Functional alignment minimizes changes to joint line obliquity in robotic-assisted total knee arthroplasty: a CT analysis of functional versus kinematic alignment in 2,116 knees using the Coronal Plane Alignment of the Knee (CPAK) classification

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Aims

Functional alignment (FA) in total knee arthroplasty (TKA) aims to achieve balanced gaps by adjusting implant positioning while minimizing changes to constitutional joint line obliquity (JLO). Although FA uses kinematic alignment (KA) as a starting point, the final implant positions can vary significantly between these two approaches. This study used the Coronal Plane Alignment of the Knee (CPAK) classification to compare differences between KA and final FA positions.

Methods

A retrospective analysis compared pre-resection and post-implantation alignments in 2,116 robotic-assisted FA TKAs. The lateral distal femoral angle (LDFA) and medial proximal tibial angle (MPTA) were measured to determine the arithmetic hip-knee-ankle angle (aHKA = MPTA – LDFA), JLO (JLO = MPTA + LDFA), and CPAK type. The primary outcome was the proportion of knees that varied ≤ 2° for aHKA and ≤ 3° for JLO from their KA to FA positions, and direction and magnitude of those changes per CPAK phenotype. Secondary outcomes included proportion of knees that maintained their CPAK phenotype, and differences between sexes.

Results

Overall, 71.6% had an aHKA change ≤ 2°, and 87.0% a JLO change ≤ 3°. Mean aHKA changed from -1.1° (SD 2.8°) in KA to -1.9° (SD 2.3°) in FA (mean difference (MD) -0.83 (SD 2.0); $p < 0.001$). Mean JLO changed from 173.9° (SD 3.0°) in KA to 174.2° (SD 2.6°) in FA (MD 0.38 (SD 2.3); $p < 0.001$). CPAK type was maintained in 58.1% of knees, with the proportion highest for Types I (73.9%), II (61.1%), and IV (51.2%). In valgus knees, 67.5% of Type III and 71.7% of Type VI were shifted to neutral phenotypes. There was minimal change to constitutional JLO across all CPAK types (MDs -2.0° to 1.2°).

Conclusion

Functional alignment may alter CPAK type, but does not significantly change JLO. A kinematic starting point minimizes changes to native anatomy, while final position with FA provides an optimally balanced TKA.

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Take home message

- By combining the individual's constitutional anatomy with soft-tissue balance, functional alignment minimizes changes to joint line obliquity, but may alter constitutional Coronal Plane Alignment of the Knee (CPAK) type. These changes were most pronounced in constitutional valgus knees, which often shift into neutral coronal alignment.
- Functional alignment is considered a safe compromise between an unrestricted kinematic alignment and a fixed mechnical alignment approach to total knee arthroplasty.

Introduction

Functional alignment (FA) is a relatively new technique in total knee arthroplasty (TKA) that aims to achieve balanced coronal and sagittal gaps by orienting and sizing implants prior to bone resection.[1-3] The implant position can be virtually modified from either a mechanical alignment (MA) or kinematic alignment (KA) start plan, most often utilizing robotic technology.[4] Individualized FA starts with a KA plan, which preserves joint line obliquity (JLO), compared to a MA starting plan, which unintentionally alters JLO.[4-6] FA, however, differs from KA TKA, in which the final implant position is determined by the osseous anatomy only.[1] The benefits of FA include more consistent soft-tissue balance than KA, and thinner bone resections and fewer soft-tissue releases than MA.[4,6-8]

A final FA position is often shifted away from a knee's KA position due to the asymmetric and patient-specific native laxities of the knee.[5,8,9] Another reason for this variation is that the individualized pre-arthritic, or constitutional, alignment may have been altered, first by bone remodelling, and later, by secondary bone loss.[10-12] However, this alignment change from KA to final FA position has not been examined in detail.

Therefore, the purpose of this study was to articulate the differences between KA and final FA position in TKA. The Coronal Plane Alignment of the Knee (CPAK) classification was used to define and quantify these differences.[13] The primary hypothesis was that in the majority of patients, the arithmetic hip-knee-ankle angle (aHKA) and JLO after individualized FA would not be significantly different from their KA positions. The secondary hypotheses were that following FA TKA, most patients would remain within their (constitutional) CPAK phenotype, and that any differences in CPAK distribution between sexes would be minimal.

In the era of personalized surgery, the importance of restoring native alignment while reconstructing a well-balanced knee is increasingly considered vital in TKA. Defining the proportion, magnitude, and direction of alignment change, and the effect that initial alignment has on final FA position will improve our understanding of optimal implant positioning in TKA.

Methods

Study group

A retrospective CT analysis was undertaken comparing virtual intraoperative changes from KA to final implant position when performing FA TKA. Patients underwent Mako robotic arm-assisted primary TKA (Stryker, USA) by four specialist orthopaedic surgeons (SJM, DBC, GWC, DC) in two private hospitals (Centre 1: St George Private Hospital; Centre 2: St John of God Subiaco Private Hospital) in Australia between August 2018 and July 2022 (Centre 1) and between January 2018 and December 2023 (Centre 2). Ethics approval was provided by Ramsay Health Care Human Research Ethics Committee A (#2023/ETH/0072). The study was conducted in accordance with the principles of the Declaration of Helsinki.[14]

Patients were included if they were diagnosed with end-stage knee osteoarthritis, inflammatory arthritis, or post-traumatic osteoarthritis, and scheduled for primary robotic arm-assisted TKA with a FA strategy. Exclusion criteria included prior femoral or tibial osteotomies, prior malunions of the femur and tibia, a history of soft-tissue procedures or releases around the knee, significant preoperative ligamentous instability requiring increased constraint, and absence of signed consent. A total of 2,116 knees (1,801 patients) were included in the analysis (Figure 1). Baseline characteristics and radiological data for the cohort are presented in Table I. The Triathlon Total Knee System (Stryker) was implanted, using cruciate-retaining components in most cases. If the posterior cruciate ligament (PCL) was incompetent, a posterior-stabilized (PS) prosthesis was used instead. These PS cases were included in the analysis, as PCL resection has been shown to have minimal impact on extension balance.[15]

Surgical technique

Preoperative CT imaging with rendering and segmentation was obtained as part of standard planning to develop a 3D bone model for each patient. This allowed determination of the lateral distal femoral angle (LDFA) and medial proximal tibial angle (MPTA). A detailed description of how the LDFA and MPTA are measured on CT has been published previously.[16] The LDFA and MPTA were then used to calculate the aHKA (MPTA − LDFA), JLO (MPTA + LDFA), and CPAK types. The CPAK classification categorizes knees into nine constitutional phenotypes,[8] and allows surgeons to estimate the patient's pre-arthritic alignment. Importantly, it also serves as a universal template for comparing and evaluating alignment strategies.[13,17,18]

The surgical technique of Clark et al[4] provides a detailed description and rationale for individualized FA.[4] Intraoperatively, after verifying that the bone morphology and position were consistent with the preoperative CT plan, implants were virtually positioned with matched resections. This is the unrestricted KA start plan, which defined the KA of the knee. Next, predefined boundary restrictions were applied to the LDFA and MPTA (the restricted KA start plan), and maximum stressed medial and lateral gap laxities were measured in 10° extension and 90° flexion. These boundaries, detailed in Table II, have been shown to capture 85.4% of native alignment types.[19] Virtual implant position was then adjusted within the boundaries, aiming for equal extension gaps (lateral = medial) and equal medial sagittal gaps (medial extension = medial flexion) to preserve medial collateral ligament isometry. The lateral flexion gap was maintained at its constitutional laxity, which in most cases was equal or greater than the lateral extension gap. Compartmental gap differentials ≤ 2.0 mm were accepted, but anything greater required soft-tissue release. The virtual implant angles were then recorded as the final FA position.

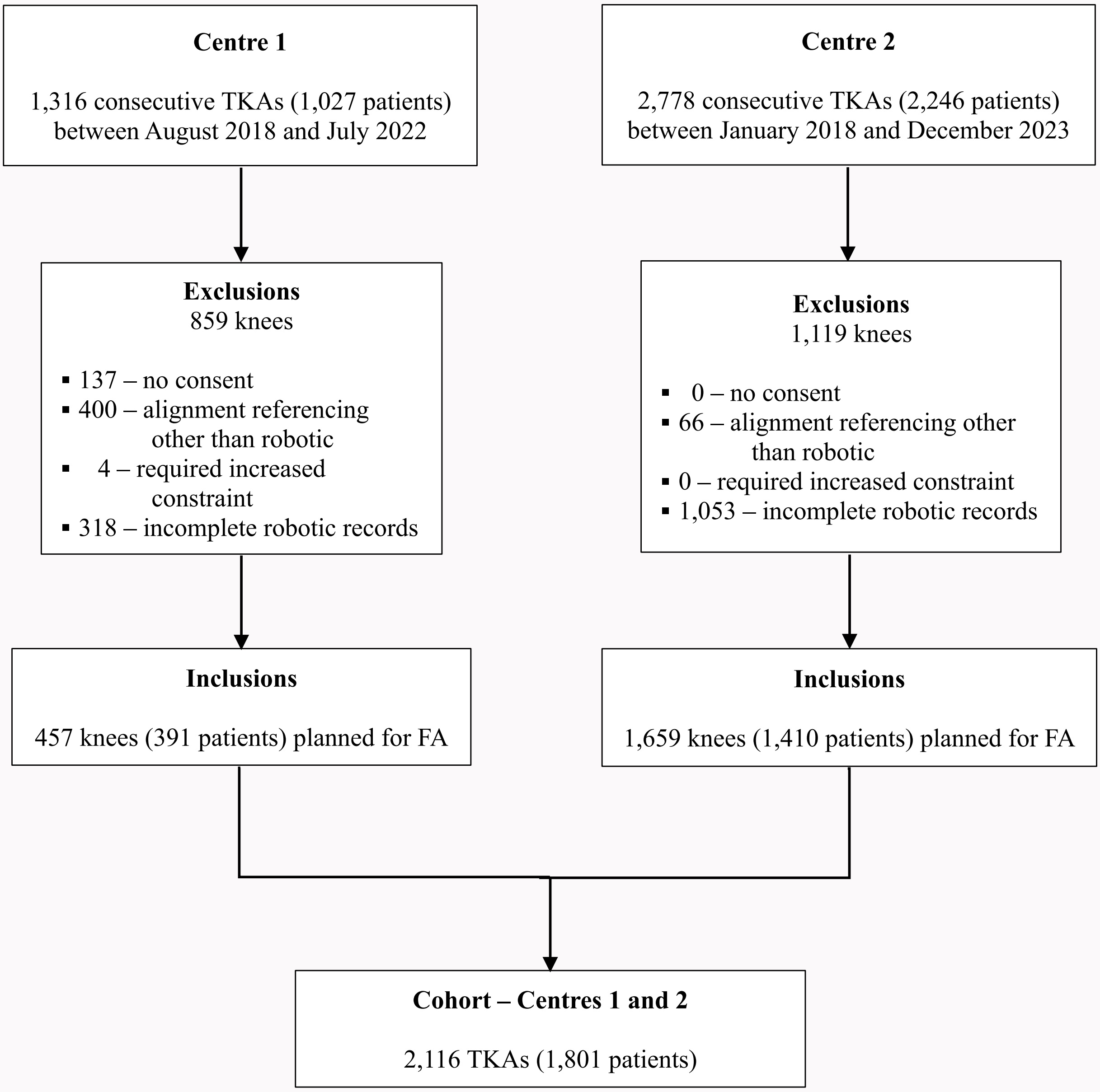

Fig. 1
Study flowchart. FA, functional alignment; TKA, total knee arthroplasty.

Outcomes

The primary outcome compared the proportion of knees in KA to those in FA that were ≤ 2° different in aHKA and ≤ 3° in JLO, and determined the direction and magnitude of the differences per CPAK phenotype. These aHKA and JLO boundaries are based on fundamental CPAK boundary definitions, and reflect one standard deviation (SD) from the phenotype means.[13] Secondary outcomes included the proportion of knees that maintained their original CPAK phenotype, and any differences in aHKA change, JLO change, and CPAK distribution between sexes with FA.

Statistical analysis

Due to the rarity of CPAK Types VII to IX, these phenotypes were excluded from the primary analysis. All continuous data were presented as means (SD) and discrete data as frequencies with percentages. Normality of data distribution was assessed using histograms, Q-Q plots, and the Shapiro-Wilks test for group sizes < 50 and Kolmogorov-Smirnov test for group sizes ≥ 50. Differences between preoperative and postoperative groups for normally distributed continuous data were analyzed with paired *t*-tests, and with Wilcoxon signed-rank tests for non-parametric continuous data. Differences between groups for categorical data were analyzed with chi-squared tests. Level of statistical significance was set at $p \leq 0.05$. Statistical analyses were performed using SPSS Statistics v. 27 (IBM, USA).

Results

CPAK Types I (31.0% and 44.8%) and II (44.1% and 40.4%) were the most common types both preoperatively and postoperatively, respectively. The preoperative and postoperative CPAK distribution are presented in Figure 2.

Table I. Baseline characteristics.

Variable	Value
Number of knees (patients)	2,116 (1,801)
Mean age, yrs (SD)	67.9 (8.5)
Mean BMI, kg/m^2 (SD)	30.8 (5.7)*
Female sex, n (%)	1,101 (52.0)
Laterality, left, n (%)	1,015 (48.0)
Mean kinematic angles, ° (SD)	
LDFA	87.5 (2.0)
MPTA	86.4 (2.1)
aHKA	-1.1 (2.8)
JLO	173.9 (3.0)

*BMI was available for 97.9% (2,071 patients).
aHKA, arithmetic hip-knee-ankle angle; JLO, joint line obliquity; LDFA, lateral distal femoral angle; MPTA, medial proximal tibial angle.

Table II. Functional alignment boundaries (capturing 85.4% of native phenotypes).

Parameters	Boundaries for FA protocol
Coronal alignment	HKA angle: 6.0° varus to 3.0° valgus Tibial coronal: 6.0° varus to 3.0° valgus Femoral coronal: 6.0° valgus to 3.0° varus
Femoral rotation	6.0° internal to 6.0° external rotation from the sTEA
Tibial rotation	Akagi's line
Femoral flexion	0 to 7.0° to optimize sizing
Tibial slope	0 to 7.0° to match LTP slope
Combined component flexion	Not to exceed 10.0°

FA, functional alignment; HKA, hip-knee-ankle angle; LTP, lateral tibial plateau; sTEA, surgical transepicondylar axis.

Primary outcome

Overall, 71.6% had an aHKA change≤ 2° and 87.0% had a JLO change≤ 3° from KA to FA position. The mean aHKA changed from -1.1° (SD 2.8°) varus in KA to -1.9° (SD 2.3°) varus in FA (mean difference (MD) -0.83, SD 2.0; p < 0.001, paired *t*-test), and the mean JLO changed from 173.9° (SD 3.0°) in KA to 174.2° (SD 2.6°) in FA (MD 0.38, SD 2.3; p < 0.001, paired *t*-test). Figure 3 and Figure 4 present the proportions and mean changes for each CPAK type. JLO was maintained in the majority of CPAK types. The aHKA was maintained to a similar degree across CPAK types with FA, except for CPAK Types III and VI.

Secondary outcomes

Overall, 1,229 (58.1%) of knees maintained their CPAK phenotype with FA. This proportion was highest for CPAK Types I (n = 485, 73.9%), II (n = 579, 61.1%), and IV (n = 44, 51.2%). However, the majority of valgus CPAK Types III (n = 129, 67.5%) and VI (n = 33, 71.7%) were shifted to neutral phenotypes, with insignificant changes to JLO across the six CPAK types. An overview of the alignment changes for each CPAK type is presented in Table III and Figure 5. Table IV shows the postoperative CPAK distribution for each of the constitutional CPAK phenotypes. Only 0.1% of the entire cohort (n = 3) had a postoperative apex proximal JLO.

The mean aHKA in females changed from -0.68° (SD 2.8°) varus in KA to -1.6° (SD 2.3°) varus in FA (MD -0.93, SD 2.1; p < 0.001, paired *t*-test), and in males from -1.5° (SD 2.8°) varus in KA to -2.2° (SD 2.2°) varus in FA (MD -0.73, SD 2.0; p < 0.001, paired *t*-test). The mean JLO in females changed from 173.7° (SD 3.0°) to 174.1° (SD 2.6°) (MD 0.45, SD 2.3; p < 0.001, paired *t*-test), and in males from 174.1° (SD 3.1°) to 174.4° (2.7°) (MD 0.31, SD 2.2; p < 0.001, paired *t*-test). Preoperative and postoperative distribution of CPAK types across sexes is presented in Figure 6.

Discussion

This is the first study to evaluate phenotype changes in knee alignment in patients undergoing robotic FA TKA. Overall, a FA strategy resulted in minimal changes to JLO (87.0% had≤ 3° change) and aHKA (71.6% had≤ 2° change), and 1,229 (58.1%) of knees maintained their CPAK type. Importantly, across the primary six CPAK types, JLO was not significantly altered, which is a key objective of FA. Maintenance of CPAK type was most pronounced in constitutional varus (CPAK Types I and IV) and neutral (CPAK Types II and V) coronal alignments. However, constitutional valgus alignments (CPAK Types III and VI) shifted horizontally into neutral coronal alignment.

Previously, conflicting results have been reported when comparing personalized and fixed alignment strategies in terms of clinical outcomes.[20–24] However, when looking more closely at alignment subgroups, several differences have been demonstrated. Restoration of JLO and varus alignment are associated with a positive effect on clinical outcomes in patients with constitutional varus.[25–28] Also, a significant positive correlation has been reported between postoperative neutral limb alignment and patient-reported outcomes in patients with constitutional neutral and valgus alignment.[29] In the present study, patients with constitutional varus and neutral coronal alignment were more commonly restored to their CPAK type with FA, while patients with valgus alignment were more often realigned to a more neutral coronal alignment (while still maintaining their JLO). It remains unclear whether a preference for achieving balanced gaps (as in FA) versus retaining native laxities (as in unrestricted KA) will result in different outcomes.

Knees with a constitutional apex proximal JLO (CPAK Types VII to IX) are extremely rare (< 1%),[13,30,31] a statistic that was confirmed in this study cohort (< 1%). Corban et al[32] reported that a MA strategy resulted in a substantial proportion of patients (11.1%) with an unintentional postoperative apex proximal JLO. Because restoration of joint line is so sensitively tied to satisfaction,[25] it is possible that this increase in JLO may contribute to a higher dissatisfaction rate in TKA,[33] making the knee feel 'unnatural'. In the present

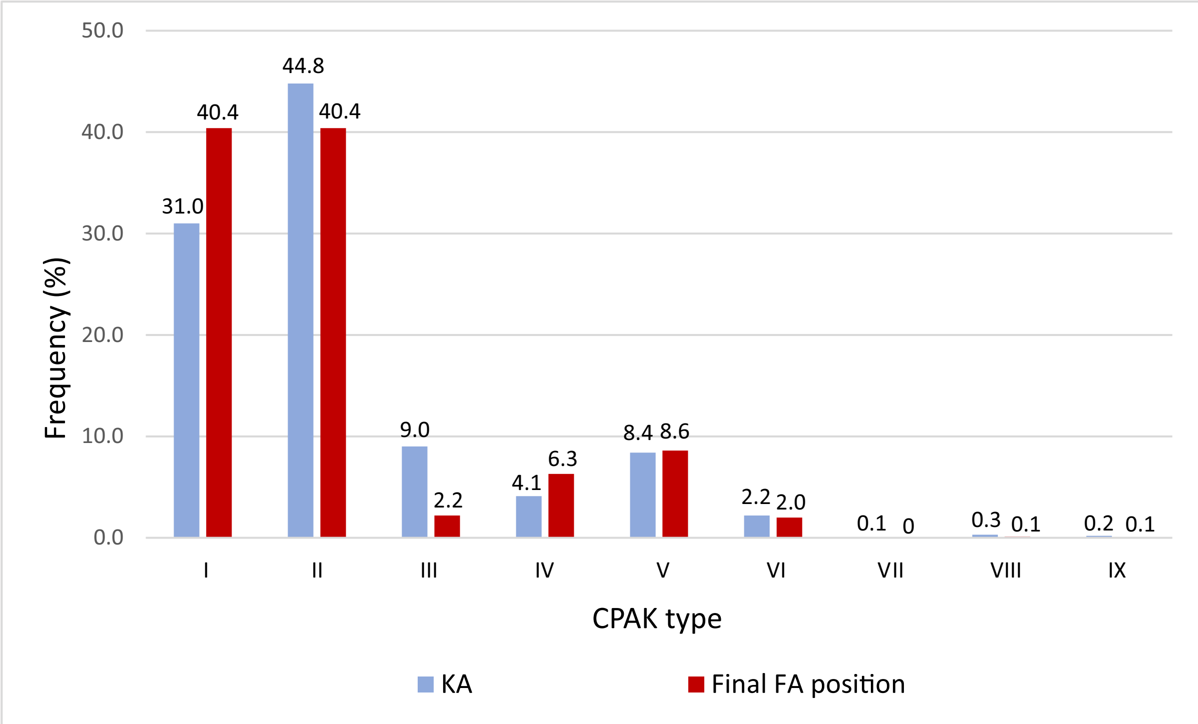

Fig. 2
Frequency of Coronal Plane Alignment of the Knee (CPAK) type distribution for kinematic alignment (KA) and final functional alignment (FA) positions.

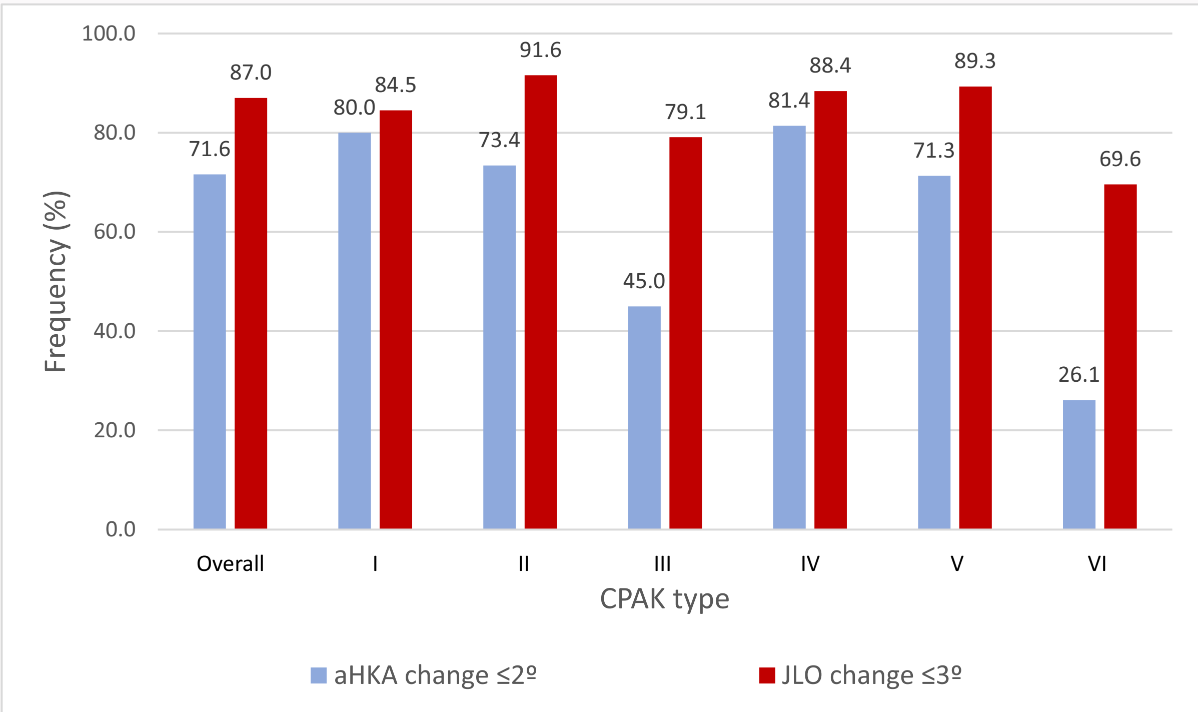

Fig. 3
Proportion of arithmetic hip-knee-ankle angle (aHKA) change ≤ 2° and joint line obliquity (JLO) change ≤ 3° overall per Coronal Plane Alignment of the Knee (CPAK) type.

study, only 0.1% (n = 3) had a postoperative apex proximal JLO (CPAK Types VII to IX), reflecting expected proportions among native phenotypes and highlighting both the precision and accuracy of robotic-assisted TKA with FA in preventing significant changes to constitutional JLO.

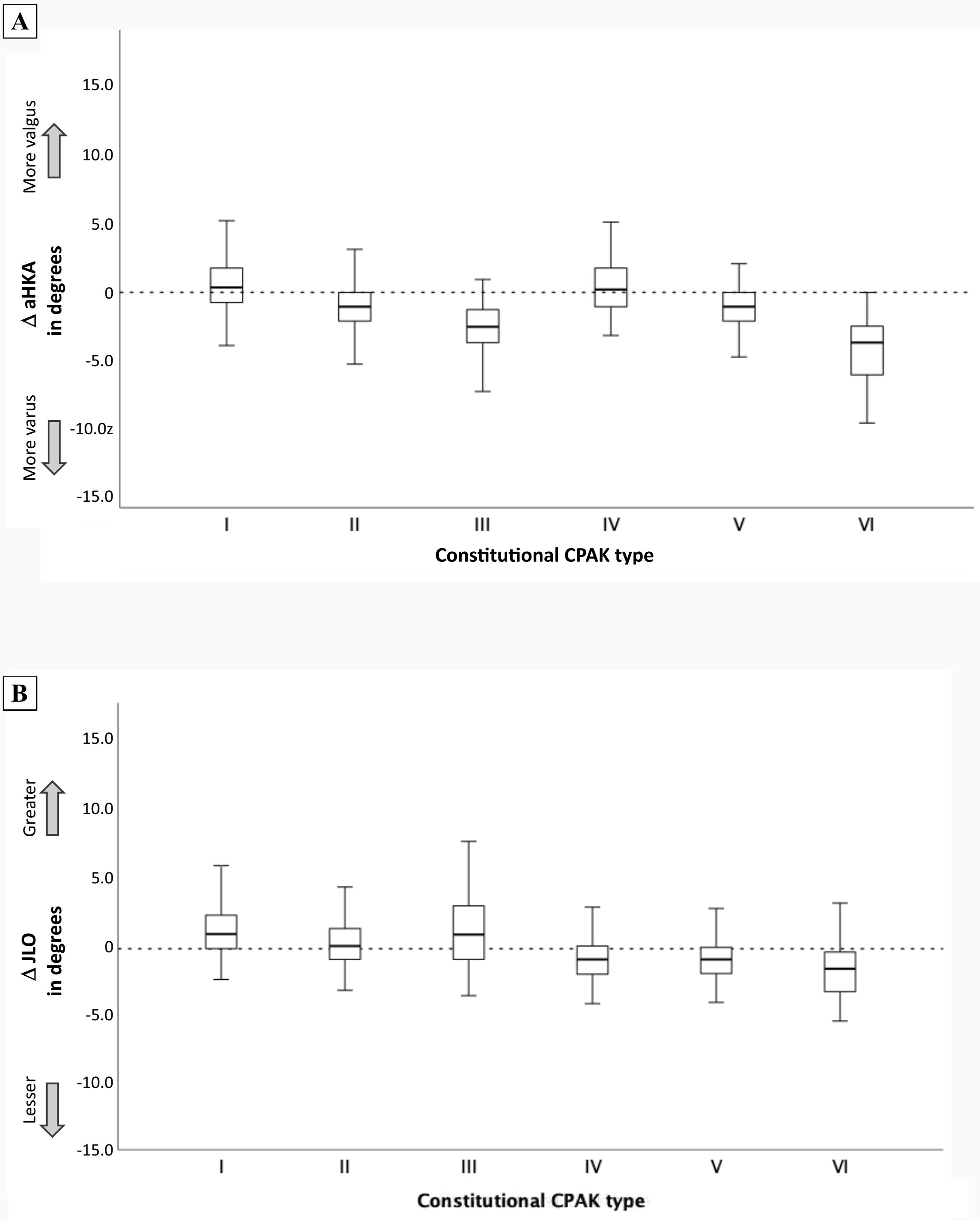

Fig. 4

Mean changes in a) arithmetic hip-knee-ankle angle (aHKA) and b) joint line obliquity (JLO) from kinematic alignment (KA) to final functional alignment (FA) position, per Coronal Plane Alignment of the Knee (CPAK) type. Whiskers are 95% CIs.

This is also the first study that has compared the alignment alterations between sexes after FA TKA. The absolute change in both aHKA and JLO in this study was found to be similar in females and males (although males started with 0.8° more varus than females). Therefore, alignment alterations from a kinematic position do not differ between sexes with FA. Several studies have examined alignment differences between sexes. All, including ours, have found males to have greater constitutional varus than females,[34,35] with CPAK Type II being the most common type among both males and females. The overall proportion of varus knees reported in the literature (33.7% to 68.5% in males and 19.7% to 50.8% in females) was similar to our results (40.4% in males and 30.2% in females). However, the proportion of valgus knees (11.8% to 17.2% in males and 25.8% to 34.1% in females) is higher in the literature than in our results (8.9% in males and 10.4% in females).[31,36] It is important to note that this study was CT-based, whereas most previous studies used long-leg radiographs. Plain radiological analysis has been shown to underestimate the degree of constitutional JLO compared to CT, and this needs to be considered in the context of these new findings.[16]

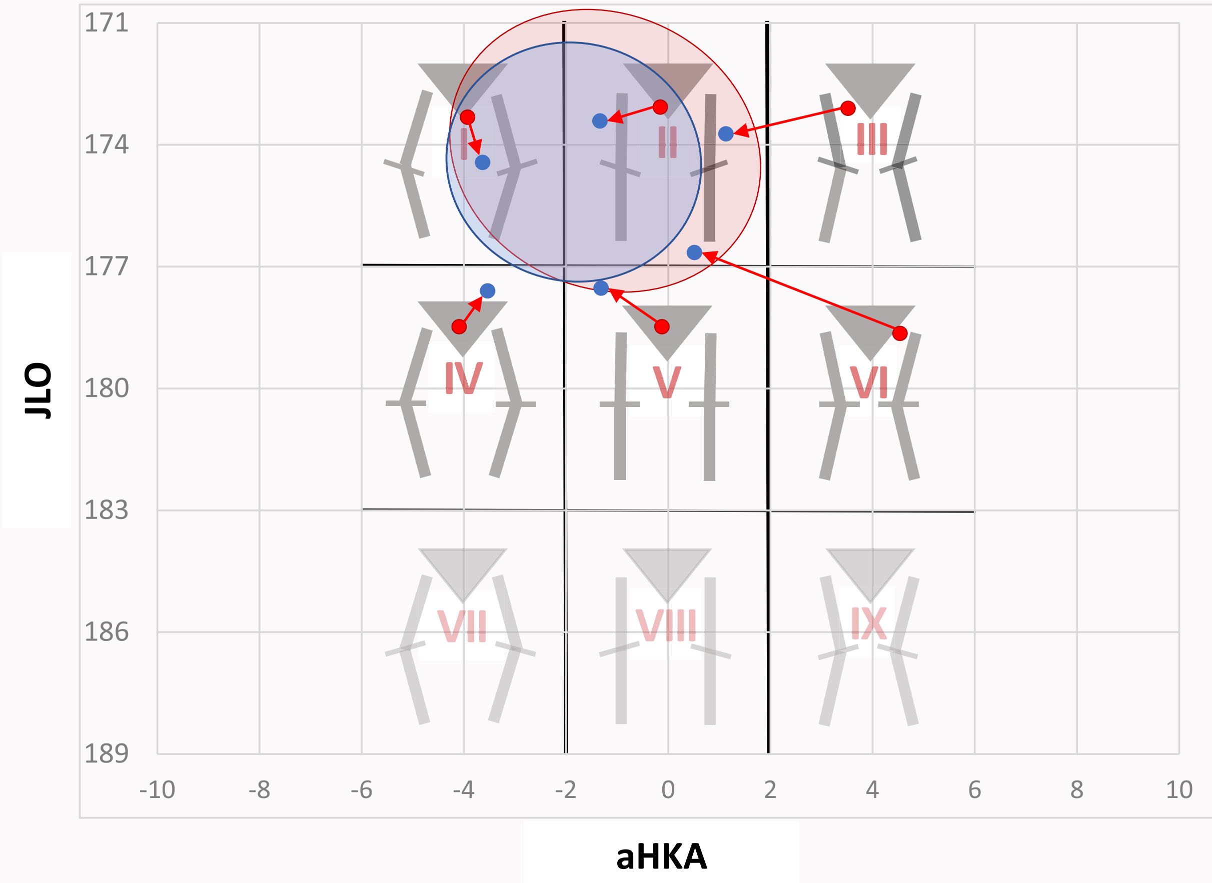

Fig. 5

Mean changes from kinematic alignment (KA) to final functional alignment (FA) position for Coronal Plane Alignment of the Knee (CPAK) Types I to VI. KA position means across all CPAK types for the full cohort (n = 2,116; 95% CI). The light red circle indicates the KA position across all CPAK types for the full cohort (n = 2,116; 95% CI). The light blue circle indicates the final FA position across all CPAK types for the full cohort (n = 2,116; 95% CI). The small red circles indicate the KA point for each CPAK type. The small blue circles indicate the final FA point for each CPAK type. The red arrows indicate the size and direction of changes from KA to final FA positions. aHKA, arithmetic ankle-hip-knee angle; JLO, joint line obliquity.

Table III. Alignment changes from kinematic alignment to final functional alignment position.

		LDFA, °		MPTA, °		aHKA, °		JLO, °	
CPAK type	Constitutional proportion, n (%)	Mean KA (SD)	Mean final FA position (SD)	Mean KA (SD)	Mean final FA position (SD)	Mean KA (SD)	Mean final FA position (SD)	Mean KA (SD)	Mean final FA position (SD)
Overall	2,116 (100)	87.5 (2.0)	88.1 (1.7)	86.4 (2.1)	86.2 (1.8)	-1.1 (2.8)	-1.9 (2.3)	173.9 (3.0)	174.2 (2.6)
I	656 (31.0)	88.5 (1.3)	89.0 (1.3)	84.6 (1.4)	85.3 (1.3)	-3.9 (1.5)	-3.7 (1.6)	173.1 (2.3)	174.3 (1.9)
II	947 (44.8)	86.6 (1.3)	87.3 (1.3)	86.3 (1.3)	86.0 (1.6)	-0.2 (1.2)	-1.3 (1.8)	172.9 (2.3)	173.3 (2.3)
III	191 (9.0)	84.7 (1.4)	86.3 (1.4)	88.3 (1.4)	87.4 (1.7)	3.6 (1.7)	1.1 (1.5)	173.0 (2.1)	173.7 (2.7)
IV	86 (4.1)	91.3 (1.2)	90.6 (1.2)	87.2 (1.1)	87.0 (1.5)	-4.1 (1.8)	-3.6 (1.7)	178.5 (1.4)	177.6 (2.2)
V	178 (8.4)	89.3 (0.9)	89.4 (1.1)	89.2 (0.9)	88.1 (1.5)	-0.1 (1.2)	-1.3 (1.8)	178.5 (1.3)	177.5 (2.0)
VI	46 (2.2)	87.2 (1.0)	88.0 (1.3)	91.5 (1.7)	88.7 (1.9)	4.3 (2.2)	0.6 (2.0)	178.7 (1.8)	176.7 (2.6)
VII	1 (0.1)	97.5 (N/A)	92.0 (N/A)	86.5 (N/A)	88.0 (N/A)	-11.0 (N/A)	-4.0 (N/A)	184.0 (N/A)	180.0 (N/A)
VIII	7 (0.3)	92.5 (0.9)	92.1 (1.0)	92.8 (0.7)	87.6 (1.2)	0.3 (1.0)	-4.5 (1.5)	185.3 (1.3)	179.7 (1.7)
IX	4 (0.2)	88.8 (1.9)	90.3 (1.7)	95.5 (2.1)	87.5 (2.9)	6.7 (3.8)	-2.8 (3.9)	184.3 (1.1)	177.8 (2.6)

aHKA, arithmetic hip knee-ankle angle; CPAK, Coronal Plane Alignment of the Knee; FA, functional alignment; JLO, joint line obliquity; KA, kinematic alignment; LDFA, lateral distal femoral angle; MPTA, medial proximal tibial angle; N/A, not applicable.

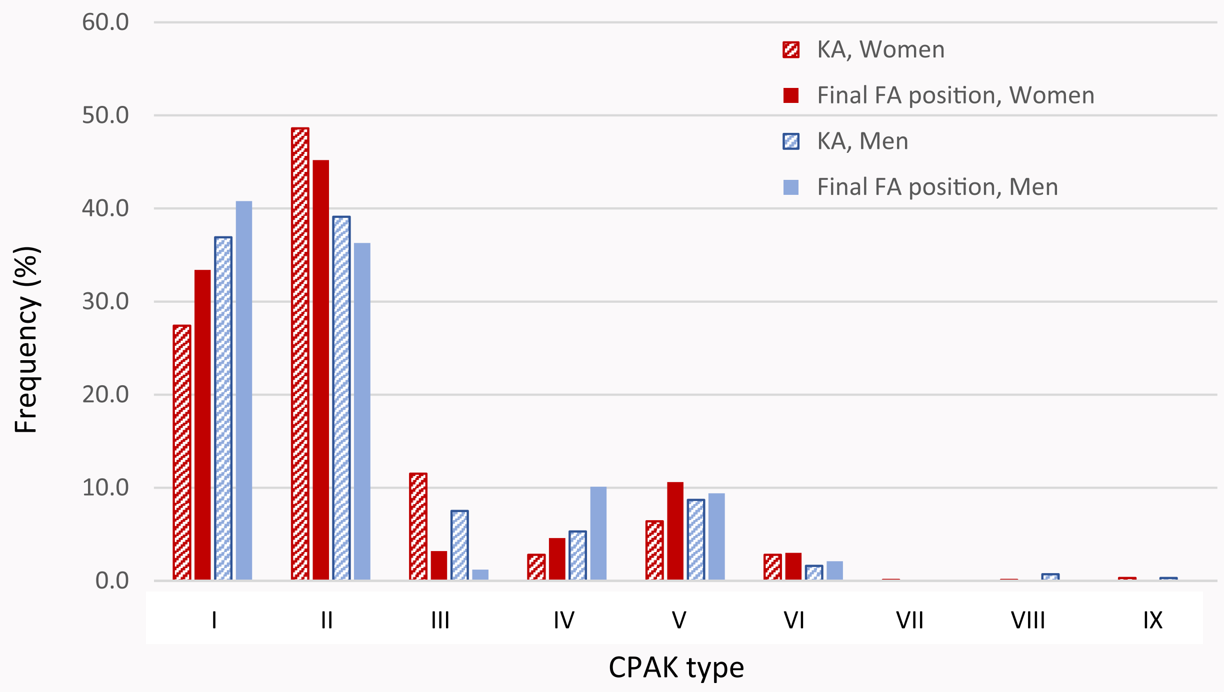

Fig. 6
Coronal Plane Alignment of the Knee (CPAK) distribution for kinematic alignment (KA) and final functional alignment (FA) position, by sex.

Table IV. Constitutional versus final Coronal Plane Alignment of the Knee distribution after functional alignment total knee arthroplasty.

Constitutional CPAK type	Final CPAK type after FA implant positioning, %								
	I	II	III	IV	V	VI	VII	VIII	IX
I n = 656	73.9	15.4	0	7.0	3.7	0	0	0	0
II n = 947	31.8	61.1	1.1	0.6	4.3	1.1	0	0	0
III n = 191	3.1	61.3	17.8	0	6.3	11.5	0	0	0
IV n = 86	30.2	3.5	1.2	51.2	12.8	0	0	1.2	0
V n = 178	19.1	20.2	0.6	14.0	44.4	1.1	0	0	0.6
VI n = 46	4.3	39.1	2.2	4.3	30.4	17.4	0	2.2	0

Blue cells indicate the proportion of knees that maintained their constitutional CPAK phenotypes after FA.
CPAK Types VII to IX have been excluded from the first column of this table due to the low constitutional frequency (n = 1, n = 7, n = 4, respectively).
CPAK, Coronal Plane Alignment of the Knee; FA, functional alignment.

Understanding the valgus-to-neutral change in limb alignment

The present study showed that patients with valgus phenotypes (CPAK Types III and VI) shifted horizontally into a more neutral alignment, with a final aHKA of 1.1° and 0.6°, for CPAK Types III and VI, respectively. Similar changes with FA have been reported by Clark et al,[25] with fewer CPAK Type III knees with FA. There are several possible explanations for this finding.

First, after accounting for a patient's bony alignment, final implant orientation is defined by the patient's soft-tissue profile. This alignment shift is contingent upon the lateral soft-tissue laxity being equivalent to, or greater than, the medial laxity in near-extension. This has been substantiated by several in vivo and in vitro studies,[37–41] all reporting a more pronounced lateral compared to medial joint opening when a load is applied in near-extension. Near-extension, as opposed to full extension, alleviates tension from the posterior capsule and mitigates the effect of posterior osteophytes. Despite this, constitutional coronal laxity in normal individuals remains poorly understood, and to date, consensus on normative values is absent. This truism is an example of the complex and highly variable nature of knee alignment and soft-tissue balance.

Second, the unrestricted KA position, considered by many to represent constitutional alignment of the knee once chondral loss is accounted for, is unlikely to represent that actual pre-arthritic state. Bone remodelling occurs in moderate degrees of OA, while secondary bone loss eventuates in later stages. Although we consider CPAK-defined alignment as the best current method to estimate the pre-arthritic state, the precision of this estimate reduces as the arthritic process advances, a fact that may also contribute to differences between KA and final FA position. Ultimately, future modelling techniques that can account for morphological bone changes may improve our understanding in this area.

Third, with the restricted boundaries used in the present study, a small alteration to aHKA will convert these knees into neutral CPAK types, as the boundary for these is 2°. It is therefore essential to further define normative laxity values and address potential variations among different patient characteristics (e.g. knee phenotype, sex, age) for a more individualized approach to TKA.

This study has limitations, primarily the fact that CPAK does not consider sagittal or axial alignment. A recent study was unable to demonstrate a relationship between axial or sagittal alignment to CPAK type, and we therefore believe CPAK is at present an appropriate framework to report alignment changes.[42] Although CT imaging was used for the measurement of the alignment parameters, which is more reliable compared to long-leg radiographs,[16] certain conditions, such as bone remodelling and bone loss, can still affect measurement precision and determination of the individualized constitutional alignment. Furthermore, this was a radiological analysis without the associated gait analysis, patient-reported outcomes, and survival data that may further inform the effectiveness of this alignment strategy over other techniques. Future research should focus on validating these CT findings with gait studies, patient-reported outcomes, and survival analyses. Finally, we analyzed two populations originating in the same country. These results may not be generalizable to other regions, as geographical differences in alignment have been well documented.[30]

This study provides valuable insight into the ways in which soft-tissue laxities alter implant position when performing FA TKA, specifically differences between CPAK types. Additionally, functional alignment may alter CPAK type, but it does not significantly change JLO. Patients with constitutional varus phenotypes (CPAK Types I and IV) and neutral phenotypes (CPAK Types II and V) maintained their CPAK category, while patients with constitutional valgus (CPAK Types III and VI) were aligned to a more neutral coronal alignment, but again without significant changes to JLO.

The advantage of a tailored approach to both the patient's constitutional anatomy and laxity profile is avoidance of soft-tissue releases and JLO alterations that pre-resection balancing affords. KA should be considered as a baseline reference to minimizing changes to native anatomy, while a final position achieved by FA provides an optimally balanced TKA. This combined strategy may be considered a safe compromise between an unrestricted KA and a fixed MA approach.

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Data sharing

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