Detailed Weight Bearing Patellofemoral Contact Mechanics for Four Activities of Daily Living

Michael LaCour PhD[1], Seth Coomer MS[1], Richard Komistek PhD[1]
[1]University of Tennessee, Knoxville, TN
mlacour@utk.du

Disclosures: Michael LaCour (N), Seth Coomer (N), Richard Komistek (N)

INTRODUCTION: The femorotibial and patellofemoral joints are key aspects that contribute to successful total knee arthroplasty (TKA). Orthopaedic research more commonly focuses on the femorotibial compartment and its mechanics, often leaving the patellofemoral joint as an afterthought. Consequently, less information is available to surgeons and researchers regarding weight-bearing patellofemoral kinematics and contact mechanics. The objective of this study is to use three-dimensional modeling to analyze detailed mechanics of the patellofemoral joint during four common activities of daily living.

METHODS: A previously validated forward solution model of the knee was used to evaluate patellofemoral mechanics for a single subject implanted with an Attune® CR TKA construct with Medialized Dome patella (DePuy Synthes) performing a chair rise, a step-up, a step-down, and a high flexion deep knee bend activity. The model uses a contact detection algorithm, which also allows for predictions of contact area, to evaluate the contact between articulating surfaces, and a muscle-controlled algorithm to drive the different activities. Specific parameters of interest include patellofemoral contact forces, patellofemoral contact area, and patellofemoral contact stress, all compared to previously evaluated femorotibial mechanics.

RESULTS SECTION: There are three interesting trends that can be observed when comparing patellofemoral mechanics to femorotibial mechanics. First, the patellofemoral contact forces were 1 - 2 xBW less than the femorotibial contact forces for all activities except chair rise (Figure 1). For all four activities, the maximum femorotibial contact force was approximately 3.5 xBW. Conversely, the maximum patellofemoral contact force ranged between 1.5 xBW and 3.5 xBW depending on activity, with lower flexion activities logically producing lower patellofemoral forces. Second, patellofemoral contact area was lesser than the femorotibial contact areas for all four activities (Figure 2), likely due to both the size and the shape of the joint. The changing curvature of the femoral condyles tended to yield a consistent decrease in femorotibial contact area with increasing flexion, while the trochlear groove shape led to an increase in patellofemoral contact area through mid-flexion as the patella became more seated within the trochlear groove followed by a decrease in contact area in deeper flexion as patellar contact became split between the medial and lateral aspects of the trochlea. Finally, the corresponding contact stresses of the two joints had varied relationships (Figure 3). Specifically, in higher flexion activities such as a chair rise and a deep knee bend, the patellofemoral contact stresses were larger than those of the femorotibial joint. However, for lower flexion activities where the bulk of the body's weight is transferred directly into compression of the tibial/bearing component, the contact stresses were more similar between the two joints.

DISCUSSION: The results determined by this model correlate well with previous experimental and theoretical analyses showing peak patellofemoral contact areas within the range of 150 – 600 mm^2 and peak patellofemoral stresses within the range of 15 – 30 MPa [1] [2] [3] for lunge and flexion-based activities. Given the function of the patella in deep flexion, it is unsurprising that the overall contact mechanics were dependent on activity. In lower flexion activities, the bulk of the bodyweight is placed directly inferiorly on the femorotibial joint, and therefore the patellofemoral forces and stresses are encouragingly lower. However, in higher flexion activities, the patellofemoral joint experiences larger contact forces due to the large amounts of quadriceps musculature wrapping that must occur. Combined with a decrease in contact area in late flexion, it is clear that the patellofemoral joint has the potential of experiencing larger amounts of overall contact stress, occasionally larger than the femoral condyles. With this in mind, continuing to focus on the patellofemoral joint during the design and implementation phase of TKA will help further improve implant longevity and postoperative outcomes.

SIGNIFICANCE/CLINICAL RELEVANCE: The patellofemoral joint is largely an afterthought during TKA procedures, but this study shows that the patellofemoral joint can experience larger contact stresses than the femorotibial joint during deep flexion, reiterating the importance of proper patella button size selection and placement.

REFERENCES

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[2] Emodi GJ, et al. "Posterior Cruciate Ligament Function Following Total Knee Arthroplasty." Iowa Orthop J. 1999; 19: 82–92.
[3] Luyckx T, et al. "Is there a biomechanical explanation for anterior knee pain in patients with patella alta?" The Journal of Bone & Joint Surgery British Volume. 2009 Mar, 91-B(3): 344-350.

FIGURES:

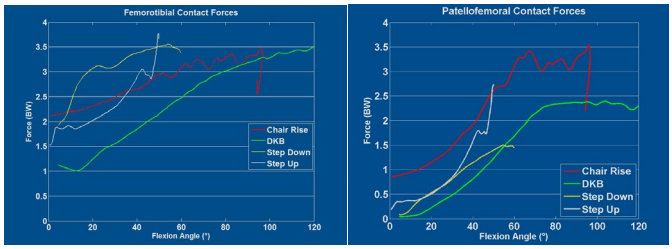

Figure 1: Femorotibial and Patellofemoral Contact Forces.

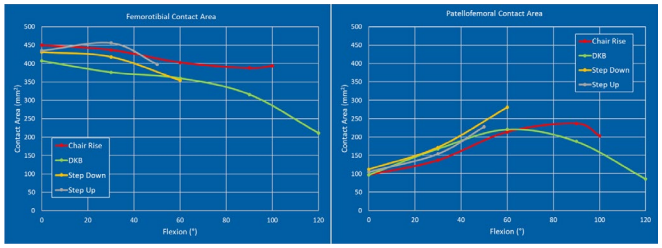

Figure 2: Femorotibial and Patellofemoral Contact Area.

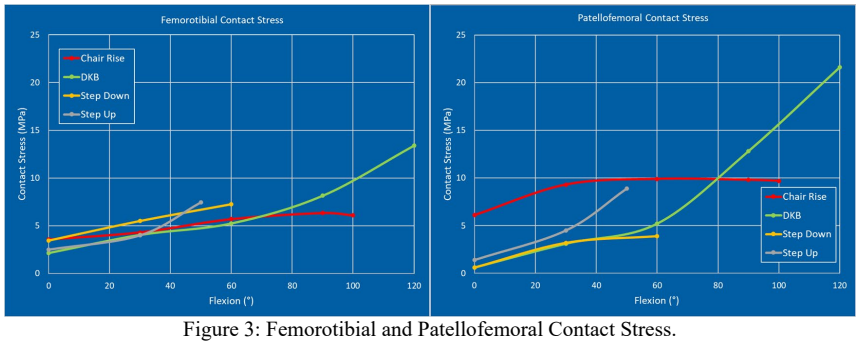

Figure 3: Femorotibial and Patellofemoral Contact Stress.