Pictorial Essay

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대한영상의학회지

# Preoperative Meniscus: Pitfalls and Traps to Avoid

## 수술 전 반월연골: 피해야 할 함정들

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**Recipient of a Gold medal award for an education exhibit at the 2019 KCR Annual meeting.**

To accurately interpret knee MRI, it is important not only to know the basic meniscal anatomy but also to distinguish it from that under pathological conditions. Thus, it would be helpful to know the normal meniscus variants (false positives) that could be mistaken for meniscal tears, and tears that could easily be missed and incorrectly diagnosed as normal (false negatives). False positives include synovial recesses, meniscal flounce, the relationship between the popliteus tendon and lateral meniscus, transverse ligament, the anterior root of the meniscus, and meniscofemoral ligament. False negatives include focal radial tears, flap tears, posterior root tears, meniscocapsular separation, and discoid meniscal tears. In this pictorial essay, we reviewed the imaging data obtained in the aforementioned cases.

**Index terms** Knee; Meniscus; Tibial Meniscus Injuries; Knee Joint; Magnetic Resonance Imaging

## INTRODUCTION

MRI is one of the most commonly used techniques to evaluate the knee meniscus. The diagnostic sensitivity and specificity of MRI for medial meniscal tears are 87%–96% and 84%–94%, respectively, and for lateral meniscal tears are 70%–92% and 91%–98%, respectively (1). Therefore, accurate diagnosis is possible, and a correct diagnosis of meniscal pathology is one of the most important tasks in interpreting knee MRI.

This pictorial essay summarizes key points regarding the meniscus to improve the accuracy of diagnosing meniscal tears. The study objectives are as follows: learn about the anatomical structures associated with the meniscus, study radiological findings of these structures, and learn about the types of meniscal tears that are often ignored.

## NORMAL ANATOMY AND NORMAL VARIANTS (FALSE POSITIVES)

### SYNOVIAL RECESS

The medial menisci (MM) and lateral menisci (LM) are composed of anterior horn, body, posterior horn, and roots. Meniscus attaches firmly to the central tibial plateau by its roots. Meniscus is attached to the peripheral tibial plateau by the coronary ligament (2). The periphery of the medial tibial plateau is concave and the area of it is similar to are of the MM, therefore MM sticks to tibia without any excess portion. Therefore, the medial coronary ligament tightly connects tibial edge and MM (Fig. 1).

In contrast, the periphery of the lateral tibial plateau is convex and the area of it is larger than area of LM, resulting spare area around tibia. Therefore, when the lateral coronary ligament is attached to the tibial edge, it is redundant.

Synovial recesses are formed between the outer margin of meniscus and edge of tibial plateau. Large recess is easily formed around the LM rather than the MM because of the aforementioned difference in the anatomical structure (Fig. 2).

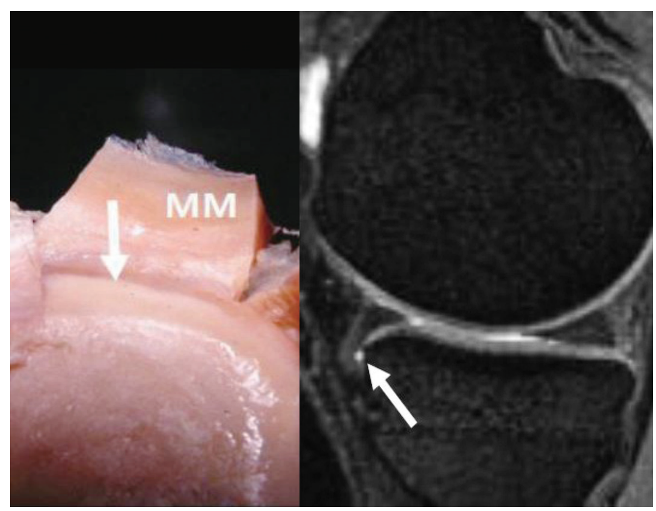



Fig. 1. MM on autopsy and sagittal fat-saturated proton-weighted density image. The MM is tightly attached to the tibial plateau; therefore, only a small recess is seen (arrows).
MM = medial meniscus

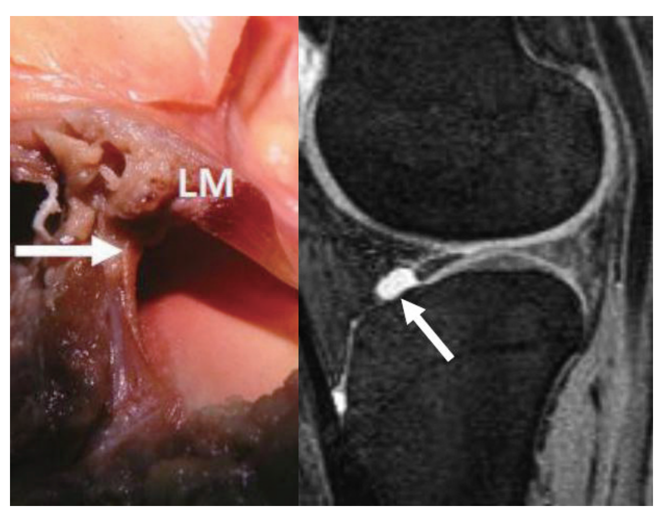



Fig. 2. LM on autopsy and sagittal fat-saturated proton density-weighted image. The lateral coronal ligament is redundant; therefore, a large recess (arrows) can be formed, and fluid collection at the recess could be mistaken for a meniscal tear.
LM = lateral meniscus

Radiologists should be careful because fluid collection in this recess can be mistaken for pathological cysts such as meniscal or ganglion cyst (Fig. 3).

## MENISCAL FLOUNCE

Meniscal flounce is a phenomenon in which the medial part of the meniscus appears to be wrinkled (Fig. 4). It is mostly observed in the MM and rarely in the LM. A study found that the incidence of meniscal flounce in asymptomatic knees was approximately 0.2%–0.3% (3); however, another study reported that it was 5% (4). An initial report on meniscal flounce indicated that meniscal flounce should be evaluated and observed only in the absence of meniscal tears because sometimes tears may appear similar to flounce-like folds (5).

According to Park et al. (4), meniscal flounce is a phenomenon in which the free edge is

Fig. 3. Lesions that can be mistaken for the recess of the lateral meniscus.
A. Loose body (arrow) on proton density-weighted image.
B. Cartilage defect is seen at the lateral femoral condyle (double arrow) and fragment of articular cartilage is seen adjacent to lateral meniscus (arrow) on T2 weighted image.
C. Fluid-fluid levels is seen in patient with hemarthrosis on fat-saturated proton density-weighted image (arrows).

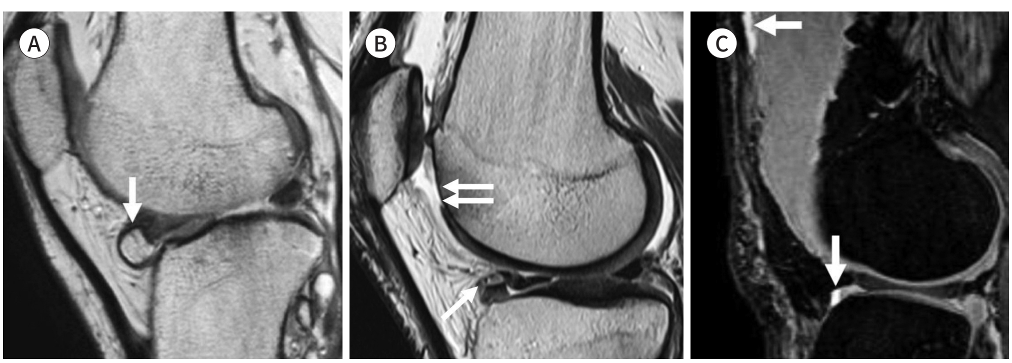



Fig. 4. Meniscal flounce on left knee MRI in a 27-year-old male.
On Sagittal proton density-weighted image, ripple-like meniscus (arrow) is observed.

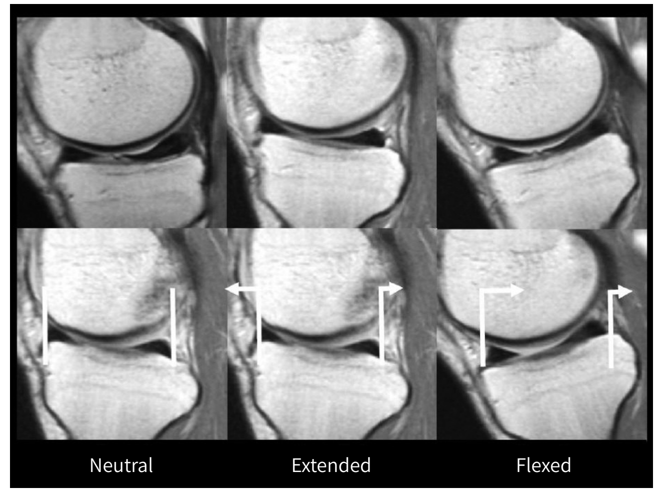



Fig. 5. Dynamic study of meniscal flounce.
The size of the arrows indicates the amount of movement. Meniscal flounce is observed in a neutral position. Meniscal flounce is not observed on extension. Meniscal flounce is clearly observed on flexion.

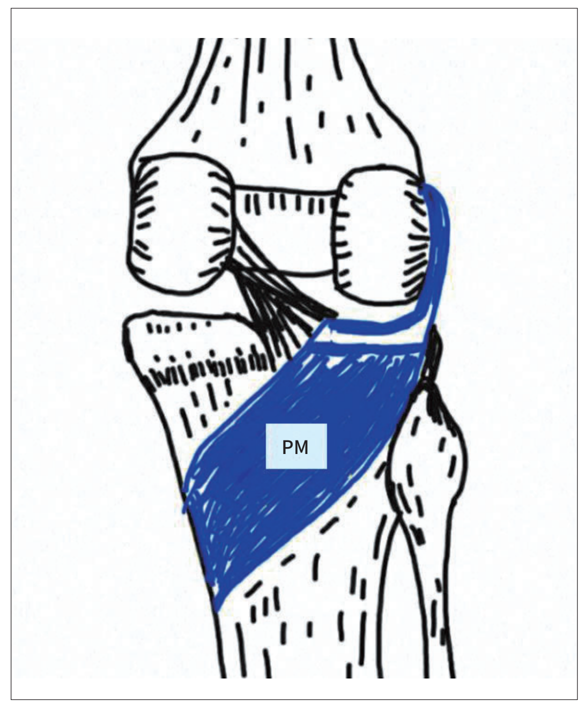



Fig. 6. Schematic of the PM.
The PM covers the lower half of the posterior fossa. The medial two-thirds of the PM is attached to the posterior surface of the posterior horn of the lateral meniscus. The lateral compartment of the PM (popliteus tendon) is attached to the anterior portion of the popliteal groove.
PM = popliteus muscle

folded. The anterior and posterior horns of the MM are tightly attached to the tibia. Therefore, during knee joint flexion and extension, the distance between them changes, resulting in folding of the free edge (Fig. 5). Therefore, it is rarely observed in the LM, which is loosely attached to the tibia.

Meniscal flounce is not related to the incidence of meniscal tears (5). However, the wavy-shape can be mistaken for meniscal tear and degeneration. All coronal, sagittal, and axial images should be reviewed to distinguish meniscal flounce from meniscal tear. Readers should confirm if a signal change in proton density (PD) or T2 weighted image (T2WI) is observed.

## RELATIONSHIP BETWEEN THE POPLITEUS TENDON AND LM

The popliteus muscle covers the lower third of the popliteal fossa and is divided into medial and lateral compartments. The medial compartment is attached to the posterior surface of posterior horn of the LM. The lateral compartment (popliteus tendon) is attached to the popliteal groove after passing through the joint (Fig. 6).

The popliteus tendon enters the joint through the popliteal hiatus, where the meniscus and capsule are separated from the posterolateral portion of the LM. The popliteal hiatus is attached to capsules with posterosuperior popliteal fascicle and anteroinferior fascicle (6).

The popliteus tendon passing through the popliteal hiatus may be mistaken for vertical tearing of the posterolateral portion of the LM because of increased MRI signal intensity (SI) in the hiatus due to fluid (Fig. 7) (7). Therefore we reviewed a series of sagittal images to follow the driving course of the popliteus tendon.

The bifurcated popliteus tendon is a normal variant of the popliteus tendon. Studies have reported that its incidence is approximately 0.4% (8). However, it is important because it can be mistaken for meniscal tear due to its morphological shape.

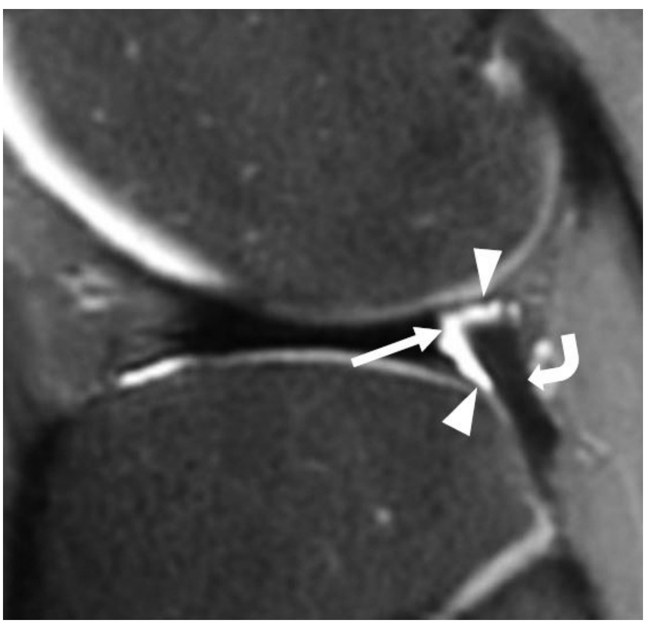


Fig. 7. Popliteal hiatus on sagittal fat-saturated proton density-weighted imaging.
The popliteus tendon (curved arrow) enters the joint through the popliteal hiatus (arrow) (arrowheads: fascicles).

Fig. 8. Bifurcation of the popliteus tendon on fat-saturated proton density-weighted imaging.
A. Bifurcation of the popliteus tendon at the level of the joint space (arrow: lateral branch, double arrow: medial branch).
B. The lateral branch (arrow) is directed to the lateral femoral condyle.
C. The medial branch (arrow) is attached to the anterior horn of the lateral meniscus.

The popliteus tendon, which is originally a single strand, is divided into two strands at the joint space level. The lateral branch of the bifurcated popliteus tendon is attached to the lateral femoral condyle and the medial branch is attached to the anterior horn of the LM (Fig. 8). The bifurcated popliteus tendon can be mistaken for LM tears if one slice is observed at this time of division. Therefore, making a practice of following the popliteus tendon on the sagittal image and confirming that it is not divided is necessary.

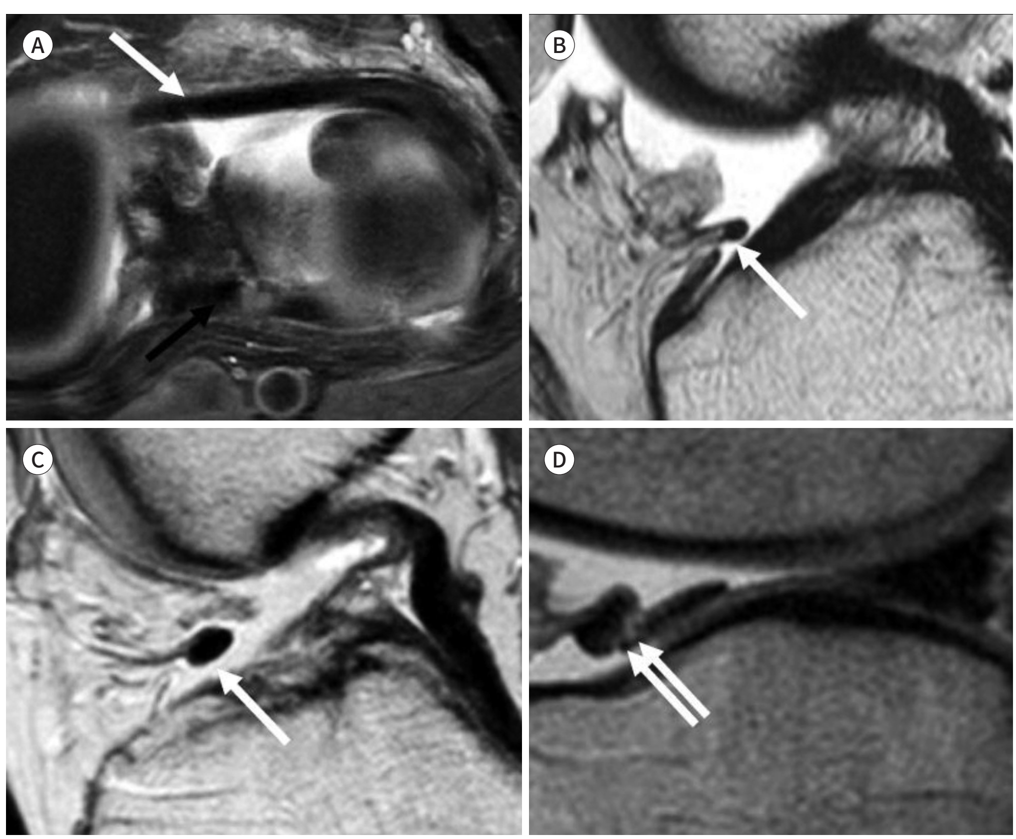
## TRANSVERSE LIGAMENT

The anterior transverse ligament connects the anterior margin of the LM and the anterior end of the MM. This helps the meniscus to stay in place by preventing anterior subluxation and excessive posterior translation of the meniscus (9).

The transverse ligament is divided into 3 types based on the attachment pattern to the meniscus. Type 1, the most common type, connects the anterior LM to the anterior MM. Type 2 connects the anterior margin of MM and the capsule of LM. Type 3 connects the capsules of MM and LM (10).

The shape of type I transverse ligament gradually changes from flat near the MM anterior

Fig. 9. Transverse ligament.
A. Transverse ligament (arrow) on axial fat-saturated proton density-weighted image.
B-D. Sagittal proton density-weighted image. (B) The shape of the transverse ligament (arrow) is flat when it leaves the medial meniscus. (C) The shape of the transverse ligament (arrow) is round just before it attaches to the lateral meniscus. (D) The space (double arrow) between the transverse ligament and the anterior horn of the lateral meniscus at the site of attachment can be mistaken for meniscal tears.



horn to round toward the LM, where it is attached to the upper part of the LM anterior horn (Fig. 9). The space between the LM anterior horn and round-shaped transverse ligament is observed as a high-intensity signal on T2WI, which can be misunderstood as an oblique meniscal tear (9). This error can be prevented with the verification of ligament adherence to the opposite meniscus in a continuous image.

## ANTERIOR ROOT OF MENISCUS

The anterior root of the meniscus typically attaches to the central tibial plateau (3) and prevents the meniscus from anterior subluxation or excessive posterior translation. The anterior root has supplemental fibers in addition to the dense root in the center (11). Supplemental fibers are sparse and therefore, can appear as a linear high-intensity signal on T2WI and can

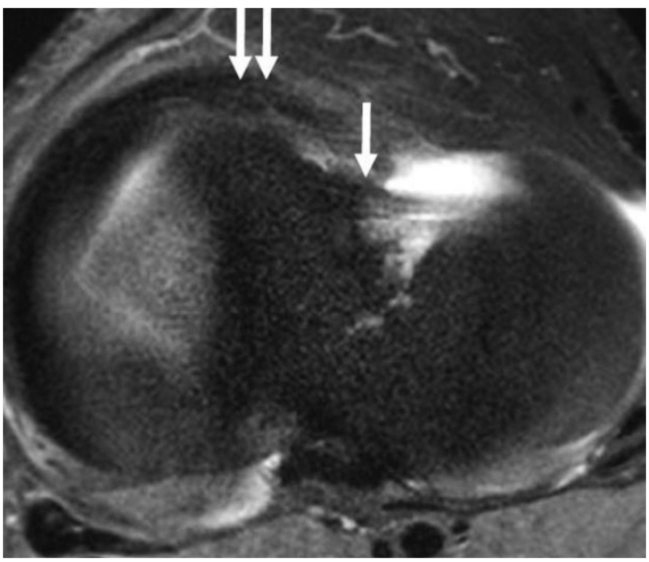


Fig. 10. The anterior root of the meniscus on fat-saturated proton density-weighted image.
Meniscal supplemental fibers develop cracks that could be mistaken for tears (double arrow: anterior root of the medial meniscus, arrow: anterior root of the lateral meniscus).

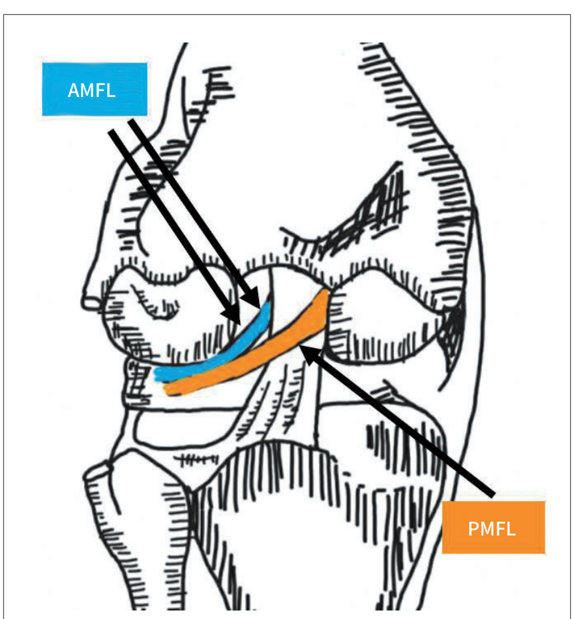



Fig. 11. Schematic of the meniscofemoral ligament.
The AMFL and PMFL originate from the posterior horn of the lateral meniscus. The AMFL passes from the front of the PCL and the PMFL passes from behind the PCL.
AMFL = anterior meniscofemoral ligament, PCL = posterior cruciate ligament, PMFL = posterior meniscofemoral ligament

be mistaken for meniscal tears (Fig. 10).

## MENISCOFEMORAL LIGAMENT

The meniscofemoral ligament originates from the posterior horn of the LM and attaches the lateral aspect of the medial femoral condyle (Fig. 11). The anterior meniscofemoral ligament or ligament of Humphrey passes from the anterior to the posterior cruciate (Fig. 12). The posterior meniscofemoral ligament or ligament of Wrisburg passes from behind the posterior cruciate ligament (Fig. 13). These two ligaments keep the meniscus in place.

Immediately after the meniscofemoral ligament is separated from the LM posterior horn, the space between the ligament and LM may appear as a high-intensity signal on T2WI, which may be mistaken for vertical meniscal tear (Fig. 14) (12).

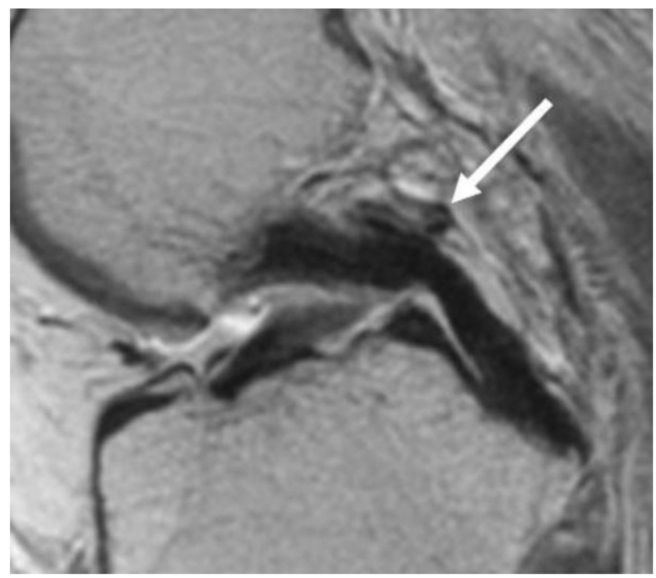


Fig. 12. The ligament of Wrisberg on proton density-weighted imaging.
The ligament of Wrisberg (arrow) is attached to the posterior horn of the lateral meniscus and passes through the posterior boundary of the posterior cruciate ligament.

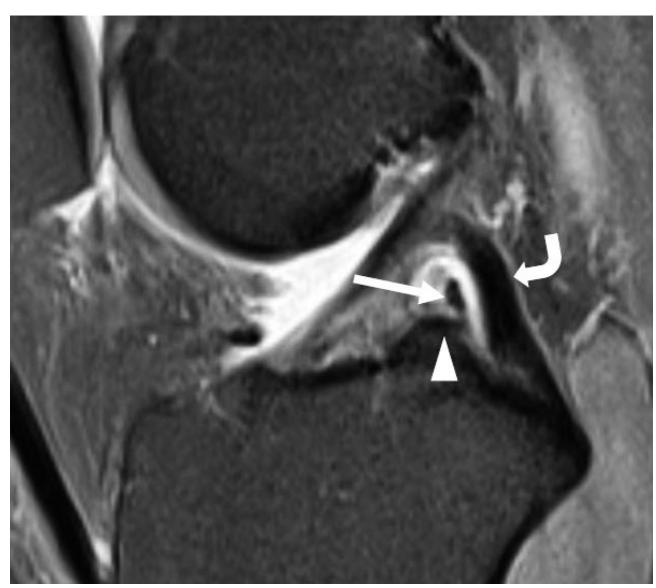


Fig. 13. The ligament of Humphrey on sagittal fat-saturated proton density-weighted imaging.
The ligament of Humphrey (arrow) is attached to the posterior horn of the lateral meniscus (arrowhead) and passes through the anterior boundary of the posterior cruciate ligament (curved arrow).

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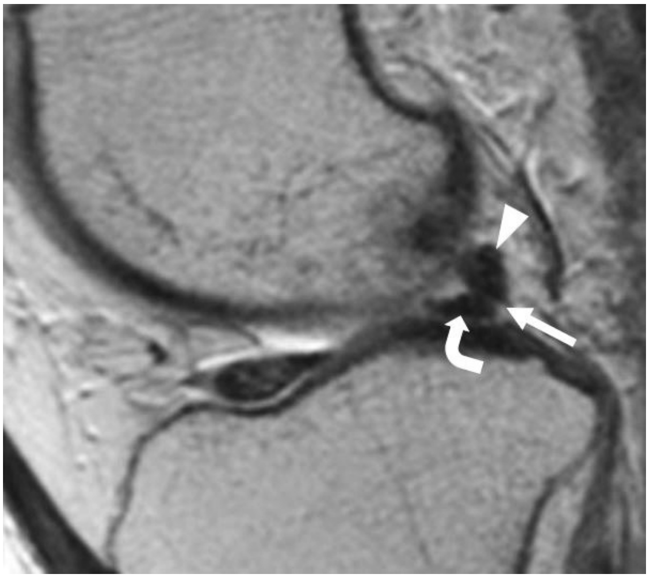


Fig. 14. The ligament of Wrisberg on sagittal proton density-weighted imaging.
Immediately after the posterior meniscofemoral ligament (arrowhead) is separated from the LM posterior horn (curved arrow), the space (arrow) between the ligament and the LM might appear as a high-intensity signal on T2 weighted image, which could be mistaken for a vertical meniscal tear.
LM = lateral meniscus

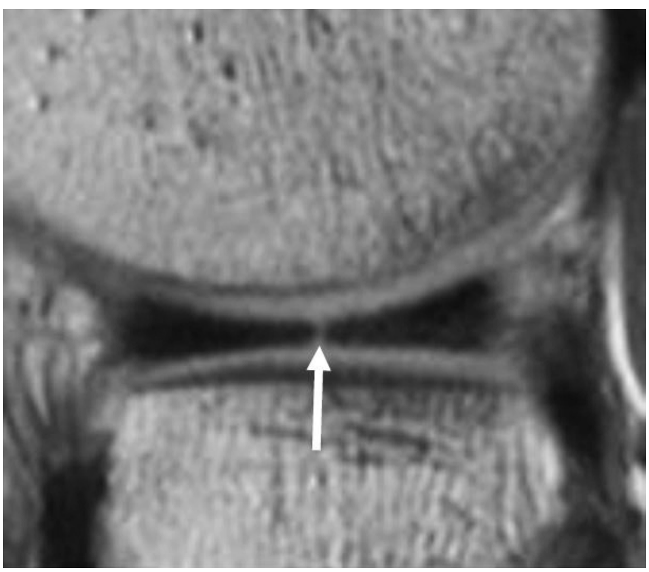


Fig. 15. Focal radial tear of the body of the lateral meniscus on sagittal proton density-weighted imaging.
The cleft sign (arrow) is observed as a linear, vertical high-signal-intensity signal on sagittal imaging.

## UNFAMILIAR TYPES OF TEARS (FALSE NEGATIVES)

### FOCAL RADIAL TEAR

Radial tear occurs perpendicular to the long axis of the meniscus (13), with common locations being the posterior horn of MM, anterior horn of LM, and junction of the body. Radial tears are commonly located in the avascular area (3).

If a radial tear occurs, the load bearing role of the meniscus disappears and the meniscus is extruded by axial loading. Consequently, degeneration easily occurs due to persistent articular cartilage damage because of friction between the femoral condyle and tibial plateau. Partial meniscectomy is commonly performed and therefore, it is important for detecting radial tear in many ways (14).

Focal radial tear is observed as a truncated triangle, cleft, marching cleft, and ghost meniscus signs. Truncated triangle sign on sagittal and coronal images means that the normal triangular meniscal contour is suddenly truncated. Cleft sign indicates a tear through the meniscus, which can be confirmed as a linear, vertical high-intensity signal on coronal and sagittal images (Fig. 15). Marching cleft sign means cleft appears to be marching inward or outward in an image series. Ghost meniscus sign means that the meniscus is not visible or it appears as a normal triangle with abnormally high SI on the image and as a normal meniscus on the next successive image (14). If the size of the radial tear is small, a small cleft is observed only on one slice or the triangular shape is observed only slightly bunched, which is easy to miss unless careful (9).

Therefore, to avoid missing the small radial tear, it is necessary to determine whether the sharpness of the free margin of the meniscus is maintained in all planes and cleft is not present.

## FLAP TEAR

Flap tears mostly occur in the center half of the meniscus and are largely divided into vertical and horizontal flap tears. The former occurs as radial tears progress and change direction to a C-shaped axis. The flap shape resembles a parrot beak and therefore, it is called a parrot-beak tear (Fig. 16). The latter is caused by the dislocation of the lower or upper leaflets on the horizontal tear. Flap tears generally cover all tears with flaps (15).

A vertical flap tear may appear similar to the cleft sign of radial tear or as a truncated inner free edge. However, unlike radial tears, linked flaps can be found on the same or adjacent cross-section images. The horizontal flap tear can be suspected if some of the upper or lower parts of the flap are displaced and the boundary of the meniscus appears blunt or the slope changes suddenly. The flap tears can be confirmed by finding displaced fragments (Fig. 17). Although the fragments are usually displaced in the central direction, they can be displaced in any direction (Fig. 18). In severe cases, the flap may disintegrate completely (16). Although flaps are often observed on sagittal images, radiologists should confirm that no flaps are observed on coronal as well as axial images.

## POSTERIOR ROOT TEAR

The posterior root of the MM resists tibial external rotation and lateral translation. The posterior root of the LM contributes to stabilization by supporting the anterior cruciate liga-

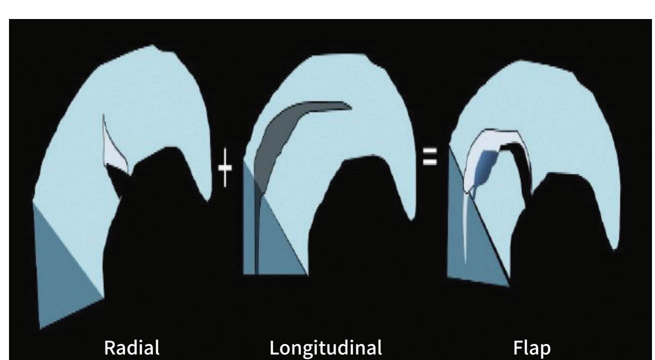



Fig. 16. Vertical flap tear (parrot beak tear).
A parrot beak tear is a combination of a radial tear of the inner meniscal edge and a longitudinal tear of the meniscal periphery.

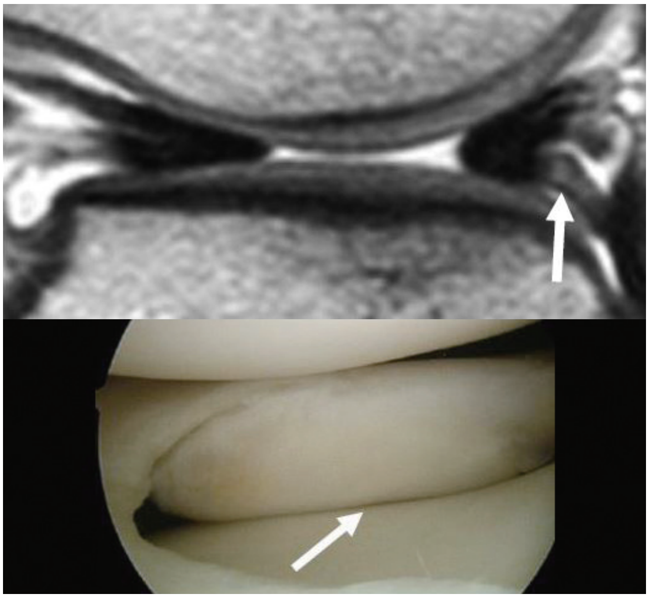


Fig. 17. Displaced flap tear on sagittal proton density-weighted imaging and arthroscopic imaging.
A flap tear of the lateral meniscus is observed with the torn segment (arrows) folded and overlapped beneath the posterior horn.

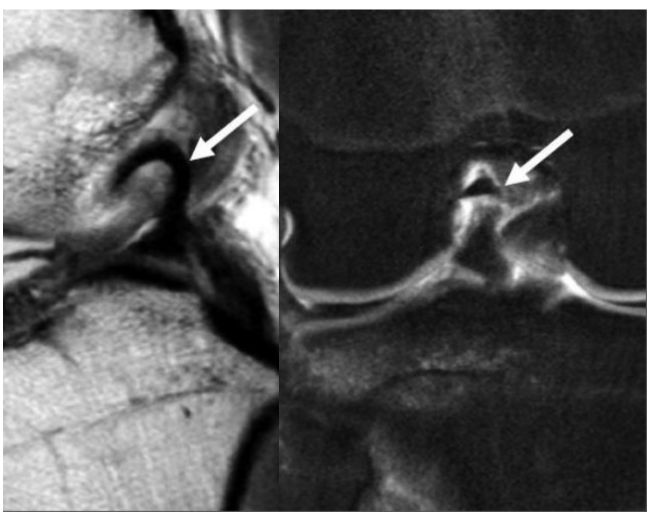


Fig. 18. Vertical flap tear of the lateral meniscus on sagittal proton density-weighted imaging and coronal fat-saturated proton density-weighted imaging.
The torn fragment (arrows) of the posterior horn of the lateral meniscus is bent and displaced upward.

ment (ACL) during pivot shift loading (17).

Meniscal root tear is a radial tear that usually occurs within 1 cm from the tibial attachment of the meniscal root (18). The most common site of tear occurrence is the posterior root of the MM and is often accompanied by meniscal extrusion (Fig. 19). The incidence of posterior root tear of the LM increases up to 3 times with the presence of an ACL tear (18). If ACL damage is suspected, the posterior root should be examined.

In addition, if marrow edema or insufficiency fracture in the tibiofemoral compartment is present, it may be accompanied by posterior root tear (11).

## MENISCOCAPSULAR SEPARATION

Meniscocapsular separation is the detachment of the meniscus from the capsule, which occurs more often in the MM because the MM is firmly attached to the capsule and is less

Fig. 19. Posterior root tear of the medial meniscus.
A. On axial fat-saturated proton density-weighted imaging, a meniscal root tear (arrow) is a radial tear within 1 cm of the meniscal root attachment.
B. On coronal fat-saturated proton density-weighted imaging, a meniscal root tear (arrow) is seen with meniscal extrusion (double arrow).

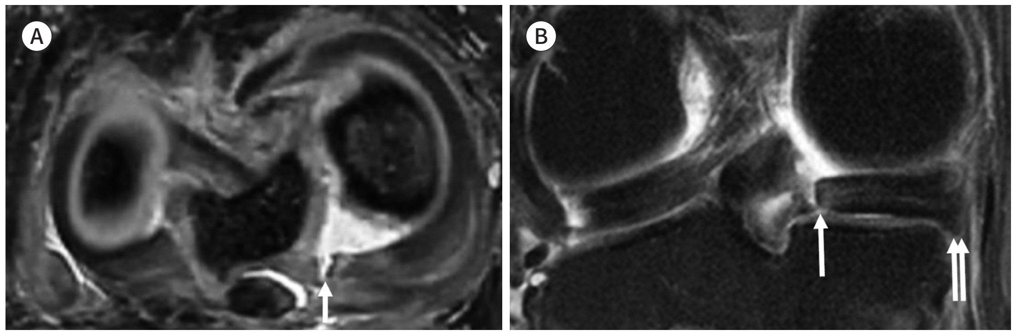
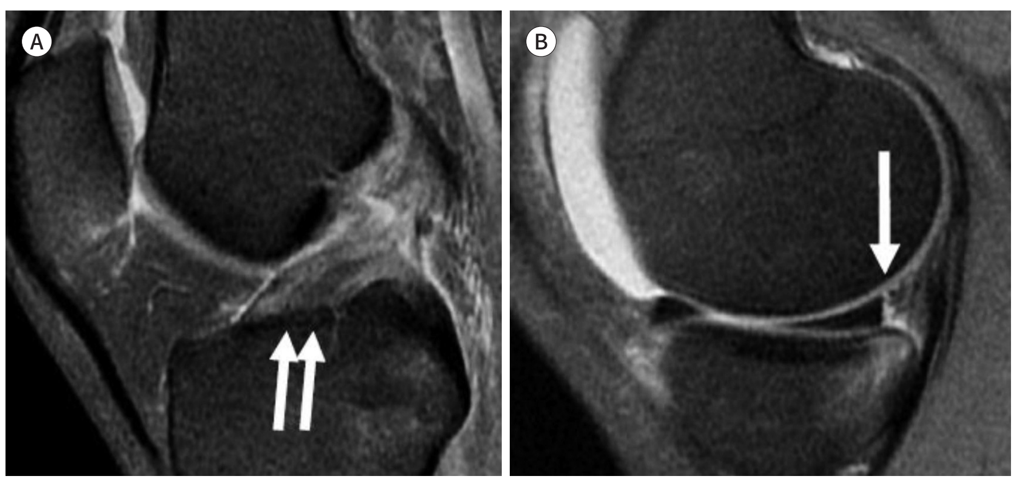



Fig. 20. Meniscocapsular separation with an anterior cruciate ligament tear on sagittal fat-saturated proton density-weighted imaging.
A, B. Meniscocapsular separation (arrow) is observed in the posterior horn of the medial meniscus in patients with anterior cruciate ligament tears (double arrow).




flexible under force. To understand meniscocapsular separation, understanding the anatomy of the medial meniscocapsular area is necessary. Anatomy of the medial meniscocapsular area from the outside of the knee: the crural fascia (layer 1), superficial portion of the MCL (layer II), and the deep MCL and capsule (layer III). The meniscofemoral and meniscotibial ligaments are extensions of the deep MCL. No clear distinction is noted between the peripheral MM and capsule (19).

However, under ACL injury-induced valgus force, meniscocapsular separation may occur, detaching the MM from the capsule (Fig. 20). In this case, posterior horn injury of the MM or bone contusion is often accompanied. Perimeniscal fluid and irregular meniscal outline are visible on MRI. However, a high-intensity signal on T2WI is prominent if significant amount of fat is present between layers II–III, which can be mistaken for separation. In addition, pitfalls that can mimic perimeniscal fluid include perimeniscal joint recess, MCL bursitis, and meniscal cysts (19).

The meniscocapsular separation is easier to miss than meniscal tear. Therefore, making a practice of confirming that no abnormal finding at the meniscus attachment site is present is necessary.

## DISCOID MENISCUS

The discoid meniscus is larger than the normal meniscus and extends to the tibial articular surface (3). It is more common (0.4%–17.0%) in the LM than the MM (0.1%–0.3%). It is bilateral in approximately 20.0% (20).

According to the Watanabe classification, the discoid meniscus has three types. The complete discoid meniscus covers the entire tibial plateau, whereas the incomplete discoid meniscus covers less than 80% of the tibial plateau (20). Diagnosis of the complete discoid meniscus is relatively easy on the image because the anterior and posterior horns are not distinguished. Additionally, the free edge of the center is in contact with the intercondylar notch.

However, the incomplete discoid meniscus is only slightly thicker than normal meniscus and differentiating the anterior horn from the posterior horn is easy. Considering that the normal LM radial diameter is approximately 11–12 mm, the discoid meniscus can be diagnosed when the radial diameter is > 15 mm on a coronal image (21) or > 3 bow-tie appearances of 4–5 mm thickness on continuous sagittal images (3).

The Wrisberg variant has relatively normal semilunar appearance. However, there is a lack of posterior meniscal attachement and only Wrisberg ligament connects the posterior horn of the lateral meniscus. On T2WI image, high SI between the LM and capsule is characteristic and can be mistaken for tear. A ring-shaped meniscus is rare, but sometimes referred to as the discoid meniscus.

The discoid meniscus is more vulnerable to tears due to less collagen fiber, destroyed orientation of normal collagen, and frequent intrameniscal mucoid degeneration (21). In addition, if the degeneration is severe, it may be difficult to distinguish degeneration of discoid meniscus from horizontal tears.

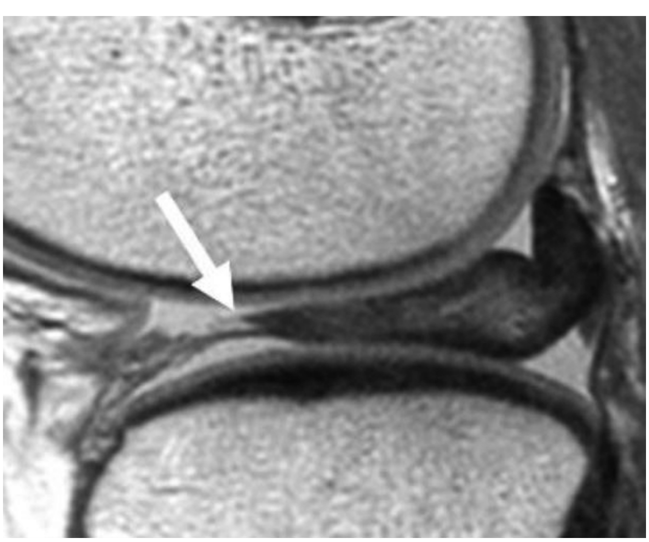


Fig. 21. Tears of the discoid meniscus in a 14-year-old boy.
Meniscocapsular separation of the anterior horn of the discoid meniscus (arrow) and the posteriorly displaced meniscus are observed on proton density-weighted imaging.

Tear of the discoid meniscus can be suspected if the size of the remaining meniscus is large enough despite the displacement of a large fragment (22). Meniscocapsular separation and complex tears are common in the discoid meniscus (Fig. 21).

## CONCLUSION

To read knee MRI, understanding meniscus anatomy is important. Knowledge of normal variants that can be mistaken for lesions and tears that can be easily missed will assist to properly interpret the pathology of the meniscus in daily practice.

### Author Contributions

Conceptualization, R.K.N.; data curation, Y.H.J.; formal analysis, Y.H.J., K.H.J., K.H.S.; investigation, Y.H.J., K.G.H.; methodology, R.K.N., J.W., P.J.S., P.S.Y.; project administration, R.K.N.; resources, R.K.N.; supervision, R.K.N.; validation, J.W., P.J.S. P.S.Y.; visualization, Y.H.J. J.W.; writing—original draft, Y.H.J., R.K.N.; and writing—review & editing, J.W., P.J.S.

### Conflicts of Interest

The authors have no potential conflicts of interest to disclose.

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## 수술 전 반월연골: 피해야 할 함정들

유혜진[1] · 류경남[1*] · 박지선[1] · 진 욱[2] · 박소영[2] · 강혜진[1] · 김현수[1] · 권진혁[2]

무릎 MRI를 정확하게 판독하려면 기본적인 반월연골 해부학을 아는 것뿐만 아니라 병적 상태와 구별하는 것이 중요하다. 따라서 반월연골 열상으로 쉽게 오인될 수 있는 정상 변이(위양성)와 쉽게 놓쳐서 자칫 정상으로 오인될 수 있는 반월연골열상들(위음성)을 아는 것이 판독에 도움이 될 것이다. 위양성에는 활막 오목, 반월연골 주름, 슬와 힘줄과 외측 반월연골 사이의 관계, 가로 인대, 반월연골 앞 근 및 반월대퇴 인대가 포함된다. 위음성에는 국소 방사열상, 피판 열상, 뒤 근 열상, 반월연골-관절낭 분리, 원반모양반월연골의 열상이 있다. 이번 임상화보에서는 앞서 언급한 상황들로부터 얻은 영상자료들을 검토해보았다.

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