Does Posterior Tibial Slope Impact Anterior Cruciate Ligament Bundle Stress in Bi-Cruciate Retaining Total Knee Arthroplasty?

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INTRODUCTION: By preserving both the anterior and posterior cruciate ligaments (ACL and PCL respectively), Bi-cruciate retaining (BCR) total knee arthroplasty (TKA) may provide patients with more natural knee kinematics than TKA designs which sacrifice one or both of the cruciate ligaments. However, alterations to posterior tibial slope (PTS) may occur during BCR TKA, potentially impacting ligament behavior. With current clinical studies publishing conflicting reports on the association between increased PTS and increased likelihood of ACL rupture, it is critical to understand how these alterations may impact stress in the preserved ACL. The purpose of this study was to investigate the relationship between PTS and both the anteromedial (AM) and posterolateral (PL) bundles of the ACL during the sit-to-stand (STS) activity in patients with BCR TKA.

METHODS: With institutional Internal Review Board approval, twenty-nine consenting unilateral BCR TKA patients (14 males, 15 females; 65.7±7.7 years; BMI 29.8±4.0), all with no history of surgical complication, were selected for this study. 3D surface models of each patient's knees were created from computed tomography (CT) scans to determine PTS, as shown in Figure 1. The footprints of the ACL as well as an anatomical coordinate system were ascertained on the contralateral, non-operated, knee and mapped to the operated knee using a previously validated 3D mirroring technique to reduce surface-to-surface registration errors between the operated and contralateral knees [1]. Fluoroscopic images of each patient performing the sit-to-stand (STS) maneuver were captured using a dual fluoroscopic imaging system (DFIS). These 2D fluoroscopic images, as well as the patient's 3D knee models, were used to determine knee six degree-of-freedom (6DOF) kinematics within a virtual DFIS environment. Knee model position was found by matching the model's projection to the outline of the 2D fluoroscopic image [2]. The length of ACL was defined as the distance between the femur and tibial footprint at that flexion angle [3]. The stresses within the AM and PL bundles were determined from the relative strains of each bundle using a finite element analysis (FEA) of the ACL [4]. A Pearson's Chi-Squared analysis was performed to determine if a significant correlation between PTS and bundle stress was present ($\alpha = 0.05$).

RESULTS: An inverse relationship between degree of flexion and stress in both the AM and PL bundles was observed. Stress within the AM and PL bundles was maximized at an average of 6.76º and 6.15º respectively with average stress minimization occurring at 87.09º for the AM bundle and 83.41º for the PL bundle. A negative correlation was found between PTS and stress within both the AM and PL bundles (r=-0.435, -0.398). Through a Pearson's Chi-Squared test the relationship between PTS and stress in both bundles was determined to be statistically significant (p=0.018 and 0.033 for AM and PL bundles respectively). Maximum stress decreased an average of 3.68% and 3.29% with each additional degree of PTS for the AM and PL bundles respectively. The maximum stress within both bundles occurred at a PTS of 3.71º. Stress was minimized at a PTS of 8.51º for the AM bundle and 9.28º for the PL bundle.

DISCUSSION: There is a paucity of *in-vivo* data available which correlates PTS to the preserved ACL in patients with unilateral BCR TKA. This study evaluated the relationship between PTS and ligament stress during STS, which demonstrated that PTS and stress in both the AM and PL bundles displayed a significant inverse correlation. Further studies are required to determine the impact of increased PTS on stress within the posterior cruciate ligament (PCL) and to determine the ideal operative PTS to minimize stress within both preserved cruciate ligaments.

SIGNIFICANCE/CLINICAL RELEVANCE: This study quantified the relative stress within the AM and PL bundles of the ACL through an in-vivo kinematic analysis of patients with unilateral Bi-Cruciate Retaining TKA implants performing the sit-to-stand activity.

REFERENCES
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Figure 1. Posterior tibial slope defined as the angle between the long axis of the tibia (A) and the line orthogonal to the tibial plateau (B)

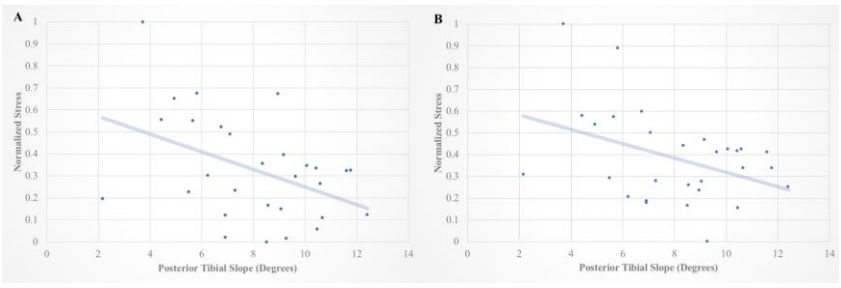

Figure 2. Normalized maximum stress in the anteromedial (A) and posterolateral (B) bundles of the anterior cruciate ligament during sit-to-stand