Biomechanics of Joints and Orthopaedic Implants
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Lecture: 05
The Knee Joint

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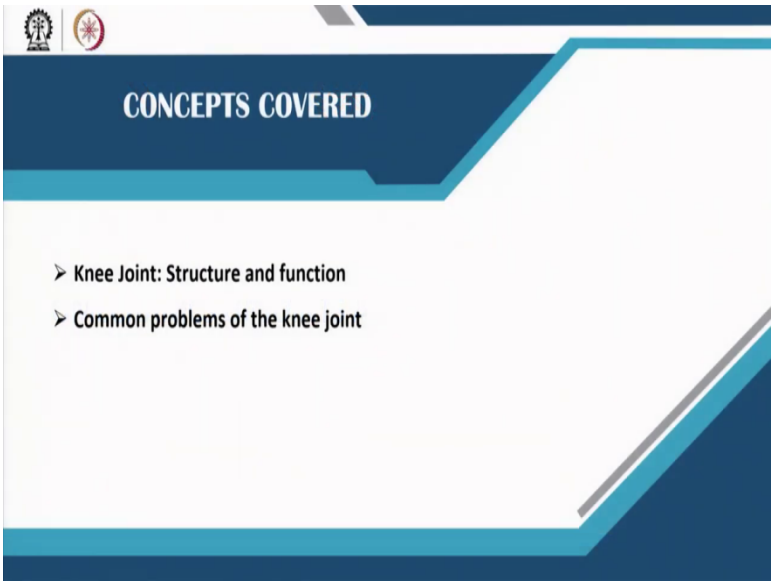

Good morning everybody, welcome to the lecture on the knee joint in the first module. In this lecture, we will be discussing about the structure and function of the knee joint and the common problems associated with the knee joint.

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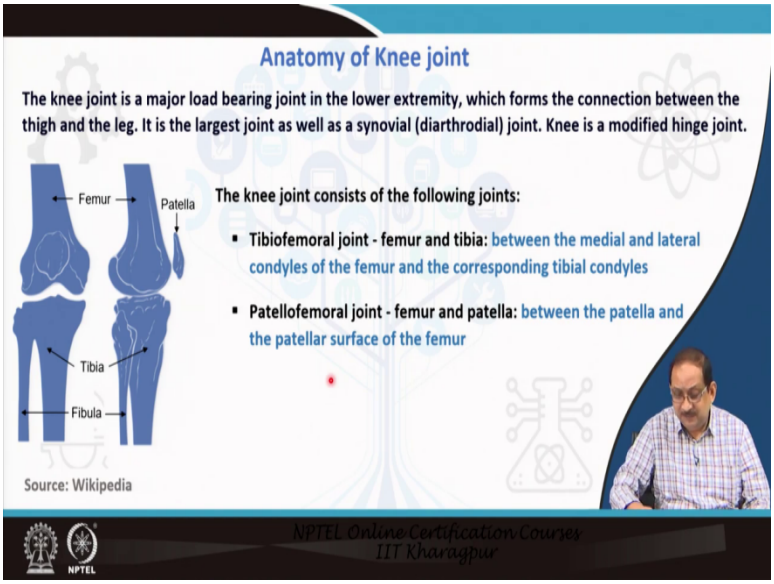

Let us first consider the anatomy of the knee joint. The knee joint is a major load-bearing joint in the lower extremity, forming the connection between the thigh bone and the leg. It is the largest joint as well as is a synovial joint. The knee is a modified hinge joint—the knee joint consists of the following joints.

The Tibiofemoral joint is formed between the femur and the tibia, specifically between the medial and lateral condyles of the femur and the corresponding tibial condyles. The other joint is the patellofemoral joint which is formed by the connection of the femur and the patella. It is the joint between the patella and the patella surface of the femur. The knee joint is essential in the linkage system responsible for human locomotion. The knee is extremely vulnerable to injuries during games and sports activities.

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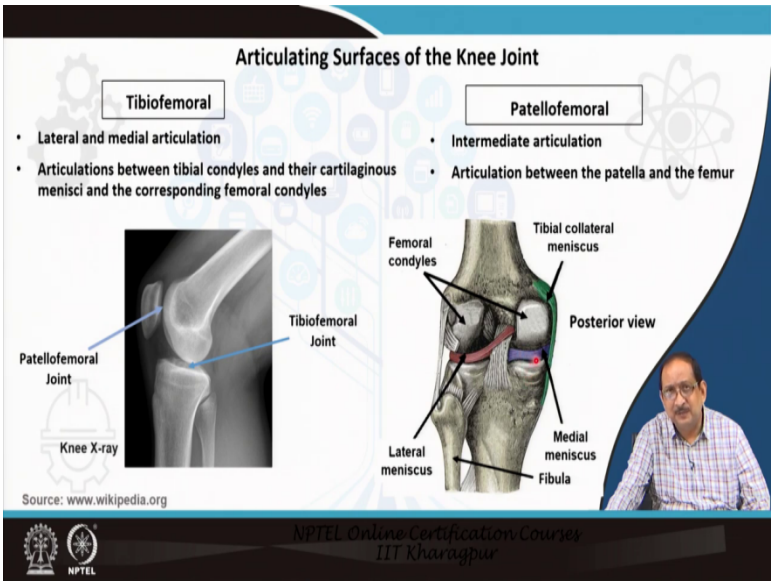

The articulating surfaces of the knee joint are presented in this slide. We have a tibiofemoral articulation it is indicated here. So, basically, it is a lateral and medial articulation between the condyles of the femur and the corresponding condyles of the tibia. So, the articulation between the tibial condyles and their cartilaginous menisci, and the corresponding femoral condyles is referred to as tibiofemoral articulation or tibiofemoral joint.

The patellofemoral articulation, on the other hand, as shown in the figure as well as in this slide, is an intermediate articulation. It is an articulation between the patella and the patella surface of the femur. A posterior view of the knee joint is shown here where the femoral condyles are indicated, and it articulates with the corresponding tibial condyles, and in between, we have the menisci or the meniscus.

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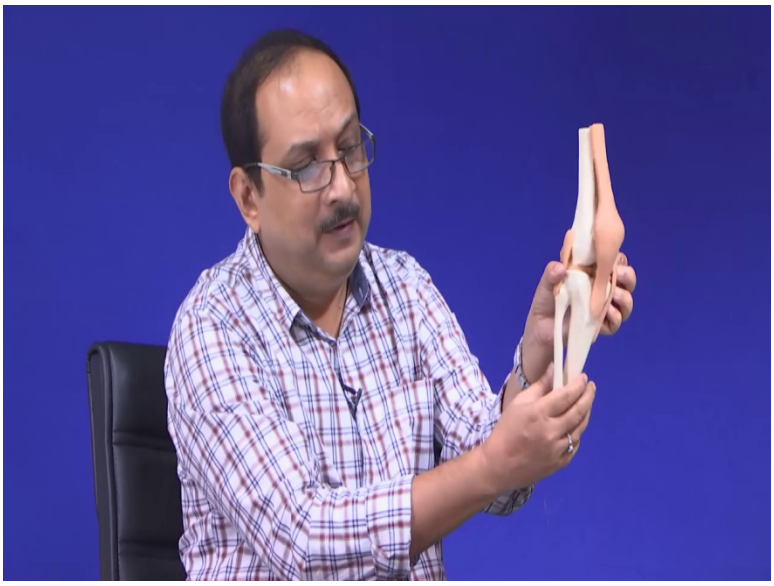

This is the model of a knee joint. So, we are looking from the front. I will now rotate the model to show you. You can see, on the top, you have the femur bone, and on the bottom, you have the tibia. I will rotate the bone slowly. What you are now seeing is the posterior view of the knee joint. You have the meniscus, and you can see the patella, how the patella is fixed, and it forms the articulation of the patellofemoral joint. This is another bone which is called the fibula, so tibia, fibula, and the femur, and the patella.

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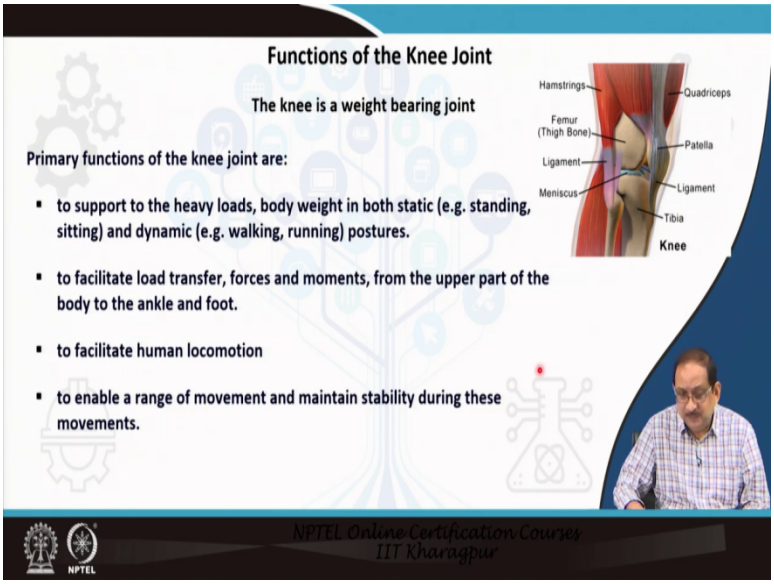

The function of the knee joint is listed or discussed in this slide. We have to keep in mind that the knee is a major weight-bearing joint in the lower extremity. So, the primary functions of the knee joints are to support heavy loads, body weight in both static and dynamic conditions, to facilitate load transfer i.e., forces and moments from the upper part of the body to the ankle and foot, to facilitate human locomotion and to enable a large range of movements and maintain stability during these movements.

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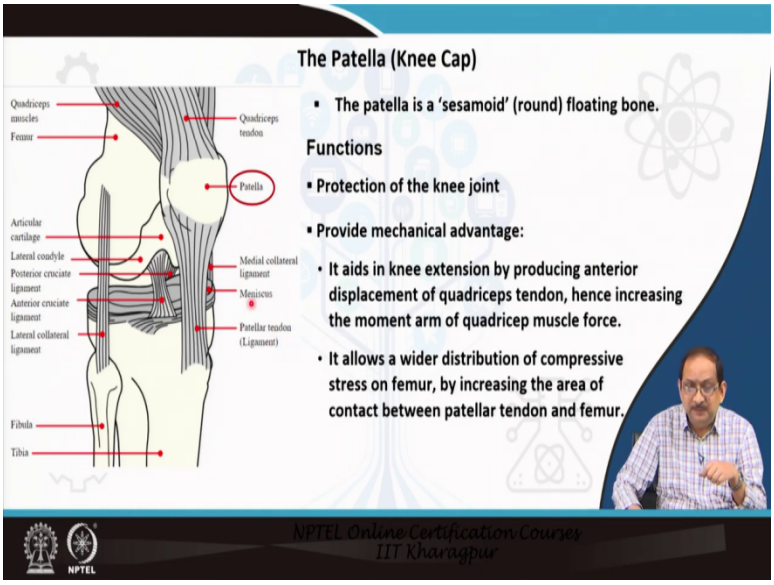

Let us consider now the patella or the knee cap. The patella is a sesamoid bone around the floating bone in the knee joint complex, which is indicated here in the slide. The function of the patella is to provide protection to the knee joint. It is located on the anterior side of the knee joint, the front, and it provides protection from the anterior side of the knee joint.

It also provides mechanical advantages. These advantages are: it aids in knee extension by producing an anterior displacement of the quadriceps tendon. So, anteriorly the quadricep tendon is displaced hence, increasing the moment arm of the quadriceps muscle force. It also allows wider distribution of the compressive stress on the femur by increasing the area of contact between the patellar tendon and the femur.

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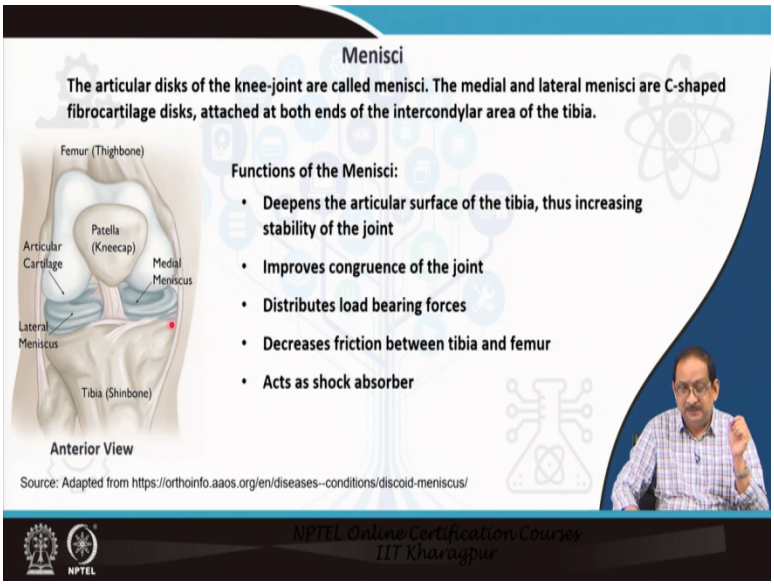

Menisci are referred to as the articular disks within the knee joint. The medial and lateral menisci are C-shaped fibrocartilage disks. These are articular disks, and it is fibrocartilage disks attached at both ends of the intercondylar area of the tibia. The menisci of the knee are basically two pads of fibrocartilaginous tissue, which serves to disperse friction in the knee joint. They are concave on the top and flat on the bottom, articulating within the tibia.

They are attached to the small depressions between the condyles of the tibia, which is the intercondyloid fossa. Let us come to the functions of the menisci. Menisci deepen the articular surface of the tibia, thus increasing the stability of the joint. It improves the congruence of the joint. It distributes the load-bearing forces more evenly, decreases friction between the tibia and femur, and finally, it acts as a shock absorber.

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Let us now discuss the knee deformities, the Varus and valgus knees. Now, you can see on the left-hand side, the leftmost figure represents a normal knee. A varus deformity causes the knee to bend outwards, giving it a bow-legged appearance. This configuration puts additional pressure on the inner medial compartment of the knee joint. The opposite deformity refers to the valgus deformity where the knees are bend inwards.

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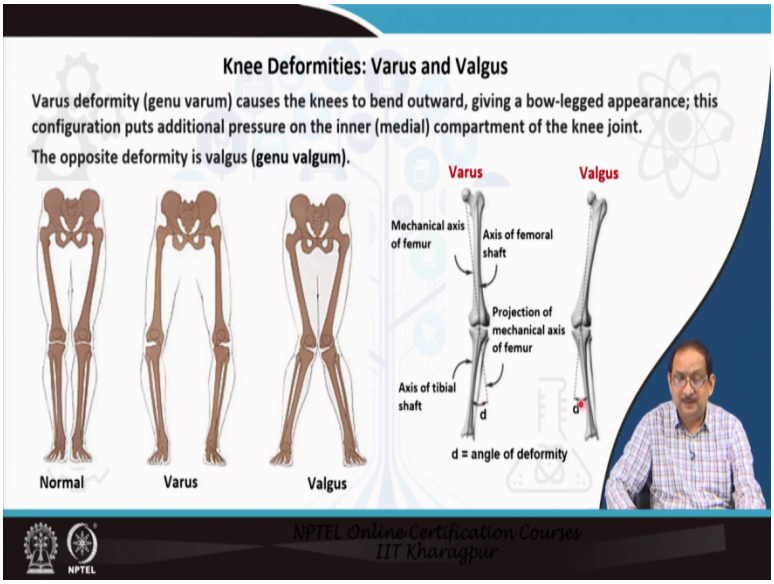

The Varus and valgus deformity can be measured as the angle of deformity. It is defined as the angle between the projections of the mechanical axis of the femur; as you can see, the mechanical axis connects the center of the femoral head with the center of the knee joint and extends. So, the angle between the projection of the mechanical axis of the femur and the axis of the tibial shaft as indicated in the figure and the angle subtended between these two imaginary lines is the measure of the angle of deformity. This can be measured for the varus case as well as the valgus case.

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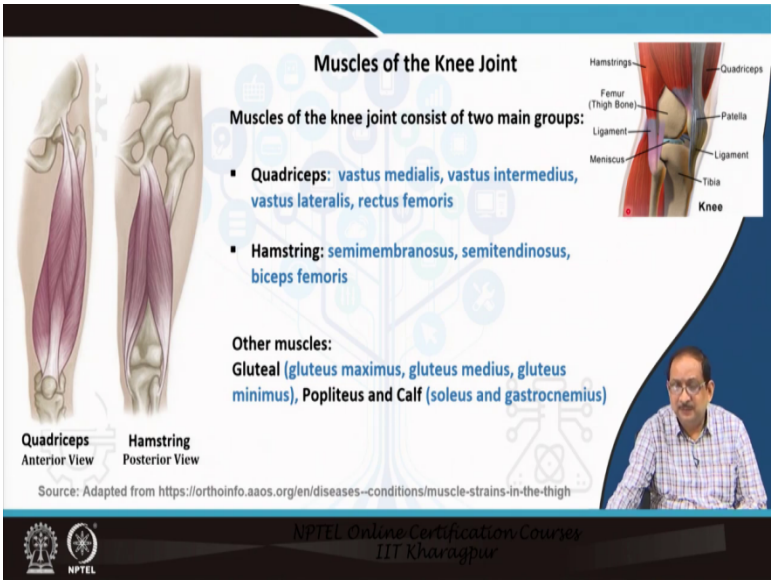

The muscles of the knee joint consist of two main groups. The quadriceps muscles: vastus medialis, vastus lateralis, vastus intermedius and rectus femoris. The hamstring is a group of muscle and consists of the muscles semimembranosus, semitendinosus, and the biceps femoris.

The other muscles which actually take part in movements of the knee joint are the gluteal, popliteus and calf muscles. In the anterior view, as presented, you can see the quadriceps muscles in the knee joint, and in a posterior view, we can see the hamstring muscles in the knee joint. These are also visible somewhat here in oblique view of the knee joint.

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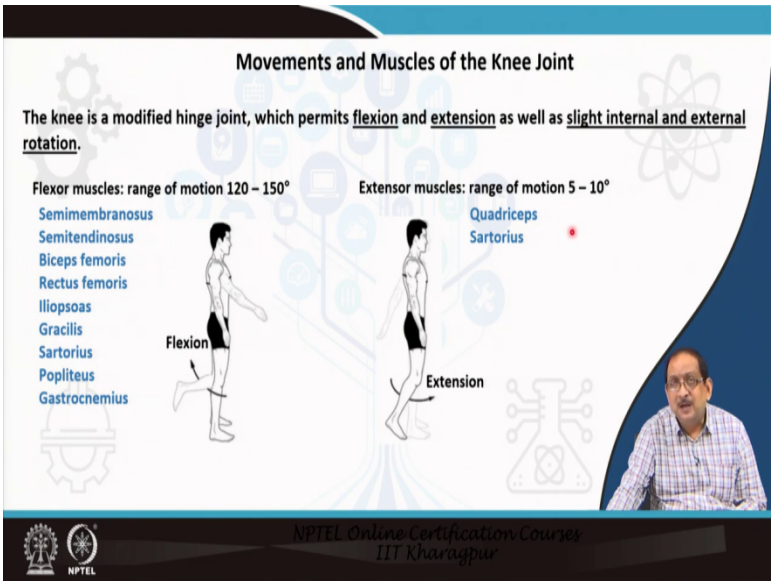

Now, let us come to the movements offered by the knee joint and the muscles responsible for these individual movements. As indicated earlier, the knee is a modified hinge joint that permits primarily flexion and extension as well as slight internal and external rotation. So, the gross movement of the knee joint is flexion and extension.

Now, flexion of the knee is bending of the knee. So, we try to bend the knee that means we try to rotate the leg, the lower part backward, and the extension refers to moving the leg towards the front. These are two opposite movements; the flexor muscles responsible for the flexion movement are listed here.

And the maximum range of motion that can be obtained during flexion varies from 120 to 150 degrees for different subjects. On the other hand, the extensor muscles quadriceps and sartorius are the extensor muscles responsible for the extension movement, and the range of motion can vary from 5 degrees to 10 degrees for different subjects.

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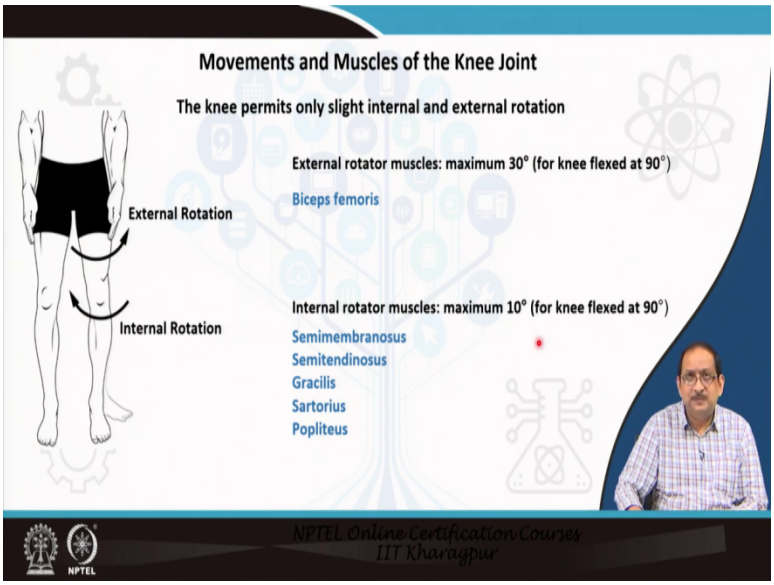

As indicated earlier, the knee permits only slight internal and external rotation, as indicated in the figure. The external rotator muscle is the bicep femoris, and the maximum degree of rotation that can be obtained is 30 degrees, for a particular position of the knee flexed at 90 degrees. So, this maximum range of motion, 30 degrees for external rotation and 10 degrees for internal rotation, corresponds to the condition that the knee is flexed at 90 degrees.

The internal rotation is the opposite movement. And you can see that about five major muscles take part in the movement of the internal rotation. But these are generally very small because the knee permits only slight internal and external rotations.

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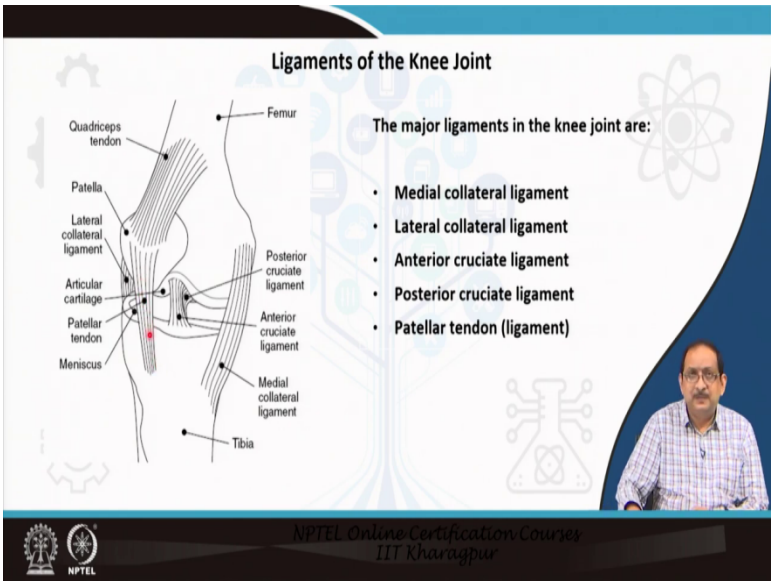

Let us now discuss the ligaments of the knee joint. The ligaments are the primary stabilizers of the knee joint, and the major ligaments in the knee joints are the medial collateral ligament and the lateral collateral ligament, as indicated in the figure, on the medial and lateral sides of the knee joint. The anterior cruciate ligament and posterior cruciate ligament are located more in the middle portion of the knee joint, and there is also the patellar ligament which is also called patellar tendon, as indicated in the figure.

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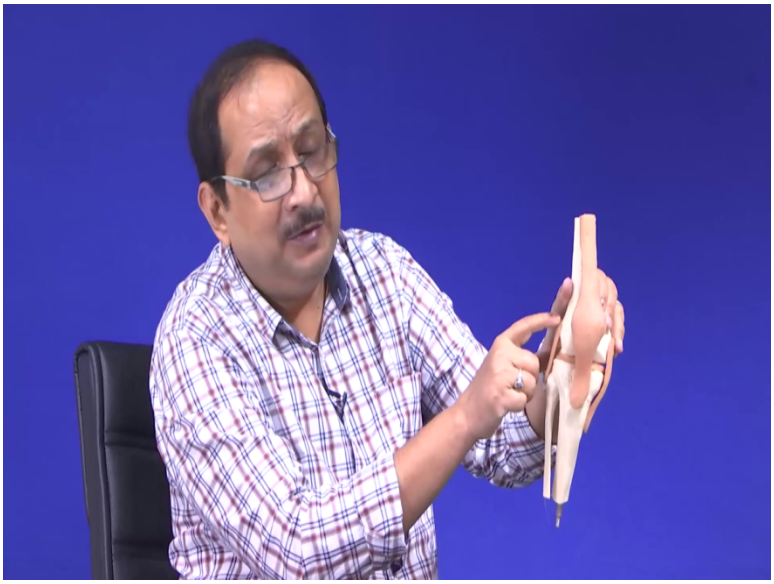

Now, in the model of the knee joint that I am showing you, I would like to indicate the ligaments. You are looking from the front, so we have the two ligaments, the medial and lateral collateral ligaments, on the two sides. We also have the anterior cruciate ligament, which is inside possibly. It is difficult to view from here, but there is a ligament inside, which is the anterior cruciate ligament.

If I move to the posterior side, we can clearly see the posterior cruciate ligament and the patellar tendon or ligament. As you can see, that medial collateral ligament is attached between the femur and the tibia, whereas the lateral collateral ligament is attached between the lateral epicondyle of the femur with the head of the fibula.

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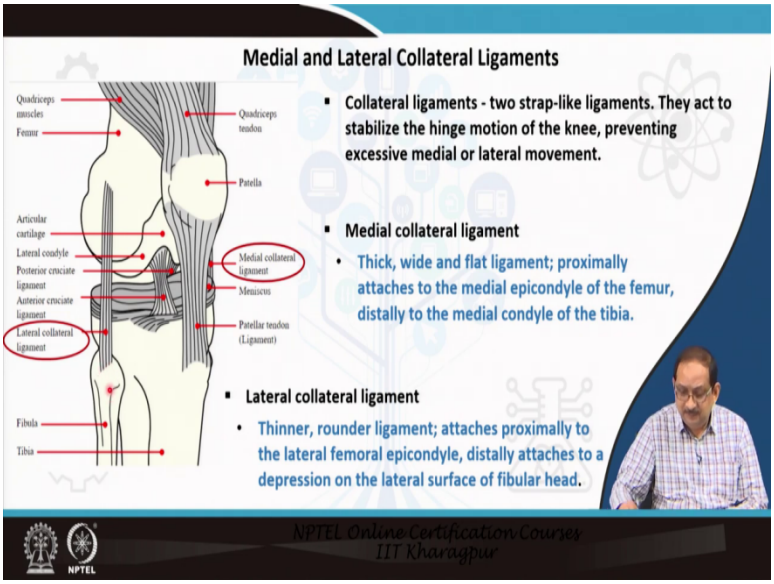

The medial and lateral collateral ligaments are two strap-like ligaments. So, this is one strap, the lateral collateral ligament. The other strap cannot be seen as it is hidden behind, so that is the medial collateral ligament, and they act to stabilize the hinge motion of the knee, preventing medial or lateral movements. So during the hinge rotation or hinge motion, it prevents excessive medial or lateral movements.

The medial collateral ligament is a thick, wide, and flat ligament that proximally attaches to the medial condyle of the femur and distally attaches to the medial condyle of the tibia. The lateral collateral ligament in comparison, is thinner and rounder ligament, and as you can see here, that it attaches proximally to the lateral femoral epicondyle, and distally it attaches to a depression on the lateral surface of the fibula bone. So, there is another bone fibula, and it attaches to the lateral surface of the fibular head.

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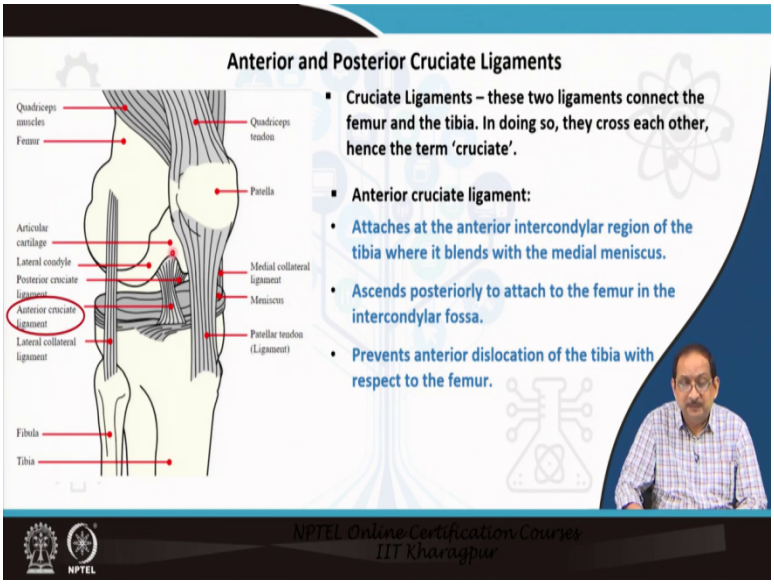

The patellar tendon or ligament, as it is called, is a continuation of the quadriceps tendon, and it is distal to the patella. So, it is clearly shown here, although it is a continuation of the quadriceps tendon, it is distal to the patella and attaches to the tibial tuberosity. Let us now discuss two very important ligaments, the anterior and posterior cruciate ligaments. These two ligaments connect the femur and the tibia.

In doing so, they crisscross each other and hence the name cruciate, which is a Latin name. The anterior cruciate ligament attaches at the anterior intercondylar region of the tibia, and it blends with the medial meniscus. It ascends posteriorly to attach to the femur in the intercondylar fossa. It prevents anterior dislocation of the tibia with respect to the femur.

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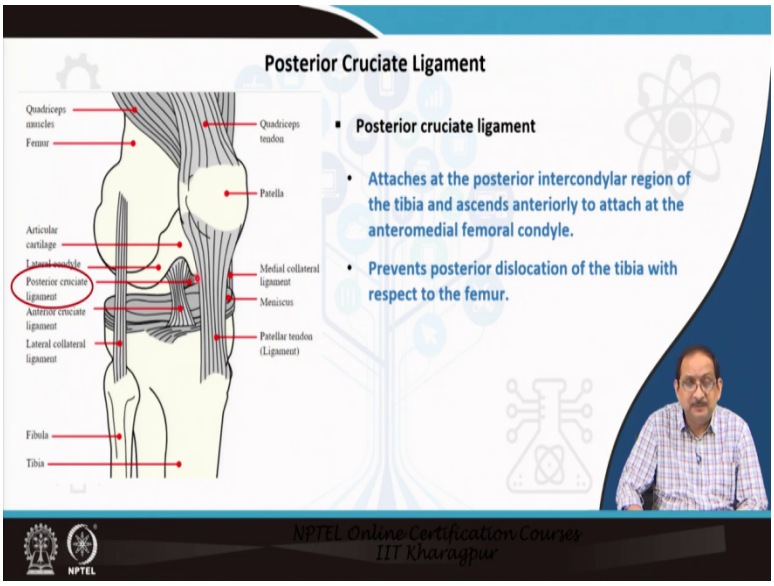

The posterior cruciate ligament, on the other hand, attaches at the posterior intercondylar region of the tibia and ascends anteriorly to attach at the anteromedial femoral condyle. It prevents posterior dislocation of the tibia with respect to the femur.

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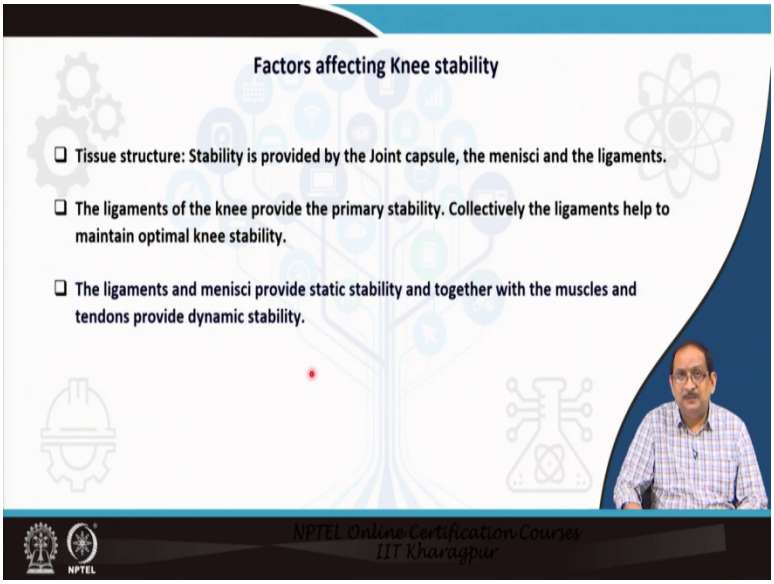

Let us summarize the factors affecting knee stability. The first important factor is the tissue structure. The stability in the knee joint is provided by the joint capsule, the menisci, and the

ligaments. The ligaments of the knee provide the primary stability, as discussed earlier, and collectively the ligaments help to maintain optimal knee stability. The ligament and the menisci provide static stability to the knee joint and, together with the muscles and tendons, provide dynamic stability as well.

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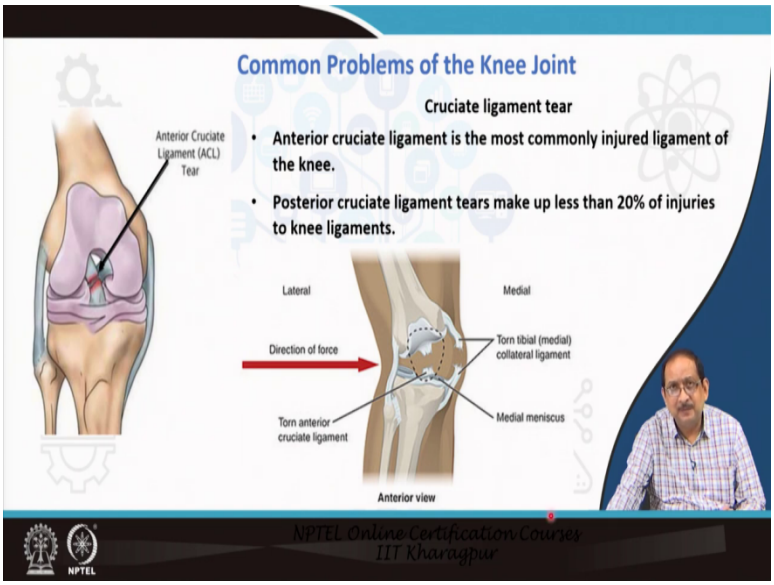

The common problems of the knee joints are now discussed in the second part of the lecture. The cruciate ligament tear is a common problem in the knee joint. As discussed earlier, the knee joint is extremely vulnerable to injuries during games and sports activities. The anterior cruciate ligament is the most commonly injured ligament of the knee, as indicated here in the figure and also here. In comparison, posterior cruciate ligament tears make up less than 20 percent of the injuries to the knee ligament.

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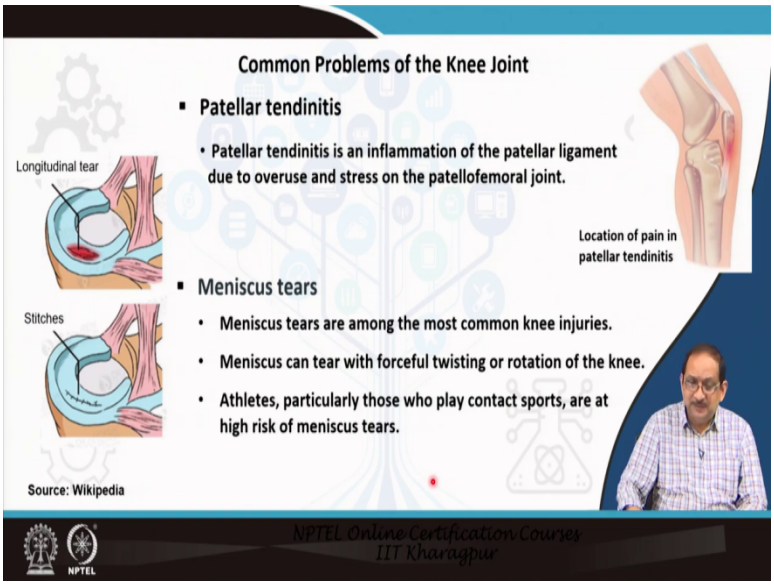

The other problems are patellar tendinitis and meniscus tears. Patellar tendonitis is an inflammation of the patellar ligament, as shown in the figure, due to overuse and excessive stress on the patellofemoral joint. The location of the pain in the patellar tendinitis is indicated herein red color.

Meniscus tears are among the most common knee injuries. As indicated here on the left-hand side of the figure, there is the C Shaped meniscus, and a longitudinal tear in the meniscus is shown, which can be repaired by stitches. The meniscus can tear with forceful twisting or rotation of the knee. Athletes, particularly those who play contact sports, are at high risk of meniscus tears.

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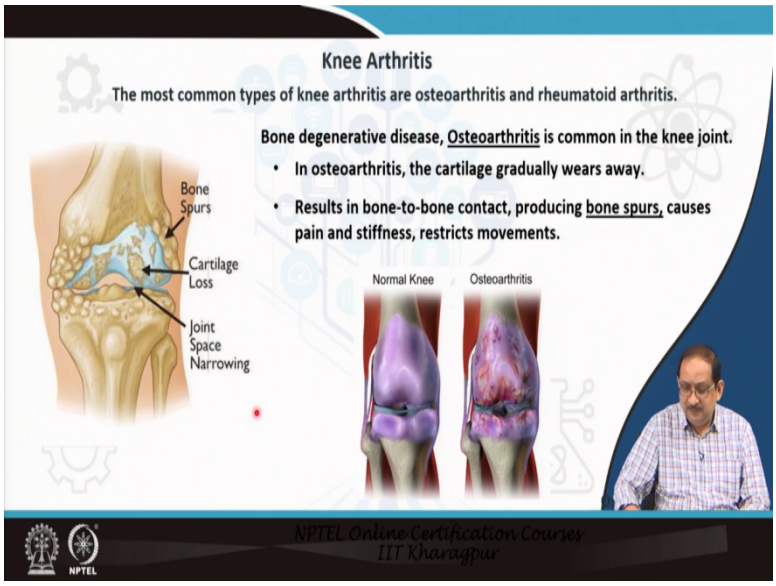
e 

Knee arthritis in the form of osteoarthritis and rheumatoid arthritis is common in patients. Arthritis is a degenerative bone disease, and osteoarthritis is common in the knee joint. As you can see, the cartilage in the knee joint is gradually worn away.

A normal knee joint is shown in this figure. A very smooth layer of the cartilage is worn away, and it takes a spiky pattern and results in bone-to-bone contact, producing bone spurs; and it finally causes a lot of pain and stiffness in the joint and it restricts normal movements. It should, however, be noted that there is decreasing joint space or narrowing of joint space in either of the two sides of the knee joint.

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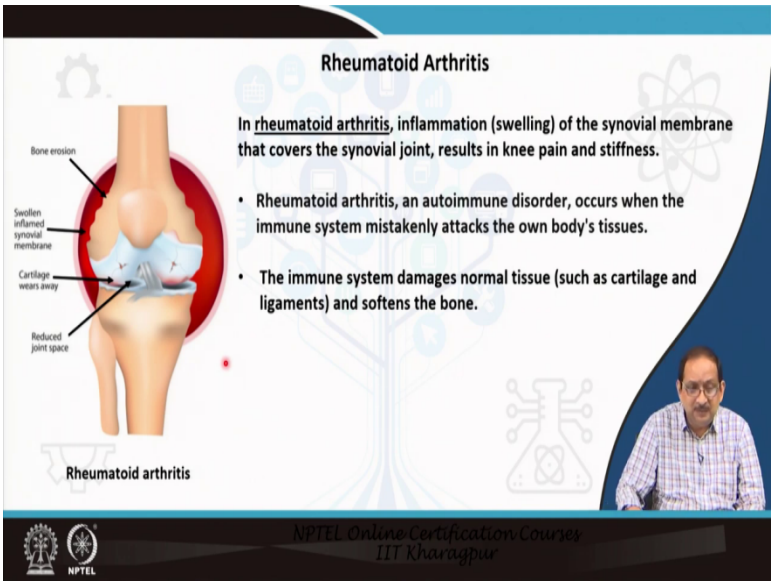

In rheumatoid arthritis, inflammation or swelling of the synovial membrane occurs, and it results in knee pain and stiffness. As you can see on the left-hand side, rheumatoid arthritis, as I have already indicated in the case of a hip from the discussion in the hip joint, is an autoimmune disorder. And it occurs when the immune system attacks the tissue of its own body. The immune system damages the normal tissue such as the cartilage and the ligaments, and it softens the bone.

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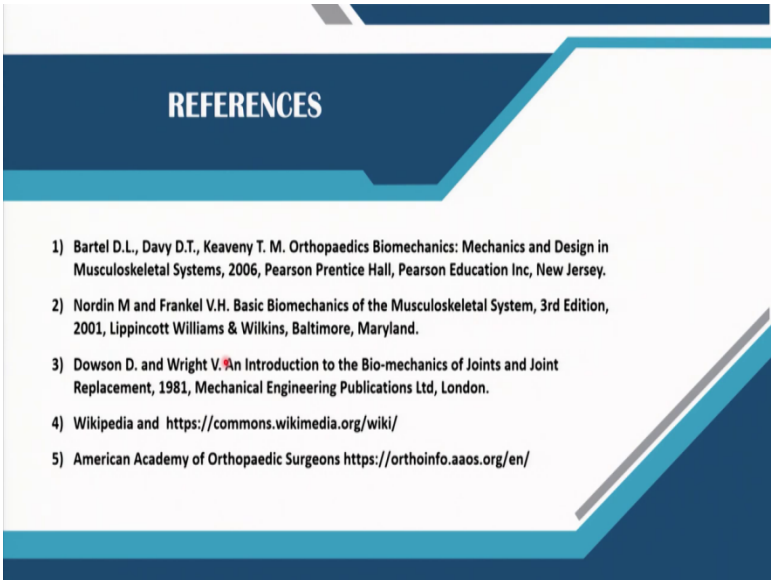

The list of references are indicated in this slide based on which the lecture on the knee joint was prepared. Thank you for listening.