

# Influence of Preoperative Alignment Phenotype and Correctability on Alignment Variability and Outcomes in Robotic-Assisted Total Knee Arthroplasty

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## INTRODUCTION:

Preoperative alignment and correctability of deformity may impact targeted alignment and implant positioning in robotic total knee arthroplasty (TKA) with a restricted functional alignment paradigm. This study examines how differences between planned, corrected, and achieved alignment relate to patient factors and preoperative characteristics.

## METHODS:

We retrospectively reviewed 862 robotic-assisted primary TKA performed between April 2023 and August 2024 using the MAKO system (Stryker, Kalamazoo, MI). Patients were stratified by preoperative coronal alignment phenotypes (neutral, mild valgus and varus, and severe valgus and varus). Intra-operative correctability of the arthritic deformity, prior to bone resection but after removal of accessible osteophytes, was measured with the robotic system. Corrected, planned, and achieved alignment values were recorded from the robotic software. The difference between corrected and planned alignments was calculated. Patient demographics, surgical features, and patient-reported outcome measures (PROMs) which included Knee Injury and Osteoarthritis Outcome Scores (KOOS, JR) and Patient Reported Outcome Measurement Information System (PROMIS) scores were compared.

## RESULTS:

Correctability of deformity prior to bone resections varied by phenotype, with most neutral (64.4%) and minor valgus (65.9%) cases correcting to neutral, while minor varus was correctable to slight deformity (55.9%) or neutral (34.3%). Major valgus was correctable to neutral or slight deformity (48.2% each), with three cases being non-correctable. Major varus often corrected to slight deformity (58.4%) or remained uncorrected (31.6%). Planned and achieved alignment varied significantly with the correctability of deformity. Knees with severe varus showed the greatest difference between corrected alignment (7.6°) and planned alignment (3.9°, p<0.001).

## DISCUSSION AND CONCLUSION:

Preoperative alignment correlates with correctability of deformity and predicts planned and achieved alignment in robotic TKA. Patients with fixed valgus deformities had the lowest baseline KOOS, JR scores. Patients with fixed varus deformities had the largest difference between corrected and planned alignment. These findings suggest a measurable shift in soft tissue envelope behavior during TKA that may impact intraoperative strategy and alignment outcomes.

Figure 1. Box plots demonstrating the absolute change from planned to corrected alignment as well as the achieved alignment among the various alignment groups.

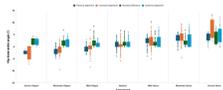


Table 1. Patient demographics and factors not tied to impact on the discrepancy between planned and corrected alignment. SD, Standard Deviation; % Neutral, % Nonneutral; BMI, Body Mass Index; ASA, American Society of Anesthesiologists; CVI, Clavicle-Vertebral Index; \* Statistical significance at p < 0.05; † Pearson's correlation coefficient.

Parameter	Impact on discrepancy between planned and corrected alignment	
	OR (95% CI)	P-value (%)
Mean age at surgery (range) (years)	63.2 (51-74)	0.26
Mean BMI (range) (kg/m <sup>2</sup> )	26.1 (18-40)	0.26
Mean height (range) (cm)	169.7 (147-188)	0.001
Mean weight (range) (kg)	180.2 (104-314)	0.001
Sex, n (%)		
Male	588 (68.2)	
Female	274 (31.8)	
Race, n (%)		0.687
White	631 (73.2)	
Black or African American	131 (15.2)	
Asian	47 (5.5)	
Other	21 (2.5)	
Missing	24 (2.8)	
Other	27 (3.1)	
Missing	27 (3.1)	
ASA, n (%)		0.024
I	18 (2.1)	
II	220 (25.6)	
III	582 (67.3)	
IV	2 (0.2)	
Missing	148 (17.1)	

Table 2. Mean and standard deviation of the discrepancy between planned and corrected alignment. SD, Standard Deviation; % Neutral, % Nonneutral; \* Statistical significance at p < 0.05; † Pearson's correlation coefficient.

Parameter	Impact on discrepancy between planned and corrected alignment	
	OR (95% CI)	P-value (%)
Mean length of follow-up (SD) (months)	23.5 (11.1)	<0.001
Mean length of stay (SD) (days)	3.2 (2.4)	0.001
Mean duration of surgery (SD) (minutes)	106.8 (30.8)	0.019 (0.009)
Preoperative malalignment, n (%)		
Major valgus	17 (2.0)	
Minor valgus	111 (12.8)	
Neutral	511 (59.3)	
Minor varus	111 (12.8)	
Major varus	10 (1.2)	
Missing	2 (0.2)	
Total uncorrected	123 (14.2)	
Total corrected	739 (85.8)	

Table 3. Planned and corrected values of the overall alignment stratified by the various preoperative alignment phenotypes as well as the impact of fixed deformity on the variability. HKA, Hip-knee-ankle angle; Δ, Difference between planned and corrected alignment; Correctability, % of knees that were corrected; % Neutral, % of knees that were neutral; % Mild valgus, % of knees that were mild valgus; % Severe valgus, % of knees that were severe valgus; % Mild varus, % of knees that were mild varus; % Severe varus, % of knees that were severe varus; \* Statistical significance at p < 0.05; † Pearson's correlation coefficient.

Alignment	Planned		Corrected		Δ	Impact†
	Mean (SD)	95% CI	Mean (SD)	95% CI		
Major valgus	20.2 (4.1)	16.1-24.3	17.2 (3.2)	14.0-20.4	3.0 (0.9)	0.012
Minor valgus	11.4 (3.2)	8.2-14.6	10.1 (2.8)	6.9-13.3	1.3 (0.5)	0.012
Neutral	0.1 (1.1)	-1.0-1.2	0.1 (1.1)	-1.0-1.2	0.0 (0.1)	0.001
Minor varus	-1.1 (2.1)	-3.2-1.0	-0.8 (1.8)	-2.9-1.3	0.3 (0.7)	0.001
Major varus	-14.1 (3.1)	-17.2-21.0	-7.6 (2.1)	-10.7-14.5	6.5 (1.0)	<0.001

Table 4. Planned and achieved values as well as the difference between planned and corrected alignment stratified by the correctability of each knee. Analysis of variance performed to assess differences between correctability groups. HKA, Hip-knee-ankle angle; Δ, Difference between planned and corrected alignment; Correctability, % of knees that were corrected; High flexion, % of knees that were high flexion; \* Statistical significance at p < 0.05; † Pearson's correlation coefficient.

Correctability	Planned		Achieved		Δ	Impact†
	Mean (SD)	95% CI	Mean (SD)	95% CI		
Correctable	0.1 (1.1)	-1.0-1.2	0.1 (1.1)	-1.0-1.2	0.0 (0.1)	0.001
Not correctable	7.6 (2.1)	5.5-9.7	0.1 (1.1)	-1.0-1.2	7.5 (1.0)	<0.001

Table 5. Analysis of variance (ANOVA) for the assessment of differences in patient-reported outcome measures (PROMs) based on their correctability in the preoperative alignment group as well as their correctability in the postoperative alignment group. KOOS, Knee Injury and Osteoarthritis Outcome Score for Pain Symptoms; PROMIS, Patient Reported Outcome Measurement Information System; \* Statistical significance at p < 0.05; † Pearson's correlation coefficient.

Parameter	Correctable		Non-correctable		p-value
	Mean (SD)	95% CI	Mean (SD)	95% CI	
KOOS	61.1 (10.1)	51.0-71.2	51.1 (10.1)	41.0-61.2	<0.001
PROMIS	51.1 (10.1)	41.0-61.2	41.1 (10.1)	31.0-51.2	<0.001

Table 6. Analysis of variance (ANOVA) for the assessment of differences in patient-reported outcome measures (PROMs) based on their correctability in the preoperative alignment group as well as their correctability in the postoperative alignment group. KOOS, Knee Injury and Osteoarthritis Outcome Score for Pain Symptoms; PROMIS, Patient Reported Outcome Measurement Information System; \* Statistical significance at p < 0.05; † Pearson's correlation coefficient.

Parameter	Correctable		Non-correctable		p-value
	Mean (SD)	95% CI	Mean (SD)	95% CI	
KOOS	61.1 (10.1)	51.0-71.2	51.1 (10.1)	41.0-61.2	<0.001
PROMIS	51.1 (10.1)	41.0-61.2	41.1 (10.1)	31.0-51.2	<0.001