Associations of Quadriceps and Prefemoral Fat Pad MRI Parameters With Postoperative Pain and Functional Outcomes After Total Knee Arthroplasty in Patients With Knee Osteoarthritis

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AIM: To investigate the relationship between quantitative magnetic resonance imaging parameters of the quadriceps fat pad (QFP) and prefemoral fat pad (PFP) and pain and functional outcomes at 1 month after total knee arthroplasty (TKA) in patients with knee osteoarthritis.

METHODS: We retrospectively collected the clinical and imaging data of patients with knee osteoarthritis who underwent primary unilateral TKA at Shihezi People's Hospital between October 2025 and April 2026 and had completed knee magnetic resonance imaging before surgery. The following imaging parameters were extracted: (1) QFP: the craniocaudal diameter, anteroposterior diameter, oblique diameter, T1 value, T2 value, proton density (PD) value, high signal intensity, and mass effect; and (2) PFP: maximum thickness and high signal intensity. Postoperative pain and physical function scores at 1 month after surgery were obtained from the medical record system. Spearman correlation analysis and multiple linear regression analysis were performed to identify imaging markers associated with postoperative clinical outcomes.

RESULTS: Spearman correlation analysis showed that the T2 value, hyperintensity, and mass effect of the QFP, as well as the hyperintensity and maximum thickness of the PFP, were positively correlated with postoperative pain and physical function scores. Multiple linear regression analysis showed that the T2 value of QFP, mass effect, QFP hyperintensity, and PFP hyperintensity were significantly associated with postoperative pain. The T2 value of QFP, mass effect, and PFP hyperintensity and maximum thickness were significantly associated with postoperative physical function scores.

CONCLUSIONS: This retrospective study showed that quantitative and morphological parameters of the QFP and PFP extracted from preoperative routine magnetic resonance imaging (MRI) were significantly associated with postoperative pain and functional outcomes in patients with knee osteoarthritis undergoing TKA. These findings suggest that specific imaging features may be associated with poorer outcomes and provide preliminary evidence for clinical consideration. However, prospective studies with larger sample sizes are warranted to validate these exploratory findings.

Keywords: knee osteoarthritis; total knee arthroplasty; magnetic resonance imaging; quadriceps fat pad; prefemoral fat pad

Introduction

Knee osteoarthritis (KOA) is a common degenerative joint disease and one of the main causes of chronic pain and functional disability in middle-aged and older adults [1]. With the aging of the global population and the increasing prevalence of obesity, the prevalence of KOA continues to increase, and it has become a major public health burden [2]. In the treatment of KOA, total knee arthroplasty (TKA) is an effective treatment option that can significantly relieve pain, correct deformity, and restore joint function [3].

Although TKA is considered a mature surgical procedure for the treatment of KOA, clinical practice has shown that some patients experience persistent pain or unsatisfactory functional outcomes after surgery [4,5]. Traditionally, mechanical factors such as surgical technique, prosthesis design, and alignment angle have been considered core variables affecting the prognosis of TKA [6]. However, growing evidence suggests that periarticular soft-tissue conditions play a crucial role in postoperative outcomes [7]. There are three different fat pads in the anterior space of the knee joint, namely, the infrapatellar fat pad (IPFP), quadriceps fat pad (QFP), and prefemoral fat pad (PFP). These fat pads, located within the joint capsule and outside the synovium, are considered protective structures that can adapt to changes in the volume and shape of the irregular joint space during joint movement [8,9]. In addition, they may directly affect joint homeostasis by secreting a variety of adipokines and inflammatory factors, such as interleukin-6 and adiponectin [10,11]. A previous study on the IPFP confirmed its association with postoperative outcomes af-

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ter TKA [12]. However, the roles of the PFP and QFP, as components of the knee extensor mechanism, have rarely been investigated in depth. During knee movement, these fat pads may undergo degeneration and hyperplasia due to repeated impacts or biomechanical changes, thereby affecting postoperative TKA outcomes by altering local biomechanical strain and intrinsic secretory mechanisms [13].

Magnetic resonance imaging (MRI) technology is currently recognized as a valuable tool for knee joint research and one of the most accurate non-invasive methods for knee joint evaluation [14]. MRI has unique imaging advantages for soft-tissue components such as fat, ligaments, synovium, cartilage, and bone marrow, and can clearly distinguish signal differences between adipose tissue and other structures using specific fat-suppression sequences. Increasing evidence has shown that changes in the signal intensity of knee fat pads are closely associated with local inflammatory responses, fibrosis, nerve infiltration, and other pathological changes on fat-saturated MRI images without the use of contrast agents, and may serve as a potential imaging biomarker for monitoring KOA and assisting disease staging and prognostic assessment [15,16].

Although the infrapatellar fat pad has been extensively studied, the roles of the QFP and PFP in TKA outcomes remain unclear. The QFP is located adjacent to the quadriceps tendon and suprapatellar bursa; its inflammation or enlargement may impair tendon gliding and quadriceps function, thereby hindering early rehabilitation [17]. The PFP serves as a cushion to reduce friction during knee flexion; its thickening may compromise this function and contribute to anterior knee pain [18]. Additionally, both fat pads are metabolically active and can secrete pro-inflammatory adipokines that may sensitize peripheral nerves and sustain local inflammation [10,11]. We therefore hypothesized that preoperative MRI parameters of the QFP and PFP would be associated with postoperative pain and functional outcomes after TKA.

No study has demonstrated an association between MRI parameters of the QFP and PFP and postoperative pain and functional outcomes after TKA. Therefore, this study aimed to systematically evaluate the associations between MRI parameters of the QFP and PFP and postoperative pain and functional outcomes after TKA through a retrospective cohort analysis to identify imaging features that may be associated with poorer outcomes. These findings may provide preliminary imaging evidence to inform future hypothesis-driven studies on perioperative considerations, such as preoperative prerehabilitation and anti-inflammatory therapy. However, further prospective validation is required.

Methods

Patients

This study was approved by the Ethics Committee of Shihezi People's Hospital (approval number: KYLL-2026-10) and was conducted in accordance with the Declaration of Helsinki. All patients were informed of all possible clinical outcomes of the different treatments and signed a written informed consent. Patients who underwent TKA at Shihezi People's Hospital between October 2025 and April 2026 were retrospectively and consecutively enrolled. The inclusion criteria were as follows: (1) age ≥50 years; (2) primary unilateral TKA; and (3) complete clinical and preoperative knee MRI data. The exclusion criteria were as follows: (1) a history of ipsilateral knee surgery or trauma; (2) concomitant neurological or systemic diseases that seriously affected lower limb function; and (3) incomplete clinical or imaging data. A total of 116 patients met the eligibility criteria and were enrolled.

No a priori sample size calculation was performed because this was an exploratory retrospective study. The sample size of 116 patients, with five variables, was considered adequate for the planned multiple linear regression analyses, based on the commonly applied rule of approximately 10 observations per predictor variable.

Collection of Clinical Data

The following demographic and clinical data were extracted and recorded from the medical record system: age, gender, and body mass index (BMI). The Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC), version 3.1, was used to evaluate the clinical symptoms of patients with KOA, which included three parts: pain score (5 items, 0–50), stiffness score (2 items, 0–20), and physical function score (17 items, 0–170) [17]. In this study, the pain and physical function components of the scale were selected as quantitative indicators of knee joint pain and functional status in patients with knee osteoarthritis. Each item was scored on a numerical rating scale (NRS) from 0 to 10, with 0 indicating no symptoms and 10 indicating the most severe symptoms. Subscale scores were calculated by summing the item scores, yielding a total pain score of 0–50 (5 items) and a physical function score of 0–170 (17 items), with higher scores indicating greater pain severity and worse physical function, respectively. Postoperative WOMAC scores were assessed at 1 month after surgery during routine follow-up visits. Because preoperative WOMAC scores were unavailable in this retrospective cohort, the postoperative pain and physical function scores at 1 month were prespecified as the primary clinical outcome measures.

Imaging Data Acquisition and Processing

All patients underwent preoperative knee MRI examination before TKA. MRI examinations were performed using a Siemens 3.0-T magnetic resonance system (Siemens Healthineers, Erlangen, Germany). The imaging protocol included a sagittal synthetic MRI sequence for quantitative Synthetic MR-derived quantitative T1/T2 maps, and Synthetic MR-derived quantitative proton density (PD) maps, together with conventional knee joint plain MRI sequences, including sagittal T1-weighted imaging (T1WI), sagittal T2-weighted imaging (T2WI), sagittal three-dimensional

SPACE proton density-weighted imaging (Sag-3D SPACE-PDWI), coronal T2WI, and axial T2WI.

MRI Acquisition Parameters

The conventional MRI scanning parameters were as follows. For the sagittal T1-weighted fast spin-echo (T1-FSE) imaging: repetition time (TR), 510 ms; echo time (TE), 11 ms; number of excitations (NEX), 1; field of view (FOV), 220 × 220 mm; matrix, 320 × 256; slice thickness, 3 mm; and acquisition time, 2 min 05 s. For sagittal proton density fat-suppressed (Sag-PD-FS) imaging: TR, 3000 ms; TE, 40 ms; NEX, 1; FOV, 220 × 220 mm; matrix, 320 × 256; slice thickness, 3 mm; and acquisition time, 3 min 26 s. For coronal T2-weighted fast spin-echo imaging with fat suppression (Cor-T2-FS): TR, 3000 ms; TE, 40 ms; NEX, 1; FOV, 220 × 220 mm; matrix, 320 × 256; slice thickness, 3 mm; and acquisition time, 2 min 51 s. For axial proton density fat-suppressed imaging (Ax-PD-FS): TR, 3000 ms; TE, 40 ms; NEX, 1; FOV, 220 × 220 mm; matrix, 320 × 256; slice thickness, 3 mm; and acquisition time, 2 min 35 s. For sagittal three-dimensional SPACE proton density-weighted imaging (Sag-3D SPACE-PDWI): TR, 2000 ms; TE, 36 ms; NEX, 1; FOV, 220 × 220 mm; matrix, 320 × 256; slice thickness, 2 mm; slice gap, 0 mm; and acquisition time, 2 min 37 s.

For quantitative synthetic MR-derived quantitative T1 map, the acquisition parameters were as follows: TR, 15 ms; TE, 2.7 ms; flip angle, 5°; FOV, 220 × 220 mm; matrix, 320 × 256; slice thickness, 3 mm; and acquisition time, 2 min 09 s. For quantitative synthetic MR-derived quantitative T2 map, the parameters were as follows: TR, 1000 ms; TE, 13.8 ms; flip angle, 90°; FOV, 220 × 220 mm; matrix, 320 × 256; slice thickness, 3 mm; and acquisition time, 3 min 45 s.

Data Processing

All MRI scan data were transferred to the PACS system (version 11, Carestream Health, Rochester, NY, USA) of Shihezi People's Hospital to identify the level of the maximum QFP area. Morphological measurements were performed on sagittal fat-suppressed PD-weighted images at the level of the maximum QFP area using the PACS measurement tools. The craniocaudal diameter was defined as the distance between the superior and inferior poles of the QFP; the anteroposterior diameter was defined as the distance from the posterior edge of the QFP to the dorsal contour of the distal quadriceps tendon; and the oblique diameter was defined as the maximum distance parallel to the superior margin of the patella. The maximum PFP thickness was measured as the perpendicular distance from the highest point of the anterior margin of the PFP to the anterior femoral cortex. Quantitative T1, T2, and PD values were derived from Synthetic MR-derived quantitative T1, T2, and PD maps. Regions of interest (ROIs) were manually drawn along the margins of the QFP on the slice showing the maximum QFP area, excluding adjacent tissues, and the mean values were recorded automatically.

The grading criteria for binary MRI variables were defined as follows. QFP hyperintensity was defined as focal or diffuse high signal intensity within the QFP on fat-suppressed T2-weighted or proton density-weighted images, compared with adjacent skeletal muscle, and was scored as 0 = absent or 1 = present. QFP mass effect was defined as visible bulging, enlargement, or impingement of the QFP on the adjacent quadriceps tendon or suprapatellar bursa, and was scored as 0 = absent or 1 = present. PFP hyperintensity was defined as increased signal intensity within the PFP on fat-suppressed T2-weighted or proton density-weighted images compared with adjacent normal adipose tissue, and was scored as 0 = absent or 1 = present.

Image Analysis and Reproducibility

All MRI measurements and qualitative assessments were performed independently by two musculoskeletal radiologists. Both readers were blinded to patients' clinical outcomes, including WOMAC pain and physical function scores, during image evaluation. To assess interobserver reliability, intraclass correlation coefficients (ICCs) were calculated for continuous variables (T1, T2, PD, QFP diameters, and PFP thickness) using a two-way mixed-effects model with a consistency definition. Cohen's κ coefficients with asymptotic standard errors were calculated for binary variables (QFP hyperintensity, QFP mass effect, and PFP hyperintensity). An ICC or κ value >0.90 was considered excellent, 0.75–0.90 good, 0.50–0.75 moderate, and <0.50 poor agreement.

Statistical Analysis

SPSS version 25.0 (IBM Corp., Armonk, NY, USA) was used for statistical analysis. The Shapiro–Wilk test was used to assess the normality of continuous variables. Variables conforming to a normal distribution were presented as mean ± standard deviation (SD), whereas non-normally distributed variables were presented as the median and interquartile range (IQR). All continuous variables presented as mean ± SD met the assumptions of normal distribution, as verified by the Shapiro–Wilk test. Spearman's rank correlation analysis was used to assess the associations between the QFP and PFP measurement parameters and pain and physical function scores. The strength of the correlation coefficient (r) was defined as follows: 0.2–0.4, weak; 0.4–0.6, moderate; 0.6–0.8, strong; and >0.8, very strong. Correlation coefficients below 0.2 were considered small.

For multiple linear regression analysis, all MRI parameters that showed significant associations with the outcome variables (pain or function) in the Spearman correlation analysis ($p < 0.05$) were entered as variables into the corresponding regression models. Pain score and physical function score were treated as dependent variables in separate models. Variables were entered using the forced-entry (Enter) method to assess the associations of each MRI parameter

with the outcomes. Multicollinearity was assessed using the variance inflation factor (VIF) and tolerance, with a VIF >10 indicating significant multicollinearity. Residual normality was assessed using the Shapiro–Wilk test. All statistical tests were two-sided, and $p < 0.05$ was considered statistically significant. Linearity and homoscedasticity were assessed by visual inspection of residuals versus fitted values plots to identify potential nonlinear patterns and heteroscedasticity. Given the exploratory nature of this study, no adjustment for multiple comparisons was applied to the Spearman correlation analyses, and the resulting *p*-values were interpreted as unadjusted exploratory findings.

Results

Interobserver Reproducibility of MRI Measurements

Interobserver reliability was assessed for all MRI parameters. For continuous variables, ICC values ranged from 0.770 to 0.975. Specifically, the ICC values were 0.770 for T1, 0.819 for T2, 0.930 for PD, 0.878 for QFP craniocaudal diameter, 0.847 for QFP anteroposterior diameter, 0.975 for QFP oblique diameter, and 0.946 for PFP maximum thickness. For binary variables, Cohen's κ values were 0.793 for QFP hyperintensity, 0.809 for QFP mass effect, and 0.759 for PFP hyperintensity (all $p < 0.01$), indicating good interobserver agreement.

Characteristics of the Included Patients

A total of 116 patients with knee osteoarthritis were included in this study, with a mean age of 63.991 ± 5.713 years, including 55 males and 61 females, and a mean BMI of 24.537 ± 5.061 kg/m^2. The diameter and thickness parameters of the QFP and PFP are presented in Table 1.

Table 1. Demographic, clinical, and MRI characteristics of the included patients.

Variables	Value
Age, years	63.991 ± 5.713
Gender, male/female	55/61
BMI, kg/m^2	24.537 ± 5.061
QFP T1, ms	685.500 ± 97.597
QFP T2, ms	119.377 ± 8.477
QFP PD, pu	101.226 ± 13.022
QFP craniocaudal diameter, mm	16.840 ± 2.905
QFP anteroposterior diameter, mm	8.715 ± 1.154
QFP oblique diameter, mm	11.004 ± 1.650
PFP maximum thickness, mm	14.417 ± 3.393
PFP hyperintensity, absent/present	52/64
QFP hyperintensity, absent/present	56/60
QFP mass effect, absent/present	63/53
Pain score	15.629 ± 6.015
Physical function score	37.526 ± 13.757

MRI, magnetic resonance imaging; BMI, body mass index; QFP, quadriceps fat pad; PD, proton density; PFP, prefemoral fat pad.

Correlation Between Each Parameter of QFP and PFP and Postoperative Pain

The correlation analysis of pain (Table 2) showed that the QFP T2 value (r = 0.602) was strongly positively correlated with pain, suggesting that an increase in the QFP T2 value was closely associated with greater pain severity. QFP mass effect (r = 0.404) showed a moderate positive correlation, whereas QFP hyperintensity (r = 0.364) and PFP hyperintensity (r = 0.379) showed weak positive correlations with pain. The maximum PFP thickness (r = 0.193) also showed a small positive correlation with pain.

Table 2. Spearman correlations between QFP and PFP parameters and postoperative pain.

Variables	r	*p*-value
QFP T1	0.103	0.270
QFP T2	0.602	<0.001
QFP PD	0.024	0.795
QFP craniocaudal diameter	0.037	0.695
QFP anteroposterior diameter	0.071	0.449
QFP oblique diameter	0.116	0.214
QFP hyperintensity	0.364	<0.001
QFP mass effect	0.404	<0.001
PFP hyperintensity	0.379	<0.001
PFP maximum thickness	0.193	0.038

Correlations Between QFP and PFP Parameters and Postoperative Physical Function Scores

The results of functional correlation analysis (Table 3) showed that QFP T2 values (r = 0.500) and QFP mass effect (r = 0.433) had moderate positive correlations with physical function scores, indicating that increases in these parameters were associated with higher physical function scores. PFP hyperintensity (r = 0.286), QFP hyperintensity (r = 0.214), and PFP maximum thickness (r = 0.307) showed weak positive correlations with physical function scores.

Table 3. Spearman correlations between QFP and PFP parameters and postoperative physical function scores.

Variables	r	*p*-value
QFP T1	0.133	0.155
QFP T2	0.500	<0.001
QFP PD	–0.033	0.727
QFP craniocaudal diameter	0.061	0.516
QFP anteroposterior diameter	0.036	0.701
QFP oblique diameter	0.065	0.491
QFP hyperintensity	0.214	0.021
QFP mass effect	0.433	<0.001
PFP hyperintensity	0.286	0.002
PFP maximum thickness	0.307	0.001

Table 4. Multiple linear regression analyses of MRI parameters associated with postoperative pain and functional outcomes.

Dependent variable	variable	Standardized β	*t*	*p*-value	B (95% CI)	VIF
Pain score F = 19.190 $p < 0.001$ Adjusted $R^2 = 0.442$	QFP T2	0.333	3.811	<0.001	0.236 (0.113, 0.359)	1.575
	QFP hyperintensity	0.181	2.384	0.019	2.165 (0.365, 3.965)	1.183
	QFP mass effect	0.239	3.130	0.002	2.843 (1.043, 4.643)	1.176
	PFP hyperintensity	0.217	3.235	0.002	2.879 (1.115, 4.642)	1.124
	PFP maximum thickness	0.058	0.765	0.446	0.102 (–0.162, 0.366)	1.165
Physical function score F = 15.310 $p < 0.001$ Adjusted $R^2 = 0.384$	QFP T2	0.258	2.809	0.006	0.419 (0.123, 0.714)	1.575
	QFP hyperintensity	0.055	0.689	0.492	1.504 (–2.821, 5.830)	1.183
	QFP mass effect	0.305	3.847	<0.001	8.397 (4.071, 12.723)	1.176
	PFP hyperintensity	0.164	2.114	0.037	4.520 (0.283, 8.758)	1.124
	PFP maximum thickness	0.223	2.818	0.006	0.903 (0.268, 1.538)	1.165

VIF, variance inflation factor.

Multiple Linear Regression Analysis

The Shapiro-Wilk test indicated that the residuals of both regression models were approximately normally distributed ($p = 0.271$ for the pain model; $p = 0.542$ for the function model). The adjusted R^2 of the regression model with pain score as the dependent variable was 0.442, indicating that the selected variables (QFP T2, QFP hyperintensity, QFP mass effect, PFP hyperintensity, PFP thickness) collectively explained 44.2% of the variance in pain score. Among these variables, QFP T2 value ($\beta = 0.333$, $p < 0.001$), QFP mass effect ($\beta = 0.239$, $p = 0.002$), QFP hyperintensity ($\beta = 0.181$, $p = 0.019$), and PFP hyperintensity ($\beta = 0.217$, $p = 0.002$) showed positive associations with pain in the regression model. Maximum PFP thickness ($p = 0.446$) was not significantly associated with pain in the regression model.

The adjusted R^2 of the model with physical function score as the dependent variable was 0.384, indicating that the selected variables collectively explained 38.4% of the variance in physical function scores. Among these variables, QFP T2 value ($\beta = 0.258$, $p = 0.006$), QFP mass effect ($\beta = 0.305$, $p < 0.001$), PFP hyperintensity ($\beta = 0.164$, $p = 0.037$), and PFP maximum thickness ($\beta = 0.223$, $p = 0.006$) showed positive associations with physical function scores in the regression model (Table 4). However, because the models only included MRI parameters that were significant in the Spearman correlation analyses and did not adjust for potential clinical confounders such as age, sex, and BMI, these results should be interpreted as exploratory associations rather than independent predictors.

Discussion

This study is the first to systematically investigate the associations between MRI parameters of the QFP and PFP and pain and functional outcomes after TKA. Our results showed that QFP T2, QFP hyperintensity, QFP mass effect, PFP hyperintensity, and PFP thickness were associated with pain and functional outcomes after TKA. These findings suggest that the preoperative MRI characteristics of the QFP and PFP may be associated with early postoperative pain and physical function scores after TKA.

The T2 value of the QFP is a parameter correlated with both postoperative pain and dysfunction. On MRI, a prolonged T2 value usually reflects increased tissue water content, which is closely associated with pathological processes such as inflammation, edema, or early fibrosis [19]. Located adjacent to the suprapatellar bursa, an increased T2 value of the QFP may indicate an active local inflammatory response or tissue damage. This chronic low-grade inflammatory environment may affect postoperative outcomes in two ways: on the one hand, inflammatory factors (such as IL-6) can directly sensitize peripheral nerve endings, thereby reducing the pain threshold [20]. On the other hand, an inflammatory environment can promote fibrosis and sclerosis of the QFP, thereby impairing its biomechanical function [21]. The mass effect of the QFP was associated with functional outcomes. The mass effect refers to the physical compression of the adjacent quadriceps tendon and suprapatellar bursa caused by an increase in QFP volume due to hyperplasia or edema [22]. During the early rehabilitation stage after TKA, active contraction of the quadriceps and a wide range of knee motion are cornerstones of functional recovery. Increased QFP volume may hinder knee flexion and extension, causing painful impingement [17], thereby reducing the patient's willingness and ability to perform rehabilitation exercises such as straight-leg raising and active knee flexion and ultimately affecting the rehabilitation process. In addition, the mass effect was moderately correlated with postoperative pain, consistent with a previous study showing that the QFP mass effect was correlated with pain [23]. However, these previous studies primarily examined associations between fat pad imaging features and knee symptoms or structural changes rather than postoperative outcomes after TKA, limiting direct comparisons with the present findings.

QFP and PFP hyperintensity was associated with postoperative pain and functional outcomes. This high signal intensity usually reflects an abnormal increase in the signal

of adipose tissue, which may be due to steatosis, inflammatory cell infiltration, or fibrovascular tissue proliferation [24]. Through the continuous release of adipokines and inflammatory mediators, it may participate in the regulation of local inflammation and the repair balance after surgery [25]. Thus, pain perception and functional outcomes may be affected. Schwaiger et al. [26] found that high signal changes in the QFP were significantly associated with patellofemoral joint degeneration. However, in the multiple regression analysis, PFP hyperintensity remained associated with pain and function, whereas QFP hyperintensity was associated only with pain, suggesting that PFP hyperintensity may be a more consistent imaging marker of poorer outcomes.

The maximum thickness of the PFP was weakly positively associated with functional outcomes and was small positive correlation with postoperative pain in the primary analysis. In the multiple regression analysis, it was associated only with functional outcomes, but not with pain. Increased thickness may reflect hyperplastic or edematous hypertrophy of the fat pad. During knee flexion, the PFP extends to fill the space between the distal femur and the quadriceps tendon to reduce friction [18]. After TKA, a thickened PFP may occupy more space between the anterior femur and the prosthesis, thereby limiting soft tissue sliding. This may potentially restrict knee flexion and affect the functional range of motion.

The findings of this study highlight several preoperative MRI parameters, including QFP T2 values, QFP mass effect, and PFP signal intensity, that were associated with postoperative pain and functional outcomes. These exploratory findings suggest that patients presenting with such imaging features may warrant closer perioperative assessment and monitoring, although this hypothesis requires prospective validation. However, given the observational and retrospective design of this study, these findings should not be interpreted as evidence supporting specific clinical interventions, such as anti-inflammatory therapy or targeted rehabilitation, at this stage. Future prospective studies are needed to determine whether these MRI parameters provide incremental value for clinical assessment and decision-making.

Our study has several limitations. First, because of its retrospective design, residual and unmeasured confounders cannot be excluded, including potential influences of patients' pain sensitization status and psychosocial factors. Second, our MRI assessment was based on a single preoperative time point and therefore could not characterize dynamic changes in these fat pad parameters or their longitudinal relationships with the trajectory of postoperative outcomes during rehabilitation. The interval between preoperative MRI examination and TKA was not systematically recorded, which may have introduced variability in the temporal relationship between imaging findings and postoperative outcomes. Third, the sample size was relatively limited, and the study was conducted at a single center. Therefore, the generalizability of our findings requires further evaluation in larger, multicenter prospective cohorts. Fourth, postoperative assessment was limited to a single time point at 1 month after surgery, representing the early postoperative phase. Consequently, longer-term pain and functional outcomes were not evaluated. Additionally, because preoperative WOMAC scores were unavailable in this retrospective study, postoperative scores were used as outcome measures rather than changes from preoperative baseline. Future prospective studies incorporating standardized preoperative and longitudinal postoperative assessments are needed to address this limitation. Fifth, because of the retrospective and exploratory nature of this study, the regression models included only MRI parameters selected based on significant unadjusted Spearman correlations and did not adjust for potential demographic confounders, such as age, sex, and BMI. Therefore, residual confounding and selection bias cannot be excluded, and the observed associations should be interpreted as exploratory rather than independent effects. Additionally, multiple correlation tests were performed without adjustment for multiple comparisons, and candidate variables for the regression models were selected based on these unadjusted results, potentially increasing the risk of false-positive findings and model instability. Future prospective studies with adequate sample sizes and appropriate covariate adjustment are needed to confirm these findings.

Conclusions

In conclusion, this study demonstrates that preoperative MRI parameters of the quadriceps and prefemoral fat pads, particularly QFP T2 values and mass effect, are associated with early postoperative pain and functional outcomes after TKA. These findings suggest that the preoperative biological and mechanical status of these fat pads, as reflected by routine MRI, may be associated with early postoperative recovery outcomes. Although these exploratory results do not support immediate changes in clinical management, they may inform future prospective studies evaluating the prognostic value of periarticular fat pad MRI parameters and their potential clinical applications.

Availability of Data and Materials

The data analyzed are available from the corresponding authors upon reasonable request.

Author Contributions

YCD, JT, FZ and XLZ designed the research study. YCD, LLZ and FZ performed the research. XLZ, LLY and BCL analyzed the data. YCD drafted the article. All authors have been involved in revising the manuscript critically for important intellectual content. All authors gave final approval of the version to be published. All authors have participated sufficiently in the work to take public responsibility for appropriate portions of the content and agreed to be account-

able for all aspects of the work in ensuring that questions related to its accuracy or integrity.

Ethics Approval and Consent to Participate

This study obtained approval from the Ethics Committee of Shihezi People's Hospital (approval number: KYLL-2026-10). All patients were informed of all possible clinical outcomes of the different treatments and signed a written informed consent. This study was conducted in accordance with the Declaration of Helsinki.

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Conflict of Interest

The authors declare no conflict of interest.

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