In-vivo Function of the Medial and Lateral Collateral Ligaments in Posterior Cruciate Retaining Total Knee Arthroplasty

Kwan Kyu Park, M.D., Ph.D.¹, Ali Hosseini, Ph.D.², Tsung-Yuan Tsai, Ph.D.², Young-Min Kwon, M.D., Ph.D.², Harry E. Rubash, M.D., Ph.D.², Guoan Li, Ph.D.².
¹Yonsei University, College of Medicine, Seoul, Korea, Republic of, ²Massachusetts General Hospital and Harvard Medical School, Boston, MA, USA.


Introduction: The collateral ligaments play an important role in maintaining stability of the knee after TKA [1, 2], however the current knowledge on the medial and lateral collateral ligament (MCL and LCL) before and after TKA is limited [3], especially under in-vivo weight bearing conditions. The objective of this study was to investigate the changes in lengths of different portions of the superficial MCL (sMCL) and the LCL during weight bearing flexion before and after a posterior cruciate retaining (PCR) TKA in osteoarthritis patients. We hypothesized that a PCR TKA cannot reproduce the normal elongation patterns of the collateral ligaments and thereby affecting the maximal flexion of the TKA knees.

Methods: Eleven primary TKA patients (age 51-73; 6 lefts and 5 rights) with advanced knee osteoarthritis were recruited. Three dimensional (3D) models of the tibia and femur, including the insertions of the collateral ligaments, were created using MR images. The sMCL and LCL were each divided into three equal portions: the anterior portion (AP), the middle portion (MP) and the posterior portion (PP). Before and after PCR-TKA, dual fluoroscopic images of each knee were acquired during a weight-bearing flexion and the in vivo motion of the knee was reproduced. The shortest 3D wrapping path of each ligament portion around the knee was measured along the flexion path of the knee [4] (Fig. 1). The relative elongation of each ligament portion was calculated using its length at full extension in the preoperative condition as a reference. The relationship between the differences of the relative elongations of the ligaments and the differences of the maximal knee flexion angles measured before and after TKAs were calculated using a regression analysis.

Results: In sMCL of the OA knees pre-operatively, the PP showed a decreasing elongation pattern as the knee flexed, while the AP showed an increasing elongation pattern up to 90° following by a decreasing pattern thereafter (Fig. 2a). In the PCR-TKA knees, the PP showed a decreasing elongation pattern, while the AP showed an increasing elongation pattern up to maximum flexion (Fig. 2b). The differences of the relative elongations of the AP and MP of the sMCL between the OA and post-operative PCR-TKA knees were positively correlated with the differences of the maximum flexion angles between the OA and PCR-TKA knees (p=0.010, r=0.733 in AP; p=0.049, r=0.604 in MP) (Fig 4), which means that the larger the differences of the AP and MP lengths between PCR-TKA and OA knees, the larger the differences of the maximum flexion angles between the PCR-TKA and OA knees. In the LCL, the elongation pattern of all portions showed a decrease with flexion in OA knees (Fig. 2c); while in the PCR-TKA knees, an increase up to mid-flexion followed by a decrease was observed (Fig. 2d). The differences of the relative elongation of AP between OA and PCR-TKA knees was also positively correlated with the differences of the maximum flexion angles between OA and PCR-TKA knees (p=0.010, r=0.733) (Fig 3).

Discussion: The elongation patterns of the collateral ligaments were changed after the PCR-TKA implantation. In general, the collateral ligaments were over stretched after mid-range of knee flexion. Interestingly, our data demonstrated that the reduction in the maximal knee flexion after TKA is strongly correlated with the amount of overstretching of the collateral ligaments at maximal knee flexion. This suggests that soft tissue balancing during TKA should not only be done at full extension and 90° of flexion, but also may need to be evaluated at higher flexion in order to optimize maximal knee flexion after TKA.

Significance: Our data provides insight into in vivo biomechanical function of the collateral ligaments in OA knees before and after PCR-TKA, suggesting excessive elongation of the collateral ligaments post-operatively adversely affects the maximal flexion of the TKA knees.

Acknowledgments:

Fig. 1 Measurement of bone surface + joint space length by the shortest 3D wrapping path.

- a) sMCL of OA Knees
- b) sMCL of PCR-TKA Knees
- c) LCL of OA Knees
- d) LCL of PCR-TKA Knees

Fig. 2 Mean relative elongation of each portion of ligaments; sMCL of OA knees (a), sMCL of PCR-TKA knees (b), LCL of OA knees (c), and LCL of PCR-TKA knees (d).
Fig. 3 Correlations between the $\Delta$ elongation (%) and $\Delta$ angles ($^\circ$) of maximal flexion between OA knees and PCR-TKA knees