Commentary 3

Structural and Functional Features of the Knee Joint and Their Relevance to Injury and Osteoarthritis

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Articulation

The knee joint is comprised of three bones: the femur, tibia, and patella. It is primarily a hinge joint for extension and flexion of the leg. Additional motions such as gliding between the femur and patella, rolling between the femur and tibia, and rotation between the femur and tibia also occur to a lesser degree. There are three compartments in the knee joint: medial femorotibial compartment between the medial condyle of the femur and the medial plateau of the tibia, lateral femorotibial compartment between the lateral condyle of the femur and the lateral plateau of the tibia, and femoropatellar compartment between the femoral trochlea and the patella. The articulating surfaces of the femur are curved in ball-shapes comparing with the flat but uneven articulating surfaces of the tibia and patellar [1]. The boney articulation of the knee is inherently unstable, and knee stability is primarily established by both static and dynamic stabilizers. Static stabilizers include the menisci, anterior cruciate ligament (ACL), posterior cruciate ligament (PCL), medial collateral ligament (MCL), and lateral collateral ligament (LCL). Dynamic stabilizers include the surrounding muscles of the quadriceps, hamstrings, gastrocnemius, and popliteus. Albeit the unstable feature of the knee joint, it bears a significant amount of body weight when one is in standing position. This body weight is not only endured by the joint itself, but also distributed to the associated structures. Healthy knee joint-associated structures including muscle strength help to

prevent knee joint injury and also play a role in preventing osteoarthritis (OA) [2-8].

Joint Capsule and Synovial Membrane

The knee joint has a fibrous joint capsule which thickens in some areas to become the intrinsic joint ligaments. The anterior fibrous joint capsule blends with the quadriceps tendon, the patella, and the patellar ligament. Posteriorly, the fibrous joint capsule has an opening that allows the tendon of the popliteus muscle, which originates from the lateral epicondyle of the femur, to exit the joint capsule and attach to the posterosuperior aspect of the tibia.

The synovial membrane lines the inside surface of the fibrous joint capsule in most area except the center region of the joint where the intercondylar fossa of the femur houses the anterior and posterior cruciate ligaments. Here, the synovial membrane leaves the posterior fibrous capsule and reflects anteriorly into the intercondylar fossa area forming the "infrapatellar synovial fold". This synovial fold excludes the cruciate ligaments and the infrapatellar fat pad from the joint cavity and almost sub-divides the knee joint cavity into medial and lateral halves (Figure 1). This unique anatomical feature provides convenience to approach the cruciate ligaments through the posterior fibrous joint capsule without breaking the synovial membrane and entering the synovial joint cavity [1]. The synovial membrane does not cover the following joint structures: articular cartilages on femur and tibia, the posterior surface of the patella, and the menisci.

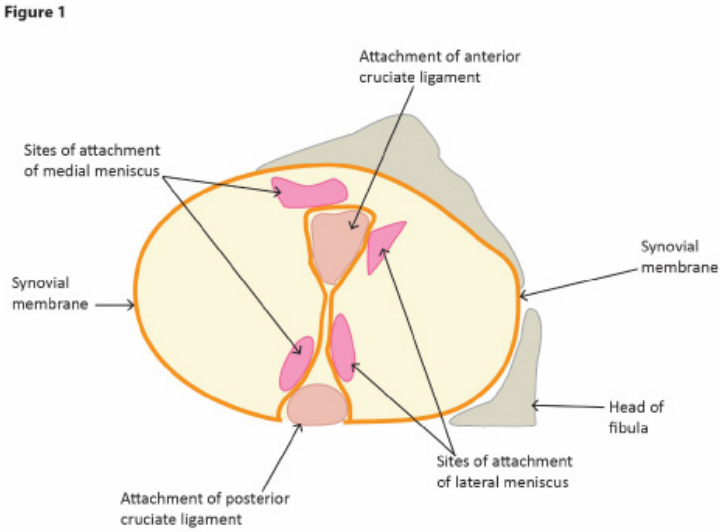

Figure 1: An illustration of the superior view of the tibia. The orange line indicates the passage of the synovial membrane, which leaves the fibrous capsule in the posterior aspect and reflects anteriorly to exclude the cruciate ligaments from the synovial joint cavity.

Bursae

There are 12 bursae around the knee joint with some of them communicating with the joint cavity [1]. There are 5 bursae anteriorly. The suprapatellar bursa is a large, deep bursa located above the patella and under the quadriceps tendon. It communicates with the joint cavity with its synovial membrane continues with that of the joint. There are 2 prepatellar bursae, the sub tendinous prepatellar bursa located between the patellar tendon and the patella and

the subcutaneous pre patellar bursa located between the skin and the patellar tendon. There are two bursae located below the patella, deep infrapatellar bursa between the patellar tendon and the tibia, subcutaneous infra patellar bursa between the skin and the patellar tendon.

Posteriorly, there are several bursae associated with muscle attachments such as the gastrocnemius bursae, the semi membranous bursa, and the popliteus bursa. These bursae are less clinically significant than those located in the anterior aspect of the knee.

Ligaments

The knee joint is strengthened by two groups of ligaments, external and internal [9]. There are five external knee joint ligaments and most of them are part of the fibrous joint capsule (intrinsic). The patellar ligament is the distal portion of the quadriceps tendon between patella and tibial tuberosity. On each side of the patellar ligament, extending from the aponeurosis of the vastus medialis and vastus lateralis, are the medial and lateral "patellar retinacula", which help to maintain the position of the patella. Varus and valgus stresses on the knee joint are primarily resisted by collateral ligaments on the medial and lateral aspects of the knee. The medial collateral ligament (MCL) is comprised of superficial and deep components. The superficial MCL fibers are a primary restraint to valgus forces and the deep MCL fibers are directly connected to the medial meniscus. Thus, MCL injuries may be associated with medial meniscus tears, and the medial meniscus

is inherently less mobile due to its additional attachments. The lateral collateral ligament (LCL) is an extra-articular cord-like strong ligament. It is separated from the joint capsule by the tendon of the popliteus muscle, and is not connected to the lateral meniscus. Distally, it attaches to the fibular head splitting the tendon of the biceps femoris muscle. The oblique and arcuate popliteal ligaments are part of the posterior fibrous joint capsule.

The internal or intra-articular ligaments include the cruciate ligaments and the meniscal ligaments. The cruciate ligaments are located inside the fibrous joint capsule in the intercondylar fossa of the femur but outside the synovial membrane joint cavity. They cross each other and play the most important role in maintaining the contacts between the femur and the tibia when the knee is flexed. At least one of the cruciate ligaments is maintained in tension no matter how the knee joint is positioned [10].

The anterior cruciate ligament (ACL) arises from the anterior intercondylar area of the tibia posterior to the attachment of the medial meniscus, travels posterolaterally inside the intercondylar fossa of the femur, crosses anterior to the PCL and attaches to the medial surface of the lateral condyle of the femur.The ACL prevents the posterior movement of the femur from the tibial plateau when the knee is extended. When the knee joint is flexed, the ACL prevents the anterior movement of the tibia from the femur [11,12].

The posterior cruciate ligament (PCL) arises from the posterior intercondylar area of the tibia, travels anteromedially, crosses the ACL on the medial side, and attaches to the lateral surface of the medial condyle of the femur. It is stronger than the ACL. The primary function of the PCL is to prevent posterior tibial translation.

Because of the anatomical relationship between the two cruciate ligaments, the medial rotation of the tibia is limited to about 10° when the knee is flexed. This is because the ACL is pushed against the PCL and the latter blocks the ACL from moving medially during the rotation. Under the same situation but reversing direction, the lateral rotation of the tibia is about 60° because the two cruciate ligaments are moving away from each other.

Menisci

The medial and lateral menisci are crescent-shaped fibrocartilage structures located on the articular surface of the tibial plateau. They are thicker at the external margins and thin in the central edges, thereby deepening the surface of the tibial articular surface. They attach to the intercondylar area of the tibia centrally and to the fibrous joint capsule at peripheral. Other than these attachments, the menisci are free and mobile along with the knee joint movement. The medial meniscus is C-shaped, attaches to the medial collateral ligament and is less mobile. The lateral meniscus is almost O-shaped and has more mobility.

When the knee joint undergoes extension or flexion, the contact area between the femur and the tibia moves anteriorly or posteriorly. As a result, the menisci, particularly the lateral meniscus, moves anteriorly during extension, and posteriorly during flexion.

Blood Supply and Nerve Innervation

The blood supply to the knee joint is from the genicular arteries branched from the popliteal artery, which travels posteriorly to the knee joint capsule. There are usually 4-6 genicular branches distributed on medial and lateral side of the joint and they form extensive anastomoses around the joint. In addition to provide blood supply to the knee joint, these genicular branches and their anastomoses may provide collateral blood circulation when the knee joint is completely flexed which causes the popliteal artery to be bent nearly 180 degrees. The nerve innervation of the knee joint follows Hilton's law (the nerve that innervates the muscles moving the joint also innervates the joint) by femoral, obturator, and sciatic nerves.

Clinical Relevance

The prevalence of OA in specific joints is closely related to their structural and functional features. The knee joint is the most vulnerable joint for injury due to its structural instability, weight bearing location, and involvement in pivoting sports. Structures that are most frequently injured are the ACL, MCL, and the medial meniscus. In some cases, injuries involve more than one element. Be-

cause of its weight bearing feature, the knee joint is also the most affected joint for OA [3-5,13-18]. In addition, the incidence of traumatic damage to the articular cartilage is higher in the knee joint than in other synovial joints. Adult articular cartilage is an avascular, aneural, and alymphatic tissue with little capacity for self-repair after injuries. Articular cartilage remains one of the most difficult tissues to heal.Even with the best current care of joint injuries, such as anatomic reduction and rigid fixation of intra-articular fractures and reconstruction of ruptured ACL with successful restoration of joint biomechanics, the risk of post-traumatic OA after joint injuries ranges from 20% to more than 50% [19,20].

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