

EVIDENCE SUMMARY

Trochlear dysplasia and trochleoplasty

Anatomy & Pathophysiology

BONY ANATOMY

- The bones of the knee are the distal femur, the proximal tibia, and the patella [1].
- The medial femoral condyle is larger and projects farther posteriorly and distally than the lateral condyle [3].
- The lateral femoral condyle projects farther anteriorly and is wider in the medial-lateral direction than the medial femoral condyle [3].
- The trochlear groove separates the two condyles anteriorly and constitutes the patellofemoral articulation [3].
- The sulcus terminalis is a small ridge on the lateral femoral condyle just distal to the intercondylar notch that separates the patellofemoral and tibiofemoral articular surfaces [3].
- The intercondylar notch is of variable width and is the site of attachment of the cruciate ligaments [3].
- The lateral trochlear facet resists lateral subluxation of the patella [17].
- The sulcus terminalis is a transverse ridge extending from the oblique facets of the femoral trochlea that is deeper on the lateral condyle than on the medial condyle [17].
- The patella is the largest sesamoid bone in the body [3].
- The patella averages 2.5 cm in thickness [3].
- The patella has the thickest articular surface in the body, approximately 5 mm in the midportion and 2 mm on the sides [3].
- The patellar articular surface contains a vertical, central ridge that separates the broader lateral facet from the medial facet, and a smaller, more medial facet called the odd facet [3].
- The tibial articular surface slopes 7° to 10° in the sagittal plane [3].
- The medial tibial plateau is larger than the lateral plateau and is concave in its frontal and sagittal planes [3].
- The lateral tibial plateau is smaller and more circular than the medial plateau, concave in the frontal plane and convex in the sagittal plane [3].

- The posterior slope of the tibia is a mean of 10.7° in the medial plateau and 7.2° in the lateral plateau [17].
- The tibial tuberosity is the site of attachment of the patellar tendon and is typically located in the midline anteriorly but may be slightly lateral [3].
- Gerdy's tubercle is the insertion site of the iliotibial band and is located 2 to 3 cm lateral to the tibial tubercle on the proximal tibia [3].

LIGAMENTS

- The anterior cruciate ligament (ACL) travels from the medial border of the lateral femoral condyle to its insertion site anterolateral to the medial tibial spine [1].
- The ACL prevents anterior translation and rotation of the tibia on the femur [1].
- The posterior cruciate ligament (PCL) prevents posterior subluxation of the tibia on the femur [1].
- The PCL runs from the lateral aspect of the medial femoral condyle to the posterior aspect of the tibia, just below the joint line [1].
- The medial collateral ligament has superficial and deep portions which stabilize the knee to valgus stresses [1].
- The lateral collateral or fibular collateral ligament runs from the lateral femoral condyle to the head of the fibula and is the main stabilizer against varus stress [1].
- The popliteofibular ligament is present in 90% of knees and runs from the tendon of the popliteus muscle to the styloid on the posterior fibular head [1].
- The ACL is composed of 90% type I collagen and 10% type III collagen [3].
- The mean length of the ACL is 33 mm and the mean midsubstance width is 11 mm [3].
- The femoral attachment of the ACL is a semicircular area (20 mm long and 10 mm wide) on the posteromedial aspect of the lateral femoral condyle [3].
- The tibial attachment of the ACL is a broad, irregular, oval-shaped area (30 mm long and 10 mm wide) slightly medial and anterior to the midline and between the medial and lateral tibial spinous processes [3].
- The ACL consists of anteromedial and posterolateral functional bundles [7].
- The anteromedial bundle of the ACL is tighter in knee flexion [7].
- The posterolateral bundle of the ACL is tighter in extension [7].
- The PCL has a mean length of 38 mm and a mean width of 13 mm [17].
- The femoral attachment of the PCL is a broad, crescent-shaped area on the anterolateral medial femoral condyle with a mean length of 30 mm and mean width of 5 mm [17].
- The tibial insertion of the PCL onto the posterior central sulcus is 10 to 15 mm distal to the joint line of the knee [17].
- The anterolateral bundle of the PCL is stronger and stiffer than the posteromedial bundle [17].
- The anterolateral bundle of the PCL is tight in knee flexion [17].
- The posteromedial bundle of the PCL is tight in knee extension [17].

- The medial patellofemoral ligament runs from the patella near the junction of the middle and superior thirds to the medial femoral epicondyle [6].
- The medial patellofemoral ligament is more important for patellar stability than other structures in that region [6].

MENISCI

- The menisci are C-shaped fibrocartilaginous disks in the knee that provide shock absorption, allow for increased congruency between joint surfaces, enhance joint stability, and aid in distribution of synovial fluid [1].
- The medial meniscus is firmly attached to the joint capsule along its entire peripheral edge [1].
- The lateral meniscus is attached to the anterior and posterior capsule, but there is a region posterolaterally where it is not firmly attached [1].
- The medial meniscus has less mobility than the lateral meniscus and is more susceptible to tearing when trapped between the femoral condyle and tibial plateau [1].
- The lateral meniscus is larger than the medial meniscus and carries a greater share of the lateral compartment pressure than the medial meniscus carries for the medial compartment [1].
- The medial meniscus has a semicircular shape, which covers approximately 50% to 60% of the medial tibial plateau in adulthood [13].
- The posterior horn of the medial meniscus averages 11 mm in the anterior-posterior dimension [13].
- The lateral meniscus has a more circular C-shape with symmetric sizes of the anterior and posterior horns [13].
- The popliteomeniscal fascicles extend from the lateral meniscus to the posterior capsule to create the popliteal hiatus [13].
- The meniscofemoral ligaments are variably present structures which connect the posterior horn of the lateral meniscus to the medial femoral condyle [13].
- The ligament of Humphrey crosses anterior to the PCL and the ligament of Wrisberg crosses posteriorly [13].
- The less continuous attachment of the lateral meniscus to the capsule allows for greater meniscal mobility [13].
- Mean lateral meniscus excursion is 11.2 mm versus a mean medial meniscus excursion of 5.1 mm occurring from knee extension to flexion [13].
- Menisci have three zones discernible based on vasculature and extracellular matrix composition: white-white (ww), red-white (rw), and red-red (rr) [13].
- The inner one-third of the meniscus is avascular and called the white-white zone [13].
- The middle zone is called the red-white zone because it has limited vasculature [13].
- The back one-third is called the red-red zone because it is the most vascularized tissue region that has access to blood supply through vessels arising from the geniculate arteries [13].

- Vascular supply to the menisci is derived from the geniculate arteries, which penetrate into 20% to 30% of the peripheral medial meniscus and 10% to 25% of the peripheral lateral meniscus [17].

VASCULAR AND NERVE ANATOMY

- The blood supply to the knee is formed from an anastomosis around the knee derived from the descending geniculate artery, medial and lateral superior geniculate arteries, medial and lateral inferior geniculate arteries, middle geniculate artery, and anterior tibial recurrent arteries [3].
- The middle geniculate artery supplies both the anterior and posterior cruciate ligaments [3].
- The inferior geniculate arteries pass deep to their respective collateral ligaments [3].
- The blood supply of the patella is derived from the geniculate artery complex with some contribution from the anterior tibial recurrent artery and primarily exists in the middle to inferior portions of the patella [3].
- The knee is innervated by branches of the femoral nerve (L2, L3, L4), obturator nerve (L2, L3, L4), and sciatic nerve (L4, L5, S1, S2) [3].
- The largest nerve providing innervation of the intra-articular knee is the posterior articular branch of the tibial nerve [3].
- The posterior articular branch of the tibial nerve supplies the infrapatellar fat pad, the synovial covering over the cruciate ligaments, and the periphery of the meniscus [3].
- Nerves to the cruciate ligaments contain vasomotor and pain fibers as well as mechanoreceptors that may be involved in proprioception [3].
- The infrapatellar branch of the saphenous nerve arises proximal to the knee joint medially and crosses distal to the patella to innervate the skin over the region of the anterior knee and proximal tibia [3].

KINETICS AND JOINT FORCES

- The knee is a hinge joint that also incorporates both gliding and rolling, which are essential to its kinematics [4].
- The “screw-home” mechanism involves the tibia externally rotating 5 degrees in the final 15 degrees of extension [4].
- The ACL is typically subjected to peak loads of 170 N during walking and up to 500 N with running [18].
- The ultimate strength of the ACL in young patients is about 1750 N [18].
- ACL failures occur by serial tearing at 10% to 15% elongation [18].
- Sectioning the PCL increases contact pressures in the medial compartment and the patellofemoral joint [18].
- Knee joint surface loads are three times body weight during level walking and up to four times body weight with stair walking [18].
- The menisci help with load transmission and bear one-third to one-half body weight [18].
- Removal of the menisci increases contact stresses, with up to four times the load transfer to bone [18].
- The quadriceps produces maximum anterior force on the tibia at 0 to 60 degrees of knee flexion [18].

- The patella aids in knee extension by increasing the lever arm and stress distribution [18].
- The patella has the thickest cartilage in the entire body and bears the greatest load [18].
- The patella bears half the body weight with normal walking and seven times the body weight with squatting and jogging [18].
- Patellofemoral loads are proportional to the ratio of quadriceps force to knee flexion [18].
- In descending stairs, compressive force in the patellofemoral joint reaches two to three times body weight [18].
- Patellectomy decreases the length of the moment arm by the width of the patella and decreases the power of extension by 30% [18].

Investigations

RADIOGRAPHY

- Plain radiographs are appropriate initial imaging studies for most knee conditions because they allow the assessment of traumatic injury, arthritis, patellofemoral alignment, osteochondral injury, bone neoplasm, and surgical implants [21].
- Imaging studies should include at least two perpendicular views: AP and lateral [21].
- Weight-bearing AP (extension) views are used to assess cartilage loss from the distal femur and tibial plateau [21].
- Weight-bearing PA (Rosenberg; flexion) views are used to assess cartilage loss from the posterior femur and tibial plateau [21].
- Patellofemoral views are used to assess patellofemoral alignment (tilt/subluxation), patellar and trochlear morphology, osteochondral injury, and patellofemoral arthritis [21].
- The notch view is used to assess posterior femoral cartilage, notch width, and osteophytes [21].
- Radiographs can underestimate isolated chondral lesions but may demonstrate joint space narrowing, osteophytes, sclerosis, and cysts [25].
- Weight-bearing AP and lateral views and an axial view of the patellofemoral joint should be reviewed for articular cartilage evaluation [25].
- The ability to detect subtle narrowing or an isolated chondral defect on the flexion surface may be improved with a semiflexed PA view [25].
- Long leg alignment views are used to determine the mechanical axis [25].
- If the mechanical axis traverses the involved compartment (varus knees with medial compartment lesions or valgus knees with lateral compartment lesions), realignment may need to be considered as an initial procedure or as an adjunct to a cartilage restorative procedure [25].
- Radiographs should be inspected for acute fracture, lateral capsular avulsion (Segond fracture), loose bodies, Pellegrini-Stieda lesion (MCL calcification), and evidence of patellar dislocation [9].

- Stress radiographs should be obtained in patients prior to skeletal maturity to rule out an epiphyseal fracture [9].
- Radiographs are still the standard for initial evaluation of knee arthritis [29].
- Images for knee arthritis evaluation should include weight-bearing AP and lateral views, a view of the weight-bearing knee flexed at 45-degree angle imaged posterior to anterior, a sunrise view (Merchant view), extension and flexion lateral views, and a standing full-length AP radiograph [29].
- The Kellgren-Lawrence (KL) rating grades extent of OA based on review of AP knee radiograph [29].
- Primary features used for KL rating include osteophytes (periarticular and tibial spine), joint space narrowing, subchondral sclerosis with or without subchondral cysts, and altered shape of periarticular bones [29].
- KL Grade 0 indicates normal knee features with no OA [29].
- KL Grade 1 indicates OA possibly present [29].
- KL Grade 2 indicates OA present with minimal severity [29].
- KL Grade 3 indicates OA present with moderate severity [29].
- KL Grade 4 indicates OA present with severe severity [29].
- Knee arthroplasty is recommended when Grade 4 findings are present [29].

COMPUTED TOMOGRAPHY

- Computed tomography provides a three-dimensional study with ionizing radiation that provides enhanced bone detail [21].
- Imaging in the axial, sagittal, and coronal planes may help visualize fracture lines and displacement, osteolytic lesions around joint arthroplasty, and cortical disruption in cases of infection or neoplasia [21].
- Three-dimensional reconstructions may help with preoperative planning for complex intra-articular fractures, multiplanar osteotomy for limb malalignment, and reconstitution of bone loss in joint arthroplasty [21].
- Axial plane imaging of the hip and knee can help assess the rotational alignment of components of a total knee arthroplasty in cases of patellar maltracking [21].
- Three-dimensional CT with remodeling is used for preoperative planning for reconstruction associated with dysplasia, post-trauma planning, and complex total knee arthroplasty (TKA) planning [29].

MAGNETIC RESONANCE IMAGING

- Increasing strength of the magnetic field (measured in Tesla units) increases the resolution of images [21].
- An injected contrast agent (intravenous or intra-articular) may help delineate specific tissues of interest [21].
- MRI may identify the degree of articular cartilage injury (chondrosis, full-thickness cartilage loss), the presence of associated bone marrow edema, and the location (medial condyle, lateral condyle, trochlea, patella; anterior, posterior) [21].

- MRI can be used to evaluate articular cartilage morphology [25].
- MRI is useful for confirming MCL injury and identifying the site of injury [9].
- MRI is useful to detect the presence of meniscal and other injuries to the knee [9].
- Relative indications for an MRI include an uncertain ACL status despite multiple examinations, evaluation of a suspected meniscal tear, or preoperative evaluation for a planned MCL reconstruction or repair [9].
- MRI is often a useful adjunct for diagnosing posterolateral corner and LCL injuries in the severely injured knee [30].
- MRI findings can refocus the examination to the posterolateral structures when pain and guarding at the time of injury obscure posterolateral injury [30].
- MRI is grossly overused in the arthritic patient population [29].
- If the joint space is significantly narrowed on radiograph, then MRI is not indicated [29].
- MRI is used when osteonecrosis is suspected [29].
- The presence of edema, intra-articular fluid, disruption of ligament fibers, and an atypical ligament contour may suggest cruciate ligament injury [21].
- Patterns of meniscal injury can be identified by location (anterior, midbody, posterior, peripheral, articular), pattern (horizontal, longitudinal, radial, complex), and displacement [21].
- Edema, avulsion, or discontinuity may be identified for the MCL/lateral collateral ligament (LCL) or associated posteromedial and posterolateral ligamentous complexes [21].
- MRI may be used to assess the continuity of the quadriceps or patellar tendon [21].
- MRI may be used to assess the margin of resection for a neoplasm, identify vascular malformation, or define the location of nerves or vessels relative to popliteal cysts [21].

NUCLEAR MEDICINE

- Nuclear medicine involves labeled radionuclide injection followed by delayed imaging of gamma radiation [21].
- Areas of increased radionuclide concentration appear bright or “hot” [21].
- Nuclear medicine provides a nonspecific study that does not define the etiology of an abnormality but rather the presence of an abnormality that may correlate with a clinical concern [21].
- Increased radionuclide activity in bone may be a normal postoperative finding for up to 6 to 12 months after a fracture repair or arthroplasty [21].
- Technetium-99 (Tc-99) is a radionuclide that may help identify infection, neoplasia, occult fracture, bone healing, active phases of heterotopic ossification, implant loosening, or failure of osseointegration [21].
- Gallium-67 (Ga-67) is a radionuclide that may help differentiate between aseptic and septic prosthetic loosening [21].
- 24 to 72 hours are needed for a complete Gallium-67 study [21].

PHYSICAL EXAMINATION

- The physical examination begins with observation of the patient's gait [1].
- The uninjured knee is examined as a basis of comparison with the injured knee [1].
- Any swelling or effusion should be noted [1].
- A small effusion will cause obliteration of the recesses on the medial and lateral aspects of the patellar tendon [1].
- With a larger effusion, diffuse swelling is present in the region of the suprapatellar pouch [1].
- A fluid wave can be palpated on the sides of the patella [1].
- Active and then passive range of motion is tested carefully [1].
- The knee is palpated to define areas of localized tenderness [1].
- The joint lines are located at the level of the inferior pole of the patella when the knee is flexed to 90 degrees [1].
- An effusion, motion deficits, or limb malalignment may be observed in patients with articular cartilage injuries [25].
- Knee stability should be compared with the normal side in patients with articular cartilage injuries [25].
- Laxity to valgus stresses is assessed by the amount of medial joint space opening that occurs at 30 degrees of flexion [9].
- It is important to stress the knee at 30 degrees of flexion because with the knee in full extension the posterior capsule and PCL will stabilize the knee to valgus stress [9].
- Zero opening is considered normal for MCL injury evaluation [9].
- 1–4 mm of medial joint space opening indicates a grade I MCL injury [9].
- 5–9 mm of medial joint space opening indicates a grade II MCL injury [9].
- 10–15 mm of medial joint space opening indicates a complete or grade III MCL injury [9].
- Grade I and II MCL injuries typically have a firm end point, whereas a grade III injury tends to have a soft end point to valgus stress [9].
- The integrity of the LCL is assessed by placing a varus stress, with the knee in full extension and 30 degrees of flexion [30].
- The average baseline for varus opening is 7 degrees [30].
- Exam findings with an isolated LCL injury should include varus laxity at 30 degrees of flexion and no instability in full extension [30].
- The dial test is the most useful test to evaluate for posterolateral instability [30].
- The dial test is performed at 30 and 90 degrees of flexion with a significant difference being an angle 5 degrees or greater than the contralateral leg [30].
- Injury to the posterolateral capsule alone is confirmed with greater external rotation at 30 degrees [30].
- An isolated PCL injury is confirmed with greater external rotation at 90 degrees [30].

- Injury to both posterolateral capsule and PCL is confirmed when there is greater rotation at 30 and 90 degrees compared to the uninjured leg [30].
- A careful neurovascular examination should be performed as the incidence of neurovascular injury, particularly peroneal nerve injury, has been reported in 12–29% of posterolateral knee injuries [30].
- An examination under anesthesia can be valuable when physical examination is unreliable because of the patient guarding the knee [9].
- Diagnostic arthroscopy can be used to evaluate for coexisting pathology [9].
- Both examination under anesthesia and diagnostic arthroscopy have largely been replaced by MRI [9].

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