



Coronal tibiofemoral subluxation is correlated to correction angle in medial opening wedge high tibial osteotomy

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Abstract

Purpose This study aimed to analyse the change in coronal tibiofemoral (CTF) subluxation after high tibial osteotomy and to determine demographic variables associated with CTF subluxation. The change in CTF subluxation was hypothesised to be associated with the magnitude of correction of lower limb alignment and medial proximal tibial angle (MPTA).

Methods A total of 103 consecutive knees in 86 patients who underwent medial opening wedge high tibial osteotomy for symptomatic medial compartment knee osteoarthritis were retrospectively analysed. The normal %CTF subluxation value, which was defined as a subluxation of the proximal tibia relative to the distal femur on the lateral edge of the femorotibial joint, was determined from 60 normal knees. The association between CTF subluxation and the Knee Society Score (KSS) and radiographic parameters was examined.

Results The normal range for %CTF subluxation was defined as – 1.8 to 5.6%. Following osteotomy, $\Delta\%$ CTF subluxation reduced from a mean of 4.5% (– 12.1 to – 4.6%) to 0.7% (– 6.8 to 8.2%), resulting in a decrease in lateral tibiofemoral subluxations concomitant with an increase in medial subluxations. The reduction in CTF subluxation correlated moderately with MPTA change ($r = -0.454$, $p < 0.001$) and weakly with preoperative lower limb alignment as represented by hip–knee–ankle angle and %weight-bearing line. Multivariate regression analysis showed that Δ MPTA was a significant contributor of $\Delta\%$ CTF subluxation.

Conclusion Osteotomy reduced CTF subluxation, which was correlated with MPTA change. Postoperative MPTA should be considered during surgical planning, and a postoperative MPTA of approximately 93.5° may be an appropriate target to reduce CTF subluxation by obtaining normal CTF congruency.

Level of evidence Level IV therapeutic, retrospective, cohort study.

Keywords High tibial osteotomy · Tibiofemoral subluxation · Medial proximal tibial angle · Osteoarthritis

Introduction

A coronal tibiofemoral (CTF) subluxation typically develops in the early stages of the joint degeneration process, which gradually becomes knee OA and varus deformity [10–12]. CTF subluxation contributes to impaired load transmission across the medial compartment of the knee; thus, it is an important radiographic finding because it is associated with

clinical symptoms of medial compartment knee OA [3]. As CTF subluxation can be corrected by either a lateral closed wedge high tibial osteotomy or opening wedge high tibial osteotomy (OWHTO) [1, 8, 27], CTF subluxation appears to be influenced by the congruency of the articular surfaces and the inclination of the coronal joint line [11, 12]. Recently, CTF subluxation has been shown to be associated with a loss of correction after OWHTO, a change in femorotibial angle, and clinical outcomes based on the Knee Society Score (KSS) [1]. However, factors affecting CTF subluxation are unclear, as studies on factors influencing the normal range of CTF subluxation are insufficient.

In this study, the normal CTF subluxation value was defined, and this study aimed to analyse the change in CTF subluxation after high tibial osteotomy and to determine demographic variables associated with CTF subluxation.

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Moreover, the change in CTF subluxation was hypothesised to be associated with the magnitude of correction of the lower limb alignment and medial proximal tibial angle (MPTA).

Materials and methods

All patients who underwent an OWHTO in Gifu University Graduate School of Medicine between 2012 and 2016 were eligible for inclusion in our retrospective study. Surgeries were performed by experienced surgeons. The inclusion criteria were as follows: medial compartment knee OA and spontaneous osteonecrosis of the knee, impaired activity of daily living due to persistent knee pain after at least 3 months of conservative treatment, location of the centre of the deformity around the proximal tibia, less than 15° of flexion contracture, no evidence of severe OA of the patellofemoral joint, and a required bony correction angle of <20°, as calculated preoperatively. Patients were excluded if they underwent simultaneous anterior cruciate ligament (ACL) reconstruction and OWHTO or a hybrid lateral closing wedge high tibial osteotomy, as described by Takeuchi et al. [26] Over the study period, 94 patients (111 knees) underwent high tibial osteotomy. Among these patients, eight were excluded for simultaneous OWHTO and ACL reconstruction ($n = 4$) and a hybrid lateral closing wedge high tibial osteotomy ($n = 4$). Overall, 103 consecutive knees in 86 patients (median [age], 62.6 [37–80] years; 64 women and 22 men) were included (Fig. 1).

Surgical technique and postoperative rehabilitation

The surgical technique and preoperative planning have been described previously [19–21]. The target mechanical tibiofemoral angle was 2°–3° of valgus. The postoperative mechanical axis was designed to pass across the knee at the Fujisawa point (a point at 62.5% of the cross-sectional

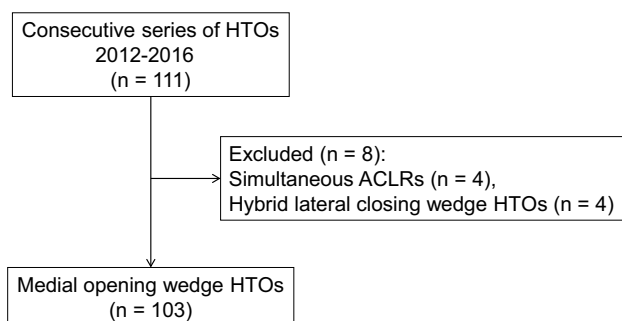


Fig. 1 Flowchart of the number of patients initially assessed and the number of patients finally analysed. ACLR, anterior cruciate ligament reconstruction; HTO, high tibial osteotomy

diameter of the tibial plateau) [6], providing slight overcorrection according to Miniaci's method [16]. Prior to the OWHTO, the knee arthroscopic microfracture was used to treat an articular cartilage lesion, and a meniscectomy was used for meniscal degenerative tear. A biplanar osteotomy was utilised with 110°–120° angle between them in the coronal plane to increase primary stability [14, 24, 25], and the osteotomy was internally fixed with a TOMOFIX osteotomy system (DePuy Synthes, Switzerland) or Tris medial HTO Plate system (Olympus Terumo Biomaterials, Japan) using two β -tricalcium phosphate wedge spacers (Osferion60, Olympus Terumo Biomaterials, Tokyo, Japan).

Patients were allowed partial and full weight bearing on postoperative days 7 and 14, respectively.

Clinical evaluation

Preoperative patient data, including age, sex, height, body weight, and body mass index, were recorded. Clinical outcomes were evaluated using the Knee Society Score (KSS), with a comparison of the total knee score and total function score obtained preoperatively and at the latest follow-up examination.

Radiographic evaluation

A full-length, standing, anteroposterior (AP) radiogram of the lower extremities, with the patella facing anteriorly, was obtained preoperatively and at the latest follow-up examination (Fig. 2). CTF subluxation was defined, based on these radiograms, as a subluxation of the proximal tibia relative to the distal femur on the lateral edge of the femorotibial joint and quantified by a small modification of the previously reported method [1, 27]. Specifically, CTF subluxation was quantified as the distance between a line drawn perpendicular to the ground and passing through the most lateral point of the lateral femoral condyle and a second line drawn perpendicular to the ground and passing through the most lateral point of the lateral tibial condyle, ignoring changes caused by osteophytes (Fig. 2). If the line passing through the tibial condyle was lateral to the line passing through the femoral condyle, a positive value was assigned. To adjust for differences in knee size and allow for between-subject comparison, the measured CTF subluxation was converted to a percentage of CTF subluxation (%): (CTF subluxation/tibial plateau width) \times 100 (%).

The hip–knee–ankle (HKA) angle (valgus, positive), joint line convergence angle (JLCA) [21], and %WBL [2, 6] were measured on full-length AP radiograms of the lower extremity. The mechanical lateral distal femoral angle (LDFA) and MPTA [22] were measured on AP radiograms of the knee (Fig. 1). For analysis, the change in the measured outcome parameters, pre- to postoperatively, was obtained by

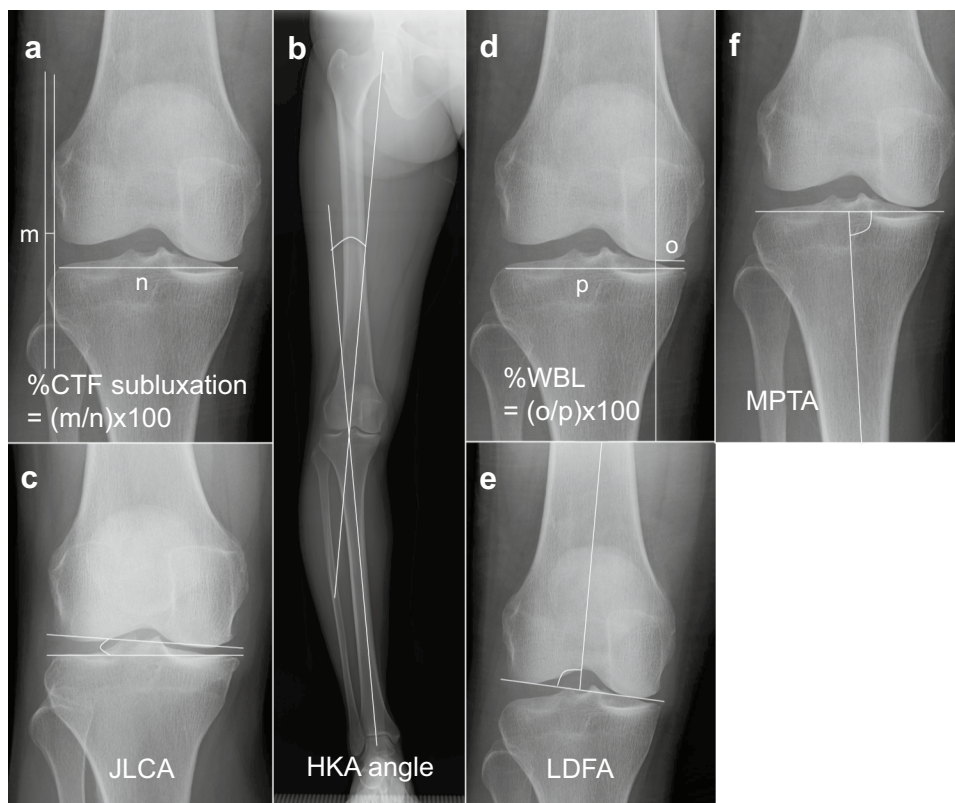


Fig. 2 Radiographic assessments of measured outcome parameters. **a** Coronal tibiofemoral (CTF) subluxation is defined as the distance between a line drawn perpendicular to the ground and passing through the most lateral point of the lateral femoral condyle and a line drawn perpendicular to the ground and passing through the most lateral point of the lateral tibial condyle. To normalise this distance for between-subject comparison, the distance was converted to a percentage of the width of the tibial plateau width $\{(m/n) \times 100\}$. **b** Hip–knee–ankle (HKA) angle, defined as the angle between the mechanical axis of the femur and the tibia (varus, negative; valgus, positive). **c** Joint line convergence angle (JLCA), defined as the angle

formed by the two tangential lines drawn along the joint line of the distal femur and the proximal tibia (varus, positive; valgus, negative). **d** Percentage weight-bearing line (%WBL), defined as the percentage of the horizontal distance from the WBL (a line passing through the centre of the femoral head to the midpoint of the proximal talar joint surface) to the medial edge of the tibial plateau, divided by the width of the tibial plateau $\{(o/p) \times 100\}$. **e** Mechanical lateral distal femoral angle (LDFA), defined as the angle between the tangential line to the femoral condyles and femoral mechanical axis. **f** Mechanical medial proximal tibial angle (MPTA), defined as the angle between the tibial plateau and the mechanical axis of the tibia

subtracting pre- from postoperative values of each parameter. Degenerative changes of the knee joint were evaluated using Kellgren–Lawrence (KL) grades [9].

Definition and stratification for CTF subluxation

To determine the normal %CTF subluxation value (mean \pm 2SD), asymptomatic knees (KL grade 0, no history of knee injury or surgery) of patients, who came to our hospital for any reason in the study period, were involved. Patients' sex and age were matched to those of patients undergoing OWHTO. All knees were stratified into three groups based on a defined normal value: lateral tibiofemoral subluxation group, normal group, and medial tibiofemoral

subluxation group. Clinical and radiographic parameters were analysed between groups.

IRB approval

Informed consent for the use of medical data was obtained from all patients, and this study was approved by the institutional review board of the Graduate School of Medicine, Gifu University (Approval no. 27–100).

Statistical analysis

All radiographic measurements were performed by two independent observers in a blinded manner. The intra- and interobserver reliabilities were expressed as intra-class correlation coefficients (ICC), which varied from '0' (no

agreement at all) to ‘1’ (total agreement). ICC values were characterised as follows: poor agreement (less than 0.40), fair to good agreement (0.40–0.75), and excellent agreement beyond chance (larger than 0.75) [13]. Statistical comparisons were performed using SPSS version 13.0 (SPSS Inc., Chicago, IL, USA). Tests for normality and distribution were performed using the Kolmogorov–Smirnov test. Student’s *t* test was used to analyse parametric data. Pearson’s correlation analysis was used to assess the correlation between $\Delta\%$ CTF subluxation and other parameters. Fisher’s exact test was used to evaluate sex distribution within each group. Multivariate regression analysis was conducted to examine the correlation of CTF subluxation and radiographic parameters. *p* values less than 0.05 and odds ratio (OR) with a 95% confidence interval (CI) that does not include 1 were considered significant. A post hoc analysis for the correlation between $\Delta\%$ CTF subluxation and radiographic parameters was performed to determine the statistical power by using G*Power (version 3.0.3). Statistical power was 0.89 with an effect size of 0.3, alpha of 0.05, and sample size of 103. The level of significance was set at *p* value < 0.05 for all analyses.

Results

Patient characteristics

No delayed union or loss of correction in any patient was found during follow-up (mean, 25.7 months: 9–62). Patient demographic parameters and clinical outcomes are shown in Table 1.

Table 1 Patient demographic parameters and clinical data (*n* = 103)

Parameter	Data	
Age (years)	62.6 (37–80)	
Sex (female/male)	64/22	
Height (m)	1.57 (1.42–1.77)	
Body weight (kg)	63.0 (37.6–116)	
Body mass index	25.6 (15.9–41.6)	
Preoperative K-L grade	3.0 (2–4)	
Follow-up period (month)	22.7 (6–59)	
KSS	Mean (range)	<i>p</i> value*
Total knee score (/100)		
Preoperative	62.6 (15–100)	
Postoperative	94.0 (65–100)	< 0.0001
Total function score (/100)		
Preoperative	65.0 (24–100)	
Postoperative	85.8 (30–100)	< 0.0001

KSS Knee Society Score

*Student’s *t* test comparing preoperative and postoperative values

Radiographic evaluation

The role of OWHTO in reducing a CTF subluxation was confirmed with a significant decrease in $\Delta\%$ CTF subluxation from a preoperative mean of 4.5% (range – 4.6–14.2%) to a postoperative mean of 0.7% (range – 13.0–8.2%). Significant pre- to postoperative improvement in other measures of lower limb alignment (HKA angle, JLCA, %WBL, and MPTA) were also identified, as shown in Table 2. The ICC of the radiographic parameters is shown in Table 3.

Definition and stratification for CTF subluxation

The normal %CTF subluxation value was determined from 60 asymptomatic knees of 50 age- and sex-matched patients (mean age, 61.7 [41–79] years; 40 women and 10 men). No significant difference was found in terms of age and sex ratio between the control knees and those undergoing OWHTO. The normal %CTF subluxation value (mean \pm 2SD) was defined as – 1.8 to 5.6%. Furthermore, CTF subluxation was stratified into three groups, namely, lateral tibiofemoral subluxation group (%CTF subluxation > 5.6%), normal group (\geq 5.6%, \geq – 1.8%), and medial tibiofemoral subluxation

Table 2 Radiographic parameters (*n* = 103)

Radiographic parameter	Mean (range)	<i>p</i> value*
%CTF subluxation		
Preoperative	4.5 (– 4.6 to 14.2)	
Postoperative	0.7 (– 13.0 to 8.2)	< 0.0001
$\Delta\%$ CTF subluxation	– 3.9 (– 13.5 to 3.1)	
HKA angle (°)		
Preoperative	– 8.6 (0.8 to – 17.7)	
Postoperative	3.1 (– 3.0 to 8.6)	< 0.0001
Δ HKA angle	11.7 (3.7 to 21.6)	
JLCA (°)		
Preoperative	4.1 (0.2 to 10.5)	
Postoperative	2.5 (– 0.6 to 8.2)	< 0.0001
Δ JLCA	1.6 (– 0.5 to 5.0)	
%WBL		
Preoperative	12.6 (– 45.0 to 50.0)	
Postoperative	60.2 (44.0 to 79.0)	< 0.0001
$\Delta\%$ WBL	48.6 (14.0 to 97.0)	
LDFA (°)	88.7 (82.8 to 99.4)	NA
MPTA (°)		
Preoperative	84.8 (77.9 to 91.9)	
Postoperative	93.6 (85.4 to 100.9)	< 0.0001
Δ MPTA	8.39 (3.3 to 16.6)	

CTF coronal tibiofemoral, HKA hip–knee–ankle, JLCA joint line convergence angle, WBL weight-bearing line, LDFA lateral distal femoral angle, MPTA medial proximal tibial angle, NA not applicable

*Paired *t* test comparing preoperative and postoperative values

Table 3 Intra-class correlation coefficient of radiographic parameters

	Intra-rater	Inter-rater
%CTF subluxation	0.92	0.86
HKA angle	0.99	0.98
JLCA	0.98	0.94
%WBL	0.98	0.95
LDFA	0.98	0.96
MPTA	0.99	0.89

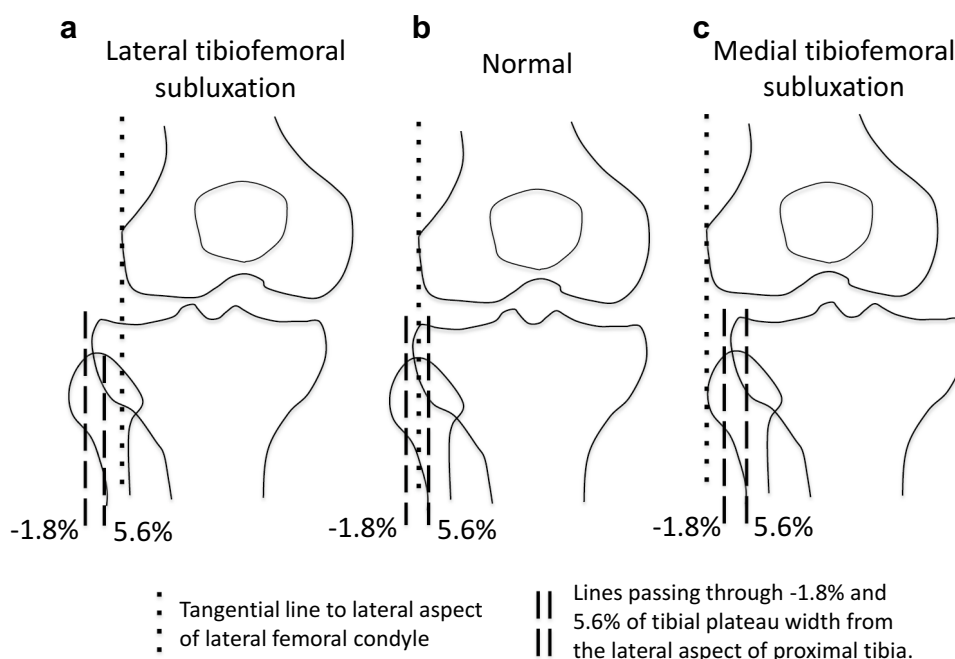
CTF coronal tibiofemoral, HKA hip–knee–ankle, JLCA joint line convergence angle, LDFA lateral distal femoral angle, MPTA medial proximal tibial angle, WBL weight-bearing line

group ($> -1.8\%$) (Fig. 3). The OWHTO reduced the lateral tibiofemoral but increased the medial subluxation, showing that OWHTO induces the medial translation of the tibia relative to the femur (Figs. 4, 5).

Relationship between postoperative CTF subluxation and knee alignment

The relationship between knee alignment parameters and CTF subluxation groups is shown in Table 4. Postoperative MPTA and LDFA in the medial tibiofemoral subluxation group were significantly higher than those in the lateral tibiofemoral subluxation and normal groups. Δ MPTA in the medial tibiofemoral subluxation group was significantly higher than that in the lateral tibiofemoral subluxation group.

Fig. 3 Definition of CTF subluxation. **a** Lateral tibiofemoral subluxation. $\Delta\%$ CTF subluxation $> 5.6\%$. **b** Normal. $-1.8\% \leq \Delta\%$ CTF subluxation $\leq 5.6\%$. **c** Medial tibiofemoral subluxation. $-1.8\% > \Delta\%$ CTF subluxation



KSS according to postoperative CTF subluxation groups

No significant relationship was found between postoperative CTF subluxation groups and KSS (Table 5).

Correlation analysis and multivariable regression analysis

The correlation analysis between $\Delta\%$ CTF subluxation and radiographic parameters is shown in Table 6. Weak correlations were noted between $\Delta\%$ CTF subluxation and preoperative HKA angle, Δ HKA angle, preoperative %WBL, $\Delta\%$ WBL, preoperative MPTA, and postoperative MPTA. Δ MPTA showed moderate correlation with $\Delta\%$ CTF subluxation. Multivariate regression analysis showed that Δ MPTA was a significant contributor of $\Delta\%$ CTF subluxation (p value < 0.001 ; adjusted OR, -0.474 ; 95% CI, -0.63 to -0.27).

Discussion

The most important finding in this study was that OWHTO induced medial translation of the proximal tibia relative to the femur, resulting in a decrease in lateral tibiofemoral subluxations. The reduction in CTF subluxation was significantly correlated with MPTA change.

Although lateral tibiofemoral subluxation is a well-recognised radiographic finding associated with knee OA,

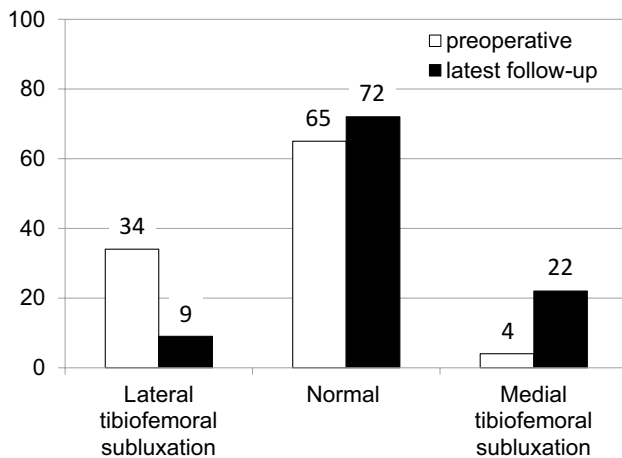


Fig. 4 Distribution of CTF subluxation. There were 34 knees (33.0%) in the lateral tibiofemoral subluxation group, 65 knees (63.1%) in the normal group, and 4 knees (3.9%) in the medial tibiofemoral subluxation group preoperatively, and 9 knees (8.7%), 72 knees (69.9%), and 22 knees (21.4%) postoperatively

very little research is known regarding its effect on clinical symptoms and biomechanics [1, 10–12, 15]. A possible reason is the lack of availability of a normal CTF subluxation value. In this study, the normal CTF subluxation value was defined by using normal, age- and sex-matched knees, and then, the influence of OWHTO on CTF subluxation was analysed. This study showed that CTF subluxation in the normal knees ranges from -1.8 to 5.6% , implying

that the tibia is positioned lateral to the femur. Although the causes of subluxation in normal knees are rarely reported, a recent study evaluating CTF subluxation after unicompartmental knee arthroplasty suggested that CTF subluxation might be influenced by bone density around the knee. Osteoarthritic knees with hard, sclerotic subchondral bone may not permit any structural bone changes; therefore, deforming forces across the knee will be translated into CTF subluxation [18]. Intriguingly, OWHTO not only reduced lateral tibiofemoral subluxation, but also increased the number of medial tibiofemoral subluxation (Fig. 3). Postoperative MPTA was significantly higher in the medial tibiofemoral subluxation group (mean 95.1°) than those in the lateral tibiofemoral subluxation (mean 91.9°) and normal (mean 93.5°) groups, suggesting that an excessive valgus MPTA may lead to even medial tibiofemoral subluxation, whereas a moderate varus MPTA may be necessary to obtain the normal coronal congruency of the tibiofemoral joint. To obtain the normal CTF congruency after OWHTO, an MPTA of approximately 93.5° , which was the mean in the normal CTF subluxation group, may be an optional target.

Little is known about the association between CTF subluxation and clinical scores. Chang et al. [3] found that CTF subluxation was a significant predictor of poor Western Ontario MacMaster pain and function scores. Contrary to our results, Akamatsu et al. reported that the preoperative KSS (total knee and total function scores) correlated with %CTF subluxation preoperatively and the total KSS

Fig. 5 A case of a 61-year-old man with lateral tibiofemoral subluxation that shifted to a normal tibiofemoral congruency after OWHTO. **a** Preoperative lateral tibiofemoral subluxation with $\Delta\%CTF$ subluxation of 11.1% . Preoperative MPTA is 82.8° . **b** Corrected tibiofemoral subluxation with $\Delta\%CTF$ subluxation of -1.2% , 3 years after OWHTO. The postoperative MPTA is 93.7°

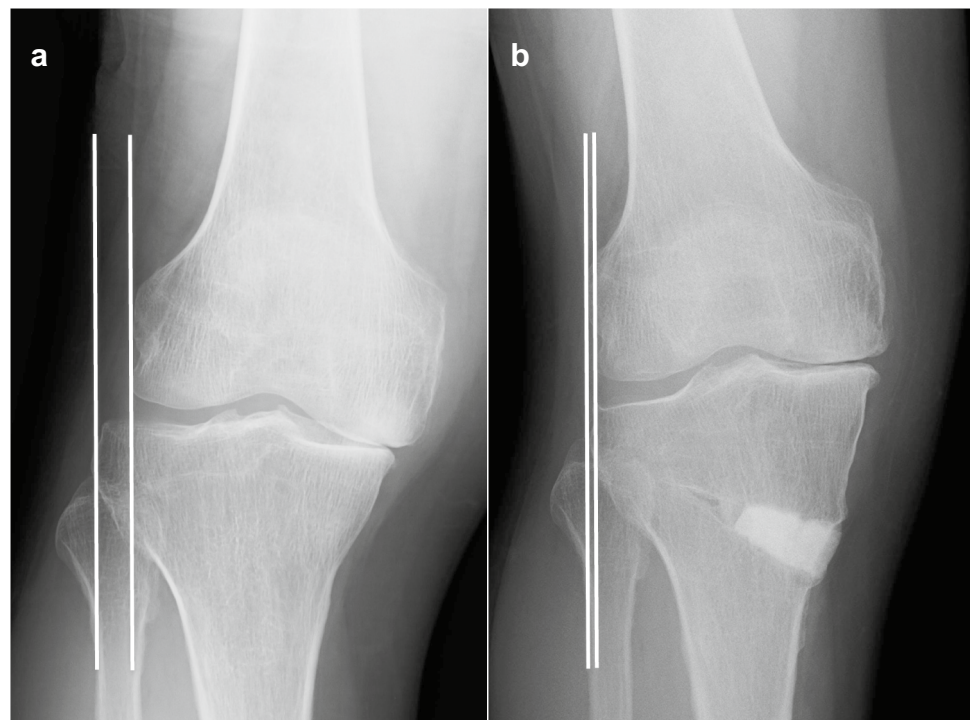


Table 4 Comparison of alignment parameters between postoperative CTF subluxation

Parameters	CTF subluxation group		
	Lateral (<i>n</i> =9)	Normal (<i>n</i> =72)	Medial (<i>n</i> =22)
MPTA (°)			
Preoperative	83.7 (80.1 to 87.8)	85.0 (77.9 to 91.9)	84.7 (81.1 to 89.0)
Postoperative	91.9 (89.0 to 95.0)	93.5 (85.4 to 100.9)	95.1 (91.0 to 100.2)***
Δ	8.2 (4.6 to 10.8)	8.4 (3.3 to 16.3)	10.4 (5.0 to 16.6)**
L DFA (°)	87.3 (84.7 to 89.6)	88.5 (84.2 to 93.8)	90.1 (85.4 to 99.4)***
HKA (°)			
Preoperative	− 9.8 (− 13.9 to − 6.3)	− 8.0 (− 17.7 to 0.0)	− 10.1 (− 16.2 to 0.8)
Postoperative	2.4 (− 0.9 to 6.3)	3.2 (− 0.7 to 8.6)	3.0 (− 0.1 to 8.3)
Δ	12.1 (8.5 to 18.0)	11.2 (6.1 to 21.6)	13.1 (3.7 to 20.3)
JLCA (°)			
Preoperative	3.6 (0.9 to 5.9)	4.1 (0.6 to 10.5)	4.3 (0.2 to 9.1)
Postoperative	2.2 (0.4 to 5.9)	2.5 (− 0.6 to 8.2)	2.6 (0.6 to 7.4)
Δ	1.2 (− 0.2 to 2.5)	1.7 (− 0.3 to 4.8)	1.7 (− 0.5 to 4.2)

CTF coronal tibiofemoral, HKA hip-knee-ankle, L DFA, lateral distal femoral angle, JLCA, joint line convergence angle, MPTA medial proximal tibial angle, Δ change from preoperative to postoperative values

**p* < 0.05 compared with the lateral group in *t* test

***p* < 0.05 compared with the normal group in *t* test

Table 5 KSS according to postoperative CTF subluxation groups

	CTF subluxation group		
	Lateral (<i>n</i> =9)	Normal (<i>n</i> =72)	Medial (<i>n</i> =22)
Total knee score (/100)	94.4 (86–100)	94.4 (83–100)	92.6 (65–100)
Total knee function (/100)	90.0 (80–100)	86.8 (55–100)	81.5 (30–100)

CTF coronal tibiofemoral, KSS Knee Society Score

correlated with %CTF subluxation postoperatively at 1 year after OWHTO [1]. This discrepancy may be due to the difference in patient selection. Their patients showed poorer preoperative total knee score and better preoperative total function score compared to those in our study.

In this study, MPTA change and lower limb alignment correlated with the change in CTF subluxation, and MPTA change was a significant contributor of medial translation of the tibia relative to the femur. There is no doubt about the association between postoperative alignment and clinical outcomes in OWHTO, as the correction of the femorotibial angle from 6° to 14° of valgus is associated with an optimal clinical result [4, 5, 7, 17], and an undercorrection to < 5° of tibiofemoral valgus is associated with a high failure rate of the procedure [23]. The correction of coronal deformity including CTF subluxation, which may consequently lead to good clinical scores [1, 3], could also be an important goal in OWHTO. Therefore, optimal postoperative MPTA and types of tibiofemoral subluxation that may affect long-term outcomes should be investigated. Given that our results showed that the mean postoperative MPTAs of 93.5° and 95.1° were associated with normal CTF alignment and medial CTF

subluxation, respectively, postoperative MPTA should be considered in surgical planning. If the expected postoperative MPTA is higher, double-level osteotomy (distal femur osteotomy plus OWHTO) should be considered instead of single OWHTO.

This study has certain limitations that should be acknowledged. First, the follow-up period was short. A study on the association between CTF subluxation and long-term clinical outcomes is necessary because CTF subluxation may change in a long follow-up period. Particularly, medial tibiofemoral subluxation induced by OWHTO with relatively high postoperative MPTA should be analysed, which may provide information on the optimal postoperative MPTA in OWHTO. Second, bone morphology was not considered in the measurement of CTF subluxation with simple radiography. Further study is necessary to investigate the relationship between CTF subluxation and OWHTO with 3D imaging. Third, the accuracy of CTF subluxation measurement is limited. Some factors, including opening of the lateral joint space and foot position while standing, may influence CTF subluxation measurement. Hence, it is difficult

Table 6 Correlation analysis between $\Delta\%$ CTF subluxation and radiographic parameters

Parameter	Correlation coefficient (<i>r</i>)	<i>p</i> value
HKA angle (°)		
Preoperative	0.336	<0.001
Postoperative	0.049	n.s
Δ HKA angle	– 0.315	<0.001
JLCA (°)		
Preoperative	– 0.183	n.s
Postoperative	– 0.142	n.s
Δ JLCA	– 0.116	n.s
%WBL		
Preoperative	0.349	<0.001
Postoperative	0.034	n.s
$\Delta\%$ WBL	– 0.359	<0.001
LDFA (°)	– 0.103	n.s
MPTA (°)		
Preoperative	0.268	<0.01
Postoperative	– 0.226	<0.05
Δ MPTA	– 0.454	<0.001

CTF coronal tibiofemoral, HKA hip-knee-ankle, JLCA joint line convergence angle, LDFA lateral distal femoral angle, MPTA medial proximal tibial angle, n.s. not significant, WBL weight-bearing line

to completely exclude these factors in the measurement of CTF subluxation.

Conclusion

The OWHTO procedure influenced CTF subluxation and was significantly correlated with MPTA change. Although OWHTO with moderate postoperative MPTA (average 93.5°) reduced preoperative lateral CTF subluxation, higher postoperative MPTA (average 95.1°) was associated with postoperative medial CTF subluxation.

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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 research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent Informed consent was obtained from all individual participants included in this study.

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