Title: Analysis of Planned vs. Achieved Alignment in Robotic-Assisted Total Knee Arthroplasty: Impact of Deviations on Patient-reported Outcomes.

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INTRODUCTION: Robotic technology may enhance individualized preoperative alignment planning via robotic-assisted total knee arthroplasty (RA-TKA). However, the consistency with which these plans are achieved intraoperatively and the clinical relevance of alignment deviations from preoperative planning remain undetermined, particularly in association with changes in patient-reported outcomes (PROs). Therefore, this study aims to evaluate the accuracy of alignment execution in RA-TKA and assess whether deviations from planned alignment correlate with changes in PROs. We hypothesized that greater deviations from the planned alignment in RA-TKAs would be associated with differences in PROs.

METHODS: We conducted a retrospective review of 142 patients who underwent RA-TKA at a single academic institution. At the time of analysis, a review of radiographic measurements, robotic preoperative planning, and patient-reported outcomes had been reviewed for 100 patients. Preoperative alignment data were compiled from the institution's robotic operative planning archive. These preoperative alignment plans were compared to radiographic measurements obtained at three time points: preoperatively, 6 weeks postoperatively, and 1 year postoperatively, when available (using short- or long-leg views). Four angles were measured at each time point: lateral distal femoral angle (LDFA), medial proximal tibial angle (MPTA), joint line congruency angle (JLCA), and tibial slope. Patient-reported outcomes were obtained from the institution's affiliated database and included: the Knee injury and Osteoarthritis Outcome Score for Joint Replacement (KOOS-JR), Patient-Reported Outcomes Measurement Information System (PROMIS), Forgotten Joint Score (FJS-12), and Veterans RAND 12-item health survey (VR-12). PROs were collected at baseline, 3 months, 1 year, and 2 years postoperatively when available.

RESULTS: This preliminary analysis included 100 patients (mean age of 70.27 ± 7.36 years, 62% female); each patient had at least one set of post-operative radiographs and one set of PROs. Achieved coronal alignment deviated an average of 2.58° varus ($p < 0.001$, $d = -0.84$) from the robotic planned alignment (Table 1A). Moderate correlations were observed between robotic computed anatomic alignment and preoperative radiographic measurements including LDFA ($r = 0.579$), MPTA ($r = -0.633$), and arithmetic hip-knee-ankle angle ($r = 0.389$) (Table 1B). Notably, each 1° increase in anatomic-to-mechanical axis (AA–MA) offset was associated with a 1.68° increase in alignment error ($\beta = 1.68$, $p = 0.043$). Alignment deviations >3° from planned alignment, were not found to correlate with changes in PROs. Patients with <3° or >3° deviations from planned alignment had similar reoperation, infection, and implant failure rates.

DISCUSSION: Our preliminary findings suggest that RA-TKA systems allow for significant deviations in achieved alignment, particularly in the coronal plane. We also found that increases in the AA-MA offset are associated with progressively larger alignment errors, indicating that increasing the deviation of anatomical and mechanical axes may compromise the precision of alignment execution. Further comparisons of the remaining PROs and radiographic parameters may help increase the power to detect meaningful associations and assess the clinical relevance of deviations from the planned alignments.

SIGNIFICANCE/ CLINICAL RELEVANCE: Robotic-assisted total knee arthroplasty allows for deviations from planned alignment, but the clinical impact on patient-reported outcomes appears limited in preliminary analysis.

Table 1. Accuracy of Alignment in Robotic Assisted-Total Knee Arthroplasty			
1A: Planned vs. Achieved Alignment			
Alignment Parameter	Mean Difference (Achieved – Planned)	*p*-value	Effect Size (Cohen's *d*)
Coronal Alignment	-2.58°	**<0.001***	-0.84
Tibial Slope	-1.47°	0.41	-0.08
1B: Correlation Between Robotic Computed Alignment and Preoperative Radiograph Measurements			
Radiographic Measurement	Correlation with Robotic Computed Alignment (*r*)	*p*-value	
LDFA	0.579	**<0.001***	
MPTA	-0.633	**<0.001***	
JLCA	0.065	**<0.001***	
aHKA	-0.389	**<0.001***	
LFDA, Lateral Distal Femoral Angle, MPTA, Medial Proximal Tibial Angle, JCLA, Joint Line Congruency Angle, aHKA, arithmetic hip-knee-ankle angle. * Statistically significant (*p* < 0.05).			