Review paper

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Static and dynamic ultrasound assessment of peripheral meniscal lesions: diagnostic value and clinical applications

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Abstract

Meniscal injuries are frequent findings in clinical practice and may arise from acute trauma, progressive degeneration, or joint instability. While MRI remains the gold-standard modality for identifying these lesions, ultrasound has emerged as a valuable complementary technique thanks to its accessibility, low cost, real-time capability, and ability to perform dynamic assessments at the point of care. Increasingly, clinicians and radiologists are relying on ultrasound to detect and characterize subtle meniscal abnormalities that might otherwise be missed or underestimated. This review summarizes the principal static and dynamic sonographic features associated with meniscal tears, complex disruptions, and unstable flap fragments. Particular attention is given to the identification of ramp lesions, which involve the meniscocapsular junction and can be challenging to diagnose using conventional imaging alone. The article also discusses the evaluation of meniscal extrusion, a key indicator of structural compromise and a predictor of osteoarthritic progression. By highlighting characteristic ultrasound patterns and demonstrating how dynamic maneuvers can enhance diagnostic confidence, this work underscores the expanding role of ultrasound as an efficient, patient-centered imaging tool that complements MRI and supports a more comprehensive assessment of meniscal mechanical pathology. These insights ultimately contribute to more accurate treatment planning and improved patient outcomes.

Introduction

Meniscal injuries are common and may result from trauma, degeneration, or joint instability. MRI is considered the reference imaging technique, but ultrasound offers advantages such as availability, dynamic assessment, and patient proximity. Ultrasound is therefore increasingly used for the evaluation of meniscal lesions. This article reviews the static and dynamic ultrasound features of meniscal tears, flaps, ramp lesions, and meniscal extrusion, with emphasis on the role of ultrasound as a complementary imaging modality.

Ultrasound analysis of the meniscus

Meniscal assessment is performed using high-frequency probes ranging from 12 MHz to 24 MHz. The anterior and middle horns are examined with the patient in the supine position, while the posterior horns are evaluated with the patient in the prone position. The anterior horn cannot be completely visualized by US because it is not possible to place the transducer perpendicular to the structure. Some authors recommend performing dynamic maneuvers involving knee flexion and rotation to detect meniscal instability, particularly in cases of anterior cruciate ligament (ACL) rupture[(1)].

The meniscus appears as a well-defined triangular echogenic structure on longitudinal scans. At the level of the middle horn of the medial meniscus, it lies in close contact with the medial collateral ligament. Axial views of the meniscus are feasible but generally contribute little, except in the presence of parameniscal cysts. The superficial and deep surfaces of the meniscus are in contact with the hyaline cartilage of the femoral condyle and the tibial plateau[(2)].

Posterior to the posterior horn of the lateral meniscus, the popliteal recess appears as a hypoechoic linear structure, which should not be mistaken for a capsulomeniscal detachment. Capsular attachments vary depending on the horn and are difficult to identify precisely. On color Doppler imaging, a small vascular structure– a genicular artery – is often observed and should not be misinterpreted as pathological hypervascularization[(3,4)].

Ultrasound of meniscal tears

Several ultrasound features can be identified:

- disruption (hypoechoic or anechoic) of this echogenic structure on longitudinal scans;
- presence or absence of a meniscal flap: a displaced meniscal fragment still in continuity with the meniscal body;
- internal meniscal subluxation defined as meniscal extrusion greater than 3 mm beyond the bicortical line;
- perimeniscal synovitis seen as hypervascularity on color Doppler;
- abnormalities of the meniscal horn such as root or longitudinal tears(5,6).

Osteophytes (echogenic beak-like projections on the tibial or femoral side) may also be present (Fig. 1).

Ultrasound of meniscal flaps

A meniscal flap results from a horizontal, vertical, or oblique fissure that causes displacement of a meniscal fragment into the superior or inferior meniscotibial recess, or into the intercondylar notch. These unstable lesions are important to identify on MRI, as they may be difficult for surgeons to detect if the fragment has migrated into a meniscotibial or meniscofemoral recess(7). The main differential diagnosis is meniscal subluxation. Occasionally, these fragments may cause osteomeniscal impingement on the medial and proximal portion of the medial tibial plateau. MRI remains the gold standard for diagnosing flaps, and coronal sequences are particularly useful to describe the characteristic "comma-shaped" appearance and assess fragment migration into the meniscotibial recess. Differentiating between a meniscal flap and meniscal subluxation is essential: flaps are often highly symptomatic and may require surgical treatment for osteomeniscal impingement, whereas meniscal subluxation (without meniscal root injury) is typically managed conservatively(8). Although MRI and CT arthrography are reference imaging techniques, ultrasound offers many advantages, such as wide availability, the possibility to perform dynamic maneuvers or upright evaluations, patient proximity (helping correlate symptoms with imaging findings), and the ability to perform therapeutic tests using lidocaine and corticosteroids.

Ultrasound is increasingly used as a first-line diagnostic tool in trauma assessment to complement clinical and initial radiographic evaluations(9). A meniscal flap may be identified in the meniscotibial or meniscofemoral recess, appearing as an echogenic structure in continuity with the meniscal body. Peripheral hypervascularization on color Doppler may also be observed (Fig. 2, Fig. 3).

Ultrasound of ramp lesions

The "meniscal ramp" refers to the capsulomeniscal junction located posterior to the posterior horn of the medial meniscus. Ramp lesions were first described in 1980. Arthroscopic repair techniques were first reported in 1991, and later in 2004 using a posteromedial approach. These lesions have sometimes been referred to as "hidden lesions" because of the difficulty in identifying them using imaging and arthroscopy(10). Ramp lesions are relatively common, found in 9–17% of anterior cruciate ligament (ACL) tears. Although spontaneous healing is the most frequent outcome, detecting these lesions is important because they may contribute to posteromedial instability and are considered a potential cause of graft failure and early degenerative changes. Furthermore, the performance of MRI in detecting ramp lesions is variable, as they are often mistaken for vertical longitudinal intrameniscal tears(11,12). With the increasing use of ultrasound and the improved performance of matrix transducers, numerous studies on meniscal pathologies have emerged in the orthopedic literature, with variable diagnostic accuracy depending on the lesion type. Ramp lesions are peripheral lesions (i.e., not involving the fibrocartilage) and therefore have healing potential due to peripheral vascularity.

Classification of ramp lesions is based on tear topography(13):

- Type 1: capsulomeniscal (synovial) lesion;

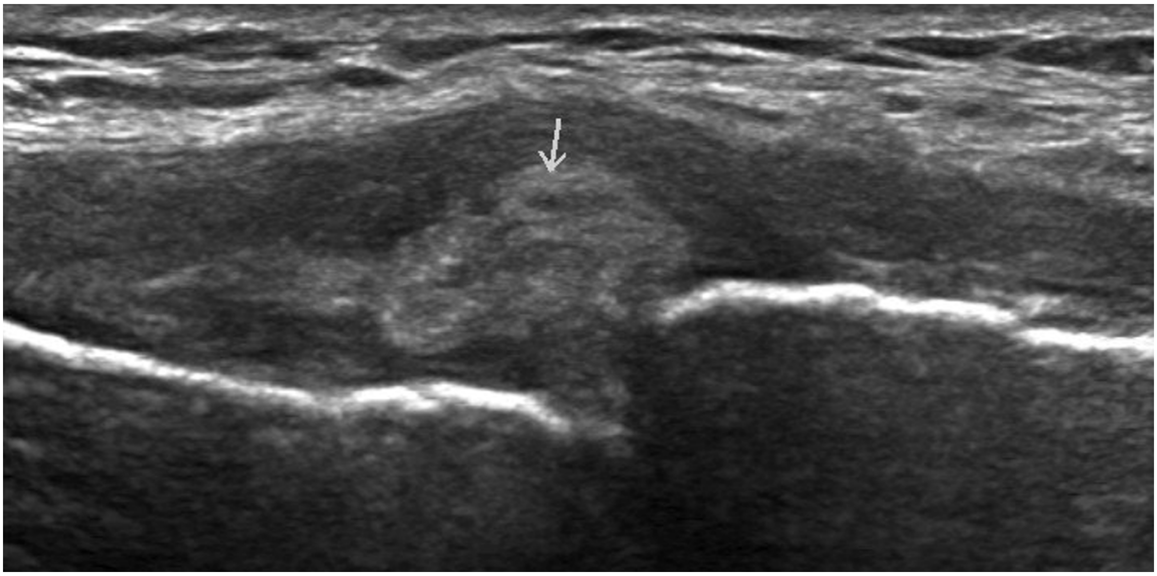

Fig. 1. *Medial sagittal US image showing a central meniscal tear in the meniscotibial recess (white arrow)*

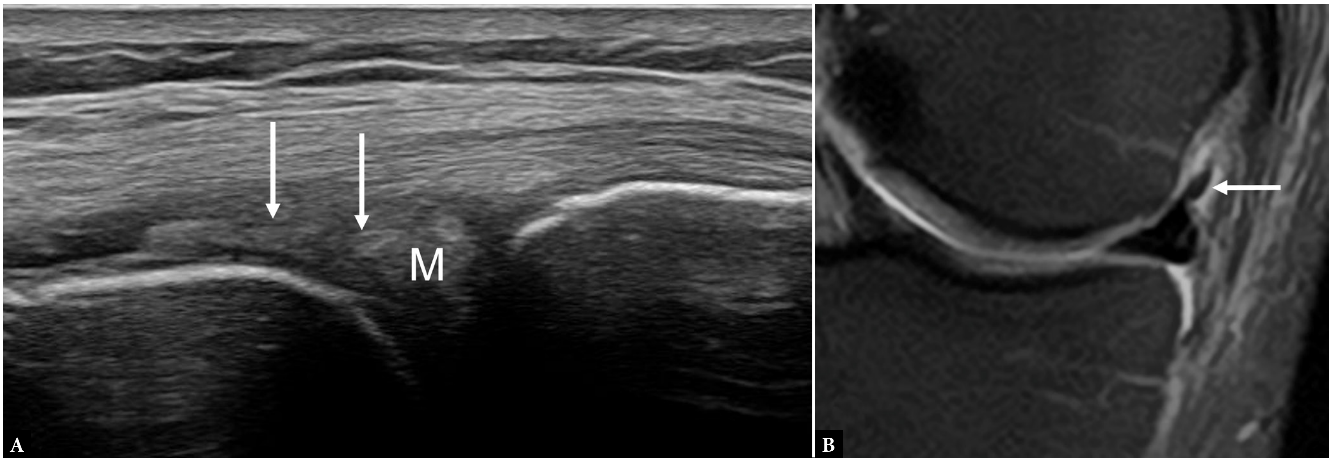

Fig. 2. A. *Medial sagittal US image showing a flap tear (white arrow) of the medial meniscus in the meniscofemoral recess.* **B.** *Comparison with coronal DP-FS MRI*

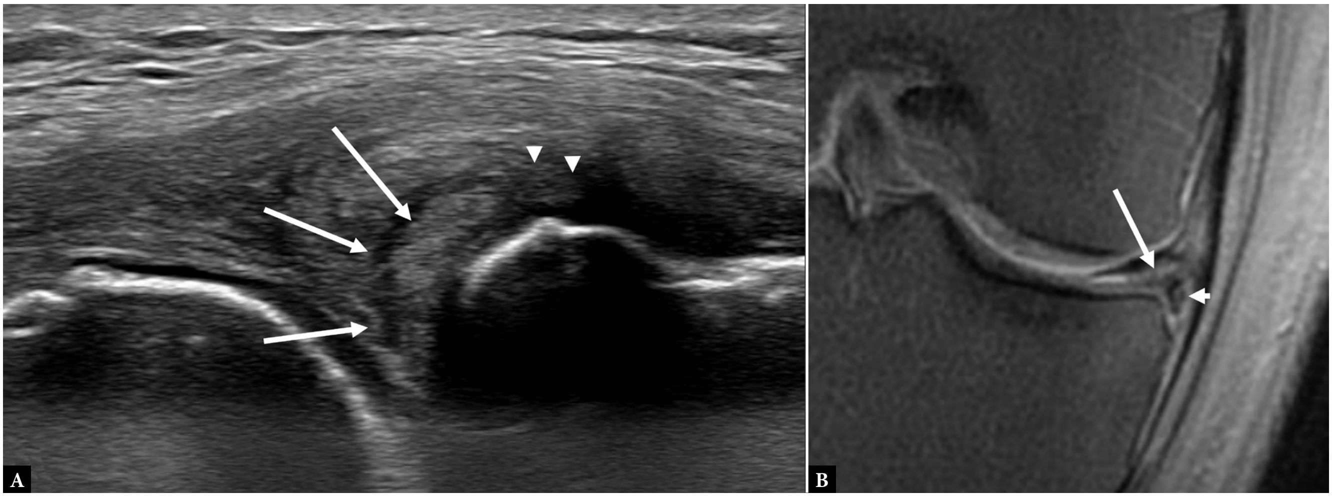

Fig. 3. A. *Medial sagittal US image showing a flap tear (white arrow and arrowhead) of the medial meniscus in the meniscotibial recess.* **B.** *Comparison with coronal DP-FS MRI*

- Type 2: partial superior lesion;
- Type 3: partial inferior lesion;
- Type 4: complete full-thickness lesion;
- Type 5: complete double lesion (with associated vertical longitudinal intrameniscal tear).

In our experience, ultrasound shows an anechoic linear image, best visualized on sagittal and axial views. In some cases, this area was considered equivocal: the junction appeared heterogeneous but without a clear fissure. No Doppler hyperemia was observed in any patient (Fig. 4, Fig. 5, Fig. 6, Fig. 7).

Ultrasound of dynamic meniscal snapping

Meniscal snapping or clicking denotes a mechanical phenomenon often associated with partial meniscal tears, flap tears, meniscocapsular detachment, or anatomical variants such as a discoid meniscus. Clinically, these phenomena may present as intermittent audible or palpable snapping, often provoked by movement, flexion-extension, or weight-bearing changes. Accurate diagnosis is crucial for guiding conservative versus surgical treatment, minimizing morbidity[14]. Dynamic ultrasound involves real-time imaging, with the knee moved through maneuvers that reproduce the snapping, including flexion-extension and internal/external rotation, often in both non-weight-bearing and weight-bearing positions. Transient displacement or translation of meniscal tissue, particularly at the periphery or toward parameniscal recesses can be observed. Cine loops and video capture during provocative maneuvers can further enhance diagnostic yield[15].

Different findings may be observed:
- Meniscal instability: Flap tears or peripheral tears may allow fragments or parts of the meniscus to translate beyond their normal anatomical confines, producing snapping when the fragment impinges or suddenly re-enters the joint with movement. Dynamic US may show a heterogeneous hypoechoic mass-like lesion that moves in and out of the meniscal recess with flexion/extension[16].
- Medial meniscal subluxation in osteoarthritis (OA): In knee OA, the medial meniscus tends to subluxate medially under

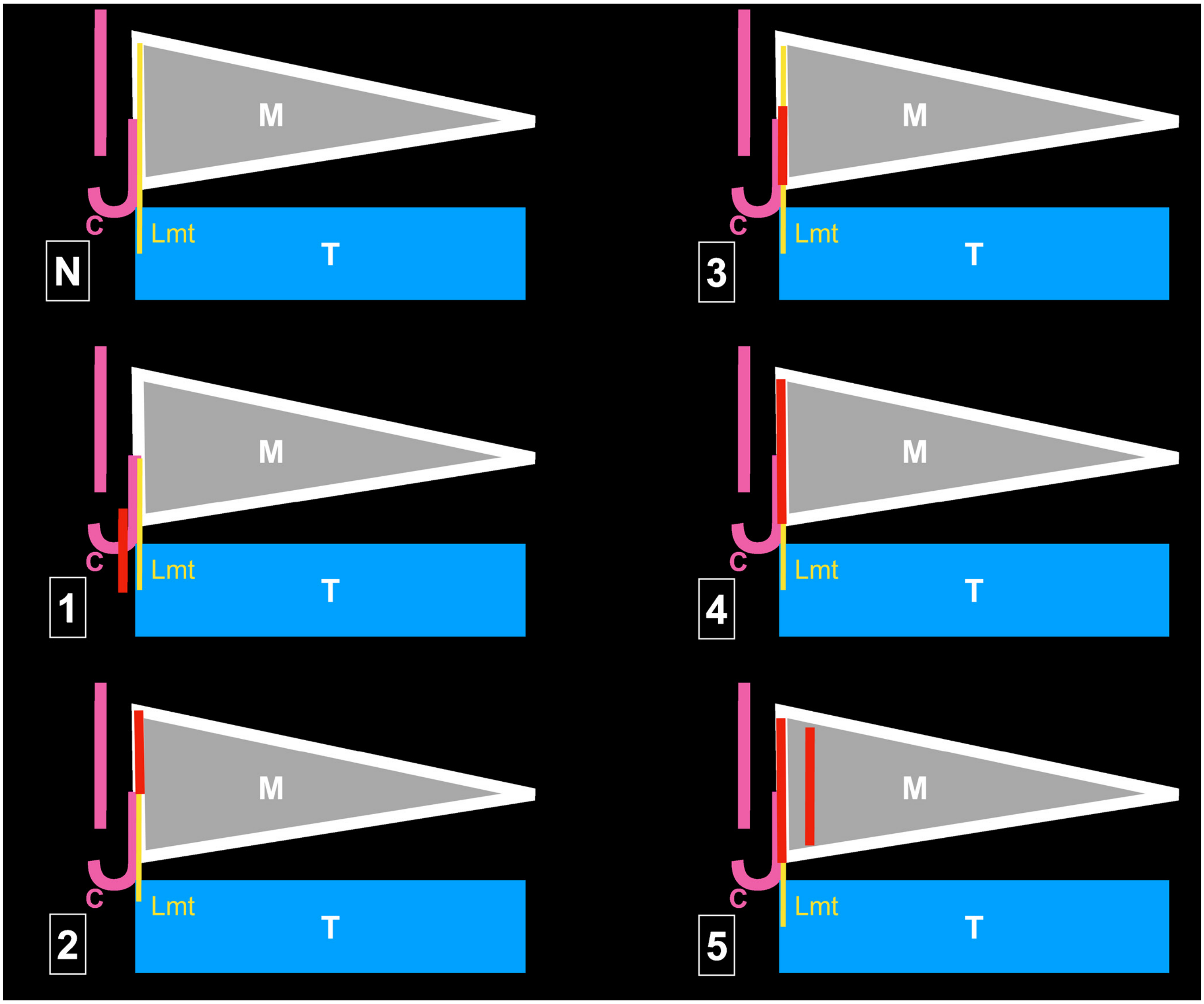

Fig. 4. *Classification of ramp lesions. Type 1: capsulomeniscal (synovial) lesion; Type 2: partial superior lesion; Type 3: partial inferior lesion; Type 4: complete full-thickness lesion; Type 5: complete double lesion (with associated vertical longitudinal intrameniscal tear)*

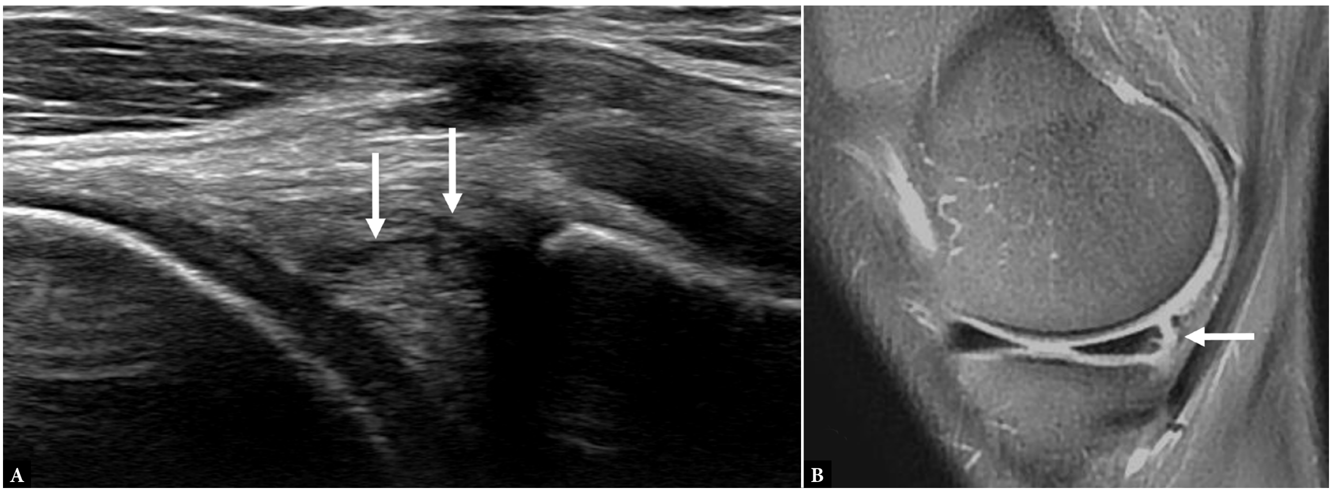

Fig. 5. A. *Medial sagittal US image showing a type 4 ramp lesion (white arrow) of the posterior horn of the medial meniscus.* **B.** *Comparison with sagittal DP-FS MRI*

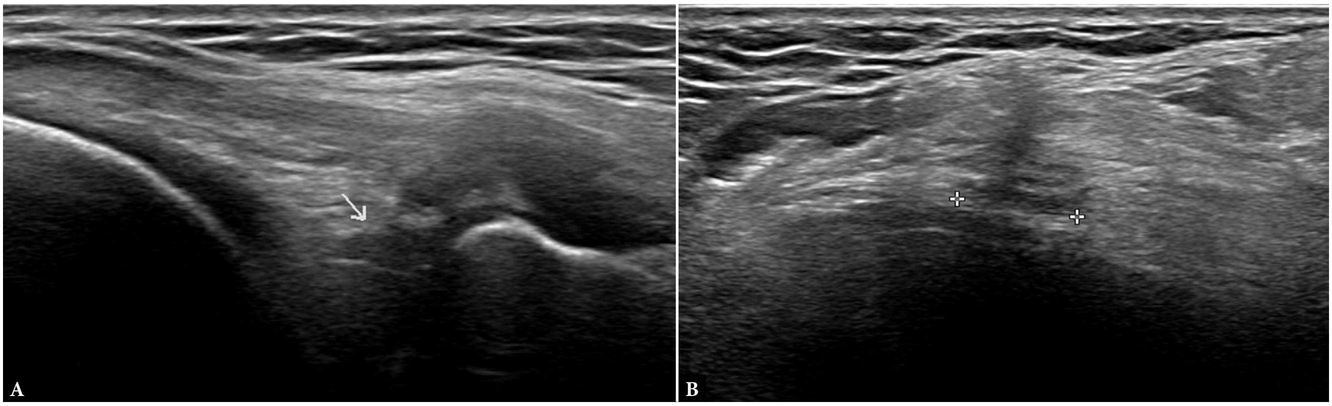

Fig. 6. *Medial sagittal (**A**) and axial (**B**) ultrasound images showing a type 1 ramp lesion (white arrow) of the posterior horn of the medial meniscus*

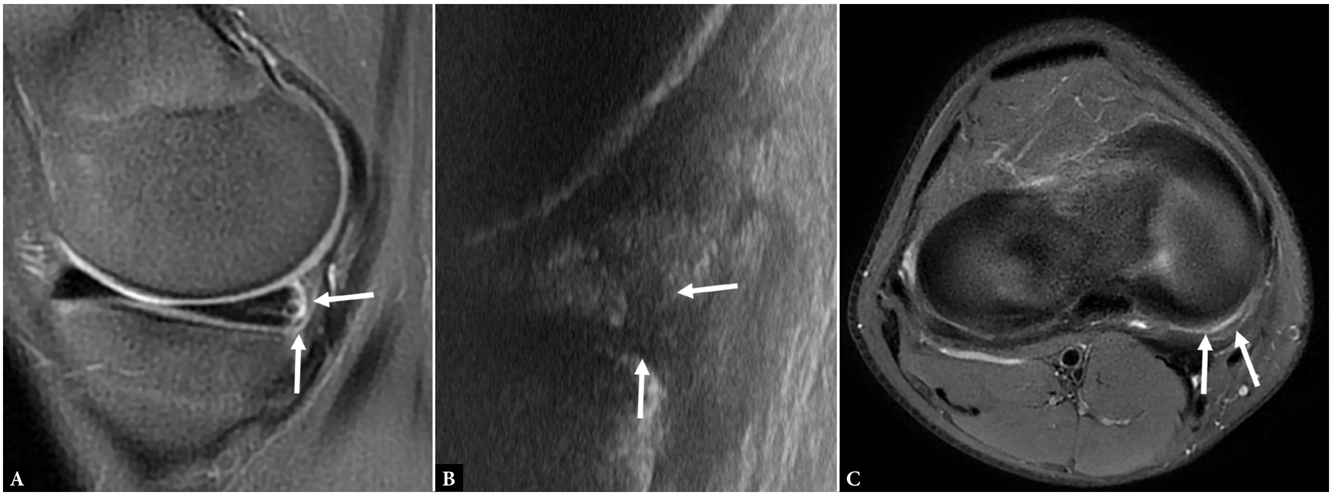

Fig. 7. *Sagittal DP-FS MRI (**A**), medial sagittal US image (**B**), and axial DP-FS MRI (**C**) showing a type 3 ramp lesion (white arrow) of the posterior horn of the medial meniscus*

weight bearing; dynamic sonography reveals significantly greater displacement in a single-leg stance vs the neutral position.

- Meniscal extrusion: Dynamic and weight-bearing US evaluation reveals extrusion (i.e. the meniscus displaced beyond the tibial margin), which can vary with loading. A systematic review showed high sensitivity (~96%) and specificity (~82%) of US compared with MRI for detecting meniscal extrusion when dynamic or standing evaluations are included with a 4 mm cut-off[13].

When meniscal snapping or clicking is suspected, especially with symptom reproduction during movement or loading, dynamic US should be considered among the first-line imaging techniques because of its real-time feedback and lower cost. Ensuring proper patient positioning and provocative maneuvers is essential: non-weight-bearing vs weight-bearing, flexion vs extension. Recording dynamic sequences also facilitates interdisciplinary communication. If US findings suggest a peripheral tear or fragment instability, or if US is inconclusive, MRI (preferably with some dynamic component, if available) or arthroscopy may be necessary for confirmation and surgical planning[17] (Fig. 8).

Discussion

This review highlights the value of ultrasound in diagnosing meniscal lesions such as flap tears and meniscal extrusion. Our experience suggests that ultrasound may be useful for detecting meniscal lesions. Most meniscal injuries can be diagnosed using this technique. The performance of ultrasound compared to MRI appears satisfactory, especially in younger populations[18]. One study reported ultrasound sensitivity for detecting arthroscopically confirmed meniscal tears to be 91% and 84%, while MRI sensitivity was 92% and 67%, respectively. Ultrasound has an overall sensitivity of 85.4% and a specificity of 85.7% for detecting meniscal tears. The positive predictive value was low, while the negative predictive value was high (94.4%), indicating that a normal ultrasound examination is a strong indicator of the absence of a meniscal tear. If a lesion is detected on ultrasound, MRI should be performed to confirm the diagnosis. A meta-analysis including seven studies on ultrasound performance in diagnosing medial meniscal pathology supports this view. Ultrasound performance appears to be satisfactory compared with MRI and may even be superior in younger populations[19,20].

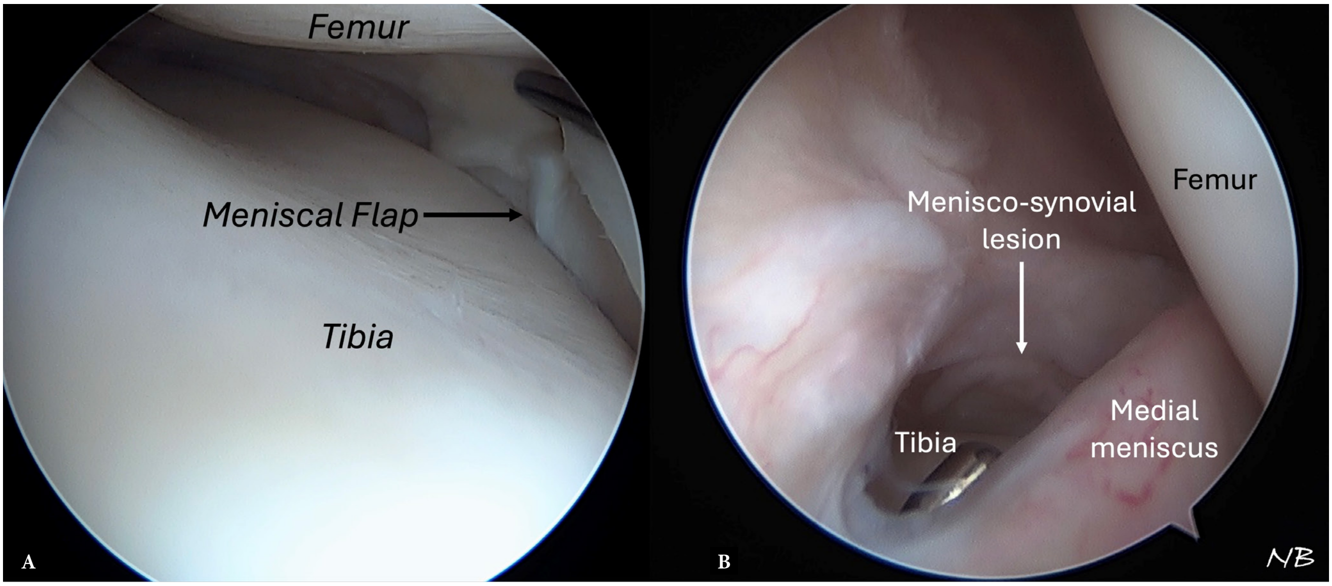

Fig. 8. A. *Arthroscopy of the right knee showing a meniscal flap in the medial meniscus in the meniscotibial recess before removal with the probe.* **B.** *Arthroscopy showing a meniscosynovial tear (ramp-lesion type 1) of a right knee using a trans-notch approach*

Our experience supports the feasibility of diagnosing internal meniscal flaps via ultrasound, as previously suggested in 2008. A displaced meniscal flap appears as an echogenic fragment of variable size, most frequently displaced medially, more often into the meniscotibial recess than into the meniscofemoral recess. The characteristic "comma-shaped" appearance seen on MRI is not always visible on ultrasound. Therefore, it is important to know whether a previous meniscectomy has been performed before the ultrasound. A displaced meniscal fragment may cause inflammation of the perimeniscal fat pad, especially deep to the medial collateral ligament, as well as focal synovitis or osteochondral impingement (menisco-osseous conflict)[21–25].

In our center, surgeons frequently request ultrasound-guided corticosteroid or lidocaine injections for both diagnostic and therapeutic purposes in symptomatic meniscal flap cases (Fig. 9, Fig. 10).

Inferior displacement into the meniscotibial recesses is much more common than superior displacement into the meniscofemoral recess. The main differential diagnoses include intra-articular loose bodies and meniscal extrusion. An osteochondroma, although variable in echogenicity depending on the degree of ossification, is rarely found in the meniscotibial or meniscofemoral recesses. Meniscal extrusion is defined as medial meniscal displacement >3 mm or lateral >4 mm beyond the bicortical line between the femoral condyle and tibial plateau[13]. Extrusion is usually associated with peripheral osteophytes, more often tibial initially, then femoral. The affected meniscal horn often loses its typical triangular shape and becomes more quadrangular. In normal conditions, the meniscotibial and meniscofemoral recesses are empty, except in cases of meniscal extrusion or meniscal flap. The diagnostic performance of ultrasound for detecting meniscal extrusion is comparable to that of MRI[26].

Ultrasound examinations may be performed in both supine and standing positions. It is not possible to determine whether the standing position improves visualization of meniscal flaps, although some studies suggest that extrusion is more visible under weight-bearing conditions. Dynamic US is more effective when the meniscal pathology is peripherally located or when fragments are mobile enough to move into parameniscal recesses. When tears are deeper or central, or in intra-articular locations not well reachable by the US beam, MRI remains superior. MRI provides excellent soft-tissue contrast and detailed anatomy, better for mapping tear morphology, detection of complex tear patterns, discoid meniscus, and intra-articular bodies. However, standard MRI is often static and may miss certain forms of functional instability[27–29].

Conclusion

Although ultrasound is not intended to replace MRI, it can play an important role in diagnosing peripheral meniscal tears and may eventually serve as a follow-up tool for monitoring the healing of le-

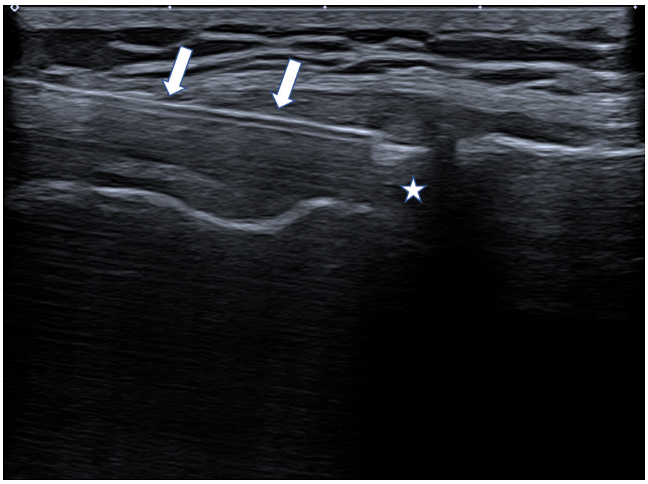

Fig. 9. *Medial sagittal US image showing a tear of the medial meniscus (white star) with the needle in the meniscal recess*

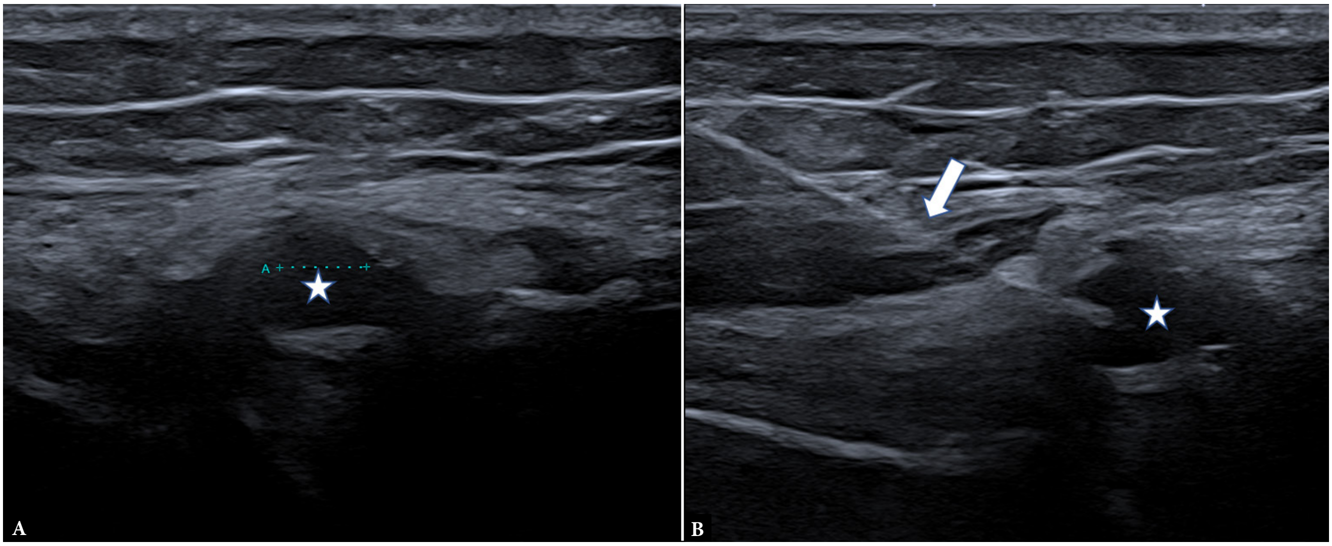

Fig. 10. *Medial sagittal US image (**A**) showing a cyst of the lateral meniscus (white star) with the needle (white arrow) in the parameniscal cyst (**B**)*

sions that do not require surgical repair. Moreover, there is growing interest in standardizing dynamic US protocols, improving inter-operator reliability, integrating video documentation, and potentially combining ultrasound with novel imaging or computational methods.

Conflict of interest

The authors do not report any financial or personal connections with other persons or organizations which might negatively affect the contents of this publication and/or claim authorship rights to this publication.

Author contributions

Original concept of study: BD, LP. Writing of manuscript: BD, LP, NB. Analysis and interpretation of data: PN, NG, NB. Final acceptance of manuscript: BD, PM, LP. Collection, recording and/or compilation of data: NB, BD. Critical review of manuscript: BD, NB, NG, PM, LP.

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