COMPUTATIONAL QUANTIFICATION OF THE INFLUENCE OF THE Q-ANGLE ON THE PATELLOFEMORAL CONTACT PRESSURE DISTRIBUTION

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INTRODUCTION

Patellar maltracking is often attributed to an excessive Q-angle. The Q-angle is defined as the angle between a line from the patella center to the tibial tubercle and a second line from the patella center to the anterior superior iliac spine when the knee is fully extended. The lateral component of the resultant force applied by the quadriceps and patella tendon to the patella increases as the Q-angle increases. For patients with anterior knee pain due to maltracking, surgery may be performed to reduce the Q-angle.

Dynamic simulation of knee flexion is typically performed to characterize patella tracking. The relationship between patella tracking and the patellofemoral contact pressure distribution is not clear, however. A computational model has been developed to quantify the patellofemoral contact pressure distribution based on knee kinematics obtained through dynamic knee simulation. The model has been used to characterize the influence of the Q-angle on the pressure within the patellofemoral joint.

METHODS

Six cadaver knees were tested on a dynamic knee simulator to determine the influence of the Q-angle on patellofemoral kinematics (Mizuno et al., 2001). The Q-angle was increased and decreased by shifting the simulated quadriceps insertion point laterally and medially, respectively. The average Q-angles were $4^\circ \pm 3^\circ$, $11^\circ \pm 5^\circ$, and $20^\circ \pm 4^\circ$ for the decreased, normal and increased Q-angle cases, respectively.

A graphic model of the Visible Human Male knee (National Library of Medicine) was positioned to reproduce the alignment of a cadaver knee within the simulator and the local coordinate systems used to describe knee kinematics. The patella was shifted in the medial-lateral direction and rotated based on the average kinematic data. The rotated and shifted patella was aligned with a parallel surface within the trochlea at each angle of knee flexion (Fig. 1).

A surface midway between the patella and the femur was created to represent the potential area of cartilage contact between the two bones. A layer of compressive springs was modeled on the contact surface. Rows of tensile springs were modeled between the medial and lateral edges of the patella and the femur to represent the joint capsule. The joint capsule was assumed to be ten times stiffer than the cartilage.

A static analysis was performed at individual flexion angles to quantify the joint pressure distribution. With the femur fixed in place, a resultant force and moment were applied to the patella centroid. The resultant force and moment were calculated from the average experimental quadriceps load acting at the proximal patella and a calculated patella tendon load acting at the distal patella (Huberti et al., 1984). The deformation of each spring in response to the applied load was quantified using the discrete element analysis technique. This technique minimizes the potential energy within the springs based on Castigliano's theorem. The deformation of each spring, which determines the contact pressure distribution, was quantified at 40º and 80º of flexion for all three Q-angles.

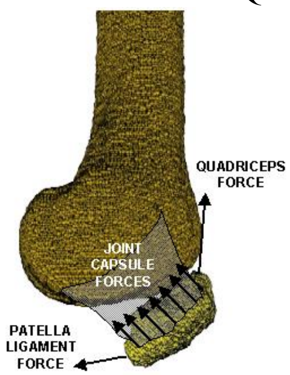

Figure 1: The model of the patellofemoral joint at 80º of flexion.

RESULTS AND DISCUSSION

Increasing the Q-angle from the normal value increased the average patellar lateral shift by more than 5 mm, increased the average medial tilt by approximately 4.5º, and increased the medial rotation by more than 3º throughout flexion. Decreasing the Q-angle had little influence on the average shift or rotation, but decreased the medial tilt by approximately 2.5º throughout flexion.

For the normal Q-angle, the contact pressure was concentrated at the distal patella at 40º of flexion. At 80º of flexion, the contact area was more proximal, with a predominately lateral pressure concentration. The peak pressure was approximately 0.6 MPa for both flexion angles.

At 40º of flexion, increasing the Q-angle decreased the contact area and approximately doubled the peak contact pressure on both the lateral and medial condyles. Decreasing the Q-angle increased the contact area and reduced the peak contact pressure by 0.1 MPa. At 80º of flexion, decreasing the Q-angle increased the medial contact pressure. Increasing the Q-angle shifted the lateral concentration in contact pressure proximally (Fig. 2). .

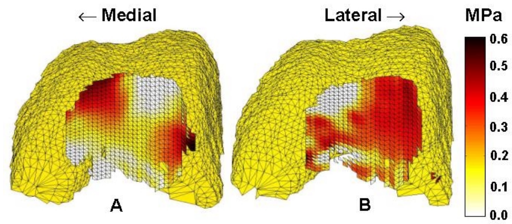

Figure 2: The contact pressure distribution superimposed over the femur surface at 80º of flexion for a decreased (A) and increased (B) Q-angle.

DISCUSSION

Varying the Q-angle altered the region of contact within the patellofemoral joint. In general, the lateral contact pressure increased as the Q-angle increased. Because the patella tilted in the opposite direction of the shift as the patella rode up each condyle, increasing and decreasing the Q-angle did not completely unload the medial and lateral cartilage, respectively. The patellofemoral model developed for this study is a valuable tool to improve the clinical relevance of the conclusions that can be drawn from knee simulation studies.

REFERENCES

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