

Meniscal Extrusion

A Narrative Review

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Background: Meniscal extrusion, referred to as an external displacement of the meniscus, is a commonly encountered but often overlooked magnetic resonance imaging finding in the knee joint. Meniscal extrusion alters the biomechanical properties of the meniscus, leading to accelerated cartilage degeneration and early osteoarthritic changes. The literature contains discrepancies about meniscal extrusion on topics ranging from definition to diagnosis. This narrative review outlines the pathogenesis, natural history, diagnosis, and treatment of meniscal extrusion.

Purpose: To review the current literature on meniscal extrusion, from pathogenesis to treatment, and to provide recommendations for future research.

Study Design: Narrative review.

Methods: A computer-based search of the PubMed, Ovid Medline, and Cochrane Library databases was used to perform a comprehensive literature review on meniscal extrusion. A total of 81 studies was ultimately included in the review.

Results: The literature review highlighted the current ambiguity in definition, difficulty in clinical diagnosis, and low level of awareness of this condition. This review covers all aspects related to meniscal extrusion and identifies many of its lesser known aspects.

Conclusion: In the current literature, meniscal extrusion remains a lesser known albeit common condition because of its relatively silent nature along with lack of knowledge among orthopaedic surgeons. Further studies are warranted to provide better understanding and management of this condition.

Keywords: meniscal extrusion; knee; meniscus root tear; meniscotibial ligament; osteoarthritis

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Menisci are wedge-shaped, semilunar fibrocartilages located between the medial and lateral femoral and tibial condyles of the knee joint. Histologically, the meniscus is composed of water and type I collagen fibers surrounded by elastin, proteoglycans, and glycoproteins. The function of the menisci is intricately related to their structure and composition. These include load transmission, shock absorption, stability, nutrition, joint lubrication, and proprioception. The menisci also decrease contact stresses by increasing the contact area and congruency of the knee.²⁷

Meniscal horns have similar arrangement to epiphyseal ligaments and tendons at the attachment site of the bone, with a zone of uncalcified fibrocartilage separated from a zone of calcified tissues by the tidemark.⁷ Differences in thickness of these layers give rise to differences in the biomechanical behavior of the individual roots. The presence of more uncalcified fibrocartilage and greater thickness gives more strength to the anterior roots compared with the

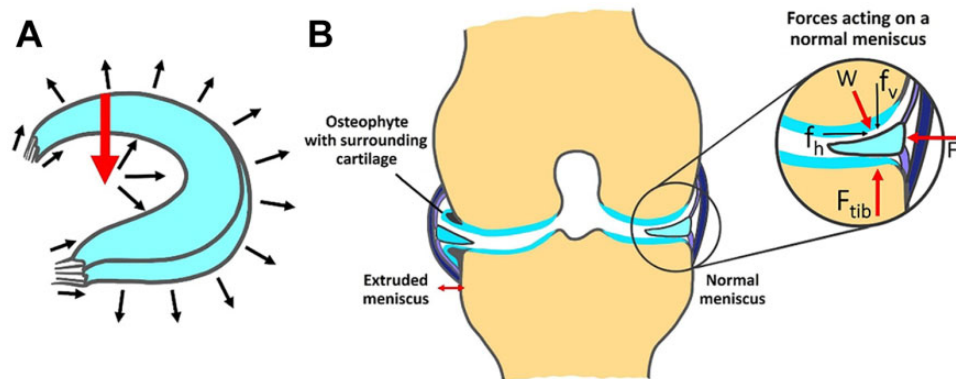


Figure 1. Illustration of the biomechanics of the meniscus. (A) Forces acting on the meniscus throughout its length (red arrow). Outward radiating forces create hoop stresses within the meniscus, converting the tensile stresses on the roots (black arrows). (B) Free body diagram depicting forces on the meniscus in a single offset image on weightbearing; these are resisted by the tissues in the roots. f_h , horizontal component of weight acting on meniscus; F_r , reaction force; F_{tib} , reaction force from tibial plateau; f_v , vertical component of weight acting on meniscus; W , body weight component transmitted from femoral condyle.

posterior roots.³⁷ The shiny white fibers offer some 47% of the ultimate tensile strength to the roots.²⁴

Biomechanical studies have demonstrated that approximately 40% to 60% of load acting on the extended knee joint is transmitted to the meniscus (65%-70% lateral and 40%-50% medial), and this increases up to 90% in flexion.²⁷ When the knee joint is loaded, compressive, tensile, and shear forces are generated, some of which are converted into hoop stresses.^{27,64}

In a dynamic magnetic resonance imaging (MRI) study on normal meniscal movements, Vedi et al⁷⁴ concluded that the lateral meniscus is more mobile than the medial meniscus and the anterior horns are more mobile than the posterior horns. During normal loading, compressive forces generate radial hoop stresses in the meniscus (Figure 1). These stresses are countered by integrity of the collagen bundles within the meniscus along with the attachment of the roots and the intermeniscus attachments. Disruption in these resistive structures leads to meniscal extrusion.

As seen in Figure 1, the vertical component of loading on the meniscus is resisted by the tibial plateau, and the horizontal component of the vector is responsible for extrusion. This component is resisted by the longitudinal fibers of collagen within the meniscus, causing hoop stresses within them as well as the meniscotibial (coronary) ligament, which is attached to the meniscus along the periphery of the tibial plateau on the medial side and incompletely on the lateral side.⁷⁷ Hence, any disruption, discontinuity, or stretching of these structures could lead to limited restraint or lack of restraint on the horizontal component, leading to extrusion of the meniscus.⁷⁶ In addition, on the lateral side, the convexity of the tibial plateau encourages sliding out of the meniscus, leading to extrusion.

Epidemiological data are lacking in the literature regarding meniscal extrusion. In this article, we review the available literature on meniscal extrusion in terms of its definition, causes and association, progression (natural history), diagnostic criteria, and available treatment options.

METHODS

A PubMed search for medial and lateral meniscal extrusion revealed 330 and 238 articles, respectively; of these, 399 had been published in the past 10 years. A similar search in Ovid Medline resulted in 44 and 3 articles, respectively. A search in the Cochrane Library for “meniscus extrusion” or “meniscus subluxation” provided 41 results, of which 5 were relevant.

Exclusion criteria were articles in languages other than English and articles that discussed meniscal extrusion after meniscal allograft transplant. The reference lists of the articles were searched for further relevant studies. After we accounted for duplication of articles and overlap of search results, we included 81 articles in this narrative review.

RESULTS

Definitions

The definition of meniscal extrusion has varied in reports. We define meniscal extrusion as partial or total displacement of the meniscus off the tibial plateau and the tibial articular cartilage. Meniscal extrusion on MRI scan is defined as ≥ 3 mm of external displacement of the meniscus with respect to the central outer rim or edge of the tibial plateau quantified in the midcoronal plane for an unloaded knee.^{1,3,48,55,57,68} The midcoronal plane is the section that covers the largest area of the tibial spine. When 2 consecutive slices demonstrate a similar area of the tibial spine, the slice with the greatest width of the tibial plateau is selected. A limitation of this definition is that it does not consider variability in the size of the knee and hence the proportionate displacement of the meniscus and it is not specific for the medial and lateral sides. Hence, studies are warranted that evaluate more sensitive assessment methods, for example, defining extrusion in terms of percentage

obtained by dividing the amount of displacement from the outer rim of the tibial plateau by the width of the meniscus.

Etiopathogenesis

Meniscal injury, which is very common among middle-aged and older people, is one of the most important risk factors for the onset and development of knee osteoarthritis (OA).⁸¹ Meniscal degeneration implies breakdown of collagen fibers in the meniscus due to a multifactorial process involving overload, overuse, and failure of biological repair. Although meniscal damage and degeneration are predisposing factors for extrusion,⁸ female sex, high body mass index (BMI), varus mechanical axis angle, and lower sports activity level are risk factors for posterior horn root tears.³⁴ Extrusion effectively defunctionalizes the meniscus and reduces contact area of the joint surfaces, increasing point loading on the articular cartilage.⁵⁷ Normal hoop stress dissipation is also impaired in the extruded meniscus, which accelerates the articular degeneration with resultant progression of knee joint OA.⁸ Due to convexity of the lateral femoral and tibial condyles, the lateral compartment is more adversely affected than the medial.⁸

Additional malalignment can cause sustained loads on the collagen bundles, which, coupled with age-related degenerative changes within the meniscus, can lead to microscopic rupture or stretching of the longitudinal collagen fibers that normally resist hoop stresses, leading to extrusion of the meniscus.

Extrusion can have meniscal as well as nonmeniscal causes (Table 1), of which posterior root tear is considered to be most important.^{28,45,48,49} When associated with root tears, medial meniscal extrusion has been reported to be 3 times more prevalent than lateral meniscal extrusion.¹³ Various other types of meniscal tears, such as large radial tears (>50% width) and large complex tears, are also related to meniscal extrusion.^{4,15,45} However, extrusion is not seen with horizontal or longitudinal tears. The nonmeniscal causes include knee malalignment, female sex, high BMI, meniscocapsular separation, isolated meniscal extrusion, knee effusion, and posteromedial and posterolateral corner injuries.

There is inconsistent evidence of an association of medial and lateral joint laxity with cartilage loss.⁷¹ As well, no studies have determined the association between meniscal mobility or laxity of knee and the incidence of extrusion.

Natural History

Isolated meniscal extrusion is rare. Meniscal extrusion is commonly seen with other knee pathologies, among which meniscal tears and OA are prominent. Meniscal extrusion presents with knee pain on the side of extrusion that occurs secondary to meniscotibial ligament abnormality.⁴³

Meniscal extrusion is usually a chronic process that is part of the progression of knee joint OA, which occurs after meniscal pathology or surgery, or that is seen in patients with high-risk characteristics. However, rarely it can present as acute extrusion.

Numerous studies have depicted meniscal extrusion as an independent predictor of tibiofemoral cartilage loss^{50,68} and degenerative subchondral bone marrow lesions.^{25,75} Extrusion has been associated with joint space narrowing,^{3,29} osteophytosis,^{48,52} chondral lesion,⁶⁵ and meniscal tear^{9,15,48} in cross-sectional studies. The association between meniscal extrusion and loss of cartilage volume^{9,66} and focal loss³³ has been confirmed by longitudinal studies.

Foreman et al²⁶ found meniscal extrusion and meniscus root tears to be the most common structural abnormalities with a role in accelerated OA of the knee joint. The initial joint space narrowing could be due to a combination of meniscal and cartilage wear, as demonstrated by macroradiography with double contrast by Bennett and Buckland-Wright,⁸ indicating that it is part of the natural history of degeneration of the knee joint due to any cause.

Investigators have found a high association between medial meniscal extrusion and femorotibial angle and the radiological stage and volume of the spontaneous osteonecrosis of the knee lesion.⁸⁰ Osteophyte size and the Kellgren-Lawrence OA grade have been associated with medial meniscal extrusion with posterior horn root tear.⁴⁰ Meniscal extrusion has been thought to be causally related to BMI, previous knee injury, and osteophytes.²² Meniscal extrusion was found to be associated with a higher rate of loss in tibiofemoral cartilage volume and an increased risk of cartilage defects over a period of 2 years, indicating a possible role of these lesions in initiating OA and a similar relationship between meniscal pathology and cartilage in early and late disease.²² Meniscal extrusion does not always precede the onset of OA and thus appears to be the consequence of the complex interactions between the biomechanical loading involved in OA and the joint tissues.

Types of Extrusion

Physiological. Healthy individuals have a physiological extrusion of <3 mm for both medial (2 mm) and lateral (0.8 mm) menisci while weightbearing.⁶³ However, in most cases, extrusion is measured on supine (unloaded) MRI scans. Gale et al²⁹ compared meniscal extrusion in patients with OA and in asymptomatic volunteers on conventional MRI scans in the coronal plane in the supine position. The investigators found that the mean extrusion of the medial and lateral menisci was 5.1 and 0.8 mm, respectively, in patients with OA versus 2.8 and 0.2 mm, respectively, in asymptomatic volunteers. Similar observations of the normal knee were reported by Boxheimer et al,¹² who found a mean extrusion of 2 mm for the medial meniscus and 1.1 mm for the lateral meniscus in the supine neutral position in coronal sections of MRI scans. Boxheimer et al also found that meniscal extrusion was more frequent in the upright weightbearing position due to hoop stresses that arise under load bearing.^{54,72} It can thus be concluded that meniscal extrusion in healthy individuals is generally <3 mm in the coronal plane.

Pathological. Extrusion is said to be present when the outer edge of the meniscus extends beyond the edge of the tibial plateau by ≥ 3 mm. Bone spurs and osteophytes, when present, should be excluded in the estimation of the outer

TABLE 1
Causes of Meniscal Extrusion

Cause	Possible Mechanism
Meniscal Causes	
Meniscus root tears	Longstanding physiological loading after meniscus root tear results in an increase in the tear gap, leading to meniscal extrusion. A loss of hoop stress in root tears leads to extrusion of the meniscus. ^{28,45,48,49}
Other meniscal tears	Loss of resistance to hoop stress, due to discontinuity of the intermeniscal fiber connection, influences the resistance to hoop strain. ¹⁵
Age-related meniscal degeneration	Exact reason unknown; a possible cause is structural change of the knee in osteoarthritis. ^{23,32,65,68}
Nonmeniscal Causes	
Knee malalignment	Increased load transmission to the meniscus leads to extrusion. Malalignment is also a risk factor for osteoarthritis-related structural changes in the knee, and meniscal extrusion is one of them. Genu varum and valgum are independent risk factors for medial and lateral meniscal extrusion, respectively. ¹⁶
Female sex, high body mass index	No evidence of direct correlation, but both are strong risk factors for posterior root tears of the medial meniscus, which in turn may lead to extrusion. ^{49,66}
Meniscocapsular separation	Can lead to meniscal extrusion along with other changes like perimeniscal fluid collection and meniscal corner tears, but the evidence is controversial. ^{18,19}
Isolated meniscal extrusion (with otherwise normal meniscus and minimal knee joint pathology)	Krych et al ⁴³ found meniscotibial ligament abnormality in 65% of cases. However, the investigators were unable to comment on the cause of the remaining 35% of isolated meniscal extrusions and did not find correlation with increasing age and body mass index.
Knee effusion	Displacement of the joint capsule by fluid can externally displace the tightly attached medial meniscus. This is not seen with lateral meniscus due to a lax capsule ⁵² probably because joint fluid tends to collect in the lax capsule and the yielding meniscocapsular attachments.
Posteromedial/posterolateral corner injuries	Meniscocapsular ligament injuries lead to altered extruded menisci.
Postoperative Meniscal Extrusion	
After meniscus root repair	Studies have suggested that, postoperatively, extrusion is reduced but does not revert completely. ^{2,35,58,79}
Saucerization procedure of discoid meniscus	Because the ultrastructure of the discoid meniscus is different from the normal meniscus ⁶ (discontinuity and inhomogeneity of the circumferential collagen network in discoid meniscus) after the surgical procedure, remaining meniscal collagen fibers are unable to resist the hoop stress, leading to extrusion. ⁵¹
After meniscal allograft transplant	Possible causes include nonanatomic placement, fixation technique (suture only compared with a bone fixation technique leads to more extrusion), and imprecise sizing of the graft. ³⁹
After anterior cruciate ligament reconstruction surgery	Insufficient evidence, but possible reasons are graft tensioning and tibiofemoral rotational mismatch. ⁵⁶

margin of the tibial plateau.⁴⁸ Unloaded (supine) MRI tends to underdiagnose the existence of pathological meniscal extrusion, as studies have shown that the meniscus is mobile with varying knee positions⁷⁴ in the absence of associated meniscal tear.¹⁶ Loaded MRI of the knee carries the benefit of early evaluation and diagnosis of peripheral meniscal extrusion, especially in the absence of associated meniscal tear or significant OA.

Extrusion is best measured in the coronal plane at the posterior border of the medial collateral ligament.^{10,17} Although most MRI studies are performed with the knee in full extension in the supine/unloaded position, the degree of extrusion increases as the knee is loaded and flexed to 90°.¹⁷

Extrusion has also been measured in the sagittal plane based on the position of the anterior and posterior horns.⁴ However, it is still debatable whether it is essential to quantify meniscal extrusion of the anterior horn, the posterior horn, and the body in both coronal and sagittal planes. It is known that the different segments of the meniscus display different amounts of displacement with knee joint motion. The medial meniscus extrudes more than the lateral meniscus in extension, and the anterior horn shows maximal anterior-posterior excursion in extension.⁴⁶

Svensson et al⁷³ concluded that the 3-mm cut-off for the diagnosis of extrusion of the body of the medial meniscus had high sensitivity but low specificity with respect to its

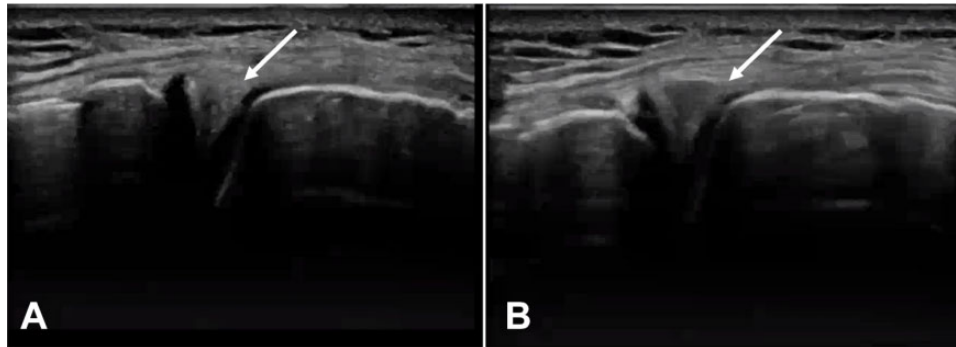


Figure 2. Dynamic ultrasound images. (A) Absent meniscal extrusion at rest (arrow). (B) Varus stress test showing medial meniscal extrusion (arrow).

relation to cartilage damage, bone marrow lesions, and OA. However, when the cutoff was set at 4 mm, the sensitivity and specificity were maximized with respect to these conditions. No similar assessment exists for the diagnosis of lateral meniscus and its sensitivity in relation to OA or cartilage damage.

Diagnosis

Clinical Presentation. Meniscal extrusion is an imaging finding commonly observed in patients >50 years of age assessed for other knee pathology and hence is often overlooked.²⁹ Patients may have features consistent with meniscal tear, such as pain, swelling, clicking, effusion, joint line tenderness, or painful flexion on the involved side of the knee.³⁶ Pain usually occurs after an episode of deep flexion, and a sudden increase in pain accompanied by a popping sound could arise due to a meniscus root tear leading to meniscal extrusion.

Kaukinen et al³⁶ studied the association between MRI-defined structural pathology and generalized and localized knee pain, finding that only medial meniscal extrusion was associated with joint line pain whereas lateral joint line pain was not encountered in patients with lateral meniscal extrusion.

Rarely, meniscal extrusion can present as acute extrusion or subluxation that causes locked knee without any other underlying pathology like meniscal tear, loose bodies, or discoid meniscus in young individuals. Several case reports^{30,31} have described lateral meniscal extrusion causing locked knee, although, to our knowledge, similar acute presentations have not been documented for medial meniscal extrusions.

Imaging. The common imaging methods used to detect meniscal extrusion are plain radiography, ultrasonography (USG), computed tomography (CT), and MRI.

Weightbearing plain radiographs can provide findings such as narrowing of the joint space and the presence of buttressing osteophyte. However, these are findings of early OA, and addressing meniscal extrusion at this stage is unlikely to prevent OA.

USG has the advantage of being dynamic (Figure 2) and can detect the knee joint line, the integrity of meniscus

body, and the presence of extrusion.⁶⁷ Marcello et al⁵⁰ found USG examination for extrusion of the meniscus to be reliable with the possibility of quantification of the condition. They reported excellent diagnostic performance of USG in the detection of extrusion of the meniscus when compared with MRI. The midcoronal plane on ultrasound images and MRI scans corresponds to the measurement in the coronal plane at the posterior border of the medial collateral ligament.¹⁷ USG, however, cannot assess tears of the anterior and posterior horns or roots of the menisci and the tibiofemoral cartilage.⁵⁷

On CT scans, menisci can be seen as hyperdense structures. Meniscal extrusion, chondrocalcinosis, and large tears can be identified on CT scans.⁵⁷ CT arthrography can be useful to visualize the integrity and position of the menisci. However, although case reports are available, there is no high-level evidence describing the diagnostic performance of these imaging techniques in the detection of meniscal extrusion.

MRI can reveal meniscal extrusion along with the primary cause of extrusion. MRI has become established as the most important imaging modality in the assessment of knee pathology, exhibiting excellent diagnostic performance in the detection of meniscal pathologic abnormalities.²⁰ Coronal STIR (short-tau inversion recovery) MRI has proved to be a useful tool in the assessment of meniscal extrusion.^{13,33,69} The MRI-based criteria for diagnosis of meniscal extrusion are as mentioned in the “Definitions” section (Figure 3).

Grading. Costa et al¹⁵ classified the degree of meniscal extrusion observed on imaging as major (>3 mm) and minor (≤3 mm). Adams et al³ graded meniscal extrusion on MRI scans depending on the relation of the outer margin of the meniscus to both the femoral and tibial condyles; extrusion of less than one-third of the meniscus was graded as mild (grade 1); extrusion of two-thirds, as moderate (grade 2); and complete extrusion, as severe (grade 3).

Crema et al¹⁶ assessed extrusion of the medial and lateral meniscal bodies by using coronal STIR images. The investigators used the section with the greatest volume of the medial tibial spine as the reference section for assessing extrusion. The edge of the tibial plateaus (excluding osteophytes) was used as the reference for measuring extrusion

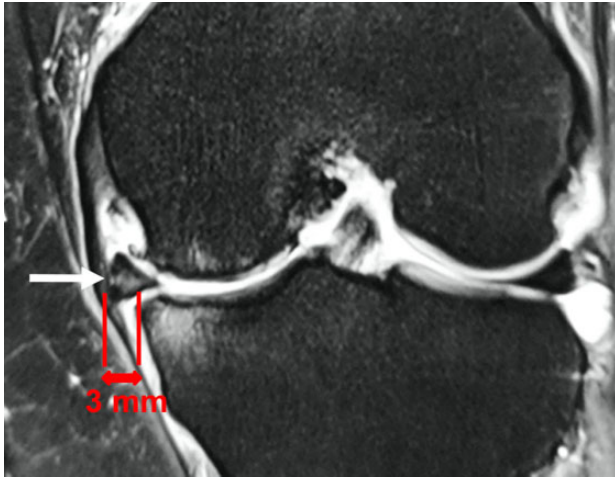


Figure 3. Coronal MRI scan showing 3-mm meniscal extrusion (white arrow). MRI, magnetic resonance imaging.

of the bodies of both menisci. Medial and lateral meniscal extrusion was classified as follows: no extrusion (grade 0), extrusion of $\leq 50\%$ of the body (grade 1), and extrusion of $>50\%$ of the body (grade 2).¹⁶

Hunter et al³³ described the following scoring as part of semiquantitative MRI scoring systems for OA: medial meniscal extrusion <2 mm (grade 0), 2 to 2.9 mm (grade 1), 3 to 4.9 mm (grade 2), and >5 mm (grade 3). Paletta et al⁶⁰ classified the meniscotibial ligament lesion (MTLL) with extrusion on ultrasound images into 4 stages (called the “Crane classification”): MTLL with no extrusion (stage 1), MTLL with $<50\%$ extrusion (stage 2), MTLL with $>50\%$ extrusion (stage 3), and MTLL with osteophytes (stage 4). Each stage was further subclassified into A (reducible) and B (nonreducible).

Recently, manual or automated segmentation techniques have been used to fully quantify meniscal extrusion 3-dimensionally.^{11,59,62,78} Three-dimensional evaluation has been used to assess the percentage of meniscal coverage of the tibial plateau. Studies have found that the medial meniscus in an osteoarthritic knee exhibited smaller tibial plateau coverage and more extrusion of the body of the medial meniscus in comparison to the controls without OA.^{11,59,78} To our knowledge, similar studies are not available for the lateral meniscus. We believe that among the currently available methods, grading on a dynamic or weightbearing position (ultrasound images or MRI scans) into major (>3 mm) and minor (≤ 3 mm) types would be a simple, reliable, and accurate method for evaluation of meniscal extrusion.

Management

Extrusion ultimately leads to articular cartilage loss due to coverage defect and OA.²⁶ Hence, early detection and management may delay the progress of degenerative changes in the knee joint. Treatment is primarily based on the cause of meniscal extrusion.

Nonoperative management is an option for certain causes of meniscal extrusion (eg, high BMI), isolated meniscal extrusion, or meniscal tear in the presence of advanced OA.⁷⁰ After failure of nonoperative treatment and in the presence of meniscal pathology, surgery is advocated. Meniscal extrusion is commonly seen in association with meniscal tear and is less commonly seen in isolation due to meniscotibial ligament lesion after injury. Although meniscal tear, except in young patients after trauma, is mostly associated with the aging knee, meniscotibial ligament lesion is seen in the young patient without any cartilage pathology. The most common meniscal pathology in association with extrusion is posterior horn root tear, and the goals of surgery are to repair the meniscus root and correct the meniscal extrusion; debriding the root tear without correcting meniscal extrusion provides only short-term benefit, with subsequent deterioration in patient outcomes in the mid- to long-term due to progression of OA.³⁸ Similarly, repair of large tears (eg, radial tears) corrects extrusion and can restore meniscal function.¹³

Numerous studies^{39,44,47,53} have reported successful clinical outcomes after isolated meniscus root repairs. However, the presence of associated extrusion remains a problem and can persist despite well-performed meniscus root repair.³⁵ Extrusion develops rapidly⁵⁸ and increases with age, high BMI,² and varus malalignment.⁷⁹ Hence, more recently, extrusion correction techniques have been developed. Extrusion correction surgery involves releasing the peripheral attachments of the extruded meniscus, namely the meniscofemoral attachments, which allows reduction of the meniscus to its native location on the tibial plateau.

Ozeki et al⁵⁹ studied the role of centralization (restoration of the meniscus to its native position on the tibial plateau) of the extruded medial meniscus via pull-out suture technique in terms of preventing cartilage degeneration in rats and found delayed cartilage degeneration. Various surgical techniques have been described for the centralization of meniscal extrusion. In a prospective study of lateral meniscal centralization in 26 patients with extrusion and Kellgren-Lawrence OA grades 0 to 2, Koga et al⁴² used suture anchors on the edge of the tibial plateau with suture loops passing through the meniscocapsular junction (Figure 4, A and B). The body of the meniscus was centralized and stabilized onto the rim of the tibial plateau after placement of the anchor knots, thereby restoring and maintaining the functional anatomic features of the meniscus. Koga et al reported significant improvement in patient satisfaction, sports performance level, and functional outcome scores and a significant reduction in the meniscal extrusion width at 1 year.

In a case report, Chernchujit and Agrawal¹⁴ used a similar technique with a double-loaded suture anchor for centralization of an extruded medial meniscus in a >50 -year-old patient with a traumatic posterior meniscal tear. The anchor-based fixation technique is appropriate in cases where release of the peripheral attachment of the meniscus is performed to reduce the extrusion (Crane classification subtype B).⁶⁰ Depending on the extent of release

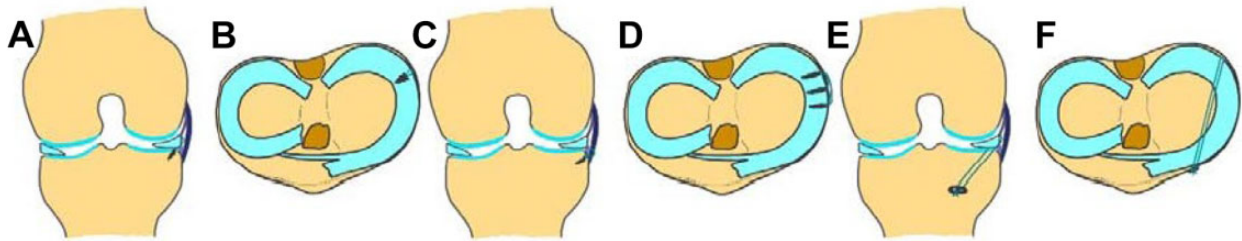


Figure 4. Illustration of repair techniques for meniscal extrusion. (A) Coronal and (B) axial anchor-based centralization technique. (C) Coronal and (D) axial meniscotibial ligament repair. (E) Coronal and (F) axial transosseous centralization pull-out suture technique.

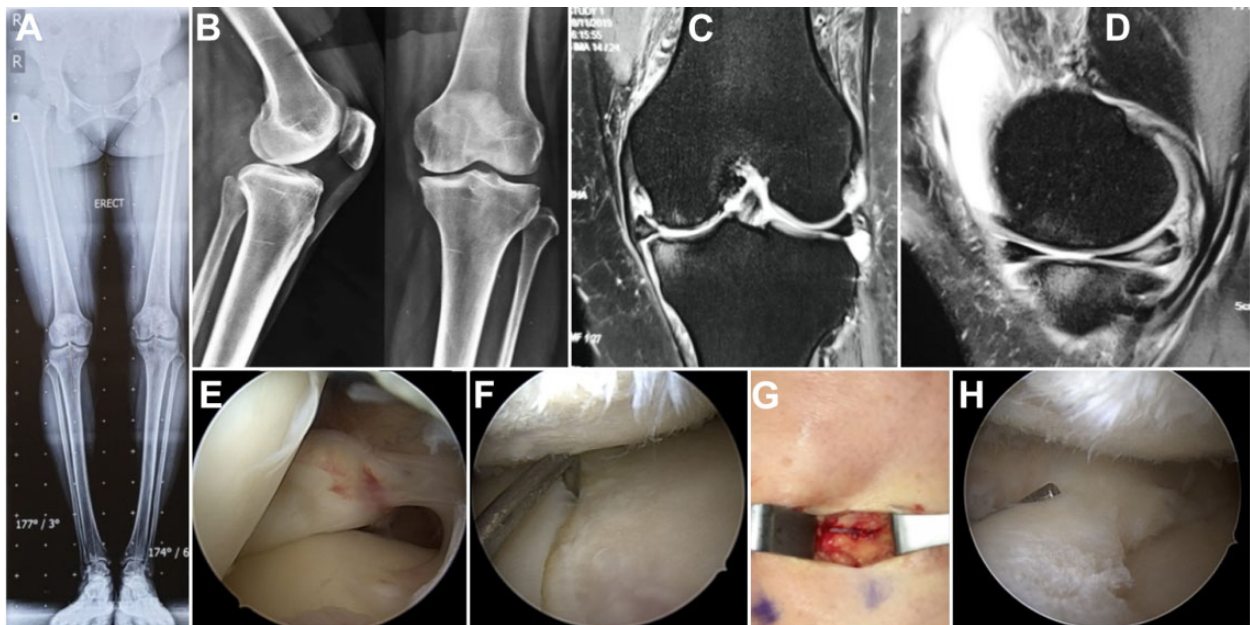


Figure 5. (A) No malalignment on long-leg alignment views. (B) Preoperative weightbearing radiographs of the knee. (C) MRI coronal section showing >3 mm of extrusion of the medial meniscus. (D) Sagittal MRI view showing posterior horn medial meniscus root tear. (E) Arthroscopic view showing root tear. (F) Arthroscopic view showing meniscal extrusion with exposed tibial plateau rim. (G) Medial mini-incision wound showing meniscotibial ligament repair with bridging technique. (H) Arthroscopic view showing reduction of meniscus over the tibial plateau.

required, single or multiple anchor-based fixation sutures may be required to maintain reduction of the meniscus on the tibial plateau (Figure 4, C and D). Dean et al²¹ used a transosseous pull-through technique for centralization of medial meniscal extrusion in a patient requiring revision meniscus root repair. Those investigators believed that placing a peripheral stabilization suture through an additional transtibial tunnel at the apex of the posterior horn helps prevent additional extrusion of the meniscus tissue outside the joint (Figure 4, E and F). Paletta et al⁶¹ placed greater emphasis on an anatomic repair of the meniscotibial ligament. The investigators biomechanically tested this method of repair and showed significant reduction in the amount of meniscal extrusion after placement of a series of anchors horizontally just beneath the tibial plateau with sutures linking one another. This suture bridging technique, by

virtue of its wide area of fixation, provides good correction for extrusion after meniscotibial ligament injury and in cases alongside root repairs where the meniscal extrusion is self-reducible (Crane classification subtype A)⁶⁰ without having to release its peripheral attachments (Figure 5).

Although several surgical techniques have been proposed in the literature to address meniscal extrusion, none have long-term follow-up data assessing efficacy.

Future Directions

Many aspects of meniscal extrusion are not well described, and epidemiological data on the incidence and prevalence are lacking, warranting further studies. Our review of the literature has identified the following areas that need further investigation:

1. Medial extrusion and lateral extrusion behave differently, with different kinematics. A study is needed that compares the characteristic findings of medial and lateral extrusion, outlining the exact value for diagnosing extrusion on either side.
2. To our knowledge, no studies have examined congenital occurrence of meniscal extrusion.
3. Histological changes in extruded menisci are unknown and need to be examined.
4. The amount of meniscal extrusion may be underestimated on supine MRI scans; hence, MRI studies under loading conditions should be conducted.
5. The exact amount of meniscal extrusion that causes biomechanical changes remains unknown.
6. We believe that reporting a percentage of extrusion with respect to the width of the meniscus may be a better measure than an absolute value.
7. Research should be conducted to evaluate the benefits of early detection and surgical treatment of meniscal extrusion in the absence of meniscal pathologies, including prevention of articular cartilage volume loss and progression of OA.
8. Laboratory-based studies are needed to develop the optimal surgical technique to restore joint contact biomechanics, and subsequent in vivo studies of such a surgical technique are required to determine any resultant improvement in functional outcomes. Prospective randomized controlled studies should be conducted to compare high tibial osteotomy (HTO) with and without meniscal extrusion correction surgery, given that Kim et al⁴¹ and Astur et al⁵ found improved pain relief with better outcomes after HTO in patients with less preoperative meniscal extrusion. However, other factors (eg, unloading of the joint, lesser OA changes) that were not identified in these studies might influence outcome after HTO.
9. Finally, randomized studies with long-term follow-up comparing isolated root repairs and root repairs with extrusion correction are needed.

CONCLUSION

Meniscal extrusion appears to be a lesser known albeit common condition that most likely contributes to accelerated degenerative changes of the articular cartilage. Due to the relatively silent nature of the condition, current ambiguity in definitions, difficulty in clinical diagnosis, and a low awareness among surgeons, a high index of suspicion is warranted for timely diagnosis. Operative treatment involves addressing the underlying pathology, commonly meniscus root or substance tear, and correcting the meniscal extrusion. Surgical techniques to correct meniscal extrusion are evolving, and mid- to long-term results are awaited to determine whether these procedures prevent progression of OA. For now, research on this topic is insufficient, and further studies are needed to allow better understanding and management of this condition.

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