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ORIGINAL ARTICLE

A new and simple method for patellar height measurement: Fibula-condyle-patella angle

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ABSTRACT

Objectives: This study aims to evaluate the inter-observer reliability of fibula-condyle-patella angle measurements and to compare it with other measurement techniques.

Patients and methods: Between January 01, 2023 and January 31, 2023, a total of 108 patients (20 males, 88 females; mean age: 47.5±12.0 years; range, 18 to 72 years) who underwent X-rays using the fibula-condyle-patella angle, Insall-Salvati, Caton-Deschamps, Blackburne-Pell, and plateau-patella angle (PPA) methods were retrospectively analyzed. Knee lateral radiographs taken in at least 30 degrees of flexion and appropriate rotation were scanned. All measurements were made by two orthopedic surgeons who were blinded to measurement methods.

Results: Right knee patellar height measurements were conducted in 56 patients, while left knee patellar heights were assessed in 52 patients. The highest inter-observer concordance was found in the fibula-condyle-patella angle. The second highest concordance was found in the Insall-Salvati. The highest concordance correlation was found with PPA in the measurements of both researchers.

Conclusion: The fibula-condyle-patella angle is a reliable technique with a good inter-observer reliability for measuring patellar height. We believe that this study will inspire future research to establish comprehensive reference values for clinical applications.

Keywords: Insall-Salvati, patella alta, patella baja, patellar height, patellofemoral pain, plateau-patella angle.

The patella, which acts as a lever arm in the knee joint, has a crucial place in knee biomechanics.[1] The measurement is essential, as patellar height abnormalities cause clinical conditions such as patellar instability, knee pain, and tendinitis.[2-4] In 1938, Blumensaat[5] described the first patellar height measurement technique. In the following years, many different techniques were defined. However, the methods described by the authors such as Insall-Salvati,[6] Blackburn and Peel,[7] and Caton et al.[8] gained popularity. In recent years, it has been attempted to evaluate the patellar height after surgeries that change the anatomy of the knee, such as high tibial osteotomy and total knee replacement, and to assess it correctly after these surgeries.[9-11] Numerous techniques have been described for this purpose. One is the plateau-patella angle (PPA), which assesses the patellar height angularly.[12]

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Despite the many defined methods, the inability to develop a measurement technique that is entirely reliable, reproducible, and easy to use in daily clinical practice leads orthopedic surgeons to seek to develop new techniques. In the present study, we aimed to evaluate the inter-observer reliability of fibula-condyle-patella angle measurements and to compare it with other measurement techniques.

PATIENTS AND METHODS

This single-center, retrospective study was conducted at Department of Orthopedics and

Traumatology of Mersin City Training and Research Hospital between January 01, 2023 and January 31, 2023. Patients aged between 18 and 70 who underwent lateral knee radiography in the outpatient setting for various clinical indications were reviewed. Lateral knee radiographs of the patients were scanned through the Picture Archiving and Communication System (PACS) of our hospital. Inclusion criteria were as follows: having a minimum of 30 degrees of knee flexion on radiographs and a true lateral projection with appropriate superimposition of the femoral condyles. Exclusion criteria were having a history of previous trauma or surgery that may have affected the alignment of the knee joint. Radiographs that did not meet the established technical standards were also excluded from the study. These stringent criteria were implemented to ensure the quality and reliability of the data collected during the study.

A total of 108 patients (20 males, 88 females; mean age: 47.5±12.0 years; range, 18 to 72 years) who underwent X-rays using the fibula-condyle-patella angle, Insall-Salvati, Caton-Deschamps, Blackburne-Pell, and PPA methods by two orthopedists who were blinded to measurement methods.

Radiological measurement technique

In the assessment of non-weight-bearing lateral knee radiographs, taken with a minimum of 30 degrees of flexion, a standardized methodology is employed. A reference point is established by drawing a line (x) extending from the distal to proximal aspect of the posterior cortex of the fibula, intersecting the knee joint. A second line (y) is then drawn perpendicular to line x, tangential to the inferior articular surface of the femur. Subsequently, a third line (z) is delineated at the point of intersection between lines x and y, coinciding with the inferior articular surface of the patella.

The fibula-condyle-patella angle is quantified by measuring the acute angle formed between lines x and z. This meticulous technique ensures a standardized and reproducible approach for evaluating knee joint dynamics on lateral radiographs, particularly, when the joint is positioned with a flexion angle of at least 30 degrees (Figure 1).

Statistical analysis

The study power and sample size calculation were performed. For power analysis, we determined that we would need 102 participants to achieve 80% power, assuming a minimal acceptable reliability of concordance correlation coefficient (CCC) = 0.60 and a moderate level of expected reliability of intra-class correlation coefficient (ICC) = 0.75. The sample size was increased to 108 considering a 5% dropout rate.

Statistical analysis was performed using the Jamovi Version 2.3 software (Sydney, Australia). Descriptive data were expressed in mean ± standard deviation (SD), median (min-max) or number and frequency, where applicable. The concordance correlation coefficients were calculated in the same knees of the same patients by two researchers. The Pearson correlation coefficient was used to evaluate the correlation of the new patellar height

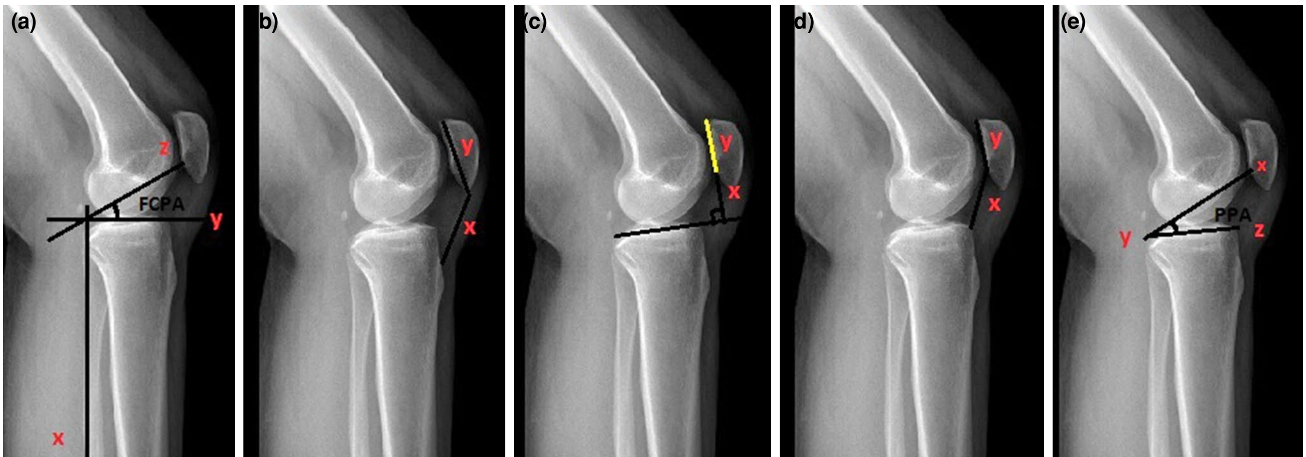

FIGURE 1. Demonstration of five different measurement techniques on X-ray knee lateral radiograph. **(a)** Fibula-condyle-patella angle (FCPA); **(b)** Insall-Salvati=x/y; **(c)** Blackburne-Peel index=x/y; **(d)** Caton-Deschambs index=x/y; **(e)** Plateau-patella angle (PPA)=XYZ.

TABLE I
Statistical data of two different investigators' measurements of fibula-condyle-patella angle, Insall-Salvati, Caton-Deschamps, Blackburne-Pell and PPA values

	n	Mean±SD	Median	Min-Max
FCPA-1*	108	32.4±5.95	32.2	19.0-49.0
IS-1	108	1.09±0.163	1.06	0.750-1.84
BP-1	108	0.801±0.135	0.800	0.540-1.33
CD-1	108	0.937±0.149	0.910	0.60-1.33
PPA-1	108	24.8±3.57	24.7	17.7-39.8
FCPA-2**	108	33.6±6.70	33.5	17.1-47.1
IS-2	108	1.17±0.144	1.17	0.780-1.55
BP-2	108	0.815±0.138	0.810	0.440-1.40
CD-2	108	0.965±0.165	0.960	0.520-1.40
PPA-2	108	24.0±3.28	24.2	14.5-33.1

FCPA: Fibula-condyle-patella angle; PPA: Plateau-patella angle; SD: Standard deviation; IS: Insall-Salvati; BP: Blackburne-Pell; CD: Caton-Deschamps; * Measurements by the first orthopedist; ** Measurements by the second orthopedist.

TABLE II
Inter-observer correlation analysis of fibula-condyle-patella angle, Insall-Salvati, Caton-Deschamps, Blackburne-Pell, and PPA

	CCC	95% CI Upper	95% CI Lower
FCPA1* *vs.* FCPA2**	0.731	0.806	0.633
IS1 *vs.* IS2	0.612	0.704	0.501
BP1 *vs.* BP2	0.392	0.540	0.222
CD1 *vs.* CD2	0.449	0.540	0.290
PPA1 *vs.* PPA2	0.547	0.664	0.405

FCPA: Fibula-condyle-patella angle; PPA: Plateau-patella angle; CCC: Concordance correlation coefficient; CI: Confidence interval; IS: Insall-Salvati; BP: Blackburne-Pell; CD: Caton-Deschamps; * Measurements by the first orthopedist; ** Measurements by the second orthopedist.

TABLE III
Correlation analysis of fibula-condyle-patella angle 1 and fibula-condyle-patella angle 2 measurements with Insall-Salvati, Caton-Deschamps, Blackburne-Pell and PPA measurements

	Pearson's r	*p*	95% CI Upper	95% CI Lower
FCPA1* *vs.* IS1**	0.178	0.033	1.000	0.020
FCPA1 *vs.* BP2	0.268	0.003	1.000	0.114
FCPA1 *vs.* CD1	0.121	0.121	1.000	–0.039
FCPA1 *vs.* PPA1	0.323	<0.001	1.000	0.172
FCPA2 *vs.* IS2	0.184	0.028	1.000	0.026
FCPA2 *vs.* BP2	0.321	<0.001	1.000	0.171
FCPA1 *vs.* CD1	0.260	0.003	1.000	0.106
FCPA1 *vs.* PPA1	0.433	<0.001	1.000	0.294

FCPA: Fibula-condyle-patella angle; PPA: Plateau-patella angle; CI: Confidence interval; IS: Insall-Salvati; BP: Blackburne-Pell; CD: Caton-Deschamps; * Measurements by the first orthopedist; ** Measurements by the second orthopedist

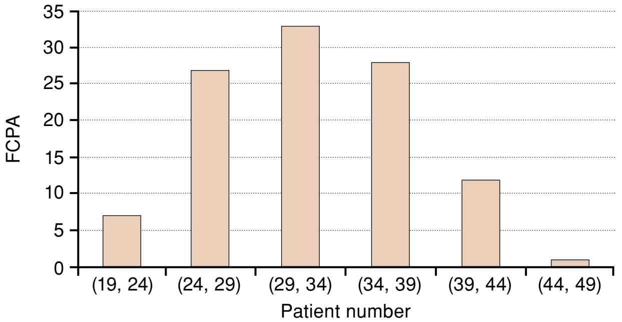

FIGURE 2. Histogram showing the bell-shaped normal distribution of participant measurements.
FCPA: Fibula-condyle-patella angle.

measurement technique with Insall-Salvati, Caton-Deschamps, Blackburne-Pell, and PPA. A *p* value of <0.05 was considered statistically significant.

RESULTS

Right knee patellar height measurements were conducted in 56 patients, while left knee patellar heights were assessed in 52 patients.

Two researchers independently measured the patellar heights using the fibula-condyle-patella angle, Insall-Salvati, Blackburne-Pell, Caton-Deschamps, and PPA techniques. The results are summarized in Table I.

The highest inter-observer agreement was for fibula-condyle-patella angle (CCC=0.731), followed by Insall-Salvati (CCC=0.612), PPA (0.547), Caton-Deschamps (CCC=0.449), and Blackburne-Pell (CCC=0.392). The detailed inter-observer concordance correlation coefficients are presented in Table II.

The correlation analysis demonstrated that the fibula-condyle-patella angle measurements of both researchers exhibited the highest correlation with PPA (r=0.433), indicating a robust relationship. The correlation coefficients between fibula-condyle-patella angle and other techniques are shown in Table III.

Figure 2 shows the histogram in which the data are bell-shaped. In our study, we did not aim to determine the normal patellar height. However, our data showed that more than 90% of the participants were between 24 and 44 degrees.

DISCUSSION

In our study, we compared the fibula-condyle-patella angle patellar height measurement technique with Insall-Salvati, Blackburne-Pell, Caton-Deschamps, and PPA techniques. We found that fibula-condyle-patella angle had the highest inter-observer reliability and the highest correlation with PPA among the other measurement techniques.[13]

Despite the many methods used in patellar height measurement, searching for the most optimal method still continues. There are various reasons why these methods should be adopted more. For the Insall-Salvati method, difficulties in the visibility of the soft tissue shadow of the patellar tendon, differences in the dimensions of the lower pole of the patella, changes in the joint line after total knee arthroplasty and the appearance of false patella baja can be listed.[14-16] Despite this, the Insall-Salvati method has been shown to have better intra-observer and inter-observer reliability than the other measurement methods.[17]

In the Blackburne-Peel method, the more sophisticated measurement technique, the difficulties in finding bone landmarks in osteoarthritis knees, and most importantly, the fact that the tibial slop is highly affected can be listed as the limitations of the technique.[18,19] To eliminate these difficulties that may occur in measurements made using radiography and to make measurements more clearly, Kızılgöz[20] evaluated the patellar height using the Blackburne-Peel method via magnetic resonance imaging (MRI). Determining the anterosuperior tibial and patella inferior articular surface in measurements made with the Coton-Deschamps method is difficult in patients with osteoarthritis.[18,21] The fact that there is only one angle measurement without calculation in the measurements made with PPA makes it technically easy to apply. However, the fact that one of the references in the measure has a tibial plateau causes it to be highly affected by the tibial slope, similar to Blackburne-Pell. Therefore, it has been shown that the highest correlation is with the Blackburne-Pell method.[12]

In recent years, deep learning, a subset of artificial intelligence, has played an important role in evaluating the patella-femoral relationship.[22] By introducing the parameters used in the measurement methods to the system, patellar height measurements are made automatically. Recent studies have demonstrated the accuracy and usefulness of measurements made using deep learning.[23,24] We believe that patellar height measurement using fibula-condyle-patella angle can be used with the deep learning method, as the measurement parameters used are easy and objective to determine radiographically.[25]

While evaluating the patellofemoral joint, many researchers, such as Blumensaat,[5] have described measuring the patellofemoral relationship directly, as some have measured indirectly through the relationship of the patella with the tibia, such as Insall-Salvati,[6] Caton-Deschamps,[8] Blackburne-Pell,[7] and PPA.[26-32] The most significant difficulty in direct measurement methods was the effect of knee flexion angles.[2] On the contrary, a recent study reported that patellar height would not be affected by knee flexion.[33]

The fibula-condyle-patella angle has several advantages. The first advantage is the use of the long axis of the fibula as a reference point instead of tibial landmarks. This is easily seen on the lateral radiograph and is not anatomically affected by high tibial osteotomies and arthroplasties. The second advantage is that the fibula-condyle-patella angle reflects changes at the level of the tibiofemoral joint. Fibula-condyle-patella angle does not require length measurement and calculation, but relies on angle measurement instead of ratio, similar to PPA. However, the most critical point where it differs from PPA is that it is not affected by the tibial slope. This may be because fibula-condyle-patella angle and PPA are both angular measurements; the highest correlation was found between the two. In the Portner and Pakzad's study,[12] PPA and Insall-Salvati, Caton- Deschamps, and Blackburne-Pell measurements were compared, and the highest inter-observer reliability was found in PPA. In our study, the highest inter-observer concordance was found in the fibula-condyle-patella angle. The second highest concordance was found in the Insall-Salvati. The highest concordance correlation was found with PPA in the measurements of both researchers.

Nonetheless, this study has certain limitations, including its single-center, retrospective nature, lack of data on the clinical status of patients whose radiological images were evaluated, and absence of inferences about normal and pathological values related to the technique developed. To establish normal and pathological reference values for fibula-condyle-patella angle, further detailed studies should be conducted on both normal and clinically symptomatic populations with patellar height issues. The primary objective of this study was to introduce a logical perspective on fibula-condyle-patella angle. We refrain from making inferences about average fibula-condyle-patella angle values due to the limited sample size and nature of our study. We believe that this study will serve as a pioneer for future studies that would explore these values.

In conclusion, fibula-condyle-patella angle is an effective method to measure patellar height with high inter-observer reliability. This study introduces fibula-condyle-patella angle as a promising perspective for patellar height measurement. We believe that it will inspire future research to establish comprehensive reference values for clinical applications.

Ethics Committee Approval: The study protocol was approved by the Mersin University Rectorate Clinical Research Ethics Committee (date: 02.05.2023, no: 296/2023). The study was conducted in accordance with the principles of the Declaration of Helsinki.

Patient Consent for Publication: A written informed consent was obtained from each patient.

Data Sharing Statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

Author Contributions: Idea/concept: F.G., Ö.K.; Design: F.G., Ö.K.; Data collection/processing: F.G., Ö.K.; Analysis/interpretation: F.G., M.A.; Literature review: F.G., M.A., Drafting/writing: F.G., Ö.K., M.A.; Critical review: F.G., M.A.

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