Validation of finite element model prediction of patellofemoral joint mechanics

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Purpose: The purpose of this study was to compare measured patellofemoral contact pressure and area during knee flexion between cadaver measurements and specimen-specific finite element models of the knee joint.

Materials & Methods: Three cadaveric lower limbs were tested in a custom-built apparatus. The ankle was potted, soft tissues dissected to isolate bone, cartilage, patellar tendon, and quadriceps tendon. A Tekscan sensor was sutured to the femoral trochlea to measure contact pressure. A 70 N load was applied to three quadriceps tendons. Contact pressures and area of contact were collected at 0, 15, 30, 45, and 60 degrees of knee flexion. 3D models of the cadaveric specimens were segmented (Mimics, Materialize, NV), along with femur and patella cartilage. Bones were modeled as rigid bodies, and cartilage as linear elastic (E = 14MPa, ν = 0.45) [1]. Patellar and quadriceps tendons were modeled with hyperelastic material properties. Boundary conditions were applied to the model to replicate the cadaver tests. Finite element predicted contact pressure and area were compared to cadaveric measurements.

Results: Areas of contact predicted with the finite element models qualitatively matched the cadaver experiments. Contact pressure differences were quantified by normalizing the average contact pressure of the finite element models to the experiments (Fig. 2). Contact pressures had excellent agreement between the experiment and model for all 3 cadaveric specimens.

Conclusion: The finite element model had reasonable agreement with cadaveric specimens for a range of flexion angles. These results provide confidence that the model can reliably replicate in-vitro patellofemoral contact mechanics and can serve as a foundation for future investigations into predictive modeling.

Significance/Clinical Relevance: A validated finite element model of the patellofemoral joint could be used to predict the effect of surgical procedures on changes in patellofemoral contact mechanics and determine any correlations with patient-specific factors.

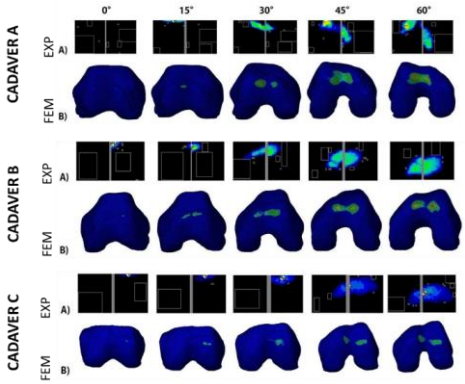

Figure 1. Contact pressures for the 3 cadaver experiments and finite element models show that area of contact is qualitatively similar.

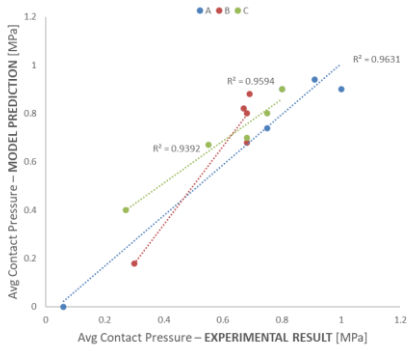

Figure 2. Correlation between model predicted contact pressure (y-axis) and experimental results (x-axis). A perfect correlation would have R2=1 for all specimens (A, B, and C), with slope=1 and intercept = 0.