

Periprosthetic fracture (knee)

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 [4].
- The lateral femoral condyle projects farther anteriorly and is wider in the medial-lateral direction than the medial femoral condyle [4].
- The tibial articular surface slopes 7° to 10° in the sagittal plane [4].
- The posterior slope of the medial tibial plateau averages 10.7° and the lateral plateau averages 7.2° [9].
- The medial tibial plateau is larger than the lateral plateau and is concave in its frontal and sagittal planes [4].
- The lateral tibial plateau is smaller, more circular, concave in the frontal plane, and convex in the sagittal plane [4].
- The patella is the largest sesamoid bone in the body with a mean thickness of 2.5 cm [4, 9].
- The patellar articular surface contains a vertical central ridge separating the broader lateral facet from the medial facet, and a smaller medial odd facet [4].
- The fibular head is located a mean of 1.5 cm distal to the joint line, with a range of 6 to 32 mm [9].

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 (MCL) stabilizes the knee to valgus stresses [1].
- The lateral collateral ligament (LCL) is the main stabilizer against varus stress [1].
- The ACL is composed of 90% type I collagen and 10% type III collagen [4, 9].
- The mean length of the ACL is 33 mm and the mean midsubstance width is 11 mm [4, 9].

- The femoral attachment of the ACL is a semicircular area on the posteromedial aspect of the lateral femoral condyle [4, 9].
- The tibial attachment of the ACL is a broad, irregular, oval-shaped area between the medial and lateral tibial spinous processes [4, 9].
- The anteromedial bundle of the ACL is tight in knee flexion and the posterolateral bundle is tight in knee extension [9].
- The PCL has a mean length of 38 mm and a mean width of 13 mm [9, 17].
- The PCL femoral footprint is a broad, semicircular attachment on the anterolateral aspect of the medial femoral condyle [9, 17].
- The PCL tibial insertion is located 10 to 15 mm distal to the joint line on the posterior tibia [9, 17].
- The anterolateral bundle of the PCL is larger and comprises 85% of the PCL's cross-sectional area [17].
- The popliteofibular ligament is present in 90% of knees and runs from the popliteus tendon to the posterior fibular head [1].
- The posterolateral corner (PLC) consists of the fibular collateral ligament, iliotibial band, popliteofibular ligament, biceps femoris, and popliteus tendon [14].

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 mobility of 5 mm and the lateral meniscus has a mobility of 10 mm [9].
- Vascular supply to the menisci penetrates into 20% to 30% of the peripheral medial meniscus and 10% to 25% of the peripheral lateral meniscus [9].

VASCULAR AND NERVE ANATOMY

- The blood supply to the knee is formed from an anastomosis including the descending geniculate artery, superior and inferior geniculate arteries, middle geniculate artery, and anterior tibial recurrent arteries [4].
- The middle geniculate artery supplies both the anterior and posterior cruciate ligaments [4].
- 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) [4].

- The posterior articular branch of the tibial nerve is the largest nerve providing innervation to the intra-articular knee [4].
- The popliteal artery travels through the adductor hiatus where it is relatively immobile and distally through the fibrous arch deep to the soleus muscle [14].
- The common peroneal nerve travels along the posterior edge of the biceps femoris and continues distally around the fibular neck [14].

KINEMATICS

- The knee is a hinge joint that incorporates both gliding and rolling motions [5, 6].
- The “screw-home” mechanism involves the tibia externally rotating 5 degrees in the final 15 degrees of extension [5, 6].
- The greatest range of motion occurs in the sagittal plane at approximately 160° [21].
- Knee rotation ranges from 45° in external rotation to 30° in internal rotation [21].
- In the frontal plane, the range of motion in both abduction and adduction reaches a maximum of 10° [21].
- During walking, knee range of motion reaches approximately 70° in the sagittal plane, 15° in the frontal plane, and 10° in the transverse plane [21].
- The normal instant center of the knee joint follows a semicircular path related to the tibiofemoral surface and ligaments [21].
- Rupture of the cruciate ligaments or disruption of the tibiofemoral surface causes a major change in the path of the instant center, leading to articular dysfunction [21].
- In full extension, the knee slightly hyperextends with slight tibial external rotation while collateral and cruciate ligaments tighten to lock the knee [22].
- The popliteus muscle initiates flexion by pulling the lateral femoral condyle backward while the medial femoral condyle slides forward, resulting in tibial internal rotation [22].

PERIPROSTHETIC FRACTURE PATHOPHYSIOLOGY

- The incidence of periprosthetic fracture of the distal femur in total knee arthroplasty is 0.3% to 2.5% [31].
- The incidence of periprosthetic tibial fracture in primary total knee arthroplasty is 0.7% or less [31].
- Anterior femoral notching during femoral preparation weakens the anterior femur at the bone-component interface [31].
- Notching decreases the fracture resistance of the distal femur but does not necessarily equate to a higher risk of supracondylar femur fracture [31].
- Risk factors for periprosthetic distal femur fracture include rheumatoid arthritis, neurologic disorders, chronic steroid therapy, osteopenia or osteoporosis, and osteolysis with bone loss [31].
- Risk factors for periprosthetic tibial fracture include insertion of a long-stem component, a loose tibial component, periprosthetic osteolysis, malalignment of components, component removal during revision, and tibial tubercle osteotomy [31].

- The fracture line in periprosthetic fractures may be obscured by a metallic component on plain radiographs [31].

Investigations

PLAIN RADIOGRAPHY

- Plain radiographs are appropriate initial imaging studies for most knee conditions, allowing assessment of traumatic injury, arthritis, patellofemoral alignment, osteochondral injury, bone neoplasm, and surgical implants [3].
- Imaging studies should include at least two perpendicular views: AP and lateral [3].
- Weight-bearing AP (extension) views are used to assess cartilage loss from the distal femur and tibial plateau [3].
- Weight-bearing PA (Rosenberg; flexion) views are used to assess cartilage loss from the posterior femur and tibial plateau [3].
- Patellofemoral views are used to assess patellofemoral alignment, patellar and trochlear morphology, osteochondral injury, and patellofemoral arthritis [3].
- Notch views are used to assess posterior femoral cartilage, notch width, and osteophytes [3].
- Non-weight-bearing radiographs may identify acute injury without the risk of fracture displacement [3].
- Radiography may identify subchondral sclerosis, joint space narrowing, subchondral cysts, osteophytes, and joint subluxation in osteoarthritis [3].
- Radiography may identify linear radiolucency or radiodensity in stress fractures, most commonly in the proximal medial tibia [3].
- Radiography may identify a mixed sclerotic pattern with a subchondral, epiphyseal, or metaphyseal location in osteonecrosis [3].
- Supine AP knee radiographs do not adequately estimate the joint space width needed to estimate the degree of osteoarthritis progression [27].
- A 45° standing flexion view was introduced to better evaluate joint space due to inaccuracies in plain frontal radiographs [27].
- The fixed flexion view (FFV) technique uses a 10° caudal irradiation angle and fixed limb position for improved reproducibility and joint space evaluation [27].
- The Lyon Schuss view (LSV) requires fluoroscopic adjustment of the irradiation angle relative to the medial tibial plateau for more accurate joint space width measurement but involves higher radiation exposure and complex positioning [27].
- Goniometer readings of long limb alignment or measured on an FFV correlate well with angles measured on long limb radiographs, providing an alternative if long limb radiographs are not available [27].
- The Kellgren-Lawrence (KL) classification grades osteoarthritis severity from 0 to 4 based on AP knee radiograph features including osteophytes and joint space narrowing [23].

- Knee arthroplasty is recommended when KL Grade 4 findings are present [23].

COMPUTED TOMOGRAPHY

- CT provides enhanced bone detail through a three-dimensional study performed with ionizing radiation [3].
- CT imaging in axial, sagittal, and coronal planes helps visualize fracture lines, displacement, osteolytic lesions around joint arthroplasty, and cortical disruption in infection or neoplasia [3].
- Three-dimensional CT reconstructions may help with preoperative planning for complex intra-articular fractures, multiplanar osteotomy for limb malalignment, and reconstitution of bone loss in joint arthroplasty [3].
- Axial plane CT imaging of the knee can help assess the rotational alignment of components of a total knee arthroplasty in cases of patellar maltracking [3].
- Three-dimensional CT with remodeling is used for preoperative planning for reconstruction associated with dysplasia, post-trauma planning, and complex total knee arthroplasty planning [23].

MAGNETIC RESONANCE IMAGING

- MRI may help assess overall limb alignment and further delineate intra-articular and extra-articular soft tissues, including cartilage, menisci, ligaments, tendons, muscles, and nerve and vascular structures [3].
- MRI findings of edema, intra-articular fluid, disruption of ligament fibers, and atypical ligament contour may suggest cruciate ligament injury [3].
- MRI can identify patterns of meniscal injury by location, pattern (horizontal, longitudinal, radial, complex), and displacement [3].
- MRI may identify the degree of articular cartilage injury, associated bone marrow edema, and lesion location [3].
- MRI may identify edema, avulsion, or discontinuity for extra-articular ligaments such as the MCL/LCL or associated posteromedial and posterolateral ligamentous complexes [3].
- MRI may be used to assess the continuity of the quadriceps or patellar tendon [3].
- MRI may be used to assess neurovascular structures, including the margin of resection for a neoplasm, vascular malformation, or location of nerves relative to popliteal cysts [3].
- MRI is the most useful study for differentiating osteonecrosis from other conditions such as osteochondritis dissecans, transient osteoporosis, bone bruises, or occult fractures [29].
- A serpentine lesion within a well-demarcated border is a specific finding on MRI for osteonecrosis [29].
- MRI is not indicated if the joint space is significantly narrowed on radiograph in the arthritic patient population [23].
- MRI is used when osteonecrosis is suspected in the arthritic patient population [23].

NUCLEAR MEDICINE

- Increased radionuclide activity in bone may be a normal postoperative finding for up to 6 to 12 months after a fracture repair or arthroplasty [3].
- Technetium-99 (Tc-99) may help identify infection, neoplasia, occult fracture, bone healing, active phases of heterotopic ossification, implant loosening, or failure of osseointegration [3].
- Gallium-67 (Ga-67) may help differentiate between aseptic and septic prosthetic loosening, requiring 24 to 72 hours for a complete study [3].

GENERAL ASSESSMENT

- Radiographic studies help confirm the clinical diagnosis of a joint disorder determined using the patient's history and physical examination [3].
- Physical examination along with radiographic or advanced imaging findings must be used concomitantly to determine the source of symptoms and appropriate surgical intervention [7].
- Assessment of the joint must combine physical examination along with radiographic (including full-length alignment views) and MRI findings for cartilage injury [30].

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