Effect of simulated PCL fiber release on compartmental contact forces in cruciate retaining total knee arthroplasty: a computational study

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INTRODUCTION:

In cruciate retaining (CR) total knee arthroplasty (TKA), partial or total release of the PCL is often used intraoperatively to reduce excessive PCL tension in flexion. The effect of complete or selective PCL release on femoral rollback was recently elucidated in a computer model; however, the effect of releasing the PCL on contact forces acting on the medial and lateral compartments of the tibia is not well understood. Therefore, we employed a computational model to quantify how releasing the PCL fibers affects the articular contact forces at the medial and lateral compartments at 90° of the knee flexion.

METHODS:

Computational models derived from nine independent cadaveric left knees (five males, four females; age: 63.7 ± 10.5 years) were virtually implanted with CR-TKA (Persona, Zimmer-Biomet). The model utilized 33 spring elements to represent the geometry and nonlinear stiffness of the following major ligaments: PCL and the collateral and capsular ligaments. The PCL was represented by seven spring elements: four for the posteromedial bundle (PMB) and three for the anterolateral bundle (ALB). Passive flexion was simulated for the PCL-retained condition and after serially releasing each fiber of the PCL starting from the most anterior fiber of the ALB to the most posterior fiber of the PMB (Fig. 1). The contact force on the medial and lateral compartments of the tibial insert was calculated after releasing each fiber and reported as median and quartiles. Outcomes were compared for each condition using Kruskal-Wallis with Bonferroni post hoc correction ($\alpha = 0.05$)

RESULTS:

The largest reduction in contact force occurred after sectioning the ALB together with the most anterior fiber of the PMB (i.e., selective release of the PCL central fibers) by 22 N [20.2, 36.4] (P=0.02) medially and 11.0 N [8.2 39.5] (P=0.04) laterally (Fig. 2). The computational model demonstrated that releasing the PCL created an asymmetric reduction of contact forces.

DISCUSSION AND CONCLUSION:

Releasing the PCL fibers reduced both medial and lateral contact forces. The largest reduction in contact forces occurred after resecting the central fibers of the PCL. Interestingly, the reduction in contact force was asymmetrical with twice the reduction on the medial compartment. Based upon this study, after complete or selective release of the PCL, surgeons should consider reassessing knee balance of the medial and lateral compartments in 90° of knee flexion.

P<0.01



Figure 1: Femoral insertions of PCL fiber numbered from 1 to 7 where fibers 1-4 represent the posteromedial and fibers 5-7 represent the autorolateral bundle (a). The serial release of the fibers in the computational modeling was performed from fiber 7 to fiber 1.



Figure 2: Boxplots of the contact forces for each posterior cruciate ligament (PCL) fiber release for (a) medial compartment, (b) lateral compartment. PCL-Ret is PCL-retained. Red lines and boxes represent medians and quartiles, respectively. The whiskers extend to the most extreme data points not considered outliers. An outlier (re cross) is a value tait is more than 1.5 interquartile range (UQR) away from the top or bottom edge of the box.