European Journal of Radiology Open 11 (2023) 100526

Contents lists available at ScienceDirect

European Journal of Radiology Open

journal homepage: www.elsevier.com/locate/ejro

Difference in quantitative MRI measurements of cartilage between Wiberg type III patella and stable patella based on a 3.0-T synthetic MRI sequence

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HIGHLIGHTS

- Articular cartilage consists of four different layers, which thickness may be affected by the morphology of the patella.
- The cartilage surface of the medial surface in the Wiberg III type patella is narrow and convex.
- There are some abnormal distribution of quantitative MRI values on the medial surface of Wiberg type III patella.
- The MRI quantitative value of cartilage on the lateral surface of the patella is relatively stable.

ARTICLE INFO

Keywords:
Patella
Morphology
Stability
Cartilage
Variation
Synthetic magnetic resonance imaging

ABSTRACT

Purpose: The purpose of this study was to investigate the difference between the quantitative MRI values of Wiberg type III and stable patellar cartilage, and to improve the accuracy of MRI quantification in early patellar cartilage damage.

Methods: The knee joints of 94 healthy volunteers were scanned by a GE Signa Pioneer 3.0-T synthetic MRI machine. According to the Wiberg classification, the patella was divided into types I-III. Types I-II made up the stable patella group, and type III made up the unstable patella group. Two radiologists independently measured patellar cartilage thickness and quantitative synthetic MRI values (T1, T2, PD) in both groups. Interobserver agreement for quantitative variables was assessed using the Bland—Altman method. A third radiologist assessed differences in measurements.

Results: The medial T2 and T1 value of Wiberg III patella did not show a normal distribution (all $P > 0.05$). Compared with the stable group, the Wiberg type III group had thinner cartilage of the medial surface of the patella ($P < 0.05$), lower cartilage T2 and PD values ($P < 0.05$), but a similar cartilage T1 value ($P > 0.05$). There was no significant difference in the cartilage thickness, T1, T2, or PD value of the lateral patella between the Wiberg type III and the stable group ($P > 0.05$).

Conclusion: There were certain differences in the cartilage thickness of the medial surface of the patella and the quantitative value of synthetic MRI in Wiberg type III patellas. Quantitative studies of patellar cartilage MRI measurements need to consider the influence of patellar morphology.

As the global population ages and obesity becomes more common, the incidence of knee cartilage damage continues to increase. Up to 35% of the world's population over 60 years of age suffers from symptomatic (painful, disabling) osteoarthritis [1]. By 2020, osteoarthritis is estimated to be the fourth-leading cause of disability worldwide, with a huge amount of medical and healthcare costs and indirect costs caused by loss of jobs and early retirement [2]. The diagnosis and monitoring of osteoarthritis is a practical clinical need, as well as an opportunity and challenge for imaging clinicians.

Quantitative magnetic resonance imaging (MRI) is an important method by which imaging experts diagnose and monitor cartilage damage. Since the patella has a relatively superficial location, relatively easy pathological sampling, and thicker patellar cartilage, some scholars take the patella as the research object to observe the early damage or degeneration of cartilage. Some studies focus on the instability of the patellofemoral joint, and the patellar cartilage is often the important observational indicators [3–7]. At present, quantitative studies of patellar cartilage MRI rarely take into account the morphological

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https://doi.org/10.1016/j.ejro.2023.100526
Received 23 July 2023; Received in revised form 17 September 2023; Accepted 30 September 2023

variation of the patella. It would be valuable to investigate whether there is a difference between the quantitative MRI values of Wiberg type III and stable patellar cartilage for the study of early patellar cartilage damage.

Patellar morphological variation is common in clinical practice. Wiberg found that type III patella accounted for approximately 25% of the total world population [8]. From type I to type III, the medial articular surface of the patella gradually decreases, and the lateral articular surface gradually becomes larger. In type I and II patella, due to the relative proximity of the medial and lateral cartilage surfaces, the centre of gravity of the patellar ridge is close to the middle of the patella, and the patella's motion trajectory is relatively stable during the knee flexion movement. The medial articular surface of type III is convex and narrower than the lateral articular surface. The centre of gravity of the central ridge of the patella is relocated medially. and the patella tends to dislocate outwards [9]. Some studies in recent years have shown that Wiberg type III anatomy is an important cause of patellofemoral joint instability, chondromalacia patellae, and cartilage damage [8,10]. However, there are few reports on whether the Wiberg type III patella affects the quantitative measures of patellar cartilage in healthy volunteers.

This study used GE Signa Pioneer 3.0-T synthetic MRI technology to scan the knee joint of healthy volunteers to explore the effect of Wiberg type III patella on MRI cartilage quantification to improve the clinical understanding of this anatomy.

1. Methods

1.1. Study design

This was a prospective study. 94 healthy volunteers were recruited from June 2020 to April 2023, and synthetic MRI data of their knee joints were collected. All volunteers were informed about the study and agreed and signed the relevant consent form. This study passed the ethics review of the AAAAAAAAA [review number: 2023 (KY-0352)].

1.1.1. Subjects

Healthy volunteers were recruited as research subjects from June 2020 to April 2023. Inclusion criteria: 1) healthy volunteers aged 20–30 years without knee pain; 2) negative knee grinding test; 3) the Rose MRI grade of articular cartilage was normal[11]. Exclusion criteria: 1) athletes or fitness enthusiasts; 2) patients with a history of slipping patella or patellar tendon–lateral femoral condyle friction in the knee joint; 3) patients with a history of trauma, surgery, tumour, or synovium in the knee joint; 4) patellar anomalies(patella alta, bipartit patealla.etc); And 5) patients with contraindications to MRI examination. A total of 94 volunteers participated in the study. MRI was performed on one knee joint of the volunteers, in accordance with the random number table.

1.1.2. Image acquisition

The scanning equipment was a GE Signa Pioneer 3.0-T MRI scanner, and the coil (produced by GE) was a 16-channel knee joint surface coil. Before scanning, all volunteers were required to sit still for half an hour. During scanning, they were in a supine position, with the arms raised above their heads, feet in advanced mode, knee joint naturally flexed 10–15°, and the scanning centre positioned at the center of patella. Sandbag immobilization was used for knee joint scanning. The volunteers were asked to keep the knee joint as still as possible.

MRI scan sequence and parameters: ① conventional sequence: sagittal fat-saturation proton density–weighted imaging (FS-PDWI) [TR 2800 ms, TE 32 ms, filed of view(FOV), 160 × 160 mm, matrix 320 × 320]; axial FS-PDWI (TR 2800 ms, TE 42 ms, FOV 160 ×160 mm, matrix 320 ×224); sagittal T_1 fast spin-echo (TR 450 ms, TE 12.5 ms, FOV 160 ×160 mm, matrix 320 ×256). ② Synthetic MRI axial MAGiC sequence: TR 4000 ms, TE 16.2/89.3 ms, FOV 160 × 160 mm, matrix 280 × 224, slice thickness 4 mm, slice interval 0.5 mm, scanning time 4 min; the MAGiC sequence positioning copied conventional serial axial FS-PDWI localization.

1.1.3. Image analysis

The patellar morphology and patellar cartilage quantitative values of all volunteers were independently judged and measured by two diagnosing physicians in the bone and joint group, each with more than 8 years of diagnostic experience. If the two diagnosing physicians had different judgements of patellar morphological classification, they reached a consensus by discussion. Two diagnosing physicians independently quantitatively measured the patellar cartilage; the third diagnosing physician took the average of the two measured values as the final measurement value and made a clinical evaluation of the knee.

The morphological variation of the patella was classified by the Wiberg classification[8,12]: Type I, the medial patellar articular surface is concave and has the same width as the lateral articular surface; Type II, the medial patellar articular surface is concave and narrower than the lateral articular surface; Type III, the medial articular surface is convex and narrower than the lateral articular surface. Type I and II patellas made up the stable patella group, and type III patellas made up the unstable patella group (Fig. 1).

Patellar cartilage quantification: the raw data were imported into MAGiC postprocessing software. T_1 mapping, T_2 mapping, and proton density (PD) mapping quantitative images were automatically generated. The measurement point of the patellar cartilage was the middle of the patella. The patellar ridge was used to draw the midline dividing the Patellar surface into two parts. In the process of two parts of whole patellar cartilage selection, the full thickness of the cartilage was included as much as possible, while joint effusion and subchondral bone were avoided. The T1, T2, and PD values were automatically generated and recorded in the background. The patellar cartilage thickness was drawn in the middle of the medial and lateral surfaces of the patella. Cartilage thickness was measured along a line perpendicular to the articular surface from the articular surface to the calcified cartilage in the same position. The medial articular surface of the patella was convex. The highest convex point was used to draw the midline dividing the medial surface into two parts. The thickness of the two parts of the cartilage were measured, and the average of the measured values of the two parts was taken as the final value; if the convex part was obviously offset (relocated towards the patellar edge or patellar ridge), only the other portion was measured. Each data point was measured three times in a row, and the average value was taken as the final result. The detailed process is shown in Fig. 2.

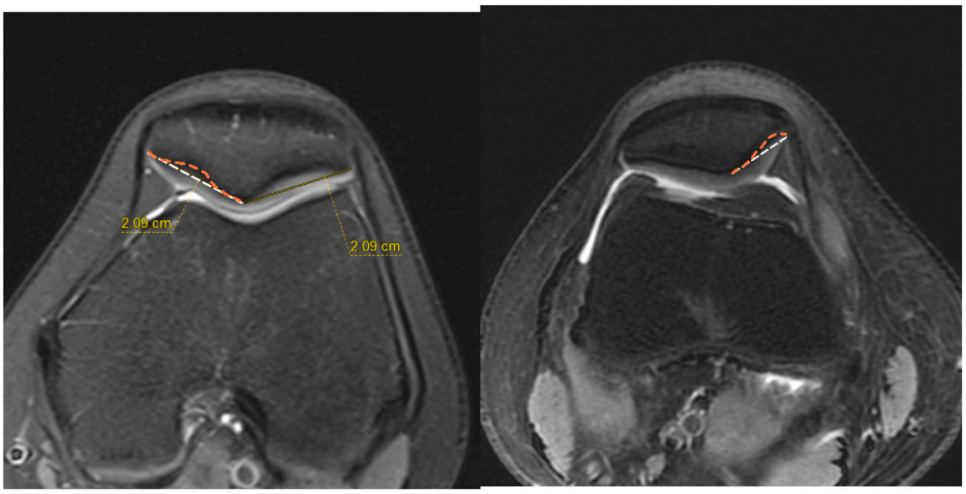
1.1.4. Statistical methods

SPSS 24.0 and MedCalc 20.0 software were used for statistical analysis. The Shapiro—Wilk normality test was performed on the patellar cartilage thickness, T1, T2, and PD quantitative values in each group. The measurement data that met the normal distribution are expressed as mean±standard deviation and were compared between groups by the two-independent-samples t test. Measurement data that did not meet the normal distribution are described by median (quartile) [M (P_{25}, P_{75})] and were compared by the Mann—Whitney U test. Count data are expressed as frequency (%). The frequency distribution between groups was compared using the χ^2 test. The consistency between the measurement results of the two radiologist was evaluated by the Bland—Altman method. All statistical tests were two-sided, and $P < 0.05$ was statistically significant.

2. Results

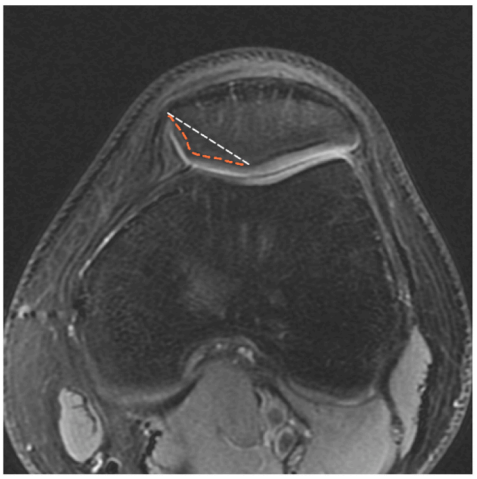
2.1. General Information

The 94 subjects were divided into 6 cases of type I, 50 cases of type II, and 38 cases of type III according to the Wiberg classification criteria. Type I and II patellas (the stable patella group) had 56 cases; type III



a Type I patellar

b Type II patellar



c Type III patellar

Fig. 1. shows the morphological variation of the patella by the Wiberg classification.

patellas (the unstable group) had 38 cases. There was no significant difference in the sex composition, average age, or average body mass index (BMI) between the two groups of subjects (all $P > 0.05$) (Table 1).

2.2. Consistency analysis of the measurement results of patellar cartilage thickness and T1, T2, and PD by two radiologists

The Bland—Altman method was used to evaluate the consistency of the T1, T2, and PD values measured by the two radiologists. The results showed that the two measurers had high consistency in all measurement results (all $P > 0.05$) (Fig. 3).

2.3. Normality of quantitative MRI measures of the patella in the two groups

The Shapiro—Wilk normality test showed that the thickness of the lateral and medial surfaces of the patellar cartilage and the T1, T2, and PD values on the lateral surface of the patella in the two groups were all normally distributed (all $P > 0.05$). The medial T2 and T1 value of Wiberg III patella did not show a normal distribution (all $P > 0.05$),The medial T1, T2 and PD value of stable patella and the PD values on the medial Wiberg type III patellas showed a normal distribution (all $P > 0.05$) (Table 2).

2.4. Comparison of quantitative values of patellar MRI between the two groups

Compared with the stable group, the Wiberg III type patella had thinner cartilage of the medial surface ($P < 0.05$), lower cartilage T2 and PD values ($P < 0.05$), but similar cartilage T1 values ($P > 0.05$).

Compared with the stable group, there was no significant difference in the cartilage thickness of the lateral surface of the Wiberg III patellar, cartilage T1, T2 and PD values ($P > 0.05$), as shown in Table 3, Fig. 4, and Fig. 5.

3. Discussion

From the GE Signa Pioneer 3.0-T synthetic MR images of healthy volunteers' knee joints, the quantitative values of patellar cartilage MRI showed that the cartilage on the medial surface of the patella was thinner in the unstable group, the quantitative values of cartilage T2 and PD values was significantly lower than those of the stable group. Determining the relationship between patellar morphological variation and cartilage MRI quantification is still challenging, but this study

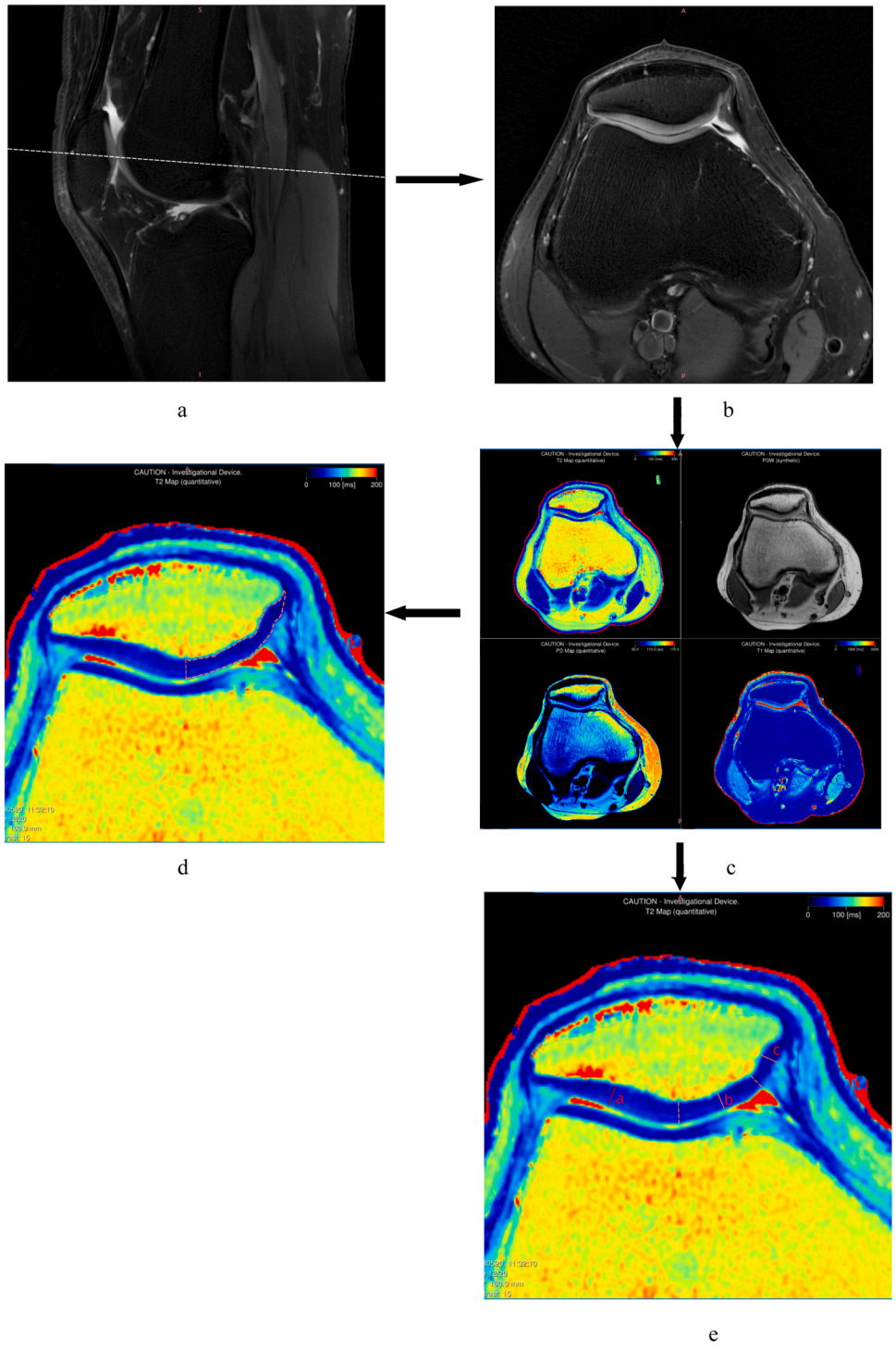


Fig. 2. shows the process of cartilage quantification. Fig. 2a. First we identified the middle part of the patella (indicated by the dotted line) on the sagittal PD image of the knee joint according to the scanning reference line. Fig. 2b. We determined the axial image of the middle part of the patella according to the sagittal PD image positioning of the knee joint, and observed the shape of the patella and its cartilage on this image. This case was a type III patella. Fig. 2c. The knee joint scan data of the volunteers were imported into MAGiC postprocessing software. T1 mapping, T2 mapping, and PD mapping quantitative images were automatically generated. Fig. 2d. The patellar ridge was used to draw the midline dividing the Patellar surface into two parts. In the process of two parts of whole patellar cartilage selection, the full thickness of the cartilage was included as much as possible, while joint effusion and subchondral bone were avoided. Fig. 2e.The Thickness of medial surface of the patella = a, The Thickness of lateral surface of the patella = (b+c)/2.

preliminarily shows that Wiberg type III patella (unstable patella) can affect the MRI quantification of some cartilage.

Patella is the largest sesamoid bone in the body, the inferior pole of which connects to the patellar ligament. The patellar cartilage forms the patellofemoral joint with the trochlea of the femur. During knee flexion and extension, the patella slided between the inner and outer condyles of the femur. When various abnormal stress repeatedly imposed on the patella, structural destruction of the cartilage collagen fibers, and finally, cartilage wear, tear and degeneration.In general, the radiologist classified patellar chondropathy according to the International Cartilage

Table 1
Comparison of general data of the two groups of subjects.

Group/comparison	Male/female ratio	Age (years)	BMI (kg/m^2)
Stable group	26/30	24.8 ± 1.2	22.16 ± 2.64
Unstable group	18/20	24.9 ± 0.9	21.27 ± 2.15
c^2/t value	0.008	-0.563	1.722
P value	0.929	0.575	0.088

Repair Society (ICRS) (Grade 1: Softening of the cartilage. It may show superficial lesions. Grade 2: Cartilage fraying. Lesions covering less than 50% of the articular surface. Grade 3: Substantial loss of articular cartilage representing more than 50% of the thickness of the articular surface. Grade 4: Complete loss of articular cartilage, with exposure of the subchondral bone)[13].

Owing to the high contrast resolution, MRI has the highest diagnostic imaging performance for detecting cartilage lesions, in particular when applying high spatial resolution and cartilage-accentuating contrast pulse sequences[14]. However, the detection of early patellar cartilage injury without cartilage defects or with slight defects by MRI is still a challenge. Chaudhari AS et al.applied 5-minute 3D quantitative dual-echo steady-state sequence to detect articular cartilage damage. For grade 1 cartilage lesions, sensitivity and specificity were 33% and 56%, respectively, for conventional MRI; 23% and 53% for qDESS; and 46% and 39% for qDESS with T2 mapping. For grade 2A lesions, values were 27% and 53% for conventional MRI, 26% and 52% for qDESS, and 58% and 40% for qDESS with T2 mapping[15].

Many quantitative MRI biomarkers, such as T2, T2*, and T1rho, have been used to detect the early degeneration of cartilage, but their clinical use remains limited due to the lack of standard values defined as normal. Therefore, further summarizing the distribution of MRI quantitative values of normal patellar cartilage in different parts and form may effectively improve the accuracy of MRI diagnosis of early patellar cartilage injury.

To date, spin–lattice relaxation time constant in rotating frame (T1ρ) and T2 mapping are the MRI techniques best established for assessing cartilage composition[16–20]. Of the quantitative values of synthetic MRI, T2 can reflect the changes in water volume, collagen content, and the orientation of collagen fiber in cartilage. Emanuel et al. found that in articular cartilage, the T2 value was weakly correlated with proteoglycan (r = 0.38) but had no correlation with collagen fibre concentration (r = 0.02), and the T2 value was highly correlated with cartilage structure and cartilage water molecule content[21]. The reason for the abnormal distribution of cartilage T2 values on the medial surface of the Wiberg III patella may be (1) the pressure difference between the medial and lateral articular surfaces of the patella caused by the morphological variation of the type III patella. The cartilage surface of the medial surface of the patella in the Wiberg III type is narrow and convex; when the knee is flexed, the centre of gravity of the central ridge of the patella deviates to the medial surface, and there is a difference in joint pressure between the medial and lateral articular surfaces of the patella. Some studies also showed that type III patellas made only a small amount of

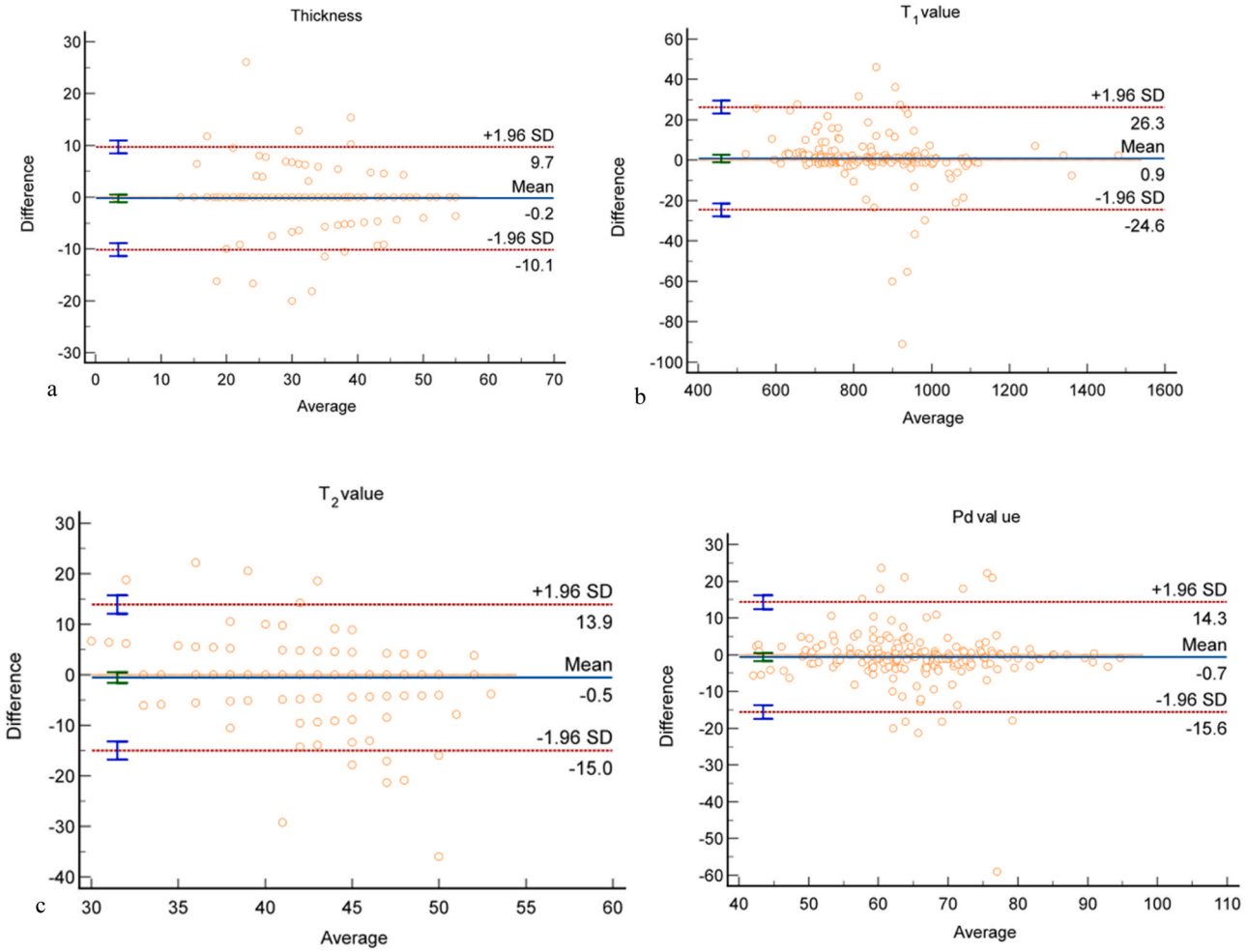


Fig. 3. a: Bland—Altman plot of joint thickness measurements by the two measurers. Fig. 3b: Bland—Altman plot of the T1 value of articular cartilage measured by the two measurers. Fig. 3c: Bland—Altman plot of articular cartilage T2 values measured by the two measurers. Fig. 3d: Bland—Altman plot of the PD values of articular cartilage measured by the two measurers.

Table 2
Results of normality test of patellar cartilage synthetic MRI quantitative value.

Indicator	Group	N	Mean±SD	*W* value	*P* value
Thickness (mm)	Stable lateral surface of the patella	56	36.1 ± 7.7	0.974	0.269
	Wiberg III lateral surface of the patella	38	34.8 ± 7.1	0.983	0.811
	Stable medial surface of the patella	56	33.7 ± 7.8	0.974	0.276
	Wiberg III medial surface of the patella	38	23.6 ± 6.3	0.953	0.111
PD (pu)	Stable lateral surface of the patella	56	65.7 ± 9.6	0.968	0.138
	Wiberg III lateral surface of the patella	38	65.7 ± 10.1	0.983	0.826
	Stable medial surface of the patella	56	67.0 ± 9.6	0.968	0.150
	Wiberg III medial surface of the patella	38	61.6 ± 12.0	0.968	0.330
T1value (ms)	Stable lateral surface of the patella	56	832.0 ± 128.2	0.971	0.201
	Wiberg III lateral surface of the patella	38	890.7 ± 156.6	0.954	0.124
	Stable medial surface of the patella	56	830.2 ± 124.6	0.979	0.428
	Wiberg III medial surface of the patella	38	865.9 ± 186.8	0.895	**0.002**
T2 value (ms)	Stable lateral surface of the patella	56	43.8 ± 3.6	0.971	0.201
	Wiberg III lateral surface of the patella	38	43.9 ± 5.3	0.977	0.597
	Stable medial surface of the patella	56	43.2 ± 4.2	0.985	0.711
	Wiberg III medial surface of the patella	38	40.5 ± 5.3	0.920	**0.010**

Table 3
Comparison results of synthetic MRI quantitative values of patellar cartilage between the two groups.

Group	Thickness (mm)	PD (pu)	T1 (ms)	T2 value (ms)
Stable lateral surface of the patella	36.1 ± 7.7	65.7 ± 9.6	832.0 ± 128.2	43.8 ± 3.6
Wiberg III lateral surface of the patella	34.8 ± 7.1	65.7 ± 10.1	890.7 ± 156.6	43.9 ± 5.3
t value	0.853	-0.005	-1.915	-0.138
P value	0.396	0.996	0.060	0.891
Stable medial surface of the patella	33.7 ± 7.8	67.0 ± 9.6	824.0 (735.5938.5)[a]	43.0 (41.0,48.0)[a]
Wiberg III medial surface of the patella	23.6 ± 6.3	61.6 ± 12.0	847.0 (727.5938.0)[a]	42.0 (36.0,45.0)[a]
t/Z value	6.618	0.248	0.455	-2.048
P value	**< 0.001**	**0.018**	0.649	**0.041**

[a] median (quartile) [M (P_{25}, P_{75})]

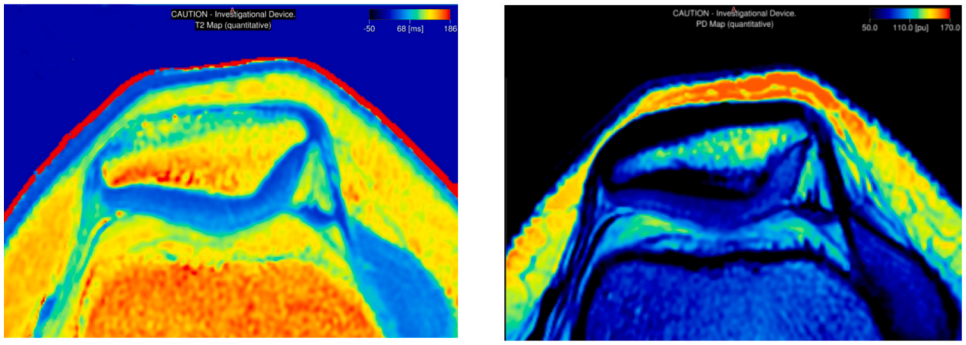
contact with the medial femoral condyle due to the low surface area of the medial facet, which increased the contact pressure of the lateral patella facet on the lateral femoral condyle during knee flexion[4,22,23]. As articular cartilage lacks a capillary network, the maintenance of nutrition, structure, and function of articular cartilage mainly depends on the diffusion activity of small molecules between articular cartilage and surrounding tissues[24–26]. Appropriate joint pressure can ensure the smooth progress of small molecule diffusion activity. The medial surface of the convex type III patella may be characterized by a decrease or irregular distribution of the pressure on the medial articular surface, the diffusion activity of small molecules in the articular cartilage, and the relative decrease in the water molecule content, which in turn affect the articular cartilage structure and T2 relaxation time. On the medial surface of the Wiberg III patella, the superficial layer of cartilage containing more water may be thinner. Of course, the above hypothesis needs testing by further pathological research to confirm. (2) Type III patellas have a wide variation in shape. Wiberg did not further subclassify type III patella. From a slightly convex to obviously abnormal morphology of type III patella medial surface, this variation itself may not be normally distributed. The pressure difference between the medial and lateral articular surfaces of the patella caused by the slight convexity is small, and the changes in cartilage thickness and MRI quantitative values are small. As the convexity becomes greater, the pressure difference between the medial and lateral articular surfaces of the patella becomes greater, and the differences in its cartilage structure and composition become increasingly obvious.

Both PD and T2 values are often used to monitor changes in articular cartilage structure and composition. However, the first approach requires an external phantom for calibration and requires a T2 measurement if compensation for T2 effects is desired[27]. Moreover, the TE time of the T2 sequence was significantly longer than that of the PD sequence. As the TE relaxation time increases, the observed tissue T2 value decays more rapidly. Compared with PD sequences, T2 sequences can more sensitively detect changes in the structure or composition of the observed tissue theoretically, such as water molecules. In this study, there was significant difference in the PD and T2 value of the medial surface between patellas of type III and of type I-II. The medial surface of Wiberg type III group had lower cartilage T2 and PD value, which supported and confirmed each other.

Although some studies have shown that the T1 relaxation time can also serve as a surrogate marker for interstitial water and is more sensitive to intrachondral interstitial water content[27]. However T1 relaxation time is not yet recognized as a main indicator for monitoring early articular cartilage damage, T1 relaxation time is often used in combination with dGEMRIC, T2 mapping, T1ρ, and other techniques [28–32]. In this study, there was no significant difference in T1 relaxation times of the medial surface between Wiberg III patella and stable group, which may also indirectly prove the limitations of T1 relaxation times to monitor changes in articular cartilage structure and composition.

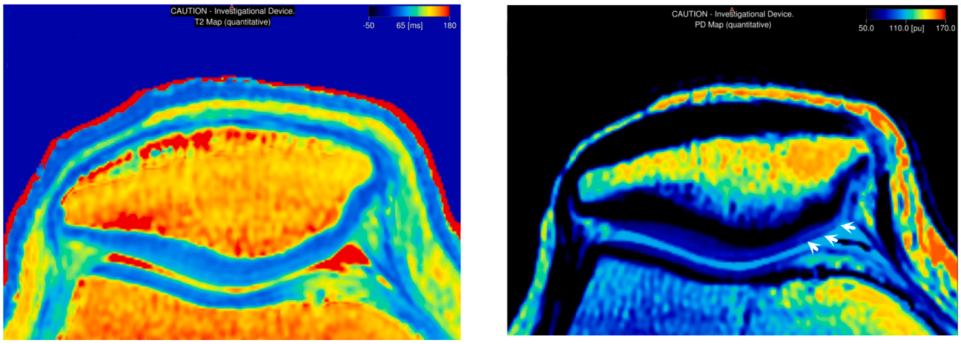
Cartilage thickness is another key indicator often used to diagnose and predict osteoarthritis[33]. Patellar cartilage thickness can be influenced by age, BMI, and level of physical activity[34] Therefore, this study put relatively strict restrictions on the age, sex, BMI, and physical activity level of the volunteers. The results showed that the cartilage thickness of Wiberg III medial surface of the patella was significantly lower than that of the stable medial surface of the patella and significantly lower than that of the lateral surface of the Wiberg III patella (23.64 ± 6.30 mm vs 34.80 ± 7.06 mm). This is similar to the results of some studies[35]. By comparing the thickness of articular cartilage in patellofemoral pain patients and the control group, Farrokhi et al. found that the cartilage thickness on the medial surface of the patella of patellofemoral pain patients was significantly thinner[35]. The Wiberg type III patella is an important cause of patellofemoral pain. The reason for the thin articular cartilage thickness on the medial surface of the Wiberg III type patella may be related to congenital patellar dysplasia (abnormal protrusion of the medial surface) and secondary decreased articular surface pressure.

Synthetic MRI sequences have the problem of overestimating cartilage T2 values. In this study, the T2 value of the lateral surface of the patella in the stable group was 43.8 ± 3.6 ms, which was slightly higher than the quantitative value of the normal patellar cartilage (31.8 ± 4.1 ms, Vogrig et al.; 32.1–35 ms, Siriwanarangsun et al.)[36,37]. This may be related to the slice thickness of the synthetic MRI sequence and the artificial delineation of the ROI. The overestimated T2 value of the synthetic MRI sequence did not affect the results of this study. This study did not emphasize the accuracy of cartilage quantitative values but focussed on the distribution of quantitative values and the



a: MAGiC sequence T2 mapping b: MAGiC sequence PD mapping

Fig. 4. Healthy volunteer, 28-year-old male, with type II patella. Fig. 4 shows the cartilage thickness and colour scale of the stable patellar cartilage T2 mapping and PD mapping was uniform and roughly similar(Fig. 4,The image size and appropriate window width and window level were adjusted).



a: MAGiC sequence T2 mapping b: MAGiC sequence PD mapping

Fig. 5. Healthy volunteer, 22-year-old male, Wiberg type III. Fig. 5 MAGiC sequence shows that the cartilage of medial surface the unstable patella was thinner than that of the lateral surface, the colour scale of the unstable patellar cartilage T2 mapping mapping was uneven. Compared with the the lateral surface, the superficial layer of cartilage was thinner(short arrow).

comparison of data between different groups. If the measurement data are all overestimated, the impact on the final result is limited.

All measurements were taken from a single axial slice through "the middle of the patella", even though volumetric scans were performed. This was mainly due to the following reasons: (1) Cartilage damage could occur in any part of the articular cartilage. Abnormal distribution of quantitative MRI values in any single axial slice could disturb the results of cartilage damage. (2) Type III patellas had a wide variation in shape. In some single axial slice, there was not convex in medial articular surface. There probably was no significant difference in the cartilage thickness and quantitative value in medial surface of Wiberg type III patellas accordingly. If the patellar cartilage was studied as a whole (at all axial slices), the difference in one single axial slice would be hard to detect.

This study has a few limitations: (1) The sample was relatively small. There were too few cases of type I patella, so they were not kept as a separate group, and the quantitative difference in cartilage under different shapes was not compared. (2) ROIs were determined manually. The accuracy of the research results will be further improved if methods such as automatic delineation can be adopted. (3) The inclusion criterion of the cases were MRI Rose grade, and there is no arthroscopic gold standard to further confirm that all the subjects had normal patellar cartilage.

4. Conclusion

Patellar morphological variation may affect the quantitative MRI values of cartilage, especially on the medial surface of type III patellas. Due to the convex structure on the medial surface of Wiberg type III patellas, the thickness of cartilage and quantitative values of cartilage T2 and PD values were significantly lower in synthetic MRI. The medial T2 and T1 value of Wiberg III patella did not show a normal distribution. All these changes may affected the early detection of patellar cartilage injury. The MRI quantitative value of cartilage on the lateral surface of the patella is relatively stable, and the patellar morphological variation is small, making it an ideal site for the study of early knee cartilage injury.

Funding statement

The authors declare that they have no funding that could have appeared to influence the work reported in this paper.

CRediT authorship contribution statement

Li Min: Writing – original draft, Conceptualization. **Xia Zhenyuan:** Methodology, Investigation. **Li Xiaohua:** Data curation. **Lan Lan:** Software, Investigation. **Mo Xinxin:** Formal analysis. **Xie La:** Formal analysis, Data curation. **Zhan Yu:** Formal analysis, Data curation. **Li Weixiong:** Project administration.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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