Knee ankle joint line angle: a critical value at 10° for decompensated knee joint line obliquity in medial opening wedge osteotomy.

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Research article

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Abstract

Background: Medial opening wedge high tibial osteotomy (MOWHTO) changes the knee joint inclination in the coronal plane, which can be compensated by the ankle joint. Once there is a decompensated knee joint obliquity, it can induce excessive shear force on the articular cartilage. This study aimed to investigate the capacity of the compensation by analyzing the correlation of the knee-ankle joint line angle (KAJA) and the knee joint line obliquity (KJLO).

Methods: The correlations between postoperative KJLO and body mass index (BMI), correction amount, KAJA, mechanical lateral distal femoral angle (mLDFA), preoperative medial proximal tibia angle (MPTA), ankle joint line obliquity (AJLO), KJLO and mechanical hip-knee-ankle angle (mHKA) were analyzed using Pearson correlation coefficient. The contribution of significant factors was further analyzed using multiple linear regression. The KJLO between $\leq 5^\circ$, 5° - 10° and $\geq 10^\circ$ KAJA groups were compared using Kruskal-Wallis test.

Results: Postoperative KAJA and preoperative KJLO moderately correlated to postoperative KJLO. Preoperative MPTA, mHKA, AJLO weakly correlated to postoperative KJLO. After multiple linear regression, only postoperative KAJA, preoperative MPTA and mHKA still showed significant contribution, while preoperative KAJA made the greatest contribution. The KJLO was substantial higher in the $\geq 10^\circ$ KAJA group with a high rate (68%) of high-degree KJLO.

Conclusions: 10° postoperative KAJA is a critical value for decompensated KJLO. The results suggest us carefully assess the KAJA intraoperatively. Double osteotomy should be considered if ideal alignment cannot be achieved when the KAJA reach 10° .

Background

Medial opening wedge high tibial osteotomy (MOWHTO) is a commonly performed procedure for medial osteoarthritis of the knee[1–4]. In order to relieve the stress at medial compartment, MOWHTO shifts the mechanical axis of the lower extremity laterally. However, this procedure inevitably changes the joint inclination in the coronal plane since the medial tibia is elevated[5–9]. In cases of severe varus deformity of the knee joint due to proximal tibial deformity or combined deformity of both the distal femur and proximal tibia, single-level osteotomy can result in high-degree joint obliquity because a large amount of correction is required[5–7], which can induce excessive shear force on the articular cartilage[10]. Increased shear force may subsequently cause chondrocyte death[11, 12]. Therefore, in the circumstances, double osteotomy is indicated to ensure a physiologically oriented joint line[6, 13].

There have been several studies discussing preoperative parameters associated with greater postoperative knee joint line obliquity[9, 14]. Preoperative mechanical hip-knee-ankle angle (mHKA), medial proximal tibial angle (MPTA) and joint line convergence angle (JCLA) are well-established predictors of postoperative abnormal joint obliquity. The reason why these parameters can predict

abnormal obliquity was explained by the necessity of a large correction in previous studies. However, in some cases, we observed that after MOWHTO, even a relatively small correction can still result in high-degree joint obliquity. Therefore, there must be some other factors which was not found yet.

The postoperative knee joint obliquity can be compensated by the ankle joint[8, 15–18]. The capacity of compensation was suggested to be determined by the mobility of the subtalar joint[17, 19], which differs by individual. Therefore, we speculated that the compensation of the ankle joint has its limits. Exceeding the limits may result in an unacceptable rate of high-degree knee joint obliquity even after a small correction. This study aimed to investigate the correlation of the knee-ankle joint line angle (KAJA) and the knee joint line obliquity (KJLO). The hypothesis of our study was that higher postoperative KAJA would result in higher KJLO, and there would be a critical value of KAJA above which the KJLO could not be well compensated.

Methods

We conducted a retrospective observational study at the corresponding author's hospital. The study was approved by the Ethics Committee of the hospital with a waiver of informed consent for the retrospective use of patient data (approval number: 201910040RIND). We investigated 111 consecutive patients who underwent MOWHTO between January 2016 and April 2019. The indications for MOWHTO were as follows: symptomatic medial unicompartmental osteoarthritis with a mechanical tibio-femoral angle of at least 5°, and flexion contracture of less than 10°. Fourteen patients were excluded owing to lack of preoperative or postoperative standing anteroposterior radiographs of the lower extremities. One patient was excluded because proximal fibulectomy was performed concurrently with MOWHTO. Finally, 96 patients were included.

Surgical technique

We performed arthroscopic examination before MOWHTO. Arthroscopic drilling was performed if there was subchondral bone exposure. After arthroscopy, we made a skin incision on the anteromedial aspect of the tibia. Generally, the detailed steps were the same as those described previously[20, 21]. We used a locking plate designed for the medial proximal tibia for fixation of the biplanar MOWHTO. The procedure aimed to align the weight-bearing line through the Fujisawa point[1]. We used “the alignment rod” method[22] to check the correction intraoperatively.

Radiological evaluations

On the standing radiographs, we measured the preoperative and postoperative MPTA, KAJA, weight bearing line (WBL) ratio, KJLO. The measurement methods are described as follows:

(1) MPTA: It was the medial angle between the mechanical axis of the tibia and the articular surface of the proximal tibia. (Fig. 1a)

(2) KAJA: It was the angle between the lines tangent to the articular surfaces of the proximal tibia and distal tibia. A positive value represented a valgus relationship of these two surfaces, and a negative value represented a varus relationship. (Fig. 1b)

(3) mHKA: It was the angle between the mechanical axes of the femur and tibia. (Fig. 1c)

(4) Mechanical lateral distal femoral angle (mLDFA): It was the lateral angle formed between the femoral mechanical axis and the joint line of the distal femur. (Fig. 2a)

(5) WBL ratio: It was determined by the intersection of the articular surface of the proximal tibia and a line from the center of the femoral head to the center of the talus. The ratio was obtained by dividing the distance measured from the edge of the medial tibial plateau by the total width of the articular surface. The discrepancy between preoperative and postoperative WBL ratios was defined as the correction amount.

(6) KJLO: It was the angle between a line tangent to the articular surface of the proximal tibia and a line parallel to the ground. A positive value represented that the medial articular surface is higher than the lateral surface. A $\geq 5^\circ$ KJLO was defined as a high-degree KJLO[10]. (Fig. 2b)

(7) Ankle joint line obliquity (AJLO): It was the angle between a line tangent to the articular surface of the distal tibia and a line parallel to the ground. A positive value represented that the medial articular surface is higher than the lateral surface. (Fig. 2c)

All the angles were by two authors (T.H.T and K.H.H) in a blinded manner (Observers 1 and 2). T.H.T is an orthopaedic surgeon and K.H.H is a nurse practitioner who participates in orthopaedic surgeries as daily work. The first observer measured the angles again in a blinded manner more than four weeks later (Observer 3).

Statistical analysis

All statistical analyses were performed using SPSS version 20 (IBM Corp., Armonk, NY) on a Microsoft Windows-based computer. The correlation between continuous data was analyzed using Pearson correlation coefficient. The parameters significantly correlated with postoperative KJLO were further analyzed using multiple linear regression analyses. The cases were divided into three groups according to their KAJA degree: (1) $\leq 5^\circ$, (2) 5° - 10° and (3) $\geq 10^\circ$. The comparison of KJLO between different groups were analyzed using Kruskal-Wallis test. The interobserver and intraobserver reliabilities of the measured angles were assessed using the intraclass correlation coefficient (ICC). A p-value < 0.05 was considered statistically significant.

Results

35 male patients and 61 female patients were included. The mean age was 60.0 ± 8.5 years (mean $\pm$ standard deviation, SD). The preoperative and postoperative WBL ratio was $15.3^\circ \pm 15.4^\circ$ and $63.3^\circ \pm 15.1^\circ$,

respectively. The correlations between postoperative KJLO and BMI, KAJA, mL DFA, preoperative MPTA, AJLO, KJLO, correction amount and mHKA were shown in Table 1. The postoperative KAJA (Pearson correlation coefficient: 0.504, $P < 0.001$) and preoperative KJLO (Pearson correlation coefficient: 0.484, $P < 0.001$) moderately correlated to postoperative KJLO. Preoperative MPTA (Pearson correlation coefficient: 0.252, $P = 0.013$), mHKA (Pearson correlation coefficient: 0.322, $P = 0.001$), AJLO (Pearson correlation coefficient: 0.221, $P = 0.031$) weakly correlated to postoperative KJLO. After multiple linear regression, only postoperative KAJA, preoperative MPTA and mHKA still showed significant contribution to postoperative KJLO. Preoperative KAJA made the greatest contribution. The results of multiple linear regression were shown in Table 2.

Table 1

The correlations with postoperative KJLO		
	Pearson correlation coefficient	<i>P</i> -value
BMI	-0.093	0.367
Pre-KJLO	0.484	< 0.001
Pre-KAJA	0.112	0.279
Post-KAJA	0.504	< 0.001
mL DFA	0.094	0.366
Pre-MPTA	0.252	0.013
Pre-AJLO	0.221	0.031
Pre-mHKA	0.322	0.001
Pre-: preoperative, post-: postoperative		
BMI: body mass index		
KJLO: knee joint line obliquity ankle		
KAJA: knee ankle joint angle		
mL DFA: mechanical lateral distal femoral angle		
MPTA: medial proximal tibial angle		
AJLO: ankle joint line obliquity ankle		
mHKA: mechanical hip-knee-ankle angle		

Table 2

Multiple linear regression				
	β -coefficient	t-value	P-value	VIF
Pre-KJLO	0.074	0.582	0.562	2.818
Post-KAJA	0.405	3.792	< 0.001	1.960
Pre-MPTA	0.296	2.462	0.016	2.491
Pre-AJLO	0.149	1.202	0.233	2.654
Pre-mHKA	0.360	3.128	0.002	2.275
Pre: preoperative, post: postoperative KJLO: knee joint line obliquity ankle KAJA: knee ankle joint angle MPTA: medial proximal tibial angle AJLO: ankle joint line obliquity ankle mHKA: mechanical hip-knee-ankle angle				

The postoperative KJLO significantly differed between $\leq 5^\circ$, 5° - 10° and $\geq 10^\circ$ KAJA groups. The mean KJLO value were 1.6° , 1.9° and 5.6° , respectively. The rates of high-degree KJLO were 8.5%, 14.8% and 68%, respectively. The results of different KJLO groups were shown in Table 3. Intraclass correlation coefficients of intraobserver and interobserver agreement of radiologic evaluations were all acceptable, > 0.87 (range 0.87–0.98).

Table 3
The KJLO in different KAJA groups

	N	KJLO (mean ± SD)	KJLO ≥ 5°(N, %)	P-value
KAJA ≤ 5°	47	1.6°±2.7°	4, 9%	< 0.001
KAJA 5–10°	27	1.9°±3.1°	4, 15%	
KAJA ≥ 10°	22	5.6°±2.7°	15, 68%	
KJLO: knee joint line obliquity ankle KAJA: knee ankle joint angle SD: standard deviation				

Discussion

The most important finding of this study was that the postoperative KAJA significantly correlated with the KJLO. The contribution of KAJA was stronger than that of previously reported factors. The rate of $\geq 5^\circ$ KJLO achieved 68% when the postoperative KAJA exceeded 10° . Therefore, double osteotomy at the distal femur and proximal tibia should be considered if ideal alignment cannot be achieved even when the KAJA reach 10° .

Non-anatomic knee joint obliquity can cause excessive shear force on the articular cartilage. When the obliquity angle is 5° , the shear force in the medial compartment elevate to almost twice as high as the normal knee[10]. The force value becomes even higher as the obliquity angle increases. Although some studies have shown that there was no difference of short-term outcome with high-degree obliquity[8, 23, 24], it is reasonable there would be a long-term adverse effect on the articular cartilage[12]. Lee et al found that the change of KJLO was significantly less than that of anatomical geometry of the proximal tibia. This phenomenon can be explained by the compensation of the ankle joint[8, 18]. However, the capacity of compensation differs among individuals[9, 15, 25], and currently there is no information about the maximum of the capacity for most of the patients undergoing MOWHTO. Understanding when the knee obliquity will be “decompensated” is essential to ensure a satisfactory outcome. In this study, although the postoperative KAJA moderately correlated with the KJLO, the difference of the mean KJLO between the $\leq 5^\circ$ Group and 5° - 10° group was as small as 0.3° , which may be lack of clinical relevance. The mean KJLO became substantially higher when the KAJA was larger than 10° . Therefore, these results suggest that the change of the anatomical geometry of the proximal tibia caused by MOWHTO could not be well compensated by the mobility of the subtalar joint once the KAJA exceeded 10° . When performing MOWHTO, the 10° KAJA as a critical value should be kept in mind.

In accordance with previous studies, higher preoperative mHKA and MPTA were also predictors of higher postoperative KJLO[9, 14]. It was reasonable that higher mHKA might require a larger correction, which was supposed to result in greater obliquity. However, to our surprise, the correction amount evaluated by the change of WBL ratio was not a significant factor. The postoperative mean WBL ratio was 63.3% in this study, which was remarkably close to the classic aim at 62.5%[1]. Therefore, correcting a lower limb from a higher mHKA to the classic surgical goal, adherence the WBL to the Fujisawa point, tended to have greater postoperative obliquity. We speculated that the change of WBL ratio can be affected by multiple factors, such as different anatomical variance of the femur and tibia. Thus, it did not necessarily represent a large angle correction. In contrast, a higher preoperative mHKA could be a more representative factor. Furthermore, a higher preoperative MPTA implied that the proximal tibia attribute less to the varus deformity of the lower extremity. Therefore, MOWHTO on the knees with higher MPTA may result in a less physiologically oriented joint line.

The KAJA of all cases increased after MOWHTO. Although postoperative KAJA contributed the most to the postoperative KJLO, preoperative KAJA did not correlated to it. Similarly, after multiple linear regression, preoperative KJLO did not contribute to it. In other words, only a sufficient KAJA increase really resulting in high postoperative KAJA caused high-degree KJLO regardless of the preoperative value

of KJLO and KAJA. These results suggest that the KAJA be assessed carefully during the operation to avoid exceeding the critical 10° KAJA. Because a full-tibia image cannot be obtained by fluoroscopy, we recommend assessing the intraoperative KAJA by measuring the angles between the tibia articular surfaces and a reference rod at the knee and ankle joints. KJLA can be simply calculated by subtraction of these two angles. The measurements do not add additional tasks because they can be done along with the assessment of the mechanical axis by the “cable method”[26] or “alignment rod” method[22].

The limitations of this study are as follow: first, avoiding $\geq 10^\circ$ KAJA did not prevent all high-degree KJLO. Further studies are required to identify other possible factors affecting knee joint obliquity. Second, this study only focused on knee joint obliquity. Whether the compensation caused further adverse effect on the ankle joint was not clear. A prospective long-term study may be needed to clarify this issue. Third, since the capacity of the ankle joint compensation differs by individual, the health status of the subtalar joint may play an important role in knee joint obliquity after MOWHTO. There was no such data in this study, and it merits further prospective studies to investigate its effect. Furthermore, because previous studies have analyzed short term clinical outcome, we did not provide such information since the post-operative period was also short.

Conclusion

10° postoperative KAJA is a critical value for high-degree KJLO, which can induce excessive shear force on the articular surface. The results suggest us carefully assess the KAJA intraoperatively. Double osteotomy should be considered if ideal alignment cannot be achieved when the KAJA reach 10° during the operation.

Abbreviations

AJLO

ankle joint line obliquity

BMI

body mass index

JCLA

joint line convergence angle

KAJA

knee-ankle joint line angle

KJLO

knee joint line obliquity

mHKA

mechanical hip-knee-ankle angle

mLDFA

mechanical lateral distal femoral angle

MOWHTO

Medial opening wedge high tibial osteotomy

MPTA

medial proximal tibial angle

WBL

weight bearing line

Declarations

Ethics approval and consent to participate

The study was approved by the Ethics Committee of National Taiwan University Hospital with a waiver of informed consent for the retrospective use of patient data (approval number: 201910040RIND). All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and National Research Committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards

Consent for publication

Not applicable.

Availability of data and materials

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests

Funding

No funding was received.

Authors' contributions

THT and JHW designed the study; THT and KHH performed the assessments, THT performed statistics, THT wrote the first draft of the manuscript, All authors wrote the final version of the manuscript. The authors read and approved the final manuscript.

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Figures

Figure 1

a. MPTA: the medial angle between the mechanical axis of the tibia (indicated by the green line) and the articular surface of the proximal tibia (indicated by the orange line), b. KAJA: the angle between the lines tangent to the articular surfaces of the proximal tibia (indicated by the orange line) and distal tibia(indicated by the green line), c. mHKA: the angle between the mechanical axes of the femur (indicated by the orange line) and tibia (indicated by the green line).

Figure 2

a. mLDFA: the lateral angle formed between the femoral mechanical axis (indicated by the orange line) and the joint line of the distal femur (indicated by the green line), b. KJLO: the angle between a line tangent to the articular surface of the proximal tibia (indicated by the orange line) and a line parallel to the ground (indicated by the green line), c. AKLO: the angle between a line tangent to the articular surface of the distal tibia (indicated by the orange line) and a line parallel to the ground (indicated by the green line).