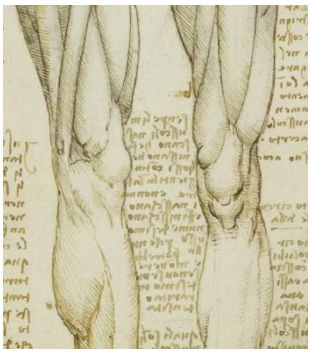
Anatomy of the Lower Limb

Dr. Ali Mohsin



THE KNEE JOINT

The knee joint is the largest synovial joint in the body. It consists of:

- the articulation between the femur and tibia, which is weightbearing; and
- the articulation between the patella and the femur, which allows the pull of the quadriceps femoris muscle to be directed anteriorly over the knee to the tibia without tendon wear.

The axes of the femoral & tibial shafts are not in a straight line, there is a slight angle between them (the Q-angle).

Two C-shaped fibrocartilages (the menisci), one on each side, are present between the femoral condyles and tibia. They deepen the flat tibial condyles & facilitate joint movements.

Like all hinge joints, the knee joint is reinforced by collateral ligaments, one on each side of the joint. In addition, two very strong ligaments (the cruciate ligaments) interconnect the adjacent ends of the femur and tibia and maintain their opposed positions during movement. Because the knee joint is involved in weightbearing, it has an efficient "locking" mechanism to reduce the amount of muscle energy required to keep the joint extended when standing.

Articular surfaces

The complex knee joint includes 2 articulations: one between the femoral & tibial condyles (the tibiofemoral joint), & the other between the patella & distal femur (the patellofemoral joint). There is no articulation between the tibia & patella.

- The (posterior) surfaces of the femoral condyles that articulate with the tibia in flexion of the knee are curved, whereas the (inferior) surfaces that articulate in full extension are flat.
- The tibiofemoral articulation is deepened by the menisci.
- The femoral articular surfaces for the patella is the anterior V-shaped depression where the two condyles join. It accommodates the convex posterior surface of the patella.
- The joint surfaces are all enclosed within a single articular cavity, as are the intra-articular menisci between the femoral and tibial condyles.

Menisci

There are medial & lateral menisci, which are C-shaped fibrocartilages, in the knee joint. Both are attached at each end to facets in the intercondylar region of the tibial plateau. The medial meniscus is larger & oval in shape, it is attached around its margin to the capsule of the joint and to the tibial collateral ligament medially. The lateral meniscus is smaller, rounded in shape, & is separated from the joint capsule by the popliteus muscle tendon (posterolaterally). Therefore, the lateral meniscus is more mobile than the medial meniscus. The menisci are interconnected anteriorly by a transverse ligament of the knee.

In vertical section, the meniscus is triangular in shape, being thickest at its periphery. Thus, the meniscus separates the tibia from the femur in the periphery of their condyles, keeping direct contact between them at the center of each condyle.

Fibrous Capsule

The fibrous capsule of the knee joint is extensive and is partly formed and reinforced by extensions from tendons of the surrounding muscles. In general, the fibrous capsule encloses the articular cavity and the intercondylar region:

- Medially, the fibrous capsule blends with the tibial collateral ligament and is attached on its internal surface to the medial meniscus;
- Laterally, the external surface of the fibrous capsule is separated by a space from the fibular collateral ligament, and the internal surface is not attached to the lateral meniscus;
- Anteriorly, the fibrous capsule is attached to the margins of the patella & patellar ligament, where it is reinforced with tendinous expansions from quadriceps femoris muscles.

The fibrous capsule is reinforced anterolaterally by an extension from the iliotibial tract, and posteromedially by an extension from the tendon of semimembranosus (the oblique popliteal ligament), which reflects superolaterally across the back of the fibrous capsule.
The upper end of the popliteus muscle passes through an aperture in the posterolateral aspect of the fibrous capsule of the knee. Inside the capsule, popliteus tendon travels around the joint to insert on the lateral aspect of the lateral femoral condyle.

Ligaments
The major ligaments associated with the knee joint are the patellar ligament, the tibial (medial) and fibular (lateral) collateral ligaments, and the anterior and posterior cruciate ligaments.

Patellar ligament
The patellar ligament is basically the continuation of the quadriceps femoris tendon inferior to the patella. It is attached above to the margins and apex of the patella and below to the tibial tuberosity.

Collateral ligaments
The collateral ligaments, one on each side of the joint, stabilize the hinge-like motion of the knee.
The cord-like fibular collateral ligament is attached superiorly to the lateral femoral epicondyle, & inferiorly to the lateral surface of the fibular head, where it bifurcates the tendon of biceps femoris muscle. It is separated from the fibrous capsule by a bursa.
The broad and flat tibial collateral ligament is divided into superficial & deep parts. Both are attached superiorly to the medial femoral epicondyle. The *deep part* blends with the joint capsule, to be attached by its deep surface to the medial meniscus. Inferiorly, it is attached to the medial tibial condyle above the semimembranosus tendon. The *superficial part* passes superficial to the tendon of semimembranosus & inferior medial genicular vessels, to be attached to the medial margin of tibia below the semimembranosus tendon.

Cruciate ligaments
The two cruciate ligaments are in the intercondylar region of the knee and interconnect the femur and tibia. They are termed "cruciate" (Latin for "shaped like a cross") because they cross each other in the sagittal plane between their femoral and tibial attachments:

- The anterior cruciate ligament attaches to the anterior part of the intercondylar area of the tibia and ascends posteriorly to attach to the back of the lateral wall of the intercondylar fossa of the femur;
- The posterior cruciate ligament attaches to the posterior part of the intercondylar area of the tibia and ascends anteriorly to attach to the medial wall of the intercondylar fossa of the femur.

The anterior cruciate ligament crosses lateral to the posterior cruciate ligament as they pass through the intercondylar region. The anterior cruciate ligament prevents anterior displacement of the tibia relative to the femur and the posterior cruciate ligament restricts posterior displacement.

Synovial membrane
The synovial membrane of the knee joint attaches to the margins of the articular surfaces and to the superior and inferior outer margins of the menisci. The two cruciate ligaments are outside the synovial cavity, but inside the fibrous capsule of the knee joint.
Posteriorly, the synovial membrane reflects off the fibrous capsule of the joint and loops forward around both cruciate ligaments (thereby excluding them from the articular cavity), to go back & re-join the capsule. The anterior end of this loop forms the "infrapatellar fold" of the synovial membrane.
Anteriorly, the synovial membrane is separated from the patellar ligament by an infrapatellar fat pad.
The synovial membrane of the knee joint forms pouches (expansions) in 3 locations to reduce friction surfaces for the movement of tendons associated with the joint:

1. The subpopliteal recess (bursa): small posterolateral extension from the synovial cavity between the lateral meniscus and the popliteus tendon;
2. The suprapatellar bursa: large superior extension from the synovial cavity between the distal end of the shaft of femur and the quadriceps femoris muscle and tendon. The apex of this bursa is attached to the small articularis genus muscle, which pulls the bursa away from the joint during extension of the knee.

Other bursae exist around the knee joint, lying outside the capsule (thus, not normally communicating with the synovial cavity). They include:

- The subcutaneous prepatellar bursa,
- The deep and subcutaneous infrapatellar bursae,
- The anserine bursa, separates the tendons of sartorius, gracilis, and semitendinosus from each other and from the tibial collateral ligament,
- The bursae between the joint capsule & the medial & lateral heads of gastrocnemius,

Many other bursae associated with tendons and ligaments around the joint.

Movements:

The detailed movements of the knee joint are complex, but basically the joint is a hinge joint that allows mainly flexion and extension. Note the following:

- Knee flexion is mediated by the hamstring muscles, assisted by other muscles (see the table). Flexion is limited by the contact between the leg & the thigh.
- Knee extension is mediated by the quadriceps femoris muscle. It ends when the leg makes a straight angle (180^o) with the thigh, due to the tension of the anterior cruciate ligament, & the anterior border of the lateral meniscus coming into a groove in the lateral femoral condyle.
- The last 30^o of knee extension is accompanied by slight medial rotation of the femur on the tibia if the foot in on-ground (or: lateral rotation of the tibia on the femur if the foot is off-ground).
- Oppositely, the first 30^o of knee flexion is accompanied by slight lateral rotation of the femur on the tibia if the foot in on-ground (or: medial rotation of the tibia on the femur if the foot is off-ground).
- Those 2 rotatory movements are parts of flexion-extension of the knee, without voluntary control by the person. They are mandatory for "locking & unlocking" of the joint (see below).
- When the knee is 90^o flexed, the leg can rotate medially & laterally at the knee joint. The range of movement is limited ($< 45^o$ laterally & $< 30^o$ medially), & becomes more & more limited when the knee is more flexed or more extended than 90^o. These movements are voluntary, & has nothing to do with locking-unlocking of the knee joint. See the table for the muscles mediating rotation.

Locking & unlocking of the knee:

When standing, the knee joint is locked into position, thereby reducing the amount of muscle work needed to maintain the standing position.

Locking mechanism: the flexed knee is unlocked. During the last phase of knee extension, the anterior cruciate ligament tightens, preventing further extension than 180^o. Here, the anterior border of the lateral meniscus contacts a groove in the articular surface of the lateral femoral condyle, preventing further posterior movement of the lateral femoral condyle on the tibia. However, the groove on the medial femoral condyle is more anterior to that of the lateral condyle, so the medial femoral condyle moves slightly more posteriorly than the fixed lateral condyle, resulting in medial rotation of the femur on the tibia at the end of knee extension. Medial rotation and full extension tightens all the associated ligaments of the knee joint, resulting in "locking".

Unlocking mechanism: to unlock, the knee has to reverse the above movements. So, unlocking should start with "lateral rotation of the femur on the tibia", & this is mediated by the **popliteus muscle**, the "*key*" of the locked knee. Then all of the ligaments will relax, allowing the hamstring muscles to flex the knee joint.

Two other factors further stabilize knee locking:

1. During full knee extension, the inferior (flat) surfaces of the femoral condyles are contacting the tibia-menisci, increasing the contact area & adding more stability to the articulation (unlike in flexion, where the femoral condyles contact the tibia by their posterior curved surfaces, reducing the contact area & stability).
2. The body's center of gravity is positioned along a vertical line that passes anterior to the knee joint.

Movement at the patellofemoral joint:

When the knee is flexed, the patella is in contact with the inferior surface of the femoral condyles. With knee extension, the patella is pulled up to glide over the femoral condyles, to reach the anterior surface (where the condyles join each other) at the full knee extension. With this movement, the area of contact with the femur moves from the superior to the inferior region of the articular surface of patella.

Vascular supply and innervation

Arterial supply of the knee joint is provided by the anastomosis around it, which consists of:

- Five genicular branches of the popliteal artery (superior medial, inferior medial, superior lateral, inferior lateral, & middle genicular arteries),
- Descending genicular branch of the femoral artery (medially),
- Descending branch of the lateral circumflex femoral artery (laterally),
- Recurrent branch of the anterior tibial artery,
- Circumflex fibular branch of the posterior tibial artery.

The knee joint is innervated by branches from:

- The femoral nerve (via branches to vasti muscles, especially that of vastus medialis),
- Obturator nerve (posterior division),
- Tibial and common peroneal nerves (via their genicular branches).

Clinical Applications:

Genu valgus & genu varus: *excessive increase or decrease in the Q-angle between femoral & tibial axes, respectively. These conditions can occur in childhood or old ages, & are caused by variable causes.*

Meniscal tears: *The injuries to menisci are commonly caused by the twisting strains in a slightly flexed knee, as in kicking a football or turning on a fixed leg during basketball. The meniscus may get separated from the capsule, or it may be torn longitudinally or transversely.*

The medial meniscus is more prone to injury than the lateral because of its firm fixity to tibial collateral ligament, and greater excursion during the rotatory movements. The lateral meniscus is protected by the popliteus muscle because its medial fibers pulls the posterior horn of meniscus backward, so that it is not crushed between the articular surfaces.

Pain on the medial rotation of tibia on the femur indicates injury of the medial meniscus. Whereas pain on the lateral rotation of tibia on the femur indicates injury of the lateral meniscus.

Osteoarthritis*: Being a weight-bearing joint, the knee joint is commonly involved by the osteoarthritis (degenerative wear and tear of articular cartilages). The movements may be painful, & limited. Radiographs of the knee region reduction of joint space & other signs.*

Injuries to cruciate ligaments*: The anterior cruciate ligament is more commonly damaged than the posterior ligament. These are common injuries in football. The anterior cruciate ligament is injured in the anterior dislocation of the tibia, whereas the posterior ligament is injured in the posterior dislocation of the tibia. Tear of the cruciate ligaments leads to abnormal anteroposterior mobility. If the anterior cruciate ligament is torn the tibia is pulled excessively forward on the femur (anterior drawer sign) and if the posterior cruciate ligament is torn the tibia is pulled excessively backward (posterior drawer sign).*

Aspiration of the knee joint*: The collections of fluid are common in the knee joint. It gives rise to swelling above and at the sides of the patella. Aspiration of the fluid can be done on either side of the ligamentum patellae. But the joint is usually approached from its lateral side using three bony points as landmarks for the needle insertion: (a) tibial tuberosity, (b) lateral epicondyle of the femur, and (c) apex of patella. This triangular area is also used for drug injection in treating the knee pathology.*

Arthroscopy of the knee joint*: It is an endoscopic examination (visualization) of the interior of the knee joint cavity with minimal disruption of the tissues. The ligament repair or replacement can also be performed by using an arthroscope.*

Knee replacement*: If the knee joint is badly damaged by the osteoarthritis, the artificial joint consisting plastic tibial component and metal femoral component is connected to the tibial and femoral bone ends after removal of the damaged areas.*

Unhappy triad of the knee joint*: A combination of injury of the (a) tibial collateral ligament, (b) medial meniscus, and (c) anterior cruciate ligament is called 'unhappy triad' of the knee joint*.

END