Advanced Magnetic Resonance Imaging Using T2 Mapping Sequence in Assessment of Osteochondral Lesions of the Ankle Joint

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Abstract

Background: Osteochondral lesions (OCLs) are a collection of lesions that affect both the articular hyaline cartilage and the subchondral bone plate.

Objectives: This study was aimed to analyse the use of advanced magnetic resonance imaging (MRI) using T2 mapping sequence in evaluating OCLs of the ankle joint.

Patients and Methods: This study was carried out on 30 cases; were divided in to two groups: patients' group (n=20): clinically presented with ankle pain 13 females and 7 males. Control group (n=10): five males and five females. All patients were subjected to simultaneous measurement by MRI.

Results: The number of diagnoses more than number of patients because there is overlap of diagnosis. By using routine MRI & T2 Mapping at the ankle joint, we found that 14 cases have OCLs, sex cases were diagnosed as grade 1a, four cases were diagnosed as grade 2a, and four cases were diagnosed as grade 3a. Multiple rows were placed at regions of interest of the ankle articular cartilage; we found that T2 values were significantly increased in our cases in comparison to the control group.

Conclusion: Intact articular cartilage is characterized by a normal signal intensity in various pulse sequences. In T2 maps, normal ankle articular cartilage at different locations often has a value below 60 milliseconds. An assessment was conducted to compare the effectiveness of MRI alone against MRI using a T2 mapping sequence. There is a considerable level of agreement between using merely MRI and using MRI with a T2 mapping sequence.

Keywords: Magnetic Resonance Imaging; T2 Mapping Sequence; Osteochondral lesions; Ankle Joint.

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Introduction

The osteochondral lesions (OCLs) are a group of lesions that involving articular hyaline cartilage & the subchondral bone plate. The patients with OCLs of the ankle region can be clinically presented with chronic pain and decreased function at the ankle joint. A single or series of traumas that cause the osteochondral fragment to partially or fully detach, together with or without osteonecrosis, is the most common cause of an OCL**(Gerards et al., 2014)**.

Consequently, there is a rising need for accurate and objective evaluation of cartilage tissue and its restoration in the ankle joint due to the growing number of surgical procedures utilizing various approaches for cartilage repair **(Schreiner et al., 2017)**.

Sequences that assess cartilage morphology, such as (coronal proton density-fat suppressed, axial PD, axial T2 STIR, sagittal T1 weighted image, and sagittal T2 STIR), are usually used to evaluate articular cartilage in symptomatic patients undergoing routine magnetic resonance (MR) imaging of the ankle joint**(Kijowski et al., 2010)**. When it comes to detecting early signs of cartilage degradation, morphologic imaging sequences have a poor sensitivity, which is their biggest drawback**(Quatman et al., 2011)**.

Recent advancements in biochemical magnetic resonance imaging (MRI) have enabled the creation of sequences that are responsive to molecular alterations in the composition of cartilage matrix. This has yielded crucial understanding of both the first phases of cartilage deterioration and the development of healing tissue, at a molecular level. Sodium imaging, delayed gadolinium-enhanced MRI of cartilage (dGEMRIC), water-and collagen-sensitive T2\T2* mapping, and glycosaminoglycan-sensitive sequences are all included in this [2].

Compared with other biochemically sensitive MRI techniques **(Chan and Neu, 2013)**, The capacity to perform isotropic three-dimensional (3D) cartilage assessment, rapid imaging, and excellent picture quality are some of the distinctive properties of T2 mapping. Clinical MRI systems may easily include it since commercially available pulse sequences and inline processing tools are already in place to generate quantitative T2 maps. Contrast media management and specialized hardware are also unnecessary**(Bittersohl et al., 2012)**.

The collagen matrix experiences early degradation, leading to an increase in the amount of water entering. The increased permeability causes strain throughout the matrix, leading to the eventual decay and depletion of cartilage tissue. These physiological changes manifest as a rise in T2 signal. By analysing the spatial distribution of T2-relaxation durations inside articular cartilage, it is feasible to identify areas with elevated or reduced water content, which often signify cartilage deterioration**(Smith et al., 2001)**.

The objective of this study is to determine how well T2 mapping sequence advanced MRI performs in evaluating ankle OCLs.

Patients and methods

This study was carried out on 30 cases, 20 patients clinically presented with ankle pain (13 females & 7 males) & suspicious to have articular cartilage lesion and 10 volunteers' (5 males & 5 females) as a control group. aged from 20 to 60 years old with a mean age of 40 years, both sexes, with clinical criteria of ankle pain with clinically suspicious to have articular cartilage lesion. Following permission from the Ethical Committee Tanta University Hospitals, the research lasted from May 2018 until December 2019. Patients or their legal guardians gave their signed, informed permission.

Inclusion criteria: patients with ankle pain suspecting to have osteo-chondral lesions **Exclusion criteria**: patients with metal implants used in orthopedics, intravascular stents, coils,cardiac

pacemakers, aneurysmal clips were all disqualified from the study. Also patient's weight over 150 kg were not allowed to use MRI device.

Patients were divided in to two groups: patients' group: clinically presented with ankle pain 13 female's (65.0%) & 7 males (35.0%) and control group: 10 volunteers' 6 males (60.0%) & 4 females (40.0%).

All patients were subjected to clinical history, clinical provisional diagnosis, X-ray study including (Anteroposterior, Lateral & oblique views) & MRI study was performed using **MRI device(G.E.)1.5 T.** using an ankle coil with the patient in a supine position & the foot at a 90_o angle to the leg.

Routine MRI sequences: T1WI (axial, Coronal and sagittal), TR 624 msec, TE 17 msec, 4 mm slice thickness, 18 cm FOV, fat tissue suppressed Gradient (sagittal and coronal), T2WI (axial, coronal, and sagittal), TR 488 msec, TE 14 msec, slice thickness 4 mm, field of view 18 cm, and TE 50 msec.

T2 Mapping sequence:

Sagittal or coronal T2 mapping were displayed by using these parameters:TR:1083 msec, TE: 8,16,24,32,40,48,56 &65 msec, matrix: 320x256, slice thickness:3mm and field of view:18 cm.

Imaging analysis: An analysis was conducted on the MR data to identify any abnormalities in the cartilage, such as lesions, as well as any bone-related issues such an os trigonum, a Stieda process, a significant postero-superior calcaneal tuberosity, bone marrow edema, and soft-tissue lesions.

Data processing and post processing: The T2 mapping photos were sent to the workstation (Advantage Window 4.7), where they were automatically turned into color-coded map images by the loaded application, based on the color mapping images. Typically, healthy ankle cartilage appears as yellow to green in T2 mapping. The T2 values for the areas of interest were determined as the mean values. Several rows were positioned in areas of interest inside the articular ankle cartilage, ensuring a safe distance from the subchondral articular bone.

Statistical analysis

We used SPSS v26, developed by IBM and located in Chicago, IL, USA, to do the statistical analysis. An unpaired Student's t-test was used to compare the two groups for the quantitative variables, which were reported as the mean and standard deviation (SD). The frequency and percentage (%) values of the qualitative variables were then assessed using either Fisher's exact test or the Chi-square test, as the case may have been. A statistically significant result was defined as a two-tailed P value below 0.05.

Results

The age of the patients varied between 22 and 60 years, with an average age of 37.70 ± 13.81 years. The age of the participants varied between 30 and 58 years, with an average age of 40.20 ± 9.39 years. All patients in our research had standard MRI of the ankle, as well as T2 mapping. The patient's sex was 8 (40.0%) males and 12 (60.0%) females. The volunteers' sex was 6 (60.0%) males and4 (40.0%) females, (**Table. 1).**

Table 1. Distribution of the studied cases according to the age and sex

Variables		Patients	Control	P. value
Age		37.70 ± 3.81	40.20 ± 9.39	0.611
Sex	**Male**	7 (35.0%)	5 (50.0%)	0.301
	Female	13 (65.0%)	5 (50.0%)	

Data are presented as Mean ± SD.

Twelve patients in our study were presented clinically with ankle pain, eight patients were presented OCLs by ankle pain that follow trauma to ankle joint. Our research includes 20 individuals with OCLs, with twelve located at the medial surface of the talus bone and eight at the lateral surface of the talus bone. The study

assessed the morphological alterations of articular cartilage using OnT2-mapping. Swelling occurred in 12 patients (60%), whereas fractures were found in 6 patients (30%) and abnormalities in 2 patients (10%). By using routine MRI & T2 Mapping at the ankle joint, we found that 8 cases were diagnosed by osteoarthritis (40%), 6 cases were diagnosed by Charcot joint (30%) and 4 cases were diagnosed by osteochondritis (20%), 2 cases were diagnosed by osteochondral defect (10%), 2 cases were diagnosed by sinus tarsi syndrome (10%), 2 cases were diagnosed by complex regional pain syndrome (10%). The number of diagnoses more than number of patients because there is overlap of diagnosis. By using routine MRI & T2 Mapping at the ankle joint, we found that 14 cases have OCLs ,6 cases were diagnosed as grade 1a (30%),4 cases were diagnosed as grade 2a (20%), and 4 cases were diagnosed as grade 3a (20%), (**Table. 2).**

Table 2. Distribution of the studied cases according complain, site of lesions, damage of articular cartilage, diagnosis and grading of osteochondral lesions

Complain	
Trauma	8 (40%)
Pain	12 (60%)
Site of lesion	
Medial talar surface	12 (60%)
Lateral talar surface	8 (40%)
Damage of the cartilage	
Defect	2 (10%)
Swelling	12 (60%)
Cracking	6 (30%)
Diagnosis	
Osteochondral defect	2 (10%)
Osteochondritis	4 (20%)
Osteoarthritis	8 (40%)
Charcot Joint	6 (30%)
Sinus tarsi syndrome	2 (10%)
Complex regional pain syndrome	2 (10%)
Osteochondral lesions grading	
1 a	6 (30%)
2 a	4 (20%)
3 a	4 (20%)

Data are presented as number (%).

Multiple rows were placed at regions of interest of the ankle articular cartilage, we found that T2 values were significantly increased in our cases (OCLs, osteoarthritis & Charcot joints) in comparison to the control group, (**Table. 3).**

Table 3. Distribution of the studied cases according to T2 Mapping values

Vriables	Patients	Control	P. value
T2 Mapping values	80.60 ± 8.31	45.50 ± 3.81	**0.001***

Data are presented as Mean ± SD.

Case 1:

Diagnosed normal MRI of the right Ankle joint. Male 29 years old healthy volunteer (**Fig.1).**

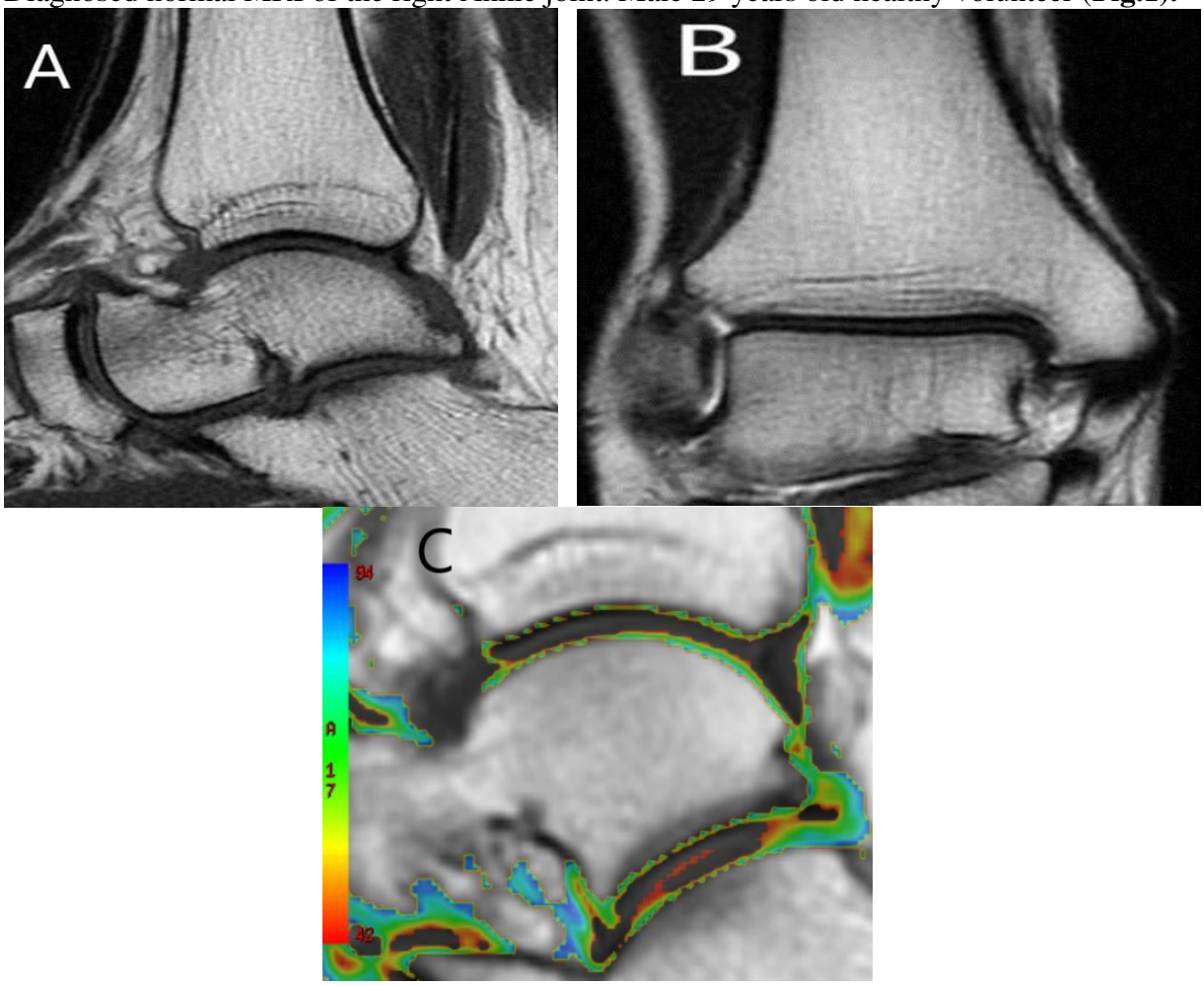

Fig.1. Routine MRI (A and B) showed Sagittal T1 & Coronal T2 WI MRI showed normal thickness and normal SI of tibial & talar articular cartilage. A note is done for prominent os-trigonum and post processing sagittal colored T2 mapping MRI (C) showed Sagittal T2 mapping MRI, Multiple ROIs placed on ankle joint cartilage (anterior, middle & posterior zones) and showed normal T2 mapping values (Green to yellow & less than 60)

Case 2:

Diagnosed as talar dome edema with suspected avascular necrosis. Female patient aged 27 years old presented with chronic left ankle joint pain (**Fig.2).**

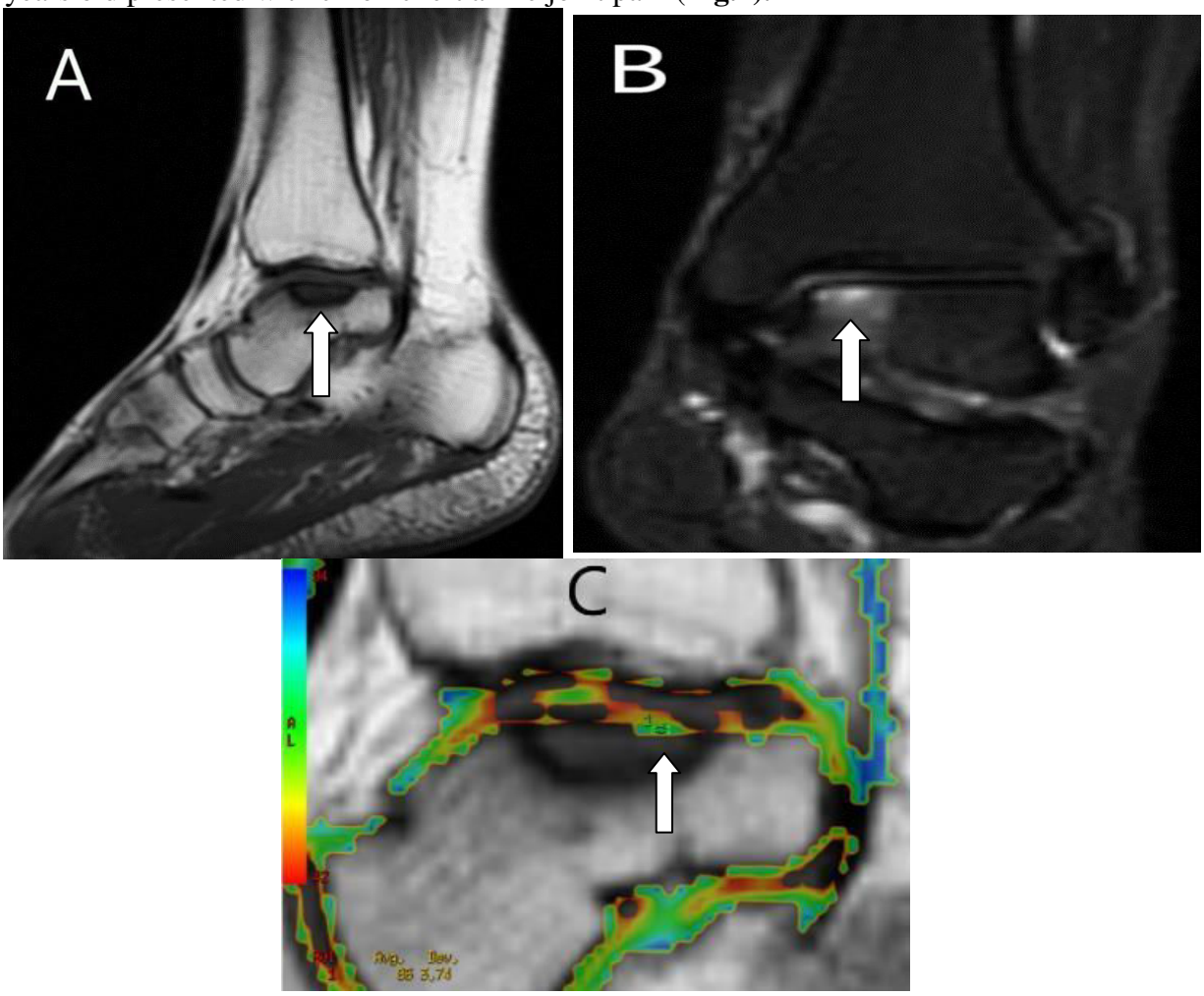

Fig.2. Routine MRI showed A) Sagittal T1 WI MRI shows talar dome subchondral (arrow) low SI, B) Coronal PD FAT SAT MRI shows cystic changes at the talar dome and the underlying cartilage still intact (arrow) and Post processing sagittal colored T2 mapping MRI showed C) Sagittal colored post processing T2 mapping MRI, Multiple ROIs placed on ankle joint cartilage and showed increased T2 value (86) and thinning of the talar cartilage at the site of the cystic changes of the talar dome (arrow)

Case 3:
Diagnosed as Charcot joint of left ankle & subtalar joints with superadded infection of the tarsal bones. Female diabetic patient aged 60 years old presented with chronic left ankle joint pain (**Fig.3).**

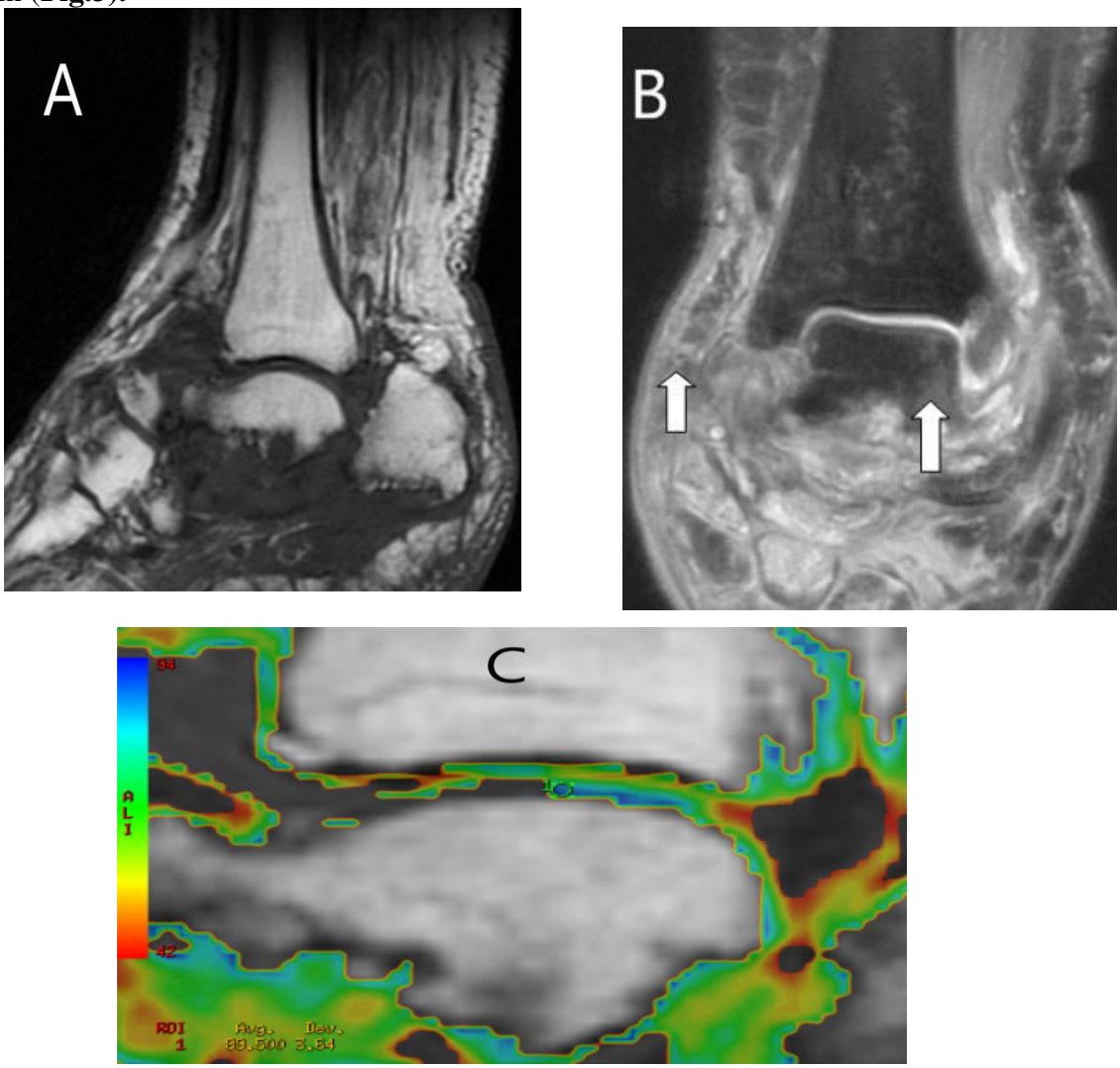

Fig.3. A: Sagittal T1 WI MRI shows marked osteoarthritic changes of the ankle joint. with surrounding soft tissue thickening B) Coronal PD FAT SAT MRI reveals soft tissue edema, high SI of the tarsal bone, and mild ankle joint effusion (arrows) and C) Sagittal colored post processing T2 mapping MRI, with multiple ROIs placed on regions of interest at the ankle joint cartilage and an increased T2 value (80-89), as shown in routine MRI

Discussion

Most OCLs in the ankle are found on the talar dome, but lesions on the distal tibia are uncommon due to the mechanical and anatomical characteristics of the joint surfaces. OCLs, albeit less often, have the potential to impact many articular surfaces of the bone. The talar dome ranks as the third most prevalent location for OCLs in the human body, behind the knee and the elbow(**Cuttica et al., 2012, Hembree et al., 2012**). Although distal fibula OCLs are very uncommon, they may be defined as potentially occurring on the articular surface of the distal fibula(**Riaz et al., 2012**).

In our study 20 patients were presented clinically by ankle pain, 12

patients were presented by ankle pain that follow trauma to ankle joint & 8 patients presented by ankle pain without trauma which is similar to S. Lee et al. **(Lee et al., 2013)** in their study, 52 people with ankle pain joined part. T2-mapping looked at changes in the shape of the joint cartilage in this study: area of growth in 12 patients (60%), cracks in 6 patients (30%), and flaws in 2 patients (10%), which is the same as what Dutova, I. et al. In their study, they found areas of swelling in 43 patients (46%), cracks in 12 patients (13%), and flaws in 6 patients (6.5%)**(Dutova, 2015)**. This study included 20 patients with OCLs, 12 patients at the medial talar surface and 8 patients at the lateral talar surface, which is similar to Dutova, I. et al. **(Dutova, 2015)** in their study which showed 21 patients with OCLs at the medial talar surface & 8 patients at the lateral talar surface.

Our findings indicate a consistent pattern of higher T2 values in the ankle joint cartilage of symptomatic patients compared to the control group. This aligns with the results of a previous study (**Shiomi et al.,2013**), which showed that physically active individuals had higher T2 values than those who were physically inactive. In addition, other investigations [14, 15] have also shown a favourable correlation between T2 levels and the likelihood of developing morphologic cartilage lesions. These findings indicate that detecting higher T2 values in cartilage might potentially be used to forecast the early stages of cartilage degradation, even before a cartilage lesion can be seen using traditional MR imaging techniques. A reason for the greater T2 value in individuals with high activity levels might be the secretion of substances into the synovial fluid that initiate the breakdown of cartilage matrix in structurally intact regions (**Smith et al.,2001).** Hence, our data indicates that symptomatic individuals with higher cartilage T2 levels may have an increased susceptibility to the early signs of osteoarthritis, as compared to the healthy control group. Prior research has shown that the cartilage in weight-bearing regions of healthy knee joints had elevated T2 values compared to non-weight-bearing regions **(Shiomi et al., 2013, Hannila et al., 2009)**. In a study conducted by **Krause et al (2010)**, it was shown that individuals with pes cavovarus who had symptomatic ankle arthrosis had substantially greater cartilage T2* values in the lateral compartment compared to the medial compartment. In addition, our findings revealed that patients had elevated T2 values in both the medial and lateral zones of the talar cartilage. These results indicate that the evaluation of T2 values may reliably identify cartilage lesions in the tibiotalar joint at an early stage, regardless of qualitative MR findings or clinical information.

So, Yoon Park et al. [19] found that In six compartments: medial anterior (M1), medial middle (M2), medial posterior (M3), lateral anterior (L1), lateral middle (L2), and lateral posterior (L3), the average T2 relaxation values of the talar trochlear cartilage were assessed in two layers, superficial and deep, respectively. Compared to the control group, patients had substantially higher values for these variables. Patients averaged 46.2 on the M1 test, whereas healthy participants scored 39.6. When it came to M2, the average for patients was 50.4 and for healthy subjects it was 41.1. The average M3 for patients was 52.1 while for healthy subjects it was 46.2. On average, sick had an L1 of 43.1 whereas healthy subjects had a value of 37.9. The average L2 for patients was 47.8, whereas the healthy volunteer group was 41.8. Lastly, L3 had a mean of 53.8 for patients and 49.8 for healthy volunteers. Our study found that the mean T2 relaxation values of talar cartilage were considerably greater in patients compared to the control group, indicating similarity to previous research. The T2 mapping values in the patients' group ranged from 70 to 91, which was

substantially greater than the range of 40 to 50 seen in the control group.

The findings clearly demonstrate that including a T2 mapping sequence into a standard MR imaging strategy enhances the ability to detect cartilage lesions in the ankle joint, particularly in identifying early cartilage deterioration.

Nevertheless, this research is limited by a small patient sample size and the lack of arthroscopic confirmation of OCLs in all patients.

Conclusion

Intact articular cartilage is characterized by a normal signal intensity in various pulse sequences. In T2 maps, normal ankle articular cartilage at different locations often has a value below 60 milliseconds. An assessment was conducted to compare the effectiveness of MRI alone against MRI using a T2 mapping sequence. There is a considerable level of agreement between using merely MRI and using MRI with a T2 mapping sequence.

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