

Note

Anatomy and Biomechanics of the Knee

Mohamed Rashed

Libyan Board of Medical Specialties, Tripoli, Libya

Email. mohbrashed@gmail.com

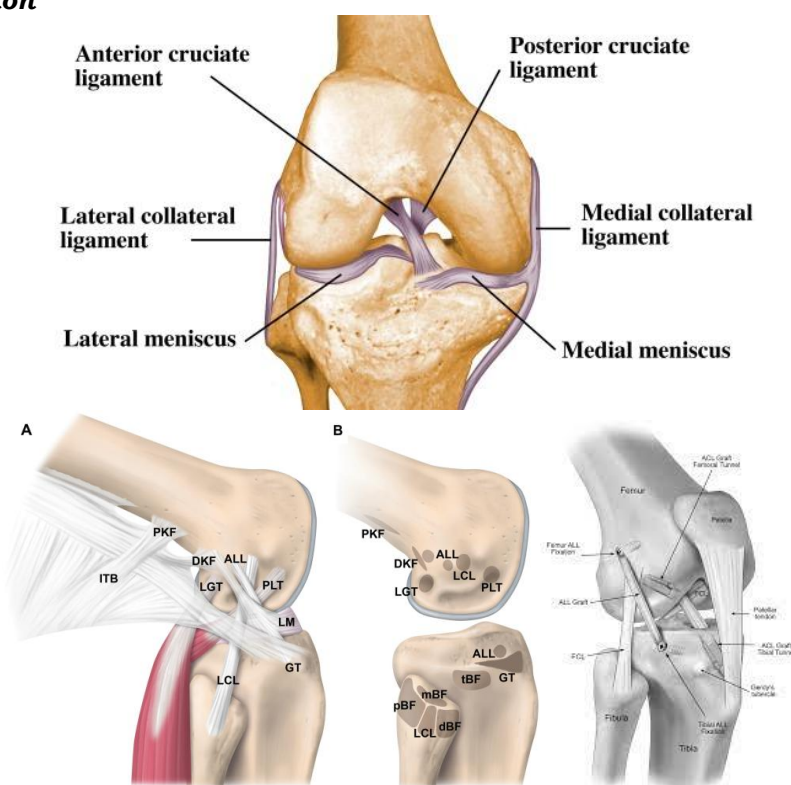
Introduction

The knee joint, as the largest synovial joint in the human body, functions as a pivotal component for lower extremity motion and load bearing. Its intricate anatomy and biomechanics are essential for maintaining stability, mobility, and overall limb function. This chapter will elaborate on the anatomical structures, biomechanical principles, and clinical implications pertinent to the knee, providing a comprehensive framework for board candidates in orthopedics and sports medicine.

The knee joint's stability is a product of interacting factors including ligaments, muscular forces, bony structure, and load. The joint, one of the body's largest and most complex, involves four bones and an extensive network of ligaments and muscles. These elements work together to facilitate movement and bear weight while maintaining stability. Understanding these components is crucial for comprehending knee function and the potential for injury. The interplay between the static and dynamic elements is particularly important in biomechanics.

Anatomy of the Knee

Structural Composition



The knee joint consists primarily of three osseous structures:

- **Femur:** The distal end features the medial and lateral condyles that articulate with the tibia.
- **Tibia:** The proximal tibia exhibits articular surfaces known as the tibial plateaus, which serve as the primary load-bearing surfaces of the knee.
- **Fibula:** The fibula stabilizes the lateral aspect of the knee but bears minimal weight in this articulation.

The knee comprises two principal articulations:

- **Tibiofemoral Joint:** A complex hinge joint allowing for flexion and extension, along with a degree of rotation, primarily functioning as a modified hinge for dynamic activities.
- **Patellofemoral Joint:** Facilitates the glide of the patella over the femur during knee flexion and extension, improving the leverage of the quadriceps.

2. Ligamentous Support

The knee joint's stability is maintained by an intricate system of ligaments:

- **Anterior Cruciate Ligament (ACL):** This ligament resists anterior tibial translation and provides rotational stability, particularly during pivoting motions.

Anterior Cruciate Ligament (ACL)

Anatomy and Function:

- The ACL is one of the key ligaments in the knee, connecting the anterior aspect of the tibia to the lateral femoral condyle.
- It plays a critical role in knee stability by:
 - **Resisting Anterior Translation:** It prevents the tibia from sliding forward relative to the femur, which is crucial in weight-bearing and dynamic activities.
 - **Providing Rotational Stability:** During activities such as cutting, pivoting, or landing, the ACL helps to control the rotational movements of the knee joint.

Biomechanics:

- The ACL is subjected to significant forces during physical activity, particularly in sports that involve rapid direction changes (e.g., soccer, basketball).
- An ACL injury often occurs during sudden stops, jumps, or awkward landings, commonly resulting in a tear.

Clinical Relevance:

- **Injury Patterns:** ACL injuries can range from mild sprains to complete tears. They are often associated with meniscal injuries and other ligamentous injuries in the knee.
- **Symptoms of Injury:** Patients typically present with acute knee pain, swelling, decreases in range of motion, and instability.
- **Diagnostic Techniques:** MRI is commonly used to confirm ACL injuries, alongside physical examination tests such as the Lachman test or the anterior drawer test.

Treatment Approaches:

- **Non-Surgical Interventions:** May include physical therapy, bracing, and activity modification for those with partial tears or less active lifestyles.
- **Surgical Interventions:** ACL reconstruction is often recommended for patients with complete tears, athletes, or individuals desiring to return to high-level sports. The procedure involves replacing the torn ligament with a graft, which may be autograft (from the patient) or allograft (from a donor).

Rehabilitation:

- Post-operative rehabilitation is crucial for a successful recovery, focusing on restoring range of motion, strength, and functional stability.
- A well-structured rehabilitation program progressively includes:
 - **Strengthening Exercises:** To enhance muscle support around the knee.
 - **Proprioception Training:** To restore balance and spatial awareness.
 - **Sport-Specific Drills:** To prepare for a safe return to athletic activities.

Outcomes:

- Successful ACL reconstruction typically yields positive outcomes, with many athletes returning to their pre-injury performance levels. However, the risk of re-injury can remain elevated, underscoring the importance of a comprehensive rehabilitation strategy.
- **Posterior Cruciate Ligament (PCL):** Counteracts posterior tibial translation and stabilizes the knee during flexion.

Posterior Cruciate Ligament (PCL)

Anatomy and Function:

- The PCL is one of the key ligaments in the knee, extending from the posterior aspect of the tibia to the medial femoral condyle.
- It functions primarily to:
 - **Resist Posterior Translation:** The PCL prevents the tibia from moving backward relative to the femur, particularly during activities that involve knee flexion.
 - **Provide Stability:** It contributes to overall knee stability, especially during movements that require dynamic control, such as running, jumping, or pivoting.

Biomechanics:

- The PCL is subject to significant forces, particularly during activities involving flexed knee positions (e.g., when descending stairs or during sports).

- It works synergistically with the ACL, with both ligaments contributing to knee stability in different planes of motion.

Injury Patterns:

- PCL injuries are less common than ACL injuries but can occur due to high-impact trauma or when the knee experiences a direct blow, such as in a motor vehicle accident or in contact sports.
- Common mechanisms of injury include:
 - **Dashboard Injuries:** When the knee strikes the dashboard during a collision.
 - **Fall on a Bent Knee:** The impact can strain the PCL if the knee is flexed.

Symptoms of Injury:

- Patients with a PCL injury may experience:
 - Sudden pain in the knee.
 - Swelling and tenderness along the joint.
 - A sense of instability, particularly with activities that involve knee flexion.

Diagnostic Techniques:

- Clinical evaluation includes physical examination tests, such as the **Godfrey Test** (sag test), and the **Posterior Drawer Test**, which helps assess posterior tibial translation.
- MRI is the gold standard for imaging, providing visualization of ligament integrity and any associated injuries (e.g., meniscal tears or injury to other ligaments).

Treatment Approaches:

- **Non-Surgical Management:** Most minor PCL injuries can be treated conservatively with:
 - **Rest, Ice, Compression, Elevation (RICE):** To reduce swelling and pain.
 - **Physical Therapy:** Focused on restoring mobility, strength, and stability.
 - **Bracing:** To provide support during recovery.
- **Surgical Interventions:** Indicated for complete tears or when the injury is accompanied by significant instability or other knee injuries (e.g., multi-ligament tears). Surgical options may include:
 - **PCL Reconstruction:** Utilizing a graft to replace the torn ligament. This can be performed through a double-bundle technique to restore both anterolateral and posteromedial bundles of the PCL.

Rehabilitation:

- Following treatment, a structured rehabilitation protocol is key to recovery:
 - **Phase 1 (Acute Phase):** Focus on reducing swelling, maintaining range of motion, and initiating gentle strengthening.
 - **Phase 2 (Mobilization and Strengthening):** Gradual introduction of range of motion and strength exercises, emphasizing closed kinetic chain activities.
 - **Phase 3 (Functional Training):** Sport-specific drills and proprioceptive training to prepare for return to activities. This phase typically lasts several months, depending on the individual's progress.

Outcomes:

- The prognosis for PCL injuries is generally favorable, particularly with appropriate intervention. Many individuals can return to a high level of athletic participation, but the timeline varies based on the injury severity and the treatment method.
- Long-term outcomes indicate that while some patients may experience persistent knee symptoms, many can regain full function and return to pre-injury activity levels with effective rehabilitation.
- **Medial Collateral Ligament (MCL):** Provides resistance against valgus stress and contributes to the overall stability of the medial compartment.

Medial Collateral Ligament (MCL)

Anatomy and Function:

- The MCL is one of the main ligaments on the inner side of the knee, extending from the medial epicondyle of the femur to the superior aspect of the tibia.
- It serves several crucial functions:
 - **Stability:** The MCL provides medial stability to the knee, preventing excessive valgus (inward) movement, which is critical during weight-bearing and dynamic activities.
 - **Support during Flexion and Extension:** As the knee flexes and extends, the MCL maintains knee alignment and integrity.

Biomechanics:

- The MCL works in conjunction with the surrounding muscles (particularly the adductors), tendons, and the other knee ligaments (ACL, PCL) to control knee motion.

- It is primarily loaded during activities that involve lateral forces, such as cutting or pivoting, making it susceptible to injury during sports.

Injury Patterns:

- MCL injuries are among the most common knee injuries, often resulting from a traumatic event. Common mechanisms include:
 - Direct Blow:** A force applied to the outer side of the knee (often seen in contact sports like football).
 - Twisting Movements:** Situations where the foot is planted while the body turns, leading to excessive stress on the ligament.

Symptoms of Injury:

- Patients with an MCL injury typically report:
 - Pain and Tenderness:** Localized on the inner side of the knee.
 - Swelling:** In the immediate area following the injury.
 - Instability:** A sensation of the knee giving way when walking or during activities.
 - Loss of Range of Motion:** Difficulty fully extending or flexing the knee.

Diagnostic Techniques:

- Physical Examination:** Common tests for MCL injury include the **Valgus Stress Test**, which assesses the stability of the ligament under valgus forces.
- Imaging:** MRI is the most effective imaging modality for evaluating MCL injuries, helping to determine the extent of the ligament damage and rule out associated injuries to other knee structures, such as menisci or cruciate ligaments.

Treatment Approaches:

- Non-Surgical Management:** Most MCL injuries (Grade I and II) are treated conservatively, involving:
 - RICE Protocol:** Rest, Ice, Compression, and Elevation to manage swelling and pain.
 - Bracing:** A knee brace may be used to stabilize and protect the knee during the healing process.
 - Physical Therapy:** A tailored rehabilitation program focusing on restoring range of motion, strengthening the surrounding musculature, and re-establishing proprioception and dynamic stability.
- Surgical Management:** Indicated for complete tears (Grade III) or when associated injuries compromise knee stability. Surgical options may include:
 - MCL Repair:** In cases where the ligament is torn but can be reattached to the bone.
 - MCL Reconstruction:** Often using a tendon graft when the ligament cannot be repaired.

Rehabilitation:

- Rehabilitation following an MCL injury is essential for returning to full function:
 - Phase 1 (Initial Recovery):** Focus on controlling pain and swelling, regaining full range of motion, and beginning gentle strength exercises.
 - Phase 2 (Strengthening and Stability):** Introduce closed kinetic chain activities, proprioceptive training, and progressive strengthening exercises.
 - Phase 3 (Functional and Sport-Specific Training):** Gradually progress to sport-specific drills and higher-level activities, ensuring an appropriate return to competitive sports.

Outcomes:

- The prognosis for MCL injuries is generally positive, with most patients experiencing full recovery, especially with appropriate management and rehabilitation.
- Many athletes return to pre-injury levels of activity, although athletes with a history of MCL injuries may have an increased risk of subsequent knee injuries.
- Lateral Collateral Ligament (LCL):** Provides resistance against varus stress on the knee.

Lateral Collateral Ligament (LCL)

Anatomy and Function:

- The LCL is a prominent ligament located on the outer side of the knee, extending from the lateral epicondyle of the femur to the head of the fibula.
- Its primary functions include:
 - Stability:** The LCL provides lateral stability to the knee joint, preventing excessive varus (outward) movement, which is crucial for maintaining knee alignment during various activities.
 - Support During Dynamic Movements:** It works to stabilize the knee when confronted with sudden lateral forces, particularly during sports involving cutting or pivoting.

Biomechanics:

- The LCL functions cooperatively with other knee stabilizers, including the ACL and MCL, to maintain knee integrity during both static and dynamic conditions.
- It is particularly active during motions where the knee bears weight while undergoing lateral stresses.

Injury Patterns:

- LCL injuries are less common than MCL injuries but can occur due to specific trauma or mechanical forces. Common mechanisms of injury include:
 - **Direct Trauma:** A blow to the inner aspect of the knee (such as during contact sports) can place excessive strain on the LCL, leading to injury.
 - **Varus Stress:** Excessive varus forces (such as those experienced during certain athletic maneuvers) can also result in LCL tears.

Symptoms of Injury:

- Patients with an LCL injury often present with:
 - **Pain and Tenderness:** Localized on the outer side of the knee joint.
 - **Swelling:** May develop in the lateral compartment of the knee.
 - **Instability:** A feeling of the knee being unstable or giving way, particularly when stressed laterally.
 - **Loss of Range of Motion:** Pain may lead to difficulty in fully bending or straightening the knee.

Diagnostic Techniques:

- **Physical Examination:** Common tests for assessing LCL integrity include the **Varus Stress Test**, which evaluates the ligament's ability to control varus forces.
- **Imaging:** MRI is the preferred imaging modality, providing detailed images to assess the extent of the injury and any potential associated injuries, such as meniscal tears or damage to other ligaments.

Treatment Approaches:

- **Non-Surgical Management:** Most LCL injuries (Grade I and II) are treated conservatively. Treatment typically involves:
 - **RICE Protocol:** Rest, Ice, Compression, and Elevation to manage swelling and pain.
 - **Bracing:** A knee brace may be used to limit movement and provide support during the healing process.
 - **Physical Therapy:** A rehabilitation program focused on restoring range of motion, strengthening the muscles around the knee, and improving overall stability.
- **Surgical Management:** Indicated for complete tears (Grade III) or combined injuries involving the ACL or PCL. Surgical options may include:
 - **LCL Repair:** If the ligament can be directly reattached to the bone.
 - **LCL Reconstruction:** This may be necessary when the ligament is irreparably damaged, using a graft to restore function.

Rehabilitation:

- Rehabilitation following LCL injuries is crucial for restoring function and preventing re-injury:
 - **Phase 1 (Initial Recovery):** Management of pain and swelling, beginning range of motion exercises, and gentle strengthening.
 - **Phase 2 (Strengthening and Stability):** Progressing to closed kinetic chain exercises, balance training, and more intense strength work.
 - **Phase 3 (Functional and Sport-Specific Training):** Incorporating sport-specific drills and agility training, focusing on full functional return.

Outcomes:

- The prognosis for LCL injuries is generally favorable with effective management. Many athletes can return to their pre-injury levels of participation, especially with an appropriate rehabilitation program.
- However, the presence of concomitant injuries (such as damage to the ACL or PCL) may influence recovery time and the overall outcome.

Coronary Ligaments

Anatomy and Function:

- The **coronary ligaments** are a set of fibers that connect the lateral and medial menisci to the tibia, providing support to the menisci and helping to stabilize the knee joint.
- Each meniscus has its own set of coronary ligaments, which run around the periphery of the menisci, anchoring them to the corresponding tibial plateau.

• **Functions include:**

- **Stabilization of the Menisci:** The coronary ligaments help maintain the position of the menisci during knee motion, contributing to the overall stability of the knee.
- **Shock Absorption:** By anchoring the menisci, they help ensure proper load distribution across the knee joint, playing a critical role in shock absorption and reducing the risk of cartilage degeneration.

Injury Patterns:

- Injury to the coronary ligaments often occurs alongside meniscal tears, particularly in cases of traumatic knee injuries or degenerative changes.
- When the ligaments are torn, they can contribute to further instability of the knee and meniscal function.

Clinical Relevance:

- **Symptoms of Injury:** Symptoms may include pain localized to the joint line, swelling, and instability in the knee.
- **Diagnosis:** MRI is typically used to evaluate injury to the coronary ligaments, often in conjunction with assessing meniscal tears.

3. Meniscal Structures

The knee contains two menisci, which are critical to joint function:

- **Medial Meniscus:** C-shaped and less mobile, this meniscus bears a greater load and is more frequently injured.

Medial Meniscus

Anatomy:

- The **medial meniscus** is a C-shaped fibrocartilaginous structure located on the medial side of the knee joint, sitting between the femur and the tibia.
- **Structure:**
 - It is thicker at its outer border and tapered at the inner border, contributing to load distribution and stability.
 - The medial meniscus is less mobile than the lateral meniscus and is more firmly attached to the MCL (medial collateral ligament), which increases its susceptibility to injury.
- **Blood Supply:**
 - The vascular supply is limited; the outer third (red zone) is vascularized and can heal better than the inner two-thirds (white zone), which lacks a direct blood supply.

Function:

- **Shock Absorption:** The medial meniscus serves as a cushioning structure that absorbs impact and distributes weight across the knee joint during activities involving loading.
- **Stability:** It enhances knee stability by increasing the congruence between the femur and tibia and helps prevent joint degeneration by spreading stress.
- **Facilitation of Movement:** The meniscus facilitates smooth movement of the femur over the tibia during flexion and extension, contributing to proper knee biomechanics.

Injury Patterns:

- **Meniscal Tears:** The medial meniscus is particularly prone to injury, often resulting from:
 - **Degenerative Changes:** Age-related wear and tear leading to tears, especially in older populations.
 - **Traumatic Events:** Injuries may occur during activities involving twisting or direct contact, such as sports (e.g., football, basketball).
- **Types of Tears:**
 - **Horizontal Tears:** Often result from degenerative changes.
 - **Vertical (Longitudinal) Tears:** Can occur due to traumatic twisting and may lead to bucket handle tears.
 - **Complex Tears:** Combinations of tear patterns and are often more challenging to treat.
- **Associated Injuries:** Medial meniscus tears frequently occur alongside ACL injuries and may coexist with injuries to the MCL.

Symptoms of Injury:

- **Pain:** Localized to the medial joint line, often exacerbated by weight-bearing activities or twisting motions.
- **Swelling:** May develop in the knee joint, often occurring within 24 hours post-injury.
- **Locking or Clicking Sensation:** Patients may experience mechanical symptoms such as locking or catching due to fragment displacement.

- **Limited Range of Motion:** Pain and swelling can lead to reduced flexibility and mobility.

Diagnostic Techniques:

- **Physical Examination:**
 - **Joint Line Tenderness:** Pain when palpating along the medial joint line is indicative of a meniscal tear.
 - **Special Tests:** Such as the **McMurray Test** and the **Apley Compression Test**, which assess the integrity of the meniscus.
- **Imaging:**
 - **MRI:** Utilized as the gold standard for diagnosing meniscal tears, providing detailed images of the meniscus and surrounding structures to assess tear type, extent, and presence of associated injuries.

Treatment Approaches:

- **Non-Surgical Management:**
 - Indicated for minor tears (e.g., partial tears or tears in the red zone) and may involve:
 - **RICE Protocol:** Rest, Ice, Compression, and Elevation to manage swelling and pain.
 - **Physical Therapy:** Focused on strengthening surrounding musculature and improving range of motion.
 - **Activity Modification:** Avoidance of activities that exacerbate symptoms.
- **Surgical Management:**
 - Indicated for significant tears or when conservative treatment fails. Options include:
 - **Meniscectomy:** Partial or total removal of the damaged meniscus, deemed necessary in cases where repair is not feasible.
 - **Meniscus Repair:** Involves suturing the meniscus back together, most successful in tears located in the vascularized red zone. This procedure is preferred when possible to preserve meniscal function.

Rehabilitation:

- **Post-Surgery Protocol:**
 - Focuses on restoring knee function, strength, and stability based on the surgical intervention.
 - **Phase 1 (Initial Recovery):** Manage pain and swelling, begin range of motion and isometric strengthening exercises.
 - **Phase 2 (Functional Training):** Introduce closed kinetic chain exercises, proprioception training, and gradual progression through higher-level activities.
 - **Phase 3 (Return to Sport):** Incorporate sport-specific drills and functional activities while ensuring the knee can withstand required stresses safely.

Outcomes:

- The prognosis following treatment varies by age, activity level, and injury severity. Individuals can often return to their pre-injury levels of activity, especially with appropriate surgical intervention and rehabilitation.
- Long-term stability and function can be ensured by adhering to post-injury rehabilitation programs and modifying activities to reduce stress on the knee.
-
- **Lateral Meniscus:** More circular and mobile, it plays an essential role in load distribution and stability.

Lateral Meniscus

Anatomy:

- The **lateral meniscus** is a C-shaped fibrocartilaginous structure located on the outer side of the knee joint, situated between the femur and the tibia.
- **Structure:**
 - It is thicker at its outer edge and tapering on the inner side, contributing to load distribution and stability.
 - The lateral meniscus is more mobile compared to the medial meniscus, allowing for better adaptation during knee motion.
 - It is less firmly attached to the LCL (lateral collateral ligament) and tends to move with the femur during normal knee movements.

- **Blood Supply:**

- Similar to the medial meniscus, it has a limited blood supply. The outer third (red zone) is vascularized and has a better potential for healing, while the inner two-thirds (white zone) has a poor blood supply and may not heal effectively after injury.

Function:

- **Shock Absorption:** The lateral meniscus acts as a cushion that absorbs impact and helps distribute loads across the knee joint during weight-bearing activities.
- **Stability:** It enhances the stability of the knee by improving the congruence between the femur and tibia and helping to prevent joint degeneration.
- **Facilitation of Movement:** The lateral meniscus allows smooth movement of the femur over the tibia during flexion and extension, contributing to normal knee biomechanics.

Injury Patterns:

- **Meniscal Tears:** The lateral meniscus is prone to injury, often due to:
 - **Traumatic Events:** Injuries can occur during twisting motions or direct contact, common in sports such as football or basketball.
 - **Degenerative Changes:** Age-related wear and tear may lead to tears, especially in older populations.
- **Types of Tears:**
 - **Horizontal Tears:** Often resulting from degenerative changes rather than trauma.
 - **Vertical (Longitudinal) Tears:** Can occur due to twisting injuries and may result in bucket handle tears, where a portion of the meniscus detaches and resembles a handle.
 - **Complex Tears:** Combinations of different tear patterns, which may complicate treatment options.
- **Associated Injuries:** Lateral meniscus tears may occur in conjunction with injuries to the ACL or other knee structures.

Symptoms of Injury:

- **Pain:** Usually localized to the lateral joint line of the knee, escalating with activity that involves twisting or squatting.
- **Swelling:** May occur within hours to days after the injury due to inflammation.
- **Locking or Clicking Sensation:** Patients may experience mechanical symptoms, including popping or locking of the knee due to loose fragments.
- **Limited Range of Motion:** Pain and swelling can lead to reduced mobility and difficulty in fully extending or flexing the knee.

Diagnostic Techniques:

- **Physical Examination:**
 - **Joint Line Tenderness:** Pain when palpating along the lateral joint line is indicative of a meniscal tear.
 - **Special Tests:** Tests such as the **McMurray Test** and the **Apley Compression Test** help assess the integrity of the lateral meniscus.
- **Imaging:**
 - **MRI:** The gold standard for diagnosing lateral meniscus tears, allowing detailed visualization of tears, associated injuries, and joint structures.

Treatment Approaches:

- **Non-Surgical Management:**
 - Indicated for minor tears, particularly those in the vascularized red zone. Treatment may include:
 - **RICE Protocol:** Rest, Ice, Compression, and Elevation to control swelling and pain.
 - **Physical Therapy:** A rehabilitation program focused on restoring range of motion, strength, and stability.
 - **Activity Modification:** Avoiding activities that exacerbate symptoms.
- **Surgical Management:**
 - Required for significant tears or when conservative treatment fails. Surgical options may include:
 - **Meniscectomy:** Partial or total removal of the damaged meniscus, often considered when repair is not feasible.

- **Meniscus Repair:** Involves suturing the torn meniscus, which is most successful for tears located in the red zone, preserving meniscal function whenever possible.

Rehabilitation:

• Post-Surgery Protocol:

- Post-surgical rehabilitation focuses on restoring knee function and strength based on the specific procedure performed.
- **Phase 1 (Initial Recovery):** Focus on pain management, swelling reduction, and range of motion exercises.
- **Phase 2 (Strengthening and Functional Training):** Introduce strengthening exercises, proprioception training, and closed-chain activities to restore stability.
- **Phase 3 (Return to Sport):** Gradual progression to sport-specific drills, ensuring safe return to athletic activity and full functional capabilities.

Outcomes:

- The prognosis for lateral meniscus injuries generally varies with the type of tear, age, activity level, and treatment approach.
- Many individuals can return to pre-injury activity levels, especially with effective surgical intervention and rehabilitation.
- Maintaining a focus on proper biomechanics and knee health is essential for preventing future injuries.

Both menisci serve to deepen the articular surface, distribute forces, and absorb shock.

4. Musculature

Key muscle groups crossing the knee joint include:

- **Quadriceps Femoris:** Comprising four heads, this muscle group is pivotal for knee extension and maintaining patellar stability.
- **Hamstrings:** This group facilitates knee flexion and assists in deceleration during activities such as running and jumping.
- **Gastrocnemius:** Active during both knee flexion and plantar flexion of the ankle, the gastrocnemius contributes to dynamic stability during ambulation.

5. Synovial Components and Bursae

The knee joint is enveloped in a synovial capsule, which contains synovial fluid for lubrication and nutrition of the cartilage. Numerous bursae aid in reducing friction during movement:

- **Prepatellar Bursa:** Located over the patella, it prevents friction between the patellar tendon and the underlying bone during kneeling.

Anatomy:

- The **prepatellar bursa** is a small, fluid-filled sac located anterior to the kneecap (patella) and beneath the skin.
- It sits between the skin and the patella, cushioning and reducing friction during movement.
- **Location:** The bursa is positioned over the front of the knee, typically extending from the superior aspect of the patella to just below the patellar tendon.

Function:

- The primary functions of the prepatellar bursa include:
 - **Friction Reduction:** It allows smooth movement of the patella over the underlying femur during knee flexion and extension, minimizing friction between the skin and the patella.
 - **Cushioning:** The bursa acts as a cushion to absorb impact forces that occur during activities such as kneeling or jumping, protecting the patella and surrounding structures from excessive stress.

Clinical Relevance:

- **Bursitis:** Inflammation of the prepatellar bursa is known as **prepatellar bursitis** or "housemaid's knee," often resulting from repetitive trauma or pressure on the knee. Common causes include:
 - **Occupational or Recreational Activities:** Frequent kneeling, such as in plumbing, flooring, or gardening, can irritate the bursa.
 - **Acute Trauma:** Direct impacts to the knee or falls can also lead to inflammation.
 - **Infection:** Septic bursitis can occur due to bacterial infection, especially if there are open wounds or injuries near the bursa.

Symptoms of Prepatellar Bursitis:

- **Swelling:** Noticeable swelling over the kneecap, which may vary in size depending on the severity of the inflammation.
- **Pain:** Tenderness at the site of the bursa, especially when kneeling or putting pressure on the knee.

- **Limited Range of Motion:** Pain and swelling may lead to difficulty in fully bending or extending the knee.
- **Heat and Redness:** In some cases, there may be localized warmth and redness over the bursa, particularly if infected.

Diagnosis:

- **Physical Examination:** The physician assesses swelling, tenderness, and range of motion in the knee. A thorough history of activities and any recent trauma is also important.
- **Imaging:** While not always necessary, imaging studies such as ultrasound or MRI can be used to evaluate the bursa's condition and rule out other knee pathologies.

Treatment Approaches:

- **Conservative Management:** Most cases of prepatellar bursitis can be treated non-surgically, including:
 - **Rest:** Avoiding activities that aggravate the condition to allow the bursa to heal.
 - **Ice Therapy:** Applying ice to the affected area can help reduce swelling and pain.
 - **Compression:** Using a compression wrap to minimize swelling.
 - **Elevation:** Elevating the knee can assist in reducing swelling.
 - **Anti-inflammatory Medications:** Nonsteroidal anti-inflammatory drugs (NSAIDs) can help alleviate pain and reduce inflammation.
- **Corticosteroid Injections:** If symptoms persist, corticosteroid injections may be administered to relieve inflammation and pain.
- **Surgical Intervention:** Rarely needed, but if bursitis is chronic or recurrent and has not responded to conservative measures, surgical removal of the bursa (bursectomy) may be indicated.

Rehabilitation:

- Rehabilitation focuses on restoring function and strength to the knee. This may include:
 - **Strengthening Exercises:** To improve the surrounding musculature and support knee stability.
 - **Flexibility Training:** To restore range of motion and prevent stiffness.
 - **Activity Modification:** Instruction on avoiding positions or activities that exacerbate symptoms, particularly prolonged kneeling or pressure on the knee.

Outcomes:

- Most individuals respond well to conservative treatments, with a significant reduction in symptoms and a return to normal activities.
- Proper management and preventive measures (like using kneepads) can help reduce the risk of recurrence in individuals who perform kneeling activities regularly.
- **Infrapatellar Bursa:** Acts to cushion the area below the patella, facilitating smooth gliding of the patellar tendon.

Infrapatellar Bursa

Anatomy:

- The **infrapatellar bursa** is a fluid-filled sac located beneath the patella (kneecap) and above the tibial tuberosity.
- **Structure:**
 - It is divided into two parts: the **superficial infrapatellar bursa**, which is located just beneath the skin over the patellar tendon, and the **deep infrapatellar bursa**, situated between the patellar tendon and the tibia.
- **Location:** It lies anterior to the knee joint, anterior to the tibial tuberosity, and serves to cushion anatomical structures during knee movement.

Function:

- **Friction Reduction:** The primary function of the infrapatellar bursa is to reduce friction between the patellar tendon and the underlying tibia during knee flexion and extension, allowing smooth movement of the knee.
- **Cushioning:** It provides cushioning during activities that involve kneeling or jumping, protecting the patellar tendon and tibia from excessive stress.

Clinical Relevance:

- **Bursitis:** Inflammation of the infrapatellar bursa is known as **infrapatellar bursitis**. This condition can arise from various factors, including:
 - **Overuse:** Repetitive activities involving bending or kneeling can lead to chronic irritation of the bursa, commonly seen in individuals like carpet layers, plumbers, and athletes.

- **Trauma:** Direct impact or injuries to the knee can cause acute inflammation of the bursa.
- **Infection:** Septic bursitis can occur due to the introduction of bacteria into the bursa, often stemming from skin penetrating injuries or infections in adjacent tissues.

Symptoms of Infrapatellar Bursitis:

- **Swelling:** Swelling or a noticeable bulge below the kneecap that may increase with activity.
- **Pain:** Tenderness at the site of the bursa, particularly noticeable when kneeling, climbing stairs, or engaging in activities that put stress on the knee.
- **Limited Range of Motion:** Pain and swelling may restrict the full range of motion of the knee.
- **Warmth and Redness:** In cases of infection or acute inflammation, there may be localized warmth, redness, and increased tenderness over the bursa.

Diagnosis:

- **Physical Examination:** The physician will assess swelling, tenderness, and range of motion of the knee and inquire about the patient's history of activities or trauma.
- **Imaging:** In most cases, imaging (such as ultrasound or MRI) is not necessary, but it may be used to rule out other knee pathologies, such as tendon injuries or osteoarthritis.

Treatment Approaches:

- **Conservative Management:** Most cases of infrapatellar bursitis respond well to conservative treatment options, including:
 - **Rest:** Avoiding activities that exacerbate symptoms for a period to promote healing.
 - **Ice Therapy:** Applying ice to the affected area to aid in reducing swelling and pain.
 - **Compression:** Using a compression wrap or bandage to minimize swelling.
 - **Elevation:** Keeping the knee elevated helps reduce swelling.
 - **Medication:** Nonsteroidal anti-inflammatory drugs (NSAIDs) may be recommended to alleviate pain and inflammation.
- **Corticosteroid Injections:** If symptoms persist despite conservative treatment, corticosteroid injections into the bursa may be performed to reduce inflammation.
- **Surgical Intervention:** Surgical removal of the bursa (bursectomy) is rarely performed but may be considered for chronic cases that do not respond to conservative measures.

Rehabilitation:

- Rehabilitation is essential to restore knee function and prevent recurrence:
 - **Strengthening Exercises:** Focus on strengthening the quadriceps and surrounding musculature to provide support to the knee joint.
 - **Flexibility Training:** Stretching exercises may be included to maintain or restore the range of motion in the knee.
 - **Education on Activity Modification:** Guidance on avoiding positions or activities that place excessive strain on the knee, particularly prolonged kneeling or repetitive bending.

Outcomes:

- The prognosis for infrapatellar bursitis is generally favorable with timely treatment. Most individuals respond well to conservative management and can return to normal activities.
- Preventive strategies can help minimize the risk of recurrence, especially for individuals engaged in occupations or sports that place stress on the knee.
- **Plica ;** A remnant of embryologic development, the synovial plica is variably developed in different individuals. Its form can range from a complete septation of the suprapatellar pouch from the more inferior joint, to a band extending from the medial fat pad through the medial gutter and across the suprapatellar pouch flaring out in the lateral gutter, to a remnant or to no structure at all. In its normal state, it is tissue-paper thin but can become thickened, scarred, and contracted as a consequence of injury and causes ankylosis and painful tethering of the quadriceps tendon.
- **Fat Pad ;** The infrapatellar fat pad is normally consisted of primarily adipose tissue and a small vascular arcade that arises from convergence of the inferior medial and inferior lateral geniculate arteries and provides the primary vascular supply to the anterior cruciate ligament (ACL). It is suspended from the superior intercondylar notch by a thin synovial fold, the ligamentum mucosum. As a consequence of injury, the structure may fibrose causing ankylosis, painful extension block, and infrapatellar contracture of both the patella and patellar tendon.

Biomechanics of the Knee

1. Kinematic Movements

The knee joint primarily facilitates:

- **Flexion and Extension:** Normal active ROM ranges from 0° extension to approximately 135° of flexion. During functional activities, range may extend beyond these limits, particularly in sports.
- **Internal and External Rotation:** This motion is most pronounced when the knee is flexed, allowing for nuanced adjustments in gait and stability during athletic maneuvers.

Kinematic Movements of the Knee Joint

The knee joint is primarily composed of two main articulating surfaces: the femur (thigh bone) and the tibia (shin bone), along with the patella (kneecap). It is classified as a **hinge joint**, allowing for primarily flexion and extension movements. However, the knee also exhibits a degree of rotational motion, particularly when flexed. Kinematics refers to the motion of points, bodies, and systems without considering the forces involved.

Range of Motion (ROM)

The knee joint typically demonstrates the following ranges of motion:

- **Extension:** 0 degrees (full extension)
- **Flexion:** Approximately 135 to 150 degrees, depending on individual flexibility.
- **Internal Rotation:** Up to about 30 degrees when the knee is flexed.
- **External Rotation:** Up to about 20 degrees when the knee is flexed.

Movements of the Knee

1. Flexion and Extension

- **Flexion:** This movement decreases the angle between the femur and tibia. It occurs primarily during activities like sitting, squatting, and running.
 - **Kinematics:** During flexion, the femoral condyles roll and glide posteriorly on the tibia. The menisci also move posteriorly to accommodate the femoral movement.
 - **Function:** Flexion is essential for sitting, walking, squatting, and athletic performance.
- **Extension:** This movement increases the angle between the femur and tibia, returning the knee to a straight position.
 - **Kinematics:** In extension, the femoral condyles roll and glide anteriorly on the tibia. The menisci move forward during this process.
 - **Function:** Full extension is critical for activities such as standing, walking, and jumping.

2. Rotation (Internal and External)

- **Internal Rotation:** This occurs when the tibia rotates inward relative to the femur, typically when the knee is flexed.
 - **Kinematics:** Internal rotation of the knee occurs during activities like deceleration phases in running and cutting maneuvers in sports. It involves a combination of rolling, sliding, and spinning of the femoral condyles relative to the tibia.
 - **Function:** Internal rotation helps stabilize and adjust the knee position during dynamic movements.
- **External Rotation:** This occurs when the tibia rotates outward relative to the femur.
 - **Kinematics:** External rotation mainly occurs in a flexed knee. It is important for movements involving lateral shifts and pivoting.
 - **Function:** Allowance for external rotation permits better maneuverability and balance during sports and physical activities.

Kinematic Changes in Different Ranges of Motion

- **Early Flexion (0-45 degrees):**
 - The knee starts from extension and flexes towards 45 degrees. As the knee flexes, the contact area of the femoral condyles with the tibia increases, providing a stable platform for weight-bearing activities.
 - During the initial phase of flexion, the major movement is rolling of the femur on the tibia with minimal translation.
- **Middle Flexion (45-90 degrees):**
 - During this range, the kinematics involve significant rolling and less sliding. The menisci also help in accommodating the femoral motion.
 - The internal and external rotation becomes more apparent as the knee flexes beyond 45 degrees, making it critical for agility and dynamic stability during sports activities.
- **Deep Flexion (90-135 degrees):**

- Deep flexion occurs during squatting and sitting positions. The femur continues to roll and slide on the tibia, and the posteromedial and posterolateral corners of the knee become involved in stability.
- It is during this range that maximum rotation and dynamic stabilization occur. The geometrical architecture of the menisci also plays a vital role in distributing forces across the joint.

Clinical Relevance

Understanding kinematic movements and range of motion is essential for several reasons:

1. Assessment of Knee Injuries:

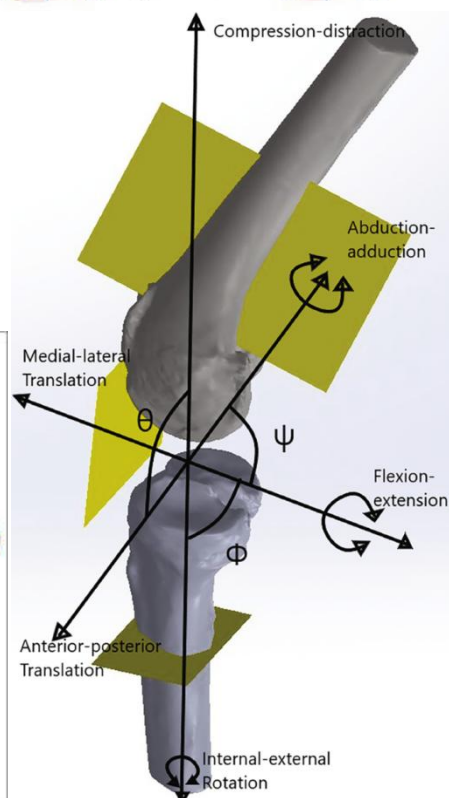
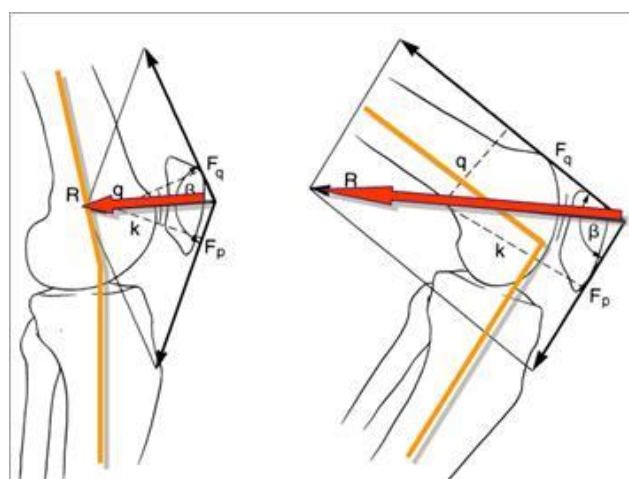
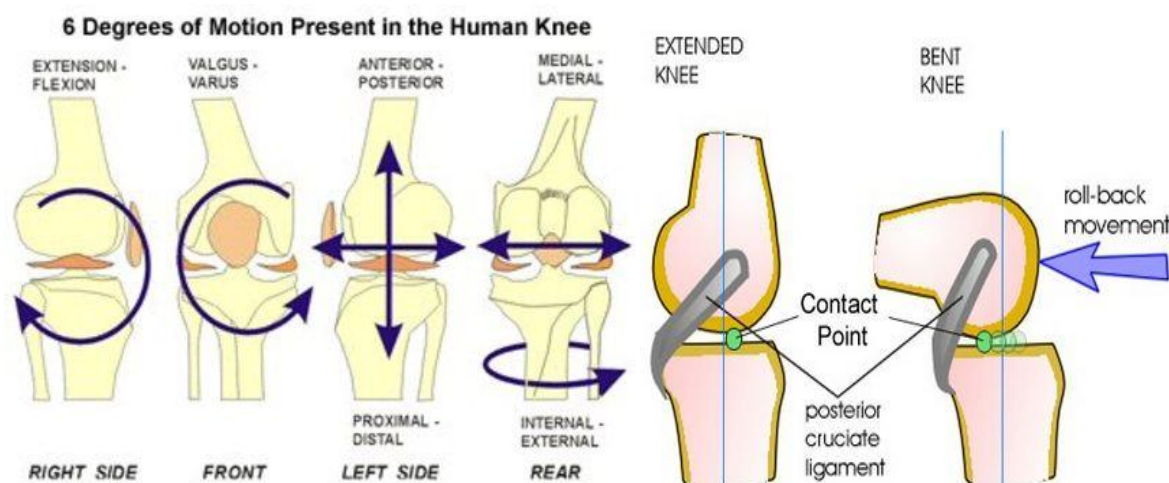
- Injuries such as ACL tears, meniscus injuries, and collateral ligament sprains can affect kinematic movements. Understanding normal kinematics helps clinicians evaluate functional impairments during physical examinations.

2. Rehabilitation Protocols:

- Rehabilitation protocols depend on restoring proper kinematics. Exercises are designed to improve range of motion, strength, and stability based on specific kinematic deficits observed in patients.

3. Surgical Techniques:

- Surgeons require an in-depth understanding of knee kinematics to optimize surgical repairs



2. Load Distribution and Joint Forces

The knee must effectively withstand considerable mechanical loads during activities such as running, jumping, and squatting. The menisci play a crucial role in distributing compressive forces across the articular surfaces—up to 50% of load can be absorbed by the menisci during weight-bearing activities. Varus and valgus alignment influences load distribution and can predispose individuals to degenerative changes or acute injuries.

3. Stability Mechanisms

Knee stability is derived from dynamic and static elements:

- **Static Stability:** Provided by the structural anatomy, including ligaments and menisci, which resist excessive translations and rotations.
- **Dynamic Stability:** Conferred by muscular contractions that stabilize the joint during various phases of movement, particularly through the co-contraction of agonist and antagonist muscles during activities involving sudden changes in direction.

4. Clinical Correlates and Common Pathologies

An extensive understanding of knee anatomy and mechanics supports the diagnosis and management of common knee injuries:

- **ACL Injuries:** Characterized by non-contact mechanisms, particularly in sports involving rapid changes in direction. The "Pivot Shift" test is invaluable in clinical assessment.
- **Meniscal Tears:** Often associated with traumatic twisting motions, whereby symptoms include joint line tenderness and a notable "locking" sensation.
- **Patellar Tendinitis:** A chronic overuse condition linked with excessive load on the patellar tendon, frequently encountered in athletes participating in jumping sports.

Conclusion

The knee joint's complex anatomy and biomechanics are fundamental to its function in mobility and weight-bearing activities. A thorough understanding of these principles is crucial for healthcare professionals dedicated to the prevention, diagnosis, and rehabilitation of knee injuries. As board candidates, integrating this knowledge will enhance patient care and improve clinical outcomes.

References

1. Bergfeld, J. A., & Kaplan, T. D. (2010). The anatomy of the knee. *Sports Medicine*, 40(3), 169-178. <https://doi.org/10.2165/11531360-000000000-00000>
2. LaPrade, R. F., & Burnett, Q. (2014). The anatomy of the anterior cruciate ligament in relation to injury. *The Journal of Bone & Joint Surgery*, 96(2), 101-110. <https://doi.org/10.2106/JBJS.L.01457>
3. Shelbourne, KD., & Nitz, P. (1990). The effect of the anterior cruciate ligament on knee joint stability. *The American Journal of Sports Medicine*, 18(2), 133-137. <https://doi.org/10.1177/036354659001800206>
4. Feller, J. A., & Webster, K. E. (2013). The role of the meniscus in knee joint biomechanics. *Knee Surgery, Sports Traumatology, Arthroscopy*, 21(1), 83-90. <https://doi.org/10.1007/s00167-012-2085-3>
5. Choi, W. S., & Lee, S. K. (2019). The biomechanics of the patellofemoral joint. *Journal of Clinical Medicine*, 8(6), 853. <https://doi.org/10.3390/jcm8060853>