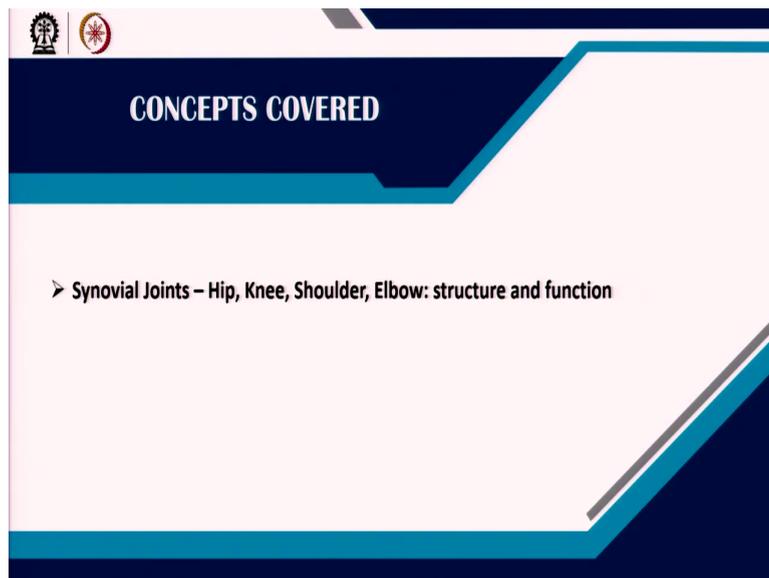


Biomechanics of Joints and Orthopaedic Implants
Professor Sanjay Gupta
Department of Mechanical Engineering
Indian Institute of Technology, Kharagpur
Lecture - 03
Synovial Joints

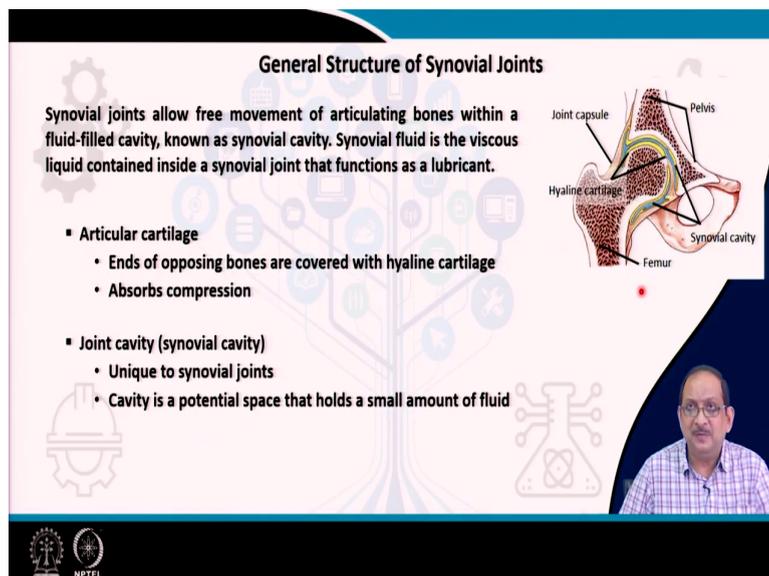
Good morning welcome to the lecture on Synovial Joints.

(Refer Slide Time: 00:39)



In this lecture, we will be discussing about the major synovial joints such as hip, knee, shoulder and elbow, from the point of view of structure and function.

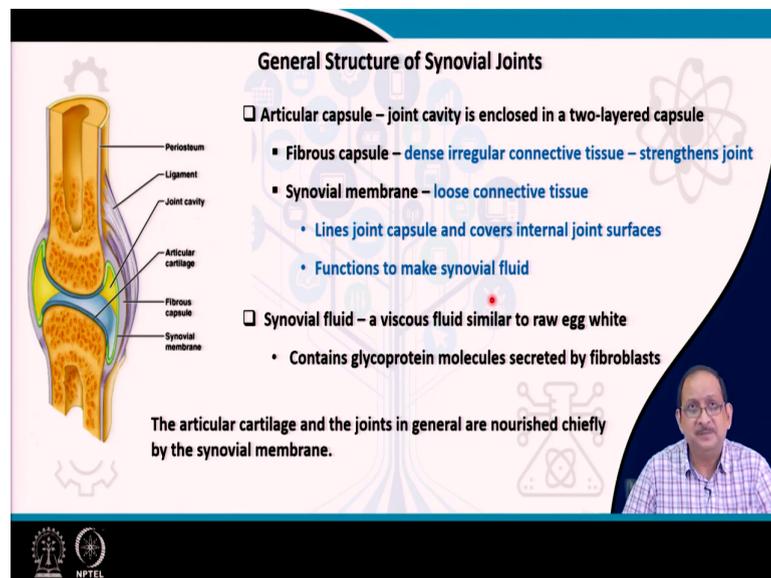
(Refer Slide Time: 00:53)



Now, let us consider the general structure of a synovial joint. The synovial joint actually allow free movement of articulating bones within a fluid filled cavity known as the synovial cavity. The synovial fluid contained in that cavity is viscous in nature and it is contained inside the synovial joint. Synovial fluid functions as a lubricant.

On the right, you can see the hip joint which is a classical synovial joint. Now, within the synovial joint there are articular cartilage. The ends of the opposing bones are actually covered by hyaline cartilage. The cartilage helps to absorb compression. The joint cavity which is also known as the synovial cavity is unique to the synovial joints. The cavity is a potential space that holds a small amount of fluid, which in this case is the synovial fluid.

(Refer Slide Time: 02:27)



Now, within the synovial joint we have a space called the articular capsule. It is actually the joint cavity; the joint cavity is enclosed in a two layered capsule. As can be seen in this picture, it has a fibrous capsule which is dense irregular connective tissue which basically strengthens the joint.

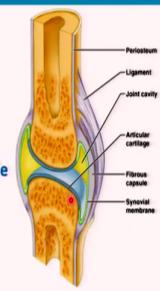
The synovial membrane is made up of loose connective tissue. It lines the joint capsule and covers the internal joint surfaces. it also functions to make the synovial fluid.

Synovial fluid is a viscous fluid quite similar to a raw egg white. It contains glycoprotein molecules secreted by fibroblasts. In general, the articular cartilage and the joints are nourished chiefly by the synovial membrane.

(Refer Slide Time: 04:04)

General Structure of Synovial Joints

- ❑ Reinforcing ligaments
 - Often are thickened parts of the fibrous capsule
 - Sometimes are *extracapsular ligaments* – located outside the capsule
 - Sometimes are *intracapsular ligaments* – located internal to the capsule
- ❑ Richly supplied with sensory nerves
 - Detect pain
 - Monitor how much the capsule is being stretched
- ❑ Have a rich blood supply
 - Most supply the synovial membrane
 - Extensive capillary beds produce basis of synovial fluid
 - Branches of several major nerves and blood vessels



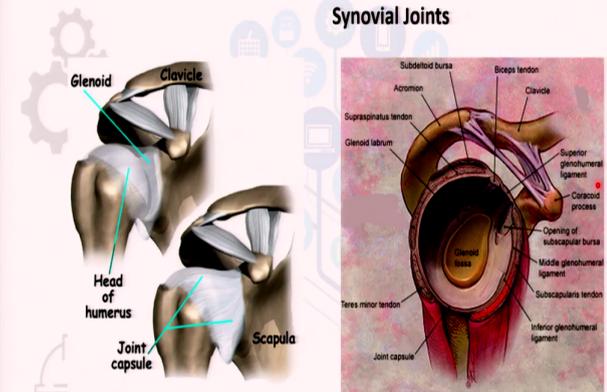
NPTEL

Now, there are actually reinforcing ligaments to this joint capsule. So, the reinforcing ligaments often are thickened part of the fibrous capsule which is indicated here. Sometimes, these ligaments are extra capsular ligaments located outside the capsule. Sometimes, they are intracapsular ligaments located inside the capsule.

Now, the synovial joint is richly supplied with sensory nerves that can actually detect pain and can monitor how much the capsule is being stretched.

(Refer Slide Time: 05:31)

Synovial Joints



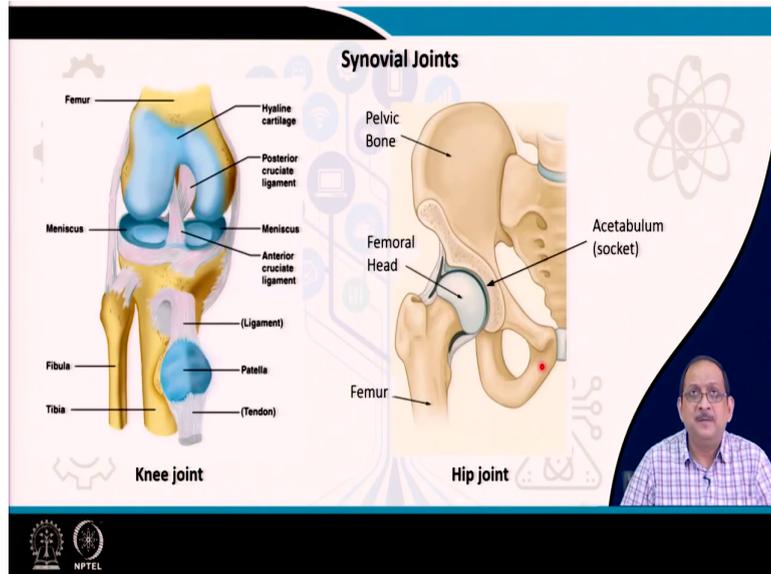
Shoulder joint



NPTEL

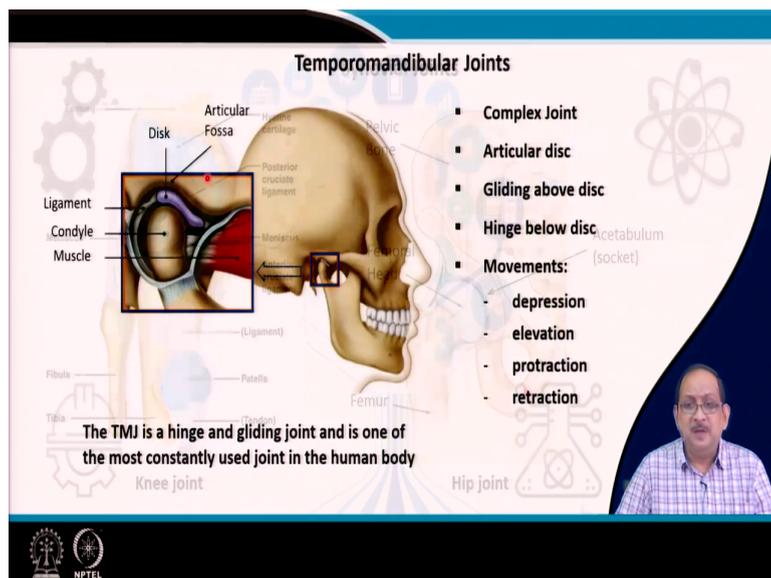
An example of synovial joint is the shoulder joint, as you can see with the joint capsule between the glenoid and the humeral head. So, the synovial joint is formed due to articulation of glenoid and the femoral head. A lateral view of the glenoid is shown here.

(Refer Slide Time: 06:05)



Another example of synovial joint is the knee joint which is formed between the distal part of the femur and proximal part of the tibia. The other example is the hip joint where the femoral head of the femur actually articulates within the acetabulum.

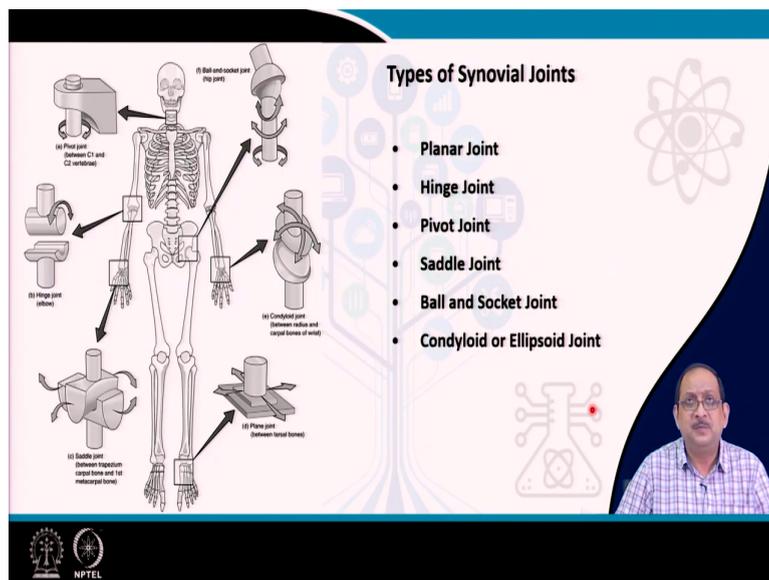
(Refer Slide Time: 06:55)



The temporomandibular joint is a special synovial joint. It is a hinge and a gliding joint and is one of the most constantly seen joint in the human body. The mandible articulates with the skull at the temporomandibular joint.

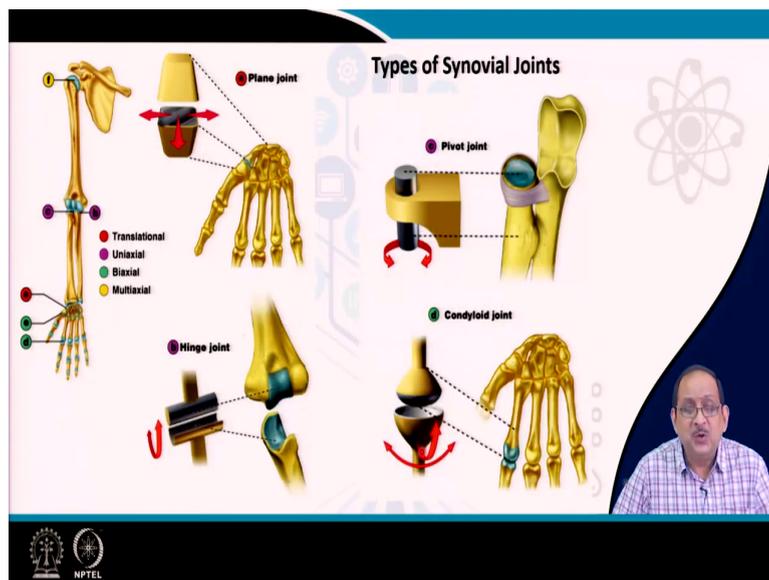
It's a highly complex joint which contains an articular disc as shown here in the picture. So, the movements in the temporomandibular joint are depression, elevation, protraction, and retraction.

(Refer Slide Time: 08:01)



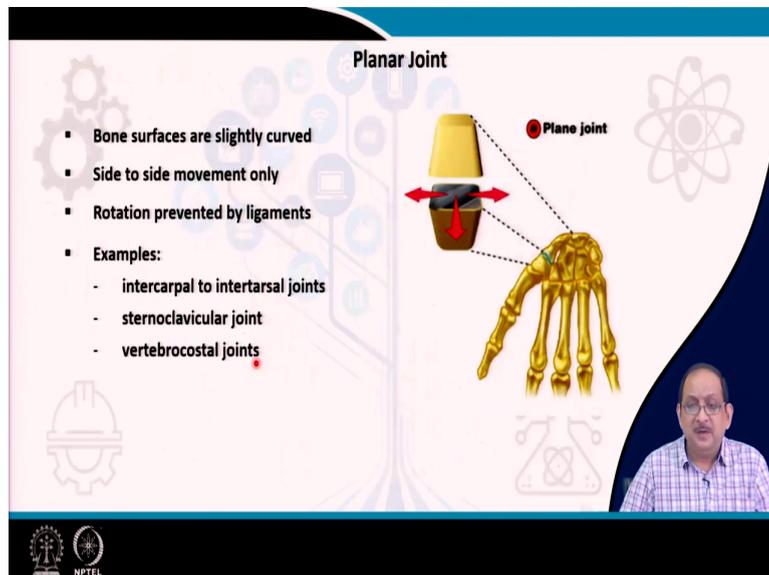
Now, let us compare the types of synovial joints with the mechanical joints. On the left, we have the skeleton and the joints within the skeletal system can be compared with planar joint, hinge joint, pivot joint, saddle joint, ball and socket joint and condyloid or ellipsoid joint.

(Refer Slide Time: 08:43)



The pivot joint can be compared with the joint formed between radius and ulna in the elbow joint. Elbow joint is an example of hinge joint. The condyloid joint or the ellipsoid joint is formed at the fingers.

(Refer Slide Time: 09:27)

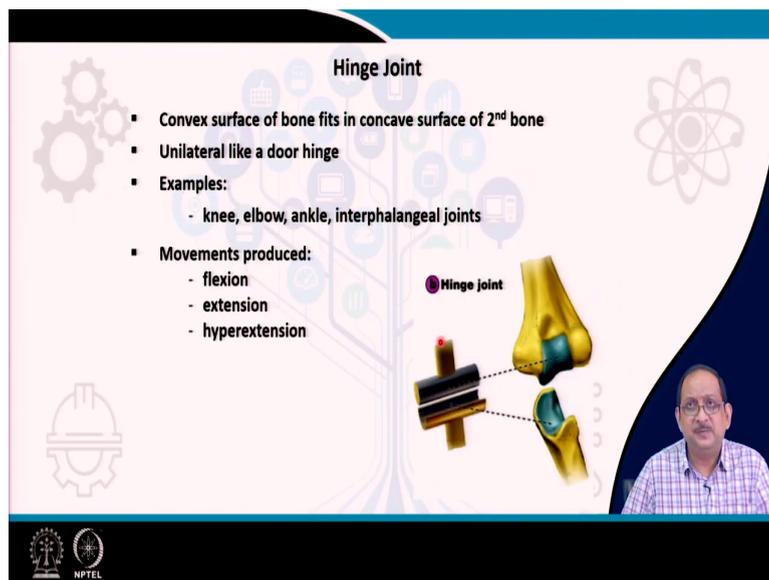


Let us consider the planar joint. The planar joint is formed by bone surfaces which are slightly curved. In the planar joint, only side to side movements are allowed and the rotations are prevented by the ligaments. The examples of the planar joint are intercarpal to intertarsal joints in the hands and fingers, sternoclavicular joint in the shoulder and vertebrocostal joints.

(Refer Slide Time: 10:10)

Hinge Joint

- Convex surface of bone fits in concave surface of 2nd bone
- Unilateral like a door hinge
- Examples:
 - knee, elbow, ankle, interphalangeal joints
- Movements produced:
 - flexion
 - extension
 - hyperextension



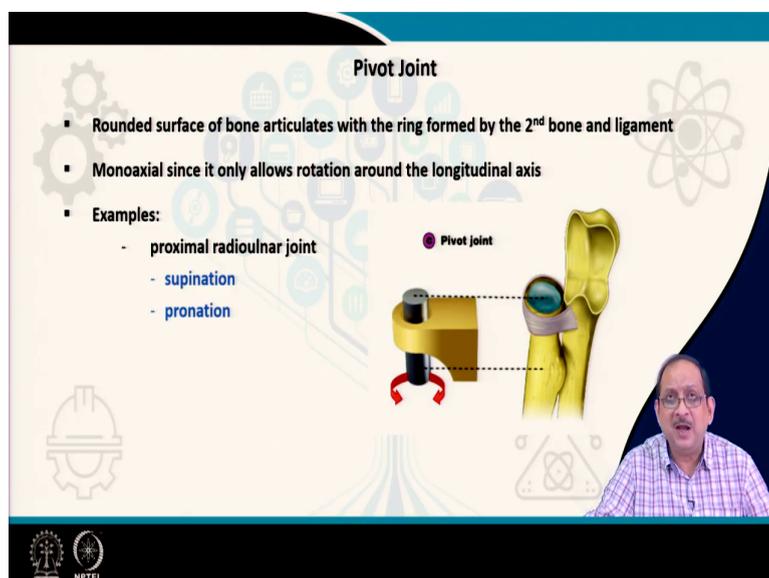
The slide features a title 'Hinge Joint' at the top. Below it is a bulleted list describing the joint's structure and movements. To the right, there is a diagram of a mechanical hinge and a 3D anatomical model of a knee joint. A small inset in the bottom right corner shows a person speaking. The NPTEL logo is visible in the bottom left corner.

Hinge joint is actually formed by convex surface of bone which fits in concave surface of the second bone. It actually behaves like a door hinge, which means that it allows rotation about one axis. Examples of the hinge joints are knee, elbow, ankle and interphalangeal joints. The movements produced in these joints are essentially flexion, extension and hyperextension.

(Refer Slide Time: 10:56)

Pivot Joint

- Rounded surface of bone articulates with the ring formed by the 2nd bone and ligament
- Monoaxial since it only allows rotation around the longitudinal axis
- Examples:
 - proximal radioulnar joint
 - supination
 - pronation



The slide features a title 'Pivot Joint' at the top. Below it is a bulleted list describing the joint's structure and movements. To the right, there is a diagram of a mechanical pivot and a 3D anatomical model of the proximal radioulnar joint. A small inset in the bottom right corner shows a person speaking. The NPTEL logo is visible in the bottom left corner.

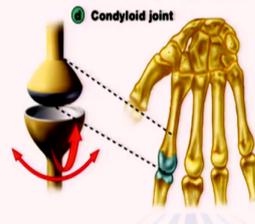
The pivot joint is formed when rounded surface of a bone articulates with the ring formed by the second bone and the ligament. The pivot joint actually offers monoaxial movement since it only allows rotation around the longitudinal axis. An example of a pivot joint is the

proximal end of the radio ulnar joint as you can see here and the movements that are offered by this joint is supination and pronation.

(Refer Slide Time: 11:55)

Condyloid Joint

- Spherically shaped bone fits into oval depression
- Biaxial: flex/extend or adduct/abduct is possible
- Examples:
 - Wrist and metacarpophalangeal joints



NPTEL

The condyloid joint is formed when spherically shaped bone fits into an oval depression. It is biaxial in nature, the movements such as flexion, extension, abduction adduction are possible movements. Examples of this condyloid joints are wrists and metacarpophalangeal joints.

(Refer Slide Time: 12:28)

Saddle Joint

- One bone saddle-shaped, other bone fits like a person riding on the saddle
- Biaxial
 - circumduction allows the tip of the thumb to travel in a circle
 - opposition allows thumb to touch tip of other fingers
- Examples:
 - Trapezium of carpus and metacarpal of thumb



NPTEL

The saddle joint is formed when one articulating bone surface is saddle shaped. The other bone fits like a person riding on the saddle. It offers biaxial movement, circumduction allows the tip of the thumb to travel in a circle whereas, opposition allows thumb to touch the finger

of the tip of the other fingers. Examples of the saddle joint are trapezium of carpus and metacarpal of the thumb.

(Refer Slide Time: 13:09)

Ball-and-socket Joint

- Ball fitting into a cup-like depression
- Multiaxial
 - flexion/extension
 - abduction/adduction
 - rotation
- Examples:
 - shoulder joint
 - hip joint

The slide features a central illustration of a ball-and-socket joint with a label 'Ball-and-socket joint' and a yellow arrow pointing to the joint. The background includes decorative icons of gears, a ball-and-socket joint, and a molecular structure. A video inset in the bottom right corner shows a man in a checkered shirt speaking.

In ball and socket joint, a ball actually fits into a cup like depression such that the movements are multi-axial flexion, extension, abduction, adduction as well as rotation. Examples of the ball and socket joint are shoulder joint and the hip joint.

(Refer Slide Time: 13:42)

Factors Influencing Joint Stability

- ❑ **Shape of the articular surfaces**
Shallow poor fitting articular surfaces hinder stability, whereas well fitting articular surfaces (i.e. hip joint) improve stability
- ❑ **Ligaments**
Ligaments unite bones and prevent excessive, undesirable motion
- ❑ **Muscle Tendon**
Muscle tendons are the most important stabilizing factor

The slide features a central illustration of a ball-and-socket joint with a red dot on the ball. The background includes decorative icons of gears, a ball-and-socket joint, and a molecular structure. A video inset in the bottom right corner shows a man in a checkered shirt speaking.

Let us now summarize the factors that influence joint stability. The first and the foremost important factor is the shape of the articular surfaces. Shallow poor fitting articular surfaces hinders stability whereas, well fitted articular surfaces improve stability.

The second is the role of the ligaments. The ligaments unite bones and prevent excessive and undesirable motion. The third important factor is the contribution of the tendons. The tendons are the most important stabilizing factor in a joint.

(Refer Slide Time: 14:46)

Movements of the Synovial Joints

The synovial joints offer a large range of movements

- Flexion – Extension
- Horizontal Flexion and Extension
- Abduction – Adduction
- Internal Rotation – External Rotation

The slide includes several diagrams:

- Flexion and Extension: A person bending forward (flexion) and backward (extension).
- Abduction and Adduction: A person moving their arms away from the midline (abduction) and towards the midline (adduction).
- Internal and External Rotation: A diagram of a ball-and-socket joint showing rotation towards the midline (internal) and away from the midline (external).
- Rotation: A person rotating their torso, with labels for lateral and medial rotation.

 A small video inset of a presenter is visible in the bottom right corner of the slide.

Now, let us consider the movements of the synovial joints. The synovial joints offer a large range of movements starting from flexion extension, horizontal flexion, horizontal extension, abduction adduction, internal rotation and external rotation as shown in the figures.

(Refer Slide Time: 15:12)

Special movements of hands and feet

- **Palmar flexion** and **Dorsal flexion** refer to movement of the flexion (palmarflexion) or extension (dorsiflexion) of the hand at the wrist.
- **Pronation** and **Supination** refer to rotation of the forearm or foot so that in the **anatomical position** the palm or sole is facing anteriorly (supination) or posteriorly (pronation) rotation of the forearm.

The slide includes diagrams:

- Palmar and Dorsal Flexion: A hand being bent towards the palm (palmar flexion) and towards the back of the hand (dorsal flexion).
- Pronation and Supination: A diagram of the forearm showing the radius rotating over the ulna in pronation, and the radius and ulna being parallel in supination.

 A small video inset of a presenter is visible in the bottom right corner of the slide.

There are special movements also of the hands and feet like the palmar flexion and dorsal flexion of the hand and wrist, pronation and supination in case of elbow.

(Refer Slide Time: 15:41)

Special movements of hands and feet

- **Dorsiflexion** and **Plantarflexion** refers to flexion (dorsiflexion) or extension of the foot at the ankle.
- **Eversion** and **Inversion** refer to movements that tilt the sole of the foot away from (eversion) or towards (inversion) the midline of the body.



The diagram shows four views of a foot illustrating special movements. Dorsiflexion is shown as the foot moving upwards towards the shin. Plantar flexion is shown as the foot moving downwards away from the shin. Inversion is shown as the sole of the foot tilting towards the midline of the body. Eversion is shown as the sole of the foot tilting away from the midline of the body.



There is also dorsiflexion and plant reflection which refers to flexion and extension of the foot at the ankle joint, respectively. There is also eversion and inversion which refers to movements that tilt the soul of the foot away which refers to eversion or towards inversion towards the midline of the body, respectively. So, the movement towards the midline of the body is called inversion and away from the midline of the body is called eversion.

(Refer Slide Time: 16:23)

Joint Disorders

▪ Pain and restricted movement and resulting in reduction in productivity and quality of life for people with damage to their major joints (hip, knee, shoulder, elbow)

• Osteoarthritis	75% of joint replacements
• Fracture	12%
• Rheumatoid arthritis	4%
• Others	9%



Labels: Decreased joint space, Exposed bone, Worn cartilage



Arthritic knee



Femoral neck fracture



Intertrochanteric fracture



NPTEL Online Certification Courses
IIT Kharagpur



Let us discuss about the joint disorders. Pain and restricted movement results in reduction in productivity and quality of life for people with damaged major joints like hip, knee, shoulder

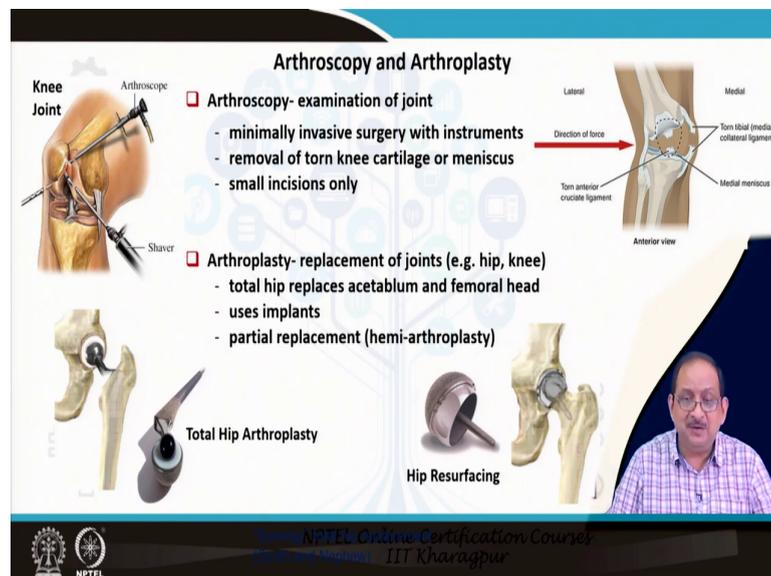
and elbow. Most of the patients who have these disorders can be classified as bone degenerative diseases like osteoarthritis and rheumatoid arthritis.

The patients with osteoarthritis and rheumatoid arthritis form the majority of the disorder patients whereas, the cases bone fracture happen in 12 percent of the population. Here, we can see that intertrochanteric fracture in the femur is shown as well as femoral neck fracture which is a common problem or joint disorder in elderly patients.

Apart from the arthritis and fracture, the other joint disorders are due to traumatic injuries. Now, in case of arthritis, worn cartilage gives rise to an articulating surface which is irregular and rough.

Moreover, the joint space, the space between the acetabular cavity and the femoral head is actually decreased and there is a potential chance of bone to bone contact giving rise to pain. In case of arthritic knee, one condyle of the femur is seen to be almost fused with the tibia and the space between the two bones is actually decreased as compared to the other part of the joint.

(Refer Slide Time: 19:17)



In order to treat joint disorders, arthroscopy and arthroplasty may be undertaken. Arthroscopy or keyhole surgery is a minimally invasive surgical procedure that can be performed on a joint. Its main instrument is an arthroscope through which the interior of the joint may be inspected or operated upon.

In this procedure, an examination and sometimes treatment of the damage is performed using an arthroscope, endoscope or other instruments that are inserted into the joint through small incisions. Arthroscopy procedure can be performed for reconstruction of torn anterior cruciate ligament.

The advantage over the traditional open surgery is that the joint does not have to be opened up fully. For a knee arthroscopy only two small incisions are made, one for the arthroscope and another for the surgical instruments to be used in the knee cavity.

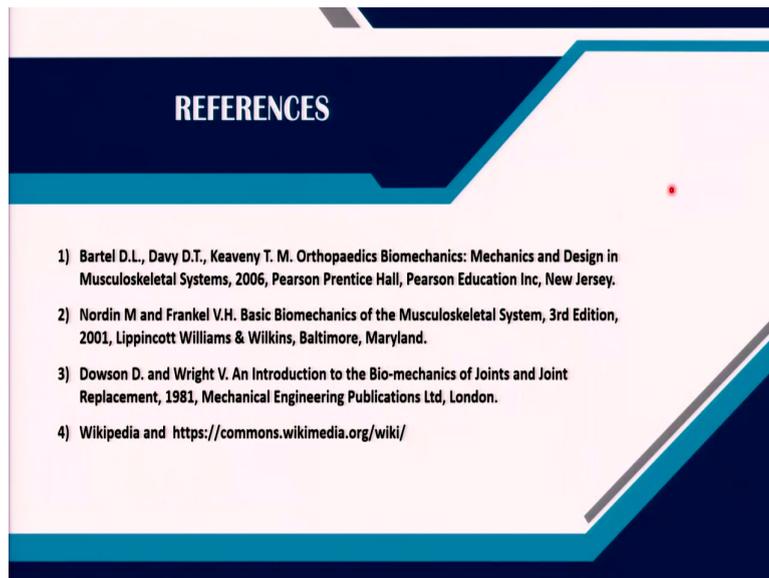
This reduces the recovery time and may increase the rate of success due to less trauma to the connective tissue. The surgical instruments are smaller than the traditional instruments and the surgeons can view the joint area on a video monitor and can diagnose and repair torn tissues such as ligaments.

On the other hand, the arthroplasty is a reconstructive surgical procedure of the joint using implants and prosthesis. A reconstructive surgical procedure of the joint using implants and prosthesis. In this procedure, the joint is actually opened up and parts of the bone near to the joints are either resected or removed using surgical tools and standard surgical procedure.

Thereafter, the implants are fixed within the resected bone structures to give rise to a newly constructed or newly reconstructed implanted joint. Arthroplasty can be of different types here in the slide total hip arthroplasty and hip resurfacing arthroplasty has been presented. Apart from the total hip and the resurfacing procedure, there can be also hemi-arthroplasty which involves partial replacement of the joint.

In the case of hip resurfacing arthroplasty, the femoral head is resurfaced using a mushroom shaped femoral component. The acetabular component in both the total hip and the resurfacing procedure is essentially a surface replacement. Although, the design of the acetabular component can actually vary from one case to the other.

(Refer Slide Time: 23:45)



The lecture is prepared based on the following references and thank you for listening.