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KNEE ARTHROPLASTY

Risk factors of postoperative valgus malalignment in mobile-bearing medial unicompartmental knee arthroplasty

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Abstract

Objective The aim of this observational study was to investigate the risk factors of postoperative valgus malalignment after mobile-bearing medial unicompartmental knee arthroplasty (UKA).

Methods We retrospectively evaluated radiographic and surgical characteristics in 122 consecutive Oxford phase 3 UKAs. According to postoperative hip–knee–ankle angle (HKAA), 24 knees were sorted into group valgus with HKAA > 180° and 98 knees were sorted into group non-valgus with HKAA ≤ 180°. Logistic regression was performed to analyze risk factors including age, gender, BMI, side, preoperative limb alignment HKAA, preoperative LDFA, MPTA, FTFA, thickness of polyethylene bearing insert, tibial prothesis size, femoral prothesis size, medial tibial cut thickness, thickness of distal femoral mill, prothesis angle of coronal, and sagittal plane.

Results The mean mechanical preoperative HKAA of 174.39°±4.23° was corrected to 178.18°±3.49° postoperatively ($t = -13.45$, $p = 0.000$). The mean of postoperative HKAA in valgus group and non-valgus group was 183.45 ± 2.21° and 176.88 ± 2.35°, respectively ($t = 12.44$, $p = 0.000$). After statistical analysis with univariate analysis, eight risk factor variables among 16 independent variables were identified as potential predictors with p value ≤ 0.1. Multivariate logistic regression analysis for these eight potential predictors revealed that tibial cut ($p = 0.046$), LDFA ($p = 0.003$), MPTA ($p = 0.011$), and FTFA ($p = 0.008$) were significant risk factors predicting postoperative valgus malalignment after mobile-bearing UKA.

Conclusions Preoperative smaller LDFA, FTFA, larger MPTA and less medial tibial cut thickness were significantly associated with postoperative valgus malalignment in mobile-bearing UKA.

Keywords Unicompartmental knee arthroplasty · Risk factor · Alignment · Radiologic · Surgical technique

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Introduction

Unicompartmental knee arthroplasty (UKA) is a minimal invasive option for anteromedial osteoarthritis with many advantages, such as a smaller incision, less soft-tissue injury, minimal bone resection, preservation of normal knee kinematics, and rapid recovery [1, 2]. UKA has gained popularity in the world since the introduction of minimally invasive surgical technique by Repicci [3–6].

The progression of osteoarthritis in the lateral compartment is one of the main failure modes of UKA, accounting for approximately 20–40% of UKA failures [7–9]. Postoperative valgus malalignment with overcorrection is the most common cause of increased lateral compartment load and leading to osteoarthritis progression [10]. Hernigou et al. evaluated 58 knees UKA with 15-year follow-up and found that an overcorrection in valgus malalignment (HKAA > 180°) was associated with an increased risk of degenerative changes in the lateral compartment [11]. Wen et al. found that 3° valgus would increase load percentage 45.78% of the lateral compartment [12]. Besides, alignment errors may have side effects on the change of knee kinematics, wear rate, implant loosening, or failure [11, 13].

As the exposure is limited in the minimally invasive technique, UKA is generally considered a technical challenge to achieve good postoperative alignment and position. Kim et al. reported 124 Oxford phase 3 UKAs, and 13% cases did not gain acceptable postoperative mechanical axis [14]. Mullaji et al. investigated 122 consecutive minimally invasive Oxford phase 3 medial UKA in 109 patients and found that 11% were in postoperative valgus (HKAA > 180°) [15]. In our clinical practice, some patients also tend to valgus, although most limbs have acceptable alignments after UKA.

Because postoperative valgus alignment may lead to osteoarthritis progression in the lateral compartment, risk factors for postoperative valgus malalignment are important considerations to avoid the complication after medial UKA. However, to the best of our knowledge, few studies have evaluated the risk factors for postoperative valgus malalignment in mobile-bearing medial UKA. Hopgood et al. reported that tibiofemoral angle correction would increase as the thickness of the tibial insert increases [16]. However, it was about the fixed-bearing system which was designed quite different from the mobile-bearing system. The mobile-bearing Oxford UKA was designed to keep knee motion stability by polyethylene insert without soft-tissue release. Therefore, an evaluation of risk factors to predict postoperative alignment in mobile-bearing Oxford UKA may be useful.

The hypothesis of this study was that some preoperative or intraoperative factors would be correlated well with the postoperative valgus malalignment and be useful for predicting postoperative valgus malalignment with mobile-bearing UKA.

Patients and methods

Approval for the present study from the institutional review board was obtained. From January 2016 to December 2017, 122 knees' consecutive UKAs were included. The indications for UKA were severe knee pain of medial compartment and considerable difficulty in walking and performing daily activities. Radiograph could demonstrate loss of articular cartilage medially by showing that the medial joint width became narrow. The other indications were an intact anterior cruciate ligament (ACL), varus deformity < 15°, flexion contracture < 15°, and intact lateral compartment [17]. The preoperative diagnosis was osteoarthritis in all patients. At baseline, the 122 knees' medial UKA cohort consisted of 25 knees' male (20.49%) and 97 females (79.51%), with a mean age of 67.99 ± 8.86 years (49–85 years) and a mean body mass index (BMI) of 26.42 ± 3.26 kg/m^2 (18.3–35.2 kg/m^2). A total of 56 (45.90%) UKAs were performed on the right knee and 66 (54.10%) on the left knee.

Surgical procedure

All UKA procedures were performed by the senior author using the same minimally invasive surgical technique with the mobile-bearing Oxford medial UKA (Oxford unicompartmental knee, Biomet, Bridgend, UK). The knee joint was exposed through a small incision with quadriceps sparing and no patellar eversion. Medial release for ligament balancing or realignment was not performed. However, all medial osteophytes were completely removed with the osteotome. The ligament balance was determined according to the thickness of the polyethylene insert.

Radiographic assessments

Standardized weight-bearing anteroposterior, lateral, skyline radiographs, and full-length radiographs were obtained at our institution both preoperatively and postoperatively. On full-length weight-bearing radiographs, the hip–knee–ankle angle (HKAA) was measured as the angle between the femoral mechanical axis (center of hip to center of knee) and the tibial mechanical axis (center of knee to center of ankle) [18, 19]. Valgus was defined as HKAA > 180°. The lateral distal femoral angle (LDFA) was measured by the lateral angle between the anatomical axis of the femur and the distal femur articular surface, while the medial proximal tibia angle (MPTA) was defined as the medial angle between the knee joint line of the tibia and the axis line of the tibia. The femorotibial facet angle (FTFA) was defined as the angle between the best-fit line along the surface of the tibial plateau and the line connecting the most distal points of the medial and lateral femur condyles [20] (Fig. 1).

The medial femoral bone mill was recorded as the number of the final spigot used in procedure. The medial tibial bone cut was measured on weight-bearing anteroposterior radiographs using the following method: On preoperative anteroposterior radiograph, both the anatomical axis of the tibia (line A) and a line perpendicular to the anatomical axis from the lowest point of the medial tibia (line B) were drawn. The distance from line B to the peak point of tibial vertices was measured (distance α). On postoperative radiograph, the perpendicular line (line C) to the anatomical axis (line A) from the bottom of tibia implant was drawn. The distance β from the same peak point of tibial vertices to the line C was measured. The difference between distance α and distance β was defined as the medial tibial bone cut thickness (Fig. 2).

The component alignments and positions were measured on postoperative radiographs: femoral A—coronal angle of femoral component, femoral B—sagittal angle of femoral

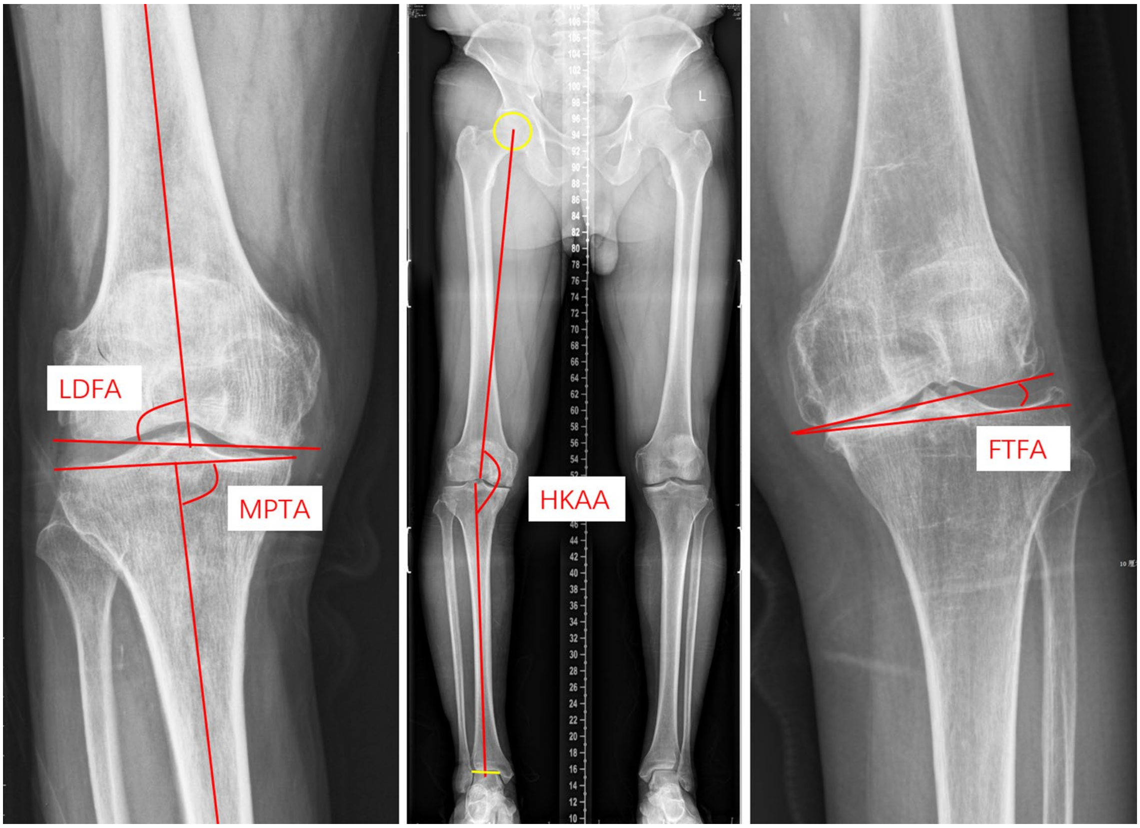

Fig. 1 Patients were assessed radiographically on preoperative weight-bearing X-rays. The overall limb alignment hip–knee–ankle angle (HKAA) was defined as the angle among hip center, notch center of distal femur, and ankle talus center. The lateral distal femoral angle (LDFA) was measured by the lateral angle between the distal femur articular surface and the anatomical axis of femur, while medial proximal tibia angle (MPTA) was defined as the medial angle between the knee joint line of tibia and the axis line of tibia

component, tibial E—coronal angle of tibial component, and tibial F—posterior–inferior slope of tibial component. Positive values represent varus and flexion alignment, and negative values represent valgus and extension alignment (Fig. 3).

Statistical analysis

All data were analyzed using SPSS 17.0 (SPSS, Chicago, IL, USA). The data were reported as the mean ± standard deviation. For logistic regression analysis of risk factors of postoperative valgus malalignment, the variables of risk factors included age, gender, BMI, side, preoperative HKAA, preoperative LDFA, MPTA, FTFA, thickness of polyethylene bearing insert, size of tibial prothesis, size of femoral prothesis, thickness of medial tibial bone cut, thickness of distal femoral mill, femoral A, femoral B, tibial E, and tibial F. To identify potential predictors of postoperative valgus malalignment, we compared the 16 variables of group valgus with group non-valgus using a univariate method. Statistical significance of the variables was determined by t test and Chi-square test with p value ≤ 0.1. For the multivariate analysis, the significant risk factors from univariate analysis were selected and a backward stepwise procedure in a multiple logistic regression model was performed with variables entered for p value ≤ 0.1. The results of regression analyses were presented as odds ratio (OR) with 95% confidence intervals (95%CI). The result was considered to be statistically significant when the null value (1.00) was absent from the 95CI or p value < 0.05.

Results

The mean mechanical preoperative HKAA of 174.39°±4.23° was corrected to 178.18°±3.49° postoperatively (t = − 13.45, p = 0.000). The mean of postoperative HKAA in valgus group and non-valgus group was 183.45 ± 2.21° and 176.88 ± 2.35°, respectively (t = 12.44, p = 0.000). There were no differences regarding gender distribution, operating side between groups. After statistical analysis with univariate analysis, eight risk factor variables among 16 independent variables were identified as potential predictors with p value ≤ 0.1.

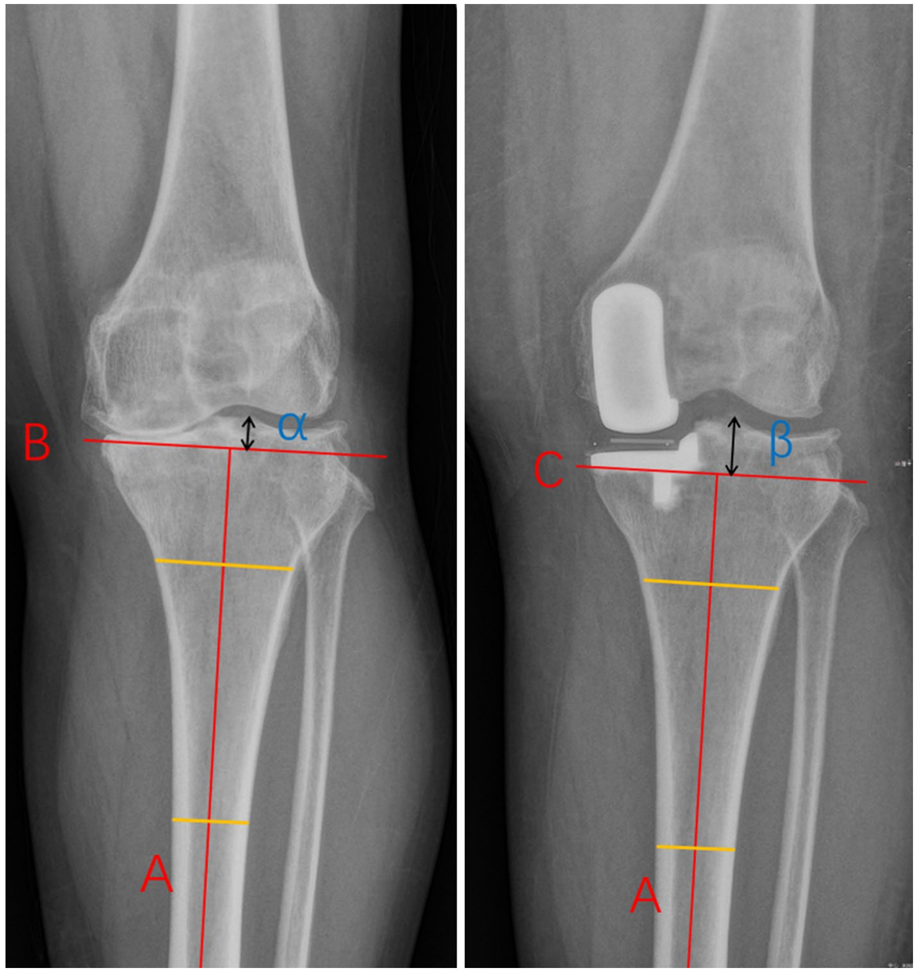

Fig. 2 Medial tibial bone cut was measured on weight-bearing anteroposterior radiographs: an anatomical axis of the tibia (line A) and a line perpendicular to the anatomical axis from the lowest point of medial tibia (line B) were drawn on the preoperative radiograph. The distance from line B to the peak point of the tibial vertices was measured (distance α). On the postoperative radiograph, the perpendicular line (line C) to the anatomical axis (line A) from the bottom of the tibia implant was drawn. The distance β from the same peak point of the tibial vertices to the lines C was measured. The difference between distance α and distance β was defined as the medial tibial bone cut amount

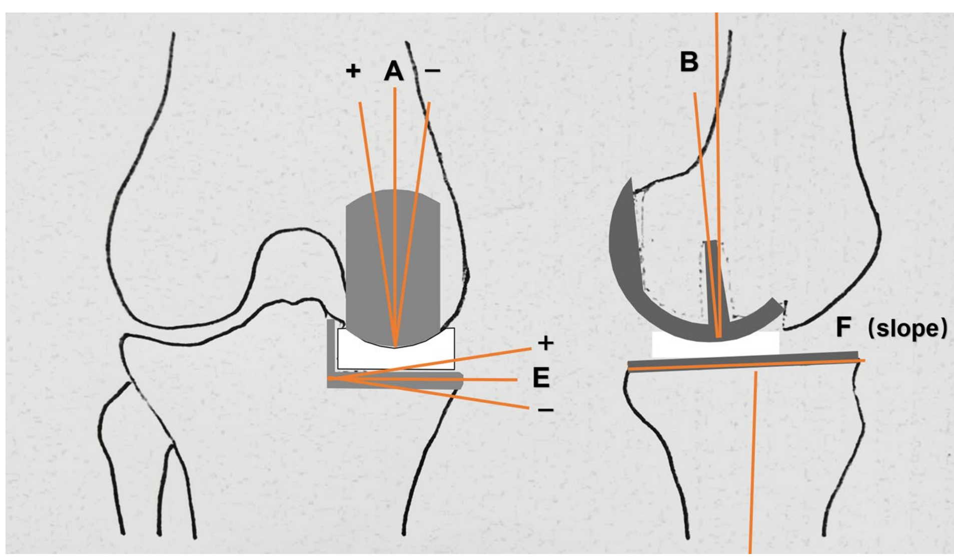

Fig. 3 Diagrams showing the postoperative radiographic assessments of component alignment and position: femoral angle A was coronal angle of femoral component; femoral angle B was sagittal angle of femoral component; tibial angle E was coronal angle of tibial component; and tibial angle F was posterior–inferior slope of tibial component. Positive values represent varus and flexion alignment, and negative values represent valgus and extension alignment

These were age, BMI, preoperative HKAA, preoperative LDFA, MPTA, FTFA, thickness of medial tibial bone cut, and tibial E. Multivariate logistic regression analysis for these eight potential predictors revealed that tibial cut ($p = 0.046$), LDFA ($p = 0.003$), MPTA ($p = 0.011$), and FTFA ($p = 0.008$) were significant risk factors predicting postoperative valgus malalignment after mobile-bearing UKA (Tables 1, 2).

Table 1 Characteristics of the patients with postoperative valgus and without postoperative valgus

Characteristic	Valgus group ($n=24$)	Non-valgus group ($n=98$)	t	p value
Age (years)	64.96 ± 9.84	68.73 ± 8.49	− 1.89	0.06
Gender (male/female)	2 (8.33%)/22 (91.67%)	23 (23.47%)/75 (76.53%)	2.689	0.156
Side (left/right)	9 (37.50%)/15 (62.50%)	57 (58.16%)/41 (41.84%)	3.288	0.108
BMI (kg/m^2)	25.23 ± 3.32	26.72 ± 3.20	− 2.03	0.04
Preoperative HKAA (degree)	178.87 ± 2.61	173.30 ± 3.81	6.78	0.00
Preoperative LDFA (degree)	76.53 ± 2.21	82.06 ± 2.34	− 10.49	0.00
Preoperative MPTA (degree)	87.64 ± 1.91	85.42 ± 2.61	3.90	0.00
Preoperative Slope (degree)	82.38 ± 3.68	82.22 ± 3.97	0.17	0.87
Preoperative FTFA (degree)	2.56 ± 1.91	4.06 ± 2.06	− 3.24	0.00
Femoral mill (mm)	3.58 ± 0.72	3.62 ± 0.68	− 0.25	0.80
Tibial cut (mm)	6.59 ± 1.64	7.49 ± 2.41	− 1.72	0.09
Size of femoral component (n (%))			2.904	0.407
Extra small	5 (20.83%)	21 (21.43%)		
Small	16 (66.67%)	57(58.16%)		
Medium	3 (12.50%)	14 (14.29%)		
Large	0 (0)	6 (6.12%)		
Size of tibial component [*n* (%)]			1.259	0.262
AA (smallest)	6 (25.00%)	24 (24.49%)		
A	11 (45.83%)	32 (32.65%)		
B	6 (25.00%)	28 (28.57%)		
C	1 (4.17%)	13 (13.27%)		
D (largest)	0(0)	1 (1.02%)		
Size of polyethylene bearing (n (%))			4.268	0.234
3 (thinnest)	6 (25.00%)	23 (23.47%)		
4	12 (50.00%)	61 (62.24%)		
5	5 (20.83%)	14 (14.29%)		
6	1 (4.17%)	0 (0)		
7 (thickest)	0 (0)	0 (0)		
Postoperative angle A (degree)	2.98 ± 3.45	2.68 ± 3.96	0.34	0.74
Postoperative angle B (degree)	7.74 ± 5.27	6.18 ± 8.17	0.89	0.38
Postoperative angle E (degree)	1.05 ± 5.03	3.86 ± 6.84	− 2.26	0.03
Postoperative angle F (degree)	7.11 ± 2.04	7.34 ± 3.02	− 0.44	0.66

Table 2 Multivariable regression results

	Odds ratio (OR)	95% CI	p value
Tibial cut	0.59	0.35–0.99	0.046
LDFA	0.18	0.06–0.56	0.003
MPTA	5.11	1.46–17.90	0.011
FTFA	0.28	0.11–0.72	0.008

The mean of tibial cut was 6.59 ± 1.64 mm in valgus group and 7.49 ± 2.41 mm in non-valgus group ($p=0.087$). The OR of tibial cut in multivariate analysis was 0.59 (95% CI 0.35–0.99, $p=0.046$). As tibial cut decreased by one millimeter, malalignment was about 1.71 times probable.

The mean of preoperative LDFA was 76.53 ± 2.21° in valgus group and 82.06 ± 2.34° in non-valgus group ($p=0.000$). In multivariate logistic regression analysis, the OR of preoperative LDFA was 0.18(95% CI 0.06–0.56, $p=0.003$). As LDFA decreased by 1°, postoperative valgus malalignment incidence was about 5.44 times increase.

The mean of preoperative MPTA was 87.64 ± 1.91° in valgus group and 85.42 ± 2.61° in non-valgus group ($p=0.000$). The OR of preoperative MPTA in multivariate analysis was 5.11 (95% CI 1.46–17.90, $p=0.011$). As MPTA increased by 1°, malalignment was about 5.11 times probable.

The mean of preoperative FTFA was 2.56 ± 1.91° in valgus group and 4.06 ± 2.06° in non-valgus group ($p=0.002$). In multivariate logistic regression analysis, the OR of preoperative FTFA in was 0.28 (95% CI 0.11–0.72, $p=0.008$). As FTFA decreased by 1°, postoperative valgus malalignment was about 3.60 times probable.

Discussion

The most important finding of the present study was that smaller LDFA, FTFA, larger MPTA, and less medial tibial cut thickness were significantly associated with postoperative valgus malalignment in mobile-bearing UKA.

Oxford mobile-bearing UKA is indicated for symptomatic anteromedial osteoarthritis with the design purpose to restore the natural knee motion and minimize polyethylene wear. As surgical techniques and instruments have improved, the procedure has shown good results both in functional outcome and survivorship. Pandit et al. reported 10-year survival rate 99.8% using revision as the end point in 1000 Oxford phase 3 medial UKAs [21]. Lisowski et al. reported that the mean knee society score and function score were all improved after Oxford mobile-bearing UKA with 94.4% 7-year survival rate [22]. Although implant developers and experienced professors reported good results for UKA, many knee replacement registries still reported relatively high failure rates and poor results, especially when compared with total knee arthroplasty (TKA) [23]. Badawy et al. evaluated the data of the Norwegian arthroplasty register from 1999 to 2012 and found that the failure rate was about 20% at 10 years, especially higher in low-volume hospitals [23]. Niinimaki et al. reported that UKA had inferior survivorship compared with TKA in Finnish arthroplasty register, and the Kaplan–Meier survivorship of UKA was only 69.6% at 15 years (TKA 88.7%) [24]. Among many failure models, osteoarthritis progression in lateral compartment almost accounted the top three reasons ranging from 0.9 to 7% [25–28]. Lewold et al. reported that osteoarthritis progressive was the cause of failure in 25% cases in Swedish knee arthroplasty registry [29]. van der List JP et al. performed a systematic review and reported that osteoarthritis progression was the major failure mode in midterm and late failures (38 and 40%, respectively) [9].

Postoperative alignment in medial UKA has been evaluated by many studies [14, 30–32]. Mercier et al. investigated 43 Oxford UKAs with 14.88-year follow-up and found a strong correlation between the postoperative valgus angle and the progression of lateral compartment arthritis ($p=0.005$) [33]. Kim et al. found that postoperative tibiofemoral angle $\geq 10°$ of valgus had the highest failure rate of implants, and the 8-year survival rate was only 69.2% [31]. Xue et al. reported that three lateral progression of osteoarthritis and found a mean postoperative valgus of $>5°$ at the short time of Oxford medial UKA [34]. Although the ideal postoperative angle is conversational, it is better to avoid postoperative valgus malalignment for UKA.

The limb malalignment deformity in frontal plane includes the intra-articular and extra-articular deformity [35]. The indication of UKA is anteromedial osteoarthritis, whose preoperative varus malalignment is from cartilage erosion in medial compartment. Oxford mobile-bearing UKA just replaces the medial lesion without releasing the ligaments that means that UKA just corrects the intra-articular deformity. The risk factors in this study may indicate the cause of limbs overcorrected to valgus. Smaller LDFA and larger MPTA indicated the physiological habitual valgus. The limb overcorrected to valgus might have a small physiological habitual valgus before developing medial compartmental OA due to medial wear. In these cases, Oxford mobile-bearing UKA corrected the genu varum and restored whatever degree of tibiofemoral valgus present before the arthritis developed. FTFA is the angle between femoral facet and tibial facet, which could reflect the intra-articular deformity [20]. Since a smaller FTFA means less intra-articular deformity, UKA may overstuff the medial compartment when the intra-articular deformity is small. Similarly, less tibial cut cannot create enough gap to insert the prothesis in theory. However, these cases may have loosing medial tissue, so even if the tibial cut is less, the gap is larger enough. Following, overcorrection may incur after UKA [36].

For the effect of the tibial insert thickness on postoperative alignment, we found that postoperative valgus was independent of tibial bearing insert thickness. The result was similar with Ahn JH's report [37] and quite different with Kim's study [14], though the latter was about the same Oxford UKA. The Oxford mobile-bearing UKA principle of the procedure was to keep knee stability by ligament tension. Soft-tissue tension must be adequate to prevent the joint from subluxation or dislocation. If UKA aims to keep the natural tension without soft-tissue release, the bearing size inserted is related to ligament relaxation, bone cut, and intra-articular deformity correctability.

The present study had several strengths. This logistic regression analysis was the first study to estimate the risk factors including preoperative radiographic features and surgical characteristics for postoperative valgus malalignment in mobile-bearing UKA. Most previous studies did not focus on the surgical factors, such as tibial cut and femoral mill, which were addressed in the present study. Besides, we introduced simple and concise parameters in the analysis, using LDFA, MPTA for extra-articular deformity and FTFA for intra-articular deformity. Third, it had great value for clinical practice. The result suggested that it might be better to select a patient for mobile-bearing UKA without smaller LDFA, FTFA, and larger MPTA.

Nevertheless, there were still some potential weaknesses in the study. First, the amount of the ligamentous balance was not quantified. However, all procedures were performed by the senior author, and the same surgical criteria of soft tissue and bone preservation were uniform throughout the study. The procedures were achieved in the absence of ligament release, and a standard 1 mm gap was persevered after protheses implant. Second, the sample size of the case series was relatively small. If we included more patients, the result might be more comprehensive. Third, as the aim of this study was to investigate the risk factors of postoperative valgus malalignment, cartilage erosion and excising osteophytes were not analyzed in the study, which might influence the deformity correctability. Further research is still needed to elaborate the result.

Despite these limitations, our study provided valuable information. Preoperative smaller LDFA, FTFA, larger MPTA, and less medial tibial cut thickness were significantly associated with postoperative valgus malalignment in mobile-bearing UKA. Regarding UKA patient selection in practice, patients with the risk factors are not indicated for medial UKA. It might be better to select patients for mobile-bearing UKA without smaller LDFA, FTFA, and larger MPTA. With respect to surgical technique, the amount of medial tibial cut should not be too small to implant a prosthesis.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent Informed consent for study participation was obtained from each patient.

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