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Original Article

Morphology of proximal tibiofibular joint, a new risk factor for knee osteoarthritis: a radiological study

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Abstract: *Background:* Little is known about the relationship between the proximal tibiofibular joint (PTFJ) and osteoarthritis (OA). The aim of our study was to evaluate the morphological features of PTFJ and determine its relation with OA. *Methods:* A total of 242 patients were included in this retrospective study. Of these, 122 patients were in the OA group, and 120 were in the control group. Data regarding height of fibular (HF), tibial width (TW), Kellgren-Lawrence (K-L), hip-knee-ankle angle (HKA), and types of PTFJ were obtained from the X-ray radiographs in the standing position, and the lateral views and the relation among them were determined. *Results:* The results revealed that the average HF was significantly smaller in the OA group ($P < 0.01$). A significant relationship was found between HF and OA ($r = 0.208$, $p < 0.01$). Furthermore, there were 28 valgus knees and 171 varus knees observed, and HF was smaller in the valgus knees compared to the varus knees but showed no significant difference. A significant relationship was observed between the types of PTFJ and OA ($\chi^2 = 9.54$, $p < 0.01$). Furthermore, the multivariate analysis revealed that the types of PTFJ and HF were the independent factors of OA and the risk of OA in oblique type PTFJ was 1.543 times (95% CI, 1.433~1.647, $p = 0.034$) that of the horizontal type PTFJ. *Conclusions:* Our data indicated that PTFJ might be associated with the occurrence and development of OA, especially with HF and the types of PTFJ. Further evaluation of the PTFJ biomechanics is warranted.

Keywords: Osteoarthritis, proximal tibiofibular joint, fibular head, radiological study

Introduction

The proximal tibiofibular joint (PTFJ) is a small supporting joint and is considered the fourth compartment of the knee [1, 2]. Due to a lack of knowledge regarding the mechanics and function of PTFJ, knee disorders such as osteoarthritis (OA) are being easily ignored [3]. In his study, Lambert reported that the fibular had a weight-bearing function, with approximately one-sixth of the static load applied at the ankle being transmitted to the PTFJ [4, 5]. While Ogden reported that the function of PTFJ is the dissipation of torsional stresses that is applied at the ankle and the lateral tibial bending moments are tensile rather than compressive weight-bearing [6]. In his study, Scott observed that the joint motion of PTFJ was largest in the anterior-posterior direction with translations of 1-3 mm in a range of physiological loading conditions [2]. However, a detailed study regarding the biomechanics of PTFJ functions is still rare.

The fibula is one of the most important supporting structures of the leg in lower animals but is different in humans. There were quite a few articles that explored the clinical importance of PTFJ. Öztuna, V *et al.* found that the PTFJ joint type was significantly related to the clinical examination findings and reported that the oblique-type PTFJ was more prone to tibio-femoral joint degenerative changes [7]. However, Ozcan *et al.* did not observe any statistically significant relationship between the types of PTFJ and the grade of the OA [8, 9]. The above-mentioned studies demonstrated that the radiographic findings of PTFJ did not affect the clinical findings in patients with severe degenerative knee OA [6-8]. There is still more to understand regarding the functions of PTFJ, which are currently unknown [6-8]. According to a recent pilot study, which included knee OA patients who underwent fibular osteotomy, demonstrated a significant improvement in the radiographic appearances and knee joint functions [10].

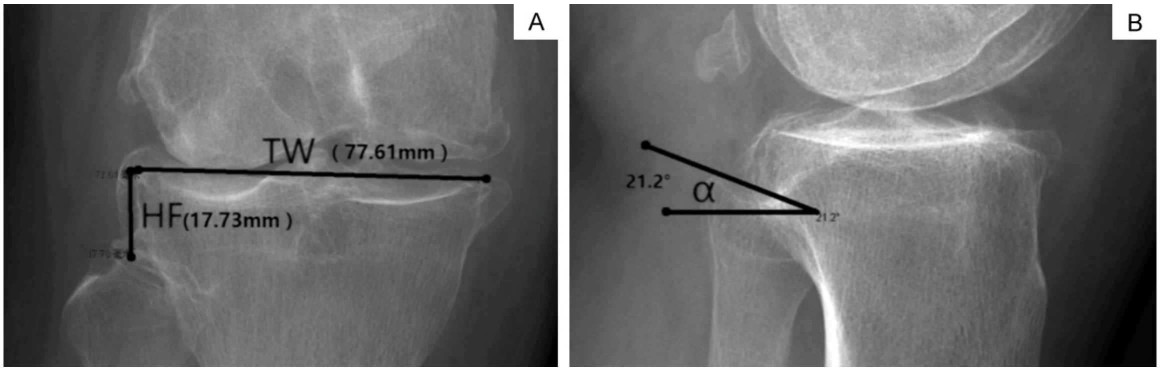

Figure 1. Antero-posterior view and drawing. TW indicates width of proximal tibia, HF indicates proximal tibiafibular head apex distance (A), α the joint of inclination (B).

Fibular osteotomy represents a unique way of treatment for knee OA that cannot be fully explained by the biomechanical studies to date. Therefore, it is worth exploring the role of therapeutic strategies for treating PTFJ. According to previous studies, the authors believed that the lateral support of the fibula to the tibial plateau in fibular osteotomy is a key factor that leads to the non-uniform settlement of the bilateral plateau and the medial shift of the mechanical axis, which results in the degeneration and varus deformities of the knee joint [10-12]. These findings suggest that OA might result due to the support of PTFJ. Based on the function and position of PTFJ, it might play a role in the development of OA. Until now, no study described the relationship between the PTFJ position and OA. In addition, whether other morphological features of PTFJ, such as the types of PTFJ, were associated with OA still remains controversial. Hence, the aim of our study is to evaluate the morphological features of PTFJ from knee radiographs and determine the relation of PTFJ with OA.

Materials and methods

Study design

This is a retrospective case-control study, which included patients who visited the orthopedic department in Huashan Hospital between January 2013 and January 2015. All of the data were anonymously analyzed and the patients and/or their families were informed that data from the cases would be submitted for publication and they also gave their consent. The study protocol was approved by the institutional review board at Fudan University and Huashan Hospital.

Patients

Between January 2013 and January 2015, a total of 242 patients were retrospectively analyzed. Of these, 122 consecutive patients who underwent total knee arthroplasty (TKA) surgery or that were diagnosed with OA as confirmed by arthroscopy as well as 120 consecutive patients without OA were enrolled into the treatment and control groups. The data were collected from all of the hospitalized patients. The exclusion criteria were as follows: 1) serious injury to the lower extremity; 2) total knee or hip replacement in either leg; 3) gout or recurrent pseudogout; 4) nerve or muscle disease associated with walking difficulty; 5) no full limb films and bilateral standing anteroposterior (AP) radiographs from PACS (Picture Archiving and Communication Systems); 6) age under 18 years old.

Data collection and measurement

All of the charts of the participants were reviewed and the basic information, such as age, gender, and height, were collected. Radiographic data of the patients were obtained in the AP plane with the knee in full extension in the standing position [13]. The full limb films were taken while total weight bearing occurred with both knees in full extension and both knee caps facing forward [14], which is routine examination for lower extremity surgery in our hospital.

All of the measurements were performed based on full limb films and lateral view radiographs. We clinically evaluated the knees with a Kellgren-Lawrence (K-L) grading system [15] and determined the types of PTFJ according to

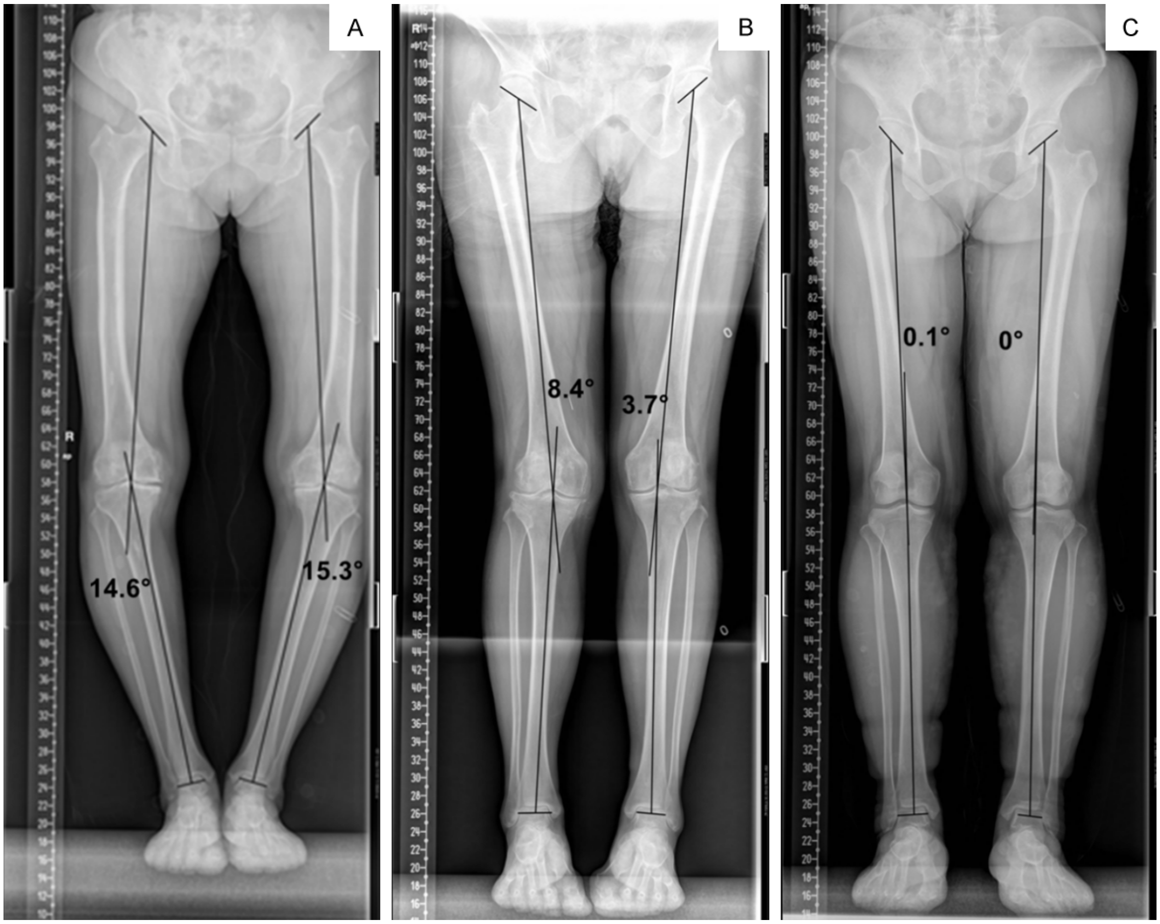

Figure 2. Full limb films antero-posterior view and drawing. HKA femoral-tibial mechanical axis, an Angle between the tibial mechanical axis and the femoral mechanical axis. (A) indicates the HKA in a valgus OA patient; (B) indicates HKA in a varus OA patient; (C) indicates HKA in a control group patient.

the Ogden classification [6] in both of the cohorts. The line that connected the most prominent parts of the medial and lateral edges was defined as the superior articular surface and the length was defined as 'the tibial width' (TW) [16]. The perpendicular distance between the superior articular surface of the tibia and the fibular head was defined as the height of fibular (HF) in the anteroposterior radiographs (**Figure 1**) [16]. We used this to refer to the positions of PTFJ due to the difficulty in determining the exact position of PTFJ. PTFJ was divided into two types depending on the obliquity of the joint surface to the horizontal plane ("horizontal" if ≤ 20° joint inclination; "oblique" if > 20° joint inclination) [6]. The hip-knee-ankle (HKA) angle was measured according to the method reported by Sampath, S [17] (**Figure 2**). To account for the variability in the absolute measurements secondary to patient size, HF measurements were converted to ratios by dividing the value of the absolute distance by the anteroposterior TW, which is defined as the height of the fibular ratio (HFR) [18]. Two trained orthopedic surgeons evaluated all of the radiographic grades and measurements.

Statistical analyses

Two observers independently performed the measurements on these X-ray films to assess the interobserver reliability. Radiographic evaluations of PTFJ were intraobserver analysis with the McNemar test. The statistical analyses were performed using the χ^2 test, Student's t-test, Spearman's correlation analysis and Pearson's correlation analysis. The χ^2 test was used to evaluate the difference of the categorical variables (such as gender, types of PTFJ, and K-L grade) and Student's t-test for continu-

Table 1. Characteristics of the subjects and PTFJ

Value	Osteoarthritis (OA) group	Control group	*P*
	n = 122 subjects/244 knees	n = 120 subjects/240 knees	
Age (years)	67.11 ± 7.003	65.08 ± 9.8711	0.07
Body Mass Index (BMI) (Kg/m^2)	26.23 ± 3.33	24 ± 4.93	0.06
Gender			0.194
Female	64	74	
Male	58	46	
Limb alignment	199		
Varus	171	-	
Valgus	28	-	
Type of PTFJ	244 knees	240 knees	
OA knees			
Horizontal	54		
Oblique	145		
Unaffected knees			
Horizontal	*7*	46	
Oblique	*38*	194	0.001[IV]
K-L of OA Knee	n = 199		
I	*0*		
II	*33*		
III	*49*		
IV	*117*		
K-L of PTFJ	n = 199		
0	*2*		
I	*16*		
II	*53*		
III	*86*		
IV	*42*		
HF (mm)	10.81 ± 3.67 (n = 244)	12.72 ± 0.69 (n = 240)	0.003
$HF_{unilateral\text{-}OA}$	10.65 ± 2.06 (n = 45)		
$HF_{unilateral\text{-}control}$	11.85 ± 2.40 (n = 45)		0.009
TW (mm)	77.19 ± 0.36 (n = 244)	77.40 ± 0.36 (n = 240)	0.67
HFR	0.14 ± 0.002 (n = 244)	0.15 ± 0.003 (n = 240)	0.002

Values are reported as mean ± standard deviation or as number (%).

ous variables (HF, HFR, and TW). The Pearson's correlation analysis and Spearman's correlation analysis were used to assess correlations between values of the proximal tibiofibular joint (HF, HFR, TW, and K-L grade) and parameters of OA (K-L grade and HKA). Both Pearson's chi-squared test and Spearman's correlation analysis were used to assess correlation between K-L grade of the PTFJ and the K-L grade of the knee. A logistic regression analysis was used for further analysis of the relevance. The results were expressed as 95% confidence intervals. The results of univariate analysis with *p*-values < 0.10 were used as the basis for the logistic regression analysis where OA was the dependent variable. The differences were reported as statistically significant if the *p*-value was less than 0.05. All of the statistical analyses were performed using SPSS version 19.0 (IBM, USA).

Results

Characteristic of study population

From January 2013 to January 2015, a total of 454 new OA patients who have undergone TKA or arthroscopy in our hospital were enrolled. Of these, a total of 122 patients (male/female:

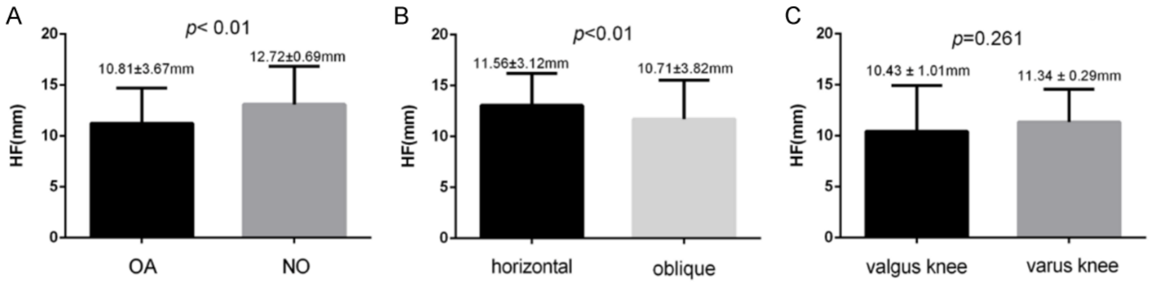

Figure 3. (A) Bar graph showing the HF in OA and control groups; (B) Bar graph showing the HF of horizontal PTFJ (N = 107 knees) and oblique PTFJ (N = 377 knees) in OA and control groups; (C) Bar graph showing the HF of valgus knee (N = 28 knees) and varus knee (N = 171 knees) in OA group.

Table 2. A summary of the correlation analysis between values of the proximal tibiofibular joint and OA

Value A	Value B	Correlation coefficent*	P
$HF_{control}$	$TW_{control}$	r = 0.099	0.12
HF_{OA}	TW_{OA}	r = 0.07	0.20
HF_{OA}	K-L of knee	r = 0.776	0.01
HF_{OA}	HKA	r = 0.03	0.55
HF	OA	r = 0.208,	< 0.01
HFR	OA	r = 0.228	< 0.01
Types of PTFJ	OA	χ^2 = 9.54	< 0.01
K-L of PTFJ	K-L of knee	χ^2 = 216.65/r` = 0.51	< 0.01

*r means Pearson's correlation coefficient r; r` means Spearman's correlation coefficient r; χ^2 means chi-squared test.

58/64; mean age: 67.11 ± 7.03 years, range: 49 to 80 years, body mass index (BMI): 26.23 ± 3.33 kg/m²) [27.9%] who fulfilled the eligibility criteria of the OA group were included in the study and 120 patients (male/female: 46/74; mean age: 65.08 ± 9.87 years, range: 45 to 95 years, BMI: 24.99 ± 4.93 kg/m²) were selected from 623 control candidate patients. There were no significant differences observed in age, BMI and gender between the two groups. No statistically significant differences between the radiographic evaluations of PTFJ were observed (p = 0.16), which was confirmed by McNemar test. The baseline characteristics of the subjects in this study are presented in **Table 1**.

Correlation analysis result of the height of fibular (HF) with OA

The average HF was 10.81 ± 3.67 mm for the OA group (N = 244 knees) and 12.72 ± 0.69 mm for the control group (N = 240 knees) with a wide range of differences in both groups. The average HF was significantly smaller in the OA group (p < 0.01) (**Figure 3A**). There was no correlation observed between HF and TW (r_{oa} = 0.07, p = 0.22; r_{contol} = 0.099, p = 0.124) in both group (**Table 2**), and the HFR showed a difference in the values between OA and control group when calculated. However, a statistically significant relationship was found between HF and OA (r = 0.21, p < 0.01), as well as between HFR and OA (r = 0.23, p < 0.01) (**Table 2**). There were 45 patients who suffered from unilateral knee OA. The healthy knee was used as the self-control. We found that the HF for the OA side ($HF_{unilateral\text{-}OA}$ = 10.65 ± 2.06, N = 45 knees) was smaller than the control side ($HF_{unilateral\text{-}control}$ = 11.85 ± 2.40, N = 45 knees; p = 0.009), (**Table 1**).

In addition, we combined the unaffected side of the unilateral OA patients and the control patients and recalculated the difference. As expected, the HF was still smaller on the OA side ($HF_{combine\text{-}unaffected}$ = 12.84 ± 3.45, N = 285 knees; $HF_{combine\text{-}OA}$ = 10.71 ± 3.34, p < 0.01, N = 199 knees). At the same time, a significant relationship between HF and the K-L grade of knee (r = 0.776, p < 0.01) in the OA patients was observed. However, we did not observe any significant relationship between HF and HKA (r = 0.03, p = 0.55) **Table 2**.

Correlation analysis of the type of the PTFJ with different values

We collected the data for all of the 242 patients from 484 PTFJ joints. In order to expand the sample size, we include unaffected side of the 45 unilateral OA patients into the control group. Of these, 54 were horizontal and 145 were oblique in the OA side group and 53 were hori-

Table 3. Associations of OA with HF and types of PTFJ

Variables	Univariate analysis			Multivariate analysis*		
	OR	*95% C.I.*	*p-value*	OR	*95% C.I.*	*p-value*
HF	0.902	0.773~1.097	0.03	0.922	0.873~0.973	0.003
Types of PTFJ						
Horizontal type				Reference group		
Oblique type	1.464	1.223~1.739	0.00	1.543	1.433~1.647	0.034

*Adjustment for age, gender, BMI.

zontal and 232 were oblique in the control group. A significant relationship was observed between the types of PTFJ and OA ($\chi^2 = 9.54$, $p = 0.002$). Moreover, HF was significantly smaller in the oblique type PTFJ joints than that in the horizontal type PTFJ joints ($HF_{horizon} = 11.56 \pm 3.12$ mm, N = 107 knees; $HF_{oblique} = 10.71 \pm 3.82$ mm, N = 377 knees, $p < 0.01$) (**Figure 3B**). There were 28 valgus knees and 171 varus knees in the study. HF was smaller in the valgus knees compared with the varus knees, but the difference was insignificant ($HF_{valgus} = 10.43 \pm 1.01$ mm, N = 28 knees; $HF_{varus} = 11.34 \pm 0.29$ mm, N = 171 knees; $p = 0.26$) (**Figure 3C**). Additionally, the K-L grade of the PTFJ joints was closely associated with the K-L grade of the knee ($\chi^2 = 216.65$, $p < 0.01$; r = 0.511, $p < 0.01$).Results are shown in **Tables 1** and **2**.

Logistic regression analysis

According to the results of the univariate analysis, a logistic regression analysis was performed with patients in OA and control groups. The results showed that HF and the types of PTFJ were independent risk factors of OA. Multivariate analysis demonstrated that the higher HF value was associated with the lower risk of OA, and oblique type PTFJ was associated with a higher risk of OA (**Table 2**). The risk of OA in patients with oblique type PTFJ was 1.543 times (95% CI, 1.433~1.647, $p = 0.034$) that of the horizontal type PTFJ (**Table 3**).

Discussion

The most important finding of the present study was that both HF and the types of PTFJ were significantly correlated with the risk of OA. Subjects in the OA group showed a smaller HF and more oblique types of PTFJ independent of age, gender, and BMI. These results not only indicated a possible new risk factor for OA but also offered a potential explanation for fibular osteotomy in treating OA.

In a few studies, the fibular head was used as an anatomical landmark to determine the normal knee joint line level [19, 20], which demonstrated that the distance from the fibular tip to the knee joint line was a stable value. However, it is still controversial as a stable anatomical landmark. A study by Servien, E [18] demonstrated that the HF measured on 200 knee MRIs concluded that HF was not a reliable factor in the revision surgery of the joint line. In another study, the authors found an important variability regarding the joint line-fibular head apex distance, particularly in the antero-posterior view [16]. The results of our study confirmed these conclusions. In addition, we found that the value of HF was associated with OA and was bigger in the control group. Our results confirmed that HF was associated with OA. Hence, this might be the reason for the differences in the values.

Previous studies have demonstrated that PTFJ was associated with OA and might be responsible for lateral knee pain [7, 8]. However, there is no study to date that evaluated the reason for their relationship. Furthermore, the distinct factors that caused PTFJ degeneration are still unknown. The passage of inflammatory enzymes through the joint space could contribute to the advancement of arthritis in the respective compartments [5, 9, 12, 21, 22]. In addition, a new method, fibular osteotomy, for the treatment of OA presented excellent results [10]. Based on these results, the investigators hypothesized that the lateral support of the fibula to the tibial plateau as a key factor that leads to the non-uniform settlement of the bilateral plateau and the medial shift of the mechanical axis, which results in the degeneration and varus deformities of the knee joint [10, 23]. Prior to this fibulectomy paper, a cadaveric study reported that the partial fibulectomy at 12 cm above the lateral malleolus resulted in decreased pressure in the knee medial compartment and increased pressure in the knee lateral compartment [11]. However, the concrete underlying mechanism is still unknown. The results of our study indicated that the HF value was associated with OA and might be a risk factor for OA. The location of PTFJ was at a higher position below the joint line when the HF values were small, which may in turn share the load from the plateau. We can assume that the value will be small and near zero, which indicates that the fibula is near to the joint line. The fibula at this position shares most of the weight bearing load. Similarly, with the lower PTFJ position, a lesser load was shared by the fibula. As the fibula shares part of the weight, fibular osteotomy significantly changes the stress on the plateau in patients with larger HF values. This might be a reason as to why the fibular osteotomy obtains such a good result. Combined with these assumptions and the new view of the study [10], we deduced that the PTFJ may play a significant role in OA, especially varus OA. Based on this conclusion, fibular osteotomy may be a new, easy and safe option to treat varus OA. Our study provides a new and reasonable explanation to support fibular osteotomy, which may greatly change the view of therapy for OA.

Our study confirmed the relationship between HF and OA. However, after analyzing the differences of HF between valgus and varus OA, no significant differences were observed. The results may be due to the sample size gap and the positive F-test. Furthermore, the significant relationship between HF and the K-L grade of knee in the OA patients indicated that HF was also associated with OA severity. Besides, the correlation analysis revealed that K-L of PTFJ and knee has a strong correlation which confirmed the results of Boya H [8]. Additionally, it was previously documented that the types of PTFJ, especially the oblique type, was associated with OA [6, 7]. Our study validates the result and found that the value of HF was smaller in the oblique type group than that in the horizontal type group, which supports the association of HF with OA. Few investigators have demonstrated that there was no relationship with the type of the fibular head and OA [8, 9]. Hence, the result still needs a larger sample size to certify its authenticity.

This study has some limitations. First, our study included a small sample size and involved the analysis of a few OA knees. Second, our study is a retrospective study and needs confirmation by conducting a prospective study with a larger OA patient population, which will provide valuable clinical information between PTFJ and OA. Third, our results still need comprehensive research regarding the functional biomechanics to verify the validity. Moreover, we obtained all of the measurements from X-ray plain film radiographs, but these are only two-dimensional pictures and might lead to some quantitative errors. Fourth, the method of the value measurement showed an error due to rotation and osteophytes, but repeated measurements were performed by the same investigator and a recruited population with moderate OA to obtain a more accurate result.

In conclusion, our results indicated that PTFJ played an important role during the occurrence and development of OA, especially the HF and the types of PTFJ. This is the first study to determine the association between HF and knee OA. It was found that small HF was more prone to OA and was associated with OA severity. Our data also validated that the types of PTFJ, especially the oblique type, was associated with OA. Particularly, our study provides a new and reasonable explanation to support fibular osteotomy, which may greatly change the view of therapy for OA. However, more evidence is needed to make the mechanism clear. Consequently, the further evaluation of PTFJ biomechanics is warranted.

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Disclosure of conflict of interest

None.

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