Ni *et al. BMC Musculoskeletal Disorders* (2025) 26:284
https://doi.org/10.1186/s12891-025-08522-1

BMC Musculoskeletal Disorders

RESEARCH

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Femoral inherent torsion is more accurate than femoral anteversion angle in evaluating femoral torsion to determine whether combine derotational distal femoral osteotomy or not

Zhengyi Ni[1†], Kehan Li[1†], Xiaobo Chen[1], Yitong Hu[2], Jingting Zhang[2] and Fei Wang[1*]

Abstract

Background Previous view is that femoral anteversion angle (FAA) is equivalent to femoral torsion (FT) and as an indication for derotational distal femoral osteotomy (DDFO) combined with medial patellofemoral ligament reconstruction (MPFLR), but posterior femoral condylar deformity affects FAA. Therefore, FAA is not accurate in assessing FT. Whether the femoral inherent torsion (FIT), which avoids the influence of the posterior condyle, can better reflect FT during surgery remains unknown. Meanwhile, the impact of the posterior femoral condyle on surgical outcomes remains unclear.

Methods Twenty-five patellar dislocation (PD) patients from 2017 to 2021 were conducted. All patients underwent both preoperative and postoperative computed tomography scans. Categorized by posterior condylar angle (PCA), they were divided into Group A (PCA $\le$ 6.4°) and Group B (PCA $>$ 6.4°). Radiographic measurements included FAA, femoral inherent torsion (FIT), patellar tilt angle, congruence angle and tibial tubercle–trochlear groove distance. For clinical outcomes, the Kujula score, Lysholm score, IKDC score to reflect the knee function. The Tegner activity score was used to assess the activity level. The VAS score was used to assess the pain control.

Results In both groups, the postoperative radiographic outcomes demonstrated a statistically significant improvement. Preoperatively, the FAA was similar in the two groups, but the FIT was greater in the Group A (21.7° ± 1.2° vs 18.4° ± 1 .3°, $P < 0.001$). However, there was no statistically significant difference between them in the postoperative period (7.4° ± 1.5° vs 7.1° ± 1.8°). In terms of clinical outcomes, both groups demonstrated a significant improvement in the postoperative period. However, the scores of the Group A significantly better (Kujula: 85.7 ± 5.0 vs 79.6 ± 4.8, $P = 0.005$; Lysholm: 86.8 ± 5.3 vs 80.2 ± 5.7, $P = 0.006$; IKDC: 86.1 ± 8.8 vs 75.5 ± 7.6, $P = 0.004$).

Conclusion FIT may be a more reliable indicator than FAA for evaluating FT in PD to determine whether combine DDFO or not, especially in the presence of posterior femoral condylar deformity. Posterior femoral condylar deformity appeared to result in a pseudo-increase in FAA. Simultaneous evaluation of FIT and FAA to identify true posterior condylar deformity offers the potential to prevent enlargement of DDFO and enable precision treatment.

[†]Zhengyi Ni and Kehan Li contributed equally to this work.

*Correspondence:
Fei Wang
wangfei@hebmu.edu.cn
Full list of author information is available at the end of the article

Keywords Patellar dislocation, Derotational distal femur osteotomy, Medial patellofemoral ligament reconstruction, Femoral inherent torsion, Posterior femoral condylar deformity

Introduction

Patellar dislocation (PD) is a knee disorder that occurs in adolescents and young adults between the ages of 15–19 years, with a higher incidence in females [1]. As a risk factor for PD, femoral torsion (FT) needs to be corrected [2, 3]. At this point, the consideration of performing derotational distal femoral osteotomy (DDFO) becomes necessary [4–7]. The procedure involves the interception of a portion of the femur and subsequent rotation, which increases the medial pressure on the patellofemoral joint, reduces the lateral force, balances the uneven force on both sides caused by FT [8, 9]. Additionally, some studies have indicated that when combined with medial patellofemoral ligament reconstruction (MPFLR), satisfactory clinical outcomes can be achieved [10, 11].

Previous studies have predominantly equated the femoral anteversion angle (FAA) with FT [7, 12–15]. Moreover, excessive increased FAA is an indication for DDFO, although the FAA cutoff value is controversial [6, 11, 16–18]. However, some studies suggested the morphology of the posterior condyle of the femur similarly affects FAA, and further confirmed that FAA is distinct from FT [19, 20]. A previous study observed that a shorter posterior lateral condyle than medial condyle was associated with increased FAA, and used the posterior condylar angle (PCA) to assess posterior condylar deformity [15].Therefore, abnormal posterior condyle morphology does affect FAA [21–23].

The majority of studies have focused on the effect of DDFO with the increased FAA alone, there is no research on whether posterior femoral condylar deformity has an impact [13, 24]. Therefore, this study was conducted to evaluate the efficacy of DDFO combined with MPFLR for patients under the condition of meeting surgical indications. Furthermore, there have been studies proposing a redefinition of femoral intrinsic torsion (FIT) as FT unaffected by the posterior femoral condyles [19, 25]. However, the objective of these studies has been limited to distinguishing FIT from FAA, without further exploring the potential applications of FIT in surgery. Based on this, an investigation was undertaken to determine whether FIT can better evaluate FT than FAA, especially in surgery. The findings of this study are expected to provide insights for the clinical application of DDFO combined with MPFLR.

Methods

This was a case–control study, approved by our hospital ethics committee (approval no. Ke2023-002–1) and informed consent was obtained from all study patients.

Participants

Patients who underwent DDFO combined with MPFLR for PD from 2017 to 2021 were retrospectively reviewed. The inclusion criteria were as follows: (1) two or more documented episodes of PD; (2) femoral anteversion angle (FAA) at least 25°; (3) a history of DDFO combined with MPFLR; (4) a minimum follow-up period of 24 months. The exclusion criteria were as follows: (1) acute first PD, including traumatic or habitual PD; (2) previous knee surgery; (3) distal femur or proximal tibia fracture; (4) knee varus or valgus (> 5°); (5) generalized joint laxity (Beighton score > 5/9) because it could adversely affect the final clinical outcome; (6) severe patellofemoral osteoarthritis; (7) missing clinical data (medical records, radiologic data, follow-up data, etc.); (8) deformed proximal femoral anatomy, including proximal femoral fracture, Perthes disease, SCFE.

A total of 28 patients were enrolled based on the inclusion criteria, of which two patients had knee valgus and one had missing data according to the exclusion criteria, yielding 25 final cases. According to the studies of J. Murgier et al. and Matsuda et al., the cutoff of PCA was set to 6.4° [26, 27]. The patients were divided into two groups, Group A consisted of 12 patients with PCA ≤ 6.4°, while Group B consisted of 13 patients with PCA > 6.4° (Fig. 1). Patient demographics, including gender, age, height and weight were extracted from the medical records, and a body mass index (BMI) was calculated for each patient.

Computed tomography (CT) protocol

All imaging was acquired using a 16-detector-row CT scanner (SOMATOM Sensation 16; Siemens Medical Solutions) with standardized parameters: 512 × 512 image matrix, X-ray tube voltage of 120 kV, tube current of 100 mAs, rotation time of 1 s, slice thickness of 1 mm, slice skip of 0 mm, field of view of 14 cm and bone kernel. The scanning range extended from the ilium to the toes. Patients were instructed to maintain full extension of the hip and knee joints and a neutral position of the feet throughout the scan.

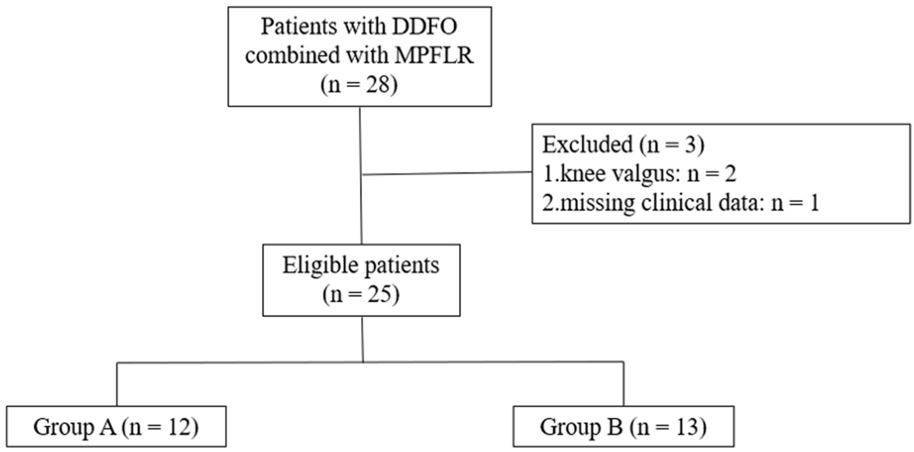

Fig. 1 Flowchart of the patient selection

Measurements

Measurements of PCA, FAA and FIT

At the most obvious level of the 'Roman Arch', the femoral talus and condylar pattern were clearly visible. The line passing through the prominences of the medial and lateral epicondyles was defined as the clinical transepicondylar axis (c-TEA, Fig. 2a), the tangent line passing through the last point of the medial and lateral posterior condyles was defined as the posterior condylar line (PCL, Fig. 2a), and the angle formed by these two lines was PCA (Fig. 2b). As described by Chen et al., the FAA was determined in the plane perpendicular to the femoral anatomical axis by a modified method based on Lee et al. [14, 19, 28]. The FAA was the angle between the line connecting the center of the femoral head and the midpoint of the femoral neck (PFA, Fig. 2b) and the PCL. The FIT was defined as the angle between the PFA and c-TEA (Fig. 2c).

Measurements of the patellar tilt angle (PTA), congruence angle (CA) and tibial tubercle–trochlear groove distance (TT-TG).

The PTA was the angle formed by the line passing through the long axis of the patella and the PCL (Fig. 3a). The CA was defined as the angle formed by the angular bisector of the trochlear groove angle and the line of the lower pole of the patella (Fig. 3b). The TT-TG distance was measured between the lowest point of the femoral trochlear and the midpoint of the tibial tuberosity, both projected onto PCL reference line (Fig. 3c).

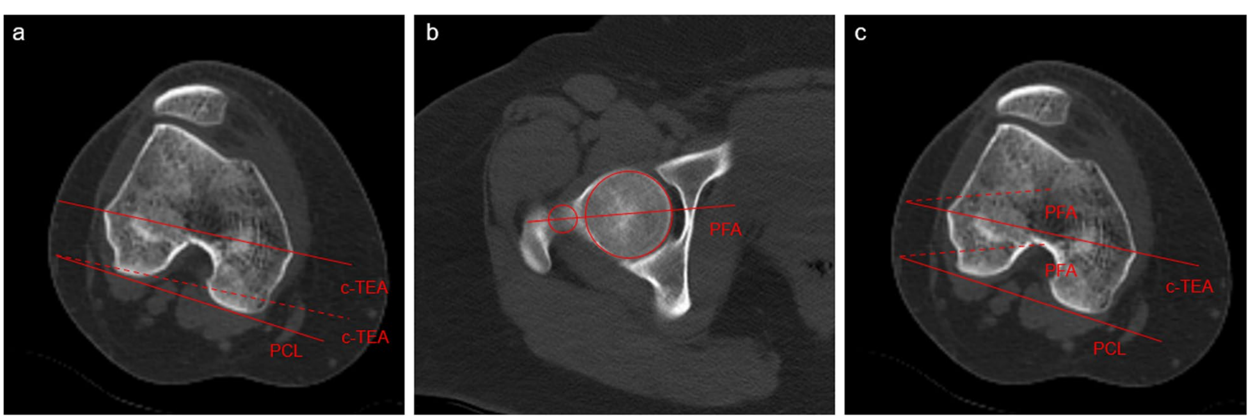

Fig. 2 Measurements of PCA, FAA and FIT. **a** The posterior condylar line (PCL) was tangent to the medial and lateral posterior condyles of the distal femur. The clinical epicondylar axis (c-TEA) connected the prominences of the medial and lateral epicondyles. The angle between PCL and c-TEA was the posterior condylar angle (PCA). **b** The proximal femur axis (PFA) passed through center of the femoral head and the midpoint of the femoral neck. **c** The femoral anteversion angle (FAA) was the angle between the PFA and the PCL. The femoral inherent torsion (FIT) was defined as the angle between the PFA and c-TEA

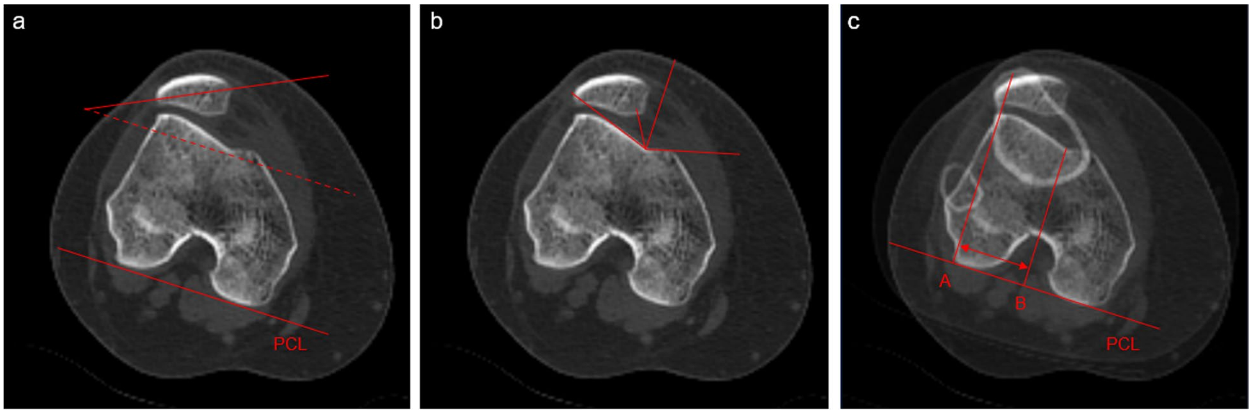

Fig. 3 Measurements of PTA, CA, TT-TG. **a** The patellar tilt angle (PTA) was defined as the angle between the patellar long axis line and the PCL. **b** The congruence angle (CA) was measured as the angle between the trochlear groove bisector and the patellar lower pole axis. **c** The tibial tubercle–trochlear groove (TT–TG) distance was the measurement between the lowest point of the femoral trochlear and tibial tuberosity midpoint projected onto the PCL reference line

Table 1 Interobserver and intraobserver reliability of radiological measurements

	Interobserver ICC	Intraobserver ICC
PCA	0.86	0.91
FAA	0.89	0.93
FIT	0.88	0.89
PFA	0.85	0.90
CA	0.84	0.88
TT-TG	0.87	0.89

All radiologic measurements were independently performed by two senior orthopaedic surgeons. Measurements were conducted using the RadiAnt-DICOM software (Medixant Co., Ltd., Poznan, Poland), which automatically displays angles and distances with an accuracy of 0.1° and 0.1 mm, respectively. The intraobserver reliability was assessed by measuring twice from the same observer every 2 weeks. To ensure the interobserver and intraobserver reliability, the intragroup correlation coefficient (ICC) was calculated. An ICC > 0.8 was considered to indicate excellent reliability (Table 1).

Surgical technique

All surgeries were conducted by a senior orthopedic surgeon with extensive experience in the treatment of patellofemoral disorders.

DDFO

All patients underwent arthroscopy to evaluate cartilage and patellar tracking before DDFO. A lateral incision was made in the distal thigh, through which two Kirschner wires were vertically inserted into the femoral bone along the mechanical axis of the lower limb extremity to determine the osteotomy plane. Two more Kirschner wires were then inserted proximal to this plane to mark the rotation angle. Following completion of the osteotomy and rotation, a lateral femoral plate was positioned and fixed with screws. Final plate positioning was confirmed through fluoroscopic verification.

MPFLR

A double-bundle MPFLR was performed using an autologous semitendinosus graft. The femoral tunnel was positioned using osseous landmarks between the medial femoral epicondyle and the adductor tubercle, with intraoperative fluoroscopy according to Schöttle et al.'s method [29]. Two patellar tunnels were drilled at the upper corner and central portion of the medial patellar border. The three ends of the graft were finally secured with absorbable screws.

Postoperative rehabilitation

All patients were enrolled in a standardized rehabilitation protocol. Postoperatively, patients were instructed to wear protective lower extremity braces and perform rehabilitation exercises. Isometric quadriceps muscle training was initiated on the first day after surgery, with progressive range of motion (ROM) exercises being systematically introduced. Then, active and passive knee flexion and extension exercises as well as straight leg raising exercises were performed on a daily basis. During the initial recovery phase, protected weight-bearing with crutch assistance was recommended. Thereafter, full weightbearing was allowed as tolerated. Typically, six to eight weeks after surgery, the patient will be discharged from crutches and will have regained full ROM.

Resumption of previous sports activities was permitted gradually around 6 months after surgery.

Clinical assessment

All patients underwent standardized preoperative assessment protocols, with a minimum 24 months of postoperative follow-up established through office visit and survey questionnaires. Knee function was reflected by patient-reported outcomes measure (PROM), including the Kujula score, Lysholm score, International Knee Documentation Committee (IKDC) subjective evaluation score, and activity level was assessed by the Tegner activity score [7, 10, 30–36]. Additionally, the visual analog scale (VAS) score was employed to assess pain control [18, 36, 37].

Statistical analysis

All data were analyzed using SPSS Statistics version 27 (IBM, Armonk, NY, USA). Continuous variables were expressed as means with standard deviations or medians with interquartile ranges, while categorical variables were presented as numbers and percentages. To ascertain the normality of the data, the Kolmogorov–Smirnov test was applied. The independent sample t-test and paired t-test were employed for data that exhibited a normal distribution, while the Mann–Whitney U test and Wilcoxon signed-rank test were used for non-parametric data. Fisher's test was utilized to compare categorical variables. Statistical significance was defined as $P < 0.05$.

A post hoc power calculation was conducted using G-Power software version 3.1.9.7 (Heinrich-Heine-Universitat Dusseldorf, Dusseldorf, Germany). Under the conditions of two-tailed, effect size (d) = 0.8, α = 0.05, the sample size consisting of 12 patients in Group A and 13 patients in Group B was found to yield a statistical power of 0.80.

Results

The demographic characteristics and PCA results for the total cohort of 25 patients across both groups were presented in Table 2, with an average follow-up period of 28.5 ± 4.1 months. No statistically significant differences were detected in demographic characteristics between the two groups.

Radiographic outcomes

There was no significant difference in FAA between Group A and B preoperatively, and both were reduced postoperatively with no difference between two groups (Table 3). However, preoperative FIT measurements demonstrated a significant intergroup difference (Group A: 21.7° ± 1.2° vs Group B: 18.4° ± 1.3°), with greater FIT observed in the group possessing PCA. Postoperative FIT measurements (Group A: 7.4° ± 1.5° vs Group B: 7.1° ± 1.8°) showed no statistically significant intergroup difference. Other imaging findings such as PTA, CA and TT-TG were also significantly improved postoperatively, with no significant difference between the two groups.

Table 2 Patient demographic and PCA data

	Group A	Group B	*p* value
Knee (n)	12	13	-
Sex (n)			n.s
Male	0	0	
Female	12	13	
Age (year)	21.4 ± 6.4	21.2 ± 5.1	n.s
BMI (kg/m^2)	25.2 ± 3.4	24.4 ± 3.7	n.s
Follow-up time (month)	28.8 ± 4.3	28.2 ± 3.9	n.s
Side (n)			n.s
Left	9	6	
Right	3	7	
PCA (°)	5.6 ± 0.8	8.8 ± 1.6	0.001

Table 3 Comparison of radiological outcomes between Group A and B

	Group A	Group B	*P* value
FAA (°)			
Preoperative	27.3 ± 1.5	27.7 ± 2.4	n.s
Postoperative	13.6 ± 1.9	14.9 ± 2.3	n.s
P value	< 0.05	< 0.05	
FIT (°)			
Preoperative	21.7 ± 1.2	18.4 ± 1.3	0.001
Postoperative	7.4 ± 1.5	7.1 ± 1.8	n.s
P value	< 0.05	< 0.05	
PTA (°)			
Preoperative	32.2 ± 6.3	33.2 ± 9.1	n.s
Postoperative	17.8 ± 3.2	16.6 ± 7.0	n.s
P value	< 0.05	< 0.05	
CA (°)			
Preoperative	37.4 ± 9.3	36.8 ± 8.9	n.s
Postoperative	16.1 ± 3.0	15.3 ± 2.6	n.s
P value	< 0.05	< 0.05	
TT-TG (mm)			
Preoperative	18.7 ± 2.3	19.2 ± 2.6	n.s
Postoperative	15.8 ± 2.5	16.0 ± 2.1	n.s
P value	< 0.05	< 0.05	

Clinical outcomes

Preoperatively, no significant differences were observed in PROM (Kujula score, Lysholm score, IKDC score), Tegner activity score and VAS score between the two groups, whereas all of them showed significant improvement after MPFLR combined with DFFO (Table 4). Significantly higher values of Kujula, Lysholm, and IKDC scores were recorded in Group A compared to Group B. In contrast, no statistically significant differences were identified in Tegner activity and VAS score.

Discussion

The most important findings of this study were that FAA may be a less accurate method for determining FT and FIT is a better indicator, especially when considering performing DFFO combined with MPFLR. Since eliminating interference from posterior femoral condylar deformity, the degree of FT should be based on the c-TEA rather than the PCL.

The PCA, defined as the angular measurement between the PCL and either the clinical transepicondylar axis (c-TEA) or the surgical transepicondylar axis (s-TEA), has been consistently referenced in prior anatomical studies [38, 39]. Comparative analyses have further established the superior reliability of the c-TEA as a reference axis, due to the most prominent point on the medial epicondyle in the c-TEA is more easily recognizable than the medial epicondylar groove in the s-TEA [39, 40]. Within this context, the PCA has alternatively been characterized as the condylar torsional angle (CTA) [41]. In knee surgery, intraoperative PCA determination using 3° of external rotation relative to the c-TEA to achieve rotational alignment [42, 43]. Consequently, it is believed that the normal PCA should be 3°. Even if there is a 2° discrepancy between s-TEA and c-TEA, the typical value of trans-s-TEA is approximately 5° [26, 44]. However, recent studies have shown that the PCA is greater in Chinese [45]. A cohort study by J.Murgier et al. reported a mean PCA of 6.4°in Chinese [26]. The finding also corroborated by Matsuda et al. through MRI scans of the knee in the axial direction [27]. Based on these studies, we set the critical value of the PCA at 6.4°.

In some studies, posterior femoral condylar deformity has been described as a longer posterior medial condyle and a shorter posterior lateral condyle in PD patients [23, 46]. It might result in an internal rotation of the PCL with respect to the transepicondylar axis (TEA). This anatomical configuration may increase PCA, with potentially an internal rotation of the PCL relative to the transepicondylar axis (TEA), and a correlation between PCA and PD was also found by Roger et al. [22, 41]. However, it should be noted that posterior condylar deformity may not be the only factor. Rougereau et al. found that an increase in PCA was also observed in patients with knee valgus in the absence of lateral condylar hypoplasia, which suggests that knee valgus is also an important influencing factor [47]. In the present study, this phenomenon was not observed as we excluded patients with knee valgus due to the focus on posterior condylar deformity.

The FAA has conventionally used to determine the degree of rotation of the femur. However, it is worth noting that FAA is affected by the measurement method, and different measurement methods will result in different sizes [48]. So using FAA as an indication for DDFO for FT may be inadequate. Meanwhile, Yang et al. observed that PCA was correlated with FAA in PD patients [15]. This finding challenges the conventional view that FAA and FT are directly equivalent, as the posterior femoral condylar deformity may also influence FAA. This issue was further highlighted by Chen et al., who proposed that the angle between c-TEA and the PFA should be used as a novel FIT measurement metric independent of posterior condylar morphology [19]. Furthermore, posterior condylar deformity might be as significant as the FIT in the increase of FA. In this study, it was observed that although the FIT was significantly smaller in patients with abnormal posterior condyles (21.7° ± 1.2° vs 18.4° ± 10.3°, $P < 0.001$), the FAA was comparable in both groups (27.3° ± 1.5° vs 27.7° ± 2.4°). These results provided radiographic evidence that posterior condylar abnormalities could lead to an increase in FAA.

MPFLR and DDFO are currently considered effective treatments for PD [6, 49–52]. While the involvement of DDFO is necessitated by excessive increases in

Table 4 Comparison of clinical outcomes between group A and B

	Group A	Group B	*P* value
Kujula score			
Preoperative	54.4 ± 8.6	53.4 ± 9.2	n.s
Postoperative	85.7 ± 5.0	79.6 ± 4.8	0.005
P value	< 0.05	< 0.05	
Lysholm score			
Preoperative	56.3 ± 6.8	55.3 ± 6.5	n.s
Postoperative	86.8 ± 5.3	80.2 ± 5.7	0.006
P value	< 0.05	< 0.05	
IKDC score			
Preoperative	54.8 ± 6.4	54.2 ± 8.0	n.s
Postoperative	86.1 ± 8.8	75.5 ± 7.6	0.004
P value	< 0.05	< 0.05	
Tegner activity score			
Preoperative	3.0 (3.0,4.0)	3.0 (2.0,4.0)	n.s
Postoperative	4.0 (4.0,5.0)	4.0 (3.0,5.0)	n.s
P value	< 0.05	< 0.05	
VAS score			
Preoperative	4.6 ± 1.2	4.8 ± 1.1	n.s
Postoperative	2.1 ± 1.0	2.2 ± 0.9	n.s
P value	< 0.05	< 0.05	

FAA, its surgical indications remain controversial among researchers [16–18]. The threshold for FAA has not been definitively established at either 25° or 30° [6, 11]. In the present study, FAA measurements of 27.3° ± 1.5° and 27.7° ± 2.4° were recorded for the two groups, which were also within this range. It is believed that this discrepancy may be related to the influence of PCA in PD patients. Based on the above, a new measurement method of femoral anteversion (S-FA) through the s-TEA was developed by Chen et al. to eliminate posterior condylar interference and better characterize femoral rotational deformity [25]. The authors further contended that FAA could not be considered as an independent risk factor for PD, while S-FA should be regarded as the real independent risk factor. Additionally, FAA measured by the s-TEA is more effective than the TT-TG in evaluating PD [53]. Subsequent investigations by both Chen et al. and Li et al. proposed that FAA may not be a reliable indicator for patients with posterior condylar deformity [19, 34]. In our study, the FIT was measured in a manner analogous to S-FA by c-TEA, free from the influence of the posterior femoral condyles. These findings suggest that FAA may not provide accurate determination of FT, whereas FIT appears to constitute a more reliable indicator.

In the study of Hao et al. and Zhou et al. [10, 35], DDFO combined with MPFLR was found to be more efficacious, particularly in patients with increased FAA. Wang et al. revealed a significant improvement in the recurrence rate of re-dislocations as well as a better patellar trajectory [18, 54]. The study also demonstrated that the combined surgery achieved favorable outcomes, showing significant improvement compared to preoperative baselines. However, differential efficacies were identified between patient subgroups, with normal posterior condyle was significantly better (Kujula: 85.7 ± 5.0 vs 79.6 ± 4.8, P = 0.005; Lysholm: 86.8 ± 5.3 vs 80.2 ± 5.7, P = 0.006; IKDC: 86.1 ± 8.8 vs 75.5 ± 7.6, P = 0.004).

The lateral patellofemoral joint was subjected to greater stress in PD patients, with this biomechanical imbalance having been predominantly attributed to attributed to the femur's intrinsic torsion [8]. Further biomechanical analysis revealed that DDFO could alter the force distribution in the patellofemoral joint, characterized by elevated medial facet joint pressure concomitant with reduced lateral pressure. Although the axial torsion of the femoral condyles could be corrected, persistent morphological anomalies were found in the posterior condyles, specifically the longer posterior medial condyle and shorter posterior lateral condyle. Similarly, in cases of posterior condylar deformity, it was found that FAA has been influenced by the posterior condyle, resulting in a mere pseudo-increase, while maintaining relatively low actual FIT. These findings collectively support the hypothesis that surgical efficacy is principally mediated through FIT correction. Consequently, the evaluation of FT correction may be more accurately achieved through FIT measurements than through FAA.

Since smaller FIT values were observed in patients with posterior femoral condylar deformity, we purposed that DDFO may not constitute an essential intervention in this population, and that MPFLR alone may be effective. A biomechanical analysis of a normal human body conducted by Kasier et.al have established that additional DDFO was necessary only when internal femoral torsion exceeded 20° [24]. Importantly, MPFLR alone was found to provide adequate correction at 10° torsion. Fan et al. evaluated the efficacy of MPFLR in combined DDFO by grouping torsions in different parts of the femur [36]. They similarly concluded that DDFO might not be necessary for distal femoral torsions affected by the femoral condyles, although satisfactory postoperative clinical outcomes were observed in the combined surgery.

Limitations

This study is subject to several limitations. First, the number of patients was limited, with a small sample size and a relatively short follow-up time. Second, this study was a retrospective analysis, and additional prospective studies are essential to corroborate the findings. Third, we have only studied the clinical aspects of posterior femoral condylar deformity, further biomechanical studies are required to assess the impact of posterior condylar developmental abnormalities on the outcomes. Forth, this study only included patients who underwent MPFLR combined with DDFO, which could affect the generalization of our results. Fifth, since the study population is Chinese, due to the racial differences in PCA, it is not representative of all populations. Finally, this retrospective study was a single-center study with potential selection bias, and the generalizability of the findings will be further verified in the future through multicenter collaboration with long-term follow-up.

Conclusion

FAA may be a less accurate method of evaluating FT in PD when performing DDFO combined with MPFLR. Our preliminary findings suggest that FIT might be a better indicator to determine whether combine DDFO or not. Posterior femoral condylar deformity appeared to result in a pseudo-increase in FAA, and DDFO combined with MPFLR might primarily correct an oversized FIT. The combined surgery is effective in PD patients with posterior condylar deformity, although not as effective as in patients with normal posterior condyles. Therefore, we suggest considering both FIT and FAA together in order to detect true posterior condylar deformity, offering the possibility for precise treatment by surgeons to selectively avoid enlargement of DDFO.

Abbreviations

PD	Patellar dislocation
FT	Femoral torsion
DDFO	Derotational distal femoral osteotomy
MPFLR	Medial patellofemoral ligament reconstruction
FAA	Femoral anteversion angle
PCA	Posterior condylar angle
FIT	Femoral inherent torsion
BMI	Body mass index
CT	Computed tomography
TT-TG	Tibial tubercle–trochlear groove distance
c-TEA	Clinical transepicondylar axis
PCL	Posterior condylar line
PFA	Proximal femur axis
PTA	Patellar tilt angle
CA	Congruence angle
ICC	Intragroup correlation coefficient
ROM	Range of motion
PROM	Patient-reported outcomes measure
IKDC	International Knee Documentation Committee
VAS	Visual analog scale
s-TEA	Surgical transepicondylar axis
CTA	Condylar torsion angle
TEA	Transepicondylar axis
S-FA	The femoral anteversion measured by SEA, the angle between the SEA and PFA

Acknowledgements
We thank all colleagues in the Third Hospital of Hebei Medical University.

Clinical trial number
Not applicable.

Authors' contributions
ZN: The first author, project design, material preparation, paper writing. KL: The co-first author, theoretical support, data analysis. XC: The co-author, patient selection, data collection. YH: The co-author, drawing graph. JZ: The co-author, data collection. FW: Corresponding author, The primary investigator, project design, theoretical support, manuscript review and revision.

Funding
This research is supported by the Natural Science Foundation of Hebei Province (H2022206534).

Data availability
The data sets used or analysed during the current study are available from the corresponding author upon reasonable request.

Declarations

Ethics approval and consent to participate
All procedures performed were in accordance with the ethical standards of the institutional review board and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. The study was approved by the Ethics Review Committee of the Third Hospital of Hebei Medical University before study commencement (approval no. Ke2023-002–1). Written informed consent was obtained from all patients for enrollment in this study.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

Author details
[1]Department of Orthopaedic Surgery, Hebei Medical University Third Hospital, Shijiazhuang, Hebei 050051, China. [2]Hebei Medical University, Shijiazhuang, Hebei 050017, China.

Received: 20 October 2024 Accepted: 12 March 2025
Published online: 22 March 2025

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