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Lateral osteoarthritis progression is associated with a postoperative residual tibiofemoral subluxation in Oxford UKA

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Abstract

Purpose Lateral compartment osteoarthritis progression (LOP) is a major complication after Oxford mobile-bearing unicompartmental knee arthroplasty (OUKA). This study aimed to identify the association between tibiofemoral subluxation (TFS) and LOP after OUKA. Patients whose TFS was uncorrectable according to preoperative stress radiographs were hypothesised to develop residual TFS even after surgery, and thought to be more likely to develop LOP.

Methods The study included 201 patients who underwent medial OUKA. Fifteen patients showed increases in LOP of at least two Kellgren–Lawrence grades after surgery [progression (P) group], while the others had no progression (N group, $n = 186$). TFS was measured on preoperative full leg weight-bearing radiographs, valgus stress radiographs and postoperative plain radiographs. Valgus stress radiographs were obtained using a firm manual valgus force with the knee flexed at 20°. Leg alignment, Oxford knee score (OKS), and revision rates were assessed.

Results The *P* group had significantly higher TFS values on preoperative valgus stress (6.8° ± 2.2° vs. 4.5° ± 2.0°; $P < 0.001$) and postoperative radiographs (6.6° ± 2.3° vs. 4.6° ± 2.9°; $P < 0.001$) than the N group. Patients with postoperative residual TFS and postoperative valgus alignment were more likely to have LOP, but 9 of the 15 LOP patients did not show postoperative valgus alignment. The P group had significantly poorer postoperative OKS (33.0 ± 10.2 vs. 37.4 ± 6.5, $P = 0.017$) and a higher rate of revision (6/15 vs 6/186; odds ratio = 19.16; 95% CI = 4.98–76.05, $P < 0.001$).

Conclusion OA progression in the lateral compartment after medial OUKA might be associated with postoperative residual TFS, but does not always coexist with postoperative valgus alignment. Preoperative assessment of TFS with valgus stress could be a potential predictor of postoperative residual TFS and LOP.

Level of evidence Level III.

Keywords Lateral · Osteoarthritis · Oxford knee · Limb alignment · Tibiofemoral subluxation · Unicompartmental knee arthroplasty

Introduction

Good clinical outcomes and long-term survival after Oxford mobile-bearing unicompartmental knee arthroplasty (OUKA) have been reported in large series [18, 20, 22–24, 32]. OUKA reportedly achieves equivalent revision rates and functional outcomes to those of fixed-bearing UKA [1, 3, 38]. Following aseptic loosening, lateral osteoarthritis progression (LOP) is the second most common cause of failure, accounting for 19% of all cases [19, 34] and 25–34% in an early series [17]. Overcorrection of varus deformity and eventual overload on the lateral compartment have been suggested as a cause of LOP [25, 29]. Although a use of thicker bearing to avoid bearing dislocation has been considered as a cause of LOP [8, 35], such dislocation can occur in knees without thicker bearings.

Tibiofemoral subluxation (TFS), the distance between the tibial axis and the line parallel to the tibial axis from the apex of the intercondylar notch [11, 26], can cause a

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mismatch in the mediolateral relationship between the femoral and tibial components and worsen clinical outcomes after UKA [11]. TFS may lead to instability, inadequate ligament balancing, proximal tibial oblique, and/or muscle weakness [26, 36]. Additionally, postoperative residual TFS can cause impingement and incongruency of lateral joint surfaces and lead to subsequent LOP. Preoperative assessment on valgus stress could be conducted to assess TFS correctability.

This study therefore aimed to determine whether the preoperative correctability of TFS and postoperative TFS were associated with LOP after OUKA. The relationship between the preoperative correctability of TFS and postoperative TFS is also evaluated. Residual TFS is hypothesised to be related to LOP and it can be estimated by preoperative valgus stress radiography as uncorrectable TFS.

Materials and methods

Subjects

This retrospective study included 236 patients who underwent unilateral Oxford mobile-bearing UKA (Zimmer Biomet, Warsaw, IN, USA) between March 2012 and March 2015. All patients were diagnosed with anteromedial OA [37] or ON. Full thickness lateral compartment articular cartilage in the weight-bearing area and an intact anterior cruciate ligament were confirmed intraoperatively. In addition to knee condition, patients whose clinical courses could be evaluated in the outpatient clinic for a minimum of 5 years after their operation were included in the study. The exclusion criteria were knees with flexion contractures > 15°, previous high tibial osteotomy or other knee surgery, or active knee joint infection. All surgeries were performed by the same senior surgeon or under his supervision. Patients were stratified into two groups based on the occurrence of LOP. This retrospective study was approved by the hospital's ethics committee (no. 2018-79), and all patients provided written informed consent to inclusion. At the time of surgery, the patients were 71.3 ± 8.1 years old (range 58–90 years), with a body mass index (BMI) of 25.4 ± 3.7 kg/m^2 (range 17.7–36.2 kg/m^2). The preoperative mean ranges of motion were − 5.2 ± 5.2° (range − 15° to 10°) in extension and 124.2 ± 12.7° (range 90°–150°) in flexion. Mean follow-up period was 80.8 ± 10.5 months (range 60–104 months).

Surgical procedure

Surgery was performed according to the standard protocols using Microplasty instruments, following the modified under-vastus approach in the leg hanging position using a leg holder [9, 10, 27]. The horizontal tibia cut was made 6 or 7 mm below the lowest point of the medial femoral condyle and the longitudinal cut directed to the anterior superior iliac spine from just medial to the tip of the intercondylar eminence using Microplasty with a 7° posterior slope. Care was taken to avoid overstress. The gauge thickness is considered to be correct when natural tension in the ligaments is achieved. Under these circumstances, the feeler gauge will easily slide in and out, but will not tilt. Confirmation of the correct size is obtained by confirming that a gauge 1 mm thicker is firmly gripped but a gauge 1 mm thinner is loose [34].

Full weight-bearing and full-knee flexion immediately after surgery were encouraged in all patients. Passive and active motion exercises, including muscle strengthening and gait rehabilitation, were applied by a physiotherapist for 2 weeks postoperatively, followed by self-training, as instructed by the therapist.

Radiological assessment

LOP was assessed using the Kellgren–Lawrence (KL) OA grading system [17] at the preoperative visit and at the final follow-up. This was conducted preoperatively for valgus stress radiographs and postoperatively for weight-bearing anteroposterior radiographs. Valgus stress radiographs were obtained using a firm manual valgus force with the knee flexed at 20° [6]. Valgus stress views were used to minimise the effect of varus deformity on lateral compartment assessment. LOP was defined as an increase of at least two grades in the KL OA grading system between 2 weeks preoperatively and the final follow-up. LOP was defined as increase of two grades or more in the KL grade because progression of one grade, which is commonly seen in more than 30% of patients after UKA [21], is of little clinical significance. Among the 201 patients who received OUKA, 15 developed LOP by the final follow-up and were included in the progression (P) group. The remaining 186 patients comprised the non-progression (N) group.

Overall coronal plane limb alignment was assessed using long-leg standing weight-bearing anteroposterior radiographs performed preoperatively and at 2 weeks postoperatively. The hip–knee–ankle (HKA) angle was assessed pre- and postoperatively with positive values for varus alignment. Preoperatively, HKA was also assessed under the valgus stress view using a previously reported method [31]. Additionally, the passing position at the knee joint of the mechanical axis was evaluated using previously described classifications [13] and then categorised as medial, neutral, or lateral to the centre of the knee, respectively.

TFS was measured using a plain weight-bearing anteroposterior radiograph preoperatively and at 2 weeks postoperatively, according to a previously developed method [26]. Briefly, the tibial anatomical axis connecting the midpoints of the outer cortex at 7.5 and 15 cm distal to the tibial joint surface was drawn, and then a line was drawn from the apex of the intercondylar notch, which was parallel to the tibial anatomical axis. The distance between the tibial anatomical axis and a line parallel to the tibial anatomical axis from the apex of the intercondylar notch was measured as the TFS (Fig. 1A). The preoperative correctability of the TFS was also measured on a valgus stress radiograph without anaesthesia at 20° flexion of the knee (Fig. 1B). Cases in which the preoperative values with valgus stress were above the mean + standard deviation (SD) were defined as preoperative uncorrectable TFS, and cases in which the postoperative values were above the mean + SD were defined as postoperative residual TFS.

All radiography was performed by musculoskeletal radiologists with more than 5 years of experience. For evaluation of radiographs, the lower limb was slightly rotated internally such that the patient's patella was placed forward with the ankle in the neutral position to unify the rotation. Voltage and current were set at 200 mA and 85 kV, respectively.

Clinical outcomes

The maximum flexion angle (MFA) assessed by a goniometer was noted preoperatively and at the final follow-up. Oxford knee score (OKS) was used as a measure of clinical outcomes preoperatively and at the final follow-up [16].

Statistical analysis

The evaluations were performed twice by the same surgeon (T.K.) at intervals of > 4 weeks and once by another examiner (T.H.). Intraclass and interclass correlation coefficients (CC) were calculated to determine the reliability of the quantitative measurements. The intraclass CCs for intraobserver reproducibility were 0.83, 0.86, 0.81, 0.89, and 0.86 for pre- and postoperative HKA, pre- and postoperative TFS and preoperative TFS under valgus stress, respectively. The interclass CCs for inter-observer reproducibility of the above-listed tibial and measurements were 0.81, 0.90, 0.87, 0.87 and 0.82, respectively.

All data are presented as means and SDs. The results were analysed using StatView version 5.0 (Abacus Concepts Inc., Berkeley, CA, USA). Patient characteristics, pre- and postoperative HKAs and TFSs, and clinical outcomes were compared between the P and N groups using the Student's unpaired *t* test. Fisher's exact tests were used to compare the postoperative limb alignment (varus/valgus) and the mechanical axis (medial or neutral/valgus) between the P and N groups. Pre- and postoperative TFSs were compared using paired *t* tests. Additionally, Spearman's rank correlation analysis was performed to assess the correlation of preoperative TFSs and the correctability of the TFS with the postoperative TFS. P value < 0.05 was considered statistically significant.

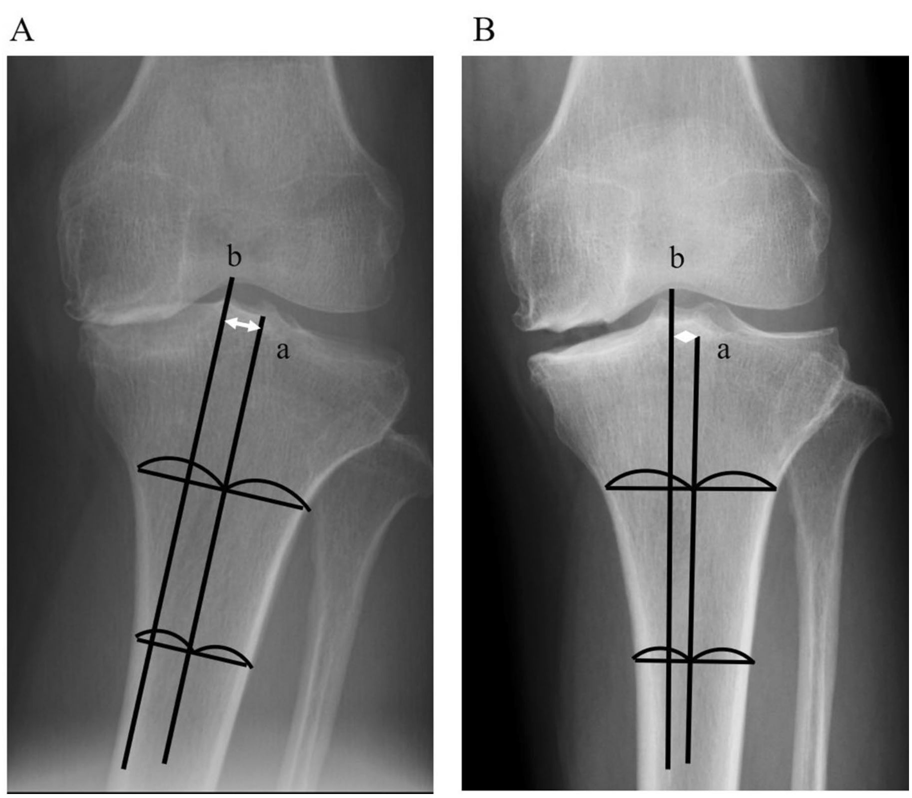

Fig. 1 Measurement of tibiofemoral subluxation. The tibial anatomical axis connecting the midpoints of the outer cortex at 7.5 and 15 cm distal to the tibial joint surface was drawn, and then a line was drawn from the apex of the intercondylar notch, which was parallel to the tibial anatomical axis. The distance between the two parallel lines was measured as the TFS (**A**). Additionally, the preoperative correctability of the TFS was measured on a valgus stress radiograph without anaesthesia at 20° flexion of the knee in the same manner (**B**)

Post hoc power analysis was performed using G*Power 3 [5]. For a sample size of 201 in two groups (15 vs 186) and a type-I error (α) of 0.05 (Fisher's exact test), the study was expected to provide a power (1-β) of 0.80 when an odds ratio of 5 was set as a clinically meaningful difference. For the paired and unpaired *t* test, the effect size was calculated using means and SDs based on the Hedges' *g* for each parameter and the 95% confidence interval (CI) for effect sizes [4].

Results

Of the 236 identified patients, 19 were excluded due to insufficient routine postoperative evaluation data. A further 16 patients were excluded due to severe flexion contractures ($n=7$) and history of knee surgery ($n=9$). In total, 201 patients ($n=49$ men) were therefore included in this study.

Table 1 Preoperative demographic data

	P group	N group	*P* value
Number of cases	15	186	
Sex, male/female	4/11	45/141	0.832
Age, years	70.8 (62–88)	71.2 (58–90)	0.846
Body mass index, kg/m^2	26.2 (17.6–29.8)	25.3 (19.2–31.5)	0.362
Follow-up period, months	80.0 (60–96)	80.6 (60–104)	0.850
KL grade in lateral compartment, none/doubtful	5/10	66/120	0.932

P group: patients who experienced lateral compartment osteoarthritis (OA) progression with an increase of at least two grades on the Kellgren–Lawrence (KL) OA grade between 2 weeks preoperatively and the final follow-up. N group: patients who did not show lateral compartment OA progression from 2 weeks preoperatively to the final follow-up

Preoperative demographic data

There were no significant differences in age, sex, BMI, or follow-up period between the patients in the P and N groups (Table 1). Additionally, the preoperative radiographic grade of OA in the lateral compartment did not significantly differ between the two groups.

Comparison of overall coronal limb alignment

The pre- and postoperative HKAs did not differ significantly between the P and N groups (preoperative, 7.8° ± 6.9° vs. 8.4° ± 4.3°; $P=0.60$, Hedges' $g=-0.13$, 95% confidence interval (CI) = − 0.66 to 0.39; postoperative, 1.6° ± 4.9° vs. 3.6° ± 3.7°; $P=0.06$, Hedges' $g=-0.52$, 95% CI = − 1.05 to 0.01). Preoperatively, the mechanical axis passed neutral and medial in 19 and 182 patients, respectively. There were no patients with valgus alignment and/or a mechanical axis passing the lateral compartment. However, the P group was more likely to have valgus alignment 2 weeks postoperatively; the P group had a significantly higher proportion of cases in which the mechanical axis passed lateral to the centre of the knee compared to the N group (Table 2).

Comparison of TFS

The preoperative TFS value did not significantly differ between the groups, but the preoperative values under valgus stress and postoperative values were significantly higher in the P group than in the N group (Table 3). The P group was more likely to have preoperative uncorrectable TFS, even under the valgus stress test as well as to have postoperative residual TFS (Table 4). Postoperative TFS also showed stronger positive correlations with preoperative TFS with valgus stress ($r=0.83$, $P<0.0001$) than with preoperative TFS without stress ($r=0.61$, $P<0.0001$).

Moreover, 66 knees (32.8%) had postoperative valgus alignment and/or residual TFS, and 14 out of 66 (21.2%) such knees had LOP. The percentage was significantly higher than the value in the remaining no valgus–no

Table 2 Postoperative overall limb alignment and mechanical axis

	P group (%)	N group (%)	*P* value	Odds ratio (95% CI)
Postoperative HKA				
Varus	9 (60)	160 (86.0)	0.019	4.09 (1.25–12.54)
Valgus	6 (40)	26 (14.0)		
Postoperative mechanical axis				
Medial or neutral	11 (73.3)	181 (97.3)	0.0021	12.82 (2.71–57.67)
Lateral	4 (26.7)	5 (2.7)		

P group: patients who experienced lateral compartment osteoarthritis (OA) progression with an increase of at least two grades on the Kellgren–Lawrence (KL) OA grade from 2 weeks preoperatively to the final follow-up. N group: patients who did not show lateral compartment OA progression from 2 weeks preoperatively to the final follow-up residual TFS knees (0.83%, $n = 1/135$), with an odds ratio of 31.42 (95% CI 6.05–774.71; $P < 0.0001$). Radiographic results from the P group are shown in Table 5.

Clinical outcomes

The mean maximum knee flexion angle preoperatively and at the final follow-up did not differ significantly between the P and N groups (preoperative, 125.0° ± 12.7° vs. 124.1° ± 12.8°; $P = 0.80$, Hedges' $g = 0.07$, 95% CI = − 0.46

Table 3 Comparison of tibiofemoral subluxation between the two groups

	P group	N group	*P* value	Hedge's *g*	95%CI	
Preoperative tibiofemoral subluxation, mm	7.6 ± 2.1	6.5 ± 2.3	0.086	0.48	− 0.05	1.01
Preoperative tibiofemoral subluxation under valgus stress, mm	6.8 ± 2.2	4.5 ± 2.0	< 0.001	1.14	0.60	1.68
Postoperative tibiofemoral subluxation, mm	6.6 ± 2.3	4.6 ± 2.9	0.011	0.70	0.17	1.23

P group: patients who experienced lateral compartment osteoarthritis (OA) progression with an increase of at least two grades in the Kellgren–Lawrence (KL) OA grade from 2 weeks preoperatively to the final follow-up. N group: patients who did not show lateral compartment OA progression from 2 weeks preoperatively to the final follow-up

CI confidence interval

Table 4 Tibiofemoral subluxation

	P group (%)	N group (%)	*P* value	Odds ratio (95% CI)
Preoperative TFS under valgus stress				
Correctable	5 (33.3)	155 (83.3)	< 0.0001	9.69 (3.16–33.84)
Uncorrectable	10 (66.7)	31 (16.7)		
Postoperative TFS				
No residual	5 (33.3)	157 (84.4)	< 0.0001	10.49 (3.41–36.72)
Residual	10 (66.7)	29 (15.6)		

TFS: tibiofemoral subluxation. P group: patients who experienced lateral compartment osteoarthritis (OA) progression with an increase of at least two grades in the Kellgren–Lawrence (KL) OA grade from 2 weeks preoperatively to the final follow-up. N group: patients who did not show lateral compartment OA progression from 2 weeks preoperatively to the final follow-up

Table 5 Result of patients with lateral osteoarthritis progression

No	Hip Knee Ankle angle, °				Tibiofemoral subluxation, °		
	Preop	Preop with valgus stress	Postop	Correction	Preop	Preop Valgus stress	Postop
1	19.3	7.4	9.0	10.3	9.0	7.7	8.1
2	5.0	1.7	2.1	2.9	8.8	8.1	7.6
3	6.4	0.8	− 1.2	7.6	8.6	7.6	5.9
4	6.1	2.1	1.0	5.1	4.0	3.8	2.2
5	2.7	0.4	− 1.1	3.8	10	9.8	9.1
6	4.0	− 0.4	− 3.2	7.2	9.8	9.1	8.6
7	3.2	0.8	− 5.5	8.7	3.5	2.2	2.1
8	2.5	0.9	− 0.5	3.0	5.7	4.9	5.3
9	6.4	1.8	2.4	4.0	7.2	6.2	6.8
10	14.3	3.6	2.6	8.7	7.1	6.7	7.0
11	0.8	− 0.2	− 3.2	4.0	5.5	3.8	4.4
12	14.6	4.6	9.4	5.2	8.5	7.2	7.7
13	18.8	8.7	10.2	8.6	8.4	8.0	8.7
14	7.2	3.1	1.2	6.0	8.0	8.2	6.7
15	2.7	0.3	0.9	1.8	10.2	8.8	9.0

to 0.60; final follow-up, 124.3° ± 11.5° vs. 128.7° ± 10.8°; $P = 0.13$, Hedges' $g = -0.40$, 95% CI = − 0.93 to 0.12).

The preoperative OKS also did not differ significantly between the P and N groups (26.0 ± 6.4 vs. 25.9 ± 7.3, $P = 0.95$, Hedges' $g = 0.01$, 95% CI = − 0.51 to 0.54), but postoperative OKS at the final follow-up was significantly lower in the P group than in the N group (33.0 ± 10.2 vs. 37.4 ± 6.5, $P = 0.017$, Hedges' $g = -0.64$, 95% CI = − 1.17 to − 0.11).

In the P group, 6 out of 15 patients required revision surgery due to LOP; there was no revision required due to loosening and/or fracture. The revision rate was significantly greater in P group (40.0%, 6/15) than in the (3.2%, 6/186) in the N group (odds ratio = 19.16; 95% CI = 4.98–76.05, $P < 0.001$).

In total, during the follow-up period, 12/201 (6.0%) patients underwent TKA revision. The reasons for revision were LOP in six (50.0%) patients, aseptic loosening in four (33.3%) patients, and tibial fracture in two (16.7%) patients. Additionally, insert dislocation occurred in one patient had, and thus the insert was exchanged for a thicker one. Finally, open drainage was performed for two cases of postoperative haematoma and one case of minor infection.

Discussion

In this study, 15 out of 201 patients had LOP after a minimum of 5 years follow-up subsequent to OUKA. The most important finding of this study was that patients with preoperative uncorrectable TFS and/or postoperative residual TFS tended to have LOP after OUKA. This is the first known study to report an association between TFS and LOP based on detailed quantitative assessments. This information may assist surgeons in deciding the indication for UKA.

Significantly worse postoperative OKS and a higher revision rate in patients with LOP were also shown in this study. Various previous studies have reported LOP to be one of the major mechanisms of failure and causes of revision in mobile-bearing UKA and that it could worsen patient-reported clinical outcomes [2, 14, 19, 21, 28, 30, 34].

In the current study, patients with OA progression (P group) were more likely to have valgus alignment in HKA and lateral weight-loading in the mechanical axis at 2 weeks postoperatively. Previous studies showed that postoperative valgus alignment was the primary contributing factor to LOP after UKA [21, 29]. The findings of the current study support the theory that overcorrection of the varus deformity causes overloading of the lateral compartment, which ultimately leads to LOP after OUKA [29]. Surgeons should therefore avoid overstuffing the medial compartment due to the increased load in the lateral compartment. At the same time, they should avoid instability, which could cause bearing dislocation. Resolving these issues is a key factor for success in mobile-bearing UKA and should be examined in further studies. However, among the 15 patients with LOP in this study, only six had valgus alignment postoperatively. Overcorrection might not therefore be the sole cause of LOP.

Regarding TFS, a significantly higher postoperative TFS was shown in the P group than in the N group in this study, although there was no noted significant difference in the preoperative value between the groups. Patients with postoperative residual TFS were more likely to experience LOP after OUKA, confirming our hypothesis. Moreover, with the exception of those patients with valgus alignment and/or residual TFS, the overall rate of LOP in this study was < 1%. Surgeons should therefore avoid postoperative residual TFS as well as postoperative valgus limb alignment in order to prevent LOP. Additionally, the P group in this study had significantly higher preoperative TFS under valgus stress compared to the N group. Postoperative TFS was also more strongly associated with preoperative TFS under valgus stress compared with preoperative TFS without stress. These results suggest that preoperative correctability under valgus stress is a sensitive and important factor for the prediction of postoperative TFS and the risk of LOP.

TFS can cause a cartilage defect on the medial edge of the lateral femoral condyle as a consequence of impingement between the lateral tibial spine and the condyle. It has been generally accepted that the lesion does not affect short-term clinical scores [12], it is not therefore a contraindication for UKA [7, 15, 33] and can be ignored. No known studies have previously investigated the association between such cartilage damage and TFS, that the residual TFS can cause uninterrupted impingement between the lateral tibial spine and the condyle, eventually leading to LOP in the long term. Future studies including assessment of the cartilage status on the lateral compartment are needed.

This study had several limitations that merit mentioning here; this was a retrospective study and multivariate analysis or detection of significant differences with a smaller effect size was not possible due to the limited number of cases with LOP. Future studies with a larger sample size are required. Also, although this study showed that patients who experienced LOP had larger preoperative TFS values under valgus stress and postoperative TFS, it is still questionable what should be used as the cutoff value when making decisions on the surgical indication.

Conclusions

OA progression in the lateral compartment after medial OUKA might be associated with postoperative residual TFS, but does not always coexist with postoperative valgus alignment. Preoperative assessment of TFS with valgus stress could be a potential predictor of postoperative residual TFS and LOP.

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Declarations

Conflict of interest The authors declare no conflicts of interest associated with this manuscript.

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