Analyzing the Effect of Posterior Tibial Tilt in Medial UKA on Kinematics and Kinetics Using Mathematical Modeling

Bradley A Meccia[1], Seth Coomer, Michael LaCour, Richard D Komistek[2]
[1]Univ of TN, [2]The University of Tennessee

INTRODUCTION: When performing unilateral knee arthroplasty (UKA), the posterior tilt of the tibial component is commonly matched to the anatomical slope of the medial plateau, creating a postoperative geometry comparable to the native geometry. This is believed to produce native-like kinematics. Therefore, this study will analyze the effect of posterior tibial tilt (PTT) of the medial tibial component in UKA using mathematical modeling.

METHODS: A previously developed and validated mathematical model of the human knee was expanded from only including total knee arthroplasty (TKA) to include UKA. In the mathematical model, a subject underwent virtual UKA reproducing this subject's native PTT of 8°. The virtual surgery was redone with PTT values ranging from 0° to 14° in 2° increments (reported PTTs ranges from 0° to 15°). For each alignment, a simulated deep knee bend was analyzed.

RESULTS: Changing the PTT had minimal effect on the resulting kinematics. The medial condyle anteroposterior (MAP) position started at approximately -5 mm (negative numbers denote posterior positioning) and translated posteriorly to approximately -20 mm in mid flexion. In deep flexion, MAP translated anteriorly to -15 mm for all simulations (Figure 1). The lateral condyle anteroposterior (LAP) position started at approximately -7 mm and rolled posteriorly to approximately -22 mm in mid flexion before sliding anteriorly to -15 mm at maximum flexion. The LAP and MAP had approximately 2 mm of variation with the different PTT with more tilt resulting in more posterior positioning. The external rotation angles at full extension ranged from 0.1° to -3.3° (negative numbers indicate internal rotation) with less PTT resulting in more externally rotated positions (Figure 2). The external rotation at maximum flexion was 7.0° for all PTT. Peak quadriceps and patella ligament forces were similar for all simulations with maximum forces of approximately 3.7 times body weight (xBW) and 2.0 xBW, respectively (Figure 3). The peak tibiofemoral forces ranged from 3.5 xBW to 4.0 xBW with more PTT resulting in less force (Figure 4). Lateral collateral ligament forces peaked at 0.45 xBW for all simulations. Peak medial collateral ligament forces ranged from 0.30 xBW to 0.55 xBW with more PTT resulting in lower forces (Figure 5). Peak ACL forces ranged from 0.40 to 0.60 xBW with increased PTT having increased ACL force (Figure 6). Peak PCL forces ranged from 0.70 to 1.2 xBW with increased PTT having decreased PCL force.

DISCUSSION AND CONCLUSION:

Based on these results, PTT has minimal effect on the kinematics with almost no effect on LAP or MAP and only a small effect on the initial axial rotation. Simulations with increased PTT did exhibit more axial rotation during the activity because they started more internally rotated and all simulations had the same axial rotation at maximum flexion. However, ligament forces are heavily affected by the PTT with the peak MCL and PCL forces increasing by almost 100% when comparing the 0° PTT simulation to the 14° PTT simulation. This increase in forces was partially offset by a decrease in ACL forces. Overall, this resulted in slightly higher tibiofemoral forces for the 0° PTT simulation. In conclusion, selecting the correct PTT is an exercise in ligament balancing which may not affect kinematics but could still affect patient satisfaction. Care must be taken not to cause any ligaments to be excessively tight in mid or late flexion. Continued research may lead to the ability to customize PTT based on preoperative templating and patient specific geometries to achieve a desired ligament force profile.