Comparing Intraoperative Robotic Measured Stability and Kinematics to Postoperative Fluoroscopic Assessment in Cruciate-Retaining TKA

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INTRODUCTION: Quantifying knee stability is central to optimizing outcomes following total knee arthroplasty (TKA). Robotic-arm assisted TKA enables precise intraoperative measurement of compartmental stability and kinematics both before resection and with trial implants, providing immediate feedback to guide surgical balance. Postoperatively, in-vivo fluoroscopy offers highly accurate characterization of tibiofemoral laxity and motion under physiologic loading. While both approaches are valuable, their relationship has not been well established. Specifically, it remains unclear whether intraoperative stability and ROM assessments capture the same aspects of joint mechanics observed postoperatively, or whether they provide complementary information. Furthermore, the extent to which intraoperative measures relate to patient-reported satisfaction has not been defined. The purpose of this study was to compare intraoperative and postoperative measures of knee stability, evaluate their agreement with low-point kinematics, and assess associations with disease severity and functional outcomes.

METHODS: With Institutional Review Board approval, 11 patients (4 F, 7 M; age: 71 ± 5.5 yrs; BMI: 26.6 ± 3.5 kg/m²) who had previously completed preoperative testing returned one year after receiving a cruciate-retaining total knee implanted with a robotic-arm assisted surgery system. Intraoperatively, medial and lateral compartment stability and knee extension kinematics were recorded with the robotic system during both pre-resection (Initial) and final implant (Trialing) states. Postoperatively, patients motions were captured in-vivo using high-speed stereo radiography (HSSR) synced with optical motion capture while performing seated knee extension and standardized laxity tests (anterior translation, internal-external rotation) at 45° of flexion using a validated rig. Patient-specific bone geometries were tracked with a CNN-based automated workflow, while femoral and tibial component positions were tracked with DSX relative to surgical bone alignment. Analyses compared intraoperative vs. postoperative fluoroscopic stability and femoral low-point ROM using repeated-measures tests, regression, concordance analysis, and effect sizes, with relationships to OA severity (B-Score) and patient-reported function (FJS).

RESULTS: Repeated-measures analysis showed strong time effects for low-point ROM (medial $\eta 2 = 0.962$; lateral $\eta 2 = 0.959$). Medial ROM increased intraoperatively but decreased slightly postoperatively ($d = 0.51$), where lateral ROM remained stable intraoperatively but dropped after surgery (mean change = –4.4 degrees, $d = 0.87$). Regression and correlation analyses indicated that medial trialing ROM during knee extension best corresponded with postoperative fluoroscopic knee extension ROM ($\rho = 0.48$, $R2 = 0.23$), while stability measures showed weaker alignment. Multivariable modeling revealed postoperative medial knee extension ROM and B-Score together explained substantial variance in patient-reported FJS ($R^2 = 0.69$), suggesting that both mechanical behavior and OA severity contribute to satisfaction. Agreement analyses indicated that intraoperative trialing and postoperative fluoroscopic measures reflect related but non-interchangeable aspects. For medial ROM, trialing slightly overestimated postoperative values (bias = –1.66°, LoA [–6.70, 3.38]), with moderate concordance (Lin's CCC = 0.39, 95% CI [–0.16, 0.80]). By contrast, lateral ROM showed wider divergence, with trialing consistently higher than postoperative values and poor concordance (bias = +0.88°, LoA [–4.02, 5.79], CCC = –0.07). These findings suggest that medial ROM retains greater continuity across surgical phases, while lateral ROM undergoes more postoperative adaptation.

DISCUSSION: This work highlights that intraoperative and postoperative assessments provide complementary but non-interchangeable perspectives on knee mechanics in TKA. Trialing tended to overestimate lateral low-point ROM relative to fluoroscopy at one year, likely reflecting the absence of soft tissue remodeling and adaptive restraint present in-vivo. By contrast, medial ROM showed greater correlation across time points, suggesting that intraoperative medial behavior is more resilient to postoperative change and may therefore serve as a more reliable surgical indicator. The weak agreement between intraoperative stability and postoperative stability underlines that these measurements reflect discrete mechanical contexts: Robotic assessments capture balance under standardized conditions, while postoperative fluoroscopic assessment reflects function during physiological activity. Importantly, medial ROM was not only the intraoperative measure most closely aligned with postoperative mechanics, but also, when combined with disease severity, explained a meaningful proportion of patient satisfaction variance. These findings support medial low-point ROM as a target metric that links intraoperative planning to long-term outcomes, while highlighting that stability and laxity assessments each contribute unique insight into knee function after TKA.

SIGNIFICANCE: Intraoperative and postoperative assessments capture different but complementary aspects of knee mechanics. Medial low-point ROM emerged as the most consistent intraoperative measure, maintaining correlations with postoperative behavior and linking to patient satisfaction when combined with disease severity. These findings highlight medial extension low-point ROM as a practical target for surgical optimization.

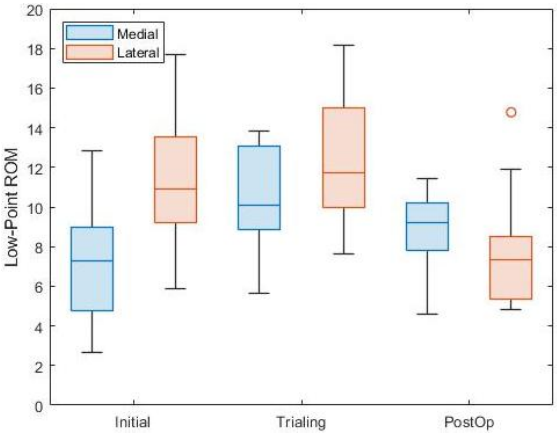

Figure 1. Low-point range of motion (ROM, mm) at three timepoints: Initial, Trialing, and PostOp.

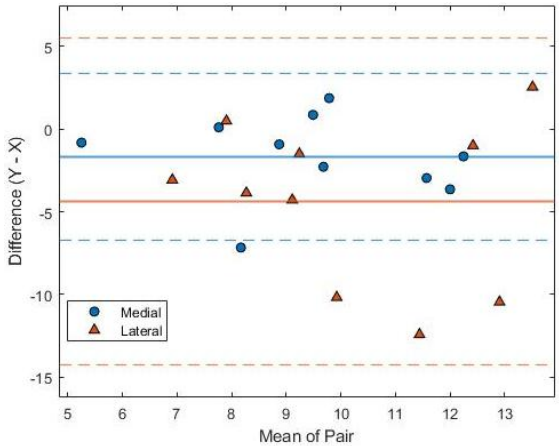

Figure 2. Agreement between Trialing and PostOp LP ROM. Solid lines denote mean bias for each compartment; dashed lines show the 95% limits of