

Revision knee replacement

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 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 patella is the largest sesamoid bone in the body, averaging 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 posterior slope of the medial tibial plateau averages 10.7° and the lateral plateau averages 7.2° [17].
- The fibular head is located a mean of 1.5 cm distal to the joint line, with a range of 6 to 32 mm [17].

LIGAMENTS

- The anterior cruciate ligament (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 medial collateral ligament stabilizes the knee to valgus stresses [1].
- The lateral collateral ligament is the main stabilizer against varus stress [1].
- The ACL is composed of 90% type I collagen and 10% type III collagen [3, 4, 17].
- The mean length of the ACL is 33 mm and the mean midsubstance width is 11 mm [3, 17].

- The femoral attachment of the ACL is a semicircular area on the posteromedial aspect of the lateral femoral condyle, measuring 20 mm long and 10 mm wide [3, 17].
- The tibial attachment of the ACL is a broad, irregular, oval-shaped area measuring 30 mm long and 10 mm wide [3].
- The ACL consists of anteromedial and posterolateral bundles named according to their tibial insertions [4, 7, 15].
- The anteromedial bundle of the ACL is tight in knee flexion [4, 7, 17].
- The posterolateral bundle of the ACL is tight in knee extension [4, 7, 17].
- The PCL has a mean length of 38 mm and a mean width of 13 mm [17].
- The PCL has a broad, crescent-shaped femoral attachment on the anterolateral medial femoral condyle, measuring 30 mm long and 5 mm wide [17].
- The tibial insertion of the PCL is located 10 to 15 mm distal to the joint line of the knee [17].
- The ACL is typically subjected to peak loads of 170 N during walking and up to 500 N with running [18, 19].
- The ultimate strength of the ACL in young patients is about 1750 N [18, 19].
- The ACL fails by serial tearing at 10% to 15% elongation [18, 19].
- Sectioning the PCL increases contact pressures in the medial compartment and the patellofemoral joint [18, 19].

MENISCI

- The menisci are C-shaped fibrocartilaginous disks that provide shock absorption, increase joint congruency, enhance stability, and aid in synovial fluid distribution [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 has 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 [1].
- The medial meniscus has a semicircular shape covering 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 mean lateral meniscus excursion from knee extension to flexion is 11.2 mm, compared to a mean medial meniscus excursion of 5.1 mm [13].
- Menisci bear one-third to one-half of body weight [18, 19].

- Removal of the menisci increases contact stresses by up to four times the load transfer to bone [18, 19].
- The vascular supply to the menisci is derived from the geniculate arteries, penetrating 20% to 30% of the peripheral medial meniscus and 10% to 25% of the peripheral lateral meniscus [17].
- The inner one-third of the meniscus is avascular and called the white-white zone [13].
- The middle zone of the meniscus is called the red-white zone because it has limited vasculature [13].
- The back one-third of the meniscus is called the red-red zone because it is the most vascularized tissue region [13].

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 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 posterior articular branch of the tibial nerve is the largest nerve providing innervation of the intra-articular knee [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 anterior knee and proximal tibia [3].

KINEMATICS AND JOINT FORCES

- The knee is a hinge joint that incorporates both gliding and rolling, which are essential to its kinematics [4, 5].
- The “screw-home” mechanism involves the tibia externally rotating 5 degrees in the final 15 degrees of extension [4, 5].
- Knee joint surface loads are three times body weight during level walking and up to four times body weight with stair walking [18, 19].
- The patella bears half the body weight with normal walking and seven times the body weight with squatting and jogging [18, 19].
- In descending stairs, compressive force in the patellofemoral joint reaches two to three times body weight [18, 19].
- The mechanical axis of the lower extremity normally passes just medial to the medial tibial spine [18, 19].
- The mechanical axis of the lower extremity is in 3 degrees of valgus angulation from the vertical axis [18, 19].
- The anatomic axis of the femur is in 6 degrees of valgus angulation from the mechanical axis [18, 19].
- The anatomic axis of the tibia is in 2 to 3 degrees of varus angulation from the mechanical axis [18, 19].

Investigations

PLAIN 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].
- Radiographic 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].
- A notch view is used to assess posterior femoral cartilage, notch width, and osteophytes [21].
- Radiographs may identify subchondral sclerosis, joint space narrowing, subchondral cysts (variable), osteophytes (variable), and joint subluxation in osteoarthritis [21].
- Radiographs may identify joint space loss and peripheral bone erosion in inflammatory arthropathy [21].
- Radiographs may identify subchondral radiolucency, most common in the medial femoral condyle, in osteochondral defects [21].
- Radiographs may identify linear radiolucency or radiodensity, most common in the proximal medial tibia, in stress fractures [21].
- Radiographs may identify a mixed sclerotic pattern with a subchondral, epiphyseal, or metaphyseal location in osteonecrosis [21].
- Radiographs may identify malalignment, osteophytes, cysts, and joint space loss in patellofemoral disease [21].
- Radiographs should be inspected for acute fracture, lateral capsular avulsion (Segond fracture), loose bodies, Pellegrini-Stieda lesion (MCL calcification), and evidence of patellar dislocation in patients with suspected significant knee injury [9].
- Stress radiographs should be obtained in patients prior to skeletal maturity to rule out an epiphyseal fracture [9].
- Stress radiographs can help to better quantify the amount of varus angulation present in LCL injuries [30].
- 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 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].
- A standing full-length AP radiograph from hip joint to ankle joint is used to evaluate limb alignment and knee deformity and to identify femoral and/or tibial bone deformity [29].
- The 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

- CT provides a three-dimensional study performed 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 in MRI [21].
- MRI may suggest cruciate ligament injury through the presence of edema, intra-articular fluid, disruption of ligament fibers, and an atypical ligament contour [21].
- MRI can identify patterns of meniscal injury by location (anterior, midbody, posterior, peripheral, articular), pattern (horizontal, longitudinal, radial, complex), and displacement [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 may identify edema, avulsion, or discontinuity 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].
- MRI can be helpful in confirming MCL diagnosis and helping to rule out concomitant meniscal injury [9].
- Relative indications for an MRI in MCL injury 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 posterolateral injury can often go unnoticed during an initial evaluation [30].
- MRI should be obtained as a useful adjunct to help diagnose posterolateral corner injuries [30].
- MRI can be used to evaluate articular cartilage morphology [25].
- 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].

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” in nuclear medicine imaging [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 (Ga-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 during physical examination [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 with a larger effusion [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].
- 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 valgus stress testing [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 to valgus stress [9].
- A grade III MCL 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 for LCL and/or posterolateral corner injury as the incidence of neurovascular injury, particularly peroneal nerve injury, has been reported in 12–29% of posterolateral knee injuries [30].
- Patients commonly present with a history of a precipitating traumatic event or previous surgery for articular cartilage defects [25].
- An effusion, motion deficits, or limb malalignment may be observed in patients with articular cartilage defects [25].
- Knee stability should be compared with the normal side in patients with articular cartilage defects [25].
- Patient assessment of knee pain includes a physical examination and diagnostic radiographic modalities [29].
- Pain with weight bearing is aggravated by stairs, inclines, and transition from sit to stand in knee arthritis [29].
- Bowing deformity and instability are seen later in the presentation of knee arthritis [29].
- Knee thrust indicates ligament stretch-out (i.e., abnormal) on the convex side of thrust and is seen later in the clinical presentation of knee arthritis [29].
- A varus thrust occurs when the knee pushes outward during stance phase of gait, overloading the medial compartment [29].
- A valgus thrust occurs when the knee pushes inward during stance phase of gait, overloading the lateral compartment [29].

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