Pre- and postoperative Coronal Plane Alignment of the Knee classification and its impact on clinical outcomes in total knee arthroplasty

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Aims

The Coronal Plane Alignment of the Knee (CPAK) classification has been developed to predict individual variations in inherent knee alignment. The impact of preoperative and postoperative CPAK classification phenotype on the postoperative clinical outcomes of total knee arthroplasty (TKA) remains elusive. This study aimed to examine the effect of postoperative CPAK classification phenotypes (I to IX), and their pre- to postoperative changes on patient-reported outcome measures (PROMs).

Methods

A questionnaire was administered to 340 patients (422 knees) who underwent primary TKA for osteoarthritis (OA) between September 2013 and June 2019. A total of 231 patients (284 knees) responded. The Knee Society Score 2011 (KSS 2011), Knee injury and Osteoarthritis Outcome Score-12 (KOOS-12), and Forgotten Joint Score-12 (FJS-12) were used to assess clinical outcomes. Using preoperative and postoperative anteroposterior full-leg radiographs, the arithmetic hip-knee-ankle angle (aHKA) and joint line obliquity (JLO) were calculated and classified based on the CPAK classification. To investigate the impact on PROMs, multivariable regression analyses using stepwise selection were conducted, considering factors such as age at surgery, time since surgery, BMI, sex, implant use, postoperative aHKA classification, JLO classification, and changes in aHKA and JLO classifications from preoperative to postoperative.

Results

The preoperative and postoperative CPAK classifications were predominantly phenotype I (155 knees; 55%) and phenotype V (73 knees; 26%), respectively. The change in the preoperative to postoperative aHKA classification was a significant negative predictive factor for KOOS-12 and FJS-12, while postoperative apex proximal JLO was a significant negative predictive factor for KSS 2011 and KOOS-12.

Conclusion

In primary TKA for OA, preoperative and postoperative CPAK phenotypes were associated with PROMs. Alteration in varus/valgus alignment from preoperative to postoperative was recognized as a negative predictive factor for both KOOS-12 and FJS-12. Moreover, the postoperative apex proximal JLO was identified as a negative factor for KSS 2011 and KOOS-12. Determining the target alignment for each preoperative phenotype with reproducibility could improve PROMs.

Cite this article: ***Bone Joint J*** **2024;106-B(10):1059–1066.**

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doi:10.1302/0301-620X.106B10.
BJJ-2023-1425.R1 $2.00

Bone Joint J
2024;106-B(10):1059–1066.

Introduction

Total knee arthroplasty (TKA) has demonstrated a long-term success rate of approximately 96%.[1] However, patient satisfaction has remained at approximately 80%.[2] Traditionally, the surgical approach for TKA has utilized a mechanical

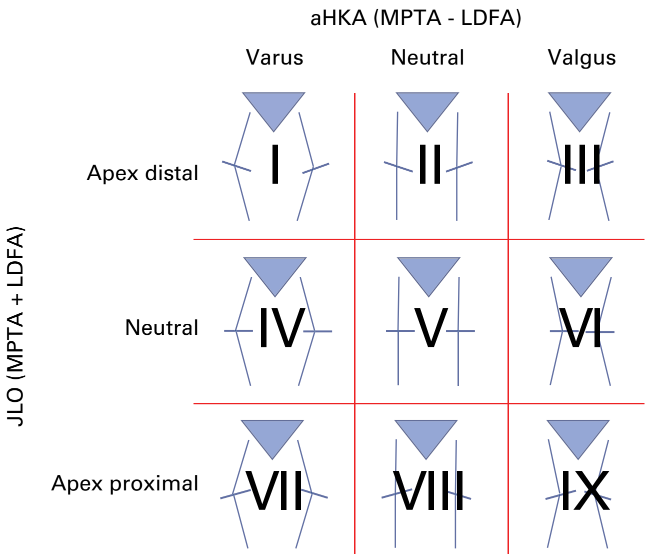

Fig. 1

Diagram of the Coronal Plane Alignment of the Knee classification, developed by MacDessi et al.[14] aHKA, arithmetic hip-knee-ankle angle; JLO, joint line obliquity; LDFA, lateral distal femoral angle; MPTA, medial proximal tibial angle.

Table I. Patient characteristics and postoperative patient-reported outcomes.

Variable	Data
Patients, n	231
Knees, n	284
Mean age at surgery, yrs (SD)	74.0 (8.0)
Sex, n of knees	
Female	238
Male	46
Mean BMI, kg/m^2 (SD)	26.7 (4.4)
Kellgren-Lawrence grade, n of knees	
3	89
4	195
Mean postoperative time interval to response, mths (SD)	55 (24)
Implant, n	
Persona PS	150
Journey II BCS	134
Mean PROM (SD)	
KSS 2011*	127 (33)
KOOS-12†	71 (20)
FJS-12†	50 (26)

*0 to 180.
†0 to 100.
FJS-12, Forgotten Joint Score-12; KOOS-12, Knee injury and Osteoarthritis Outcome Score-12; KSS 2011, Knee Society Score 2011; PROM, patient-reported outcome measure.

alignment method, targeting a hip-knee-ankle angle (HKAA) of 0° (neutral alignment).[3] Neutral alignment is believed to reduce mechanical imbalance between the medial and lateral aspects of the knee joint, thereby reducing polyethylene wear and loosening.[4] However, because this neutral alignment is not always the patient's specific native anatomical alignment,[5] there is potential to create physiological imbalance in the soft-tissues. There is an ongoing debate regarding the optimal alignment to improve overall patient satisfaction.[3] In the kinematic alignment method,[6–8] which aims to replicate each patient's inherent anatomical alignment, opinions vary, with some reports indicating improved clinical outcomes compared to the mechanical alignment method,[9,10] whereas others suggest no statistically significant differences.[11–13]

The Coronal Plane Alignment of the Knee (CPAK) classification has been proposed to predict individual variations in inherent alignment.[14,15] This system allows for a classification based solely on a full-leg radiograph, categorizing knee joint varus/valgus and joint line obliquity (JLO) into three types. Using combinations of these categories, a classification from phenotype I to IX is derived (Figure 1). In the Asian population, there is a higher prevalence of varus alignment, resulting in a frequent classification into varus alignment in the CPAK classification.[16] To address this bias, the modified CPAK classification has been proposed.[17] This classification widens the range of neutral alignment of the varus/valgus and joint line compared with the original CPAK classification. There are only limited reports on the impact of pre- and postoperative changes in the original and modified CPAK classifications on patient-reported outcome measures (PROMs).[18,19]

The objectives of this study were to examine the effect of postoperative CPAK classification phenotypes (I to IX), and their pre- to postoperative changes on PROMs, and determine which is more beneficial at predicting improvement in PROMs, either the original CPAK or the modified CPAK classification. We hypothesized that there would be no difference in PROMs between cases where varus/valgus alignment did not change pre- to postoperatively and cases that achieved neutral alignment, and that postoperative apex proximal joint line orientation would lead to a decline in PROMs.

Methods

Patients. This retrospective cohort study was conducted in accordance with the STROBE statement,[20] and was approved by our facility's Institutional Review Board (IRB number 2020-425).

This study included patients undergoing primary TKA using two implants for osteoarthritis (OA) at our institution between September 2013 and June 2019. Of the 358 patients with 448 knees, seven patients (eight knees) who underwent revision surgery due to infection and 11 patients (18 knees) who died were excluded. Questionnaires were sent in April 2021 to 340 patients (422 knees) who met the inclusion criteria; 231 patients (284 knees) responded, constituting a response rate of 68% (Figure 2).

Surgical procedure. All operations were performed using the medial parapatellar approach, and a mechanical alignment method, without navigation. The Persona PS (Zimmer Biomet, USA) and Journey II BCS (Smith & Nephew, USA) cemented prostheses were used. All cases underwent patellar resurfacing.

Radiological assessment. Weightbearing anteroposterior full-leg radiographs were obtained preoperatively and postoperatively in accordance with previous studies.[21,22] The medial proximal tibial angle (MPTA) and lateral distal femoral angle (LDFA) were measured. The MPTA was defined as the medial

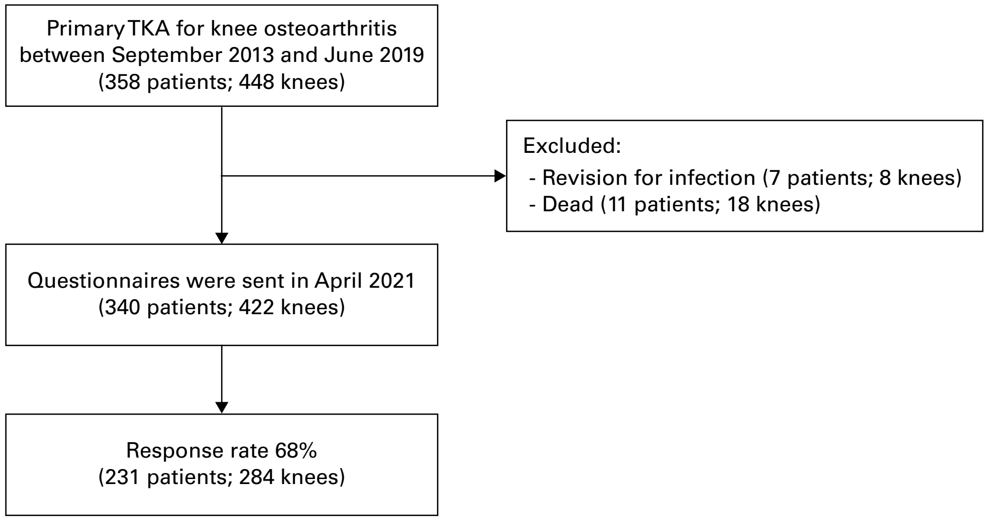

Fig. 2

Flow diagram of patient selection for the analyses. TKA, total knee arthroplasty.

angle formed between the tibial mechanical axis and the joint line of the proximal tibia, and the LDFA was defined as the lateral angle formed between the femoral mechanical axis and the joint line of the distal femur.[14] From these two parameters, the arithmetic hip-knee-ankle angle (aHKA: MPTA – LDFA) as an indicator of varus or valgus alignment and JLO (MPTA + LDFA) as an indicator of joint surface slope were calculated. Varus or valgus alignment was categorized as aHKA < -2° for varus, -2° ≤ aHKA ≤ 2° for neutral, and aHKA > 2° for valgus. JLO was classified as JLO < 177° for apex distal, 177° ≤ JLO ≤ 183° for neutral, and JLO > 183° for apex proximal. Based on these criteria, cases were categorized into nine phenotypes.[14] Further classification was performed using the modified CPAK classification, which was designed to classify diverse knee joints, especially in Asian patients, who tend to have greater varus alignment.[17] In this modified classification, aHKA calculation remained the same, categorizing aHKA < -3° as varus, -3 to 3° as neutral, and ≥ 3° as valgus. The modified JLO was calculated as 90° - 0.5(LDFA + MPTA) and was classified as apex proximal for -3° or below, neutral for -3 ° to 3°, and apex distal for 3° or more.[17]

Outcomes. To assess PROMs, the Knee Society Score 2011 (KSS 2011) was used as an indicator of symptoms, satisfaction, expectations, and activity levels.[23,24] Knee injury and Osteoarthritis Outcome Score-12 (KOOS-12) was used to evaluate symptoms, pain, daily living, sports, and quality of life.[25] Forgotten Joint Score-12 (FJS-12) was used to measure the extent to which patients were aware of their knees during daily activities.[26]

Statistical analysis. Continuous data are presented as means and SD. Statistical analyses were conducted using R software (R Foundation for Statistical Computing, Austria) and JMP Pro 16.0 (SAS Institute, USA), with a significance level set at p < 0.05. Given that the data did not exhibit a completely random missing pattern, multiple imputations were implemented using the mice 3.13.0 package (van Buuren S and Groothuis-Oudshoorn K, Netherlands), incorporating predictive mean matching.[27] To investigate the impact on PROMs, multivariable regression analyses using stepwise selection were conducted, considering factors such as age at surgery, time interval since surgery, BMI, sex, implant use, postoperative aHKA classification, JLO classification, and changes in aHKA and JLO classifications from preoperative to postoperative. Variables were added or removed based on a significance threshold of p < 0.2 in the analyses. As there were nine factors used in the multivariable analyses, a sample size of 135 or more was deemed necessary. In this study, the sample size was 284, which was considered sufficient.

Results

Table I represents the patients' characteristics and postoperative PROMs. At the time of surgery, the mean age was 74.0 years (SD 8.0), with 198 (238 knees) female and 33 (46 knees) male patients. The Persona PS and Journey II BCS prostheses were used in 150 and 134 knees, respectively. Before surgery, by the CPAK classification, phenotype I was the most common (155 knees; 55%), followed by phenotypes IV (45 knees; 16%) and II (38 knees; 13%) (Figure 3). After surgery, phenotype V was the most prevalent at 73 knees (26%), followed by II and IV at 45 knees (16%), and VI at 39 knees (14%) (Figure 4).

The mean values for KSS 2011, KOOS-12, and FJS-12 were 127 (SD 33), 71 (SD 20), and 50 (SD 26), respectively. Representative cases are shown in Figure 5.

Multivariable regression analyses using stepwise selection showed that female sex (p = 0.005) and postoperative apex proximal JLO (p < 0.001) were significant negative factors for KSS 2011. For KOOS-12, significant negative factors included postoperative apex proximal JLO (p = 0.010) and changes in varus/valgus alignment from pre- to postoperative aHKA (Table II). Female sex (p = 0.003), Persona PS (p = 0.006), and changes in varus/valgus alignment in the pre- to postoperative aHKA (p = 0.005) were negative factors for FJS-12 (Table III).

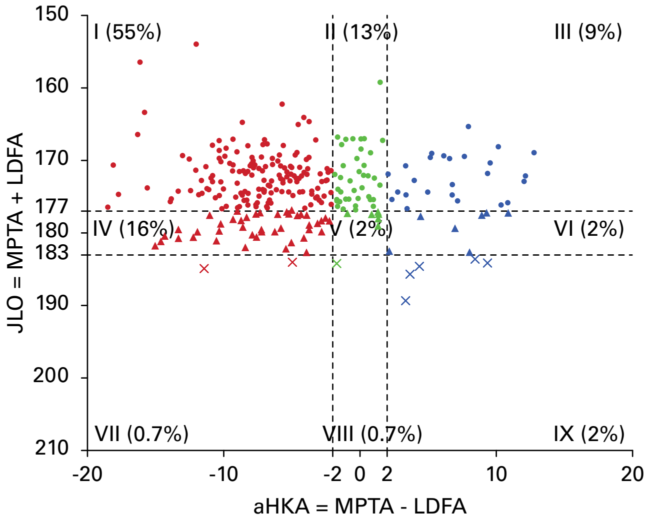

Fig. 3

Preoperative Coronal Plane Alignment of the Knee classification. aHKA, arithmetic hip-knee-ankle angle; JLO, joint line obliquity; LDFA, lateral distal femoral angle; MPTA, medial proximal tibial angle.

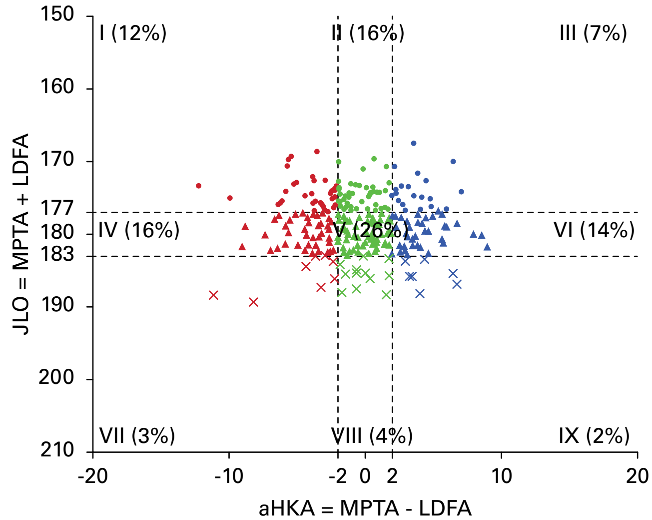

Fig. 4

Postoperative Coronal Plane Alignment of the Knee classification. aHKA, arithmetic hip-knee-ankle angle; JLO, joint line obliquity; LDFA, lateral distal femoral angle; MPTA, medial proximal tibial angle.

Comparing postoperative CPAK V and other phenotypes, there were no significant differences observed in mean KSS 2011 ($p = 0.994$), KOOS-12 ($p = 0.772$), and FJS-12 ($p = 0.856$, all Mann-Whitney U test) between the two groups. In cases without changes in pre- to postoperative aHKA and avoiding postoperative apex proximal JLO, mean KSS 2011 ($p = 0.030$), KOOS-12 ($p = 0.005$), and FJS-12 ($p = 0.019$, all Mann-Whitney U test) were all significantly higher (Table II).

As additional verification, multivariable analyses using the modified CPAK classification were performed. For KSS 2011, older age ($p = 0.046$), female sex ($p = 0.005$), and postoperative apex proximal modified JLO ($p = 0.010$) were significant negative factors. Regarding KOOS-12, no significant negative factors were detected. For FJS-12, female sex ($p = 0.005$) and the use of Persona PS ($p = 0.014$) were significant negative factors (Table IV).

Discussion

This is the first study to examine the influence of postoperative CPAK classification phenotypes and their changes from pre- to postoperative on postoperative PROMs. We have demonstrated that changes in the preoperative to postoperative aHKA classification and postoperative JLO influenced the outcomes.

In our study, preoperative CPAK classification showed that phenotype I was the most prevalent (155 knees; 55%). In the initial report by MacDessi et al,[14] who first proposed the CPAK classification, for cases of OA in Australian patients, phenotype II was the most common at 32.2%, and phenotype I was the second most common at 19.4%. In their investigation on the association between knee alignment and the onset of OA, Higano et al[28] reported that varus alignment in the proximal tibia pre-existed before the onset of OA, and in patients with advanced OA, varus alignment was more common with statistical significance. A report by Toyooka et al,[16] which investigated the preoperative CPAK classification phenotype in Japanese patients, indicated a high prevalence of varus deformity, with 53.8% classified as phenotype I, consistent with the results of our study. It has been suggested that in the Japanese population, varus alignment is common and often an innate alignment, and the higher prevalence of preoperative phenotype I in varus alignment may contribute to an increased susceptibility to the development of OA.

In our study, the postoperative CPAK classification, phenotypes II, V, and VIII, representing neutral alignment in varus/valgus, were the most prevalent, accounting for a total of 130 knees (46%). The mechanical alignment method was applied in all cases, yet the intended neutral alignment was not achieved in 154 knees (54%). In a study by Matsumoto et al,[29] a postoperative HKAA deviation of 2° or more was measured in 11.4% of cases when using a robot-assisted surgery system, compared to 40% when employing manual instrumentation. Achieving the target alignment with manual instrumentation may be more challenging, suggesting that the use of computer-assisted navigation devices may be considered preferable in achieving target alignment.

Contrary to our initial assumption, the alteration in the aHKA classification before and after surgery was identified as a significant negative factor in KOOS-12 and FJS-12. Wan et al[30] reported improved FJS-12 outcomes in knees with preoperative varus, in which postoperative alignment remained varus rather than achieving neutral alignment. Elkus et al[31] reported favourable clinical outcomes in TKA for patients with valgus alignment, with a residual valgus of approximately 5° postoperatively. These findings are consistent with the results of this study. Altering the alignment of the varus/valgus preoperatively to postoperatively may lead to an increased imbalance in soft-tissue, potentially causing pain and discomfort due to instability.

Table II. Postoperative patient-reported outcomes concerning original Coronal Plane Alignment of the Knee classification.

Outcome	Postoperative CPAK phenotype V	Others	p-value*	Cases avoiding CPAK negative factors†	Others	p-value*
Mean KSS 2011 (SD)	128 (29)	126 (34)	0.994	131 (32)	124 (33)	0.030
Mean KOOS-12 (SD)	72 (18)	71 (21)	0.772	75 (21)	69 (20)	0.005
Mean FJS-12 (SD)	51 (25)	50 (27)	0.856	55 (27)	48 (25)	0.019

*Mann-Whitney U test.
†Cases avoiding postoperative apex proximal JLO and preoperative to postoperative aHKA classification changes.
aHKA, arithmetic hip-knee-ankle angle; CPAK, Coronal Plane Alignment of the Knee; FJS-12, Forgotten Joint Score-12; JLO, joint line obliquity; KOOS-12, Knee injury and Osteoarthritis Outcome Score-12; KSS 2011, Knee Society Score 2011.

Table III. Multivariable analyses of patient-reported outcomes with original Coronal Plane Alignment of the Knee classification. The variables were selected using stepwise multiple regression analyses.

Factor	Negative factor	β value (95% CI)*	p-value
KSS 2011			
Age at surgery		-0.40 (-0.87 to 0.06)	0.088
Sex	Female	-7.2 (-12 to -2.1)	0.005
Pre- to postoperative aHKA†		-1.3 (-6.3 to 1.3)	0.198
Postoperative JLO‡	Apex proximal	-3.4 (-17 to -4.7)	< 0.001
KOOS-12			
Sex		-1.8 (-6.1 to 0.3)	0.075
Pre- to postoperative aHKA†	Change before and after surgery	-1.3 (-4.9 to -0.1)	0.043
Postoperative JLO‡	Apex proximal	-2.6 (-9.3 to -1.3)	0.010
FJS-12			
Sex	Female	-3.0 (-10 to -2.2)	0.003
Implant	Persona PS	-5.3 (-9.1 to -1.5)	0.006
Pre- to postoperative aHKA†	Change before and after surgery	-4.4 (-7.4 to -1.3)	0.005
Postoperative JLO‡		-3.2 (-7.1 to 0.7)	0.108

*β value is the standard regression coefficient.
†aHKA = MPTA - LDFA (< -3°: varus; ≥ -3° and < 3°: neutral; > 3°: valgus.)
‡JLO = MPTA + LDFA (< 177°: apex distal; ≥ 177° and < 183°: neutral; > 183°: apex proximal.)
aHKA, arithmetic hip-knee-ankle angle; FJS-12, Forgotten Joint Score-12; JLO, joint line obliquity; KOOS-12, Knee injury and Osteoarthritis Outcome Score-12; KSS 2011, Knee Society Score 2011.

Table IV. Multivariable analyses of patient-reported outcomes with modified Coronal Plane Alignment of the Knee. The variables were selected using stepwise multiple regression analyses.

Factor	Negative factor	β value (95% CI)*	p-value
KSS 2011			
Age at surgery	Older age	-0.48 (-0.94 to 0.01)	0.046
Sex	Female	-7.3 (-12 to -2.3)	0.005
Implant		-5.3 (-6.7 to 0.8)	0.128
Postoperative modified JLO†	Apex proximal	-13.3 (-23 to 3.2)	0.010
KOOS-12			
Age at surgery		-0.24 (-0.54 to 0.05)	0.108
Sex		-2.9 (-6.1 to 0.35)	0.081
Implant		-2.2 (-4.6 to 0.19)	0.071
FJS-12			
Sex	Female	-5.9 (-10 to -1.8)	0.005
Implant	Persona PS	-3.8 (-6.8 to -0.8)	0.014
Pre- to postoperative modified aHKA‡		-3.6 (-9.0 to 1.8)	0.190

*β value is the standard regression coefficient.
†Modified JLO = 90° - 0.5(LDFA + MPTA) (< -3°: apex distal; ≥ -3° and < 3°: neutral; > 3°: apex proximal.)
‡Modified aHKA = MPTA - LDFA (< -3°: varus; ≥ -3° and < 3°: neutral; > 3°: valgus.)
aHKA, arithmetic hip-knee-ankle angle; FJS-12, Forgotten Joint Score-12; JLO, joint line obliquity; KOOS-12, Knee injury and Osteoarthritis Outcome Score-12; KSS 2011, Knee Society Score 2011.

As we hypothesized, the postoperative apex proximal JLO was identified as a significant negative predictive factor for both the KSS 2011 and FJS-12. Blakeney et al[32] proposed that a postoperative apex distal joint line orientation was associated with better functional outcomes. Furthermore, Hungerford and Lennox[33] reported an apex distal physiological slope of 3°. KSS 2011 focuses on activity rather than pain,[23,24] FJS-12 addresses discomfort experienced during various activities,[26] and KOOS-12 equally evaluates pain, physical activity, and quality of life.[25] These characteristics support the findings of

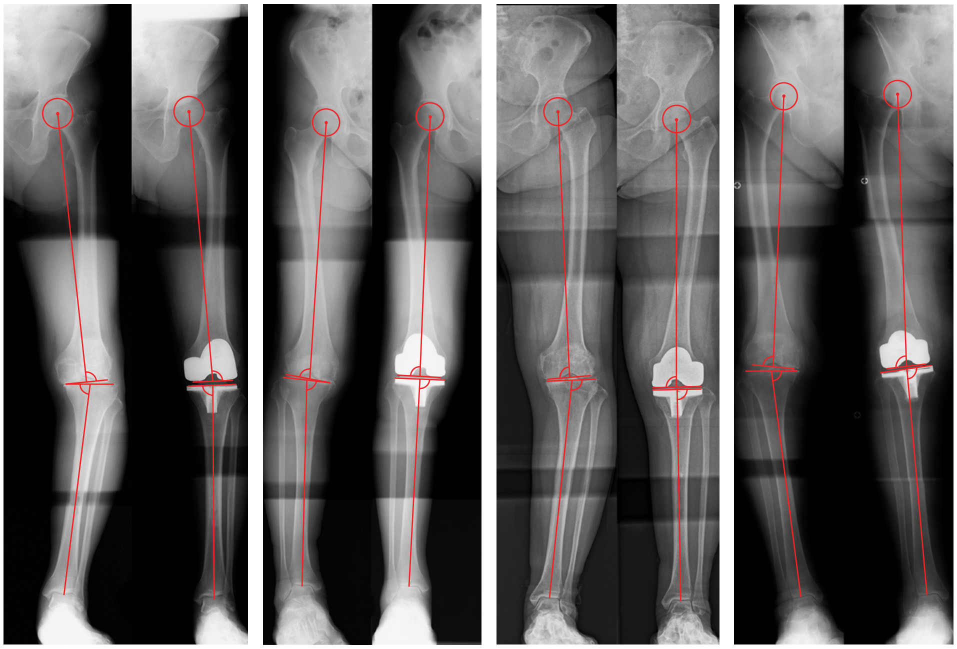

Fig. 5

Pre- and postoperative weightbearing anteroposterior full-leg radiographs of representative cases. a) Preoperative Coronal Plane Alignment of the Knee (CPAK) classification: phenotype I (varus/apex distal); postoperative CPAK classification: phenotype IV (varus/neutral). This case did not show any negative factors, including change in pre- to postoperative arithmetic hip-knee-ankle angle (aHKA) classification or postoperative apex proximal joint line obliquity (JLO). b) Preoperative CPAK classification: phenotype II (neutral/apex distal); postoperative CPAK classification: phenotype V (neutral/neutral). This case did not show any negative factors, including change in pre- to postoperative aHKA classification or postoperative apex proximal JLO. c) Preoperative CPAK classification: phenotype I (varus/apex distal); postoperative CPAK classification: phenotype V (neutral/neutral). This case showed a negative factor: change in pre- to postoperative aHKA classification. d) Preoperative CPAK classification: phenotype I (varus/apex distal); postoperative CPAK classification: phenotype VII (varus/apex proximal). This case showed a negative factor: postoperative apex proximal JLO.

our study, suggesting that the apex proximal JLO influences the decline in KSS 2011 and FJS-12 scores, both of which place greater weight on functional scores compared with KOOS-12.

Cases of postoperative CPAK type V and others showed no significant differences in PROMs. However, in cases where the factors identified as negative for CPAK were avoided, all PROMs showed a significant improvement of approximately 10%. This suggests that rather than aiming for mechanical alignment, it may be advisable to maintain the preoperative aHKA classification and avoid postoperative apex proximal JLO.

In multivariable analyses based on the modified CPAK classification, the postoperative apex proximal modified JLO was a significant negative factor for KSS 2011. However, no other significant factors related to modified CPAK were detected in these analyses. The modified CPAK classification sets the neutral range for varus/valgus at 0° ± 3°, while this is 0° ± 2° in the original CPAK classification. Preoperatively, there were many cases of significant varus, and those classified as varus in the CPAK classification were often classified as varus in the modified CPAK classification. However, there was a prevalence of mild varus postoperatively, leading to many cases in which the CPAK and modified CPAK classifications differed. To improve postoperative outcomes, planning based on the original CPAK classification rather than the modified CPAK classification may be more appropriate, even in Asian populations.

This study had several limitations. First, the postoperative time interval varied among patients. However, all cases were more than one year post surgery, and although the postoperative follow-up duration was included in the multivariable analyses, it was not a significant factor, and its impact was considered small. Second, only anteroposterior radiographs were evaluated and assessments in the sagittal and transverse planes were not conducted; this is because the primary aim of this study was to investigate the CPAK classification and coronal alignment specifically. Third, although the overall number of cases was sufficient for multivariable analyses, there were limited cases for certain phenotypes, potentially resulting in inadequate evaluations. Therefore, further studies with a larger number of cases for each phenotype are required.

In conclusion, in primary TKA for OA, the pre- and postoperative CPAK phenotype was associated with postoperative PROMs. The change in varus/valgus alignment before and after surgery was identified as a negative predictive factor for KOOS-12 and FJS-12. In addition, postoperative apex proximal JLO was a negative predictive factor for KSS 2011 and KOOS-12 scores. In cases where these negative factors were avoided, all PROMs showed a significant improvement.

Determining the target alignment for each preoperative phenotype and achieving reproducibility could lead to improvements in PROMs.

Take home message

- Maintaining consistent varus/valgus alignment from pre- to postoperative stages and avoiding postoperative apex proximal joint line obliquity are crucial for improving patient-reported outcomes in total knee arthroplasty.
- This finding underlines the importance of tailored preoperative planning based on the Coronal Plane Alignment of the Knee classification.

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References

1. **Liu C**, **Varady N**, **Antonelli B**, **Thornhill T**, **Chen AF**. Similar 20-year survivorship for single and bilateral total knee arthroplasty. *Knee*. 2022;35:16–24.
2. **Vogel N**, **Kaelin R**, **Rychen T**, **Wendelspiess S**, **Müller-Gerbl M**, **Arnold MP**. High expectations among patients who have undergone TKA do not correlate with satisfaction. *Clin Orthop Relat Res*. 2024;482(5):756–765.
3. **Rivière C**, **Iranpour F**, **Auvinet E**, **et al**. Alignment options for total knee arthroplasty: a systematic review. *Orthop Traumatol Surg Res*. 2017;103(7):1047–1056.
4. **Berend ME**, **Ritter MA**, **Meding JB**, **et al**. The Chetranjan Ranawat Award: Tibial component failure mechanisms in total knee arthroplasty. *Clin Orthop Relat Res*. 2004;428(428):26–34.
5. **Corban LE**, **van de Graaf VA**, **Chen DB**, **Wood JA**, **Diwan AD**, **MacDessi SJ**. How often do we alter constitutional limb alignment, joint line obliquity, and Coronal Plane Alignment of the Knee (CPAK) phenotype when performing mechanically aligned TKA? *Bone Jt Open*. 2024;5(2):109–116.
6. **MacDessi SJ**, **Oussedik S**, **Abdel MP**, **Victor J**, **Pagnano MW**, **Haddad FS**. The language of knee alignment: updated definitions and considerations for reporting outcomes in total knee arthroplasty. *Bone Joint J*. 2023;105-B(2):102–108.
7. **Hiranaka T**, **Suda Y**, **Saitoh A**, **et al**. Infographic: Three key elements of kinematic alignment total knee arthroplasty for clarified understanding of its approaches. *Bone Joint Res*. 2022;11(4):226–228.
8. **Hiranaka T**, **Suda Y**, **Saitoh A**, **et al**. Current concept of kinematic alignment total knee arthroplasty and its derivatives. *Bone Jt Open*. 2022;3(5):390–397.
9. **Gao Z-X**, **Long N-J**, **Zhang S-Y**, **Yu W**, **Dai Y-X**, **Xiao C**. Comparison of kinematic alignment and mechanical alignment in total knee arthroplasty: a meta-analysis of randomized controlled clinical trials. *Orthop Surg*. 2020;12(6):1567–1578.
10. **Dossett HG**, **Swartz GJ**, **Estrada NA**, **LeFevre GW**, **Kwasman BG**. Kinematically versus mechanically aligned total knee arthroplasty. *Orthopedics*. 2012;35(2):e160–9.
11. **Van Essen J**, **Stevens J**, **Dowsey MM**, **Choong PF**, **Babazadeh S**. Kinematic alignment results in clinically similar outcomes to mechanical alignment: Systematic review and meta-analysis. *Knee*. 2023;40:24–41.
12. **Shekhar A**, **Dungy D**, **Stewart SL**, **Jamali AA**. Patient-reported outcomes of kinematic vs mechanical alignment in total knee arthroplasty: a systematic review and meta-analysis of randomized controlled trials. *Arthroplast Today*. 2023;21:101127.
13. **Tran T**, **McEwen P**, **Peng Y**, **et al**. Kinematic alignment in total knee arthroplasty: a five-year prospective, multicentre, survivorship study. *Bone Jt Open*. 2022;3(8):656–665.
14. **MacDessi SJ**, **Griffiths-Jones W**, **Harris IA**, **Bellemans J**, **Chen DB**. Coronal Plane Alignment of the Knee (CPAK) classification. *Bone Joint J*. 2021;103-B(2):329–337.
15. **Nomoto K**, **Hanada M**, **Hotta K**, **Matsuyama Y**. Distribution of coronal plane alignment of the knee classification does not change as knee osteoarthritis progresses: a longitudinal study from the Toei study. *Knee Surg Sports Traumatol Arthrosc*. 2023;31(12):5507–5513.
16. **Toyooka S**, **Osaki Y**, **Masuda H**, **et al**. Distribution of Coronal Plane Alignment of the Knee classification in patients with knee osteoarthritis in japan. *J Knee Surg*. 2023;36(7):738–743.
17. **Hsu C-E**, **Chen C-P**, **Wang S-P**, **Huang J-T**, **Tong K-M**, **Huang K-C**. Validation and modification of the Coronal Plane Alignment of the Knee classification in the Asian population. *Bone Jt Open*. 2022;3(3):211–217.
18. **Sappey-Marinier E**, **Batailler C**, **Swan J**, **et al**. Mechanical alignment for primary TKA may change both knee phenotype and joint line obliquity without influencing clinical outcomes: a study comparing restored and unrestored joint line obliquity. *Knee Surg Sports Traumatol Arthrosc*. 2022;30(8):2806–2814.
19. **Streck LE**, **Faschingbauer M**, **Brenneis M**, **et al**. Individual phenotype does not impact the outcome of mechanical aligned total knee arthroplasties for valgus osteoarthritis. *Medicina (Kaunas)*. 2023;59(10):1852.
20. **von Elm E**, **Altman DG**, **Egger M**, **et al**. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. *Lancet*. 2007;370(9596):1453–1457.
21. **Bellemans J**, **Colyn W**, **Vandenneucker H**, **Victor J**. The Chitranjan Ranawat Award: Is neutral mechanical alignment normal for all patients? The concept of constitutional varus. *Clin Orthop Relat Res*. 2012;470(1):45–53.
22. **Jang SJ**, **Kunze KN**, **Brilliant ZR**, **et al**. Comparison of tibial alignment parameters based on clinically relevant anatomical landmarks: a deep learning radiological analysis. *Bone Jt Open*. 2022;3(10):767–776.
23. **Matsuda S**, **Kawahara S**, **Okazaki K**, **Tashiro Y**, **Iwamoto Y**. Postoperative alignment and ROM affect patient satisfaction after TKA. *Clin Orthop Relat Res*. 2013;471(1):127–133.
24. **Taniguchi N**, **Matsuda S**, **Kawaguchi T**, **et al**. The KSS 2011 reflects symptoms, physical activities, and radiographic grades in a Japanese population. *Clin Orthop Relat Res*. 2015;473(1):70–75.
25. **Eckhard L**, **Munir S**, **Wood D**, **et al**. The KOOS-12 shortform shows no ceiling effect, good responsiveness and construct validity compared to standard outcome measures after total knee arthroplasty. *Knee Surg Sports Traumatol Arthrosc*. 2021;29(2):608–615.
26. **Behrend H**, **Zdravkovic V**, **Giesinger J**, **Giesinger K**. Factors predicting the Forgotten Joint Score after total knee arthroplasty. *J Arthroplasty*. 2016;31(9):1927–1932.
27. **Yamate S**, **Hamai S**, **Kawahara S**, **et al**. Multiple imputation to salvage partial respondents: analysis of the Forgotten Joint Score-12 after total hip arthroplasty. *J Bone Joint Surg Am*. 2022;104-A(24):2195–2203.
28. **Higano Y**, **Hayami T**, **Omori G**, **Koga Y**, **Endo K**, **Endo N**. The varus alignment and morphologic alterations of proximal tibia affect the onset of medial knee osteoarthritis in rural Japanese women: case control study from the longitudinal evaluation of Matsudai Knee Osteoarthritis Survey. *J Orthop Sci*. 2016;21(2):166–171.
29. **Matsumoto T**, **Nakano N**, **Ishida K**, **et al**. Targeting the neutral hip-to-calcaneus axis in kinematically aligned total knee arthroplasty is feasible with fewer alignment outliers for varus osteoarthritic patients. *Knee Surg Sports Traumatol Arthrosc*. 2023;31(9):3880–3888.
30. **Wan X-F**, **Yang Y**, **Wang D**, **et al**. Comparison of outcomes after total knee arthroplasty involving postoperative neutral or residual mild varus alignment: a systematic review and meta-analysis. *Orthop Surg*. 2022;14(2):177–189.
31. **Elkus M**, **Ranawat CS**, **Rasquinha VJ**, **Babhulkar S**, **Rossi R**, **Ranawat AS**. Total knee arthroplasty for severe valgus deformity. Five to fourteen-year follow-up. *J Bone Joint Surg Am*. 2004;86-A(12):2671–2676.
32. **Blakeney W**, **Clément J**, **Desmeules F**, **Hagemeister N**, **Rivière C**, **Vendittoli P-A**. Kinematic alignment in total knee arthroplasty better reproduces normal gait than mechanical alignment. *Knee Surg Sports Traumatol Arthrosc*. 2019;27(5):1410–1417.
33. **Hungerford DS**, **Lennox DW**. Rehabilitation of the knee in disorders of the patellofemoral joint: relevant biomechanics. *Orthop Clin North Am*. 1983;14(2):397–402.

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Funding statement:
The authors disclose receipt of the following financial or material support for the research, authorship, and/or publication of this article: this study was supported by a grant from the Ogata Memorial Foundation, Inc. (No. 135) and the Medical Care Education Research, as reported by S. Hamai.

ICMJE COI statement:
S. Hamai reports a grant from the Ogata Memorial Foundation, Inc. (No. 135) and the Medical Care Education Research, related to this study. Y. Nakashima reports research grants from Zimmer Biomet, not related to this study.

Data sharing:
The data that support the findings for this study are available to other researchers from the corresponding author upon reasonable request.

Acknowledgements:
The authors would like to thank Editage (www.editage.com) for the English language editing.

Ethical review statement:
This study was approved by our Institutional Review Board (2020-425). This study was conducted in accordance with the principles of the Declaration of Helsinki.

Open access funding:
The authors report that they received open access funding for their manuscript from The Medical Care Education Research.

This article was primary edited by D. Johnstone.