In-vivo elongation of the posterior cruciate ligament in cruciate retaining total knee arthroplasty during functional activities

Ruben Oganesyan[1], Christian Klemt[1], Venkatsaiakhil Tirumala[1], Janna van den Kieboom[1], Paul Walker[1], John Drago[1], Kaya Adelzadeh[1], Andriana Velmahos[1], Saimrunali Dadigala[1], Travis Dang[1], Alina Syros[1], Young-Min Kwon[1]

[1]Bioengineering Laboratory, Department of Orthopaedic Surgery, Massachusetts General Hospital, Harvard Medical School, Boston, MA 02114, US
ymkwon@mgh.harvard.edu

Disclosures: Ruben Oganesyan (N), Christian Klemt (N), Venkatsaiakhil Tirumala (N), Janna van den Kieboom (N), Paul Walker (N), John Drago (N), Kaya Adelzadeh (N), Andriana Velmahos (N), Saimrunali Dadigala (N), Travis Dang (N), Alina Syros (N), Young-Min Kwon (5- Stryker;5- Zimmer Biomet; 5- Depuy;5- Corentec; 5- Smith&Nephew)

INTRODUCTION: Anterior and posterior cruciate ligament (ACL and PCL) sacrifice or resection in posterior stabilized (PS) total knee arthroplasty (TKA) has been considered as a potential factor leading to abnormal knee kinematics. Previous studies investigated the in-vivo ACL and PCL elongation only in bi-cruciate retaining (BCR) TKA demonstrating that BCR TKA does not fully replicate ACL and PCL elongation patterns of the healthy knee (Fig. 1). As cruciate retaining (CR) TKA allows only the retention of the PCL and thus sacrifices the ACL, this design may affect knee kinematics and associated in-vivo PCL elongation patterns. As there is limited data on PCL elongation in CR TKA, this study aimed to evaluate the in-vivo elongation patterns of the PCL between CR TKA and contralateral non-implanted knee during functional activities.

METHODS: Fifteen well-functioning unilateral CR TKA patients (6 males, 9 females) with no history of any surgical complication were included in this study with the institution's Internal Review Board approval. All fifteen patients received computer tomography (CT) scan for the creation of 3D surface models of the knees and performed sit-to-stand under dual fluoroscopic imaging system (DFIS) surveillance. The length of the PCL was measured in a previously established protocol in which the PCL attachment areas on CR TKA and the contralateral knee were first determined at each flexion angle. An optimization procedure was implemented to find the shortest 3D wrapping path of the PCL during sit-to-stand. Ligament elongation was calculated using the following formula (⌊ _ ⌊0)/⌊0_100 (%), where ⌊ represents the wrapping length. A non-parametric Mann-Whitney test was used to quantify significant differences in PCL elongation (anterolateral (AL) bundle and posteromedial (PM) bundle) between CR TKA and the contralateral knee at each flexion angle (Fig. 2).

RESULTS: The AL and AM bundles of the PCL in CR TKA demonstrated significantly ($p<0.05$) larger elongations than that of the contralateral knee throughout the sit-to-stand activity. At 60° of flexion, compared to the contralateral non-operated side, CR TKA demonstrated significantly larger PCL elongation of 3.6% ± 7.1% ($p=0.04$) for the AL bundle and 3.1% ± 6.5% ($p=0.03$) for the PM bundle. Similarly, At 90° of flexion, compared to the contralateral non-operated side, CR TKA demonstrated significantly larger PCL elongation 4.8% ± 7.9% ($p=0.02$) for the AL bundle and 4.0% ± 7.2% ($p=0.01$) for the PM bundle. Marked inter-subject variability was observed in the change of PCL elongation for both AL (min -30.1%, max 17.6%, range 48%) and PM bundles (min -28.4%, max 21.3%, range 50%).

DISCUSSION: Although, cruciate ligaments sacrifice in the PS TKA have been considered as potential contributory factor leading to patient dissatisfaction, recent studies demonstrated no clinically relevant differences between retention and sacrifice of the PCL in TKA. Previous studies on PS TKA have reported overstretching of the PCL, demonstrating realignment of the preserved PCL from a medially directed to an almost sagittal orientation. Our results support the fact that CR TKA does not fully restore healthy knee PCL elongation patterns during functional activities. We demonstrated that PCL undergoes significantly larger elongations throughout the sit-to-stand activity, at 60° and 90° of flexion compared to the contralateral non-operated side. It was previously shown that excessive PCL elongation results in PCL dysfunction which correlates with reduced posterior femoral rollback, increased flexion gap, and compromises rotational stability of the knee. Considerable heterogeneity remains in the retained ligament elongation patterns and warrants further investigation to optimize PCL function in CR TKA. This is of particular importance as non-physiological loading of the PCL has been associated with ligament mal-functioning, which in effect will lead to further asymmetries in knee kinematics between CR TKA and the contralateral non-operated knee. Because of non-physiologic stretching patterns of retained PCL, the overall performance of the operated knee may be affected.

SIGNIFICANCE/CLINICAL RELEVANCE: CR TKA does not fully restore healthy knee PCL elongation patterns during functional activities. We demonstrated that PCL undergoes significantly larger elongations throughout the sit-to-stand activity, at 60° and 90° of flexion compared to the contralateral non-operated side.

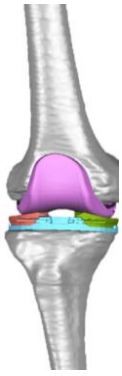

Figure 1: Three-dimensional CAD model of the CR TKA from the anterior view.

Figure 2: The AL (green) and AM (yellow) bundles of the PCL.