

# Reducing tibial slope or upsizing the femoral component can mitigate anterior-posterior laxity at expense of super-physiological MCL tension and loss of femoral rollback in PCL-resected medial congruent TKA

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**INTRODUCTION:** Clinical utilization of medial congruent (MC) Total Knee Arthroplasty (TKA) has increased drastically over the last 5 years [1]. MC-TKA utilizes a semi-constrained tibial insert with additional material to the anterior aspect of medial compartment compared to conventional cruciate-retaining TKA to increase conformity with the medial femoral condyle (Fig. 1). One purpose of this design feature is to reduce excessive anterior-posterior (AP) laxity, which is related to decreased patient satisfaction [2]. Although manufacturers indicate that the posterior cruciate ligament (PCL) can be retained in MC-TKA, in practice, it is often resected due to difficulty with intraoperative ligament balancing, particularly in flexion [3]. Unfortunately, PCL resection can lead to undesirable sagittal kinematics; namely, decreased femoral rollback and increased posterior sag by increasing reliance on the medial collateral ligament (MCL) as a primary AP stabilizer [4]. Consequently, surgeons may plan to decrease the tibial slope or upsize the femoral component in their preoperative plan to mitigate these potential undesirable outcomes [5]. However, whether the surgical options of decreasing tibial slope or upsizing the femoral component can prevent increased AP laxity in flexion after PCL resection in MC-TKA remains poorly understood. Moreover, whether these options have additional effects on MCL tension or femoral rollback is unclear. Therefore, in the setting of PCL-resected MC-TKA, we asked: 1) Does decreasing tibial slope or upsizing the femoral component decrease AP laxity in flexion? 2) Do these two options affect MCL tension in flexion or femoral rollback?

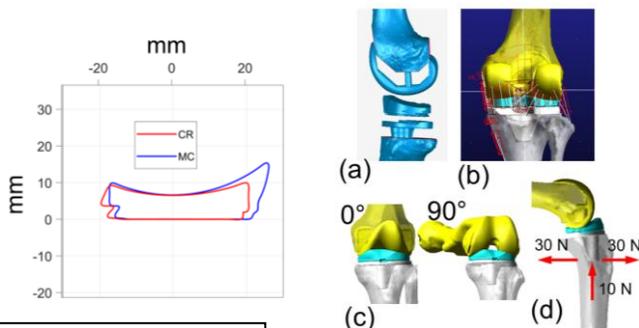
**METHODS:** Our research questions were addressed using computational models developed from CT scans of ten independent cadaveric left knees (5 males, 5 females; age: 63.7±10.5 years) that were virtually implanted with MC-TKA (Persona, Zimmer-Biomet) (Fig. 2a). For the first step of building the computational models, the 3D renderings of the tibia and femur of each knee were virtually implanted with MC-TKA implants (Persona, Zimmer-Biomet) (Fig. 2a). The tibial implants were angled at 7° of slope relative to the tibial mechanical axis, as recommended by the manufacturer. Next, 33 nonlinear spring elements were utilized to represent the soft tissue envelope of the knee consisting of the PCL, and the collateral and capsular ligaments. Ligament slack lengths were calibrated to replicate their native tension in full extension (Fig. 2b) [6]. Then, passive flexion from 0 to 90° was performed (Fig. 2c). Then, a simulated test of AP laxity was conducted at 90° of flexion by applying posterior and anterior forces of 30 N to the tibia under 10 N of compression (Fig. 2d). Passive flexion and AP laxity in MC-TKA with the PCL deactivated were simulated for three testing conditions: first, tibial component oriented at 7° of slope, and the baseline femoral component size; second, with tibial slope reduced to 3° and using baseline implant size; and third, at 7° of tibial slope with one size larger femoral component. Outcome measures were AP laxity defined as the magnitude of AP tibial translation between the peak applied anterior and posterior forces; MCL tension at 90° of flexion, and rollback of the medial and lateral femoral condyles obtained by quantifying the difference in AP position of the compartmental contact points between full extension and 90° of flexion. For the first research question, to compare AP laxity between the three testing conditions, a Friedman test with Least Significant Difference post-hoc correction ( $\alpha < 0.05$ ) was performed. For the second research question, the same test for multiple comparisons was performed to identify differences between the three testing conditions for MCL tension at 90° of flexion and for medial and lateral femoral rollback.

**RESULTS SECTION:** For the first research question, in PCL-resected MC-TKA, reducing tibial slope from 7° to 3° reduced AP laxity by a median of 4.7 mm ( $p < 0.05$ ) (Fig. 3). At 7° of tibial slope, upsizing the femur decreased AP laxity by a median of 2.8 mm ( $p < 0.05$ ) (Fig. 3). For the second research question, in the absence of the PCL, MCL tension at 90° of flexion increased by 2.2-fold median after reducing tibial slope from 7° to 3° ( $p < 0.001$ ) and by 1.9-fold after upsizing the femoral component ( $p < 0.01$ ) (Fig. 3). Neither medial nor lateral femoral rollback increased after reducing tibial slope from 7° to 3° while upsizing the femoral component at 7° of tibial slope reduced both medial and lateral femoral rollback by 1.0 mm ( $p < 0.05$ ) and 2.8 mm ( $p < 0.05$ ), respectively.

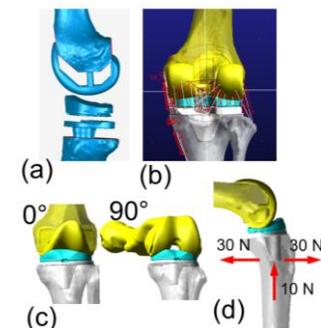
**DISCUSSION:** Our study revealed that in PCL-resected MC-TKA, reducing the tibial slope or upsizing the femoral component can mitigate AP laxity, likely by increasing MCL tension in flexion, underscoring the MCL's role as an AP stabilizer [7]. However, in the absence of the PCL, these two adjustments do not enhance femoral rollback, which is observed in MC-TKA when the PCL is retained [4]. In conclusion, when considering PCL resection during preoperative surgical planning for MC-TKA, the options of tibial slope reduction and upsizing the femoral component may reduce AP laxity, but have the trade-offs of increasing MCL tension and reducing femoral rollback.

**SIGNIFICANCE/CLINICAL RELEVANCE:** The findings of this study identify trade-offs that surgeons may recognize when compensating for PCL resection in MC-TKA. Despite mitigating AP laxity in flexion, reducing tibial slope and upsizing the femoral component result in supraphysiological MCL tension in flexion and decreased femoral rollback.

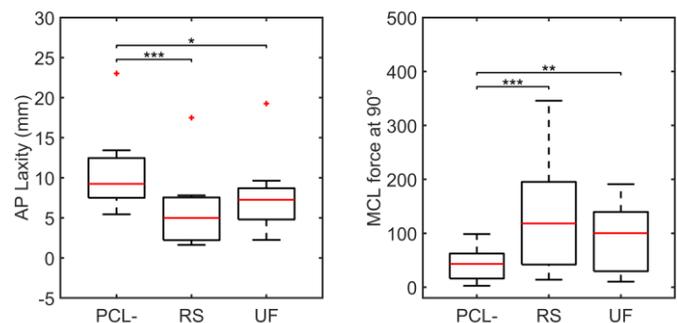
**REFERENCES:** [1] AJRR Annual Report, 2024; [2] Boume, *CORR*, 2010; [3] Scott, *JOA*, 2008; [4] Pourmodheji, *JOA*, 2025, [5] Mueller, *KSSTA*, 2014; [6] Kia, *J Biomech Eng*, 2016; [7] Berube, *JBJS*, 2024



**Figure 1:** Medial sagittal view of mid-section of medial congruent (MC) tibial insert compared to that of a conventional cruciate retaining (CR) tibial insert showing increased "anterior lip:" in MC-TKA



**Figure 2:** Computational modeling workflow: (a) Virtual implantation of medial congruent TKA; (b) incorporating soft tissues; (c) simulating passive flexion from 0 to 90° of flexion; and (d) anterior-posterior (AP) laxity test at 90° of flexion



**Figure 3:** Boxplots of anterior-posterior laxity and MCL force at 90° of flexion for medial congruent TKA without posterior cruciate ligament (PCL-) at 7° degrees of tibial slope; with reduced slope (RS) from 7° to 3°; and 7° of tibial with upsized femur (UF).