Pathway to Quantify the Effects of Peripheral Soft-Tissue and Capsule on Knee Joint Response

Introduction: Understanding the role peripheral soft-tissue and capsule play on knee joint response can influence what structures should be included in computational models and may elucidate the effects of surgical disruption of those structures. Previous work tested the effects on only anteroposterior stability [1]. This study aimed to quantify the effects peripheral tissue has on complete (6 degrees-of-freedom) joint kinematic-kinetic response.

Methods: Six cadaver knees were tested on a robotic simulator controlled with real-time force feedback using simVITRO software. The knees were evenly divided into the Repeatability Experiment (RE) and Soft-Tissue Effects Experiment (STE). For the RE, 3 laxity loading profiles were applied at 6 flexion angles. Each loading condition was applied three times to establish specimen/system repeatability. Root-mean-square error (RMSE) was calculated for each kinetic/kinematic axis. For STE, 6 laxity loading profiles were applied at 4 flexion angles. The specimens were then dissected to remove peripheral soft-tissue and capsule, preserving only salient structures (ACL, PCL, MCL, LCL, and popliteus). The same loading conditions were applied to each "cleaned" knee. RMSE was calculated for each kinetic/kinematic axis.

Results: Kinetic variation was relatively low for specimens in the RE (Table 1A), indicating consistent loading. Due to larger kinetic variation in some STE specimens, i.e., inconsistencies in loading, only specimen 2 was considered (Table 1B), as it was important to compare kinematic responses under the same loading conditions. Overall, kinematic responses were similar between the two conditions with the exception of the IR/ER axis. RMSE increased from 1.9° (RE) to 4.0° (STE), indicating peripheral soft-tissue may have a stabilizing effect. While the loading conditions included a variety of applied loads, not all directly loaded the IR/ER axis. When the IR/ER axis was directly loaded, kinetic and kinematic RMSE was lower, indicating that the contribution of peripheral soft-tissue and capsule is a function of loading.

Discussion: The results warrant further exploration of the hypothesis that peripheral soft-tissue and capsule help stabilize the joint at low loads. Future studies will focus on reproducing RE and STE conditions on the *same* specimen and ensure application of consistent loading conditions for intact and "cleaned" states.

1. Shino, K., et al. "Measurement of anterior instability of the knee. A new apparatus for clinical testing." *Journal of Bone & Joint Surgery, British Volume* 69.4 (1987): 608-613.

Table 1: RMSE associated with A) specimen/system repeatability, B) soft-tissue effects and C) IR axis only with the separation of loading conditions to those directly loading the IR/ER axis and those that did not.

A

	Specimen/System Repeatability (RE)					
	Medial	Posterior	Superior	Flexion	Valgus	IR
Kinetics (N, Nm)	0.5	1.0	2.5	0.14	0.07	0.06
Kinematics (mm, deg)	0.3	0.6	0.3	0.0	0.4	1.9

B

	Soft Tissue Contribution (STE) - Specimen 2 only					
	Medial	Posterior	Superior	Flexion	Valgus	IR
Kinetics (N, Nm)	1.4	1.6	4.6	0.28	0.15	0.14
Kinematics (mm, deg)	0.5	0.3	0.2	0.0	0.5	4.0

C

	IR			
	Specimen/System Repeatability (RE)		Soft-Tissue Contribution (STE) - Specimen 2 only	
	Loaded	Unloaded	Loaded	Unloaded
Kinetics (Nm)	0.01	0.07	0.07	0.17
Kinematics (deg)	0.6	2.3	1.7	5.0