

ROLE OF MRI T2 MAPPING IN ASSESSMENT OF ARTICULAR KNEE CARTILAGE IN OSTEOARTHRITIS

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ABSTRACT

Background: T2 mapping of hyaline cartilage is an imaging technique for the qualitative and quantitative detection of the cartilage providing convincing color mapping and quantitative detection of the cartilage mainly regarding architecture and changes in water content, proteoglycan, and collagen matrix ultra-structure associated with early cartilage degeneration.

Aim Of Work: This work aims at elucidating the role of MRI complementary T2 mapping in assessment of articular knee cartilage for improving sensitivity of early detection of Osteoarthritis. Also, compare the articular cartilage T2 relaxation values in normal subjects and patients with osteoarthritis.

Patients And Methods: This prospective case-control study was approved by the Ethical Committee of Scientific Research in Ain Shams University, and the informed consent was obtained. The material of this study included sixty (60) subjects, divided into two groups, 50 patients (symptomatic group: 33 men and 17 women) with clinical evidence of osteoarthritis, and 10 normal control group (asymptomatic group 8 men and 2 women) were included in this study, with their ages ranged between 19-75 years. All patients and controls underwent MR imaging of the knee joint. MR imaging was performed at 1.5 Tesla by using a routine protocol with the addition of a sagittal, coronal, or axial T2 mapping sequence or all. The standard imaging planes of the knee were evaluated with articular cartilage assessment as intact or not. Thereafter, these standard planes were evaluated together with T2 maps and articular cartilage was again assessed as of normal (<48ms) or elevated (≥ 48 ms) T2 value in terms of milliseconds. Generalized estimating equation models were used to compare the sensitivity and specificity of the routine MR imaging protocol and T2 maps.

Results: Both sensitivities and specificities were 82% and 100%, respectively, for the routine MR protocol alone and 100% and 90% after the addition of the T2 mapping to the routine MR protocol. The addition of T2 maps to the routine MR imaging protocol significantly improved the sensitivity (Binary Diagnostic test, $p = 0.01$). A Comparison between patients and controls as regards T2 values showed a highly statistically significant difference (Independent T-Test, $P < 0.001$).

Conclusion: A combination of both morphological and T2 mapping MRI, together with clinical evaluation represents a desirable multi-modal approach to the diagnosis of osteoarthritis. T2 mapping, as a biochemically sensitive MRI sequence of the knee improves sensitivity from 82% to 100% to detect early structural

degeneration with better diagnostic information in the knee articular cartilage.

Keywords: T2 relaxation values. MR T2 mapping. Articular knee cartilage. Osteoarthritis

Abbreviations: MRI: Magnetic resonance imaging, MR: Magnetic resonance, ms: Millisecond

INTRODUCTION:

Osteoarthritis is a slowly progressive degenerative joint disease characterized by gradual loss of articular cartilage⁽¹⁾. It ranks with cancer and heart disease as a major cause of disability in the elderly. About 30% of the persons above 65 years of age are affected all over the world⁽²⁾.

Articular cartilage pathology may be the result of degeneration or due to acute injury. The articular cartilage is composed of cartilage cell and extracellular matrix including water, type II collagen, and proteoglycan. Currently, MRI is a powerful noninvasive tool for the evaluation of degenerative changes in the articular cartilage of the knee and articular cartilage pathology because of its high sensitivity, specificity, high contrast, and multiplanar capability⁽³⁾. With advances in joint preservation surgery that are intended to alter the course of osteoarthritis by early intervention, there is a rising demand in developing accurate and reliable quantitative MRI techniques that are sensitive to early structural degeneration in articular cartilage⁽⁴⁾. There are two broad categories of MR imaging techniques according to their usefulness for morphologic or compositional evaluation of articular cartilage. Standard spin-echo (SE), Gradient-recalled echo (GRE), Fast SE, and three-dimensional SE and GRE sequences are available to assess the structure of knee cartilage. To assess the knee cartilage matrix, including the collagen network and proteoglycan content, compositional assessment techniques, such as **T2 mapping**, may be used in clinical and research settings to promote earlier and more

precise depiction of articular cartilage changes⁽⁵⁾. T2 mapping as a biochemically sensitive MRI technique can add robust biomarkers for disease onset and progression, and therefore, could be a meaningful assessment tool for the diagnosis and follow-up of cartilage abnormalities⁽⁴⁾.

T2 mapping of hyaline cartilage is an imaging technique for the **qualitative and quantitative** detection of the cartilage providing convincing color mapping and quantitative detection of the cartilage mainly regarding architecture and changes in water content, proteoglycan, and collagen matrix ultra-structure associated with early cartilage degeneration⁽³⁾. T2 mapping would combine the benefits of biochemical cartilage evaluation with remarkable features including short imaging time and the ability of high-resolution three-dimensional cartilage evaluation without the need for contrast media administration or special hardware⁽⁴⁾.

AIM OF WORK:

The aim of this study is to elucidate the role of MRI T2 mapping in assessment of articular knee cartilage for improving sensitivity of early detection of Osteoarthritis. Also, compare the articular cartilage T2 relaxation values in normal subjects and patients with osteoarthritis.

PATIENTS AND METHODS:

Patients A prospective analysis of sixty patients/controls with clinical suspicion of osteoarthritis referred to MRI knee for the

study. Patients were imaged in the MRI unit of the private radiology center. The patients were screened using the drawn inclusion/exclusion criteria. The final population enrolled in this study composed of 60 subjects, of which 50 cases had clinical evidence of OA and 10 volunteers didn't have clinical or radiological evidence of OA and served as controls. The patients underwent MRI cartilage mapping of the knee joint.

❖ **Inclusion criteria:**

All patients were referred to the MRI unit from the outpatient clinic of the Orthopedics department with no age or gender predilection.

- Patients with clinically diagnosed knee osteoarthritis.

❖ **Exclusion criteria:**

We excluded patients with history of knee surgery/arthroscopy, metallic implants, or claustrophobic patients

❖ **All patients were submitted to the following:**

- **Demographic and clinical data collection**

Including the patient's name, age, residence, phone number, complaint, duration of illness, and past history.

- **Clinical provisional diagnosis**

- **Imaging procedure**

As each patient/control had a single MRI examination followed by a single complementary T2 mapping, 60 MRI examinations, and 60 corresponding complementary T2 maps were analyzed.

Methods:

The MRI procedure that the patients had:

- GE SIGNA MR1.5 Tesla & work station 1.5 Tesla were used.
- MR imaging was performed by a phased array surface coil on the knee.

- Small Field Of View (FOV) for high spatial resolution.
- No anesthesia or contrast media used.

❖ **Patient instructions & preparation**

- Explain the procedure to the patient and obtain informed consent from patients or their guardians that are authorized to make medical decisions.
- Offer the patient ear protectors or earplugs.
- Ask the patient to change clothes (perhaps offer hospital gown and disposable booties).
- Ask the patient to remove any metal objects (hearing aids, hairpins, body jewelry, watch, etc.).
- Ask the patient to fill out the questionnaire (especially the part relating to metallic objects).

❖ **Patient positioning**

Technically, the T2 mapping sequence is easy to acquire and did not require any knee repositioning.

- Supine and extended position, feet first.
- Knee coil (wraparound).
- Place knee into the coil (check that it is the one due for investigation).
- Center the joint in the coil and secure the knee in the coil.
- Cushion the other leg.

❖ **Protocol of MR imaging (Table 1)**

- Preliminary scout localizers in axial, coronal, and sagittal planes were done. The axial images serve as a localizer for prescribing the coronal and sagittal sections.
- The coronal sections were graphically prescribed on an axial image from the patella to the posterior surfaces of the femoral condyles. The planes were

- oriented parallel to the anterior/posterior surfaces of the femoral condyles.
- The sagittal sections were graphically prescribed from the lateral to the medial collateral ligament and aligned parallel with the anterior cruciate ligament.
 - The coverage included all the anterior, posterior, medial, and lateral supporting structures of the knee. Superiorly, the distal aspects of the quadriceps tendon were included through the insertion of the patellar tendon in the tuberosity of the tibia inferiorly.
 - The standard knee protocol (sagittal proton density-fat suppressed, coronal proton density-fat suppressed, axial T2 weighted image, sagittal T1 weighted image, and sagittal T2 weighted image) was done.
 - Complementary sagittal T2 maps were displayed by using the available software tools provided by the MR scanner manufacturer.

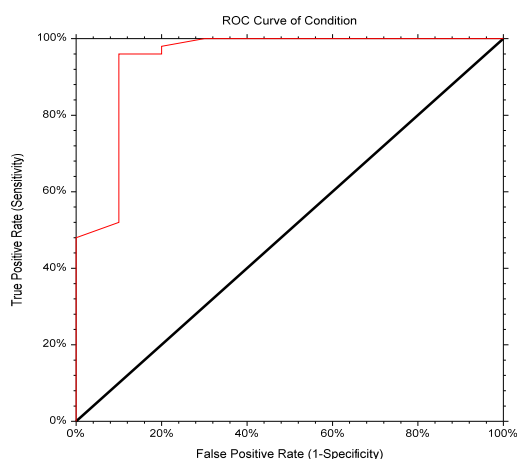
Table 1: MRI sequences that were used in the study

Sequence	TR (msec)	TE (msec)	FOV (mm)	Matrix	Slice thickness (mm)
T2 sagittal	3000	81.5	100	416x 320	3.5
T2 axial	3000	87.6	100	416 x 160	3.5
T1 sagittal	435	9.3	100	324 x 160	3.5
PDFS sagittal	2441	41.8	100	320 x 224	4
PDFS coronal	3889	40.4	100	288 x 224	4
Axial merge	750	16	100	256 x 128	4
T2 maps sagittal &/or Axial & coronal	950	8.3	90-130	256x256	3

- Duration of the examination: 4 min for each sequence.
 - Side effects or Complications: None.
- ❖ **Image Analysis(Evaluation of MR Images)**
- The ability to delineate the medial and lateral tibio-femoral articular cartilage was assessed.
 - Firstly, the standard imaging planes of the knee were evaluated with an assessment of articular cartilage as intact or thinned out. Thereafter, these standard planes were evaluated together with T2 maps and articular cartilage was again assessed as of normal or elevated T2 signal in terms of milliseconds.
 - Intact articular cartilage is the one with uniform thickness, smooth surface, and homogeneous intermediate signal on PDFS sequence covering tibial, femoral, and patellar articular surfaces.
 - On T2 maps, intact articular cartilage is the one with normal T2 values not reaching 48 milliseconds (Cut Off value ≥ 48 ms) delineated by color-coded map, represented on a color-coded scale viewed at two different windowing settings the first with T2 values ranging from 0 to 39 ms, the second with values ranging from 40 to 89 ms.
 - Affected articular cartilage in the early stages of osteoarthritis may appear in the PDFS sequence as an area with non-uniform thickness, irregular surface, or even of altered signal intensity.
 - On T2 maps, cartilage affection in early osteoarthritis can be easily delineated both **qualitatively** as it takes a green or blue color corresponding to high T2 values on the color-coded scale on at least two consecutive slices, **and**

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- quantitatively** also as a radiologist can measure the exact T2 value in terms of milliseconds for the suspected cartilage by using ‘region of interest’ property found in the scanner software on at least two consecutive slices.
- Any associated meniscal, ligamentous, muscular, or bony abnormalities in the knee were reported.
 - The MR images were transferred to a work station for the off-line quantification of T2 values in each case. The average thickness was calculated for each slice and then averaged for all the slices. Similarly, the average T2 value was calculated by means of the elliptical region of interest (ROI) for each slice and then averaged for all the slices.



ROC curve as a predictor between patients and control:

Table 2: Area under the curve & Cut off point of T2 values

Parameter	AUC	Cut off point	Sensitivity	Specificity	PPV	NPV
T2 values(ms)	0.945	≥ 48	100%	90%	81%	100%

CASE 1

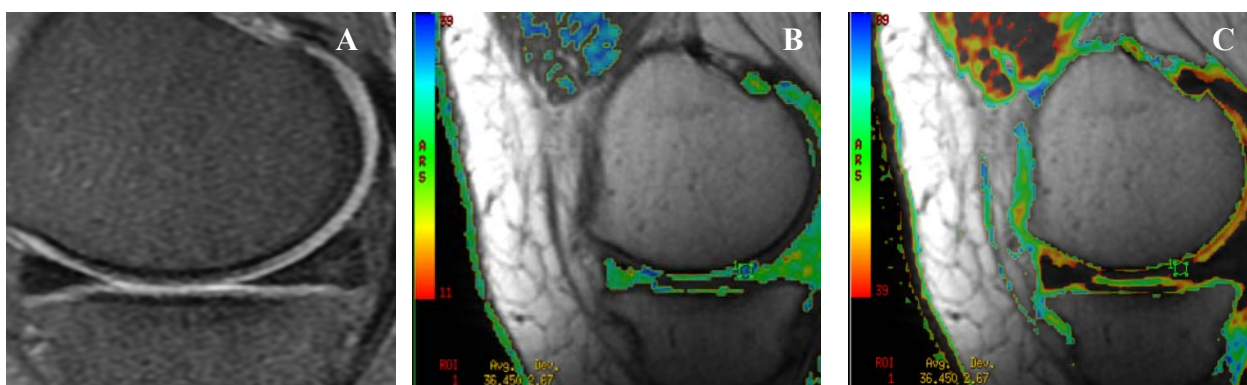


Figure 2:A male patient, 37 year-old, presenting as a volunteer (A), Sagittal fat-suppressed proton density-weighted shows preserved signal intensity of the cartilage covering the medial femoral articular cartilage with uniform cartilage thickness (blue arrow). (B & C) Corresponding T2 map shows normal cartilage T2 relaxation time (ROI). [B: $0 \text{ ms} \leq T2 \leq 39 \text{ ms}$; C: $T2=36.4(<48) \text{ ms}$].

Knee Compartment	T2 Value	Cartilage thickness
MFC (Medial Compartment)	36.4 ms	2.66 mm

CASE 2

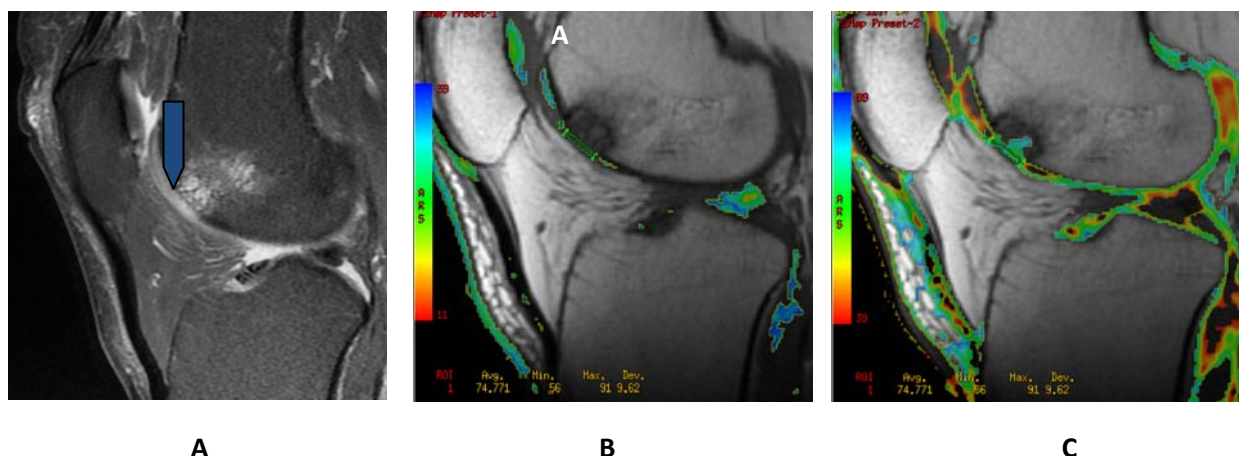


Figure 3: A male patient, 52 year-old, presenting with deep, achy knee pain and swelling in the left lateral compartment for 10 years (A), Sagittal fat-suppressed proton density-weighted image shows preserved signal of cartilage with multiple osteochondral defects at lateral femoral condyle with subchondral bone marrow reactive changes (blue arrow). Prepatellar bursitis and mid joint effusion are also noted (B & C), Corresponding T2 map shows increased cartilage T2 relaxation time (ROI). (B: $0 \text{ ms} \leq T2 \leq 39 \text{ ms}$; C: $T2 = 61.6\text{ms}$).

Knee Compartment	T2 Value	Cartilage thickness
LFC (Lateral Compartment)	74.8 ms	1.13 mm

CASE 3

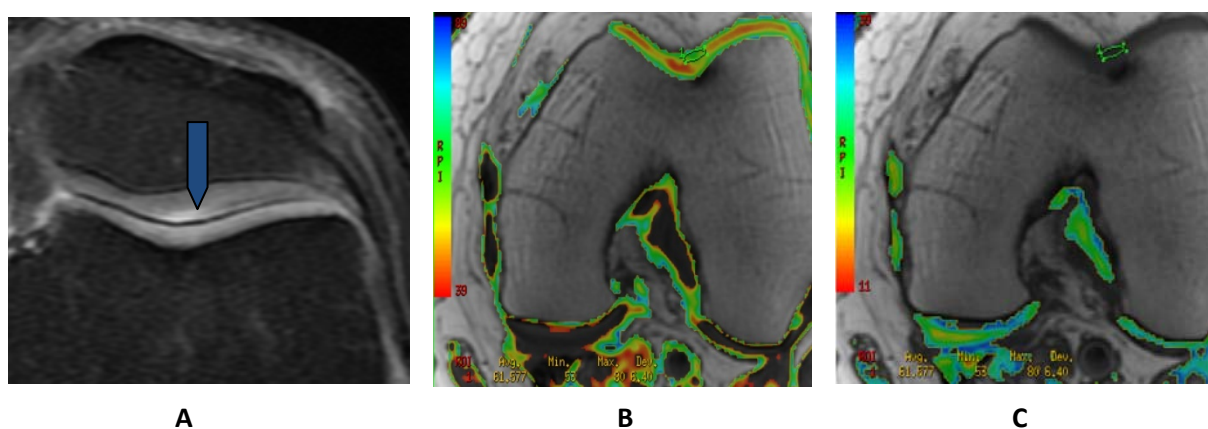


Figure 3: A male patient, 41year-old, presenting with progressive knee pain in the left patella-femoral compartment for 3 years (A), Sagittal fat-suppressed proton density-weighted image shows preserved signal intensity of the central aspect of patella-femoral articular cartilage with uniform cartilage thickness (blue arrow). (B & C), Corresponding T2 map shows increased cartilage T2 relaxation time (ROI). (B: $0 \text{ ms} \leq T2 \leq 39 \text{ ms}$; C: $T2 = 61.6\text{ms}$).

Knee Compartment	T2 Value	Cartilage thickness
PFC (Anterior Compartment)	61.6 ms	3 mm

Statistical analysis: The collected data from all the enrolled patients were analyzed with NCSS 2020 statistics software.

- To describe the data, descriptive statistics, frequency analysis, percentage analysis were used for categorical variables and the mean & Standard Deviation were used for continuous variables.
- To find the significant difference between the bivariate samples in the independent groups, the unpaired sample t-test was used.
- To find the significance in the categorical data Chi-Square test was used.
- In both the above statistical tools the probability value 0.05 is considered as a significant level..
- **Sensitivity:** the probability that a test result will be positive when the disease is present (true positive rate)
= (No. of true positive/ No. of affected cartilage i.e. true positive +false negative %).
- **Specificity P:** the probability that a test result will be negative when the disease is not present (true negative rate)
= (No. of true negative / No. of normal cartilage i.e. true negative +false positive %).
- **Accuracy:** the overall probability that a patient is correctly classified
= Sensitivity × Prevalence + Specificity × (1 – Prevalence).
- **Positive predictive value:** the probability that the disease is present when the test is positive.

$$PPV = \frac{\text{Sensitivity} \times \text{prevalence}}{\text{Sensitivity} \times \text{prevalence} + (1 - \text{specificity}) \times (1 - \text{prevalence})}$$

- **Negative predictive value:** the probability that the disease is not present when the test is negative.

$$NPV = \frac{\text{Specificity} \times (1 - \text{prevalence})}{(1 - \text{Sensitivity}) \times \text{prevalence} + \text{specificity} \times (1 - \text{prevalence})}$$

RESULTS:

The study included 60 subjects, divided into two groups, 50 patients (symptomatic group: 33 men and 17 women), and 10 normal control group (asymptomatic group 8

men and 2 women) were included in this study, with their ages ranged between 19-75 years, all of the patients suffering from chronic knee pain. The descriptive statistics for age are shown in tables 3-6.

Table 3: Description of personal characteristics among cases and control groups

	Mean	±SD	Minimum	Maximum	Number	Percentage
Age	40.4	15.3	19	75		
Gender	Male				41	68.3%
	Female				19	31.7%

The above (table3) shows that the mean age among all subjects; cases and control groups were 40.4± 15.3, with males representing 68.3% of cases.

Table 4: Frequency table showing the age range distribution of the study group. Average age of the participants in the study = 40.4± 15 years

Age range (Years)	Frequency	percentage
Up to 25	10	16.5%
26 - 35	18	30%
36 - 45	11	18.5%
46 - 55	9	15%
Above 55	12	20%
Total	60	100%

Table 5: Description of personal characteristics among cases

		Mean	±SD	Minimum	Maximum	Number	Percentage
Age		41.82	15.6	20	75		
Gender	Male					33	66%
	Female					17	34%

The above (table 5) shows that the mean age among cases was 41.82± 15.6, with males representing 66% of cases.

Table 6: Description of personal characteristics among control group

		Mean	±SD	Minimum	Maximum	Number	Percentage
Age		33.5	12	19	40		
Gender	Male					8	80%
	Female					2	20%

The above (table6) shows that the mean age among control group was 33.5± 12, with males representing 80%.

Table 7 : Frequency table showing the gender distribution among the cases and controls in the study group

Gender	Cases	Controls
Male	66%	80%
Female	34%	20%

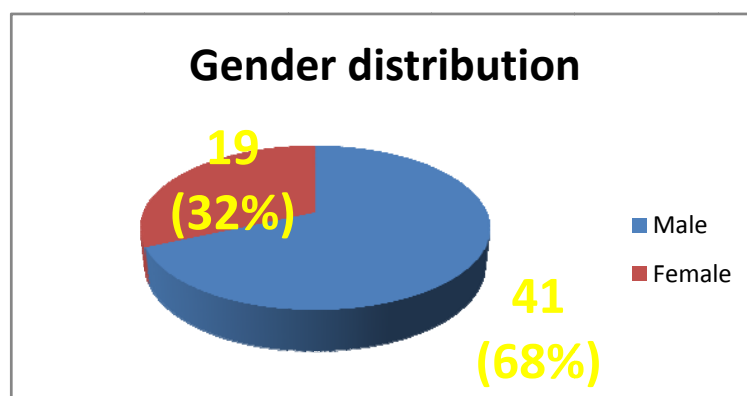


Fig. 5: Pie chart showing the gender distribution among all subjects

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- **Diagnostic indices of routine MRI:**

	Positive by MRI	Negative by MRI	Total
Cases	True Positive 41	False Negative 9	50
Controls	False Positive 0	True Negative 10	10
Total	41	19	60

Table 8: Conventional MRI findings

- Sensitivity = 82 %
- Specificity = 100 %
- Positive predictive value = 100%
- Negative predictive value = 92.8%
- Accuracy = 94.5%

- **Diagnostic indices of T2 mapping:**

Table 9: T2 mapping Findings

	Positive by T2 map	Negative by T2 map	Total
Cases	True Positive 50	False Negative 0	50
Controls	False Positive 1	True Negative 9	10
Total	51	9	60

- Sensitivity = 100 %
- Specificity = 90 %
- Positive predictive value = 81%
- Negative predictive value = 100%
- Accuracy = 93%

Comparison of the overall Diagnostic indices of routine MRI and T2 mapping:

Table 10: Comparison of diagnostic indices of routine MRI and T2 mapping

	Sensitivity	Specificity	PPV(*)	NPV(*)	Accuracy (*)
Routine MRI	82 %	100 %	100%	92.8%	94.5 %
T2 mapping	100 %	90 %	81%	100%	93 %

(*) This value is dependent on disease prevalence (30%).

Comparison of T2 values & Cartilage thickness among the knee compartments of cases and controls of the study group:

Table 11: T2 values & Cartilage thickness among the cases and controls

Knee Compartments	Number of cases		T2 Value average (ms)		Cartilage thickness average (mm)	
	Cases	Controls	Cases	Controls	Cases	Controls
Medial	22	6	61.6 ± 9.3	37.7 ± 6.7	1.5 ± 0.4	1.84 ± 0.54
Lateral	17	1	64.6 ± 8	35	1.6 ± 0.45	0.89
Anterior	11	3	64 ± 11.4	34.3 ± 2.9	2.2 ± 0.8	2.7 ± 0.6
All Compartments	50	10	63.4 ± 9.1	36.7 ± 5	1.68 ± 0.6	1.99 ± 0.78

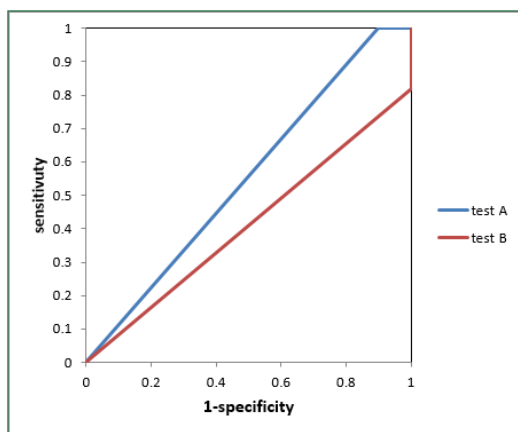


Fig. 6: ROC plot showing the diagnostic ability of Test A(T2 mapping, more sensitive) & Test B (Standard MRI, more specific).

Table 12: T-Test between the T2 values in cases and controls

		Cases	Controls	Test value	P-value	Significance
		No.=50	No.=10			
T2 value(ms)	Mean ± SD	63.4 ± 9.1	36.7 ± 5	8.96	0.00001	HS
	Range	48-87	30-50			

Above table shows the unpaired T-test regarding the T2 values in tests and controls which shows that there is a statistically significant difference. (P value < 0.05)

Table 13: Pearson's correlation between the T2 values and Age / cartilage thickness

	T2 value(ms)	
	Pearson's correlation	P-value
Age	0.43	0.001
Cartilage thickness	-0.3064	>0.05

N.B.: Age and T2 values were found to be moderately correlated positively, $r(60) = .43$, $p = .001$, while the negative correlation between cartilage thickness and T2 values was found to be non-significant.

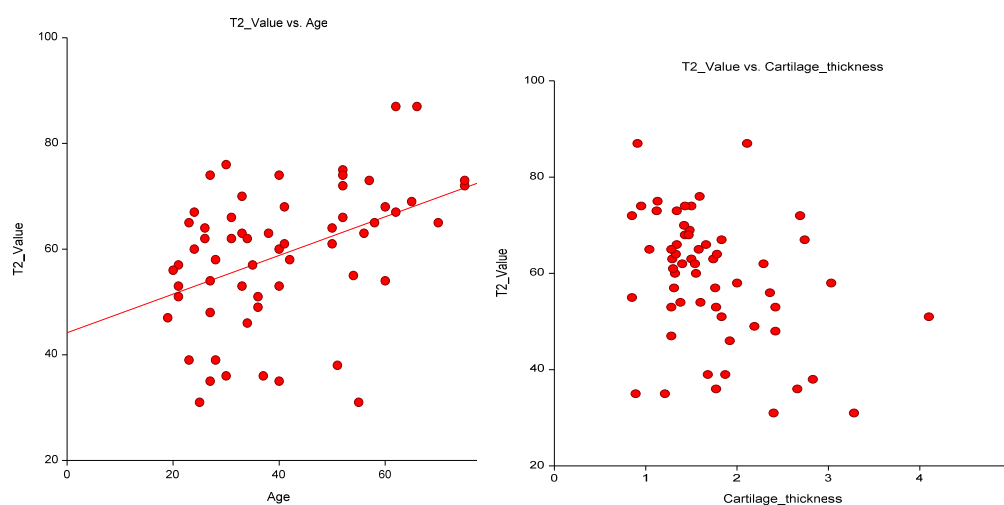


Fig. 7: Pearson's correlation between the T2 values and Age / cartilage thickness.

Table 14: Independent T-test regarding the cartilage thickness in tests and controls

		Control group	Patient group	Test value	P-value	Sig.
		No. = 10	No. = 50			
Cartilage thickness	Mean±SD	1.99 ± 0.78	1.68 ± 0.6	1.4•	0.16	NS
	Range	0.89 – 3.28	0.85 – 4.1			

P-value >0.05: Non significant (NS); P-value <0.05: Significant (S); P-value< 0.01: highly significant (HS)
Independent t-test•

Above table shows the unpaired T-test regarding the cartilage thickness in tests and controls which shows that there is a lack of statistically significant difference (P value > 0.05).

DISCUSSION:

Detection of knee osteoarthritis, which represents more than 80% of Osteoarthritis total burden⁽⁶⁾, in an early stage is a must to treat it effectively⁽⁷⁾. Early alteration in cartilage morphology can only be differentiated from the surface of normal articular cartilage on using a spatial resolution of 0.3 mm, that is beyond the spatial resolution of imaging sequences used in clinical practice for morphologic cartilage⁽⁸⁾. T2 mapping sequences do not rely on spatial resolution to detect early superficial alterations in cartilage but depict areas of excess water content and altered collagen matrix ultrastructure in degenerative cartilage⁽⁹⁻¹²⁾. So, T2 mapping helps in the detection of early and potentially reversible cartilage damage prior to the onset of symptoms and morphological alteration allowing early action by disease modifying agents⁽¹³⁾.

In our study, the addition of a T2 mapping sequence to a routine MR imaging protocol significantly improves the sensitivity for detecting cartilage lesions, especially the early ones, within the knee joint from 82% to 100% (p=0.001). This agrees with *Tulasi et al. (2017)*⁽¹⁴⁾ who carried out a prospective comparative study to evaluate the knee joint articular cartilage by T2 mapping sequence in 30 patients with knee pain and 30 normal subjects and found

that mean T2 relaxation value is more in patient group (44.8 ±3.1 ms) than control group (37.9 ± 1.4 msms). MRI T2 mapping sequence allows the diagnosis of conventionally normal MRI studies of the patients with knee pain as early osteoarthritis with a sensitivity of 90% and specificity of 93%.

Dunn et al. (2004)⁽¹⁵⁾ showed in a case/control study with 55 subjects a significant (P <0.05) increases in T2 relaxation time between healthy (32.1-35.0 ms) and diseased (34.4-41.0 ms) knees.

Also *Kijowski et al.(2013)*⁽¹⁶⁾ who prospectively studied 150 subjects and found that increased T2 values in cartilages corresponded to cartilage lesions arthroscopically, and confirmed that increased T2 value in articular cartilage can be used as an indicator of cartilage degeneration in OA.

On the other side, our study reported that T2 mapping sequence showed a significant little decrease in specificity for detecting cartilage lesions within the knee joint from 100% by routine MRI to 90%. This decrease may be due to false increase in cartilage T2 relaxation time secondary to the magic angle effect or early asymptomatic cartilage degeneration. This agrees with *Kijowski et al. (2012)*⁽¹⁷⁾, study which include 255 cartilage lesions within the knee joint confirmed by arthroscopy. The sensitivity and specificity for detecting cartilage lesions was 72% and 98% respectively for the routine MRI protocol alone and 88% and 92% respectively for the routine MRI protocol and T2 maps. There was a statistically significant differences in

sensitivity and specificity ($p < 0.05$). False positives were most common in the patellar ($n=10$), lateral tibial plateau ($n=10$) and trochlea ($n=3$). In our study, the false positives were in medial compartment ($n=2$).

While all these studies including our study showed association between increased T2 values and cartilage degeneration, a study by Hirose et al. (2012)⁽¹⁸⁾ reported that there is no significant change in T2 values with cartilage

degeneration relative to normal cartilage does exist in the literature. Also, our results contradict the claims of *Årøen et al.* (2016)⁽¹⁹⁾ that MRI T2 mapping did not demonstrate significant differences between the mean values of the articular cartilage on the affected and the unaffected medial condyles at the anterior reference point ($p > 0.05$).

Our study results show, as reported by *Crema et al.* (2011)⁽⁵⁾ and *Dautry et al.* (2014)⁽²⁰⁾, that T2 mapping imaging may add a robust value to MR imaging ability to identify focal knee chondral lesions, when T2 mapping abnormalities and pain location are correlated. In our study we found a good correlation between pain location and focal prolongations of the cartilage T2 relaxation time. T2 mapping could detect focal abnormalities in the symptomatic compartments of 50 out of 50 patients (11 out of 11 symptomatic anterior compartments, 22 out of 22 symptomatic medial compartments and 17 out of 17 symptomatic lateral compartments).

Concerning T2 values in different knee joint compartment, our study results—similar to the *Dautry et al.* (2014)⁽²⁰⁾ study—showed no significant difference ($p = 0.55$) between the mean T2 values of medial and lateral femoro-tibial cartilage and anterior patellofemoral cartilage. However, another study by *Mosher et al.* (2001)⁽²¹⁾, involving persons with and without radiographic knee OA showed positive correlation with higher

T2 values in the medial compartment cartilage and higher degree of knee pain.

In agree with *Mittal et al.* (2019)⁽²²⁾, that reported lack of difference in average articular cartilage thickness between OA patients and controls, with p value > 0.05 , our study results showed that there was a non-significant difference between cartilage thickness in OA patients and controls ($p = 0.16$), in Contrary to the cross-sectional CT arthrography retrospective study by *Omoumi et al.* (2015)⁽²³⁾ which carried on 535 consecutive knees showing that cartilage of posterior aspect of medial condyle was statistically thicker in OA knees compared to non-OA Knees ($p < 0.001$). Also, *Li et al.* (2007)⁽²⁴⁾, reported that there was no significant difference in the average cartilage thickness in OA patients and control subjects ($P = 0.37$), and suggested that there is no significant correlation was found between T2 values and cartilage thickness ($P > 0.05$), similar to our study results that observed a non-significant negative correlation ($r = - 0.3$) between T2 values and cartilage thickness ($p > 0.05$).

Regarding age, Our study showed a significant positive correlation ($r = 0.43$) between age and T2 values ($p < 0.001$) that agrees with *Mosher et al. study 50(2004)*⁽²⁵⁾, which demonstrated an association of elevated T2 values in the superficial layers of articular cartilage with age, suggesting that initial degenerative changes may occur at the articular cartilage surface with aging.

Regarding gender, Our study showed that there is no significant difference between T2 values of males and females ($p > 0.05$) that agrees with *Mosher et al. study 19 (2004)*⁽²⁶⁾, which comparing differences in T2 values between healthy men and women found no differences between genders.

Limitations of this study include lack of confirmatory arthroscopic procedures after cartilage findings at T2 mapping and

standard MRI knee, as it would be inadequate for arthroscopy to assess for early or subtle intrinsic cartilage abnormalities shown on T2 maps. Also, short T2 relaxation values of cartilage oriented at about 55° to the main magnetic field are susceptible to the magic angle effect.

Conclusion:

Our study has demonstrated that the addition of T2 mapping, as a biochemically sensitive MRI sequence, to the routine MRI protocol of the knee improves sensitivity from 82% to 100% to detect early structural degeneration with better diagnostic information in the knee articular cartilage.

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دور تخطيط الـ T2 بالرنين المغناطيسي لتقييم الغضروف المفصلي للركبة في مرض خشونة المفاصل

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الخلفية: إن تخطيط T2 للغضروف الزجاجي هو تقنية تصوير للكشف النوعي والكمي لتغيرات الغضروف؛ فهو يوفر خرائط ملونة مقنعة وكشف كمي لتغيرات الغضروف أساسا فيما يتعلق بالبنية والتغيرات في محتوى الماء، والبروتينوغليكان و مصفوفة الكولاجين الدقيقة المرتبطة بتآكل الغضروف المبكر.

هدف الدراسة: الهدف من هذه الدراسة هو توضيح دور تخطيط الـ T2 بالرنين المغناطيسي في تقييم الغضروف المفصلي للركبة من أجل تحسين حساسية الفحص للكشف المبكر عن مرض خشونة المفاصل. و أيضا، مقارنة نتائج تخطيط الغضروف المفصلي للركبة بين مرضى خشونة الركبة و الذين لا يعانون من المرض.

المرضى وطرق البحث: تمت الموافقة من قبل لجنة أخلاقيات البحث العلمي بجامعة عين شمس على دراسة الحالات وتم الحصول على الموافقة المستنيرة. شملت هذه الدراسة 60 حالة، قسمت الى مجموعتين، 50 مريضا (مجموعة تشتكى من أعراض: 33 ذكرا و 17 انثى) مع أدلة سريرية على خشونة الركبة، و 10 أشخاص في مجموعة أخرى لا تشتكى من الخشونة (مجموعة بدون أعراض: 8 ذكور و انثيين) و تراوحت الأعمار ما بين 19 - 75 عام. و قد خضعت جميع الحالات لتصوير مفصل الركبة بالرنين المغناطيسي بقوة 1.5 تيسلا و الذى أجرى باستخدام بروتوكول الركبة الروتينى مع زيادة تسلسل تخطيط الركبة بمقطع اما سهمى أو تاجى أو محورى أو الكل. تم تقييم مستويات التصوير القياسية للركبة مع تقييم الغضروف المفصلي كما هو اما سليم او لا. و بعد ذلك تم تقييم المقاطع مع تخطيط T2 للركبة من حيث المللى ثانية، فاما طبيعية (أقل من 48 مللى ثانية) أو غير طبيعية (تساوى 48 مللى ثانية أو أكثر). و لقد تم استخدام نماذج المعادلة التقديرية المعممة لمقارنة حساسية و خصوصية بروتوكول التصوير بالرنين المغناطيسى بالتسلسلات الروتينيه و تسلسل تخطيط الـ T2.

النتائج: كانت كل من الحساسيات والخصائص 82% و 100%، على التوالي، لبروتوكول الـ T2 المغناطيسي الروتينى وحده و 100% و 90% بعد إضافة تخطيط الـ T2 إلى بروتوكول الـ T2 المغناطيسي الروتينى، وأدت إضافة تخطيط الـ T2 إلى بروتوكول التصوير بالرنين المغناطيسي الروتينى إلى تحسين الحساسية بشكل كبير (اختبار التشخيص الثنائي، $p = 0.01$)، و قد أظهرت المقارنة بين المرضى والمتطوعين فيما يتعلق بقيم T2، فرقا كبيرا إحصائيا (اختبار T المستقل، $P < 0.00001$).

الخلاصة: مزيج من كل من التصوير بالرنين المغناطيسي التقليدى و تخطيط الـ T2، جنباً إلى جنب مع التقييم السريري يمثل نهج متعدد الوسائط مرغوب فيه لتشخيص مرض خشونة المفاصل، و يحسن تخطيط الـ T2، كتسلسل للرنين المغناطيسى للركبة حساس كيميائياً، الحساسية من 82% إلى 100% لاكتشاف الانحلال الهيكلي المبكر لغضروف مفصل الركبة بمعلومات تشخيصية أفضل.