A Novel Anterior Cruciate Substituting Implant can address the Abnormal Femoral Sliding in Contemporary Cruciate Retaining Total Knee Arthroplasty

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Introduction: In Cruciate Retaining (CR) Total Knee Arthroplasty (TKA), the Posterior Cruciate Ligament (PCL) is preserved but the Anterior Cruciate Ligament (ACL) is sacrificed. In contemporary CR implants, failure to substitute for ACL function causes abnormal knee motion, with the femur being located excessively posterior on the tibia in full extension (Fig. 1), and sliding forward during early flexion. To address this kinematic abnormality, we developed an ACL Substituting Cruciate Retaining (ASCR) TKA implant that substitutes for the absent ACL, while preserving the native PCL. The ASCR tibia includes an ACL substituting post that engages the intercondylar notch of the femoral component in low flexion to act for the missing ACL (Fig. 1). With continued flexion, the post disengages from the femoral component and the native PCL guides further motion of the femur (femoral rollback). Thus the ACL substituting post mimics the native ACL function. The hypothesis of this study was that the ASCR implant can address the abnormal femoral sliding seen in contemporary CR implants.

Methods: The kinematics of an ACL-preserving implant, the ASCR implant, and a contemporary CR implant during deep knee bend was simulated using KneeSIMITM software. The PCL was preserved in all implants. Anteroposterior motion of the femoral condyles relative to the tibia was measured. The implants were mounted on an average knee model created from Magnetic Resonance Imaging (MRI) of 40 healthy knees. The medial and lateral collateral ligaments, PCL, ACL (for ACL-preserving implant), quadriceps mechanism, and capsular tension were modeled. The soft-tissue insertions were obtained from the average knee model, and the mechanical properties were obtained from literature.

Results: During the simulated knee bend, the contemporary CR implant showed significant posterior shift of the femur in full extension (9.5 mm relative to the ACL-preserving implant, Fig. 2). This was followed by anterior sliding of the femur until about 60° flexion (4.5 mm lateral condyle, 7 mm medial condyle). In contrast, the ASCR implant kinematics was virtually identical to that of the ACL-preserving implant. From full extension to 15° flexion, the ACL substituting post of the ASCR implant engaged with the femoral component to substitute for the ACL function. This kept the femur at an anterior location similar to that in the ACL-preserving implant. Above 15° flexion, the ACL substituting post disengaged from the femoral component, and the femur continued to rollback under the pull of the intact PCL.

Discussion: The novel ASCR implant successfully substituted for ACL function while allowing normal function of the preserved PCL. The ASCR implant provided kinematics virtually identical to an ACL-preserving implant, and addressed the abnormalities of contemporary CR implant including excessive posterior shift of the femur in extension and paradoxical anterior femoral sliding in early flexion.

Significance: The ASCR implant is the first TKA implant to substitute for the ACL function while allowing preservation of the PCL. This implant could address the abnormal anteroposterior stability reported by TKA patients with contemporary CR implants.

Acknowledgments:
Figure 1: Schematic showing anteroposterior location of femur on tibia at 0° flexion, in an ACL preserving implant, the novel ACL substituting cruciate retaining (ASCR) implant, and a contemporary cruciate retaining implant

References:

Figure 2: Motion of medial and lateral femoral condyle relative to tibia during simulated deep knee bend in an ACL preserving implant, the novel ACL substituting cruciate retaining (ASCR) implant, and a contemporary cruciate retaining implant

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