Comparison of Kinematics and Anteroposterior Stability Between Medial-Stabilized and Cruciate-Stabilized Inserts in Robotic-Assisted Total Knee Arthroplasty

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INTRODUCTION: Insert design may influence intraoperative kinematics and anteroposterior (AP) stability in total knee arthroplasty (TKA). This study compared a prototype medial-stabilized (MS) insert and a clinically-successful cruciate-stabilized (CS) insert [1-3] in robotic-assisted TKA under posterior cruciate ligament (PCL)-retained and PCL-resected conditions using cadaver specimens.

METHODS: There were five fresh-frozen pelvis-to-toe-tip cadaver specimens (10 knees total; mean age 71 years; mean BMI 23.3 kg/m²; two females, three males) prepared for cruciate-retaining robotic-assisted TKA. Each knee underwent sequential testing in intact and trial component states: PCL-retained and PCL-resected with a +1 mm insert thickness. The AP stability was assessed at 10°, 45°, and 90° of flexion using manual stress tests. Dynamic kinematics were recorded through the full range of motion (120° to 10°). Metrics included medial AP translation (MAP) and medial pivot ratio (MPR), calculated as the lateral-to-medial contact excursion ratio (Figure 1). Insert type (MS or CS) was randomized and blinded to the surgeon. Statistical comparisons used Mann–Whitney U tests for continuous measures. Surgeon feedback on balance and kinematic preference was collected through questionnaires.

RESULTS: With PCL retained, MS inserts demonstrated significantly less medial translation than CS inserts at 10° flexion ($p < 0.05$), with a non-significant trend toward greater stability at 45° and 90°. After PCL resection, MS inserts showed significantly less medial translation at 10° and 90° ($p < 0.05$), with a similar non-significant trend at 45° (Figure 2). Median MPR was higher for MS compared to CS in both conditions: PCL-retained [3.1 (interquartile range (IQR): 2.1 to 4.5) versus 2.2 (IQR: 1.9 to 4.7), $p = 0.623$] and PCL-resected [1.3 (IQR: 1.0 to 3.4) versus 1.0 (IQR: 0.7 to 1.5), $p = 0.151$], though differences were not statistically significant. Surgeons more frequently associated MS inserts with perceived medial stability (PCL-retained: 5 vs. 3; PCL-resected: 7 vs. 1), preferred final kinematics (PCL-retained: 7 vs. 3; PCL-resected: 8 vs. 1), and selected MS as best mimicking native knee kinematics (PCL-retained: 6 vs. 2; PCL-resected 8 vs. 1) conditions. Surgeons reported sufficient PCL tension with both inserts in the PCL-retained knee.

DISCUSSION**:** The MS inserts demonstrated significantly greater AP stability than CS inserts under specific flexion angles in PCL-retained and PCL-resected conditions in this cadaver model. Differences in medial pivot ratios were not statistically significant between designs, although MS inserts tended to exhibit higher medial pivot ratios on average. Surgeon impressions favored MS inserts for perceived native-like kinematics, although these findings were subjective and reflect individual perceptions. The generally healthy condition of the cadaver PCLs may have contributed to the comparable AP stability observed at 45° and 90° of flexion in the PCL-retained state. In a more diseased or attenuated PCL, greater differences in stability between MS and CS inserts might have emerged at these flexion angles. This highlights the potential influence of native tissue quality on intraoperative kinematic outcomes and suggests that insert performance may vary *in vivo* depending on PCL integrity. Findings are based on limited cadaver samples and may not generalize to patient outcomes.

SIGNIFICANCE/CLINICAL RELEVANCE: In this cadaver study, the medial-stabilized (MS) insert showed kinematic patterns consistent with its design intent, including reduced medial translation, compared to the cruciate-stabilized (CS) insert. These differences were significant at select flexion angles but not across all measures, and further clinical research is needed to determine whether these trends translate to patient outcomes.

REFERENCES:
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2. American Joint Replacement Registry (AJRR): 2025 Annual Report. Rosemont, IL: American Academy of Orthopaedic Surgeons (AAOS), 2025.
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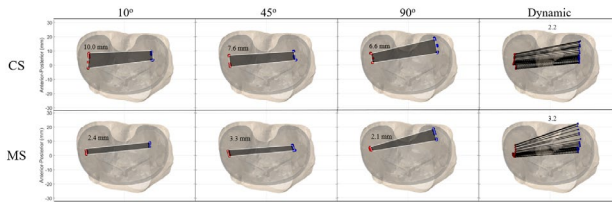

Figure 1. Example tibiofemoral low point kinematics for a single specimen during antero-posterior stress tests at 0°, 45°, and 90° flexion and dynamic passive flexion assessments (Medial: red points, Lateral: blue points).

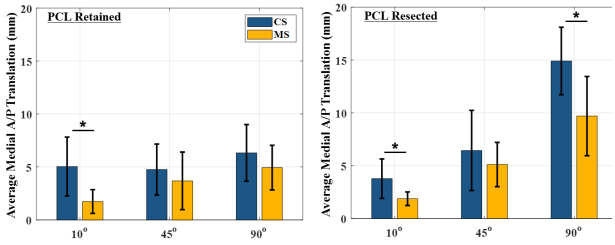

Figure 2. MS vs CS medial antero-posterior translation at 10°, 45°, and 90° flexion.