BRITISH JOURNAL OF HOSPITAL MEDICINE

ARTICLE

Diagnostic Value of Pericruciate Fat Pad Measurement by MRI in Patients With Knee Articular Cartilage Injury

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Abstract

Aims/Background The diagnosis and treatment of knee joint injuries is an important medical topic. Magnetic resonance imaging (MRI) technology can aid in the clear visualization of the knee joint's internal structure. The correlation of pericruciate fat pad (PCFP) grading with cartilage injuries offers guidance in condition assessment and treatment. Therefore, this study aimed to investigate the value of MRI measurement of PCFP in the diagnosis and assessment of patients with knee cartilage injuries.

Methods A total of 210 patients who underwent knee MRI examination in our hospital from January 2022 to June 2024 were retrospectively selected. All MRI examinations were conducted in accordance with a set of unified parameter standards, and the general data of patients were collected and analyzed. The relationship between PCFP grading and injury of various parts was analyzed, and the efficacy analysis of PCFP grading in diagnosing injury was analyzed.

Results The comparison of the infrapatellar fat pad (IPFP)_Fat Fraction (FF) value, PCFP_FF value, and PCFP_Transverse Relaxation Time (T2) value between the two groups of patients revealed significant differences ($p < 0.05$). The results of binary logistic regression analysis showed that the FF value and T2 value of PCFP were independent influencing factors for knee cartilage injury ($p < 0.05$). According to Pearson correlation results, PCFP was positively correlated with injuries to the medial femoral ankle, medial compartment, and lateral femoral ankle (r = 0.293, 0.335, 0.277, $p < 0.05$). Using arthroscopy results as the gold standard, we found that the PCFP grading-based diagnosis had a sensitivity of 92.86% (130/140), a specificity of 95.71% (67/70), and an accuracy of 93.81% (197/210). In terms of different grades, PCFP grading has an accuracy rate of 95.17% in grade 0 diagnosis, 93.55% in grade 1, 95.71% in grade 2, 90.00% in grade 3, and 77.77% in grade 4.

Conclusion MRI measurement of PCFP is highly sensitive, specific and accurate in the diagnosis of patients with knee articular cartilage injury, with a high accuracy in grading injuries, which is helpful for clinical diagnosis.

Key words: MRI; pericruciate fat pad; knee articular cartilage injury; diagnosis; disease evaluation

Submitted: 29 October 2024 Revised: 8 January 2025 Accepted: 10 January 2025

How to cite this article:
Zhang S, Zheng T, Jin J, Ye C, He R. Diagnostic Value of Pericruciate Fat Pad Measurement by MRI in Patients With Knee Articular Cartilage Injury. Br J Hosp Med. 2025. https://doi.org/10.12968/hmed.2024.0824

Introduction

The knee joint is one of the largest and most structurally complex joints in the human body, and its stability and flexibility are essential for daily activities. However, the knee joint is also one of the most vulnerable joints because it bears a large load in daily activities (Hori et al, 2024). Knee articular cartilage injury and cruciate ligament injury are two common types of joint injuries, which not only lead to knee pain, swelling and functional limitation, but also may cause secondary joint injury and osteoarthritis in severe cases (Kim et al, 2023). Therefore, it is particularly important to make a timely and accurate diagnosis and assessment of the knee articular cartilage injury. In this regard, magnetic resonance imaging (MRI), as a non-invasive and high-resolution imaging technology, plays a vital role in the diagnosis of knee joint injury (Liu et al, 2022).

Studies have shown that the signal changes of pericruciate fat pad (PCFP) are closely related to the severity of knee articular cartilage injury and osteoarthritis (Eagle et al, 2023; Kim et al, 2023). There has been remarkable progress in the application of MRI for the diagnosis of knee articular cartilage injury in recent years (Ding et al, 2024). Some studies also demonstrated that the MRI holds potential application value in preoperative diagnosis of knee ligament injury. Therefore, this study aims to explore the value of MRI measurement of PCFP in the diagnosis and disease evaluation of patients with knee articular cartilage injury.

Methods

Study Subjects

A total of 210 patients who received knee joint MRI examinations in the Second Affiliated Hospital, Zhejiang University School of Medicine from January 2022 to June 2024 were retrospectively selected. Inclusion criteria of this study are as follows: (1) patients with knee joint pain; (2) patients with complete data of arthroscopy and MRI examination; and (3) patients with clear cognition and basic communication skills. Individuals with the following characteristics were excluded: (1) other joint injuries; (2) mental disorders; (3) contraindications to MRI or unclear images; and (4) cardiac and renal dysfunction. This study has been approved by the Ethics Committee of the Second Affiliated Hospital, Zhejiang University School of Medicine (Approval No.: 20250510), and informed consent has been obtained from all participants.

Collection of MRI Examination-Related Information

All MRI examinations were performed according to unified parameter standards using a GE Discovery MR 750 3.0 T magnetic resonance scanner (Model: Discovery MR750 3.0T, WISCONSIN GE Medical Systems, LLC, Waukesha, WI, USA) with Sun Advantage Workstation version 4.5 image post-processing system, which has a gradient field strength of 50 Mt/m and a gradient switching rate of 200 T/m/s. The original 8-channel knee coil (HD TR knee) was used as the receiving device during scanning. Scanning sequences included sagittal proton density-weighted image (PDWI), fat-suppressed T2-weighted image (FsT2WI), iterative decomposition of water and fat with echo asymmetry and least squares estimation quantification (IDEAL-IQ) sequence, and T2 mapping, as well as transverse FsT2WI and IDEAL-IQ sequence. After comparing the effects of multiple pre-experiment images, the following scanning sequences and parameter settings were finally determined: (1) Sagittal fat-suppressed fast spin-echo proton density-weighted image (Sag-PD-FS-FSE): repetition time (TR)/echo time (TE) = 3376/30 ms, field of view (FOV) = 14 cm, matrix = 320 × 224, slice thickness/interslice spacing = 2.5/0.5 mm, echo train length (ETL) = 8 ms, number of excitations (NEX) = 2, bandwidth = 31.25 Hz. (2) Sagittal/axial fat-suppressed T2-weighted imaging (Sag/Axial-FsT2WI): TR = 2400 ms, FOV = 14 cm, matrix = 256 × 160, slice thickness/interslice spacing = 2.5/0.5 mm, NEX = 1, bandwidth = 83.33 Hz. (3) Sagittal/transverse IDEAL-IQ sequence: flip angle = 3°, TE = 0.9 ms to 9.3 ms (incremental step size of 0.7 ms), TR = 6.9 ms, FOV = 14 cm, matrix = 256 × 160, NEX = 1, bandwidth = 200 Hz. (4) Sagittal T2 Mapping: TR = 1300 ms, TE range: 10–90 ms, FOV = 18 cm, matrix = 512 × 512, slice thickness/interslice spacing = 3.0/1.5 mm, ETL = 8 ms, NEX = 1, bandwidth = 83.33 Hz. The patient's knee was extended. The data were carefully analyzed by two experienced radiologists. On the sagittal PDWI image, the physician manually delineated the extent of PCFP and measured the T2 value and F value according to the proportion of high signal area to total area, and semi-quantitatively graded it from 0 to 3: grade 0 represents normal; grade 1 represents mild, with high signal area accounting for less than 33%; grade 2 represents moderate, with high signal area accounting for between 33% and 66%; and grade 3 represents severe, with high signal area accounting for more than 66%. At the same time, cartilage injury was assessed using a modified Outerbridge Grading System (Deweese et al, 2019): grade 0 = normal cartilage; grade 1 = abnormal signal, grade 2 = less than 50% reduction in cartilage thickness, grade 3 = more than 50% reduction in cartilage thickness, and grade 4 = complete loss of cartilage. Grades 1 and 2 are considered low-grade cartilage injuries, while grades 3 and 4 are classified as high-grade cartilage injuries. In addition, arthroscopic examination was used as the gold standard to record the infrapatellar fat pad (IPFP) below the patella and the suprapatellar fat pad (SPFP) above the patella. Using arthroscopy combined with MRI and magnetic resonance angiography (MRA) as the gold standard, we detected knee cartilage injuries in 140 out of 210 patients. According to the injury grade, 210 patients were diagnosed with grade 0, 31 patients with grade 1, 70 patients with grade 2, 30 patients with grade 3, and 9 patients with grade 4.

In order to ensure measurement objectivity, this study adopted a rigorous double-blindness process. Specifically, all radiologists participating in the assessment were strictly restricted to PCFP grading and cartilage injury grading without having access to any other relevant information from the patients. This measure aims to eliminate possible bias among doctors based on patients' medical history, symptoms or other external factors, thereby ensuring objectivity and accuracy of assessment results. During the evaluation process, two radiologists worked independently, providing their analytical judgment based entirely on the imaging data itself and not on any other factors that might affect the judgment. When the assessment results of the two doctors were inconsistent, a third radiologist would weigh in during a repeated review by comparing and analyzing the first set of assessment results without knowing other information about the patient; the final diagnosis of the patient was determined based on the ultimate consistent results.

Table 1. General data of the study population.

Baseline data	Injury group (n = 140)	Non-injury group (n = 70)	t/χ^2 value	p-value
Age (years)	46.94 ± 5.64	47.08 ± 5.54	0.171	0.865
Sex			0.086	0.769
Male	65	31		
Female	75	39		
Height (cm)	164.69 ± 9.54	164.33 ± 9.37	0.259	0.796
Weight (kg)	64.64 ± 10.69	64.51 ± 9.94	0.085	0.932
BMI (kg/m^2)	24.61 ± 3.33	24.37 ± 3.21	0.498	0.619
Reason for admission			0.519	0.772
Traffic accident injury	46	20		
Falling injury from height	61	31		
Others	33	19		
Time from injury to admission (h)	2.33 ± 0.43	2.29 ± 0.37	0.665	0.507
Alcohol abuse			0.011	0.916
Yes	43	21		
No	97	49		

Abbreviation: BMI, body mass index.

In addition, we also strictly controlled outliers and missing values in the collected data. Various methods such as data cleaning, interpolation, and removal of outliers were utilized to ensure the integrity and accuracy of the data and provide a solid foundation for subsequent data analysis. This series of rigorous blinding processes and data processing measures together ensure an objective analysis in this study.

Statistical Analysis

The collected experimental data were analyzed using SPSS version 27.0 (IBM, Armonk, NY, USA). Bartlett's test was performed on the data to ensure homogeneity of variances. Continuous data conforming to normal distribution are expressed as mean $\pm$ standard deviation, and an independent-sample t-test was used for comparison. Categorical data are expressed as number of cases or rate. The chi-square test or Fisher's exact test was used for the comparative analysis of categorical data. The Pearson correlation test was used to analyze the correlation between variables. Binary logistic regression was used to analyze the influencing factors of knee cartilage injury. The $p < 0.05$ was considered statistically significant.

Results

General Data of the Study Population

In this study, all patients in the injury group had unilateral pain, with 64 patients suffering from right pain and 76 patients left pain. There were no statistically significant differences in the general data of the study population ($p > 0.05$), as shown in Table 1.

Table 2. Comparison of FF and T2 values in adipose tissue around the knee.

Baseline data	Injury group (n = 140)	Non-injury group (n = 70)	*t*	*p*-value
IPFP_FF value	70.21 ± 5.82	64.93 ± 5.91	6.166	0.000
IPFP_T2 value	146.20 ± 5.67	145.90 ± 5.73	0.360	0.719
SPFP_FF value	62.48 ± 5.87	62.36 ± 6.09	0.138	0.890
SPFP_T2 value	121.87 ± 5.90	120.90 ± 1.17	1.361	0.175
PCFP_FF value	69.13 ± 5.40	51.20 ± 5.95	21.918	0.000
PCFP_T2 value	142.25 ± 5.99	128.41 ± 5.90	15.863	0.000

Abbreviations: FF, Fat Fraction; IPFP, infrapatellar fat pad; PCFP, pericruciate fat pad; SPFP, suprapatellar fat pad; T2, Transverse Relaxation Time.

Comparison of FF and T2 Values in Adipose Tissue Around the Knee

The comparison of IPFP_Fat Fraction (FF) value, PCFP_FF value, and PCFP_T2 value between the two groups of patients revealed significant differences ($p < 0.05$), as shown in Table 2 and Fig. 1.

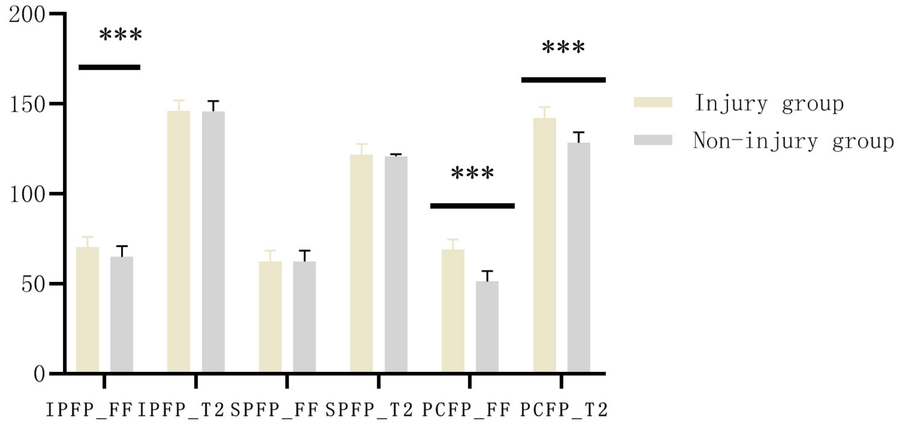

Fig. 1. Comparison of FF value and T2 value of adipose tissue around the knee. Note: *** $p < 0.001$.

Multivariate Analysis of FF Value and T2 Value of PCFP

The PCFP_FF, PCFP_ T2 and IPFP_FF values were assigned as independent variables in a multivariate analysis; the original values of these variables were incorporated into this analysis. The knee joint cartilage injury was assigned as the dependent variable (occurrence = 1, non-occurrence = 0). The results of binary logistic regression analysis showed that the FF value and T2 value of PCFP were independent influencing factors for knee cartilage injury ($p < 0.05$), as shown in Table 3.

Relationship Between PCFP Grading and Injury Sites

In this study, there were 21 cases of medial femoral ankle injuries, 16 cases of medial compartment injuries, and 17 cases of lateral femoral injuries. According to Pearson correlation results, PCFP was positively correlated with injuries to the

Table 3. Multivariate analysis of PCFP_FF, PCFP_ T2 and IPFP_FF values for knee cartilage injury.

Influencing factor	B	SE	Ward	OR	95% CI lower bound	95% CI upper bound	p-value
IPFP_FF value	0.120	0.099	1.451	1.127	0.928	1.370	0.228
PCFP_FF value	0.659	0.249	7.020	1.933	1.187	3.148	0.008
PCFP_T2 value	0.446	0.180	6.166	1.562	1.099	2.221	0.013
Constant	–108.873	32.600	11.153	0.000	-	-	0.001

Abbreviations: CI, confidence interval; OR, odds ratio; SE, standard error.

Table 4. Relationship between PCFP grading and injury sites.

Site of injury	r	p-value
Patella	0.034	0.798
Pulley	0.213	0.103
Medial femoral ankle	0.293	0.029
Medial compartment	0.335	0.010
Lateral femoral ankle	0.277	0.045
Lateral compartment	0.091	0.943

medial femoral ankle, medial compartment, and lateral femoral ankle (r = 0.293, 0.335, 0.277, $p < 0.05$), as shown in Table 4.

Diagnostic Accuracy Analysis of PCFP Grading

Among the 210 patients, the sensitivity, specificity and accuracy of PCFP grading examination were 92.86% (130/140), 95.71% (67/70) and 93.81% (197/210), respectively, with arthroscopic findings as the gold standard, as shown in Table 5.

Performance Analysis of PCFP Grading in the Diagnosis of Injury Grading

Using the arthroscopic findings as the gold standard, the accuracy of PCFP grading in diagnosing knee articular cartilage injury was 93.81% (197/210). In terms of different grades, the accuracy rates are as follows: 95.17% for grade 0, 93.55% for grade 1, 95.71% for grade 2, 90.00% for grade 3, and 77.77% for grade 4, as shown in Table 6.

MRI Findings

The MRI was used to image the PCFP in order to observe the signal intensity, its morphology and relationship with surrounding tissues. Under normal circumstances, PCFP appears as a low- or moderate-signal area on MRI images, with full shape and clear boundary, which is clearly distinguishable from the surrounding tissues. However, when PCFP undergo pathological changes, such as inflammation, edema or injury, its signal intensity, morphology and boundary are subject to changes. Abnormal increase in signal may indicate an inflammatory reaction or edema within the fat pad. Irregular shape may indicate compression or injury of the fat pad. Blurred borders may indicate that the boundaries between the fat pad and the surrounding tissues become unclear, possibly due to inflammatory cell in-

Table 5. Diagnostic accuracy of PCFP grading.

PCFP grading	Arthroscopic findings		Total
	Positive	Negative	
Positive	130	3	133
Negative	10	67	77
Total	140	70	210
Specificity	67/70 (95.71%)		
Sensitivity	130/140 (92.86%)		
Accuracy	197/210 (93.81%)		

Table 6. Performance analysis of PCFP grading in the diagnosis of injury grading.

PCFP grading	Arthroscopic findings					Total
	Grade 0	Grade 1	Grade 2	Grade 3	Grade 4	
Grade 0	67	0	0	0	0	67
Grade 1	0	29	1	1	0	31
Grade 2	1	1	67	1	1	71
Grade 3	1	1	1	27	1	31
Grade 4	1	0	1	1	7	10
Total	70	31	70	30	9	210

filtration or injury. In order to accurately determine the pathological state of PCFP, physicians need to carefully analyze every detail available on the MRI images and make a comprehensive judgment in consideration of the patient's medical history, symptoms and other examination results. In addition, it is also necessary to use the multi-sequence and multi-slice imaging characteristics of MRI to observe the morphological and signal changes of PCFP from multiple angles to improve the diagnostic accuracy.

Figs. 2,3 show some MRI images of injuries across different PCFP grades.

Discussion

The purpose of this study was to investigate the value of MRI in diagnosing and assessing PCFP in patients with knee articular cartilage injury. By retrospectively analyzing the data of 210 patients who received knee joint MRI examination in our hospital, this study deeply analyzed the relationship between PCFP grading and various sites of knee articular cartilage injury, as well as the efficacy of PCFP grading in the diagnosis of injury and injury grading.

The results of this study showed that PCFP was significantly correlated with cartilage injury in the medial femoral ankle, medial compartment, and lateral femoral ankle. As an important structure in the knee joint, PCFP not only has the functions of lubricating joints and reducing friction, but also may play a buffering role during joint injury. In the event of cartilage injury at the knee joint, PCFP may be squeezed or damaged, resulting in changes in its signal (Li et al, 2022). Therefore, observing the signal changes of PCFP by means of MRI can provide important clues for the

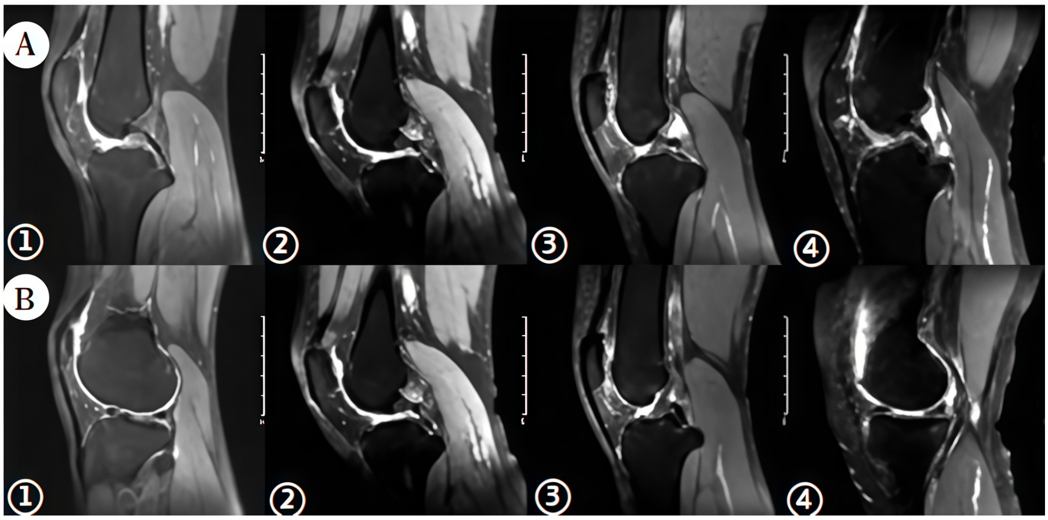

Fig. 2. Magnetic resonance imaging (MRI) of injuries across different grades. (A) Sagittal images across different PCFP grades, from grades 0 (left) to 3 (right) (from ① to ④), showcasing an increasing trend of the PCFP high-signal area. (B) Sagittal images across different levels of cartilage damage, showcasing a decreasing trend in cartilage thickness from left to right (from ① to ④).

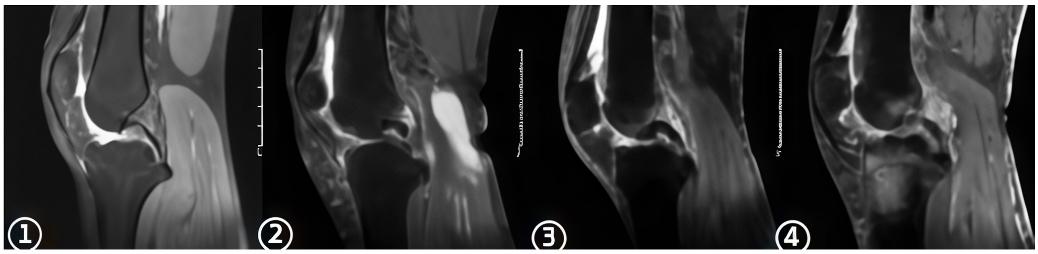

Fig. 3. Magnetic resonance imaging (MRI) of different PCFP grades, showcasing an increasing trend in PCFP high-signal area from left to right (from ① to ④).

diagnosis of knee articular cartilage injury. The sensitivity, specificity and accuracy of PCFP grading by MRI were 92.86%, 95.71% and 93.81%, respectively, in the diagnosis of joint cartilage injury. These results show that MRI measurement of PCFP has high sensitivity and specificity in the diagnosis of knee articular cartilage injury, which can accurately identify most injured cases while reducing the occurrence of misdiagnosis and missed diagnosis (Liu et al, 2024). This is mainly due to the high resolution and soft tissue imaging capability of MRI, which enables clear visualization of the internal structures of the knee joint, including cartilage, ligaments and fat pads (Skaf et al, 2012). In addition, this study also found that the accuracy rate of PCFP measured by MRI in the grading of knee articular cartilage injury was also high, measuring 93.81%. In addition, this approach presents high accuracy in diagnosing knee joint cartilage injuries at different grades, proving the reliability of its assessment. As the main tool for measuring PCFP, MRI has non-invasive and high-resolution characteristics for the clear display of the structure and lesions of knee joints, providing a strong basis for accurately assessing cartilage damage and formulating personalized treatment plans. To sum up, PCFP grading combined with MRI has optimal accuracy and reliability in the assessment of knee joint cartilage injuries, providing important support for clinical diagnosis and treatment. This result suggests that MRI measurement of PCFP can be used not only to diagnose knee articular cartilage injury, but also to evaluate the severity of the injury, providing an important basis for making individualized treatment plans. The reason is that PCFP, as an important structure in the knee joint, has the functions of cushioning and lubricating joints. It reduces friction during joint movement and protects articular cartilage from damage (Champagne et al, 2024). When the knee joint is impacted by external force or undergoes strenuous exercise, PCFP can absorb and disperse the impact force to buffer and absorb shocks, thus protecting the knee joint cartilage from damage (Rimkunas et al, 2024). The current study showed that there is a significant correlation between the signal changes of PCFP and knee articular cartilage injury. When the knee joint cartilage is damaged, PCFP may be crushed or injured, resulting in changes in its signal on MRI. By observing the signal changes of PCFP, physicians can accurately determine the presence of knee joint cartilage damage and its severity. This provides an important basis for the diagnosis and condition assessment of knee articular cartilage injury (Singh et al, 2024).

The results of this study highlight four clinical applications of MRI measurement of PCFP in the diagnosis and disease assessment of knee articular cartilage injury. First, MRI examination is a non-invasive imaging method without causing any harm to patients. In contrast, arthroscopy is an invasive procedure that may increase a patient's distress and risk of complications despite its high diagnostic accuracy. Therefore, MRI measurement of PCFP, by virtue of its non-invasiveness, can be, to a greater extent, accepted by patients for the diagnosis of knee articular cartilage injury. Secondly, MRI has a high resolution and can clearly show the internal structure of knee joint, including cartilage, ligaments and fat pads. This enables MRI to accurately identify the location, scope and degree of knee articular cartilage injury, providing an important basis for clinical diagnosis and treatment (Tong et al, 2024). Third, MRI examination has good reproducibility and can perform multiple examinations on patients at different time points to observe changes in the condition. This is important for assessing the efficacy of treatment and monitoring changes in the condition. Finally, MRI has multiplanar imaging capability and can view the internal structure of knee joint from multiple angles, providing more comprehensive diagnostic information (Wang et al, 2024; Yang et al, 2024). This helps physicians to more accurately judge the location and degree of injury and develop a more reasonable treatment regimen (Jamal et al, 2022).

Our results also suggest that PCFP may be a marker of knee osteoarthritis. This postulation lies in our understanding that the distribution of mechanical impact and the inflammatory response of the knee joint are the biological mechanisms behind knee osteoarthritis development. As a soft tissue structure in the knee joint, PCFP may have an important impact on the mechanical distribution in the joint. Its changes may affect the stress on the articular cartilage, thereby accelerating cartilage damage. In addition, the inflammatory response within PCFP may also be directly involved in the process of cartilage damage.

This study is not without limitations. The prime limitations of the present study are selection bias and missing data that may be caused by retrospective research design. This is because retrospective studies rely on existing clinical databases, which may lack the complete set of key information and may contain less-than-accurate details provided by patients. Thus, future research would consider prospective design and other imaging methods, such as more advanced MRI technology or a combination of different imaging methods (such as CT, ultrasound, etc.), to enable more accurate detection and evaluation of PCFP and knee cartilage injuries. In addition, the biological mechanism between PCFP and knee cartilage injury can be further investigated through histopathological examination, molecular biological analysis, etc., to help shed light on biological pathways for developing more accurate and effective diagnostic and treatment approaches for knee joint cartilage injuries.

Conclusion

In conclusion, this study found that PCFP grading was significantly correlated with knee cartilage injury, providing a new perspective for the clinical evaluation of knee cartilage injury. The potential applications stemming from our research results include optimizing MRI diagnostic processes, guiding personalized treatment strategies and predicting disease progression, which can help improve the diagnosis and treatment effectiveness and the prognosis management for patients with knee cartilage injuries. MRI measurement of PCFP boasts high sensitivity, specificity and accuracy in the diagnosis of patients with knee articular cartilage injury, coupled with a high accuracy in injury grading. This finding provides a new method and idea for the diagnosis and evaluation of knee articular cartilage injury. In the future, the continuous progress and innovation of medical imaging technology will further increase the adoption of MRI measurement of PCFP in the diagnosis and evaluation of knee articular cartilage injury. Nevertheless, the exploration and optimization of the application methods of MRI technology should be uninterrupted to ensure continuous improvement of their diagnostic accuracy and reliability so as to facilitate the formulation of more accurate and effective treatment regimens.

Key Points

- Observation of pericruciate fat pad (PCFP) characteristics through magnetic resonance imaging (MRI) technology provides a more accurate diagnostic basis for knee joint cartilage injury, helps optimize treatment plans, and improves patient prognosis. It has important clinical significance and practical application value.
- The study retrospectively selected 210 patients who underwent knee MRI conducted in adherence to a set of unified parameter standards. The characteristics of PCFP were observed through MRI, the relationship between PCFP grading and the site of knee cartilage injury was analyzed, and the effectiveness of PCFP grading in diagnosis and injury grading was evaluated. Arthroscopic results were used as the gold standard for comparison.
- The results of the study showed that the FF value and T2 value of PCFP were independent influencing factors of knee joint cartilage injury. PCFP grading has high sensitivity, specificity and accuracy in the diagnosis of knee joint cartilage injuries, as well as a high accuracy in grading knee cartilage injuries, showing good diagnostic efficiency.
- MRI measurement of PCFP has important value in the diagnosis of patients with knee cartilage injury due to the enhanced accuracy of clinical judgment by virtue of the high sensitivity, specificity and accuracy manifested by the approach. In addition, the highly accurate injury grading by PCFP grading provides concrete references for personalized treatment formulation.

Availability of Data and Materials

The data used to support the findings of this study are available from the corresponding authors upon request.

Author Contributions

RH and CY designed the research study. SZ performed the research. TZ and JJ analyzed the data. SZ drafted the manuscript. All authors contributed to the important editorial changes in the manuscript. All authors read and approved the final manuscript. All authors have participated sufficiently in the work and agreed to be accountable for all aspects of the work.

Ethics Approval and Consent to Participate

This study was conducted in accordance with the ethical regulations of the Declaration of Helsinki and approved by the Medical Ethics Committee of the Second Affiliated Hospital, Zhejiang University School of Medicine (Approval No.: 20250510). The principle of informed consent was followed throughout the study and information about the study was informed to the patients or their families prior to their consent.

Acknowledgement

Not applicable.

Funding

This study was supported by the National Natural Science Foundation of China (No. 32371412, 32071349, 81701820, and 82102597), Zhejiang Provincial Natural Science Foundation of China (LY23H060009 and LY24C100001), and Zhejiang Province Medical and Health Science and Technology Plan Project (2024KY1040).

Conflict of Interest

The authors declare no conflict of interest.

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