

Three Layers of the Medial Capsular and Supporting Structures of the Knee: MR Imaging–Anatomic Correlation¹

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The authors used a three-layer approach to correlate the appearance of the capsule and ligaments of the medial side of the knee on magnetic resonance (MR) images with corresponding anatomic slices. MR images of six fresh cadaveric specimens were obtained by using a proton-density-weighted fast spin-echo sequence with a 256×512 matrix. Specimens were frozen and sliced with a band saw into 3.0-mm-thick sections that corresponded to the MR images. Three layers were depicted on both anatomic slices and MR images. Layer 1 consisted of the deep crural fascia; layer 2, the superficial portion of the medial collateral ligament (MCL); and layer 3, the capsule, the deep portion of the MCL, the meniscomfemoral and meniscotibial extensions of the deep portion of the MCL, and the patellomeniscal ligament. Along the anterior aspect of the medial side of the knee, layer 1 was fused with layer 2; along the posterior aspect of the knee, layer 2 was fused with layer 3.

Abbreviation: MCL = medial collateral ligament

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Introduction

The knee is the joint most commonly examined at magnetic resonance (MR) imaging. Although the medial collateral ligament (MCL) is frequently injured, descriptions of the appearance of the medial capsular and supporting structures of the knee at MR imaging are often not very detailed (1). Existing classifications of MCL lesions do not address involvement of the superficial and deep portions of the MCL or involvement of the anterior vertical and posterior oblique portions. This may explain why classifications of MCL injuries with MR imaging have been considered inaccurate (2). Because various pathologic conditions may involve the medial aspect of the knee, a more accurate description of pathologic changes with regard to these layers may help accurately define the injured components and the precise extent of the lesions. Certain conditions may be located in or between specific layers, and precise localization of the condition with regard to these layers may help make the differential diagnosis. With this approach, MCL bursitis, meniscal cysts, pes anserinus bursitis, and semimembranosus bursitis could be differentiated with MR imaging. The purpose of this study was to correlate high-spatial-resolution MR images with anatomic slices by using a three-layer approach. Particular emphasis was placed on identification of all three layers on both anatomic slices and MR images.

Anatomic Considerations

The superficial layer (layer 1) on the medial side of the knee consists of the deep crural fascia (Figs 1, 2) (3). Anterosuperiorly, this fascia is continuous with the fascia overlying the vastus medialis muscle, whereas posteriorly it is continuous with the sartorius muscle. Anteriorly, layer 1 joins layer 2 to form the medial patellar retinaculum (4). Along the middle third of the medial side of the knee, the fascia is separated from the superficial portion of the MCL by a variable amount of fatty tissue. Posteriorly, the fascia is located superficial to the tendons of the semimembranosus, semitendinosus, and gracilis muscles. The tendons of the gracilis and semitendinosus muscles may blend with the fascia or the MCL at their insertion on the tibia (5).

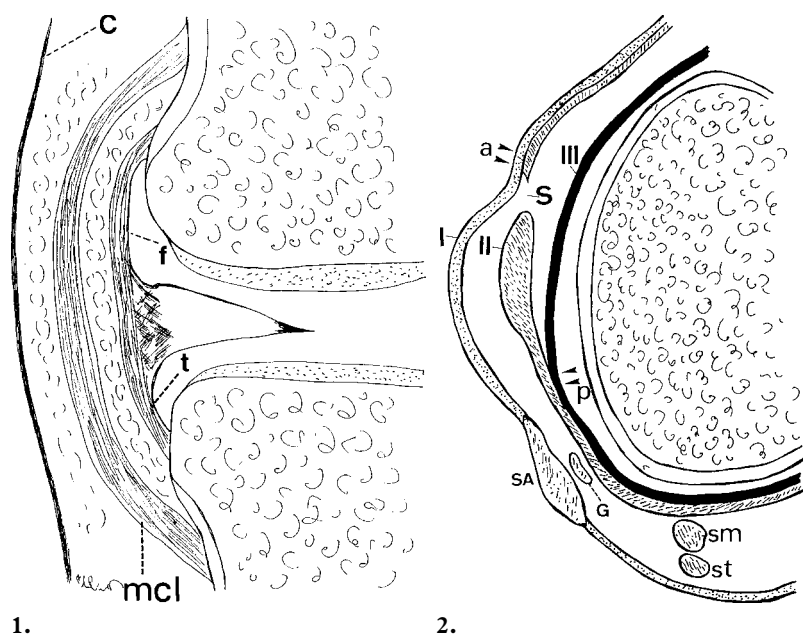
The principal component of the intermediate layer (layer 2) is the superficial portion of the MCL. The superficial portion of the MCL is found along the middle third of the knee and is composed of vertically oriented fibers. It is also referred to as the vertical component of the MCL. Posteriorly with regard to the vertical component of the MCL, the posterior oblique portion of the MCL is found. This posterior oblique portion of the MCL is fused with layer 3 and closely attached to the posteromedial meniscus (1,3,4,6). This conjoined structure is also designated as the posterior oblique ligament. Along the posterior aspect of the knee, this structure receives fibers from the semimembranosus tendon and synovial sheath. It envelops the posterior aspect of the femoral condyle, and in this area it is termed the oblique popliteal ligament.

Layer 3 corresponds to the deepest capsular layer. Anteriorly, layer 3 is continuous with the capsule of the suprapatellar recess, which extends to the margin of the patella (7). Deep to the vertical component of the superficial MCL, the capsule becomes thicker, forming the deep portion of the MCL, which is located close to the meniscus. The deep portion of the MCL is composed of fibers adjacent to the meniscus and of the meniscofemoral and meniscotibial (coronary ligament) extensions. The MCL bursa is located between the superficial and deep portions of the MCL (8), along the middle third of the knee.

Materials and Methods

Six cadaveric specimens were harvested immediately after death and frozen at -30°C . All specimens were derived from elderly patients, although the precise ages of the donors were not available. The specimens were thawed at room temperature for 20 hours. MR imaging was then performed with a 1.5-T clinical system (Vision; Siemens, Erlangen, Germany). We obtained images along the coronal, transverse, and sagittal planes by using a proton-density-weighted fast spin-echo sequence with high spatial resolution (repetition time msec/echo time msec = 3,000/15, 252×512 or 128×252 matrix, 150×240 field of view, 3-mm-thick sections, and two signals acquired).

All specimens were frozen again, and a band saw (NSV, Modena, Italy) was used to cut them into 3.0-mm-thick slices along the coronal ($n = 4$) or transverse ($n = 2$) imaging plane. The slices



Figures 1, 2. (1) Line drawing illustrates the three layers along the middle third of the medial side of the knee. The superficial layer (layer 1) corresponds to the crural fascia (C), the middle layer (layer 2) consists of the superficial portion of the MCL (mcl), and the deep layer (layer 3) consists of the deep portion of the MCL and the meniscofemoral (f) and meniscotibial (t) extensions of the deep MCL. (2) Line drawing shows a transverse section through the knee joint above the level of the joint space. Layers 1 (I) and 2 (II) are fused anteriorly (arrowheads, a), whereas layers 2 (II) and 3 (III) are fused posteriorly (arrowheads, p). G = gracilis tendon, S = split, SA = sartorius muscle, sm = semimembranosus tendon, st = semitendinosus tendon.

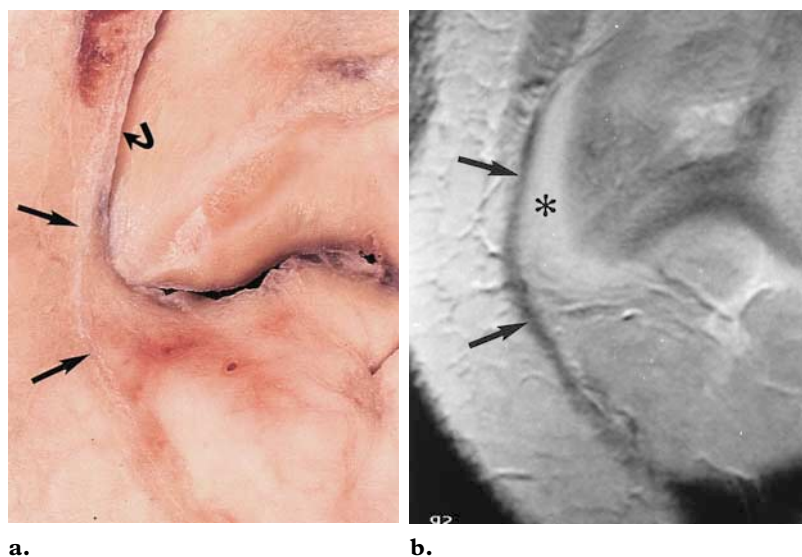


Figure 3. Coronal anatomic slice (a) and corresponding MR image (3,000/15) (b) obtained along the anterior third of the medial knee joint. The medial retinaculum (straight arrows) is seen as a band of low signal intensity on the MR image, although two delicate layers are seen on the anatomic slice. The joint capsule (curved arrow in a) and intraarticular gadolinium-based contrast material (*) in b) also are seen.

were photographed, and correlation with the corresponding MR images was performed by consensus of an experienced musculoskeletal radiologist (M.D.M.) and two anatomists (F.V.R., E.B.). A binocular magnification system (Carl Zeiss, Germany) was used to inspect selected areas of the anatomic slices in detail. Selected slices were also dissected to allow better identification of anatomic structures. For image analysis, the medial side of the knee was arbitrarily divided into an anterior, middle, and posterior third. The anterior third was located anterior to the anterior edge of the vertical portion of the MCL. The middle third was located between this edge and the region where layer 2 united with layer 3. The posterior third was located posterior to the junction of layers 2 and 3.

MR Imaging–Anatomic Correlation

Layer 1

On anatomic slices obtained along the anterior third of the medial aspect of the knee joint, layer 1 was fused with layer 2 to make up the medial patellar retinaculum. The medial retinaculum was seen as a discrete white band extending from the vastus medialis muscle superiorly to the tibia inferiorly. In two of the six cases, two bandlike structures were apparent instead of one conjoined structure. On MR images, the medial retinaculum was seen as a low-signal-intensity structure (Fig 3).

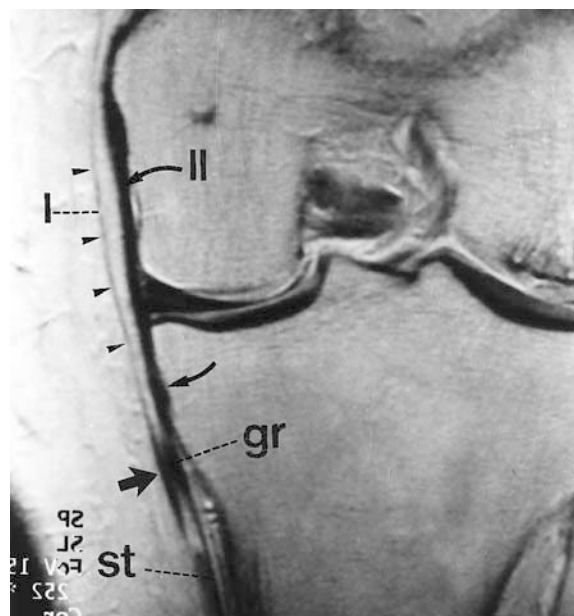
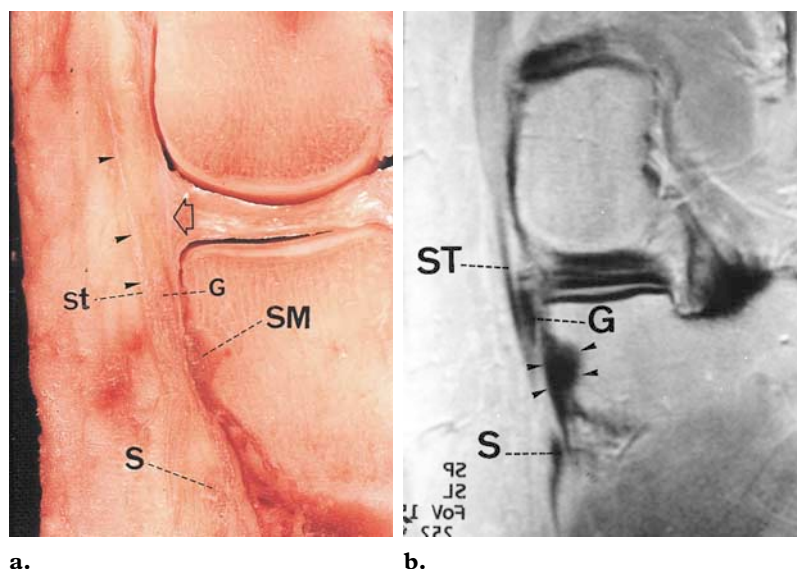


Figure 4. Coronal proton-density-weighted MR image (3,000/15) obtained along the middle third of the medial knee joint shows the fascia (layer 1 [I], arrowheads) and the sartorius (straight arrow), gracilis (*gr*), and semitendinosus (*st*) tendons. Note the superficial portion of the MCL (layer 2 [II], curved arrows).

Figure 5. Coronal anatomic slice (a) and corresponding MR image (3,000/15) (b) obtained along the posterior third of the medial knee joint show the superficial layer 1 (arrowheads in a) and the following tendons: sartorius (*st* in a, *ST* in b), gracilis (*G*), semimembranosus (*SM* in a, arrowheads in b), and semitendinosus (*S*). The deep layer (layer 3) is also seen (open arrow in a).



On anatomic slices obtained along the middle third of the medial aspect of the joint, layer 1 was depicted as a separate structure from layer 2. A variable amount of fatty tissue was interposed between layers 1 and 2. On MR images, the fascia was seen as a thin, low-signal-intensity structure superficial to the superficial portion of the MCL (Fig 4).

On anatomic slices obtained along the posterior third of the medial aspect of the knee joint, layer 1 was located superficially to the gracilis and semitendinosus tendons. Superiorly, it invested the sartorius muscle and tendon, whereas inferiorly it was continuous with the superficial fascia of the lower leg (Fig 5). On MR images, layer 1 was most easily detected posteriorly as a thin, delicate structure with low signal intensity.

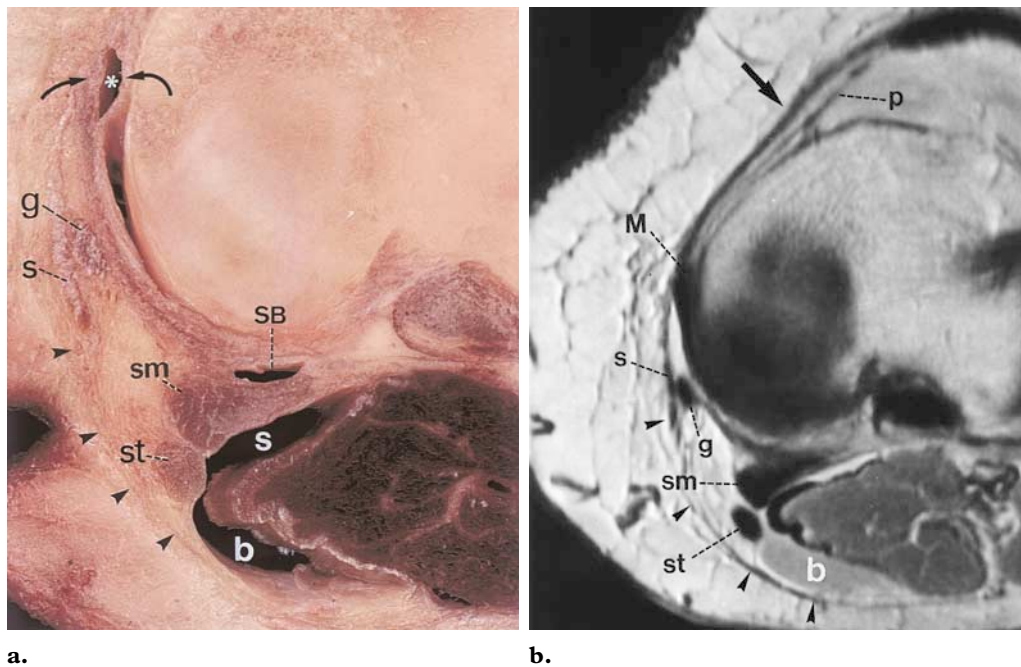


Figure 7. Transverse anatomic slice (**a**) and corresponding MR image (3,000/15) (**b**) obtained at the level of the joint space. The superficial layer (layer 1) is best seen posteromedially (arrow-heads). Also note the following tendons: sartorius (*s*), gracilis (*g*), semimembranosus (*sm*), and semitendinosus (*st*). The subgastrocnemius bursa (*S* in **a**) and a Baker cyst (*b*) are seen posteriorly, and the semimembranosus bursa (*SB* in **a**) is seen deep to the semimembranosus tendon. The superficial MCL (*M* in **b**) and deep MCL (curved arrows in **a**) are separated by the MCL bursa (* in **a**). The medial retinaculum (arrow in **b**) and patellomeniscal ligament (*p* in **b**) are also seen.

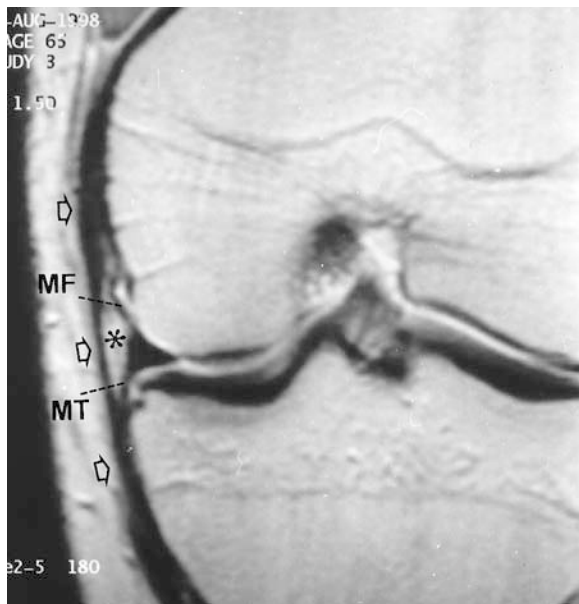


Figure 6. Coronal proton-density-weighted MR image (3,000/15) shows the meniscofemoral (*MF*) and meniscotibial (*MT*) extensions of the deep portion of the MCL, deep to the superficial portion of the MCL (arrows). Fat (*) is seen interposed between layers 2 and 3.

Layer 2

On anatomic slices obtained along the middle third of the medial aspect of the knee joint, layer 2 was composed of the superficial portion of the MCL, which was depicted as a white bandlike structure extending from the femoral cortex superiorly to the tibial cortex inferiorly (Fig 6). The vertical component of the MCL was separated from the meniscus by the capsular layer (layer 3), a variable amount of fatty tissue, and the MCL bursa. On MR images, the superficial MCL was seen as a low-signal-intensity structure about 12 cm long, 1–2 cm wide, and 2–4 mm thick (Fig 6). On transverse MR images, the femoral attachment of the vertical component of the MCL was identified adjacent to a small convexity on the femoral condyle termed the medial epicondyle (Figs 7, 8). Along the anterior edge of the vertical

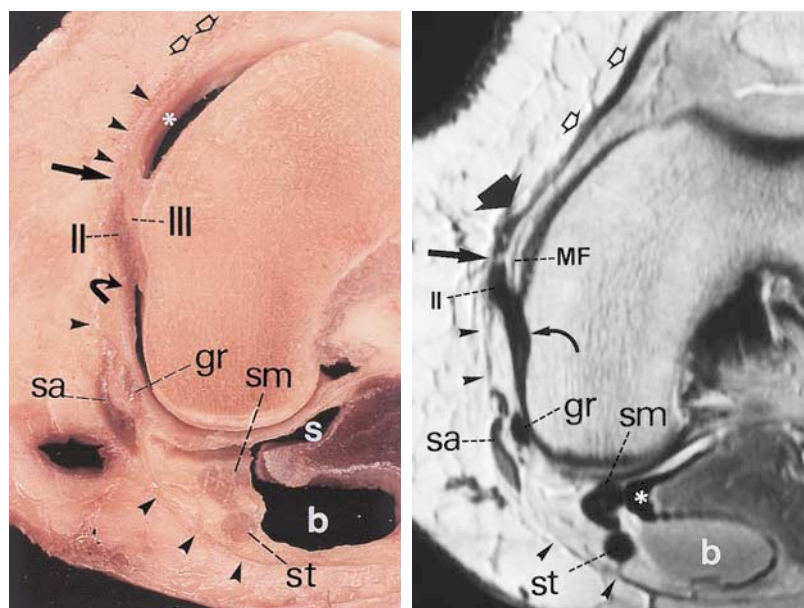


Figure 8. Transverse anatomic slice (**a**) and corresponding MR image (3,000/15) (**b**) obtained above the level of the joint space. The medial retinaculum is seen anteriorly (open arrows). Also note the joint capsule (* in **a**). Along the middle third of the joint, a split (thin solid arrow) in layer 2 is seen adjacent to the anterior edge of the superficial MCL (**II**). Along the anterior third of the knee joint, layer 1 (wide solid arrow) unites with layer 2. The meniscofemoral extension (**III** in **a**, **MF** in **b**) is seen as a separate structure from layer 2. Posteriorly, layer 2 fuses with layer 3 (curved arrow), forming the posterior oblique ligament. Posteriorly, the sartorius muscle and tendon (**sa**), gracilis tendon (**gr**), semimembranosus tendon (**sm**), and semitendinosus tendon (**st**) are seen. Also note the medial gastrocnemius tendon (* in **b**), a Baker cyst (**b**), and the subgastrocnemius bursa (**S** in **a**). Posteromedially, layer 1 is best visualized (arrowheads).

component of the superficial MCL, a split in layer 2 was observed at the level of or slightly above the joint space (Figs 9, 10). The split was best seen on transverse MR images. In our experience, the split may simulate a tear of the anterosuperior portion of the superficial MCL on coronal MR images. Anterior to this 3–6-mm-wide split, layer 2 was fused with layer 1 to form the medial patellar retinaculum.

On anatomic slices obtained along the posterior third of the medial aspect of the knee joint, layer 2 was seen to blend with layer 3 to form the posterior oblique ligament. This ligament enveloped the posteromedial portion of the femoral condyle (Fig 8) and was close to the posterior horn of the medial meniscus.

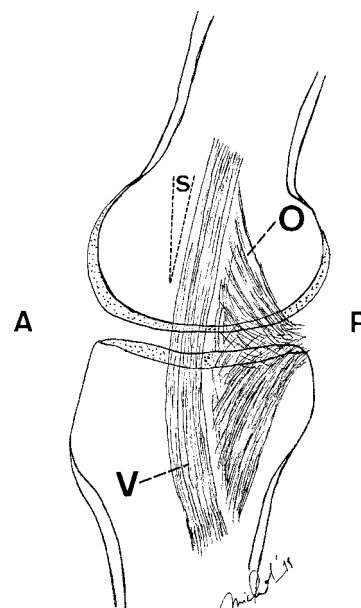


Figure 9. Line drawing illustrates a lateral view of the knee. Note the area where a split (**S**) occurs in layer 2. Both the vertical (**V**) and oblique (**O**) portions of the MCL are shown. **A** = anterior, **P** = posterior.

Layer 3

On anatomic slices obtained along the anterior third of the medial aspect of the knee joint, layer 3 was continuous with the capsule along the suprapatellar recess. The patellomeniscal ligament, which was also a component of layer 3, was seen anteriorly extending from the meniscus to the patellar margin (3,7).

Along the middle third of the knee joint, the meniscofemoral extension of the deep MCL was evident as a thin bandlike structure. The meniscofemoral extension originated from the outer superior margin of the meniscus to blend either with the superficial portion of the MCL or the femoral condyle 1–2 cm above the level of the joint space (Fig 11). The use of intraarticular contrast material or the presence of joint fluid increased detection of the meniscofemoral extension. Inferiorly, the shorter meniscotibial extension originated



Figure 10. Coronal proton-density-weighted MR image (3,000/15) shows a split (arrowheads) adjacent to the anterior edge of the MCL. This split may be mistaken for a tear of the anterosuperior aspect of the MCL. MR images obtained with edema-sensitive sequences (not shown) would reveal normal signal intensity in this area.

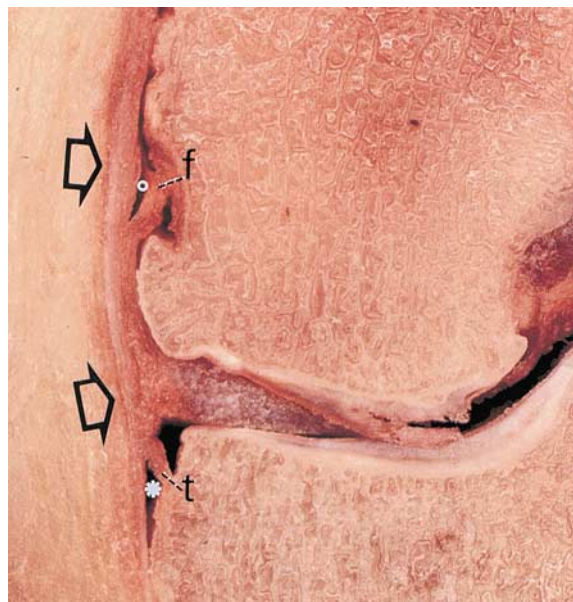


Figure 11. Coronal anatomic slice along the middle third of the medial knee joint. The superficial portion of the MCL (arrows) is separated from layer 3 by a thin layer of fat and the MCL bursa (o, *). The meniscomfemoral (f) and meniscotibial (t) ligaments, both of which are components of layer 3, are also seen.

from the outer inferior margin of the meniscus to attach to the tibial cortex inferiorly to the joint space. The outer margin of the meniscus could not be distinguished from the capsule and deep portion of the MCL. A variable amount of fatty tissue and the MCL bursa were interposed between the superficial and deep portions of the MCL. On MR images, the meniscomfemoral and meniscotibial extensions were detected as low-signal-intensity bandlike structures deep to the superficial portion of the MCL.

Conclusions

In cadaveric specimens, our findings show that a three-layered aspect may often be observed on MR images. Use of the three-layer approach may enable abnormalities involving the medial side of the knee to be described and classified in more detail (2,8). In addition, pathologic conditions may be localized with regard to these layers, limiting differential diagnostic considerations.

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