The Effect of Patellar Height on Patellofemoral Contact Pressure and Area after Medial Patellofemoral Ligament Reconstruction: A Finite Element Analysis

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Introduction: Patellar stability is maintained by soft tissue restraints, the dynamic action of the quadriceps, and bony architecture. Focusing on bony anatomy, the patella height has a role in patellar stability. Patella alta (or high riding patella) is often associated with recurrent dislocation since the patella enters the trochlear groove in deeper knee flexion [1,2]. There have been several studies that focused on techniques to measure the patellar height and what quantifies as patella alta and baja (or low riding patella). However, few studies have addressed how the differences in patella height affect patellofemoral biomechanics, specifically the patellar contact area and pressure. Therefore, the goal of this study is to provide insight into the affect patella height has on patellofemoral biomechanics, using a finite element (FE) analysis. The study will also address medial patellofemoral ligament (MPFL) reconstruction and the effect on biomechanics with respect to patellar height.

Methods: A previously validated FE knee model [3] was modified to gain a better understanding of patellar height biomechanics with regard to MPFL reconstruction. The validated model depicts a ‘normal’ knee with a Caton-Deschamps Index [4] ratio of 1.0. The patella height was adjusted to study patella alta and baja ratios of 1.4, 1.2, and 0.8 (Figure 1). To do this, the ‘normal’ patella was translated a given distance to achieve each patella height ratio. The new nodal coordinates for the entire model were output and used as the new starting coordinates for the patella alta/baja models. For each patellar height, the knee was positioned at 30° of flexion, with the femur fixed in all directions and the tibia free to translate and rotate about the anterior-posterior axis (z-axis), allowing anterior-posterior translation and varus-valgus rotation. The patella was also free to rotate and displace in all directions. The quadriceps was physiologically loaded to 178 N, along the three main muscle groups. With the quadriceps loaded, the tibia and femur were fixed in all directions and the patella was displaced laterally 10 mm. The resultant patellar restraining force, contact pressure, and contact area were compared for the intact MPFL and reconstructed MPFL. Analyses were completed using Abaqus/Standard (Version 6.12-1; Dassault Systèmes Simulia, Providence, RI). In addition to the anatomical attachment of the MPFL, the models were also modified to study various attachment sites of the MPFL (anterior, proximal, and distal on the femur) for each patella height model, resulting in 32 different scenarios.

Results: For patella alta (Ratio 1.2 and 1.4), the contact area decreased for the intact MPFL and reconstructed anatomical femoral MPFL insertion (Figure 2) as compared to the ‘normal’ knee (Ratio 1.0); the contact was between the patella bone and femoral cartilage. Whereas for patella baja (Ratio 0.8) the contact area increased and the contact was between patella cartilage and femoral cartilage. For the ‘normal’ knee (Ratio 1.0), the contact was between the patella cartilage and femoral cartilage for the reconstructed anatomical MPFL insertion, and between the femoral cartilage and patella cartilage as well as femoral cartilage and patella bone for the intact MPFL, with the majority being cartilage on
cartilage contact. The same trends were seen when the femoral MPFL insertion site was modified anterior, proximal, or distal to the anatomical attachment site. The maximum contact pressure decreased for patella baja (Ratio 0.8), and increased for patella alta (Ratios 1.2 and 1.4) after MPFL reconstruction. This correlates to the changes in contact area.

**Discussion:** This study provides insight to researchers and clinicians on the effect of patella height on patellofemoral biomechanics. The models show that contact area decreased as patellar height increases, which is the same trend previously reported by Ward et al. [5] Also, the contact anatomy changed with patella height, differing between cartilage-cartilage or cartilage-bone contact. The patella was in the trochlear groove for patella baja, allowing for cartilage-cartilage contact and a larger contact area. However, for the patella alta cases, the contact occurred between femoral cartilage and patella bone, since the patella was higher up in the trochlear groove, or out of the grove. There could be greater wear for patella alta cases, since contact occurred between bone and cartilage, thus increasing friction.

Like other finite elements studies, there are limitations to the model including boundary conditions and simplified material properties. However, this study does provide needed insight into the biomechanics of the patellofemoral joint with regards to patella height. Future work will address different flexion angles and incorporating MPFL reconstruction pretension.

**Significance:** This study examines the effect of patella height on patellofemoral contact stress, contact pressure, and restraining forces after medial patellofemoral ligament (MPFL) reconstruction.

![Figure 1. The finite element models for each patellar height.](image)
Figure 2. The contact pressure for the different patellar heights for the intact and anatomical reconstructed MPFL after 10mm lateral patella displacement.