Eklem Hastalıkları ve Cerrahisi
Joint Diseases and Related Surgery

Original Article / ***Özgün Makale***

Eklem Hastalik Cerrahisi
2018;29(2):93-99
doi: 10.5606/ehc.2018.60364

Association between patellofemoral congruence and patellofemoral chondropathy in patients with anterior knee pain: A T_2 mapping knee MRI study

Diz önü ağrılı hastalarda patellofemoral uyum ve kondropati arasındaki ilişki: T_2 MRG haritalama tekniği çalışması

İsmail Türkmen, MD,[1] Yüksel Işık, MD[2]

[1]Department of Orthopedics and Traumatology, Sağlık Bilimleri University, Ümraniye Training and Research Hospital, İstanbul, Turkey
[2]Department of Radiology, Beykoz State Hospital, İstanbul, Turkey

ABSTRACT

Objectives: In this study, the T_2 mapping magnetic resonance imaging technique was used to evaluate early cartilage changes associated with patellofemoral alignment and morphology.

Patients and methods: Fifty four patients (Study group: 38 females, 16 males) with anterior knee pain and a randomly selected and age-matched 50 controls (Control group; 37 females, 13 males) were compared by two blinded authors in terms of T_2 values of the patella medial, lateral facet, and trochlea, Insall-Salvatti index, lateral trochlear inclination angle, patellar tilt angle, sulcus angle, and patella medial and lateral facet lengths. The inter- and intra-observer reliability tests were assessed.

Results: The T_2 medial patellar facet value, T_2 lateral patellar facet value, T_2 trochlea value, Visual Analog Scale, tibial tubercle - greater trochanter distance, and patellar tilt angle measure were statistically significantly higher in the study group.

Conclusion: Based on our study findings, the T_2 mapping magnetic resonance imaging (MRI) technique was found to be reliable test that can be used to diagnose early cartilage damage in patients with anterior knee pain. In patients with anterior knee pain, especially with decreased Insall Salvatti index, low lateral trochlear inclination angle, and higher patellar tilt angle, adding a T_2 mapping sequence to the standard knee MRI protocol is recommended to help detect early cartilage damage.

Keywords: Anterior knee pain; cartilage; patellofemoral; T_2 mapping magnetic resonance imaging.

ÖZ

Amaç: Bu çalışmada T_2 haritalama manyetik rezonans görüntüleme tekniği kullanılarak patellofemoral uyum ve morfolojiye bağlı erken kıkırdak değişiklikleri değerlendirildi.

Hastalar ve yöntemler: Çalışmada diz önü ağrısı olan 54 hasta (Çalışma grubu: 38 females, 16 males) ve rastgele seçilen ve yaş olarak eşleşen 50 kontrol (Kontrol grubu; 37 females, 13 males) iki kör yazar tarafından patella T_2 değerleri, medial, lateral faset ve troklea, Insall-Salvatti indeks, lateral troklear eğim açısı, patellar eğim açısı, sulkus açısı ve patella medial ve lateral faset uzunlukları bakımından karşılaştırıldı. İnter- ve intraobserver güvenirlik testleri ile değerlendirildi.

Bulgular: Çalışma grubunda, kontrol grubuna kıyasla T_2 medial patellar faset değeri, T_2 lateral patellar faset değeri, T_2 troklea değeri, Görsel Analog Skala, tibial tüberkül - büyük trokanter mesafesi ve patellar eğim açısı ölçüsü istatistiksel olarak anlamlı derecede yüksekti.

Sonuç: Çalışma bulgularımıza göre, T_2 haritalama manyetik rezonans görüntüleme (MRG) tekniğinin, diz önü ağrısı olan hastalarda erken kıkırdak hasarını teşhis etmek için kullanılabilecek güvenilir bir test olduğu görüldü. Diz önü ağrısı olan hastalarda, özellikle düşük Insall Salvatti indeks, düşük lateral troklear eğim açısı ve yüksek patellar eğim açısı varlığında erken kıkırdak hasarının tespit edilmesine yardımcı olmak için standart diz MRG protokolüne T_2 haritalama dizisi eklenmesi önerilir.

Anahtar sözcükler: Diz önü ağrısı; kıkırdak; patellofemoral; T_2 haritalama manyetik rezonans görüntüleme.

Received: March 07, 2018 Accepted: May 21, 2018

Correspondence: İsmail Türkmen, MD. Sağlık Bilimleri Üniversitesi Ümraniye Eğitim ve Araştırma Hastanesi Ortopedi ve Travmatoloji Anabilim Dalı, 34764 Ümraniye, İstanbul, Turkey. Tel: +90 530 - 462 21 07 e-mail: dr.ismailturkmen@gmail.com

Citation:
Türkmen İ, Işık Y. Association between patellofemoral congruence and patellofemoral chondropathy in patients with anterior knee pain: A T_2 mapping knee MRI study. Eklem Hastalik Cerrahisi 2018;29(2):93-99.

The patellofemoral joint (PFJ) is a complex structure with highly functional biomechanical conditions.[1] The normal function of the PFJ is largely dependent on the alignment of the patella to the trochlea. Any developmental or acquired difference in the surface geometry of the PFJ can cause a wide variety of clinical problems, such as chondromalacia patella and patellar instability.[2,3]

Cartilage has been shown to increase water content in the presence of collagen, and collagen content is reduced by age or degeneration of the cartilage.[4] This relationship forms the basis of the T_2 mapping technique, in which T_2 relaxation time increases. Increased T_2 relaxation time can be detected using colored graphics that provide information about tissue degeneration.[5,6] Because transverse relaxation time in magnetic resonance imaging (MRI) is sensitive to the organization of collagen fibrils in the cartilage, it has become increasingly important as a noninvasive marker of age-related changes in collagen and early cartilage degeneration.[6]

Here, we aimed to determine whether patellofemoral alignment and patellofemoral morphology can cause early cartilage damage in patients with anterior knee pain using the T_2 mapping MRI technique.

PATIENTS AND METHODS

This study was approved by the Beykoz State Hospital Ethics Committee (reference number 61772955-449). All procedures performed in this study involving human participants were in accordance with the ethical standards of the institutional and national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

The inclusion criteria were giving informed consent and having closed physis. The exclusion criteria were having technically inadequate MRI, having apparent patellofemoral arthritis, osteophyte formation, any acute knee trauma, any tibiofemoral malalignment, bipartite patellae, quadriceps muscle atrophy, patellar and quadriceps tendinitis, any bursitis or apophysitis around the knee, obesity (Body Mass Index [BMI]>30), any rheumatologic disease, symptomatic parapatellar plicae with chondral damage, any previous knee surgery history, and limited range of motion of the knee.

For the control group, patients who attended the orthopedic clinic with a knee complaint other than anterior knee pain were selected. The inclusion and exclusion criteria were the same as the study group. Clinical examinations included the investigation of patients' medical records and histories. Information was gathered on the nature of each patient's complaint, onset time, history of prior medication use, previous treatment, and presence of other diseases. Height, weight, and BMI were recorded. Intraarticular pathologies seen in MRI were noted for each group. The Kujala score and a Visual Analog Scale (VAS) were used to investigate knee function and pain.[7]

Anteroposterior (AP) and lateral radiographs of both knees were taken while the patients were in standing and 30° flexion positions. Tangential patella and orthoroentgenography were taken in both lower extremities in a routine manner.

All patients underwent MRI. To determine whether or not to administer a T_2 mapping sequence, the patients were requested by the radiology technician- to pick one of two envelopes at random, with one envelope containing the note "Add T_2 sequence" and the other the note "Do not add T_2 sequence". Patients who picked the envelope with the "Do not add T_2 sequence" written note were excluded from the study. Thus, randomization was assured for both of the groups.

A total of 60 patients were enrolled in each group. Two patients with inadmissible MRI, two with hypertrophic medial plicae with cartilage damage, one with femorotibial malalignment, and one with apparent patellofemoral arthritis were excluded. The final study group consisted of 54 patients (38 female, 16 male).

In the control group, six patients with inadmissible MRI, one patient with hematologic disease, one patient with patellar tendinitis, and two patients with femorotibial malalignment were excluded. The control group consisted of 50 patients (37 female, 13 male).

Radiographic Assessment and Reliability of Measurements

The Insall-Salvatti index was determined by dividing the length of the patellar tendon in the sagittal MR section by the length of the patella (Figure 1).[8] The tibial tubercle-grater trochanter (TT-TG) distance was determined by drawing a vertical line from the deepest point of the trochlea in the axial knee MRI to the posterior condyle line which was held in place with a sticky note. A second line was then drawn parallel to the sticky note, therefore dividing the tibial tubercle into two and distance between them was measured.[9] The trochlear groove depth was determined by identifying the cortices of the ventral part of the medial and lateral trochlear sections which

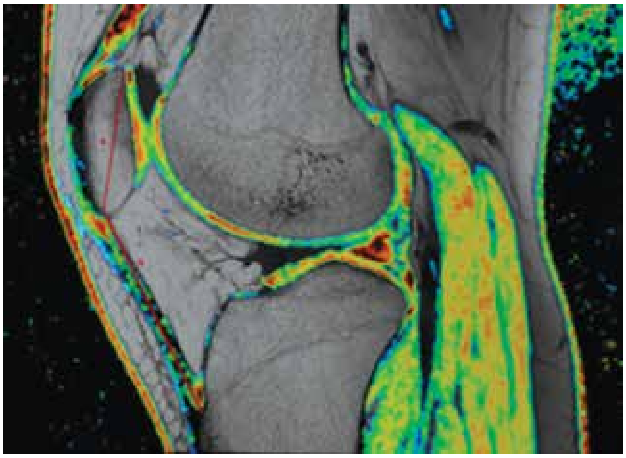

Figure 1. The Insall-Salvatti index = length of patellar tendon/ length of patella on sagittal knee magnetic resonance imaging.

were combined with a straight line on the axial MRI section. The distance from this line to the deepest part of the trochlea was determined in a similar way to the trochlear depth.[10] The trochlear facet asymmetry was determined by measuring the medial (MT) and lateral (LT) trochlea facet lengths 30 mm above the axial cross-section of the articular line and proportioned to each other.[11] The lateral trochlear inclinations (LTI) were determined by measuring the angle between the posterior femoral condyles and the lateral facet with the Cobb method in the most superior axial MR section.[11] The sulcus angle was determined on the axial MR sequence at the level of the deepest depression of the intercondylar groove by measuring the angle between the ventral articular surfaces of the medial and lateral condyle.[10] The patellar tilt angle (PTA) was determined by drawing a line along the lateral joint surface of the patella and a line drawn along the posterior condylar line using the Cobb method feature of the picture archiving and communication system (PACS) program.[12] Medial plicae thickness was measured on the axial MRI images by using the magnifying feature of the program.[13]

Each measurement was reproduced and recorded by the 1st and 2nd author blinded from the other and separated by one week. Inter-observer and intra-observer reliability for the Insall-Salvati ratio, sulcus angle, LTI angle, and TT-TG distance were assessed using intraclass correlation coefficients (ICC), calculated from measurements on a subset of 54 knee MRIs, for each observer. Agreement was classified as excellent (ICC >0.80), very good (ICC, 0.70-0.80), good (ICC, 0.60-0.70), fair (ICC, 0.40-0.60), and poor (ICC <0.40).

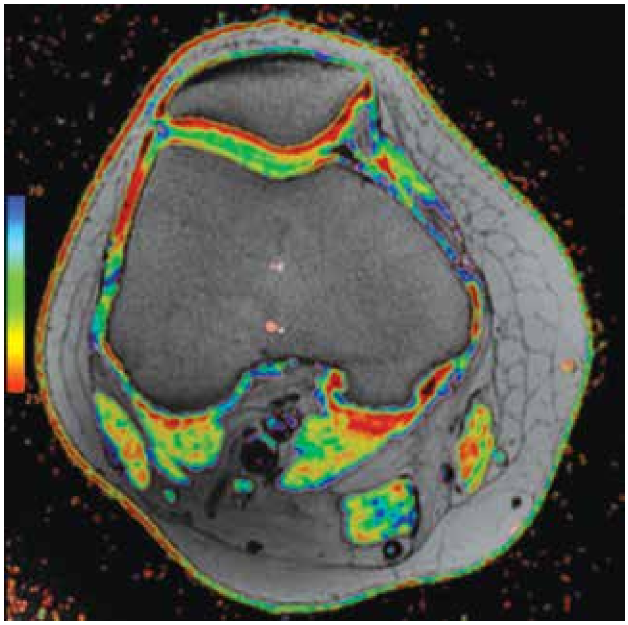

Figure 2. T_2 mapping magnetic resonance imaging of a 18-year-old woman.

T_2 Mapping MRI

Patients were scanned in supine position, so that the patellar articular surface would be parallel to B0. The weight-bearing femoral and tibial cartilage articular surface was perpendicular to B0.

Knees of both groups were evaluated with a General Electric Medical Systems LLC Optima MR 450W Gemsuite 1.5 T MR imaging-spectrometer (GE, Tokyo, Japan) using a 14 cm transmit flex 16 CH medium sized receive birdcage coil.

Axial T_2 maps of the patellofemoral joint were obtained from 13-sections, 8-echo time with TR/TE1000/6.5-51 ms and 3 mm ST, 320×224 image matrix, and a 16-cm field of view (FOV) with 2.00 NEX. The image acquisition time for the axial T_2 mapping study was 3.46 min (Figure 2).

Data analysis

To generate regions of interest (ROIs), segmentation of articular cartilage was performed on each section of the T_2 maps using a GE Medical Systems Advantage Workstation and AW 4.7 software (READY view Applications T_2 map workflow). For the entire ROI, the software automatically generates multiple T_2 profiles by defining perpendicular tangents to the cartilage/ bone interface, terminating at the articular surface.

Statistical analysis

Statistical analyses were performed using IBM SPSS for Windows, Version 21.0 software

(IBM Corp., Armonk, NY, USA). The Kolmogorov-Smirnov test (Chakravart, Laha, and Roy, 1967) was used to determine population distributions. We used the Shapiro-Wilk test for normally distributed data and Levene's test for homogeneity of the variances. We found it inconvenient to use the Student's t-test as a result of not finding an appropriate condition.

Because the data did not have a normal distribution, the Spearman's rank correlation test was used to calculate the correlation between specific variables. We used r-value to compare the magnitude of the relationship between two variables, whereas used p-value to determine the level of statistical significance. P-values less than 0.05 were considered statistically significant.

RESULTS

In the study group, 17 of 54 patients had an intraarticular pathology detected by MRI (11 with medial meniscus tear [MMT], three with lateral meniscus tear [LMT], two with medial tibiofemoral compartment bone marrow edema [BME], and one with chronic anterior cruciate ligament [ACL] tear). In the control group, 43 of 50 patients had an intraarticular pathology seen in MRI (25 with MMT, eight with LMT, five with chronic ACL tear, three with MMT and LMT together, one with lateral femoral condyle osteochondral defect [OCD], and one with medial femoral condyle BME).

T_2 medial and lateral patellar facet values, T_2 trochlea values, VAS, PTA, and TT-TG measures were found to be statistically significantly higher in the study group. We found that the values of LTI angle were statistically negatively correlated with patellar tilt angle values (Table I). Tibial tubercle-grater trochanter distance values were statistically correlated with patellar tilt angle values (Table II). T_2 trochea values statistically negatively correlated with Insall Salvatti index values. We also found that T_2 lateral patellar facet values statistically correlated with patellar tilt angle values (Table III). The correlation between the inter-observer and the intra-observer was evaluated by the ICC from the replicability analyzes. The interobserver and intraobserver alpha values were 0.95-0.99 and 0.91-0.99 respectively.

DISCUSSION

When cartilage loses its proteoglycan content, it also loses its negative charge; fluid content is inversely proportional to the proteoglycan content, which can be demonstrated with T_2 mapping.[14] However, the T_2 mapping is also affected by the distribution of water and the organization of the cartilage. Using T_2-weighted sequences, T_2 maps of different zones can be detected, from the surface of the cartilage to baseline.[6] The T_2 signal increases in elderly osteoarthritic cartilage and focal changes can be seen in damaged cartilage after trauma.

TABLE I

Comparing study group and control group measures

	Study group			Control group			
	Mean±SD	Median	Min-Max	Mean±SD	Median	Min-Max	*p**
Body Mass Index	25.2±1.8	25.78	23.22-29.43	24.7±1.9	24.12	22.52-29.33	0.133
Age	34.5±7.1	35	15-49	33.7±7.1	33	18-49	0.566
T_2 Medial patella value	43.2±8.0	43.35	31.46-59.72	38.9±8.2	38.41	31.48-58.12	0.008
T_2 Lateral patella value	45.6±10.1	43.62	33.42-59.89	40.8±10.5	37.93	30.44-59.29	0.022
T_2 Trochlea value	43.5±7.4	41.55	32.56-59.42	40.1±7.9	37.66	31.58-58.21	0.025
Kujala score	70.8±9.1	80	60-85	87.0±12.2	89.98	60-98.98	0.001
Visual Analog Scale	3.5±1.2	4	1-6	1.9±2	2	1-6	0.001
Insall-Salvatti Index	0.9±0.1	0.9	0.67-1.31	1.0±0.2	1.07	0.68-1.35	0.001
L.T.I.A.	21.4±4.0	21.65	7.7-30.8	23.2±4.5	24.57	7.47-31.4	0.026
TT-TG distance (mm)	7.2±2.7	6.6	1.4-15.4	5.8±2.7	5.54	1.4-13.17	0.011
Sulcus angle	135.7±6.6	136.1	120.6-156	133.6±6.9	133.67	117.37-152.77	0.11
Patellar tilt angle	17.0±5.0	16.02	1.93-27.77	15.1±4.7	15.35	1.8-26.5	0.049
MT/LT	0.7±0.2	0.71	0-1.03	0.7±0.2	0.72	0-1.11	0.319
Medial plica thickness (mm)	0.3±0.3	0	0-1.1	0.4±0.3	0.23	0-1.23	0.088

SD: Standard deviation; Min: Minimum; Max: Maximum; * The Student t-test; L.T.I.A: Lateral trochlear inclination angle; TT-TG Tibial tubercle-trochanter grater; MT/LT: Medial/lateral trochlea length.

TABLE II

Correlation of the measures of the study groups

	TT-TG distance		L.T.I.A.		Trochlear depth	
	r	p*	r	p*	r	p*
L.T.I.A	0.007	0.961	1	1	0.364	0.007
Patellar tilt angle	0.213	0.014	-0.351	0.009	-0.333	0.014
I.S.I	-0.058	0.678	-0.65	0.6413	0.141	0.31

* Spearman's Rank Correlation Test; TT-TG Tibial tubercle-trochanter grater; L.T.I.A: Lateral trochlear inclination angle; I.S.I. Insall Salvatti Index.

TABLE III

Correlation of T_2 values with age and other variables on the study group

	T_2 Medial patellar facet value		T_2 Lateral patellar facet value		T_2 Femoral trochlea value	
	r	p*	r	p*	r	p*
Age	0.247	0.072	0.142	0.306	0.253	0.064
Insall-Salvatti Index	-0.123	0.017	-0.229	0.006	-0.239	0.002
Sulcus angle	0.044	0.752	0.14	0.312	0.242	0.078
L.T.I.A	-0.119	0.392	-0.287	0.023	-0.158	0.255
Patellar tilt angle	-0.026	0.85	0.265	0.018	-0.024	0.865
MT/LT	-0.069	0.623	-0.082	0.557	-0.051	0.715
Trochlear depth	-0.227	0.099	-0.141	0.31	-0.302	0.027
TT-TG distance	0.138	0.321	0.066	0.636	0.038	0.784
Medial plica thickness	-0.057	0.685	0.047	0.735	0.105	0.451
Body Mass Index	0.248	0.07	-0.172	0.215	-0.06	0.666

* Spearman's Rank Correlation Test; L.T.I.A: Lateral trochlear inclination angle; MT/LT: Medial/lateral trochlea length; TT-TG Tibial tubercle-trochanter grater.

Patellofemoral alignment disorders, even if minor, cause degenerative changes in the cartilage, with repetitive minor traumas over many years.

In our study, the T_2 mapping values of the patients who attended the outpatient clinic with anterior knee pain were higher than the control group. As T_2 mapping values decreased, Kujala knee score increased, and VAS decreased. Early cartilage damage in the anterior knee pain etiology, which may be overlooked in direct radiography and conventional MRI, can sometimes be revealed earlier using a T_2 mapping MRI technique. Here, we did not see a significant relationship between BMI and age values or T_2 values. This is because we did not include obese patients in our study and included only young and middle-aged patients (Table I). Also, there was no correlation between medial plicae presence, trochlear depth, sulcus angle and patella medial-lateral facet ratio, and T_2 values (Table I).

The most common complaint of PFJ disease is anterior knee pain, which is a common problem in orthopedics and sports medicine. The PFJ is a complex structure with highly functional and biomechanical conditions. The normal function of the PFJ is largely dependent on the alignment of the patella and trochlear joint. Developmental or acquired unconformities in the surface geometry of the PFJ can lead to a wide range of clinical problems, including patellar instability, chondromalacia patella, and associated anterior knee pain. Therefore, having accurate information on the anatomy and function of this joint is extremely important.

Traditionally, many researchers have focused on the patellar side of the joint when PFJ diseases have been studied. In 1941, Wiberg classified the patella into three groups according to its medial and lateral facet lengths.[15] This classification method has been applied for many years to reveal the relationship between patellar morphology and chondromalacia patella using radiography and MRI. However, many researchers have failed to reveal the relationship between the two. Therefore, to understand cartilage changes in the PFJ, it is necessary to reassess this region with special attention to the trochlear anatomy.

Physiological thinning of the PFJ cartilage develops with older age, even in the absence of cartilage disease.[2-4] Atik et al.,[3] showed that, due to reduced interstitial fluid content, the cartilage becomes harder with older age and less adaptive with various changes. Here, we recruited the control group from patients with a similar average age as the control group, so that the relationship between cartilage structure and morphology could be more reliably compared.

Morphological evaluation of this region is of great importance for the causes of PFJ degeneration. There is a relationship between abnormal PFJ alignment and cartilage damage. Sagittal alignment is as important as axial patellofemoral alignment in the anterior knee pain. Particularly in patients with patella alta and patella baja, the risk for anterior knee pain and patellofemoral arthrosis are higher.[2] In our study, we found that the mean Insall-Salvatti index was in the normal range (0.8-1.2) in both groups, but that the ratio was statistically lower in patients in the study group than in those in the control group (Table I). We also found that the Insall-Salvatti index value was inversely related to the T_2 values when the patients in the study group were evaluated among themselves (Table III). As the patella descends towards the joint line, we believe that an increase in patellofemoral pressure leads to early cartilage damage and, consequently, anterior knee pain.

The tilt is the lateral rotation of the patella on its longitudinal axis in relation to the trochlea.[12] In the presence of a tense lateral retinaculum, the tilt is frequently seen as patellar incongruence.[12] We found that the LTI angle values were significantly lower and that the TT-TG distance and PTA values were significantly higher in the study group than in the control group (Table I). Also, when we compared the patients in the study group to each other, we found that the PTA has a positive correlation with lateral patellar facet value (Table III). Patients with relatively high TT-TG distances tend to lateralize the patellar tendon and thus the patella, thereby increasing the PTA. Also, the patella will tilt laterally if the tibial tubercle is placed in a more lateral position. This may result in over tilt of the lateral patellar retinaculum stretch, decreased medial patellar mobility, and increased pressure between the lateral aspect of the patella and the lateral trochlea. This would explain the lateral facet degeneration, especially in the long-term (Table I, II).

Our study has limitations. First, we could not perform MRI of the contralateral knees because of financial restrictions. Also, our study includes a relatively small numbers of patients. Our study's advantage is the inclusion of a randomly selected age-matched controlled group. Although the control group consisted of patients without complaints of anterior knee pain, other intraarticular pathologies could also effect the patellofemoral joint. Thus constructing a homogeneous control group was unlikely possible. Patellofemoral alingment measurements are traditionally measured on a direct X-ray or CT scan. In our study, measurements were made over the MRI, which is a much less established method.

Based on our findings, we propose that the T_2 mapping MRI technique is a reliable test that can be used to diagnose early cartilage damage in patients with anterior knee pain. Patellofemoral malalignment is associated with early cartilage damage in young and middle-aged patients. In patients with anterior knee pain, especially if accompanied by a decreased Insall Salvatti index, low lateral trochlear inclination angle, and higher patellar tilt angle, we recommend adding a T_2 mapping sequence to the standard knee MRI protocol to help detect early cartilage damage.

Acknowledgements

We thank to our radiology technician Cengizhan Cavli, for helping to randomize the patients.

Declaration of conflicting interests

The authors declared no conflicts of interest with respect to the authorship and/or publication of this article.

Funding

The authors received no financial support for the research and/or authorship of this article.

REFERENCES

1. Hart HF, Stefanik JJ, Wyndow N, Machotka Z, Crossley KM. The prevalence of radiographic and MRI-defined patellofemoral osteoarthritis and structural pathology: a systematic review and meta-analysis. Br J Sports Med 2017;51:1195-1208.
2. Atik OS. Guest Editor in Symposium on Patella and related disorders. Clin Orthop Rel Res 2001;389:4-78.
3. Atik OŞ, Erdoğan D, Seymen CM, Bozkurt HH, Kaplanoğlu GT. Is there crosstalk between subchondral bone, cartilage, and meniscus in the pathogenesis of osteoarthritis? Eklem Hastalik Cerrahisi 2016;27:62-7.
4. Akkaya S, Akkaya N, Güngör HR, Ağladıoğlu K, Ök N, Özçakar L. Sonoelastographic evaluation of the distal femoral cartilage in patients with anterior cruciate ligament reconstruction. Eklem Hastalik Cerrahisi 2016;27:2-8.
5. Dunn TC, Lu Y, Jin H, Ries MD, Majumdar S. T2 relaxation time of cartilage at MR imaging: comparison with severity of knee osteoarthritis. Radiology 2004;232:592-8.
6. Mosher TJ, Dardzinski BJ. Cartilage MRI T2 relaxation time mapping: overview and applications. Semin Musculoskelet Radiol 2004;8:355-68.
7. Kujala UM, Jaakkola LH, Koskinen SK, Taimela S, Hurme M, Nelimarkka O. Scoring of patellofemoral disorders. Arthroscopy 1993;9:159-63.

8. Insall JN, Dorr LD, Scott RD, Scott WN. Rationale of the Knee Society clinical rating system. Clin Orthop Relat Res 1989;248:13-4.
9. Hingelbaum S, Best R, Huth J, Wagner D, Bauer G, Mauch F. The TT-TG Index: a new knee size adjusted measure method to determine the TT-TG distance. Knee Surg Sports Traumatol Arthrosc 2014;22:2388-95.
10. Paiva M, Blønd L, Hölmich P, Steensen RN, Diederichs G, Feller JA, et al. Quality assessment of radiological measurements of trochlear dysplasia; a literature review. Knee Surg Sports Traumatol Arthrosc 2018;26:746-55.
11. Macri EM, Felson DT, Zhang Y, Guermazi A, Roemer FW, Crossley KM, et al. Patellofemoral morphology and alignment: reference values and dose-response patterns for the relation to MRI features of patellofemoral osteoarthritis. Osteoarthritis Cartilage 2017;25:1690-7.
12. Noehren B, Duncan S, Lattermann C. Radiographic parameters associated with lateral patella degeneration in young patients. Knee Surg Sports Traumatol Arthrosc 2012;20:2385-90.
13. Sznajderman T, Smorgick Y, Lindner D, Beer Y, Agar G. Medial plica syndrome. Isr Med Assoc J 2009;11:54-7.
14. Eckstein F, Mosher T, Hunter D. Imaging of knee osteoarthritis: data beyond the beauty. Curr Opin Rheumatol 2007;19:435-43.
15. Monk AP, Doll HA, Gibbons CL, Ostlere S, Beard DJ, Gill HS, et al. The patho-anatomy of patellofemoral subluxation. J Bone Joint Surg [Br] 2011;93:1341-7.