

Original Article

Association between patellofemoral osteoarthritis with demographic features and anatomical variants of the knee in non-traumatic patients

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Abstract: Background: Patellofemoral osteoarthritis (PFOA) is a common cause of knee discomfort and impairment, particularly among athletes. The development of PFOA has been associated with anatomical knee variations, such as trochlear dysplasia and patella alta. However, the relationship between these anatomical variants and the development of PFOA remains poorly understood. This study aimed to investigate the association between PFOA and knee anatomical variants in a cohort of patients. Methods: The study included 200 patients with PFOA and 200 healthy controls. In this study, we investigate the relationship of osteoarthritis with both anatomical variants and demographic characteristics. The participants underwent Magnetic resonance imaging (MRI) evaluation of the knee, and anatomical variants including trochlear dysplasia and patella alta were assessed. The severity of PFOA was also graded based on cartilage area and depth, as well as the bone marrow involvement and presence of osteophytes. Results: Statistically significant differences were observed between the two groups in terms of Tibial tuberosity-trochlear groove (TT-TG) distance, patella position, trochlear dysplasia, and Insall-Salvati ratio. The mean TT-TG distance, prevalence of alta patella position, and Insall-Salvati ratio were significantly higher in cases ($P < 0.001$ for all), and cases had a higher incidence of trochlear dysplasia ($P < 0.001$). There were no significant differences between cases and controls regarding patella baja. Conclusion: Anatomical knee variants, including the TT-TG distance, trochlear dysplasia, and Insall-Salvati ratio, are significant risk factors for PFOA progression. The results also indicate that higher BMI and older age are significantly associated with more measures of MRI Osteoarthritis Knee Score (MOAKS) than demographic information. Among anatomical variants, a higher TT-TG distance and an increased grade of trochlear dysplasia show a significant relationship with more measures of MOAKS. Understanding the relationship between these factors has important clinical and research implications and can help inform the development of new treatments.

Keywords: Osteoarthritis, anatomy, patellofemoral, anatomical variants, demographic features

Introduction

Osteoarthritis is a complex and multifaceted condition that often affects the knee joint [1]. Patellofemoral joint osteoarthritis is a common manifestation associated with significant discomfort, reduced function, and diminished quality of life [2]. In general, the spread of patellofemoral joint osteoarthritis is 25%, and more than 40% of these people have isolated patellofemoral joint osteoarthritis [3]. Combined osteoarthritis of both knee compartments

seems to be more common than isolated patellofemoral joint osteoarthritis in people with knee pain symptoms [4].

To date, there are no specific diagnostic criteria to officially diagnose patellofemoral joint osteoarthritis (PFOA) [5]. PFOA has a series of clinical characteristics. One of the prominent features that indicate it is pain in the front of the knee (especially when climbing stairs) [6]. Its other characteristics include knee crepitus, swelling, pain when pressing on the patellofemoral joint,

stiffness of the knee joint after sitting, knee valgus deformity, and a decrease in the strength of the quadriceps muscles [7]. Radiography is the most common imaging method used to diagnose and grade osteoarthritis of the patellofemoral joint. X-ray and Magnetic resonance imaging (MRI) can be used to diagnose patellofemoral joint osteoarthritis. Radiological findings are not necessarily related to clinical symptoms [8].

Various grading systems, such as the Sperner system and the Kellgren-Lawrence (KL) system, are employed to assess patellofemoral joint osteoarthritis [9]. The Kellgren-Lawrence (KL) grading system is commonly utilized for radiographic evaluation of patellofemoral joint osteoarthritis, especially in research settings. It typically requires the presence of osteophytes and joint space narrowing for diagnosis. However, it's important to note that this method was initially developed for tibiofemoral joint osteoarthritis, and its applicability to patellofemoral joint osteoarthritis has not been thoroughly assessed [10]. Originally designed for anteroposterior (AP) knee radiographs, the KL grading system has more recently been adapted for use with MRI sequences and modified KL criteria to accurately evaluate patellofemoral joint osteoarthritis [11].

Today, the MRI Osteoarthritis Knee Score (MOAKS) classification system is used for assessment of tendon and ligament damage, meniscus damage, synovitis effusion and changes in peri-articular [12].

Chronic instability of the patellofemoral joint and its repeated dislocations, if not adequately treated, may lead to progressive cartilage destruction and severe osteoarthritis [13]. There have been limited investigations into the influence of anatomical variations in the patellofemoral joint on the development of patellofemoral joint osteoarthritis. Given the variability and inconclusive findings in prior studies, coupled with the scarcity of research in this specific domain, the primary objective of this study is to explore the relationship between patellofemoral joint osteoarthritis, anatomical variations, and demographic data by examining knee MRI scans in non-traumatic patients.

Methods

Study design

This is a case-control research that was conducted in 2021-2022 in Kashani hospital and Sepahan Imaging center affiliated with Isfahan University of Medical Science (Ethics code: IR.MUI.REC.1400.069). The current study was conducted on patients undergoing knee MRI.

Inclusion and exclusion criteria

The inclusion criteria were being between the ages of 20 and 50, having a knee MRI, diagnosis of patellofemoral osteoarthritis, and providing a written informed agreement to take part in this study. Patients with histories of knee trauma, knee surgery and knee joint diseases were not entered. The exclusion criteria were incomplete data (not accessing patient's records) and patient's will to exit this study.

Data gathering

We assessed data of 200 patients with non-traumatic patellofemoral osteoarthritis as case and 200 healthy volunteers as controls. After obtaining informed consent, the demographic information of each patient, including age, sex, height, weight, and dominant leg, was recorded.

MRI findings

In this study, the MRI images of the patients were assessed for the presence of anatomical variations, including trochlear dysplasia, abnormal patella bone height (patella alta and patella baja), and the positioning of the upper tibial prominence concerning the lateral distance between the tibial tubercle and the trochlear groove, known as the Tibial tuberosity-trochlear groove (TT-TG) distance. Furthermore, the study aimed to determine the correlation between the severity of patellofemoral joint osteoarthritis and these anatomical variations.

The TT-TG distance was classified into three categories: normal (<15 mm), borderline (15-20 mm), and increased (>20 mm). The positioning of the patella was categorized using the Insall-Salvati ratio, where Insall-Salvati ratio <0.8 indicated patella baja and Insall-Salvati ratio >1.3 indicated patella alta. **Figure 1** shows

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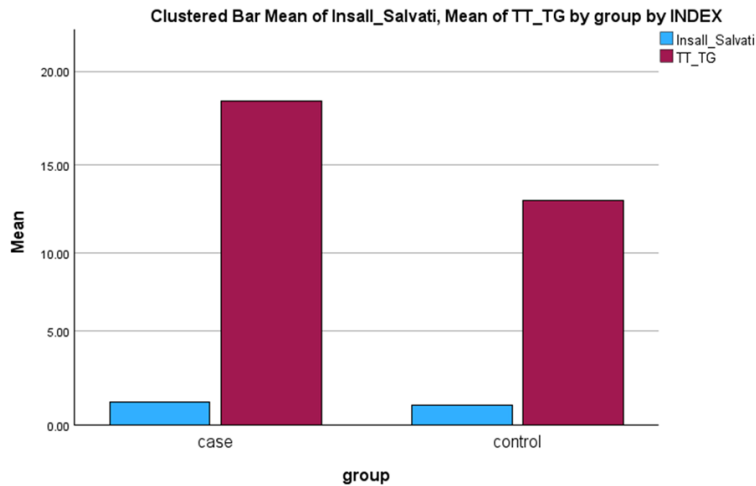


Figure 1. Comparison of Tibial tuberosity-trochlear groove (TT-TG) distance and Insall Salvati between two groups.

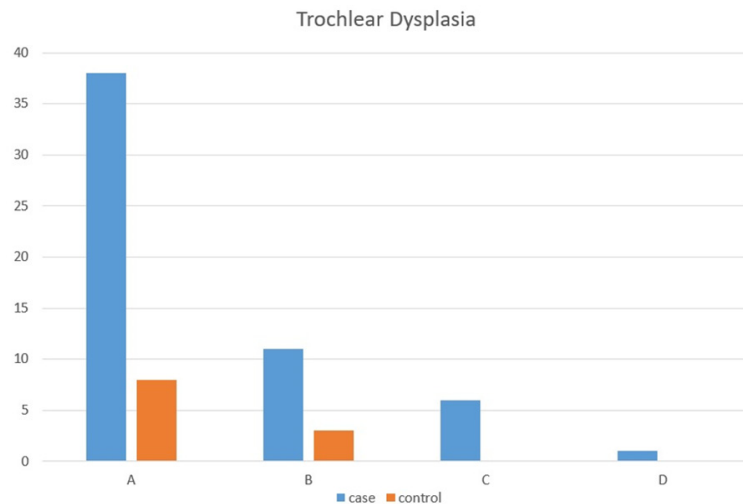


Figure 2. Frequencies of different types of trochlear dysplasia between groups.

the Comparison of Tibial tuberosity-trochlear groove (TT-TG) distance and Insall Salvati between two groups. **Figure 2** indicates the frequencies of different types of trochlear dysplasia between groups.

MOAKS criteria

In this study, we divided all patients into two groups: 20 to 40 years old and 40 to 50 years old. We graded patients with patellofemoral joint osteoarthritis using the MOAKS scoring system.

The MOAKS scoring system is a method used to evaluate and grade the severity of knee

osteoarthritis based on MRI findings. It assesses structural damage in the knee joint, including cartilage loss, bone marrow lesions, and meniscal damage, by assigning numeric scores to these components. This system helps clinicians and researchers monitor disease progression, evaluate treatment effectiveness, and make informed decisions about patient care, contributing to our understanding of knee osteoarthritis [20].

We should note that we only used the criteria of articular cartilage and bone marrow lesions and osteophyte in patellofemoral compartment (patellar and trochlear subregions) from the MOAKS criteria in our article due to the clinical importance of these factors to evaluate severity. The severity of PFOA was also graded based on cartilage area and depth, as well as the bone marrow involvement and presence of osteophytes.

Then the collected data was compared between the case and control groups.

Statistical analysis

After collecting information, it was inputted into the Statistical Package for Social Sciences (SPSS) (version 24, IBM Inc., Chicago, IL). Quantitative data were reported as mean \pm standard deviation and qualitative data as frequency distribution (percentage). Independent t-test, Chi-square were used to analyze the data. We also used coefficient correlation to determine the relationships between different factors in our study. P -value <0.05 was considered as significance threshold.

Results

General information

In this study we evaluated data of 218 knees (from 200 cases) and 218 knees (from 200

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Table 1. Comparison of different variables between case and controls

Variable	Case (N = 200)	Controls (N = 200)	P-value
Age (year) (mean ± SD)	36.83 ± 7.14	37.67 ± 8.24	0.366*
Age category (n (%))			
20-40 years	79 (39.5%)	77 (38.5%)	0.561**
>40 years	121 (60.5%)	123 (61.5%)	
Gender (n (%))			
Male	81 (40.5%)	79 (39.5%)	0.371**
Female	119 (59.5%)	121 (60.5%)	
BMI (kg/m ²) (mean ± SD)	26.31 ± 3.26	26.49 ± 4.10	0.217*
Dominant knee (Right) (N (%))	172 (86%)	175 (87.5%)	0.301**
Involved knee (Right) (N (%))	161 (80.5%)	157 (78.5%)	0.414**

SD: Standard deviation, BMI: Body mass index, *independent T-test, **Chi square test.

Table 2. Comparison of different knee abnormalities between the two groups

Variable	Case knees (N = 218)	Control knees (N = 218)	P-value
TT-TG distance (mm) (mean ± SD)	18.42 ± 2.14	13.12 ± 1.75	<0.001*
Patella position (N (%))			
Alta	41 (18.8%)	12 (5.5%)	<0.001**
Baja	2 (0.9%)	2 (0.9%)	N/A
Insall-Salvati ratio (mean ± SD)	1.21 ± 0.24	1.03 ± 0.19	<0.001*
Trochlear dysplasia (N (%))			
A	38 (17.4%)	8 (3.6%)	<0.001**
B	11 (5%)	3 (1.3%)	
C	6 (2.7%)	0	
D	1 (0.4%)	0	
Total	56 (25.7%)	11 (5%)	

SD: Standard deviation, TT-TG: Tibial tuberosity-trochlear groove, *Independent T-test, **Chi square, NA: not applicable.

controls). The mean age of the study population was 37.63 ± 8.13 years and the mean BMI was 26.37 ± 4.19 kg/m².

Demographic data of patients and controls are demonstrated in **Table 1**. There were no significant statistical differences between the two groups regarding age (P = 0.366), age categories (P = 0.512), gender (P = 0.470), BMI (P = 0.217), dominant and involved knees (P = 0.371 and 0.466, respectively).

Comparisons

Significant statistical differences were observed between the two groups concerning TT-TG distance, patella position, Insall-Salvati ratio, and trochlear dysplasia. As depicted in **Table 2**, the mean TT-TG distance, prevalence of patella alta position, and Insall-Salvati ratio were sig-

nificantly higher in the cases (P<0.001 for all), and cases exhibited a higher incidence of trochlear dysplasia (P<0.001). However, when it comes to patella baja, there were no statistically significant differences noted between the cases and controls.

Relationships between clinical and imaging data

As outlined in **Table 3**, the MOAKS exhibited significant associations with certain patient variables. These included a positive correlation between a larger TT-TG distance (particularly above 15 mm), higher patella position (alta), specific types of trochlear dysplasia, higher BMI categories (especially above 25), and certain age ranges (e.g., 40-50) in relation to the outcome variable. However, it's crucial to note that these potential associations cannot be confirmed without the corresponding p-values, which indicate statistical significance.

The results indicated that higher BMI and older age are significantly linked to a higher number of MOAKS measures compared to demographic information. Among anatomical variants, a greater TT-TG distance and an elevated grade of trochlear dysplasia demonstrated a significant relationship with a greater number of MOAKS measures. Patella alta displayed a significant relationship specifically with more severe cartilaginous involvement, whereas gender did not exhibit any statistically significant relationship.

Discussion

Osteoarthritis is a widespread degenerative joint disorder that affects millions of people worldwide, with the knee joint being a commonly affected area. Within the knee joint, PFOA is a condition that has been associated

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Table 3. Relationship between MOAKS and different patient's variables

Variables			Articular Cartilage Lesion Size	Articular Cartilage Percentage of full-thickness loss	Bone marrow lesion Volume of involvement	Bone marrow lesion vs cyst	Osteophytes
TT-TG Distance	Under 15 mm	R	+1.051	+1.022	+1.101	+1.082	+1.031
		P-value	0.366	0.011	0.021	0.814	0.554
	Between 15-20 mm	R	+1.151	+1.136	+1.221	+1.002	+1.118
		P-value	0.001	0.001	0.014	0.141	0.032
	More than 20 mm	R	+1.351	+1.277	+1.246	+1.052	+1.211
		P-value	<0.001	<0.001	<0.001	<0.001	<0.001
Patella position	Alta	R	+1.156	+1.064	+1.014	-1.002	+1.034
		P-value	0.014	0.026	0.283	0.112	0.712
	Baja	R	-	-	-	-	-
		P-value	N/A	N/A	N/A	N/A	N/A
Trochlear dysplasia type	A	R	+1.065	+1.087	+1.021	+1.014	+1.132
		P-value	0.025	0.010	0.032	0.410	0.017
	B	R	+1.087	+1.091	+1.062	+1.023	+1.027
		P-value	<0.001	<0.001	<0.001	0.011	0.010
	C	R	+1.112	+1.151	+1.078	+1.141	+1.125
		P-value	0.012	0.001	<0.001	0.002	0.016
	D	R	-	-	-	-	-
		P-value	N/A	N/A	N/A	N/A	N/A
BMI	Under 25	R	+1.024	+1.031	+1.033	-1.022	+1.049
		P-value	0.012	0.001	0.003	0.528	0.465
	Between 25-30	R	+1.057	+1.040	+1.012	+1.029	+1.050
		P-value	<0.001	<0.001	<0.001	<0.001	0.001
	Above 30	R	+1.110	+1.054	+1.023	+1.017	+1.068
		P-value	<0.001	0.001	0.010	0.002	0.021
Age	20-40	R	+1.045	+1.064	+1.030	+1.012	-0.920
		P-value	<0.001	<0.001	0.004	0.356	0.010
	40-50	R	+1.135	+1.068	+1.051	+1.018	+1.105
		P-value	0.001	0.027	<0.001	0.082	0.002
Gender	Female	R	+1.005	-1.030	-1.017	+1.020	+1.006
		P-value	0.418	0.391	0.579	0.214	0.620
	Male	R	+1.005	+1.014	+1.032	+1.045	+1.012
		P-value	0.188	0.093	0.441	0.239	0.674

with various anatomical variants. The patellofemoral joint comprises the patella (kneecap) and the femur (thigh bone). In a healthy knee, the patella moves smoothly within the trochlear groove on the femur. However, in cases of PFOA, there is damage and degeneration of the articular cartilage within the patellofemoral joint, leading to pain and functional limitations [14, 15].

The development of PFOA is influenced by a combination of factors, including age, gender, obesity, joint injuries, and anatomical variations within the knee joint [16]. Anatomical variations encompass differences in the shape,

positioning, or alignment of the bones and soft tissues in the knee joint.

The TT-TG distance, which stands for Tibial Tubercle-Trochlear Groove distance, measures the space between the tibial tubercle (TT), a bony projection located on the front of the tibia where the patellar tendon attaches, and the trochlear groove (TG), a groove on the femur where the patella moves smoothly. A larger TT-TG distance indicates a more pronounced lateral displacement of the patella, potentially resulting in increased pressure on the lateral facet of the patella and, consequently, an elevated risk of developing PFOA [17, 18].

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The Insall-Salvati ratio is a measure of patellar height and is calculated by dividing the length of the patella by the length of the patellar tendon. A higher Insall-Salvati ratio indicates a more superiorly positioned patella, which can also increase the risk of PFOA [19].

Trochlear dysplasia refers to a defect in the trochlear groove's structure or depth. This anatomical variation can result in patellar instability and consequent PFOA development. Based on the severity of dysplasia and the shape of the trochlear groove, four varieties of trochlear dysplasia can be identified. Type 1 dysplasia is the least extreme, whereas type 4 dysplasia is the most severe.

Numerous studies have explored the connection between PFOA and anatomical variations within the knee. For instance, a study published in the *Journal of Orthopaedic Surgery and Research* investigated the relationship between PFOA and knee anatomical variants in a cohort of 200 patients with PFOA and 200 age- and sex-matched controls [20]. This investigation revealed a significant difference between the two groups.

Another study delved into the link between PFOA and trochlear dysplasia among patients with knee osteoarthritis. The findings of this study indicated that individuals with PFOA were more likely to exhibit trochlear dysplasia compared to those without PFOA. Moreover, the severity of trochlear dysplasia was positively correlated with the severity of PFOA [21].

As presented before, the MOAKS had significant relationships with some patient's variables. These include a positive correlation between larger TT-TG distance (particularly above 15 mm), higher patella position (alta), certain types of trochlear dysplasia, higher BMI categories (particularly above 25), and certain age ranges (e.g., 40-50) with the outcome variable.

The association between anatomical variants of the knee and PFOA has important clinical implications. Understanding the relationship between these factors can help clinicians identify individuals who may be at increased risk for developing PFOA and implement appropriate preventative measures [22]. For example, individuals with a higher TT-TG distance or Insall-Salvati ratio may benefit from targeted exercis-

es to improve patellar tracking and reduce the risk of PFOA. Similarly, individuals with trochlear dysplasia may benefit from surgical intervention to correct the abnormality and prevent further joint damage [23].

In addition to clinical implications, the association between anatomical variants of the knee and PFOA also has important research implications. Understanding the underlying mechanisms by which these anatomical variants contribute to the development and progression of PFOA can help inform the development of new treatments and interventions. For example, interventions that target the specific mechanisms by which trochlear dysplasia contributes to PFOA may be more effective in preventing and treating the condition than interventions that target other factors [24].

This study presents some limitations that should be considered. Firstly, the potential for selection bias is a concern, as the criteria for participant inclusion and recruitment methods are not well-documented. Additionally, the cross-sectional design of the study limits its ability to establish causal relationships between anatomical variants and the development of PFOA. A longitudinal, prospective study design would have provided a more robust understanding of the temporal relationship between these factors. Furthermore, the relatively small sample size of 200 patients and 200 controls could reduce the statistical power of the study. It is important to note that while the association between anatomical variants of the knee and PFOA is well-established, the exact mechanisms by which these variants contribute to the development and progression of PFOA are not fully understood. To understand the underlying mechanisms and locate new intervention points, more study is required.

Conclusion

PFOA is a prevalent condition that can have a substantial impact on an individual's quality of life. Anatomical variations within the knee play a pivotal role as risk factors for the progression of PFOA. The study results underscore the significance of higher BMI and older age in relation to the extent of cartilage damage, as indicated by the MOAKS, in comparison to demographic factors. Among these anatomical variants, an increased TT-TG distance and higher grades of

trochlear dysplasia exhibit significant associations with greater MOAKS measures. Recognizing and understanding these relationships holds substantial clinical and research implications, providing valuable insights for the development of new treatments and interventions aimed at both the prevention and management of PFOA.

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Disclosure of conflict of interest

None.

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