# MRI-Based Prediction of Traumatic Meniscal Tear Reparability: Imaging Biomarkers, Scoring Systems, and Diagnostic Challenges

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***Abstract***

**Background:** Magnetic resonance imaging (MRI) is the principal noninvasive technique for identifying meniscal tears, yet its clinical value extends beyond confirming their presence. Preservation of viable meniscal tissue is increasingly preferred because repair maintains load transmission, joint stability, and chondroprotection more effectively than partial meniscectomy. Preoperative prediction of reparability remains difficult because the surgical decision depends on several interacting variables, including tear morphology, location, vascularity, tissue quality, displacement, chronicity, and associated ligamentous injury.

**Aim:** This review examines MRI biomarkers associated with traumatic meniscal tear reparability, evaluates available predictive scoring systems, and discusses the principal diagnostic limitations affecting agreement between preoperative imaging and arthroscopic findings.

**Main findings:** MRI features favoring repair include a peripheral tear within the vascularized meniscal zone, vertical longitudinal orientation, adequate residual tissue, limited degeneration, and concomitant anterior cruciate ligament reconstruction. Conversely, complex configuration, marked extrusion, maceration, substantial tissue loss, chronic displacement, and advanced chondral degeneration generally reduce repair potential. Tear length, distance from the meniscocapsular junction, rim width, meniscal side and segment, and the presence of displaced fragments require systematic assessment. The Prediction of Reparability of Meniscal Tears score combines selected clinical and MRI variables, while its modified version incorporates additional factors intended to improve preoperative discrimination. Nevertheless, differences in MRI technique, observer experience, tear classification, and arthroscopic judgment limit reproducibility. Ramp, root, radial, flap, and displaced bucket-handle tears remain important sources of diagnostic error.

**Conclusion:** MRI can support surgical planning by moving meniscal assessment from simple tear detection toward structured estimation of reparability. Standardized reporting, validated scoring models, and prospective multicenter evaluation are required before MRI-based predictions can replace individualized arthroscopic judgment.

**Keywords:** magnetic resonance imaging, meniscal tear, meniscal repair, PROMT score

## Introduction

Meniscal tears are among the most frequently encountered traumatic abnormalities on knee MRI, particularly in young and physically active individuals. The menisci contribute substantially to load distribution, shock absorption, joint stability, lubrication, and articular cartilage protection. Loss of functional meniscal tissue increases focal tibiofemoral contact stress and may accelerate cartilage deterioration, supporting the current preference for meniscal preservation whenever stable repair can be achieved. The 2019 European Society of Sports Traumatology, Knee Surgery and Arthroscopy consensus consequently recommended repair as the first-line surgical strategy for traumatic tears with reasonable healing potential, including several patterns previously regarded as unsuitable for preservation. [1]

MRI is well established for detecting meniscal injury and characterizing tear location, orientation, extent, displacement, and associated ligamentous or chondral abnormalities. Its preoperative role, however, is often confined to answering whether a tear is present. The more clinically useful question is whether the abnormality is technically repairable and biologically capable of healing. This distinction influences patient counseling, operative scheduling, implant preparation, rehabilitation planning, and the anticipated need for meniscectomy. Arthroscopy remains the reference standard because the surgeon can directly examine tissue quality, mobility, vascular response, fragment integrity, and the ability to obtain stable reduction. [2]

Reparability is not determined by one MRI sign. Peripheral vertical longitudinal tears generally have greater healing potential because of their proximity to the vascular meniscocapsular junction. Conversely, complex morphology, maceration, substantial tissue loss, degenerative signal, advanced extrusion, and poor-quality displaced fragments may limit successful fixation. Tear length, depth, rim width, meniscal segment, chronicity, patient age, and concomitant anterior cruciate ligament injury also modify the operative decision. Even high-resolution 3-T MRI has demonstrated limited reliability when readers attempt to reproduce arthroscopic repair criteria, partly because static images cannot fully represent tissue mobility and mechanical stability. [3]

Several predictive approaches have attempted to convert these variables into reproducible preoperative estimates. Kumaraswamy et al. introduced the Prediction of Reparability of Meniscal Tears (PROMT) score by combining clinically relevant and MRI-derived features associated with arthroscopic repair. [4] Sundar et al. subsequently proposed a Modified PROMT score intended to improve discrimination by refining the variables contributing to reparability assessment. [5] Nevertheless, external evidence remains inconsistent. Recent reader studies reported only modest accuracy and poor-to-moderate interobserver agreement, demonstrating that MRI-based prediction remains dependent on tear classification, image quality, reader experience, and the surgeon's intraoperative threshold for repair. [6]

Accordingly, the main research gap is the absence of a widely validated, reproducible MRI framework that predicts meniscal reparability across readers, institutions, and tear patterns. This review examines the imaging biomarkers associated with repair potential, evaluates existing scoring systems, and explores the diagnostic challenges that limit concordance between preoperative MRI and arthroscopic decision-making.

## Meniscal Structure and Biological Basis of Repair

The medial and lateral menisci are crescent-shaped fibrocartilaginous structures positioned between the femoral condyles and tibial plateaus. Their peripheral borders are thicker and attached to the joint capsule, while their free inner margins are thin and mobile. Circumferential collagen bundles convert axial loading into hoop stress, whereas radial tie fibers resist longitudinal splitting and maintain structural integrity. Preservation of these fibers is essential because disruption extending across the full meniscal width can abolish hoop-stress transmission even when a large amount of tissue remains visually present. [7]

The medial meniscus is relatively fixed because of its broad capsular attachment and relationship to the deep medial collateral ligament. It therefore moves less during knee flexion and is more susceptible to traumatic injury during rotation. The lateral meniscus is more mobile and has an interrupted capsular attachment at the popliteal hiatus. Its posterior horn is stabilized by the popliteomeniscal fascicles and meniscofemoral ligaments, structures that may be difficult to assess on routine MRI but are clinically important when lateral meniscal instability is suspected. [7]

Meniscal vascularity is concentrated at the peripheral capsular margin. In adults, the outer vascular region is commonly described as the red-red zone, the transitional region as the red-white zone, and the central avascular portion as the white-white zone. These divisions are useful but represent a continuum rather than sharply separated compartments. Vascular penetration decreases with age, and regional variation means that a tear assigned to the same conventional zone may not have identical biological healing potential in different patients. [8]

Peripheral vascularity favors fibrin clot formation, cellular migration, and repair tissue development. Central tears have a less favorable biological environment, although modern suturing techniques and biological augmentation have expanded repair indications beyond the traditional red-red zone. The radiologist should therefore avoid labeling a tear irreparable solely because it extends centrally. A more useful report describes the peripheral attachment, viable residual tissue, orientation, extent, and associated factors that may influence healing. [1]

Repairability contains two related but distinct concepts. Technical reparability refers to whether the tear can be reduced and securely fixed without leaving nonfunctional tissue. Biological reparability refers to the probability of healing after fixation. MRI may estimate both, but it cannot directly reproduce arthroscopic probing, tissue handling, or observation of peripheral bleeding. This distinction explains why some tears with favorable imaging morphology are excised intraoperatively, while other complex-appearing tears are successfully repaired by experienced meniscal surgeons. [6]

## MRI Technique for Reparability Assessment

### Field strength and coil selection

High-quality knee MRI requires a dedicated multichannel extremity coil, a small field of view, thin sections, and appropriate spatial resolution. Both 1.5-T and 3-T systems can identify meniscal tears effectively when protocols are optimized. Although 3-T imaging provides a higher signal-to-noise ratio and permits thinner sections or higher in-plane resolution, increased field strength does not automatically improve prediction of reparability. Reader interpretation and the ability to translate MRI morphology into surgical feasibility remain major limiting factors. [3]

Van Dyck et al. found that 3-T MRI did not uniformly outperform 1.5-T imaging for meniscal and anterior cruciate ligament lesions. Image quality, sequence selection, artifacts, and reader experience may therefore be more important than field strength alone. A technically inadequate 3-T examination should not be expected to surpass a well-performed 1.5-T study. [9]

### Pulse sequences and imaging planes

A comprehensive protocol usually includes sagittal, coronal, and axial proton-density or intermediate-weighted sequences, with fat suppression applied in at least two planes. Non-fat-suppressed proton-density or T1-weighted imaging provides anatomical contrast, while fluid-sensitive sequences demonstrate tear signal, marrow edema, ligament injury, and parameniscal fluid. Axial images are particularly useful for radial tears, displaced fragments, popliteomeniscal abnormalities, and the relationship between the meniscus and capsule. [10]

Sagittal images optimally depict the anterior and posterior horns, displaced bucket-handle fragments, root abnormalities, and longitudinal tears. Coronal imaging clarifies meniscal body tears, extrusion, radial defects, peripheral location, and meniscocapsular separation. Tear characterization should be confirmed in more than one plane whenever possible because partial-volume averaging and normal vascular or ligamentous structures can mimic linear meniscal signal. [10]

Three-dimensional isotropic imaging permits multiplanar reformation along the tear plane and may improve assessment of complex morphology. However, its practical value depends on acquisition time, image contrast, motion, and reconstruction quality. Studies correlating three-dimensional MRI with the

International Society of Arthroscopy, Knee Surgery and Orthopaedic Sports Medicine classification have demonstrated moderate agreement and systematic differences in tear-length estimation compared with arthroscopy. [11]

### Reporting strategy

A conventional report that states only "medial meniscal tear" provides insufficient information for repair planning. The radiologist should identify the involved meniscus and segment, tear orientation, approximate length, depth, peripheral rim width, displacement, extrusion, tissue loss, root involvement, meniscocapsular extension, chondral status, and associated ligamentous injuries. Uncertainty should be communicated explicitly rather than concealed in nonspecific terminology.

The report should distinguish between tear detection and inferred reparability. Phrases such as "morphology potentially favorable for repair" are more defensible than a categorical statement that a tear is repairable. Arthroscopic inspection remains necessary because MRI cannot consistently determine tissue strength, mobility, reducibility, or the quality of the residual fragment. [6]

## MRI Biomarkers of Reparability

### Tear location and vascular zone

Location relative to the peripheral meniscocapsular junction is one of the most important imaging biomarkers. Tears close to the capsule are more likely to communicate with the vascularized meniscal periphery and have traditionally been considered better repair candidates. Matava et al. evaluated MRI as a method of predicting reparability and emphasized tear location, morphology, and peripheral extension, although agreement with arthroscopic treatment remained imperfect. [2]

Distance from the meniscocapsular junction should be measured at the portion of the tear farthest from the vascular periphery rather than at a single convenient image. Curved meniscal geometry and oblique tear orientation can make the apparent rim width vary across planes. A tear may also extend through more than one vascular zone, making assignment to a single category misleading.

Peripheral location alone does not guarantee repair. Chronic peripheral tears may develop rounded edges, scarred tissue, displacement, or poor reducibility. Conversely, tears extending into the white-white region may still be repaired when a stable circumferential component remains and modern techniques permit anatomical fixation. The vascular zone should therefore be reported as one factor within a broader assessment. [1]

### Tear pattern

Vertical longitudinal tears are among the most favorable repair patterns because sutures can restore circumferential continuity while preserving a substantial amount of viable tissue. Short, stable peripheral longitudinal tears may heal without fixation in selected settings, particularly when encountered during anterior cruciate ligament reconstruction. Longer or unstable tears generally require repair to prevent displacement. [1]

Horizontal tears split the meniscus into superior and inferior leaves. They were traditionally considered degenerative and treated by partial meniscectomy, but selected traumatic horizontal tears in younger patients may be repairable, particularly when tissue quality is preserved and the tear reaches the vascular periphery. MRI should assess the relative thickness of each leaf, associated cyst formation, and whether either component is severely macerated.

Radial tears disrupt circumferential fibers and can markedly impair hoop-stress transmission. Small partial-width radial tears may be treated differently from complete radial tears extending to the capsule. Modern repair techniques have expanded preservation of radial tears, particularly near the posterior root or within structurally important segments. On MRI, a radial tear may appear as truncation, a cleft perpendicular to the meniscal circumference, or the absent bow-tie appearance. Its exact width and distance from the root attachment should be stated.

Oblique and flap tears create unstable fragments that may displace into the recesses or beneath adjacent structures. Repairability depends on fragment size, thickness, tissue quality, and peripheral continuity. Small thin flaps with frayed tissue are often excised, whereas larger traumatic fragments with a viable base may occasionally be preserved.

Complex tears contain more than one orientation and are commonly associated with degeneration or substantial structural disruption. The label "complex" should not end the assessment. The report should identify whether a dominant repairable component exists, whether viable peripheral tissue remains, and whether maceration or substance loss makes anatomical reconstruction unlikely. The Modified PROMT score assigns the greatest adverse weighting to complex tears because they were less frequently repairable in the derivation cohort. [5]

**Tear length and thickness**

Longitudinal tear length affects stability, repair technique, and required implant number. A tear longer than 10 mm has often been considered unstable and suitable for repair when other features are favorable. However, length does not have a simple directional relationship with reparability: a long clean peripheral tear may be highly repairable, whereas a short macerated white-white tear may not be.

MRI may overestimate tear length compared with arthroscopy because intrameniscal signal can extend beyond the arthroscopically visible surface defect. Curved tears are also difficult to measure on conventional two-dimensional images. Three-dimensional or multiplanar reformatted imaging may improve measurement, but the technique and plane should be standardized. [11]

Tear depth and the percentage of meniscal thickness involved help determine whether sufficient tissue remains for fixation. Full-thickness vertical tears can be suitable for repair when both components are intact, while partial-thickness surface defects may be stable and require no intervention. MRI is less reliable in distinguishing unstable partial tears from complete tears when the cleft is narrow or aligned with the imaging plane. [3]

**Tissue quality and residual meniscal substance**

Tissue quality is one of the most important arthroscopic determinants but among the least directly measurable MRI variables. Imaging features that suggest poor tissue include diffuse increased intrasubstance signal, irregular contour, fragmentation, maceration, volume loss, and multiple intersecting clefts. Associated osteoarthritis and chondral loss further support a degenerative environment.

The integrity of the inner meniscal segment has been proposed as a criterion for repair. A continuous, adequately thick inner fragment provides tissue for suture purchase and restoration of the meniscal contour. Yet reader agreement for determining inner-fragment integrity on MRI has been poor, illustrating the difficulty of predicting material strength from morphology alone. [3]

**Displacement and reducibility**

Displacement indicates instability but does not necessarily indicate irreparability. Bucket-handle tears are displaced longitudinal tears in which the central fragment migrates toward the intercondylar notch. When the fragment remains substantial and has limited degeneration, repair may restore near-normal anatomy. Chronic displacement, deformation, fragmentation, or fixed shortening may reduce the probability of successful reduction.

MRI signs include an absent bow-tie appearance, fragment within the intercondylar notch, double posterior cruciate ligament sign, flipped meniscus sign, anteriorly displaced fragment, and coronal truncation. The double posterior cruciate ligament sign is highly specific for a displaced medial meniscal fragment, whereas the absence of an individual sign does not exclude a bucket-handle tear. [12]

Static MRI cannot reliably determine reducibility. Fragment position can change between imaging and arthroscopy, and muscle tone or knee positioning may affect displacement. A report should describe fragment size, location, distortion, and signal quality rather than assuming that marked displacement requires meniscectomy.

**Meniscal extrusion**

Meniscal extrusion is usually measured on coronal images as displacement of the meniscal body beyond the tibial plateau margin. Values of 3 mm or more are frequently considered abnormal, although measurement varies with knee position, loading, osteophytes, and image selection. Extrusion may reflect root injury, radial disruption, meniscocapsular compromise, degeneration, or altered alignment. [13]

Marked extrusion suggests impaired hoop function and may reduce the likelihood that a simple tear repair will restore normal mechanics. However, extrusion should not be treated as an isolated contraindication. Root repair, centralization procedures, or combined reconstruction may be appropriate in selected patients. Weight-bearing or dynamic MRI could eventually improve functional evaluation, but such techniques are not yet routinely incorporated into reparability scoring.

### Parameniscal cysts

Parameniscal cysts are strongly associated with horizontal or complex tears that permit joint fluid to dissect through the meniscus into adjacent soft tissues. MRI should define the cyst's size, location, communication with the tear, and relationship to neurovascular structures. The presence of a cyst does not independently establish irreparability; selected horizontal tears can be repaired with cyst decompression when adequate peripheral tissue remains. [14]

### Meniscal root involvement

Posterior root tears or radial tears within approximately 1 cm of the attachment can function biomechanically like total meniscectomy by preventing conversion of axial load into hoop stress. MRI findings include a radial defect at the root, truncation on coronal images, the sagittal ghost sign, meniscal extrusion, and adjacent marrow or chondral abnormalities. [15]

Root tears require a different surgical framework from conventional body or horn tears. Transtibial pullout or anchor-based fixation may be considered when cartilage status, alignment, and tissue quality are suitable. Because the original and Modified PROMT derivation studies excluded root tears, these scores should not be extrapolated to root pathology without separate validation. [5]

### Ramp lesions and meniscocapsular injury

Ramp lesions involve the peripheral posterior horn of the medial meniscus at the meniscocapsular or meniscotibial attachment and commonly accompany anterior cruciate ligament tears. They may be missed on routine anterior arthroscopic inspection and on MRI, particularly when the knee is scanned in extension and the tear margins are approximated.

MRI features include fluid or irregular high signal at the posteromedial meniscocapsular junction, separation of the posterior horn from the capsule, meniscotibial ligament disruption, and adjacent posteromedial tibial marrow edema. A recent meta-analysis reported moderate sensitivity but high specificity, indicating that a negative MRI cannot reliably exclude a ramp lesion. [16]

The presence of a ramp lesion may favor repair when instability is demonstrated arthroscopically. Radiologists should actively search for this abnormality in anterior cruciate ligament-deficient knees and recommend targeted arthroscopic inspection when imaging findings or secondary signs raise suspicion. [17]

## Patient and Joint Factors Affecting Prediction

### Age and chronicity

Age influences vascularity, tissue composition, degenerative change, and surgical decision-making, but chronological age should not be used as an absolute exclusion criterion. Meniscal preservation may remain appropriate in active middle-aged patients with traumatic tears and limited osteoarthritis. The Modified PROMT score adjusted age categories because the original score appeared to classify some repairable tears in patients aged 40–50 years too pessimistically. [5]

Chronic tears may develop edge sclerosis, deformation, scar adherence, secondary cartilage injury, and reduced mobility. Nevertheless, chronicity alone does not establish irreparability. The original PROMT score used a 1-year threshold, whereas the modified model changed the threshold to 2 years after analysis of false-negative predictions. Such broad categories simplify scoring but may not reflect the nonlinear influence of time across different tear patterns. [4,5]

### Osteoarthritis and cartilage condition

Radiographic osteoarthritis is incorporated into both PROMT systems because advanced degeneration reduces the likelihood that isolated repair will produce durable clinical benefit. The Modified PROMT score assigns adverse weighting when the Kellgren-Lawrence grade exceeds 1. MRI additionally reveals focal cartilage defects, subchondral marrow lesions, and diffuse compartment degeneration that may not be evident on radiographs. [5]

Cartilage status should be reported separately rather than reduced to a meniscal score. A focal traumatic chondral lesion in a young patient differs fundamentally from diffuse weight-bearing cartilage loss, osteophytes, and subchondral change. Arthroscopic treatment is influenced by the entire joint environment, not only meniscal morphology.

### Associated anterior cruciate ligament injury

Meniscal repair performed with anterior cruciate ligament reconstruction often has favorable healing conditions because marrow stimulation from tunnel drilling produces an intra-articular biological response, while restoration of stability reduces repeated shear across the repair. Surgeons may consequently accept more complex or peripheral tears for repair during ligament reconstruction than they would in an unstable untreated knee.

MRI should describe anterior cruciate ligament integrity and secondary instability signs. Meniscal pathology in an acutely injured unstable knee can evolve before surgery, and a tear judged on an early MRI may differ by the time of arthroscopy. Misir et al. found that concomitant ligamentous and osteochondral findings influenced repair decisions beyond isolated meniscal morphology. [18]

### Meniscal side and segment

Medial and lateral menisci differ anatomically, biomechanically, and surgically. Lateral tears may be difficult to classify because of normal structures around the popliteal hiatus and greater meniscal mobility. The original PROMT score demonstrated substantially stronger performance for medial than lateral reparability, highlighting the danger of assuming equivalent prediction across both menisci. [4]

Posterior horn tears are common and may be difficult to visualize fully on routine planes. Anterior horn abnormalities may be obscured by magic-angle effects, transverse ligament insertion, and partial-volume averaging. Segment-specific performance should be considered in future models rather than using meniscal side alone.

## Arthroscopy as the Reference Standard

Arthroscopy permits direct assessment of tear morphology, stability, reducibility, vascular response, tissue quality, and suture-holding capacity. Probing can reveal hidden undersurface components or meniscocapsular separation that is inapparent on MRI. The surgeon can also determine whether stable anatomical reduction can be achieved without excessive tension.

Despite these advantages, arthroscopic reparability is not an entirely objective reference standard. Decisions vary with surgical training, repair technology, institutional practice, patient expectations, and willingness to accept a risk of failure. A tear excised by one surgeon might be repaired by another with advanced meniscal-preservation expertise. Therefore, studies that equate the procedure performed with an absolute biological truth may partly measure surgeon preference rather than intrinsic reparability. [6]

Blinding is also difficult in retrospective studies because radiologists may know clinical details, and surgeons usually review MRI before arthroscopy. Future diagnostic studies should use predefined operative criteria, standardized probing, photographic or video documentation, and adjudication by more than one experienced surgeon.

## PROMT and Modified PROMT Scores

### Original PROMT score

The Ortho One PROMT score was developed to provide a practical preoperative estimate of whether a traumatic meniscal tear would undergo repair or meniscectomy. It combined five domains: age, chronicity, radiographic osteoarthritis, vascular zone, and tear pattern. Lower scores indicated greater repair potential, with scores of 6 or less predicting repair and scores of 7 or more predicting meniscectomy. [4]

In the original study, the score predicted medial meniscal repair with 90.9% sensitivity and 93.2% specificity. Performance was weaker for the lateral meniscus, with repair sensitivity of 69.2% and meniscectomy sensitivity of 78.8%. The score's main strength was its integration of clinical and imaging variables rather than reliance on MRI morphology alone. [4]

Several limitations require consideration. The model was derived from a limited single-center population, and treatment decisions were influenced by local surgical practice. Broad categorical weighting can obscure important interactions; for example, a long peripheral vertical tear and a short central radial tear may receive similar aggregate scores despite different biomechanics. External validation was also limited.

**Modified PROMT score**

The Modified PROMT score retained the same five domains and the same decision threshold but revised age, chronicity, osteoarthritis, and tear-pattern categories. Age 20–40 years was combined into one category, while patients aged 40–50 and older than 50 years received progressively higher scores. The chronicity threshold was extended from 1 to 2 years. Kellgren-Lawrence grades above 1 received adverse weighting, displaced bucket-handle tears were assigned fewer points than complex tears, and complex morphology received the maximum tear-pattern score. [5]

These changes reflect an important clinical shift. Age and chronicity are no longer treated as rigid contraindications, and displaced bucket-handle tears may remain suitable for repair when the fragment is viable and reducible. Complex tears are penalized more heavily because they more frequently contain tissue degeneration, intersecting cleavage planes, and insufficient stable substance.

In the prospective evaluation of 100 tears, the Modified PROMT score achieved 96.77% sensitivity and 88.89% specificity for medial meniscal reparability, compared with 90.32% and 83.33% for the original score. For lateral tears, sensitivity improved from 64.71% to 82.35% and specificity from 79.41% to 88.24%. Areas under the curve increased from 0.868 to 0.928 medially and from 0.721 to 0.853 laterally. [5]

Although promising, these findings require external multicenter validation. The same clinical group participated in developing both scores, and arthroscopic decisions may reflect a strong institutional preference for repair. Root tears, degenerative tears, revision procedures, and advanced osteoarthritis were excluded, limiting generalizability. The score predicts the procedure likely to be performed rather than verified biological healing after repair.

**Simplified MRI criteria**

Other proposed approaches have emphasized four MRI criteria: tear location within 4 mm of the meniscosynovial junction, length greater than 10 mm, an intact inner fragment, and involvement of more than half the meniscal thickness. These variables attempt to reproduce traditional arthroscopic repair indications.

Strawbridge et al. tested several prediction strategies using 3-T MRI and found overall accuracies of only 55%–72%. Interobserver agreement was poor for several individual criteria, including inner-fragment integrity and tear pattern. [3] Holland et al. later evaluated a simplified four-point method in 202 tears and reported reader accuracy ranging from 48% to 76%, with an overall Fleiss κ of only 0.11. [6]

These results demonstrate that seemingly objective criteria remain difficult to measure reproducibly. They also suggest that a model relying only on tear geometry may omit clinical and biological information captured by the PROMT systems. Conversely, including age and osteoarthritis may improve prediction of surgeon behavior without directly improving MRI assessment of tear structure.

**Diagnostic Challenges and Pitfalls**

**Normal structures simulating tears**

Vascular channels in younger patients, the transverse intermeniscal ligament, meniscofemoral ligaments, popliteus tendon sheath, and capsular recesses can mimic meniscal signal or separation. The anterior horn of the lateral meniscus is particularly vulnerable to false-positive interpretation near the transverse ligament. Confirmation in orthogonal planes and knowledge of predictable anatomical courses reduce error. [10]

**Intrasubstance signal**

Linear signal that does not unequivocally reach an articular surface should not automatically be called a tear. Degenerative or post-traumatic intrasubstance signal may coexist with a small surface defect not visible because of slice orientation. Overcalling such signal can falsely predict an operative lesion, while undercalling a subtle surface extension may omit a clinically relevant tear.

**Radial and root tears**

Radial tears can be missed when the imaging plane runs parallel to the defect. Careful inspection for truncation, a cleft across circumferential fibers, absent meniscal tissue, extrusion, and the ghost sign is required. Small root defects may be overlooked unless thin sagittal and coronal images are correlated. [15]

### Ramp lesions

A conventional negative MRI does not exclude a ramp lesion. Knee extension may reduce meniscocapsular separation, and inferior partial lesions are particularly difficult to visualize. Suspicion should increase in anterior cruciate ligament tears accompanied by posteromedial tibial marrow edema or subtle capsular irregularity. Targeted arthroscopic inspection remains necessary. [16]

### Displaced fragments

A displaced fragment can be mistaken for a normal ligament or overlooked when the residual meniscus is not systematically assessed. Conversely, a prominent meniscofemoral ligament may mimic a displaced lateral meniscal fragment. The reader should account for the expected meniscal volume in every segment and trace abnormal low-signal structures across sequential images. [12]

### MRI–arthroscopy interval

The meniscal appearance can change between imaging and surgery. A stable tear may displace after another injury, while edema or hemorrhage may resolve. Chronic instability can enlarge the tear or produce secondary chondral damage. Studies evaluating predictive scores should record the MRI-to-arthroscopy interval and any intervening trauma.

## Interobserver Variability

Reparability prediction requires several sequential judgments: whether a tear exists, how it should be classified, where it lies relative to the capsule, how much tissue remains, and whether the fragment is likely reducible. Error or disagreement at any step alters the final prediction.

Even experienced musculoskeletal radiologists and sports surgeons have shown poor agreement for tear pattern and inner-fragment integrity. In the 3-T MRI study by Strawbridge et al., κ values for individual criteria ranged from 0.07 to 0.40. [3] Holland et al. similarly found poor overall interobserver reliability despite moderate-to-substantial intraobserver consistency, indicating that readers may be internally consistent yet apply different thresholds. [6]

Structured reporting and formal definitions could reduce variability. Measurement instructions should specify the plane, image, anatomical reference, and whether the maximum or minimum dimension is recorded. Training sets containing arthroscopic correlation may improve consistency, particularly for radial, ramp, and complex tears.

## Clinical Integration

MRI-based prediction is most useful for preparation rather than definitive exclusion. A favorable prediction allows the surgical team to plan repair implants, discuss a longer protected rehabilitation program, and counsel the patient regarding healing and reoperation. An unfavorable prediction prepares the patient for possible partial meniscectomy but should not preclude an attempt at preservation when arthroscopy demonstrates viable tissue.

Radiologists and surgeons should review complex cases together. Direct communication is particularly valuable for displaced bucket-handle tears, root injuries, radial tears, multiligament injuries, and suspected ramp lesions. Such collaboration aligns imaging terminology with operative needs and reduces the gap between a descriptive report and a treatment-oriented interpretation.

The procedure performed should not be regarded as the only outcome of interest. Future predictive studies should assess whether repaired tears heal, remain clinically functional, and avoid reoperation. A score that accurately predicts the surgeon’s immediate choice but does not predict repair survival has limited prognostic value.

## Future Directions

External validation of the Modified PROMT score should include institutions with different repair philosophies, radiologists of varying experience, and sufficiently large medial and lateral tear subgroups. Calibration, discrimination, decision-curve analysis, and interobserver reliability should be reported rather than sensitivity and specificity alone.

Quantitative three-dimensional measures may improve prediction by evaluating meniscal volume, fragment continuity, extrusion, capsular contact, and tear surface area. Compositional MRI techniques, including T2 and T1ρ mapping, may provide information about tissue matrix quality beyond conventional morphology, although their relationship to suture-holding capacity and healing remains uncertain.

Artificial intelligence may assist segmentation, tear classification, measurement, and multimodal prediction. A clinically useful model would integrate MRI morphology with age, chronicity, radiographic osteoarthritis, ligamentous injury, activity, and surgeon-defined technical criteria. Explainable models are preferable because clinicians must understand which features drive a repair or meniscectomy prediction.

Future research should also distinguish prediction of technical reparability from prediction of biological healing. These are different outcomes and may require separate models. Arthroscopic video adjudication, standardized repairability definitions, and long-term clinical or second-look confirmation would provide stronger reference standards than the operation performed alone.

## Conclusion

MRI provides valuable preoperative information about traumatic meniscal tear morphology and biological context, but reparability cannot be determined reliably from one imaging feature. Structured integration of tear location, pattern, length, tissue preservation, displacement, extrusion, root or capsular involvement, cartilage status, chronicity, and associated ligament injury offers a more clinically useful estimate. The Modified PROMT score is promising, but broader validation and standardized arthroscopic criteria remain necessary before it can support definitive treatment decisions independently.

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