal and external tibial rotation in ACL-deficient cadaveric knees.
Ramp lesions were previously underrecognized in the setting of an ACL injury because of difficulty interpreting the injuries on preoperative MRI and an inability to visualize the posteromedial compartment of the knee from the standard anterior viewing portals. Despite these challenges, they are present in 9% to 42% of patients who undergo an ACL reconstruction. Therefore, surgeons who treat ACL tears will likely encounter ramp lesions. Although abundance of preclinical information regarding the anatomy and biomechanics of ramp lesions is available, information to guide the surgeon on the optimal approach to treatment of these lesions is limited. The purpose of this review is to summarize the latest evidence on the relevant anatomy, biomechanical consequences, classification, prevalence, physical examination findings, imaging characteristics, arthroscopic diagnosis, treatment consideration, rehabilitation, and clinical outcomes of ramp lesions.

**Relevant Anatomy**

**Gross Anatomy**
The medial meniscus is a wedge-shaped semilunar structure that is fibrocartilaginous in nature with circumferential collagen fibers held together by radial tie fibers. It covers approximately 51% to 74% of the medial tibial plateau surface and is markedly wider near the posterior horn and root than the anterior horn and root. The medial meniscus is anchored to the tibial plateau primarily by the anterior and posterior roots. It is further secured by the meniscotibial ligaments and peripheral meniscocapsular ligaments. The posterior meniscocapsular attachment is inferior to the margin of the posterior medial meniscus and has a mean length of 20.2 ± 6.0 mm, which is essentially the entire length of the posterior horn of the medial meniscus (21.3 ± 2.0 mm). The posterior meniscotibial ligament attaches to the inferior aspect of the posterior horn of the medial meniscus and shares a common attachment on the meniscus with the meniscocapsular ligament. The tibial attachment of the posterior meniscotibial ligament is 5.9 ± 1.3 mm inferior to the articular cartilage of the posterior medial tibial plateau and courses obliquely to insert onto the inferior aspect of the medial meniscus, approximately 7.7 mm medial and 16.5 mm posterior to the center of the posterior medial meniscal root. These attachments are important for normal knee kinematics and are the reason the medial meniscus is less mobile when compared with the lateral meniscus. In addition, the reduced mobility allows the medial meniscus to function as a secondary stabilizer to anterior tibial translation in the setting of ACL deficiency. However, the medial meniscus is susceptible to injury in the ACL-deficient state due to increased anterior tibial translation, which increases both shear and compressive forces at the posterior horn of the medial meniscus.

**Vascular Anatomy**
The vascular anatomy of the menisci has been well described with the peripheral 10% to 20% of the menisci receiving a richer blood supply from the medial, lateral, and middle geniculate arteries. The inner 80% of the meniscus is considered avascular. This vascular asymmetry has led to the peripheral aspect of the menisci referred to as the red–red zone with vascularity on both sides of a tear in this location. The inner avascular area is referred to as the white–white zone in which there is no blood supply on either side of a tear. The region between these two areas is known as the red–white zone. Therefore, ramp lesions occur in a well-vascularized region, which theoretically increases the potential for healing. Given the richer blood supply, the more peripheral aspect of the medial meniscus theoretically has a higher likelihood of healing after meniscal repair.

**Biomechanical Consequences of Ramp Lesions**
Ramp lesions are believed to be caused by a combined valgus strain, internal tibial rotation, and axial load at the time of an ACL rupture with the pathologic forces transmitted to the posteromedial capsule. Classically, ramp lesions were believed to involve only disruption of the peripheral meniscocapsular attachments at the area of the posterior horn of the medial meniscus; however, more recent literature has shown that injury to the meniscotibial ligaments may also be present in addition to the meniscocapsular attachment. Sectioning of the meniscocapsular and meniscotibial attachments in ACL-intact and ACL-deficient cadaveric knees increases anterior tibial translation. In addition to sagittal laxity, ramp lesions are associated with both internal and external rotational laxity in ACL-deficient knees. Several studies have evaluated the effect of ramp lesions on both the native ACL and the ACL reconstruction graft. Stephen et al found...
that anterior tibial translation improved after isolated ACL reconstruction; whereas, internal/external rotational laxity and the pivot shift were improved only after repair of the meniscocapsular and meniscotibial lesions.\textsuperscript{3} The intact ACL experiences markedly increased strain at 30° and 90° of flexion in the setting of posteromedial meniscocapsular separation.\textsuperscript{5} Collectively, the biomechanical studies suggest that failure to recognize and treat ramp lesions could lead to both sagittal and rotary laxity, which could compromise the graft after ACL reconstruction.

**Classification of Ramp Lesions**

A classification system for ramp lesions was proposed by Thaunat et al.\textsuperscript{14} This system describes five types of injury to the posterior meniscocapsular region. Type 1 meniscocapsular tears are very peripheral and are located in the synovial sheath. Type 2 tears are partial superior surface lesions and are considered stable with intact meniscotibial ligaments. Type 3 tears are partial inferior surface tears and can be difficult to visualize but are suspected if there is notable mobility to meniscal probing due to disruption of the meniscotibial ligaments. Type 4 tears are complete longitudinal tears in the red–red zone, resulting in disruption of the meniscotibial ligaments. Type 5 tears involve a double longitudinal tear of the red–red zone with associated meniscotibial disruption.\textsuperscript{14}

**Prevalence of Ramp Lesions**

Given that ACL deficiency causes increased compressive and shear stress on the posterior aspect of the medial meniscus, ramp lesions are often associated with injury to the ACL. However, small meniscocapsular separations in the setting of an intact ACL have been described as a cause for chronic medial-sided knee pain.\textsuperscript{15} Recent studies have shown a variable prevalence of ramp lesions diagnosed at the time of ACL reconstruction, with a range of 9% to 42% reported in the literature.\textsuperscript{7,9} It must be considered how these lesions are identified (ie, MRI vs. arthroscopy) because many tears are only seen by specifically viewing the posteromedial compartment with a 70° arthroscope through the intercondylar notch. Viewing the medial meniscus through the standard anterior viewing portals will often fail to identify a ramp lesion given its far peripheral location. Mansori et al\textsuperscript{16} evaluated a series of patients with ACL injuries and found that ramp lesions were the third most common type of tear of the medial meniscus behind vertical tears and bucket handle tears.

Several risk factors are associated with the creation of a ramp lesion in the setting of a complete ACL rupture. A longer interval between injury and ACL reconstruction increases the risk of a ramp lesion.\textsuperscript{8,9} Male sex and age less than 30 years are noted as risk factors.\textsuperscript{8,9} Injury characteristics that are associated with a ramp lesion include a concomitant lateral meniscus tear, a contact injury mechanism, greater side-to-side ACL laxity, and revision ACL reconstruction.\textsuperscript{7,9} Anatomic risk factors for ramp lesions include varus knee alignment greater than 3° of flexion, medial tibial slope greater than 7.1° of flexion, medial meniscal slope greater than 3.2° of flexion\textsuperscript{17} to 5° of flexion,\textsuperscript{18} and a gradual lateral tibial slope.\textsuperscript{17,18}

**Physical Examination**

No studies to date have evaluated the sensitivity and specificity of the physical examination findings relevant to ramp lesions. Physical examination maneuvers that focus on the meniscus, such as tenderness to palpation at the posteromedial joint line, the McMurray test, and Thessaly test may also be positive but their sensitivity and specificity for ramp lesions has not been evaluated by high-quality studies.\textsuperscript{19} Patients with an ACL tear have a higher grade pivot shift in the setting of a ramp lesion.\textsuperscript{20} The degree of anterior tibial translation as measured with the Lachman and anterior drawer tests does not correlate with the presence of a ramp lesion.\textsuperscript{20}

**Imaging**

Although MRI has a relatively high sensitivity (89% to 93%) and specificity (81% to 88%) in diagnosing medial meniscal tears, ramp lesions are more difficult to be diagnosed by MRI.\textsuperscript{21} In a recent meta-analysis of nine studies, MRI had a sensitivity of 71% and a specificity of 94% for diagnosing ramp lesions.\textsuperscript{21} Sensitivity of identifying ramp lesions increased to 84% when the following factors were present: (1) a neutrally rotated knee positioned in 30° of flexion, (2) use of a 3.0-Tesla magnet, and (3) interpretation by a musculoskeletal radiologist.\textsuperscript{21} Several findings on MRI that are associated with ramp lesions include the following: (1) longitudinal mediolateral vertical and/or oblique high T2 fluid signal intensity between the red–red zone of the posterior horn of the medial meniscus and posteromedial capsule either
reaching the superior, inferior, or both articular surfaces, (2) irregularity along the posterior margin of the medial meniscus, leading to focal discontinuity or a step-like contour deformity at the posterior horn peripherally involving the meniscocapsular attachments, and (3) perimeniscal fluid signal intensity within the posteromedial corner.22

In a retrospective study, Nguyen et al evaluated 85 children who underwent ACL reconstruction, of which 35 were found to have a ramp lesion intraoperatively. Patients with a ramp lesion were markedly more likely to have MRI findings of peripheral meniscal irregularity, a junctional T2-weighted signal, a capsular ligament tear, and a medial meniscus tear.23 In an attempt to improve diagnostic criteria by correlating radiologic findings with arthroscopic diagnosis, Greenaway et al24 showed that diffuse increased signal near the posteromedial meniscocapsular junction in addition to a full-thickness, linear fluid-signal cleft was the most accurate criteria for diagnosing ramp lesions. In general, if a ramp lesion is present on MRI, the ACL is typically ruptured, while an intact ACL suggests the absence of a ramp lesion.22

Other more subtle MRI findings are also associated with ramp lesions. Patients with edema at the posteromedial tibial plateau have a 2.1 times greater odds of having a ramp lesion compared with those with a meniscal body tear.25 Posteromedial bone bruising is present in 72% of patients with a ramp lesion26 (Figure 1). The uncovered medial meniscus sign on MRI described by Kim et al27 is positive if a vertical line drawn tangent to the posterior aspect of the medial tibial plateau intersects any portion of the meniscus with the knee positioned in 0° to 10° of flexion.

Arthroscopic Diagnosis

Although MRI may suggest the presence of a ramp lesion, the current benchmark for diagnosis is arthroscopy. Given the high prevalence of these injuries in the setting of an ACL tear, the operating surgeon must have a high index of suspicion intraoperatively. During standard diagnostic arthroscopy, a probe may be used through the anteromedial portal to identify a tear and assess whether the tear is unstable into the joint. To visualize these injuries with the arthroscope, the surgeon must have an adequate view of the posteromedial aspect of the meniscus near the meniscocapsular junction. Several studies have identified that visualization of these injuries during standard diagnostic arthroscopy with a 30° arthroscope from the anterolateral portal without visualization through the intercondylar notch (modified Gillquist view) is difficult.28,29 Both 30° and 70° arthoscopes can be used while viewing through the intercondylar notch, although our preference is to use a 70° arthroscope because of the superior view it provides of the entire posterior horn (Figures 2 and 3, A). Some authors have suggested the use of an accessory posteromedial portal to directly view these injuries.28 One study showed that of the 50 meniscal ramp lesions diagnosed at arthroscopy, 29 (58%) were diagnosed with the arthroscope in the anterolateral portal positioned through the intercondylar notch between the posterior cruciate ligament and medial femoral condyle. Twenty-one (42%) were diagnosed after creating a
posteromedial portal to probe and detect the ramp lesion.\textsuperscript{28} Use of a 70° arthroscope while viewing posteromedially through the intercondylar notch improved the accuracy of diagnosing ramp lesions when compared with the use of a 30° arthroscope and negated the need for a posteromedial viewing portal for diagnosis.\textsuperscript{29}

**Treatment Considerations**

A variety of treatment options for ramp lesions has been described, including repair, stimulation of local biology without repair, and no treatment. In choosing repair over conservative (nonsurgical) management, the surgeon must take several factors into consideration including the length of the tear, depth of the tear (ie, full-thickness versus partial-thickness), and stability to probing. There is little evidence regarding the indications for the different approaches to treat ramp lesions. Questions to consider when contemplating various treatment options include what depth or length of tear is considered clinically relevant and how meniscal instability is defined as it relates to ramp lesion repair? Despite these limitations, meniscal excision has no role because these tears occur at the periphery of the meniscus, which means that essentially the entire posterior horn would be removed with excision.

From a surgical standpoint, options that currently exist include simple abrasion and trephination of the tear to cause local bleeding to stimulate a fibrovascular healing response versus stabilization with sutures or anchors as is done for other reparable meniscal tears. The most common repair techniques are inside-out and all-inside methods.\textsuperscript{30-33} Inside-out fixation can be technically more demanding, requiring a surgical assistant and a second 2- to 3-cm incision to capture the suture needles and tie the sutures. This method is also associated with a higher risk to the neurovascular structures (ie, saphenous nerve) around the knee that can be pierced or tethered by the needles and sutures. Despite these drawbacks, the inside-out technique provides the strongest repair construct by allowing the placement of multiple vertically oriented high-strength diverting sutures that are tied over the peripheral meniscal rim and capsule.\textsuperscript{33} Use of vertically oriented sutures allows capture of the longitudinally oriented collagen fibers on both the superior and inferior meniscal surfaces, which enhances fixation strength. An inside-out repair is impossible because a ramp tear may be difficult to visualize from the anterior viewing portals. Fenestration or pie-crusting of the deep medial collateral ligament may allow improved visualization of these peripheral ramp tears.

All-inside repair involves use of sutures or suture anchors to repair the tear without passage of the repair sutures outside of the knee. All-inside repair is commonly done for standard reparable meniscal tears, and it offers several advantages over inside-out repairs. In general, it is technically easier to perform, does not require a surgical assistant, involves less neurovascular risk, and requires no additional incisions. They are also more expensive compared with inside-out sutures, may displace resulting in a loose body or cause articular cartilage damage from misplaced anchors. All-inside suture repair has been described from the anteromedial, posteromedial, and transeptal portals with use of a curved suture passer and all-inside suture devices\textsuperscript{34} (Figures 2, B, 3, B and C).
Suture placement through a posteromedial portal while viewing through the intercondylar notch with a 70° arthroscope can be accomplished analogous to a labral or rotator cuff repair in the shoulder. Use of 45° or 60° right and left suture passing devices can be used to pass a monofilament shuttle suture across the tear. The 2-0 nonabsorbable high-strength sutures are shuttled across the tear and tied arthroscopically. One or more sutures can be placed in this manner depending on the length of the tear. We are unaware of any reports of articular cartilage damage from the suture knot stack resulting from this type of repair.

A recent questionnaire-based study of the American Orthopaedic Society for Sports Medicine fellowship program directors showed that the extent of the tear (partial-thickness or full-thickness) and degree of instability on probing were the main determining factors whether to repair a ramp lesion. Other factors that were considered to a lesser extent included the size of the tear (> 2.5 cm) and/or involvement of the meniscotibial ligaments. This same study evaluated the most common techniques used by surgeons and showed that most surgeons (67%) who responded used all-inside meniscal repair methods. This study exemplifies the limitations of the current literature on the treatment of ramp lesions in that the recommendations for or against repair were based more on expert opinion (Level V evidence) rather than on higher quality evidence-based clinical trials. Future prospective randomized trials and other more robust clinical studies are needed to assist surgeons in deciding which ramp lesions require repair and the optimal method to repair them.

Rehabilitation

Currently, no studies have compared outcomes after different rehabilitation protocols after ramp lesion repair. The rehabilitation protocol will often be dictated by the concomitant procedures done and is dependent on surgeon bias and experience. One study of Sports Medicine fellowship program directors found that the most common postoperative rehabilitation protocol after ramp lesion repair in conjunction with an ACL reconstruction was to allow weight-bearing as tolerated with use of crutches for 2 to 4 weeks with eventual return to full activity at 7 to 8 months postoperatively. Sonnery-Cottet et al recommended limiting flexion to 90° for the first 6 weeks after ramp lesion repair in the setting of an ACL reconstruction because, as they note, hyperflexion of the knee results in anterior tibial translation, which may put a tensile strain on the repair site. Therefore, existing limited information suggests that the rehabilitation protocol after the repair of a ramp lesion is analogous to that of a standard meniscal repair regarding initial restrictions on weight-bearing and knee motion. Timing of return to full activity is based more on the concurrent procedures such as an ACL reconstruction or articular cartilage repair/restoration. Again, these opinions are based essentially on expert opinion rather than on prospective or retrospective case series or clinical trials. Further research in this area is warranted to make more informed decisions regarding the postoperative rehabilitation after a ramp lesion repair.

Clinical Outcomes

The literature regarding the clinical outcomes after a ramp lesion repair is somewhat limited. Three studies have evaluated outcomes after conservative treatment of stable ramp lesions in the setting of an ACL reconstruction. Balazs et al retrospectively evaluated no treatment of 32 patients who underwent ACL reconstruction with stable ramp lesions and showed no difference regarding clinical outcome or revision surgery rates when compared with those without meniscal pathology with a median 2-year follow-up. A randomized prospective trial of 73 patients with a concurrent ACL reconstruction compared stable ramp lesions treated with either an all-inside repair or meniscal abrasion/trephination. Both groups showed improved outcomes with no differences in subjective or objective outcome measures and no evidence of knee instability based on Lachman, pivot shift, and KT-1000 tests. A retrospective review evaluated 68 patients with a stable ramp lesion in the setting of an ACL reconstruction who were treated with either an all-inside repair or arthroscopic refreshing of the meniscal injury. These authors found that both groups had improved clinical outcomes from their preoperative status with no difference in clinical outcomes between groups at the 2-year follow-up. The most important factor used to determine stability in these studies was no excessive anterior translation of the posterior horn on probing. Unfortunately, the degree of meniscal translation may be difficult to quantify and is therefore dependent on a subjective determination of excessive translation.

Several studies have evaluated repair of meniscal ramp lesions. A systematic review of eight studies evaluated 835 patients after surgical repair of a meniscal ramp lesion in the setting of an ACL reconstruction. These
studies used both all-inside suture repair and all-inside meniscal anchors. This review found markedly improved postoperative outcome scores regardless of the repair technique. Five of the eight included studies were case series. Unfortunately, it is difficult to know the degree to which the ramp lesion repair affected the clinical outcome. DePhillipo et al retrospectively compared 50 patients who underwent inside-out repair of unstable ramp lesions in the setting of an ACL reconstruction with a cohort of 50 patients who underwent an isolated ACL reconstruction. Stability was determined by probing of the meniscus and the extent of the lesion (partial-thickness versus full-thickness). No difference was found in patient-reported outcomes, knee stability as evaluated by the Lachman and pivot shift tests, return to sport, or complications/failures between the groups at a minimum of 2-year follow-up.

Determination of the healing rates of ramp lesions based on MRI showed conflicting results. In a randomized, prospective trial comparing all-inside suture repair of ramp lesions with meniscal abrasion/trephination, postoperative MRI showed no significant difference in ramp lesion healing rates between the two groups at a minimum of 2-year follow-up. Hatayama et al found that healing rates of ramp lesions based on MRI were significantly higher in patients who underwent repair with an all-inside meniscal anchor for stable and unstable tears (100%) versus no treatment of only stable tears (60%) in the setting of an ACL reconstruction. In addition, they noted that the patients with nonhealed ramp lesions had significantly greater anterior laxity (3.2 ± 1.1 mm) than those with healed ramp lesions (1.9 ± 1.6 mm) based on stress radiography.

Summary

Meniscal ramp lesions are common injuries in the setting of an ACL tear with an incidence of 9% to 42% in ACL-injured patients. Therefore, surgeons should have a high index of suspicion for these meniscal tears. MRI findings (ie, increased signal near the posterior meniscocapsular junction and/or posterior medial tibial plateau edema) can diagnose ramp lesions with relatively high sensitivity and specificity in the setting of an ACL injury before surgical intervention. The diagnosis should be confirmed intraoperatively with arthroscopic probing and/or visualization of the posteromedial compartment with a 70° arthroscope through the intercondylar notch in all patients. The size, character, and stability of the lesion must be carefully assessed, although recommendations for treatment based on these parameters are limited. If the meniscus is unstable, either an inside-out or all-inside repair should be considered. Abrasion and trephination or no treatment can be considered for stable ramp lesions. Despite the absence of high-quality evidence-based recommendations, repair of stable and unstable ramp lesions is associated with good clinical outcomes irrespective of the degree of instability. Further high-level prospective studies assessing the diagnosis, treatment, and rehabilitation of patients with ramp lesions are necessary to optimize management of these injuries.

References

References printed in bold type are those published within the past 5 years.

Meniscal Ramp Lesions


