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Anatomy and Biomechanics of Patellar Instability

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Patellar stability is governed by unique anatomy and biomechanics, which greatly influence treatment strategies in the setting of instability. The patella is stabilized by the following 4 factors: lower extremity alignment, articular geometry, dynamic muscular stabilizers, and passive ligamentous stabilizers. Lower extremity malalignment results in increased lateral forces on the patella contributing to instability. Lower extremity malalignment can also result dynamically from poor neuromuscular control. The lateral trochlear geometry resists lateral translation and when hypoplastic contributes to instability. The primary muscular stabilizer of the patella is the vastus medialis obliquus. It inserts on the patella at an oblique angle relative to the anatomic axis of the femur, and stabilizes the patella with medial and posterior forces. The medial patellofemoral ligament is the primary ligamentous stabilizer of the patella and guides it into the trochlear groove during early knee flexion. The medial patellofemoral ligament is injured in nearly all cases of patellofemoral dislocation and is considered the essential lesion in recurrent patellofemoral instability. The anatomy and biomechanics of patellar instability provide a framework to properly evaluate and treat patellar instability.
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Understanding the functional anatomy and biomechanics of the patellofemoral joint is crucial for the evaluation and treatment of patellar instability. The patella articulates with the trochlea and is a fulcrum for the quadriceps during leg extension. Patellar instability is characterized by symptomatic subluxation or dislocation of the patella relative to the trochlea. For first-time dislocators treated nonoperatively, 50% will have long-term problems related to their dislocations.[1] During lower extremity movement and activity, the following 4 factors stabilize the patella: limb alignment, articular geometry, dynamic muscle forces, and static ligament stabilizers.

Pathomechanics of Primary Patellar Dislocations

A combination of circumstances occurs during a primary patellar dislocation. Typically, the athlete or individual is in a movement involving knee flexion. The femur is relatively internally rotated and adducted, and the tibia is externally rotated and abducted (Fig. 1). This position has been termed as functional valgus. This results in high-magnitude eccentric quadriceps contraction, overpowering the stabilizing effects of the vastus medialis obliquus (VMO). Patellar stability then depends on articular geometry and the medial patellofemoral ligament (MPFL). If the lateral force overwhelms the MPFL, the patella will fail to engage the trochlea. With increasing knee flexion, the patellar further deviates laterally and the MPFL tears along with the VMO as frank dislocation occurs. Additional injury to the lateral trochlea and medial patellar chondral surfaces can also take place. Due to differences in patient anatomy, multiple factors contribute in varying degrees to the primary dislocation mechanism among individuals.

Dynamic and Positional Lower Extremity Alignment

Limb alignment is a critical component of patellofemoral stability. As it relates to the patellofemoral joint, it is defined by the origins and insertions of the quadriceps muscles and the patellar tendon. These lines are not collinear; therefore, a resultant lateral force exists at the patellofemoral joint. Re-

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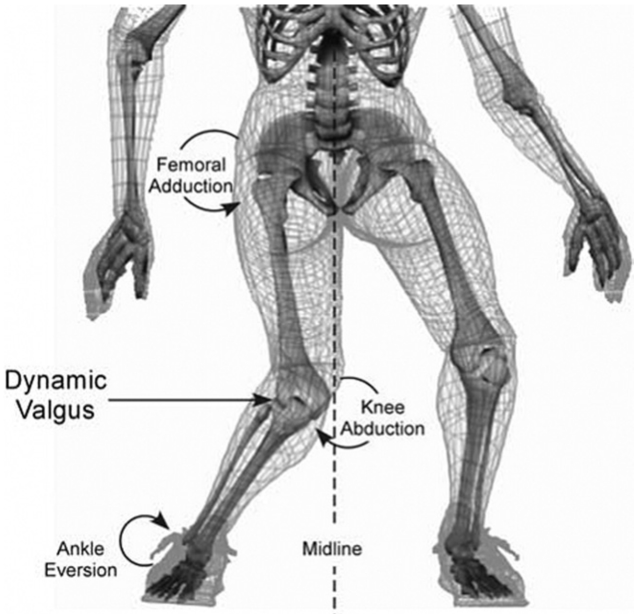

Figure 1 Dynamic valgus is defined as the position or motion where the distal femur moves toward the midline and the distal tibia away from the midline of the body. (Reprinted with permission from Hewitt TE, et al: Biomechanical measures of neuromuscular control and valgus loading of the knee predict anterior cruciate ligament injury risk in female athletes: a prospective study. Am J Sports Med 33:492-501, 2005.)

cently, lower extremity alignment that changes dynamically has been investigated for anterior cruciate ligament (ACL) injury and patellofemoral pain syndrome (PFPS). Similarities exist in patients at risk for ACL injuries, patellofemoral pain, and patellar instability, including a higher incidence in young female athletes.[2] Many of these patients demonstrate femoral anteversion. Research indicates that femoral anteversion places the ACL and patellofemoral joint at risk for injury by reducing hip external rotator length, abductor moment arm, and neuromuscular control, thereby leading to functional valgus.[3-7] The dynamic alignment of the lower extremity is in part governed by hip and core strength. Figure 1 demonstrates the valgus effect of hip adduction and internal rotation with tibial abduction and external rotation. A study by Ireland et al demonstrated diminished hip abduction and external rotation strength in patients with PFPS.[8] Consequently, hip strengthening can decrease femoral internal rotation and reduce patellofemoral pain.[9] As mentioned, the pathologic lower extremity alignment that results in PFPS is similar to patellar instability. While it is reasonable to extrapolate ACL and PFPS studies to patellofemoral instability, more research is necessary to determine the contribution of functional and positional malalignment to patellar instability.

Quantifying Lower Extremity Alignment

Lower extremity alignment can be measured on physical examination and with imaging studies. The quadriceps angle (Q-angle) is measured in extension and is formed by the intersection of lines parallel to the quadriceps vector and patellar tendon. By convention, the quadriceps vector is measured from the anterior superior iliac spine to the center of the patella and the vector of the patellar tendon is measured from the center of the patella to the tibial tubercle (Fig. 2). Therefore, the Q-angle offers a rough estimate of the lateral force of the quadriceps on the patella. After dislocation, the Q-angle often decreases because of a new lateral resting position of the patella. One study confirmed that a small Q-angle is associated with patients with chronic, recurrent dislocations.[10]

The medial-lateral position of the patella relative to the tibial tubercle is associated with malalignment. This measurement, referred to as the tibial tubercle to trochlear groove (TT-TG) distance, is typically measured with computed tomography or magnetic resonance imaging.[11] Studies have demonstrated that a distance of 20 mm or more strongly correlates with laterally instability.[12,13] Medial correction of the tibial tubercle with an osteotomy procedure decreases the TT-TG distance, and Q-angle, resulting in decreased patellar instability.[14] Although the TT-TG distance is an important indicator of current or future instability, its use is limited in instability due to lateral condylar hypoplasia or poor neuromuscular control.

Articular Geometry of the Patellofemoral Joint

The articular geometry of the patellofemoral joint becomes important after the first 20°-30° of knee flexion. This is because the patella does not engage the trochlea until 20° of knee flexion. From full extension to 20°, the patella moves 5 mm medially due to the static restraint of the MPFL and

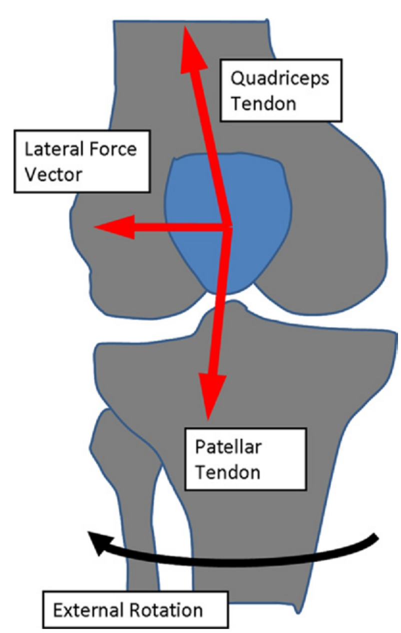

Figure 2 Illustration of quadriceps angle (Q-angle) demonstrating a correlation between external tibial rotation and increasing Q-angle.