Engagement Of PCL During Flexion With Custom TKR Implants

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Disclosures:

Introduction: Patient specific total knee implants are emerging as one of the latest advancements in arthroplasty. Custom implants utilize CT or MR imaging to that match a patient’s anatomy and restore natural kinematics. Patient specific implants like the ConforMIS iTotal G2 are designed as posterior cruciate retaining (PCR) implants. Preliminary clinical results of first generation patient specific knee implants demonstrate decreased maximal flexion. In total knee arthroplasty, the posterior cruciate ligament (PCL) stabilizes the tibiofemoral articulation, limits anterior translation of the tibia during flexion and restricts femoral roll back with deep knee flexion. It is established that a PCR implant on average results in decreased maximal weight bearing flexion and less posterior femoral roll back when compared to a posterior cruciate substituting implants (PS). Range of motion is critical to the clinical outcome of a total knee arthroplasty. Aim of our study is to compare the kinematics of intact and resected PCL in order to elucidate the role of the PCL with patient specific knee implants. Given the congruency and inheritability of a patient specific implants, we hypothesize that there is no difference in the kinematics of a PCL retaining knee compared to a PCL deficient knee.

Methods: Seven frozen human cadaveric knees were used in this study. These specimen were <70 years old, had BMI of 25-35 at time of death, and no history of radiation of the lower extremity nor obtaining t scores less than -2.5. Each knee was imaged (CT scan) according to manufacturer’s guidelines (ConforMIS, Boston MA) custom TKR implants.TKR surgery was performed under the guidance of a board-certified orthopaedic surgeon fellowship trained in joint replacement (WM). Following TKR, the knees were prepped for biomechanical testing with removal of skin and several musculature structures taking careful note to leave the biceps femoris, semimembranosus, vastus medialis, vastus lateralis, rectus femoris, and vastus intermedius and removing all other soft tissue. The femur and tibia were transected 20cm distal and proximal from the knee joint. The fibula was cut approx. 5cm distal from the joint, and secured to the tibia via a single wood screw to hold its natural position. The ends of the femur and tibia were then potted at 15cm distal and proximal from the knee joint line. The position of the knee relative to the potting adapters was conducted in accordance with the guidelines of (MacWilliams et al. 1998). Muscle-controlled squatted knee flexion was performed on all specimens in our custom-designed knee simulator based on the “Oxford rig” and “Tuebingen” machines (Mueller 2009 BT, Wuenschel 2013 Knee). Kinematics were measured with standard motion capture markers (Optotrak 3020) rigidly fixed to the tibial and femoral adapters. Coordinate systems for the tibia and femur were calculated using the method described by previously by our group (Wuenschel 2013 Knee). Knee was tested in this configuration at first with PCL intact. Following testing, PCL was resected and a subsequent range of motion test was performed. Outcome measures from testing included six degrees of freedom of the joint including anterior-posterior (AP), medial-lateral (ML), and proximal-distal (PD) translations and flexion-extension (FE), varus-valgus (VV), and internal-external (IE) rotations.

Results: Change in anterior-posterior translation increased from -0.19mm +/- 0.45mm at 68 degrees of flexion to 0.41mm +/- 0.77mm at 119 degrees of flexion. This increase represents statistically insignificant (p>0.05) shift of approximately 0.5mm of the femur anteriorly during flexion after the PCL was removed. Change in internal-external rotation decreased from -0.92deg +/- 0.85deg at 68 degrees of flexion to -6.84deg +/- 4.24deg at 119 degrees of flexion. This decrease represents a significant (p<0.05) external rotation of the femur of approximately 6 degrees after the PCL was removed. Change in medial-lateral translation increased from -0.25mm +/- 0.27mm at 68 degrees of flexion to 1.71mm +/- 1.48mm at 119 degrees of flexion. This increase represents statistically significant (p<0.05) shift of the femur medially during flexion when the PCL was removed.

Discussion: Results of our study indicate custom-designed TKR’s exhibit a profound ability to stabilize the tibiofemoral joint through deep knee flexions with or without the presence of the posterior cruciate ligament. We observed minimal differences in kinematics in knees tested with and without the PCL. The only significant difference in translations we observed were in the medial-lateral direction with a shift of the femur approximately 1.75mm medially in late (>90) flexion. Observed a significant external rotation of the femur without the PCL in late flexion as well. Did not observe any significant differences in anterior-posterior translation through flexion once the PCL was removed. Recent in vivo investigations (Rothe 2012 BMC, Li 2007 JASM, Logan 2004 AJSM) of kinematics in healthy and PCL deficient knees reported substantial anterior translation, medialization, and external rotation of the femur in the absence of the PCL through flexion. The magnitude of anteriorization of the femur observed in these studies is substantially larger than ours, indicating the stability observed in our study may be the result of the presence of the ACL in the in vivo studies or an optimal design of the TKR components or a combination of both. Additionally, the magnitude of external rotation observed in our study was much larger than in previous in vivo investigations which may indicate the tremendous effect of the ACL during the in vivo studies. This effect of the ACL has been exhibited in similar in vitro studies as well (Lo 2008, J Biomech). Large differences in kinematics indicate the engagement of the PCL during flexion; whereas,
small differences indicate minimal engagement. This engagement (or lack of) may be interpreted to have both positive and negative effects when considering proprioception and joint stiffness. Small differences may indicate patients perceive stability during flexion and conversely large differences may produce a lack of stability. Conversely, small differences in kinematics may indicate the PCL does not engage and; therefore, is not at risk of constraining the joint producing reduced range of motion. Large differences in kinematics may indicate substantial engagement of the PCL which constrains the joint and reduced range of motion, increases contact forces on the tibial component of the implant, and accelerates wear.

**Significance:** Clinical implications of our study is that current custom-designed knee replacements are optimized to maintain anterior stability of the femur during flexion and that may need further optimization to produce a similar stability for external rotation of the femur, especially during late flexion.

**Acknowledgments:** N/A

**References:**
1) Lo, 2008 J Biomech
2) Rothe, 2012 BMC
3) Li, 2007 AJSM
4) Logan, 2004 AJSM
7) Rothe. 2012 BMC Musculoskeletal
8) Wuenschel, Leasure. 2013 The Knee
10) Jong-Keun Seon, Ju-Kwon Park, et al. “Comparisons of kinematics and range of motion in high-flexion total knee arthroplasty: