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ARTICLE TITLE

Joint Effusion and Bone Outlines of the Knee: Radiographic / MRI Correlation

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The Authors have nothing to disclose.

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Knee radiograph ; patellar dislocation; Segond fracture; trochlear dysplasia

KEY POINTS

- Joint effusion, lipohearthrosis, and exuberant subsynovial frond-like fatty proliferation in *lipoma arborescens* can be depicted on a lateral view.
- Normal femoral notches should be differentiated from the lateral femoral notch sign associated with anterior cruciate ligament tears.
- Trochlear dysplasia and features reflecting its severity should be systematically sought after.
- *Patella alta*, patellar tilt, and complete lateral patellar dislocation can be associated with trochlear dysplasia.
- Analysis of the bone outlines can allow depiction of small avulsion fractures.

SYNOPSIS

Knee radiographs are widely used in clinical practice. Many features can be depicted when a systematic analysis of the different views is performed. This article will focus on different types of joint effusion and on the analysis of the bone outlines of the knee, particularly on the lateral view. Systematic analysis of these bone outlines and knowledge of several key points are particularly useful for the depiction of abnormal bone morphology or positioning, and of several conditions such as trochlear dysplasia, patellar dislocation, impaction fractures or ligament injuries and avulsion fractures.

Knee radiographs are still widely used in clinical practice. Many features can be depicted when a systematic analysis of the different views is performed. In this article, after discussing different types of joint effusion, we will focus on the analysis of the bone outlines of the knee, particularly on the lateral view. Systematic analysis of these bone outlines and knowledge of several key points are particularly useful for the depiction of abnormal bone morphology or positioning, and of several injuries.

JOINT EFFUSION

Whatever the clinical context, the presence of a joint effusion should be systematically looked for on a lateral knee radiograph. This increased intraarticular amount of fluid is not specific of a particular disorder, as can occur in a variety of settings. However, it draws attention to the presence of a joint disorder. It leads to the separation between the suprapatellar and prefemoral fat pads by a well-defined rounded suprapatellar recess (Fig 1) (1). Loss of normal posterior fat plane of the quadriceps tendon and anterior displacement of the latter and of the patella are only seen in large joint effusions.

In trauma, a fat-fluid level related to lipohearthrosis can be seen when a lateral knee view with horizontal-ray is performed (Fig 2) or on a lateral knee view performed in a standing patient (2); it is specific for the existence of an intra-articular fracture, allowing bone marrow fat to leak into the joint via the fracture and to float on top of the blood. The detection of this sign is particularly useful when the intraarticular extent of a fracture is not obvious on plain films, as it should lead to additional imaging assessment.

Sometimes, fatty lucencies which seem to be entrapped in a distended suprapatellar pouch can be detected on radiographs (Fig 3). They are related to extensive subsynovial frond-like fatty proliferation in *lipoma arborescens* and can be depicted radiographically when exuberant. This latter disorder is typically associated with chronic arthropathies such as osteoarthritis or rheumatoid arthritis (3).

LATERAL FEMORAL NOTCH SIGN

Normal anatomy

On a true lateral view, the two femoral condyles are superimposed, particularly their posterior border. However, analysis of their shape allows differentiating them: the middle third of the lateral condyle is flat and may demonstrate a mild notch whereas the medial condyle is more rounded. When the superposition of the two condyles is not perfect, which is frequently the case, a large notch can also be recognized at the junction between the anterior and middle third of the medial

condyle. These normal notches, also known as condylopatellar sulcus, represent the junction zone on the femoral condyles where the tibiofemoral and patellofemoral radii of curvature meet (Fig 4).

Lateral femoral notch sign

Normal notches should be differentiated from the lateral femoral notch sign, which results from the impaction between the lateral femoral condyle and the posterior aspect of the tibial plateau during anterior cruciate ligament tears (Fig 5). This inconstant osteochondral fracture involves the middle to anterior portion of the lateral femoral condyle; it can be recognized radiographically when it is deeper (> 1.5mm) and / or have sharper angulation than the normal lateral notch (Fig 5) (4).

TROCHLEAR DYSPLASIA

This developmental anomaly is one of the most important risk factors for lateral patellar dislocation. Its depiction relies on the analysis of the proximal part of the trochlea on a true lateral radiograph, as it has been demonstrated that this view is more reliable for the diagnosis of trochlear dysplasia than axial radiographs obtained at 30 degrees of flexion of the knee (5). Thus, it is crucial for diagnostic accuracy of trochlear dysplasia to have a correct lateral radiograph with superimposition of the femoral condyles posteriorly, as a rotational deviation of at least 5 degrees can cause false-positive or false-negative diagnosis of trochlear dysplasia (6).

Normal anatomy

Normally, the ventral outline of both femoral condyles projects at a distance from the tangent to the deepest part of the trochlear groove and should not cross it, as both condyles continue with the ventral cortical bone of the femoral metaphysis. This means there is a normal shape and depth of the proximal trochlea (Fig 6). The depth of the proximal trochlea can be assessed one centimeter below the proximal end of the trochlear groove and should be more than 5mm (Fig 6). This measure is rarely performed in clinical practice, but it constitutes a good landmark for normal anatomy in cases of doubt.

Trochlear dysplasia

Trochlear dysplasia is defined by the presence of the crossing sign, when the tangent to the deepest part of the trochlear groove crosses the ventral outline of the lateral condyle (Fig 7) (7). At this level, the trochlea becomes flat, which may lead to patellar instability as the patella cannot engage normally in the trochlea.

It is important to keep in mind that in a normal knee, the lateral femoral condyle extends higher anteriorly than the medial condyle. This feature can be used to differentiate the 2 condyles but it also explains that, quite frequently, the ventral outline of the medial condyle joins the tangent to the trochlear groove, as the proximal part of the medial trochlear facet can be in a frontal plane. This is a

normal and frequent feature; this is not a crossing sign (Fig 8). The crossing sign must involve at least the lateral condyle. This feature should be kept in mind to avoid overdiagnosis of trochlear dysplasia.

Features reflecting the severity of the trochlear dysplasia

Once the crossing sign has been recognized, other features reflecting the severity of the trochlear dysplasia should be systematically sought out (8):

- *A supratrochlear spur or bump*, which plays a role similar to a ski jump when the patella engages in the trochlea (Fig 9). This feature usually indicates ventral prominence of the trochlea, which can be measured by the distance between a line drawn through the ventral cortical bone of the femoral shaft and a parallel line tangent to the most ventral point of the trochlear floor. This measure is around 0 to 2 mm in normal knees but can be more than 3mm in severe trochlear dysplasia (Fig 10). The trochlea is usually markedly flattened or even convex in this region.

- *The double contour sign*. A double line can be depicted at the anterior aspect of femoral metaphysis above the trochlea; this is a common feature, as the anterolateral metaphysis is usually more developed and prominent than the medial one. This double line is abnormal, and called the “double contour sign” if it continues and ends below the level of the crossing sign, thus indicating that the medial femoral condyle is hypoplastic (Fig 10). This leads to a pronounced asymmetry of the height between trochlear facets, with a hypoplastic medial trochlear facet. A cliff pattern usually separates the two condyles in the axial plane.

Associated disorders

When trochlear dysplasia is depicted, 3 other types of radiographic features should be systematically sought out, as they are frequently associated (although they can be seen in isolation):

- *A patella alta*. A *patella alta* means that the patella is located too high. As a consequence, the degree of flexion required for the patella to engage in the trochlea tends to be higher, as compared to a normal knee. This increases the risk of patellar instability and dislocation in shallow degrees of flexion. Several indexes have been described on a true lateral view with a knee flexed at 30 degrees. *Patella alta* is present when the Caton-Deschamps or Insall-Salvati index is > 1.2 , or when the Blackburne-Peel index is > 1 (Fig 11) (9-11).

- *A patellar tilt*. Patellar tilt, which is a rotation of the patella in the axial plane, is favored by the presence of a *patella alta*, a trochlear dysplasia and a lateralization of the tibial tuberosity. It is more obvious and frequent on a true lateral view with a knee extended, as the patella is not yet engaged, but it may also be seen in flexion at 30°. Normally, 2 lines are seen at the posterior part of the patella. The most posterior one, which is straight or slightly concave backward, is a tangent to the vertical ridge located between the two patellar facets (Fig 12). The anterior line is a tangent to the lateral facet. An overlapping of these lines

means that there is a mild tilt of the patella; a posterior border of the patella becoming convex backward means that there is a severe patellar tilt, the lateral border of the patella then projects behind the tangent to the vertical ridge (Fig 12) (12).

- *Radiographic features indicating a prior complete lateral patellar dislocation.* They include avulsion fracture or ossification of the medial ligamentous patellar stabilizers, and osteochondral fractures resulting from impaction of the inferomedial aspect of the patella on the anterolateral aspect of the lateral femoral condyle (Fig 13). These features are usually better demonstrated on the skyline and anteroposterior views than on the lateral view. Intra-articular linear or curvilinear bone fragments (sliver sign), arising from the patella or lateral femoral condyle, can be present and might be quite specific of acute lateral patellar dislocation (Fig 13) (13).

DETECTION OF PORTERIOR TIBIAL FRACTURES

Normal anatomy

The tibial condyles also have different shapes (Fig 14). The lateral one is mildly convex upward while the medial one is concave, facing the round-shaped medial femoral condyle. The third posterior sloping line is tangent to the posterior intercondylar area, where the posterior cruciate ligament (PCL) inserts.

Posterior tibial fractures

In trauma, analysis of the 3 posterior tibial lines can allow the depiction of impaction fractures (Fig 15). Fractures of the posterior medial condyle are less common than those of the lateral condyle but better demonstrated, as the medial condyle projects posteriorly to the lateral one (Fig 16). Such lesions are typically associated with ACL injury and highly associated with damage of the adjacent structures, including the tibial insertion of the central tendon of the semimembranous muscle, and the posterior horn of the medial meniscus. Detection of a fracture involving the tangent to the posterior intercondylar area means that there is a PCL tibial avulsion fracture (Fig 17).

Avulsion of the tibial attachment of the ACL can also be detected on the lateral view (Fig 18). This is typically encountered in children and adolescents due to the relative weakness of incompletely ossified bone and increased elasticity of ligament at those ages. A bone fragment of variable size, more or less displaced, is usually well depicted on the lateral view but when small, it may be better demonstrated on the AP view (Fig 18).

OTHER FRACTURES

Many other avulsion fractures can be depicted on the lateral and AP view of the knee. Their depiction on plain films is particularly important, as these thin bone fragments can be missed on MR imaging. We only will have a look at the most frequent ones:

- *Segond fracture*, related to the tibial avulsion of the anterolateral ligament and typically associated with ACL tears (14). The classical appearance of this fracture is that of a curvilinear or elliptic vertical bone fragment projected parallel to the lateral aspect of the tibial plateau on AP view (Fig 19). Sometimes, only a defect of the tibial outline is apparent on radiographs which will be missed if this region is not systematically assessed in trauma.

- *Bone avulsion of the medial collateral ligament (MCL)*. The avulsion of the proximal aspect of the superficial MCL is sometimes very difficult to detect in the acute phase (Fig 20) and may be missed if the medial epicondyle outline is not systematically carefully analyzed on AP radiographs in trauma. A few weeks later, an ossification can develop in this area and is more or less extensive proximally due to the close proximity between the MCL, adductor tendons and medial ligamentous stabilizers of the knee (Fig 20). This Pellegrini-Stieda lesion, which may or not be associated with symptoms, is not to be confused with apatite calcifications, which are amorphous (Fig 20). The deep portion of the MCL can also be avulsed, with ossifications located more inferiorly (Fig 21). This lesion is isolated or associated with a lesion of the superficial MCL. Finally, the tibial insertion of the deep portion of the MCL can also be avulsed, and is called the reverse Segond fracture. This lesion is frequently associated with PCL and medial meniscus tears.

- *Bone avulsion of the proximal aspect of the fibular head*. Depiction of such fractures is important as they are considered to be a sign of injury to the posterior lateral corner (PLC) of the knee, frequently associated with cruciate ligament injury. Indeed, many components of the PLC insert on it, including the lateral collateral ligament (LCL), the *biceps femoris* tendon (BFT), and the arcuate complex which consists of the popliteofibular ligament, the arcuate ligament, and the variably present fabello-fibular ligament. Failing to identify injury of the PLC can lead to chronic posterolateral instability of the knee.

Originally described as an avulsed fibular styloid fragment at the insertion site of the arcuate ligament complex (15), the arcuate sign is often applied broadly to include small fractures of the fibular head. The shape, size and location of the avulsed fragment vary according to which structures of the PLC are involved (Fig 22 and Fig 23) (16-18). When any avulsion fracture in this region is

depicted, even in the absence of significant bone fragment displacement, one should perform an MRI examination of the PLC, particularly when the fracture involves the lateral aspect of the fibular head (LCL and BFT bone insertion). As such bone avulsions can be subtle; this region should be systematically carefully analyzed in trauma, particularly on the AP view.

Chronic tibial impaction fracture, highly suggestive of a meniscal tear, is sometimes depicted on the AP view of the knee. It typically involves the medial margin of the tibia and is related to a chronic horizontal or parrot beak meniscal tear, with a flap displaced in the meniscotibial recess. The meniscal fragment can be depicted on MRI or ultrasound (19) but MRI can also show edema of the adjacent bone and soft tissues, particularly in the presence of pain (Fig 24).

CONCLUSION

Despite increased use of advanced imaging modalities, plain films remain the most available and affordable diagnostic test for an efficient analysis of the knee. Through a systematic evaluation of the knee views, a great deal of information can be obtained. This is all the more important since minor radiographic features can be missed on MR images.

FIGURES

Fig 1. Joint effusion. Well-defined rounded suprapatellar recess (arrows) on (A) lateral knee radiograph and on (B) sagittal proton density (PD)-weighted image.

Fig 2. Lipohemarthrosis with a fat-fluid level on a (A) lateral knee view with horizontal ray (arrow) and on an (B) axial PD-weighted image (arrows).

Fig 3. *Lipoma arborescens*. Fatty lucencies depicted in a distended suprapatellar pouch (arrows) on a (A) lateral radiograph; (B) sagittal T1-weighted image confirms the extensive frond-like fatty proliferation.

Fig 4. Normal femoral condyle outlines. The middle third of the lateral condyle is flat and shows a mild notch (arrow) on a (A) lateral view and on a (B) sagittal T1-weighted image. The medial condyle is more rounded and shows a large notch at the junction between its anterior and middle thirds on a (C) lateral view and on a (D) sagittal PD-weighted image.

Fig 5. Lateral femoral notch sign (arrow). (A) Deep (> 1.5mm) depression and (B) depression with sharp angulation of the middle third of the lateral femoral condyle on a lateral view. Note the normal

medial femoral notch (arrowheads). (C) Deep depression of the lateral femoral condyle with surrounding bone marrow contusion, associated with contusion of the posterior aspect of the lateral tibial plateau on a sagittal PD-weighted image.

Fig 6. Normal depth and shape of the proximal trochlea. The ventral outline of the two femoral condyles (small arrow) are superimposed and project anteriorly to the tangent to the deepest part of the trochlear groove (arrowhead) on a (A) lateral view. (A) The depth of the proximal trochlea (double arrow) measured one centimeter below the proximal end of the trochlear groove (large arrow) is more than 5mm. (B) The corresponding axial PD-weighted image shows normal shape and depth of the proximal trochlea.

Fig 7. Trochlear dysplasia: crossing sign (large arrow). (A) The tangent to the deepest part of the trochlear groove (arrowhead) crosses the ventral outline of the two femoral condyles (small arrow). (B) On the corresponding level on axial PD-weighted image, the trochlea is flat.

Fig 8. Pseudo crossing sign (large arrow). The proximal ventral outline of the medial femoral condyle (small arrowheads) can join the tangent to the trochlear groove (large arrowhead) when it has a frontal direction (large arrow) on a (A) lateral view. The lateral femoral condyle (small arrows) extends higher anteriorly than the medial condyle. (B) The corresponding axial PD-weighted image shows that the proximal aspect of the medial trochlear facet is in a frontal plane (same plane as the proximal trochlear groove).

Fig 9. Ventral prominence of the trochlea, which is more than 3mm (double arrow) on this (A) lateral view. Note the associated crossing sign (arrow) and the spur (arrowhead). Spur and ventral prominence of the trochlea in another patient on a (B) sagittal T1-weighted image.

Fig 10. Double contour sign. (A) The double line depicted at the anterior aspect of femoral metaphysis above the trochlea (black arrow) means the anterolateral metaphysis is more prominent than the medial one. There is a double contour sign (black arrowhead) as this double line continues and ends below the level of the crossing sign (white arrow). This feature means that the medial femoral condyle is hypoplastic. Note the associated patellar tilt. Axial DP images show the (B) prominent anterolateral metaphysis (no covering cartilage) (white star) (level of the black arrow in A) and the (C) hypoplastic medial condyle (black star) with a cliff pattern between the 2 condyles (arrow) (level of the black arrowhead in A).

Fig 11. *Patella alta* on a lateral view with (A, B) 30 degrees of flexion and on a (C) sagittal T1-weighted image. (A) The Caton-Deschamps index is the ratio of the distance between the distal aspect of patellar articular surface and the anterosuperior aspect of the tibia (a) to the length of patellar articular surface (b); the Insall-Salvati index is the ratio between the patellar tendon length (c) to the length of the patella (d). (B) The Blackburne-Peel index is the ratio of the distance between the inferior aspect of the patellar articular surface and a line tangent to the surface of the tibial plateau (e) to the length of patellar articular surface (patella alta > 1 for this index) (f). (C) Patella alta in another patient.

Fig 12. Detection of a patellar tilt on a lateral view. (A) Normally, the tangent to the vertical ridge between the 2 patellar facets (a) is posterior to the tangent to the lateral facet (b). (B) An overlapping of these lines means that there is a mild tilt of the patella; (C) A convex posterior border of the patella (c) means that there is a severe tilt. (D) Corresponding diagram of the previous radiographs.

Fig 13. Radiographic features indicating a prior complete lateral patellar dislocation. (A) Sequela of avulsion fracture of the medial ligamentous patellar stabilizers (arrow) associated with an ill-defined tangent to the medial facet (arrowhead). (B) Intra-articular linear bone fragments (sliver sign) (arrow) arising from the patellar vertical ridge and the medial facet (arrowhead). (C) Impaction fracture of the anterolateral aspect of the lateral femoral condyle (arrow). (D) Corresponding images on PD-weighted images with avulsion of the medial ligamentous patellar stabilizers (star) with patellar osteochondral avulsion (arrow) and impaction of the lateral femoral condyle (arrowhead). Note the shallow trochlea and the fluid level related to hemarthrosis. (E) Osteochondral fragment (arrow) arising from the patella. (F) Osteochondral fracture of the antero lateral aspect of the lateral femoral condyle (arrow).

Fig 14. Different shapes of the posterior tibial condyles. On a lateral view, 3 tangents can be depicted. (A) The tangent to the lateral plateau is mildly convex upward (arrowheads) while the tangent to the medial one is concave (large arrows). The third posterior sloping line is tangent to the posterior intercondylar area (small arrows). (B-C) Corresponding sagittal PD-weighted images.

Fig 15. Impaction fracture of the posterior aspect of the lateral tibial condyle (arrow) after ACL injury on a (A) lateral radiographic view and on a (B) sagittal T1-weighted image.

Fig 16. Impaction fracture of the posterior aspect of the medial tibial condyle (arrow) after ACL injury on a (A) lateral radiographic view and on a (B) sagittal T1-weighted image. Note the associated tear of the posterior horn of the medial meniscus (arrowhead).

Fig 17. (A) Fracture interrupting the tangent to the posterior intercondylar area (large arrow) on a lateral view. The tangents to the lateral (arrowheads) and medial (small arrows) tibial condyles are not involved. (B) Sagittal CT image confirms the posterior cruciate ligament tibial avulsion fracture (arrow).

Fig 18. Avulsion of the tibial attachment of the ACL. Large fragment (arrow) detected on the (A) lateral view and on a (B) sagittal T1-weighted image. Note the associated lateral femoral notch sign (arrowhead). (C) Small bone avulsion depicted on an AP view.

Fig 19. Segond fracture. (A) Thick and (B) thin vertical bone fragments (arrow) parallel to the lateral aspect of the tibial plateau. (C) Coronal PD-weighted image of case B showing the tibial avulsion (arrow) of the anterolateral ligament (arrowhead). Note the adjacent bone marrow edema.

Fig 20. Lesions of the proximal aspect of the superficial MCL. (A) Thin femoral bone avulsion (arrow) in the acute phase; note the irregular femoral epicondyle outline (arrowhead). (B) Corresponding PD-weighted image (arrow). (C) Thick ossification 6 months after superficial MCL avulsion (arrow). (D) Amorphous apatite calcification of the superficial MCL (arrow).

Fig 21. Bone avulsion (arrow) of the deep portion of the MCL in the (A) acute and (B) chronic phases on AP radiographs. (C) Corresponding image on PD-weighted image.

Fig 22. Avulsion fracture involving the styloid process of the fibula (arrow) on (A) AP radiograph. The fragment is mildly displaced superiorly. (B) On the corresponding coronal PD-weighted image, the fragment (f) is displaced superiorly by the popliteofibular ligament (large arrow). Injury of the popliteal musculotendinous junction is also demonstrated (star). The fracture (thin arrow) does not involve the *biceps femoris* tendon (arrowhead) inserted on the lateral aspect of the fibular head.

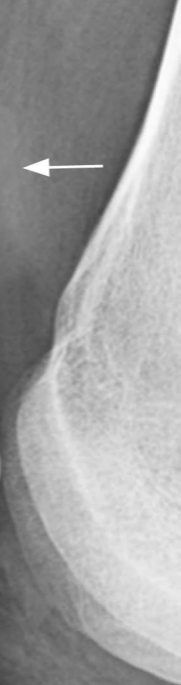
Fig 23. Avulsion fracture (arrow) involving the lateral and medial aspects of the fibular head on (A) AP radiograph. The fragment is mildly displaced superiorly. (B) On the corresponding coronal PD-weighted and (C) sagittal T1-weighted images, the lateral collateral ligament (arrowheads) and the *biceps femoris* tendon (thin arrows) are attached to the bone fragment (large arrows).

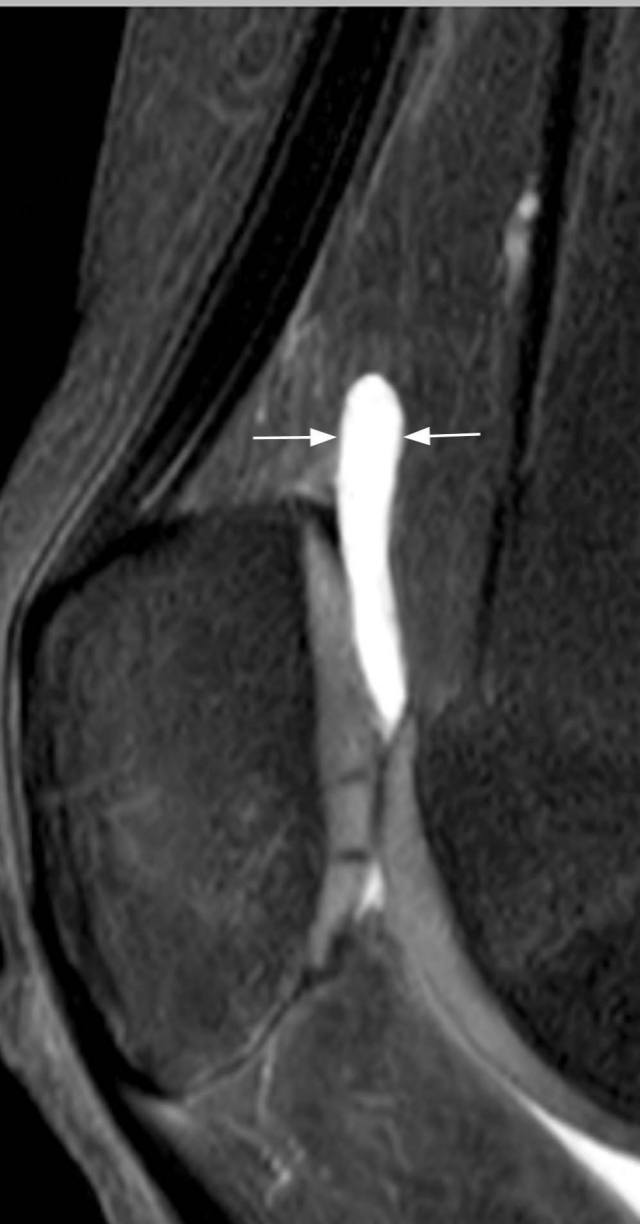
Fig 24. Impaction fracture of the medial margin of the tibia (arrowhead) on (A) AP view. (B) Corresponding PD-weighted image showing the meniscal flap displaced in the medial meniscotibial recess (arrow). Note the associated edema of the adjacent bone and soft tissues.

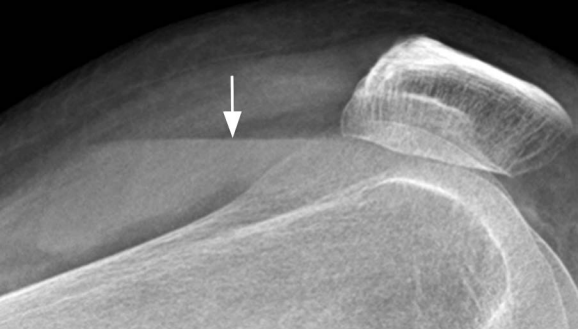
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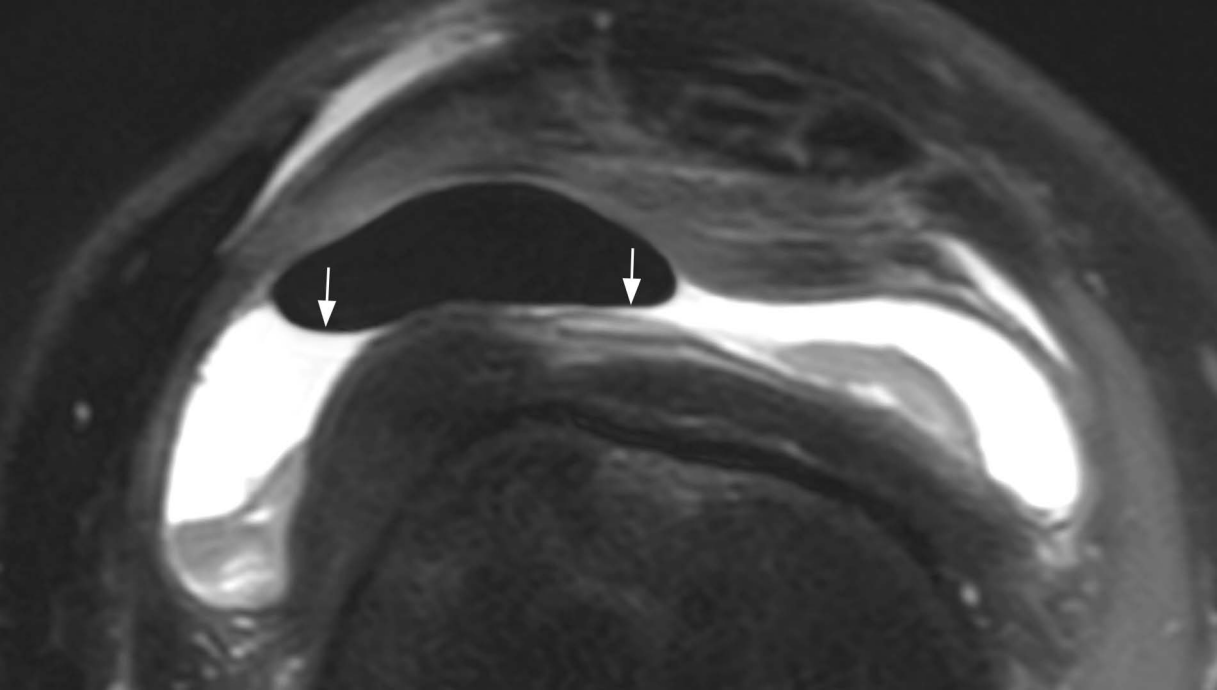
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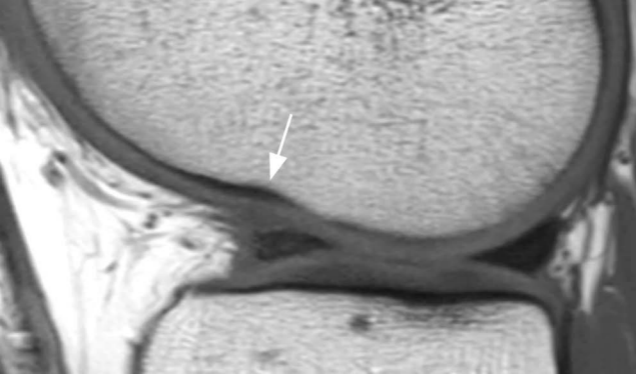


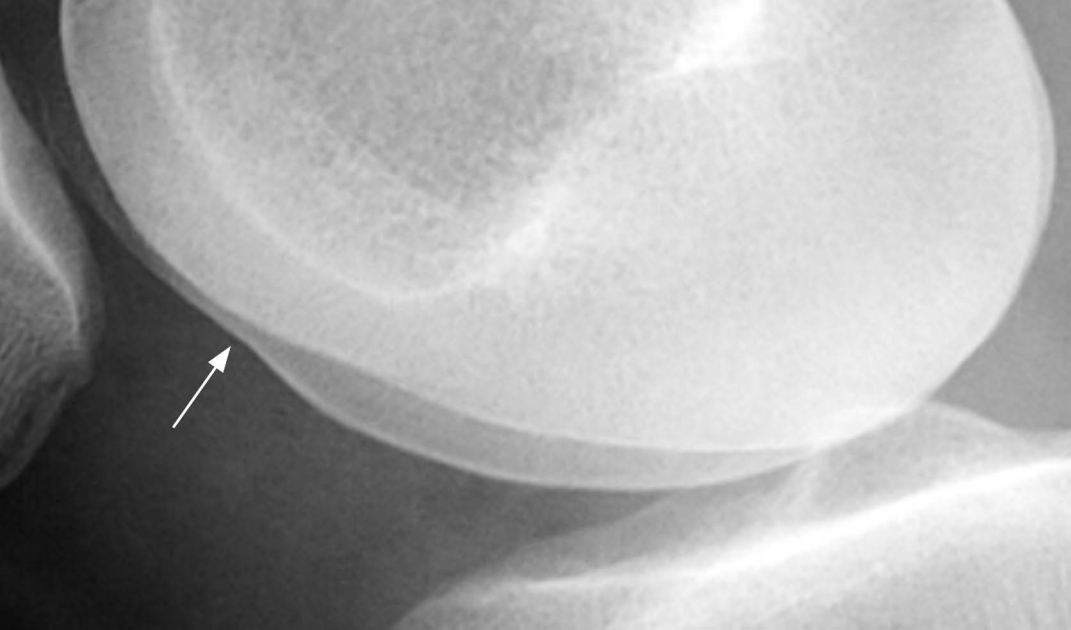


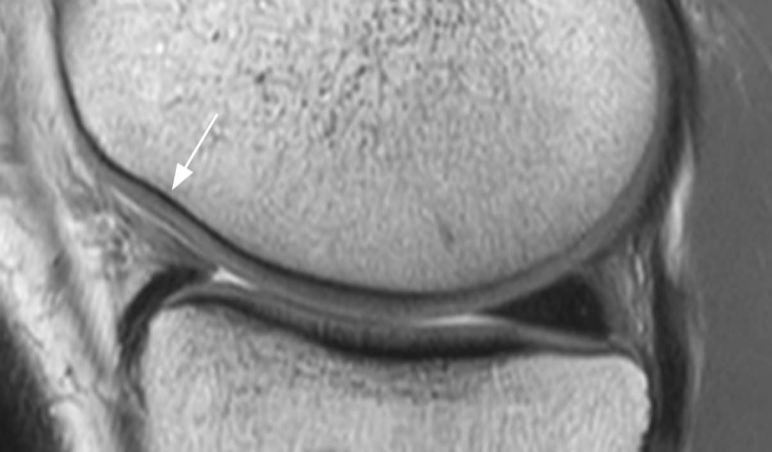


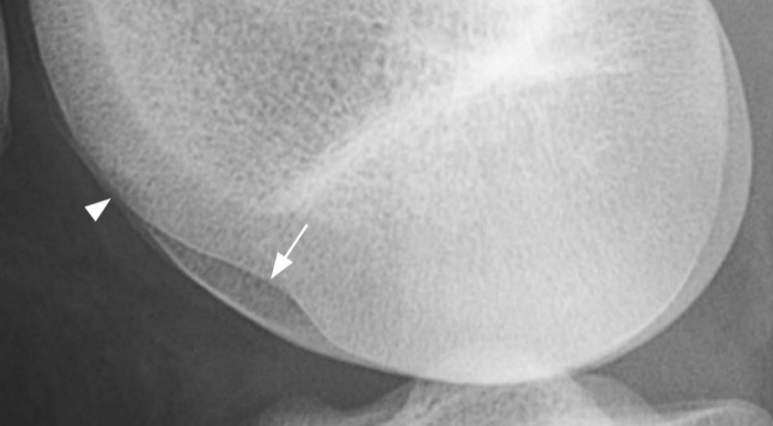


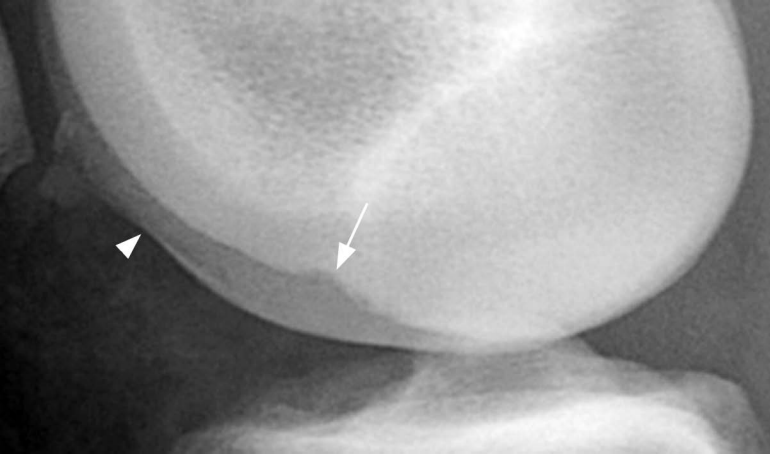


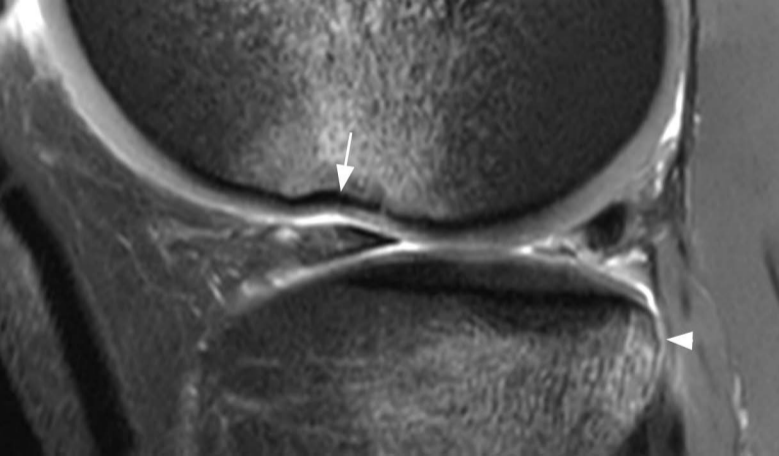






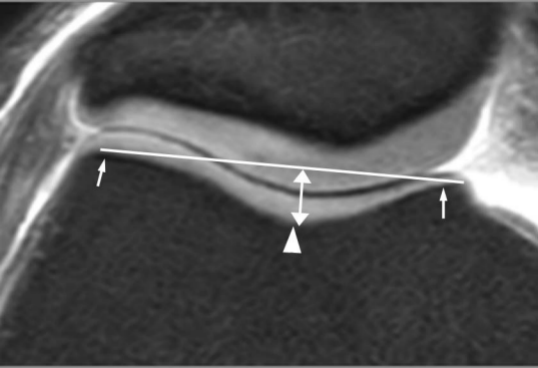


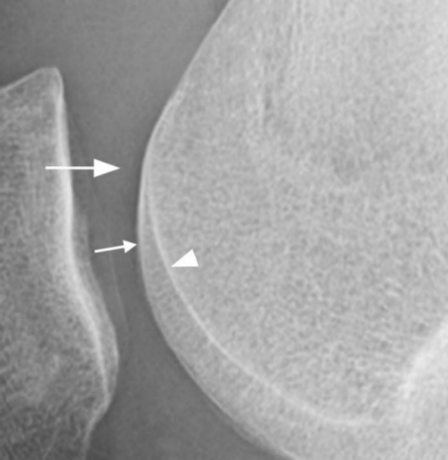


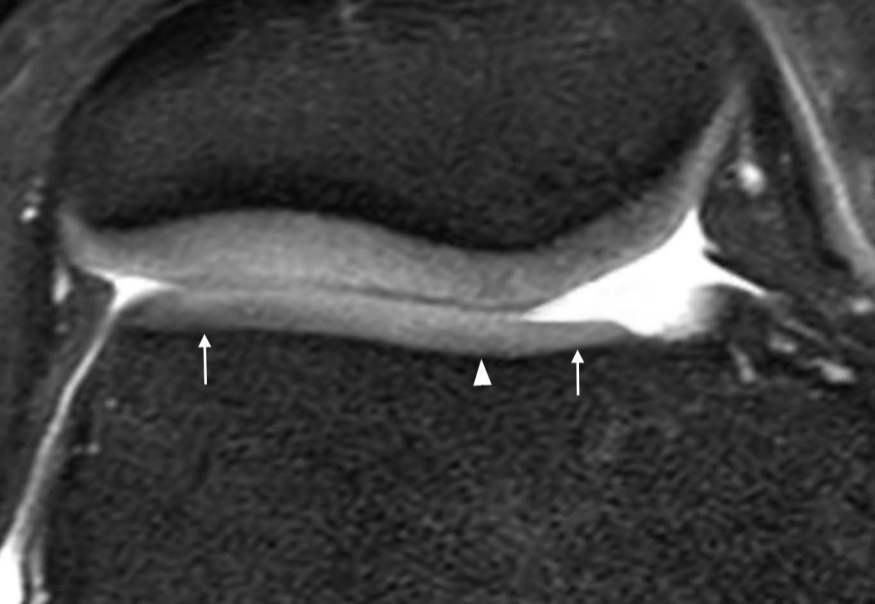




1 cm





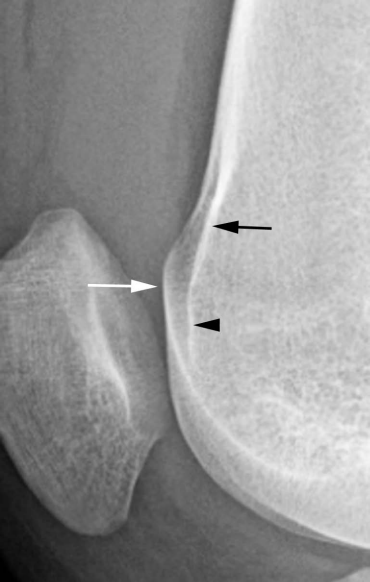




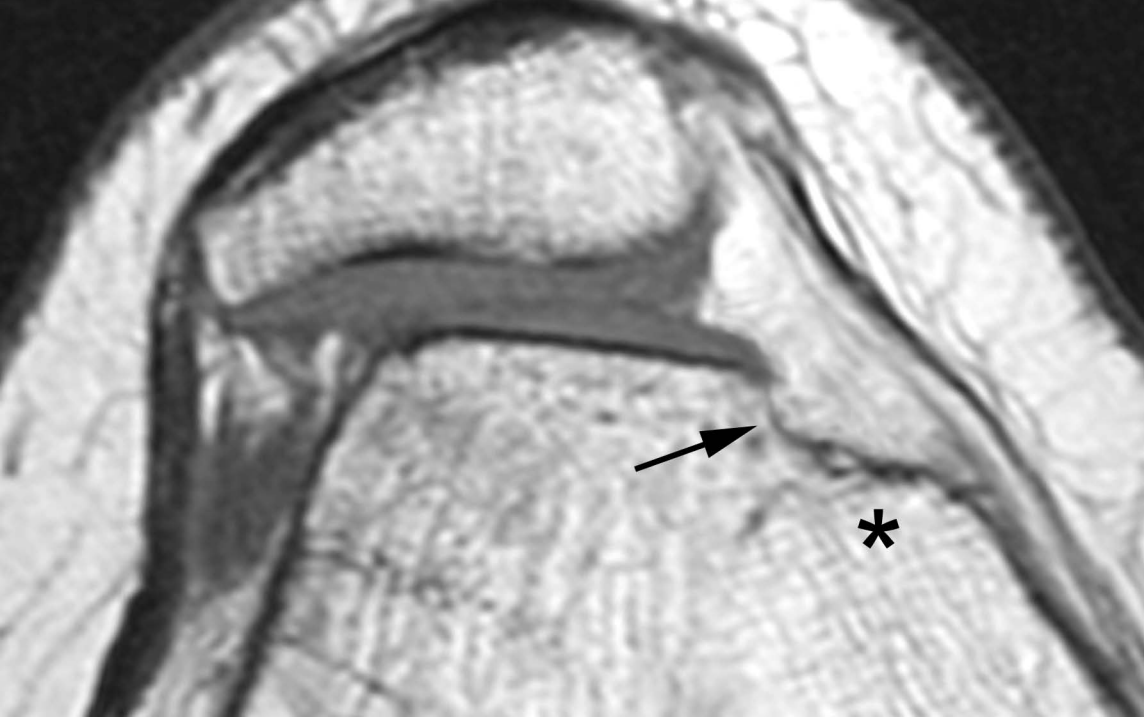


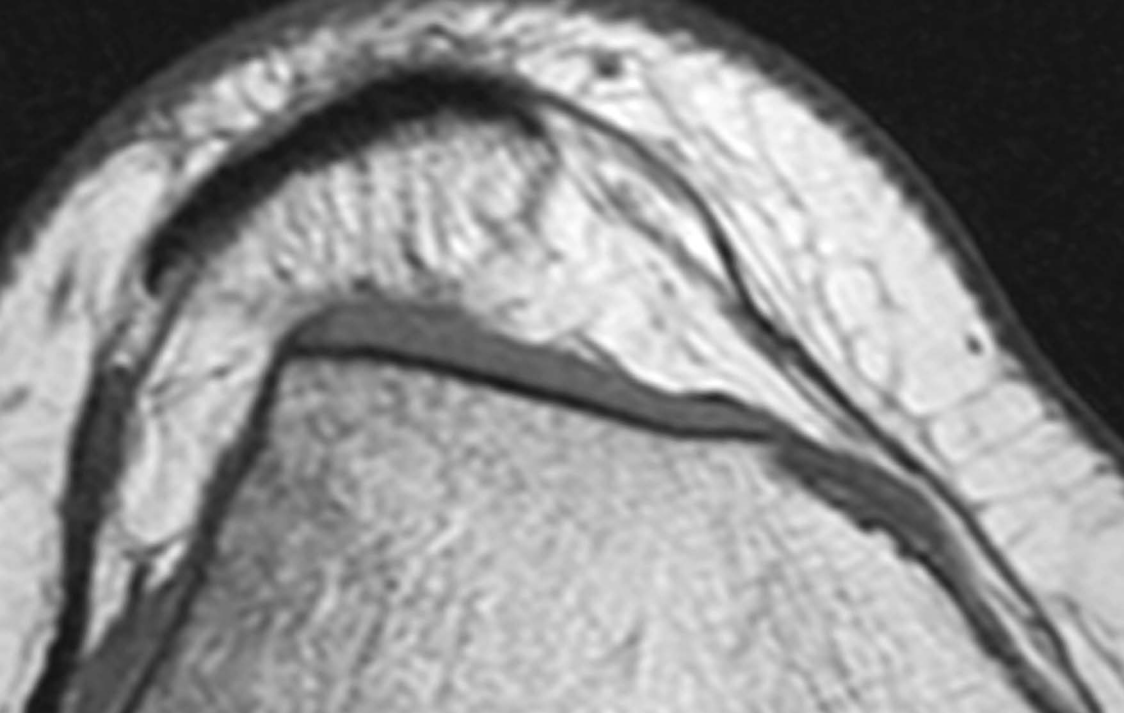


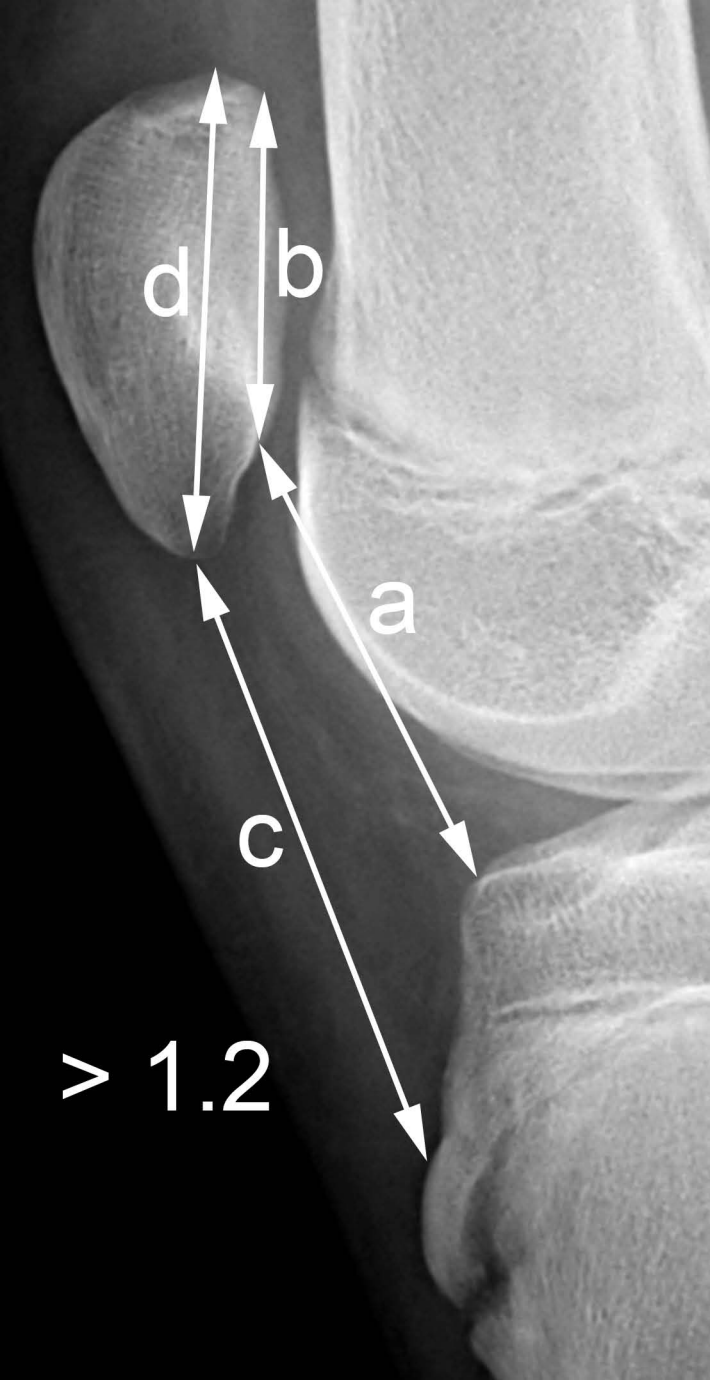












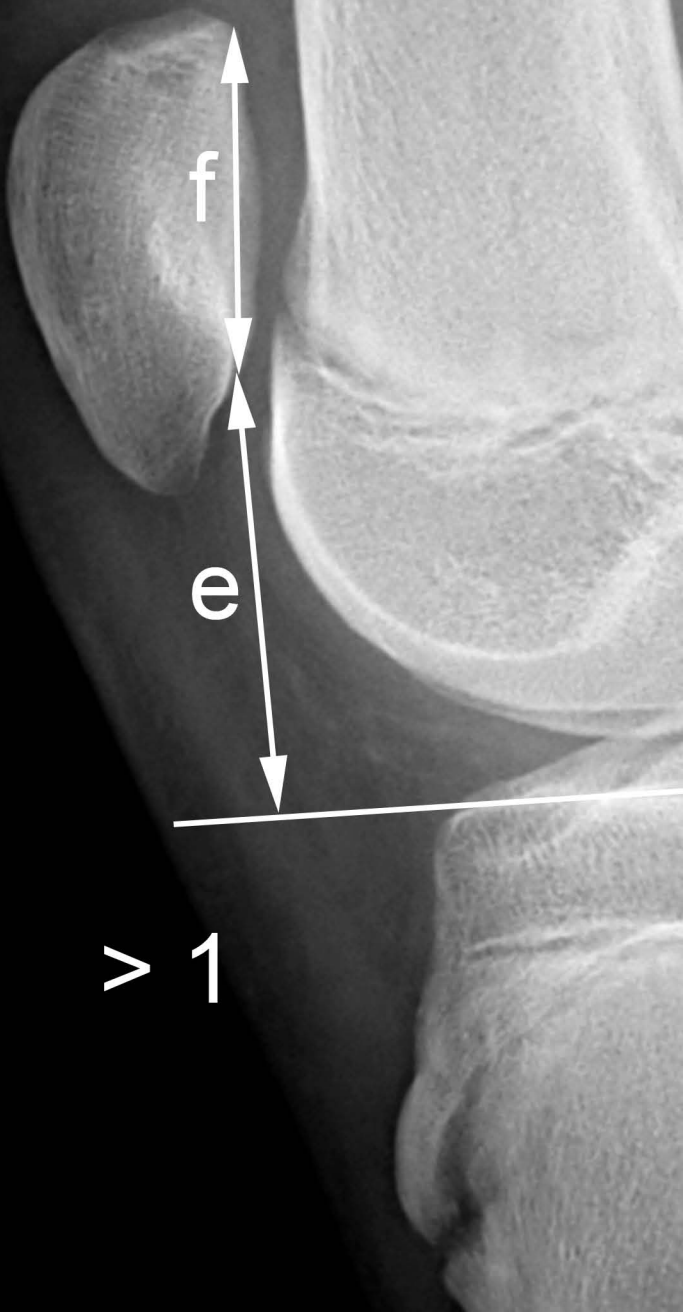
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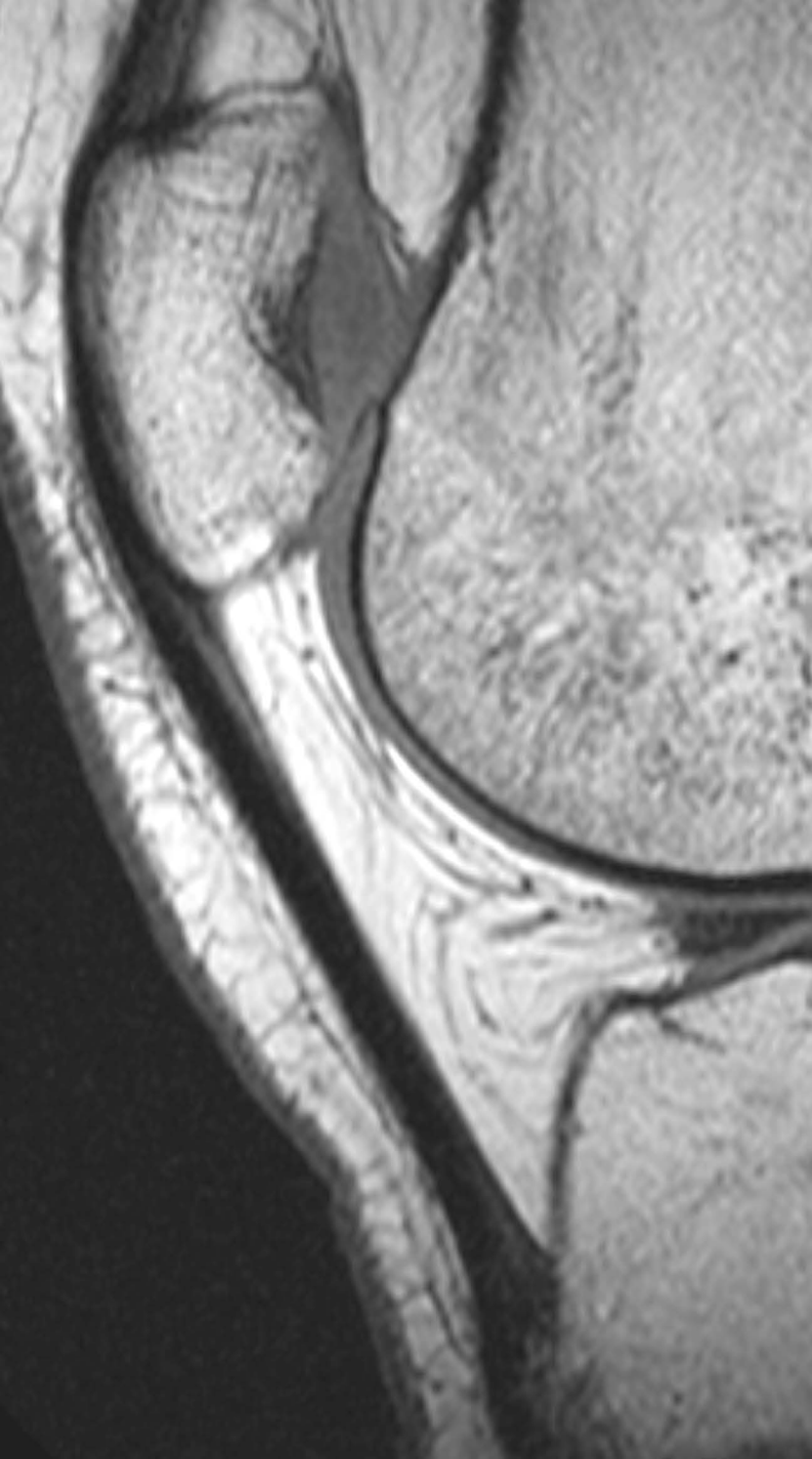
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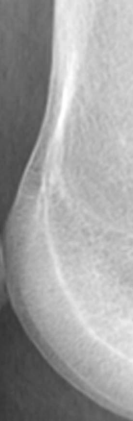


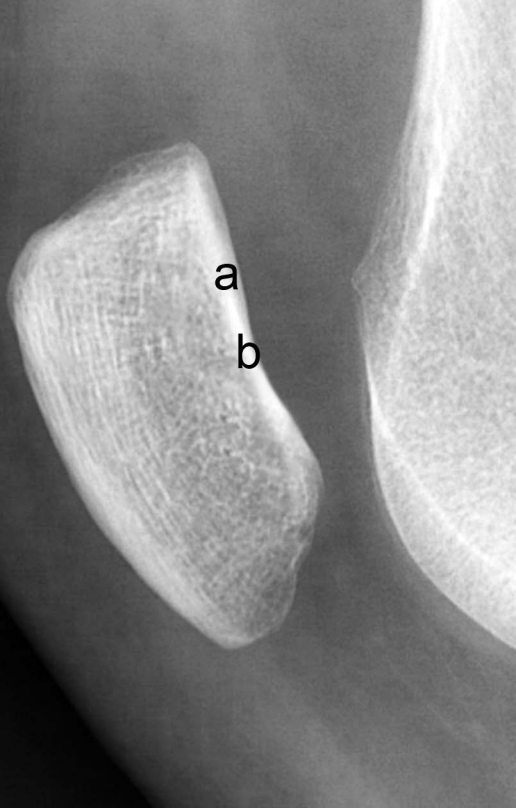
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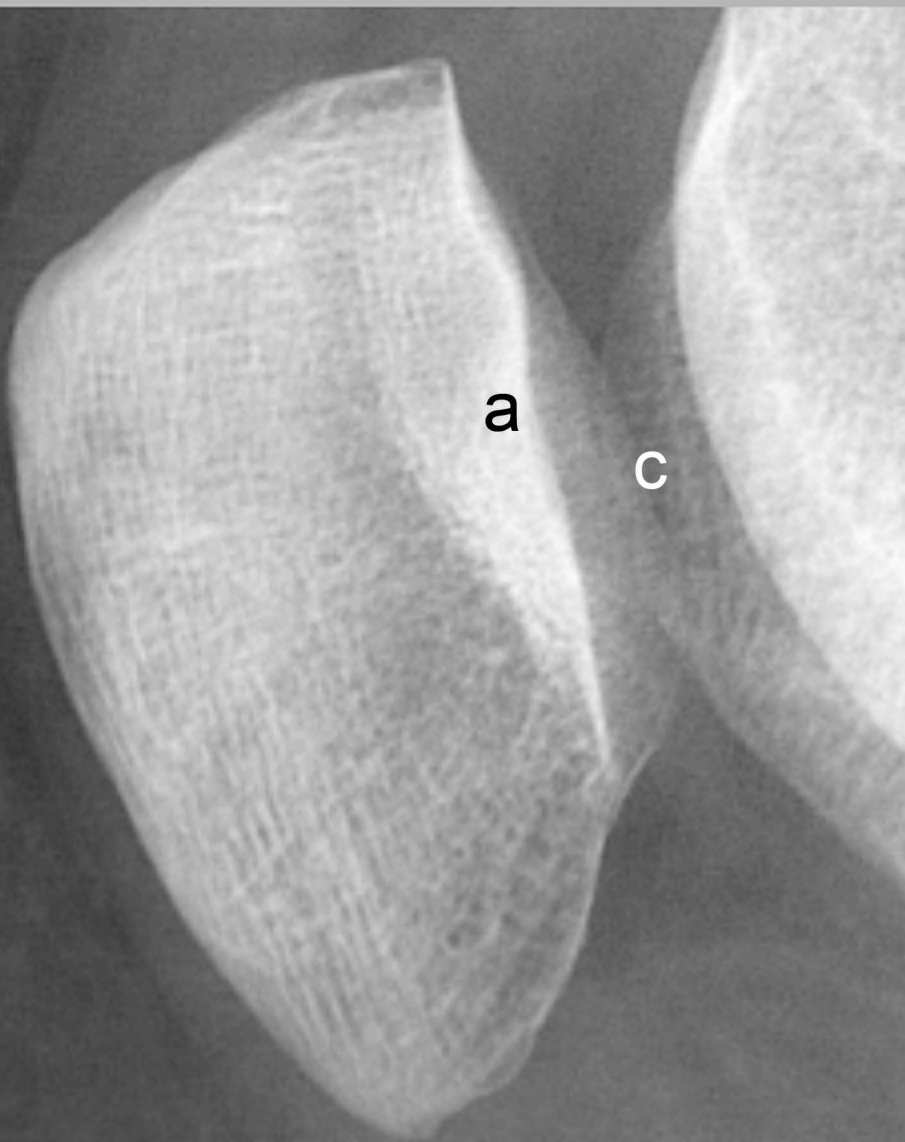


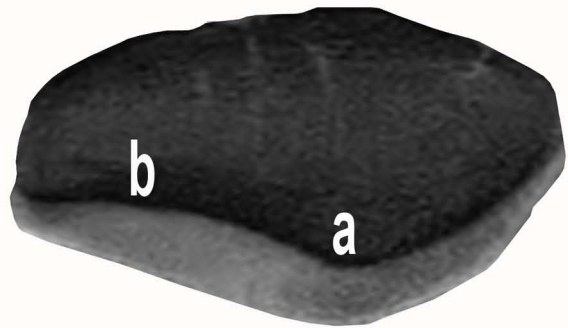




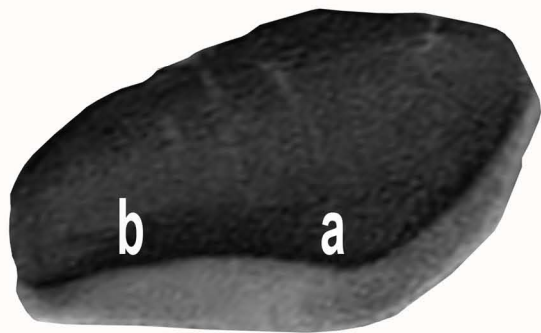
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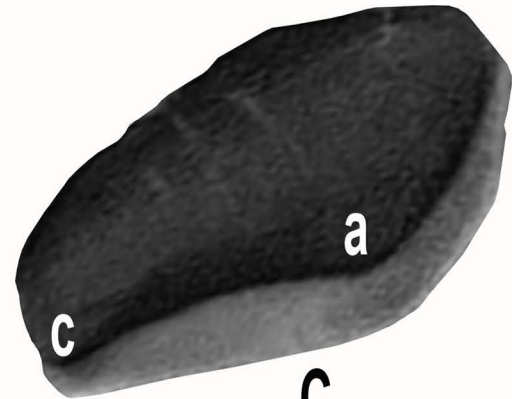




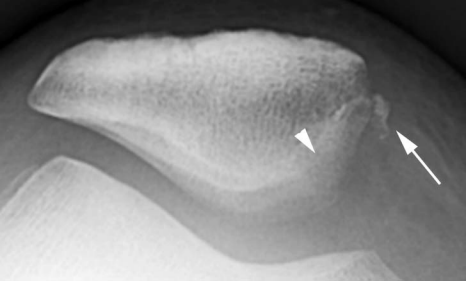
A



B



C



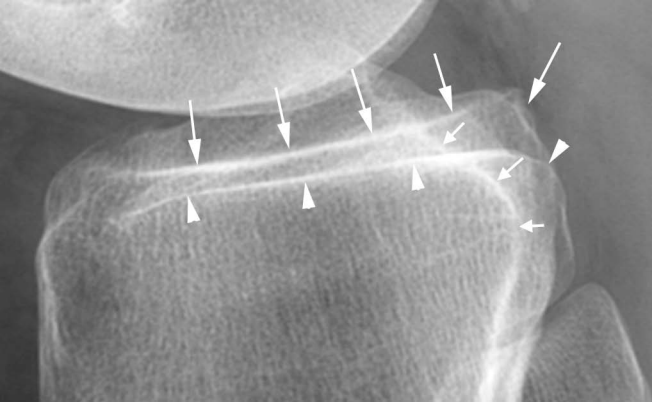


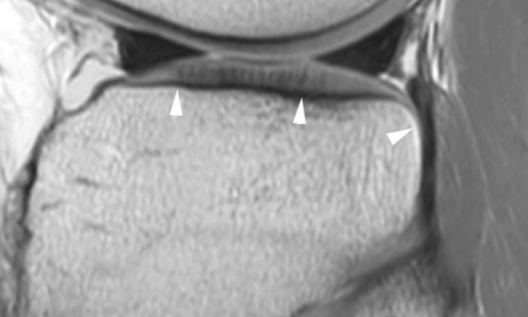




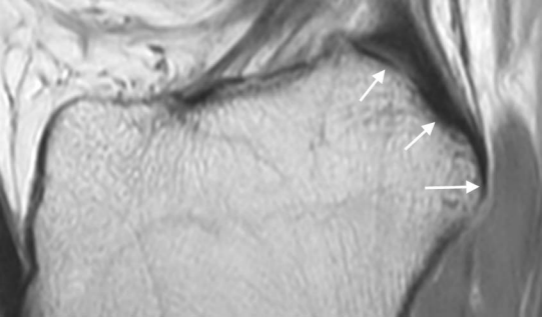




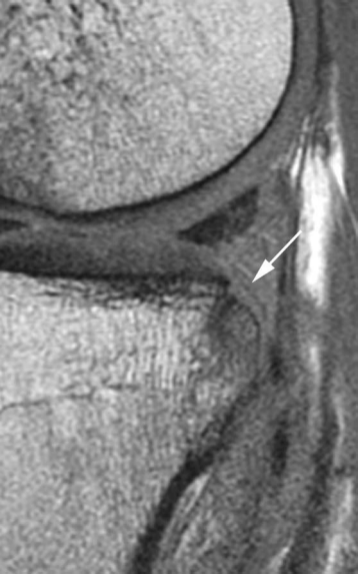




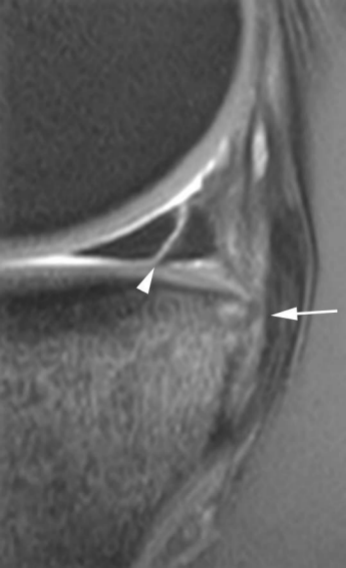


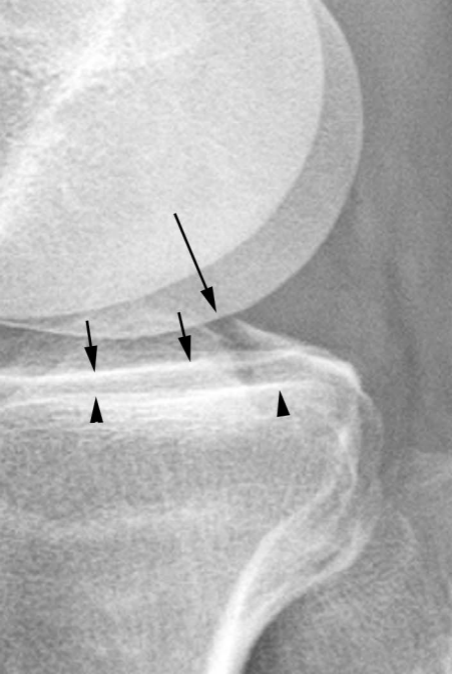


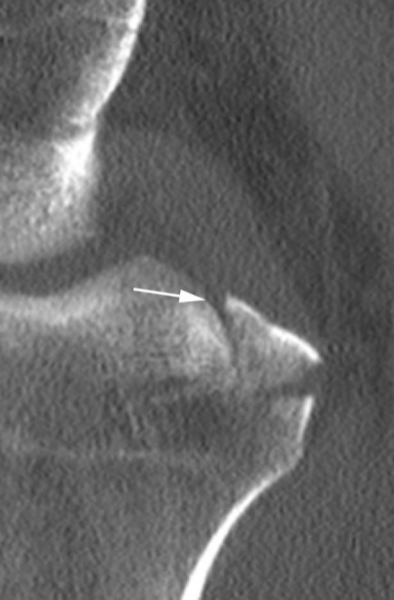


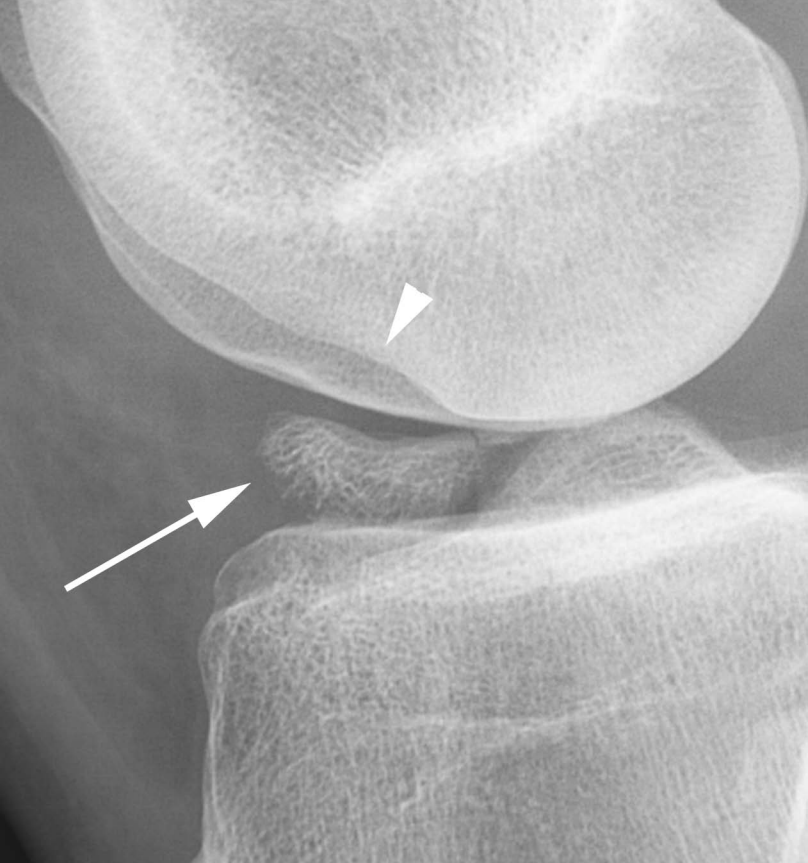


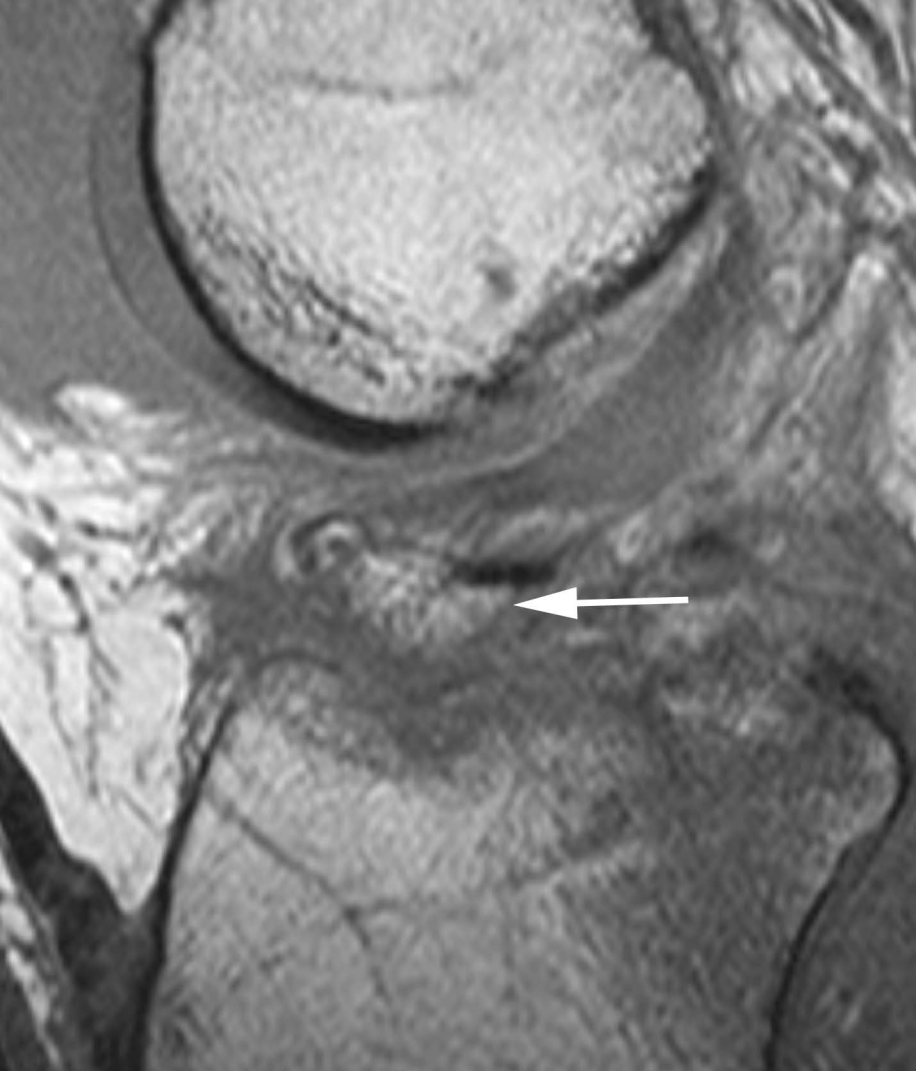




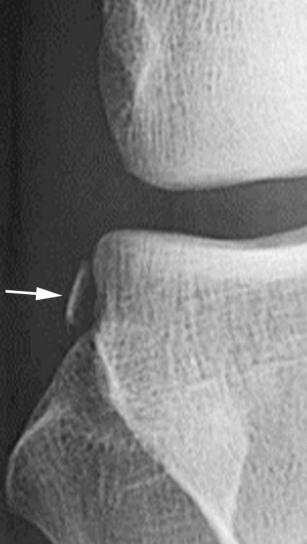


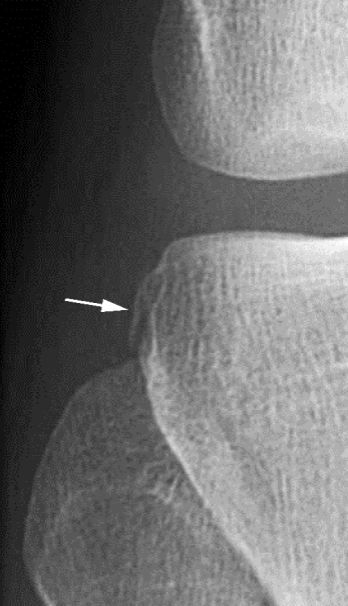




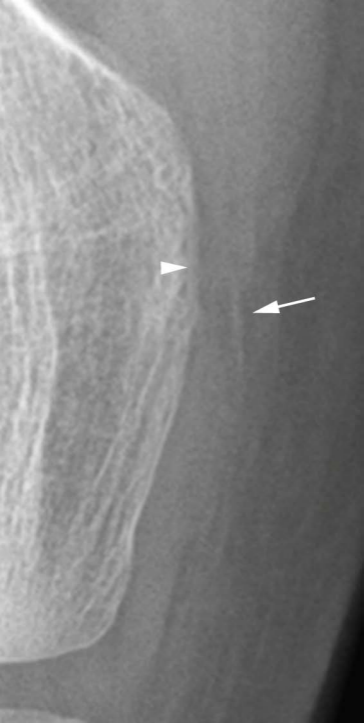












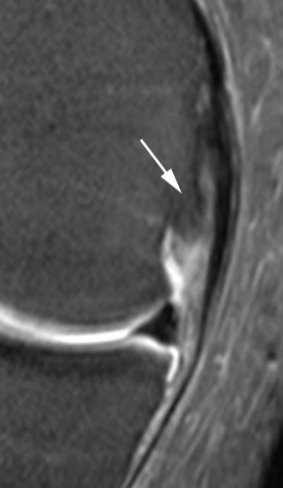
















D

