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ORIGINAL ARTICLE

The factors influencing the component sizes in Oxford Phase 3 unicompartmental knee arthroplasty

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ABSTRACT

Objectives: This study aims to investigate the Thai population characteristics that may correlate the component sizes used in the Oxford Phase 3 unicompartmental knee arthroplasty (OUKA) and to examine common matching patterns and variables affecting matching and patient-specific factors while determining the femoral component (Fc) size for Thai patients.

Patients and methods: Between June 2003 and June 2019, a total of 773 knees of 773 patients (145 males, 628 females; median age: 64.0 years; range: 44 to 86 years) who underwent OUKA using Oxford Microplasty® Instrumentation were retrospectively analyzed. The femoral and tibial components (Tc) were matched based on the patient's age, sex, height, weight, and other characteristics. The Fc sizes were compared in terms of patient characteristics. Also, the area under the receiver operating characteristic (AuROC) was calculated.

Results: A total of 6.5% of the Fcs were extra small (XS), 65.7% were small (S), 20.6% were medium (M), 7.2% were large (L), and 0% were extra-large (XL). For Tc sizes, the distribution was as follows: 20.2% AA; 31.6% A; 24.3% B; 16.3% C; 6.0% D; 1.7% E; and 0% F. Females had the most common Fc and Tc sizes of S and A, while males had the most common sizes of M and C. The S-A (32.3%) and M-C (27.5%) were the most often used matching patterns among females and males, respectively. Sex, body weight (BW), height, and body mass index (BMI) were independent predictors of Fc sizes. The AuROC for BW, height, and BMI was statistically significant.

Conclusion: The S and A for females and M and C for men were the most common sizes of Fc and Tc in Thai patients. Among females, the most prevalent pairing was S-A and, among men, it was M-C. The strongest determinants of Fc sizes were found to be male sex and height.

Keywords: Femoral component size, Oxford Phase 3 unicompartmental knee arthroplasty, prosthetic size and height, sex distribution, Thailand.

Oxford unicompartmental knee arthroplasty (OUKA) is an effective procedure for treating medial compartmental osteoarthritic knee with reportedly good long-term survivorship.[1,2] It was first introduced in 1976, and it has undergone several subsequent modifications. The OUKA Phase 3, which is the latest design, was introduced in 1998 with the new implant size and surgical instrumentation.[3,4]

As OUKA survival is directly related to the implant size, position, and alignment,[5,6] OUKA Phase 3 has five femoral component (Fc) sizes, and seven tibial component (Tc) sizes to better match patient anatomy.[4] Moreover, OUKA Phase 3 includes Oxford Microplasty® Instrumentation (Zimmer Biomet, Warsaw, IN, USA) which has been shown to reduce the risk of malalignment, help to determine an adequate level of tibial resection, and help to avoid unnecessary bone removal.[3]

However, the design of the OUKA prosthesis is based on data from Western populations. Differences in morphological features between Western and Asian knees have been reported in previous studies.[7,8] Thus, the distribution of OUKA

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size in Asian patients may be different from those observed in Western individuals. Furthermore, since determination of the proper Fc size is one of the most difficult steps during surgery, several methods have been proposed. Although preoperative radiographic templating is commonly used, Bothra et al.[9] found that it had only slight to moderate reliability. Alternatively, Fawzy et al.[10] developed and proposed a height based on sex guideline to determine the ideal Fc size. However, their guideline was established based on the Western data. Therefore, the method proposed by Fawzy et al.[10] may not be appropriate for use in the Asian population.

Since most previous researches have focused on the Western population, our primary objective was to investigate the Thai population characteristics that may correlate the component sizes used in the OUKA in the present study. As a secondary objective, we aimed to investigate common matching patterns and variables that affect whether or not matching occurs. In addition, we aimed to examine the patient-specific factors while determining the Fc size for Thai patients.

PATIENTS AND METHODS

This retrospective study was conducted at Department of Orthopaedic Surgery, Siriraj Hospital, Mahidol University between June 2003 and June 2019. A total of 773 knees of 773 patients (145 males, 628 females; median age: 64.0 years; range, 44 to 86 years) who underwent OUKA Phase 3 using Oxford Microplasty® Instrumentation were retrospectively analyzed. All operations were performed by one or more of five experienced arthroplasty surgeons. The optimal size of Fc was selected using the spoon-based reference.

The relationship between the front of the spoon and an estimate of where the articular cartilage surface would have been before the arthritis developed was considered for determination of the Fc size. The femoral sizing spoon, tibial saw guide, and G-clamp were used to determine the proper level of tibial resection. After performing tibial resection, the excised plateau was used to select the optimal size Tc. The tibial template of the opposite side was laid on the cut surface of the excised plateau to select the Tc size with the proper width. We defined ideal inserted component as the testing result after inserting all unicompartmental knee arthroplasty (UKA) components. This result indicated that the operated knee was subjected to the appropriate tension throughout the intraoperative range of motion, without spinning out or experiencing excessive tension while in motion. The ideal size of an inserted component would always correspond to the Fc size. Patient characteristics, including age, sex, operative side, body weight (BW), height, and body mass index (BMI) were collected. Prosthesis-specific details, including Fc size, Tc size, and matching of Fc-Tc size were also recorded. According to a definition by Wang et al.,[11] the optimal matching of Fc and Tcs was XL with F; L with E; M with D; S with A and B. The mismatching was defined in reverse.

Statistical analysis

Statistical analysis was performed using R and RStudio version 4.1.2 software with RMS package for data analysis (Boston, Massachusette, USA). The Kolmogorov-Smirnov test was used to check continuous data for normal distribution. Continuous data were presented in mean ± standard deviation (SD) for normally distributed data and in median (min-max) for non-normally distributed data. Categorical data ware presented in number and frequency. Comparison of continuous data among Fc sizes was performed using analysis of variance (ANOVA) or Kruskal-Wallis test. The chi-square test or Fisher exact test was used to compare categorical data. To evaluate the prediction performance of significant continuous variables to distinguish among Fc sizes, the area under the receiver operating characteristic (AuROC) curve with 95% confidence interval (CI) was calculated. The continuous variable with the largest AuROC was considered to be the factor that most strongly affected the selection of Fc size. A p value of <0.05 was considered statistically significant.

RESULTS

Demographic characteristics of the patients are shown in Table 1. The distribution of Fc size is described as follows: extra-small (XS) 6.5%, small (S) 65.7%, medium (M) 20.6%, large (L) 7.2%, and extra-large (XL) 0%. The distribution of Tc size is described as follows: AA 20.2%, A 31.6%, B 24.3%, C 16.3%, D 6.0%, E 1.7%, and F 0%. The distribution of matching between Fc and Tc sizes in overall patients is shown in Figure 1. The distribution of Fc and Tc sizes in females and in males is shown in Figure 2. The most common Fc and Tc size used in females was S and A, respectively, whereas the most common Fc and Tc size used in males was M and C, respectively. Similar to the results of matching, the most common matching pattern used in females and males was S-A (32.3% of females) and M-C (27.6% of males), respectively (Figure 3).

TABLE I

Patient demographics and anthropometric data according to four Fc sizes

	Femoral component size																			
	Overall (n=773)				XS (n=50)				Small (n=508)				Medium (n=159)				Large (n=56)				
Data	n	%	Median	Range	n	%	Median	Range	n	%	Median	Range	n	%	Median	Range	n	%	Median	Range	*p*
Age (year)			64.0	44-86			64.5	53-83			63.0	46-86			63.0	44-86			65.0	54-84	0.239
Sex																					<0.001
Female	628	81.2			47	94.0			489	96.3			89	56.0			3	5.4			
Male	145	18.7			3	6.0			19	3.7			70	44.0			53	94.6			
Side																					0.652
Right	397	51.4			29	58.0			258	50.8			84	52.8			26	46.4			
Left	376	48.6			21	42.0			250	49.2			75	47.2			30	53.6			
BW (kg)																					
Overall			66.0	42.8-117.5			59.6	42.8-73.9			64.1	43.0-110.9			71.3	46.5-108.7			80.1	57.0-117.5	<0.001
Female			64.7	42.8-110.9			60.0	42.8-73.9			64.0	43.0-110.9			72.4	46.5-108.7			71.6	60.7-84.8	<0.001
Male			71.3	48.0-117.5			58.0	48.0-61.0			67.0	51.4-76.0			69.3	50.0-88.5			81.1	57.0-117.5	<0.001
Height (cm)																					
Overall			156	139-182			150	140-165			155	139-169			161	145-176			169	154-182	<0.001
Female			155	139-175			150	140-165			154	139-169			158	145-175			161	160-162	<0.001
Male			165	145-182			153	150-156			157	145-167			167	145-176			169	154-182	<0.001
BMI (kg/m^2)																					
Overall			26.9	17.7-46.6			25.4	18.7-35.2			26.6	17.7-42.8			27.6	17.9-46.6			27.9	20.9-39.3	0.014
Female			27.0	17.7-46.6			25.4	18.7-35.2			26.7	17.7-42.8			29.0	18.4-46.6			28.0	23.4-32.3	<0.001
Male			26.6	17.9-39.3			24.8	19.7-27.1			26.2	21.1-31.0			25.3	17.9-32.4			27.8	20.9-39.3	0.002

Fc: Femoral component; XS: Extra-small; BW: Body weight; BMI: Body mass index; A p-value <0.05 indicates statistical significance.

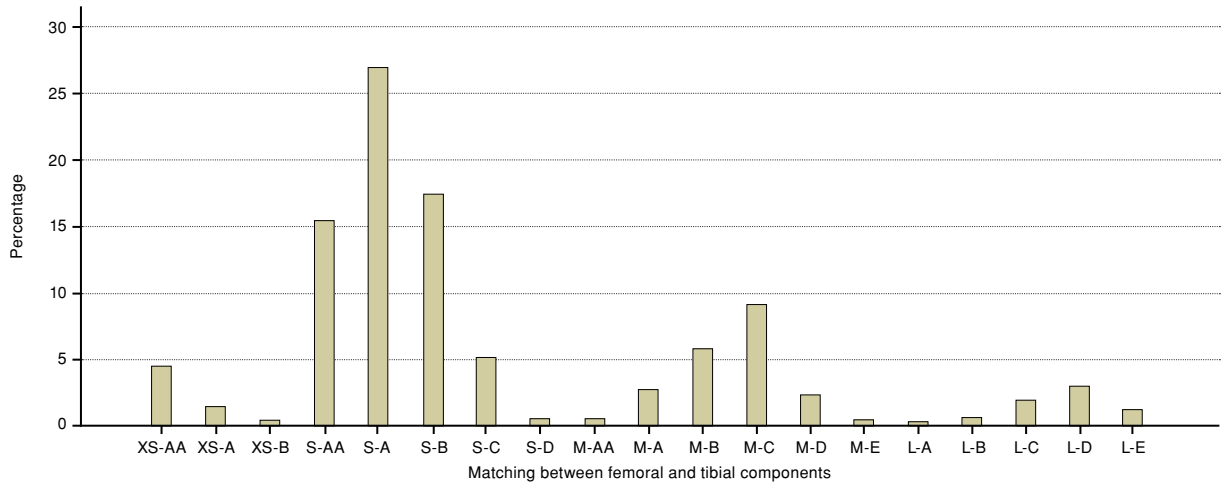

FIGURE 1. The distribution of matching between femoral and tibial component sizes in overall patients.

A comparison of study variables among the Fc sizes revealed significant differences for sex, BW, height, and BMI (Table I). Boxplots of the median (min-max) values for BW, height, and BMI compared between both sexes for each Fc size are shown in Figure 4. The receiver operating characteristic (ROC) curve analysis was performed and the AuROC for BW, height, and BMI was calculated for overall patients, and for each sex. The results showed that height had the highest AuROC value in both sexes for XS, in both sexes for S, in females for M, and in females for L. In males, the BMI had the highest AuROC value for M, while BW had the highest AuROC value for I (Table II). We also found that sex significantly affected the selection of the Tc size. The distribution of the Tc size in both sexes is shown in Table III. However, we attempted to build a regression model including participant's individual height as a predictive variable based in accordance with the previous recommendation in the literature. Unfortunately, the model with height failed to significantly improve the predictive ability compared to the model without, indicating that height could not explain the variability in the data set well.

Concerning the factors found to most significantly influence the selection of Fc size, sex was the most significant categorical variable, while height was the

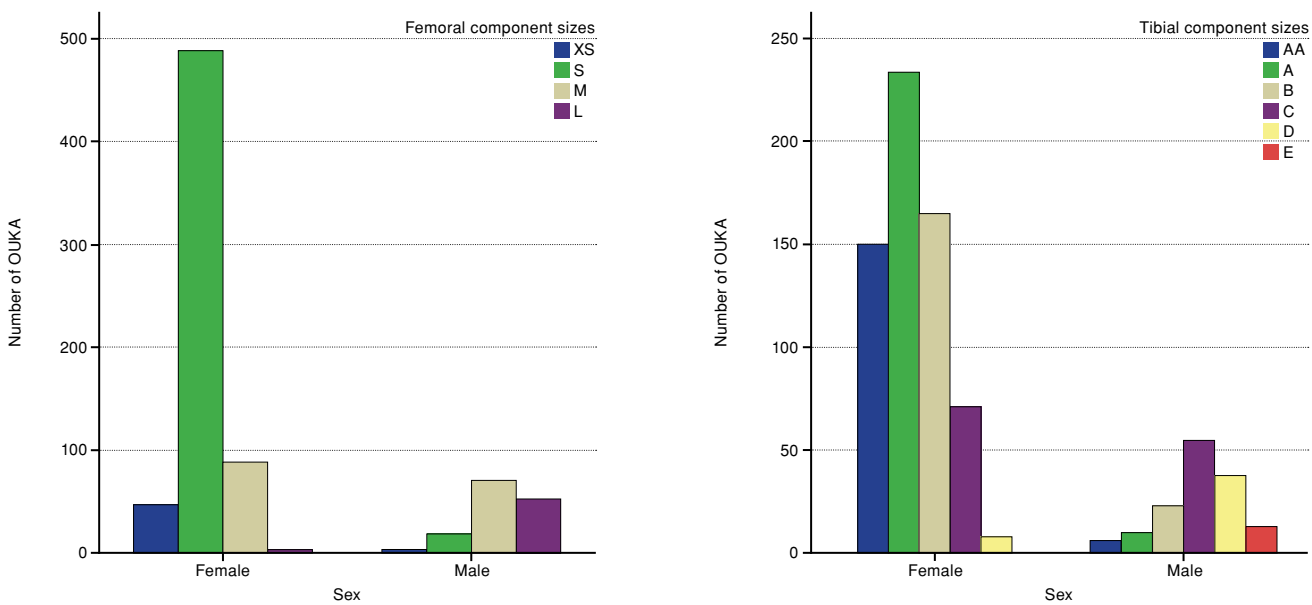

FIGURE 2. The distribution of femoral component (left) and tibial component (right) sizes in females and in males.
OUKA: Oxford unicompartmental knee arthroplasty.

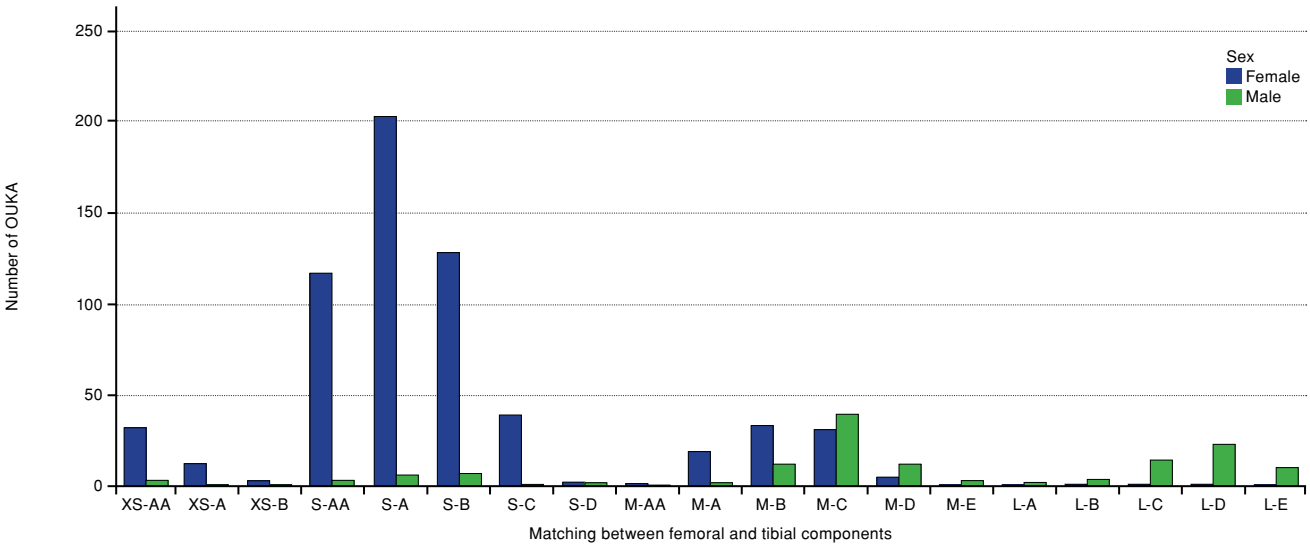

FIGURE 3. The distribution of matching between femoral and tibial component sizes compared between sexes.
OUKA: Oxford unicompartmental knee arthroplasty.

most significant continuous variable. Using these two significant factors, the distribution of Fc size relative to patient height in females and males is shown in Table IV.

DISCUSSION

To the best of our knowledge, the present study is the first and largest one in Thailand to evaluate and report the prosthesis size distribution of OUKA Phase 3. The ratio of female-to-male knees in our study was approximately 4:1. This ratio is higher than those reported from previous studies of Asian patients.[11,12] The S size and A size were the most common Fc and Tc component sizes, respectively, among females. The M size and C size were the most common Fc and Tc component sizes, respectively, among males. The male patients in our study were usually taller than the females. This factor explains the difference in implant size between two sexes. Although all Fc sizes were used (except for extra-large) with several Tc sizes, the optimal matching patterns were XS-AA, S-A, M-C, and L-D. The S-A and M-C matching patterns were the most frequently used patterns in females and males, respectively. All of our matching pattern data were similar to the data reported from a study conducted in Chinese patients.[11] In Indian patients, Malhotra et al.[12] included 130 OUKA and found the most common Fc size to be XS for females and S for males. The Fc size in that study was relatively smaller than that found in our study. In a study conducted in the Western population, Fawzy et al.[10] found that 54% of cases

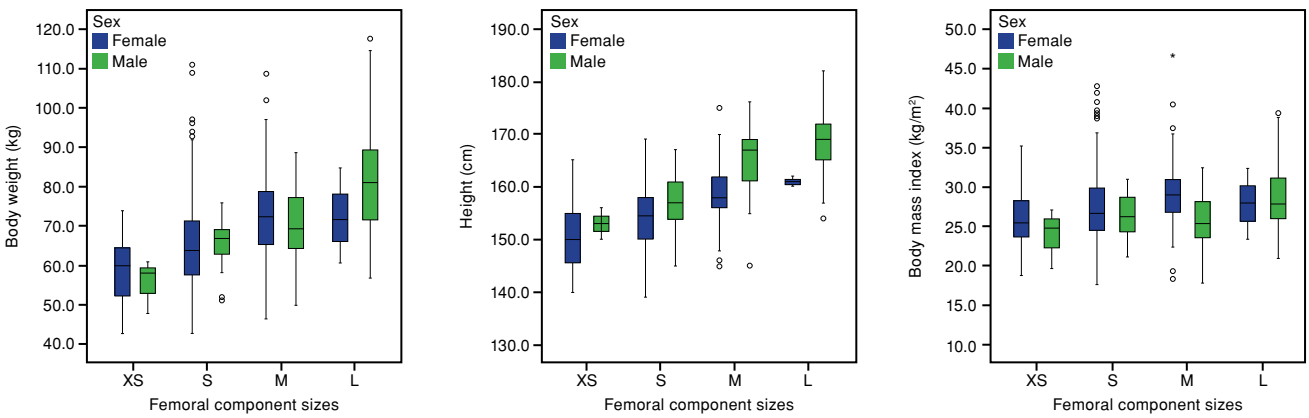

FIGURE 4. Boxplots of the median (range) values for body weight (left), height (middle), and body mass index (right) compared between sexes for each femoral component size.

TABLE II
The AuROC for BW, height, and BMI to predict Fc size

Femoral component sizes		Parameters	AuROC	95% CI	*p*
Extra-small	Overall	BW	0.74	0.68-0.80	<0.001
		Height	0.75	0.69-0.82	<0.001
		BMI	0.61	0.52-0.69	0.013
	Female	BW	0.70	0.64-0.77	<0.001
		Height	0.71	0.63-0.79	<0.001
		BMI	0.61	0.52-0.69	0.016
	Male	BW	0.95	0.90-1.00	0.007
		Height	0.95	0.90-0.99	0.008
		BMI	0.70	0.44-0.96	0.238
Small	Overall	BW	0.66	0.62-0.70	<0.001
		Height	0.75	0.71-0.79	<0.001
		BMI	0.52	0.47-0.56	0.504
	Female	BW	0.59	0.53-0.64	0.002
		Height	0.60	0.54-0.65	0.001
		BMI	0.55	0.50-0.60	0.075
	Male	BW	0.74	0.65-0.83	0.001
		Height	0.86	0.79-0.94	<0.001
		BMI	0.51	0.39-0.64	0.884
Medium	Overall	BW	0.68	0.63-0.72	<0.001
		Height	0.76	0.72-0.80	<0.001
		BMI	0.53	0.48-0.58	0.319
	Female	BW	0.73	0.68-0.79	<0.001
		Height	0.74	0.69-0.80	<0.001
		BMI	0.63	0.57-0.69	<0.001
	Male	BW	0.62	0.53-0.71	0.011
		Height	0.51	0.42-0.61	0.837
		BMI	0.65	0.56-0.74	0.002
Large	Overall	BW	0.82	0.76-0.87	<0.001
		Height	0.92	0.89-0.95	<0.001
		BMI	0.58	0.51-0.66	0.042
	Female	BW	0.68	0.39-0.96	0.291
		Height	0.88	0.84-0.93	0.022
		BMI	0.54	0.19-0.89	0.810
	Male	BW	0.79	0.71-0.87	<0.001
		Height	0.73	0.64-0.81	<0.001
		BMI	0.68	0.59-0.77	<0.001

AuROC: Area under the receiver operating characteristic curve; BW: Body weight; BMI: Body mass index; Fc: Femoral component; CI: Confidence interval; A *p* value of <0.05 indicates statistical significance.

TABLE III
Distribution of Tc size in females and males

	Overall (n=773)		AA (n=157)		A (n=244)		B (n=187)		C (n=126)		D (n=46)		E (n=13)		
	n	%	n	%	n	%	n	%	n	%	n	%	n	%	*p*
Sex															
Female	628	81.2	151	96.2	234	95.9	164	87.7	71	56.3	8	17.4	0	0.0	<0.001
Male	145	18.8	6	3.8	10	4.1	23	12.3	55	43.7	38	82.6	13	100.0	

Tc: Tibial component; A *p* value of <0.05 indicates statistical significance.

TABLE IV
Distribution of Fc size relative to patient height in females and males

	Femoral component size								
	Extra-small		Small		Medium		Large		
	n	%	n	%	n	%	n	%	*p*
Female									
Height (cm)									<0.001
≤150.0	25	16.0	124	79.5	7	4.5	0	0.0	
150.1-155.0	12	5.9	178	88.1	12	5.9	0	0.0	
155.1-160.0	9	4.6	143	73.0	43	21.9	1	0.5	
>160.0	1	1.4	44	5.95	27	3.65	2	2.7	
Male									
Height (cm)									<0.001
≤155.0	2	14.3	8	57.1	3	21.4	1	7.1	
155.1-160.0	1	4.3	5	21.7	12	52.2	5	21.7	
160.1-165.0	0	0.0	5	13.9	18	50.0	13	36.1	
165.1-170.0	0	0.0	1	2.4	27	64.3	14	33.3	
>170.0	0	0.0	0	0.0	10	33.3	20	66.7	

Fc: Femoral component; A *p* value of <0.05 indicates statistical significance.

used the M size Fc. However, they did not report the Fc sizes used in each sex.

The results of our study revealed that sex and height were the factors that most significantly affected the selection of the Fc size. These findings are similar to those reported from previous studies in both Western and Asian patients.[10,11] A study in Western individuals conducted by Fawzy et al.[10] reported the use of height alone for predicting Fc size to be correct in 56%, acceptable in 38%, and unacceptable in 6%. However, when they used height based on sex, the accuracy was higher as follows: correct in 75%, acceptable in 25%, and 25% unacceptable. Wang et al.[11] also confirmed sex alone and height based on sex to be important parameters for Fc selection in Chinese patients. On the other hand, Lustig et al.[13] found that height was correlated with Fc size in males, but not in females. Of note, their small sample size and lower size variation among implants among female patients might explain their results.

To date, various methods for determining the Fc size have been proposed. Although the use of preoperative radiographic templating is common, the lack of reliability reported from a previous study raised concerns about the OUKA templating system.[9] Fawzy et al.[10] also reported the accuracy of template prediction to be 67%. Regarding the use of Tc size to predict Fc size, our study found all Fc sizes (except for extra-large) to be matched to multiple Tc sizes. This irrelevance rendered this method useless in clinical practice. The optimal Tc size was found to be dependent upon the depth of the vertical cut that affected the excised tibial plateau width, while the optimal Fc size was dependent upon the size of the femoral sizing spoon. The height based on sex guideline proposed by Fawzy et al.[10] is currently the most popular method; however, this method was derived from data collected from the Western population. This guideline was reported to be inaccurate when applied in the Asian population.[11,12] In our study, the S-sized Fc was predominant in females with all ranges of height. Among males, the M-sized Fc was predominant in males with a height ranging with 155.1 to 170.0 cm. The S- and L-sized Fcs were predominant in males with height ≤155.0 and >170.0 cm, respectively. No patients received the XL-sized Fc in our study. Based on our results, the Fawzy et al.'s[10] guideline cannot be reliably applied in Thai patients.

In the present study, uncertainty prevailed regarding the best method to predict Fc size preoperatively. The final decision was made during the operation. Although Oxford Microplasty® Instrumentation was reported to reduce the risk of malalignment of Fc in both the coronal and sagittal planes compared to the conventional instrumentation,[3] its efficacy relative to the selection of the optimal Fc size is still questionable. Malhotra et al.[12] reported the overall accuracy of the femoral sizing spoon to be 75%, when used as an intraoperative guide. To improve accuracy during the operation, Tu et al.[14] utilized an intraoperative C-arm intensifier guide method to determine Fc size

that yielded accuracy of up to 92%. However, their method required more intraoperative steps and a longer operative time.

Nonetheless, this study has some limitations. First, although this is the largest UKA series in Thailand, with 773 knees, the number of participants is smaller than in other UKA series. The distribution of the data was uneven and strewn with outliers, with fewer males than females. This may make it difficult to construct a realistic height guideline by sex. Therefore, we failed to develop a precise size prediction threshold based on our data. However, this study implied that intraoperative measurement with a femoral spoon sizing device, not the patient's height, still provides more accurate prosthesis size guidance. Second, as our patients are smaller than their Western counterparts, our study has no data specific to XL-sized Fc for either sex. This finding was also reported in Chinese and Indian patients.[11,12] Third, our analysis focused mainly on the Fc size, since we consider it to be easier to assess the Tc size using the tibial template intraoperatively. Moreover, some errors could occur during the use of the femoral sizing spoon. Severe bone loss over the medial femoral condyle could cause underestimation of the Fc size. In contrast, posterior osteophytes or partial thickness cartilage loss could result in overestimation of the Fc size.

In conclusion, this study reported the distribution of OUKA Phase 3 prosthesis using Oxford Microplasty® Instrumentation in Thailand. In Thai patients, the predominant size of Fc was S for females and M for males. The predominant size of Tc was A for females and C for males. The most common matching pattern was S-A for females and M-C for males. Sex and height were identified as the factors that most strongly affected the prediction of Fc size. Further large-scale, prospective studies are needed to confirm these findings in this patient population.

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Ethics Committee Approval: The study protocol was approved by the Siriraj Institutional Review Board (SIRB) Ethics Committee (date: September 18, 2021, no: 722/2021). The study was conducted in accordance with the principles of the Declaration of Helsinki.

Patient Consent for Publication: Since this study was a retrospective chart review. Informed consent was obtained by phone from all individual participants included in the study. This protocol was prospectively registered before enrollment of the first participant.

Data Sharing Statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

Author Contributions: Idea/concept, analysis and/or interpretation, literature review, writing the article, references and fundings, materials: C.P., P.R.; Design: C.P.; Control/supervision: K.C.; Data collection and/or processing: J.P., R.N.; Critical review: K.C., R.N.

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