REDUCING THE LATERAL FORCE ACTING ON THE PATELLA DOES NOT NECESSARILY REDUCE THE PEAK CONTACT PRESSURE

INTRODUCTION

Lateral patellar instability and anterior knee pain are often attributed to a large Q-angle. The lateral component of the resultant force applied to the patella by the quadriceps muscle group and the patella tendon increases as the Q-angle increases. An increase in the lateral force is believed to increase the pressure applied to the lateral cartilage. Surgical and non-surgical treatment methods are used to reduce the lateral force acting on the patella. The influence of these treatment methods on the pressure applied to the patellofemoral cartilage is not well understood, however. For this study, computational simulation was used to evaluate how two treatment methods used to reduce the lateral force acting on the patella influence the patellofemoral contact pressure distribution. The two treatments studied were surgical medialization of the tubial tunnel to reduce the Q-angle and vastus medialis strengthening to increase the medial force acting on the patella.

METHODS

A surface model of a knee was created using CT data from the Visible Human Male (National Library of Medicine). Origin, insertion and wrapping points were identified for the vastus medialis, vastus intermedius, vastus lateralis, rectus femoris, and patella tendon. The knee was placed in full extension, and the tibia was flexed about the femur, up to a maximum of 90°, to model a dual limb knee squat. The patella was flexed, using a flexion lag based on experimental data [1], and aligned with the femur by aligning the posterior patella with a parallel surface within the trochlea. The total force acting through the quadriceps was divided among the four muscles [2]. The forces applied by each of the muscles were calculated to provide knee moments typical for a dual limb knee squat [3]. The patella tendon force was determined based on the quadriceps force and the flexion angle [4]. Surgically decreasing the Q-angle (from 25° to 10°, in 5° increments) was modeled by shifting the patella tendon attachment point on the tibia medially. Vastus medialis strengthening was modeled by increasing the percentage of the quadriceps force applied by the vastus medialis by 50%, while keeping the same ratio of forces for the other three muscles. Vastus medialis strengthening was modeled at all four Q-angles.

To calculate the contact pressure distribution, a surface was created midway between the patella and femur to represent the potential area of cartilage contact. The cartilage was represented by a layer of approximately 3000 compressive springs on the surface. Tensile springs were modeled between the medial and lateral edges of the patella and the femur to represent the joint capsule. The stiffness per unit area was assumed to be ten times larger for the joint capsule springs than for the cartilage springs. The quadriceps force and the patella tendon force were used to calculate an equivalent force and moment acting at the centroid of the patella. The patellofemoral pressure distribution was quantified by minimizing the total potential energy within the system of springs. This computational technique has previously been shown to accurately predict how variations in the orientation and magnitude of the quadriceps force influence the pressure distribution [5].

RESULTS

The lateral component of the force acting on the patella (lateral subluxation force), the total force applied to the lateral cartilage (total lateral force) and the area of cartilage subjected to more than 4 MPa of pressure all increased during flexion (Fig. 1). There was relatively little variation in the peak contact pressure from 70° to 90° of flexion (Fig. 2). The peak lateral contact pressure was an average of 20% larger than the peak medial contact pressure from 70° to 90° of flexion.

Decreasing the Q-angle decreased the lateral force but not the lateral peak pressure. At 90° of flexion, the lateral subluxation force, the total lateral force, and the area of cartilage subjected to more than 4 MPa of pressure decreased by 10%, 5%, and 13%, respectively, as the Q-angle decreased from 25° to 10°. The maximum lateral pressure did not decrease with the Q-angle (Fig. 3). Medializing the tubial tunnel increased the moment acting to rotate the distal pole of the patella medially. This increase in the medial rotation moment created a concentration in lateral pressure proximally, offsetting the decrease in peak pressure due to the lateral force decrease.

Increasing the vastus medialis force decreased the lateral force, but increased the peak pressure. At 90° of flexion, the lateral subluxation force and the total lateral force decreased by an average of 4% and 6%, respectively, for the four Q-angles. The peak pressure increased by an average of 4% for the four Q-angles. The peak pressure increased despite the decrease in the lateral force due to the increased medial rotation moment and the increased medial tilt moment caused by the increased vastus medialis force.

DISCUSSION

The computational simulation indicated that both vastus medialis strengthening and surgical medialization of the tubial tunnel reduced the lateral subluxation force and the total lateral force, as expected. The peak cartilage pressure did not decrease, however, due to the moments acting on the patella. Both treatments increased the medial rotation moment acting on the patella, which created a lateral stress concentration proximally. Even though this model incorporates the anatomy from a single knee, the results indicate that altered moments can offset decreases in the peak pressure produced by reducing the lateral force. Because the influence of the moments applied to the patella on the contact pressure distribution are not intuitively obvious, computational simulation can play an important role in evaluating treatments used for patients with patellofemoral pain and instability.

REFERENCES

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