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Posterior condylar offset and posterior tibial slope targets to optimize knee flexion after unicompartmental knee arthroplasty

Yong Zhi Khow[1] · Ming Han Lincoln Liow[1] · Merrill Lee[1] · Jerry Yongqiang Chen[1] · Ngai Nung Lo[1] · Seng Jin Yeo[1]

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Abstract

Purpose To evaluate the relationship between posterior tibial slope (PTS), posterior condylar offset (PCO), femoral sagittal angle (FSA) on clinical outcomes, and propose optimal sagittal plane alignments for unicompartmental knee arthroplasty (UKA).

Methods Prospectively collected data of 265 medial UKA was analysed. PTS, PCO, FSA were measured on preoperative and postoperative lateral radiographs. Clinical assessment was done at 6-month, 2-year and 10-year using Oxford Knee Score, Knee Society Knee and Function scores, Short Form-36, range of motion (ROM), fulfilment of satisfaction and expectations. Implant survivorship was noted at mean 15-year. Kendall rank correlation test evaluated correlations of sagittal parameters against clinical outcomes. Multivariable linear regression evaluated predictors of postoperative ROM. Effect plots and interaction plots were used to identify angles with the best outcomes. ($p < 0.05$) was the threshold for statistical significance.

Results There were significant correlations between PTS, PCO and FSA. Younger age, lower BMI, implant type, greater preoperative flexion, steeper PTS and preservation of PCO were significant predictors of greater postoperative flexion. There were significant interaction effects between PTS and PCO. Effect plots demonstrate a PTS between 2° to 8° and restoration of PCO within 1.5 mm of native values are optimal for better postoperative flexion. Interaction plot reveals that it is preferable to reduce PCO by 1.0 mm when PTS is 2° and restore PCO at 0 mm when PTS is 8°.

Conclusion UKA surgeons and future studies should be mindful of the relationship between PTS, PCO and FSA, and avoid considering them in isolation. When deciding on the method of balancing component gaps in UKA, surgeons should rely on the PTS. Decrease the posterior condylar cut when PTS is steep, and increase the posterior condylar cut when PTS is shallow. The acceptable range for PTS is between 2° to 8° and PCO should be restored to 1.5 mm of native values.

Level of evidence II.

Keywords Unicompartmental knee arthroplasty · Posterior tibial slope · Posterior condylar offset · Femoral sagittal angle · Correlation · Clinical outcomes · Range of motion · Component gaps

Introduction

Postoperative range of motion (ROM) is an important outcome parameter following knee arthroplasty [22, 28, 42]. This is especially so for Asian populations, that tend to require deep knee flexion in their daily activities, such as kneeling during prayers [22, 29].

Posterior tibial slope (PTS), posterior condylar offset (PCO) and femoral sagittal angle (FSA) are surgically modifiable determinants of postoperative ROM after unicompartmental knee arthroplasty (UKA) [8, 9, 11, 32]. A steeper PTS can facilitate greater flexion [16] but could result in tighter extension gaps [40]. Greater flexion in FSA can also facilitate greater knee flexion [8], but increases contact stress in the unreplaced compartment [32]. Component positioning in the sagittal plane is vital to prevent early failure in UKA [2, 32].

However, the optimal sagittal positioning remains controversial, partly because previous studies have evaluated PTS, PCO and FSA in isolation [8, 16, 32, 40]. This study aimed to propose the optimal alignment for sagittal plane

✉ Ming Han Lincoln Liow
lincoln.liow.m.h@singhealth.com.sg

[1] Department of Orthopaedic Surgery, Singapore General Hospital, 20 College Road, Academia, Level 4, Singapore 169856, Singapore

parameters in UKA by accounting for PTS, PCO and FSA alignments concurrently. We hypothesize that there is an optimal range for sagittal plane parameters that can maximize postoperative ROM.

Methods and materials

Patients

This study was approved by a Centralized Institutional Review Board (CIRB 2020/2157) and performed in accordance to the amended ethical standards laid out in the World Medical Association Declaration of Helsinki [47]. Prospectively collected data of patients who underwent primary fixed-bearing UKA at a single institution from 2004 to 2007 was reviewed. A total of 392 UKAs were performed during this period. After excluding those whose radiographs went missing when patient records went digital and PROMs of less than 2-year follow-up, 265 UKAs with complete follow up from pre operation to 10-year were available for analysis (68%). The 265 UKAs belonged to 213 patients. 52 patients had bilateral UKAs, while 161 patients had unilateral UKAs. The mean age of patients was 61.0 ± 7.6 years old, mean body mass index was 27.2 ± 4.4 kg/m^2, and 75% were females (Table 1). On latest review at mean 15-years, 19 knees have been revised. Reasons for revision included: aseptic loosening of tibial component (n = 1), progression of OA (n = 13), polyethylene failure (n = 3), subsidence of tibial tray (n = 2). Two types of implants were used in this study, the Preservation (DePuy Synthes, Leeds, UK) (n = 59) and the Miller-Galante (Zimmer Biomet, Warsaw, IN) (n = 206) UKAs. Both prostheses had a similar round-on-flat geometry. Failure rates by implants were at 8% for the Preservation (n = 5/59) and 7% for the Miller-Galante (n = 14/206). Only a minority of revisions occurred before the 10-year mark (n = 4), giving an overall 10-year survivorship of 98%. The final survivorship of mean 15-year (range 13–17 years) was 93%.

Surgical technique

All UKAs were consecutively done by the two senior authors who are fellowship-trained arthroplasty surgeons. The indication for surgery was based on the Kozinn and Scott criteria [20] and all surgeries were indicated for unicompartmental noninflammatory primary OA of the knee with intact cruciate ligaments. The surgical technique was performed in accordance with the respective manufacturer's surgical instrumentation guide using conventional instruments. An abbreviated medial approach without patellar eversion was performed.

Clinical evaluation

The patients included in this study had few medical comorbidities at index operation, which was translated into the Charlson Comorbidity Index (CCI) scores [34] (Table 1). A variety of patient-reported outcome measures (PROMs) were used to assess all patients routinely in the clinic at 6-month, 2-year and 10-year follow-up. Knee function was assessed using the: adapted Oxford Knee Score (OKS)

Table 1 Summary of patient demographics (n = 265 knees)

Age (years); mean ± SD	61.0 ± 7.6	
Body mass index (kg/m^2); mean ± SD	27.2 ± 4.4	
CCI score; mean ± SD	0.2 ± 0.5	
Gender; n (%)	65 Males (25%) 200 Females (75%)	
Operated side; n (%)	134 Left (50%) 131 Right (50%)	
Implant used; n (%)	59 Preservation (22%) 206 Miller-Galante (78%)	
FCA (°); mean ± SD	2.1 ± 4.8	(+) is varus
TCA (°); mean ± SD	3.7 ± 3.6	(+) is varus
HKA (°); mean ± SD	1.0 ± 4.0	(+) is varus
Pre-operative PTS (°); mean ± SD	4.5 ± 3.4	(+) is posterior slope
Post-operative PTS (°); mean ± SD	4.2 ± 3.4	(+) is posterior slope
Pre-operative PCO (mm); mean ± SD	26.5 ± 2.4	
Post-operative PCO (mm); mean ± SD	25.1 ± 2.7	
FSA (°); mean ± SD	− 2.0 ± 5.6	(+) is flexion

CCI Charlson Comorbidity Index, *FCA* femoral coronal angle, *TCA* tibial coronal angle, *HKA* Hip-Knee-Ankle, *PTS* posterior tibial slope, *PCO* posterior condylar offset, *FSA* femoral sagittal angle, *SD* standard deviation scoring system [30]; Knee Society knee (KSKS) and function (KSFS) scores [15], Short Form-36 (SF-36) [17, 23] health survey which was transformed into physical (PCS) and mental (MCS) component scores [43] (Table 2). Fulfilment of patients' expectations and satisfaction after surgery was done with a 6-point scale using similar questions to Bourne et al. [6]. ROM was assessed using a two-arm goniometer with the patient in a supine position. All clinical assessment was performed by physiotherapists who were not involved in this study. The electronic records of all patients were reviewed in July 2020 to determine if and when they had undergone revision, giving a mean duration of follow-up of 15 years.

Radiological evaluation

Preoperative and postoperative lateral radiograph of all 265 knee joints were used for radiological evaluation. Radiographs measurements were performed using the Picture Archiving and Communication Systems (PACS: Carestream Health, Rochester, New York, USA). Measurements were recorded to a precision of 0.1 mm and 1°. Measurements were performed using a similar method to previous authors [12, 18, 40], where PTS is the acute angle between the tibial plateau in the sagittal view, and the line perpendicular to the tibial mechanical axis (Figs. 1and 2); PCO is the perpendicular distance of the posterior-most aspect of the femoral condyle from a projection of the posterior femoral line (Figs. 1and 2); FSA is the acute angle between the cut surface of the posterior femoral condyle and the anatomical axis of the femur (Fig. 3a, b).

Radiographs were evaluated consecutively by two blinded independent assessors who were not involved in the surgical procedure. Evaluation was performed by both assessors independently, in December 2019. Subsequently, the evaluation was repeated by both assessors after 6 months. The test–retest reliability was assessed using intraclass correlation coefficient (ICC). Using a two-way random-effects model, the ICC value was 0.98 (95% CI 0.97–0.99, $p < 0.05$). An ICC > 0.9 represents excellent reliability, which suggests

Fig. 1 Preoperative lateral radiograph showing measurement of posterior condylar offset (PCO) and posterior tibial slope (PTS)

Table 2 Summary of functional outcomes

Functional outcomes	Preoperative	6-month	2-year	10-year
Oxford Knee Score	27.5 ± 7.9	41.4 ± 4.9	43.0 ± 4.8	41.2 ± 6.5
Knee Society Function Score	59.7 ± 14.9	79.3 ± 16.3	81.1 ± 15.9	74.5 ± 18.8
Knee Society Knee Score	46.6 ± 17.3	87.6 ± 10.6	87.3 ± 11.0	83.7 ± 16.6
SF-36 PCS	35.9 ± 11.1	50.9 ± 7.8	50.4 ± 8.7	47.6 ± 10.9
SF-36 MCS	51.6 ± 11.2	54.9 ± 9.1	55.3 ± 10.0	53.0 ± 10.7

Scores presented in mean ± standard deviation

SF-36 short form-36, *PCS* physical component score, *MCS* mental component score

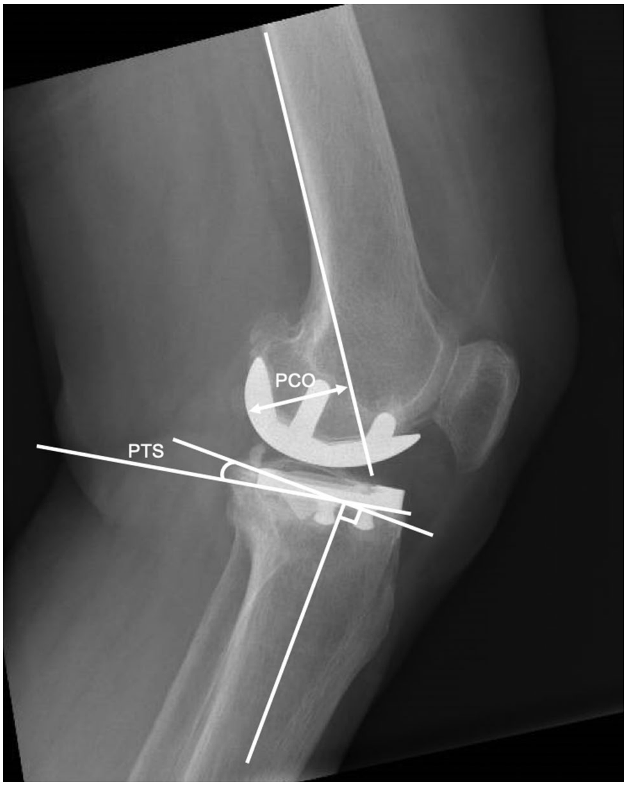

Fig. 2 Postoperative lateral radiograph showing measurements of posterior condylar offset (PCO) and posterior tibial slope (PTS)

Fig. 3 Postoperative lateral radiograph showing the measurement of the femoral sagittal angle (FSA) on **a** Preservation and **b** Miller-Galante implants

that measurement of sagittal plane parameters meticulously performed using this method, can achieve excellent reliability and reproducibility.

Statistical analysis

All statistical analysis was done using RStudio (RStudio: Integrated Development for R. Rstudio, Inc., Boston, MA). A p value of < 0.05 was used as the threshold for statistical significance. Sample size calculation was performed with power at 0.8 and a significance level at 0.05. To detect 1º of change, with a standard deviation of 3º, the minimum sample size was 142. Descriptive statistics included count, mean, standard deviation and proportions. Kendall's ranked correlation test was used to evaluate the correlation between sagittal plane parameters with various clinical outcomes. Multivariable regression analysis was performed to elucidate the significant predictors of postoperative ROM. Multivariable regression models also explored potential interaction effects between PTS, PCO and FSA. Regression models adjusted for potential confounders of outcomes, such as age [21], body mass index (BMI) [5, 13, 25, 35, 48], CCI, operated side, different implant designs, coronal and limb alignments, and preoperative ROM [16]. Subsequently, adjusted outputs from the multivariable regression models were channelled into constructing effect plots and interaction plots, to isolate the individual effect of variables on postoperative ROM and propose recommendations accordingly. Loess lines, which are locally weighted smooth polynomial regression lines set to a default span of 0.5, were utilised to better capture non-linear trends in the data and reduce any skewing effect from outliers.

Results

Correlations

PTS, PCO and FSA are significantly correlated with each other (Table 3). A steeper PTS and larger PCO was correlated with greater flexion. Greater flexion of the FSA was correlated with greater FFD. A larger PCO and greater flexion of the FSA was correlated with better PROMs (Table 3).

Predictors

There were significant two-way interaction effects between PTS and PCO (Table 4). Younger age, lower BMI and greater preoperative flexion are significant predictors of better postoperative flexion (Tables 4, 5and 6). The only significant predictor of FFD was preoperative FFD (Tables 4, 5and 6).

Table 3 Kendall's ranked correlation coefficients showing relationship of posterior tibial slope (PTS), femoral posterior condylar offset (PCO), and femoral sagittal angle (FSA) against different clinical parameters

Parameters	PTS		PCO		FSA	
	τ	*p* value	τ	*p* value	τ	*p* value
FSA	-0.136	.00	0.086	.04	-	-
PCO	0.090	.03	-	-	-	-
Range of motion						
6-month flexion	0.101	.03	0.095	.04	0.012	n.s.
6-month FFD	– 0.030	n.s.	0.030	n.s.	0.178	.00
2-year flexion	0.055	n.s.	0.063	n.s.	– 0.048	n.s.
2-year FFD	– 0.054	n.s.	– 0.001	n.s.	0.207	.00
10-year flexion	0.007	n.s.	0.118	n.s.	0.009	n.s.
10-year FFD	0.033	n.s.	0.018	n.s.	0.056	n.s.
Oxford Knee Score						
Δ 6-month	0.082	n.s.	– 0.013	n.s.	0.012	n.s.
Δ 2-year	0.106	.01	– 0.065	n.s.	0.000	n.s.
Δ 10-year	0.096	.03	– 0.037	n.s.	0.039	.01
Knee Society Knee Score						
Δ 6-month	– 0.017	n.s.	0.030	n.s.	0.044	n.s.
Δ 2-year	– 0.035	n.s.	– 0.023	n.s.	0.010	n.s.
Δ 10-year	– 0.048	n.s.	– 0.018	n.s.	0.059	n.s.
Knee Society Function Score						
Δ 6-month	– 0.032	n.s.	0.013	n.s.	0.034	n.s.
Δ 2-year	0.004	n.s.	– 0.033	n.s.	– 0.013	n.s.
Δ 10-year	0.006	n.s.	0.057	n.s.	0.112	.00
SF-36 PCS						
Δ 6-month	0.033	n.s.	0.048	n.s.	0.081	n.s.
Δ 2-year	0.029	n.s.	0.002	n.s.	0.030	n.s.
Δ 10-year	– 0.049	n.s.	0.007	n.s.	0.115	.01
SF-36 MCS						
Δ 6-month	0.025	n.s.	– 0.050	n.s.	0.075	n.s.
Δ 2-year	0.031	n.s.	– 0.006	n.s.	0.050	n.s.
Δ 10-year	0.056	n.s.	– 0.037	n.s.	0.043	n.s.
Satisfaction						
6-month	– 0.148	n.s.	0.045	n.s.	– 0.256	n.s.
2-year	0.017	n.s.	0.047	n.s.	0.191	.02
10-year	0.092	n.s.	– 0.003	n.s.	– 0.052	n.s.
Met expectations						
6-month	0.045	n.s.	0.306	n.s.	– 0.252	n.s.
2-year	0.025	n.s.	0.069	n.s.	0.175	.03
10-year	0.072	n.s.	– 0.035	n.s.	– 0.077	n.s.
Survivorship						
15-year revision	0.057	n.s.	– 0.037	n.s.	– 0.091	n.s.

PTS posterior tibial slope, *PCO* posterior condylar offset, *FSA* femoral sagittal angle, *SF-36* Short Form-36, *PCS* physical component score, *MCS* mental component score, Δ change from preoperative, *FFD* fixed flexion deformity

Sagittal plane alignment

A PTS between 2° to 8° is optimal for better postoperative flexion (Fig. 4). Restoration of PCO within 1.5 mm from preoperative values is optimal for better postoperative flexion (Fig. 5). At shallow PTS of 2°, it is preferable to reduce PCO by 1.0 mm, whereas at steeper PTS of 8°, it is preferable to restore PCO at 0 mm (Fig. 6).

Table 4 Multivariable linear regression on knee range of motion at 6-month

Variables	Flexion		FFD	
	ß	*p* value	ß	*p* value
Age	− 0.278	.01	0.011	n.s.
Body mass index	− 1.082	.00	0.117	n.s.
CCI	− 0.741	n.s.	0.727	n.s.
Operated side: Left	Ref.	–	Ref.	–
Operated side: Right	− 0.296	n.s.	− 0.431	n.s.
Implant: MG	Ref.	–	Ref.	–
Implant: Preservation	5.223	.01	− 1.139	n.s.
Preoperative flexion	0.581	.00	–	–
Preoperative FFD	–	–	0.384	.00
FCA	− 0.334	n.s..	0.038	n.s.
TCA	− 0.176	n.s.	− 0.079	n.s.
HKA	− 0.092	n.s.	0.039	n.s.
FSA	0.124	n.s.	0.199	n.s.
PTS	5.576	.02	− 0.250	n.s.
Δ PTS	0.052	n.s.	− 0.161	n.s.
PCO	0.585	n.s.	− 0.184	n.s.
Δ PCO	− 2.116	.01	− 0.929	n.s.
PTS X PCO	− 0.199	.03	0.016	n.s.
PTS X FSA	0.201	n.s.	− 0.048	n.s.
PCO X FSA	0.094	n.s.	− 0.022	n.s.
PTS X PCO X FSA	− 0.009	n.s.	0.002	n.s.

CCI Charlson Comorbidity Index, *MG* Miller-Galante, *PTS* posterior tibial slope, *PCO* posterior condylar offset, *FSA* femoral sagittal angle, *FFD* fixed flexion deformity, *FCA* femoral coronal angle, *TCA* tibial coronal angle, *HKA* hip-knee-ankle, Δ change from preoperative

Table 5 Multivariable linear regression on knee range of motion at 2-year

Variables	Flexion		FFD	
	ß	*p* value	ß	*p* value
Age	− 0.292	.00	− 0.025	n.s.
Body mass index	− 0.802	.00	0.037	n.s.
CCI	− 0.621	n.s.	0.322	n.s.
Operated side: Left	Ref.	–	Ref.	–
Operated side: Right	− 0.690	n.s.	− 0.461	n.s.
Implant: MG	Ref.	–	Ref.	–
Implant: Preservation	3.712	n.s.	− 0.816	n.s.
Preoperative flexion	0.393	.00	–	–
Preoperative FFD	–	–	0.237	.00
FCA	− 0.078	n.s.	0.059	n.s.
TCA	− 0.031	n.s.	− 0.038	n.s.
HKA	− 0.032	n.s.	− 0.016	n.s.
FSA	− 2.666	n.s.	− 0.013	n.s.
PTS	2.235	n.s.	− 0.478	n.s.
Δ PTS	0.170	n.s.	− 0.112	n.s.
PCO	− 0.029	n.s.	− 0.142	n.s.
Δ PCO	− 0.800	n.s.	− 0.482	n.s.
PTS X PCO	− 0.076	n.s.	0.023	n.s.
PTS X FSA	0.355	n.s.	0.095	n.s.
PCO X FSA	0.097	n.s.	0.007	n.s.
PTS X PCO X FSA	− 0.012	n.s.	− 0.004	n.s.

CCI Charlson Comorbidity Index, *MG* Miller-Galante, *PTS* posterior tibial slope, *PCO* posterior condylar offset, *FSA* femoral sagittal angle, *FFD* fixed flexion deformity, *FCA* femoral coronal angle, *TCA* tibial coronal angle, *HKA* hip-knee-ankle, Δ change from preoperative

Discussion

The first important finding of this study was the interaction effect between PTS and PCO. This interaction means that there are differential effects of PTS depending on different sizes of PCO, and vice versa. This finding was consistent with a previous study by Han et al. which found an interaction effect between PTS and PCO in total knee arthroplasty (TKA) [12]. Even though knee kinematics between UKA and TKA differ significantly, this finding seems to be similar for both. This is crucial because surgeons need to balance the component gaps yet be mindful that the resultant size of the posterior condyle on different tibial plateau inclination may influence the femoral roll-back mechanism [46]. A mismatch between the PTS and PCO may lead to excessive translation during weight-bearing activities [14, 46], and exacerbate stress on the native knee structures [37, 38].

The second important finding of this study was that PTS between 2° to 8° is optimal in maximising knee flexion. This finding was consistent with previous studies that have made similar recommendations [1, 37, 39]. In addition, the study by Small et al. demonstrated that contact strain in the posterior compartment increased by 80% ($p = 0.00$) when PTS was increased from 5° to 10°, suggesting that 10° PTS is not advisable [38]. The study by Weber et al. in a cohort of fixed-bearing UKA, also found that there was a significant reduction in wear rate from 10.4 mg/million cycles to 3.22 mg/million cycles when PTS was increased from 0° to 8° [45]. These findings are consistent with the recommendation regarding optimal PTS angles within 2°–8°.

The third important finding of this study was that restoration of PCO to within 1.5 mm of its preoperative value was ideal in maximising knee flexion. Restoration of PCO has been described to be an important predictor of better functional outcomes after TKA [27], but this has not yet been described in UKA. Restoration of PCO is likely to be crucial due to two reasons. Firstly, UKA may be primarily thought of as a resurfacing procedure [3, 44], restoration of PCO is more likely to maintain the complex kinematics of the native knee. Secondly, given the interactive effects between PTS and PCO detailed above, preserving the patient's native PCO will likely avoid unnecessary counter-productive effects

Table 6 Multivariable linear regression on knee range of motion at 10-year

Variables	Flexion		FFD	
	ß	*p* value	ß	*p* value
Age	− 0.136	n.s.	0.112	.03
Body mass index	− 0.572	.00	0.195	.02
CCI	− 1.412	n.s.	0.343	n.s.
Operated side: Left	Ref.	–	Ref.	–
Operated side: Right	1.075	n.s.	0.418	n.s.
Implant: MG	Ref.	–	Ref.	–
Implant: Preservation	3.331	n.s.	− 0.692	n.s.
Preoperative flexion	0.436	.00	–	–
Preoperative FFD	–	–	0.380	.00
FCA	− 0.296	n.s.	− 0.056	n.s.
TCA	− 0.235	n.s..	− 0.009	n.s.
HKA	− 0.757	n.s.	0.198	n.s.
FSA	− 0.445	n.s.	0.437	n.s.
PTS	2.717	n.s.	0.547	n.s.
Δ PTS	0.198	n.s.	0.081	n.s.
PCO	0.413	n.s.	0.265	n.s.
Δ PCO	− 0.210	n.s.	0.238	n.s.
PTS X PCO	− 0.114	n.s.	− 0.025	n.s.
PTS X FSA	− 0.052	n.s.	− 0.050	n.s.
PCO X FSA	0.007	n.s.	− 0.018	n.s.
PTS X PCO X FSA	0.005	n.s.	0.003	n.s.

CCI Charlson Comorbidity Index, *MG* Miller-Galante, *PTS* posterior tibial slope, *PCO* posterior condylar offset, *FSA* femoral sagittal angle, *FFD* fixed flexion deformity, *FCA* femoral coronal angle, *TCA* tibial coronal angle, *HKA* hip-knee-ankle, Δ change from preoperative

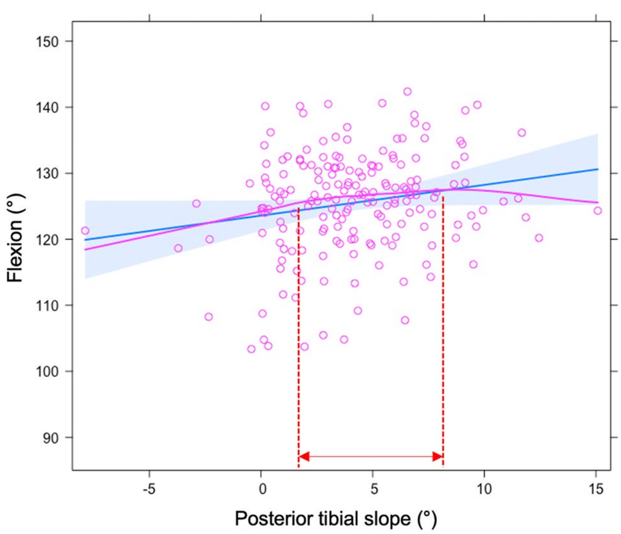

Fig. 4 Effect plot showing the adjusted influence of posterior tibial slope (PTS) on knee flexion at 6-month

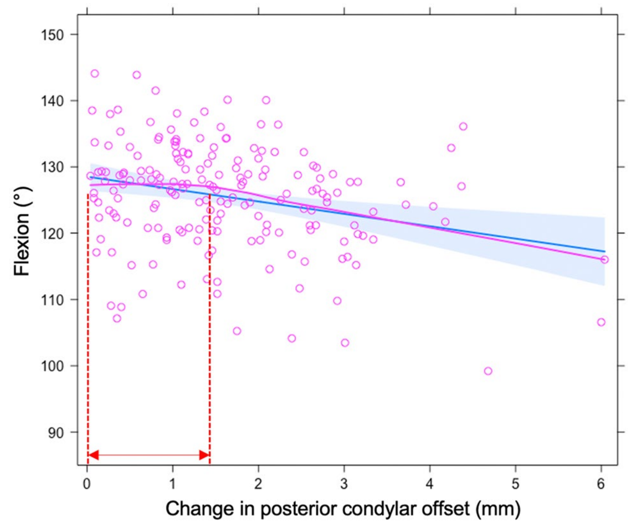

Fig. 5 Effect plot showing the adjusted influence of change in posterior condylar offset (ΔPCO) on knee flexion at 6-month

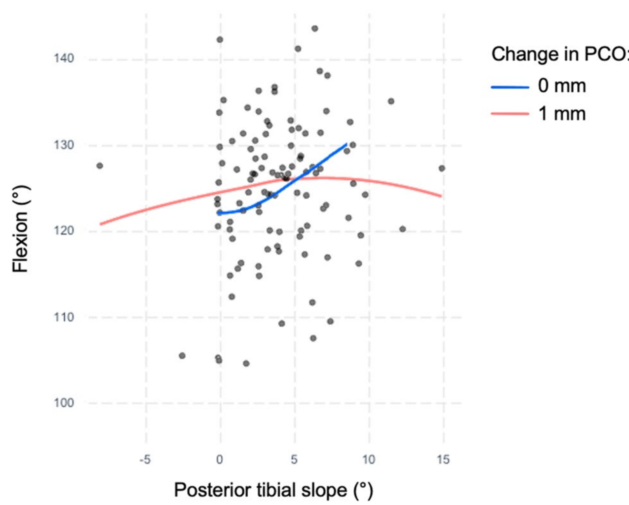

Fig. 6 Interaction plot showing the effect of posterior tibial slope (PTS) on knee flexion at 6-month, for different values of change in posterior condylar offset (ΔPCO)

when coupled with PTS. Surgeons just have to be mindful not to cut PCO > 1.5 mm when balancing the component gaps.

In terms of survivorship, PTS, PCO and FSA were not associated with failures in this study. This finding was consistent with previous studies [7, 10], although some authors have reported PTS to be a crucial factor in UKA survivorship [26, 33]. The mechanism for this is because extremes of PTS has been shown to be a risk factor for bearing dislocation [36], although this is still contested [19, 24]. However, this study is unable to corroborate if a steeper PTS might predispose patients to a higher risk of bearing dislocation as it did not include any mobile-bearing UKA. Park et al. also described that excessive flexion of FSA may contribute to the progression of lateral compartment OA due to higher contact stresses [32]. However, none of the patients with revision for the progression of OA in this study had extreme FSA positioning, which suggests that it may not be a clinically significant mechanism for failure.

Given that there has been significant improvement in implant design since 2007, the effects of these parameters may be different with newer generations of UKA implants that have a different geometry and hence biomechanics. A limitation of this study was the use of short radiographs for radiological evaluation, which has slightly lesser precision compared to long film radiographs. Although short radiographs have been described to be an acceptable alternative to long film radiographs in assessing component positioning [41]. Another limitation was the use of 2-dimensional films, therefore tilt, rotation or non-strict lateral views could influence radiological measurements. It would be useful for future studies with access to 3-dimensional imaging to corroborate the findings from this study. Despite this limitation, this study has various strengths. Firstly, it has a long duration of follow-up. Secondly, this study utilized a myriad of different yardsticks and survivorship in assessing patients. Thirdly, this study used a string of rigorous statistical approaches that adjusted for various covariates and interactions, to accurately capture the effect of each factor free from the influence of other confounders.

Clinically, UKA surgeons should aim to cut PTS between 2° to 8° and restore PCO to within 1.5 mm of its preoperative value. Since PTS is often augmented depending on the condition of the cruciate ligaments, surgeons should prioritize increasing the posterior condylar cut when PTS is shallow, and decrease the posterior condylar cut when PTS is steep. Moreover, these targets would be useful to guide planning in robotic surgery given the extremely precise cuts involved [4, 31].

Conclusion

UKA surgeons and future studies should be mindful of the relationship between PTS, PCO and FSA, and avoid considering them in isolation. When deciding on the method of balancing component gaps in UKA, surgeons should rely on the PTS. Decrease the posterior condylar cut when PTS is steep, and increase the posterior condylar cut when PTS is shallow. The acceptable range for PTS is between 2° to 8° and PCO should be restored to 1.5 mm of native values.

Author contribution YZK (Medical Student): Conceptualization, Methodology, Validation, Statistical Analysis, Data Collection, Writing—Original Draft, Writing—Review and Editing. MHLL (Orthopaedic Surgeon): Conceptualization, Methodology, Writing—Original Draft, Writing—Review and Editing, Supervision. ML (Orthopaedic Surgeon): Validation. JYC (Orthopaedic Surgeon): Supervision. NNL (Orthopaedic Surgeon): Surgeon, Supervision. SJY (Orthopaedic Surgeon): Surgeon, Supervision.

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