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Research Article

ANALYZING THE RELATIONSHIP AMONG CLINICAL SYMPTOMS, X-RAY RESULTS, AND CARTILAGE WEAR PATTERNS IN KNEE OSTEOARTHRITIS USING T2 MAPPING MRI

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ABSTRACT

Objectives: Osteoarthritis (OA) is a condition that causes joint pain, varying degrees of functional limitations, and a decrease in overall quality of life. The purpose of this study was to examine the progression of cartilage degeneration in knees affected by symptomatic OA and determine its relationship with X-ray and T2 map MRI findings.

Methods: This study was conducted at a Tertiary Care Teaching Institute in India and involved 40 patients. It was an observational type of study. For our assessment, we utilized the Western Ontario and McMaster University (WOMAC) osteoarthrosis index to evaluate function, quality of life, and joint pain. Medical imaging technique A standing AP view of the affected knee joint was taken using plain radiographs. Once the X-rays were obtained, they were graded using the Kellgren–Lawrence Classification, which ranges from 0 to 4 grades.

Results: Out of the total patients, 6.0% were <40 years old, 21.2% were between 41 and 50 years old, 27.2% were between 51 and 60 years old, 39.3% were between 61 and 70 years old, and 6.0% were above 70 years old. In this study, there were 21 females (63.6%) and 12 males (36.4%). In this study, the researchers found that there was no distinction between the sides of the limb affected. Both the left and right sides were involved in 13 cases each, accounting for 39.39% of the total cases. In addition, 7 cases, or 21.21%, reported experiencing bilateral knee pain. Merchant grade reported that out of the knees examined, 17.5% had Grade 0, 45% had Grade 1, 27.5% had Grade 2, 10% had Grade 3, and none had Grade 4.

Conclusion: The findings of this study suggest that T2 map MRI has the ability to accurately measure abnormal cartilage changes in conditions that affect the mechanical properties of the knee joint. It is crucial to have non-invasive methods that can assess early cartilage matrix changes. These methods are important for initiating early treatment, monitoring disease progression, planning operative procedures, and following up on operative cartilage repair.

Keywords: Cartilage matrix, Knee joint, X-ray, Osteoarthritis.

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INTRODUCTION

The knee joint plays a crucial role in supporting the body's weight. Repeated wear and tear can cause a variety of shearing forces within the components of the joint. The articular cartilage is crucial for distributing load to the bone, as it creates a smooth surface and prevents direct contact between bones in the joint. Damage to the articular cartilage can lead to imbalances at the joint surface, resulting in permanent bone damage and deformities. The articular cartilage is made up of chondrocytes and extra-cellular components such as water, collagen fibers, and proteoglycans. Hyaline cartilage is a delicate connective tissue made up of an intricate network of collagen fibers, water, and proteoglycan [1]. Chondral lesions typically develop gradually, with the symptoms becoming apparent later on.

Osteoarthritis (OA) is a condition that causes joint pain, varying degrees of functional limitations, and a decrease in overall quality of life. OA is characterized by the presence of specific cartilage loss, alterations in adjacent bone structure, and inflammation. It is worth noting that women are more commonly affected by OA compared to men. In addition, the likelihood of developing OA increases significantly with age, especially in individuals over the age of 60 [1,2].

OA is identified by the alterations in the biochemistry and microstructure of the cartilage. The initial changes involve a decrease in PG concentration, potential alterations in the size of collagen fibril and aggregation of PGs, an increase in water content, and an upsurge in the synthesis and breakdown of matrix macromolecules, leading to a disruption of the collagen network. These factors contribute to the breakdown and reduced content of the PGs matrix. As a result, ulcers can form and PGs can enter the synovial fluid, leading to a decrease in the water content of the cartilage. This makes the cartilage less able to withstand stress. As OA advances, there is a significant reduction in collagen, PGs, and water content, leading to a severe disruption of the collagen network [3-6].

Standard MR techniques for cartilage analysis are often inconclusive when it comes to quantifying early degenerative changes in the cartilage matrix, particularly the biochemical changes [7,8].

The MRI-based T2 mapping method enables the evaluation of collagen content and orientation, crucial indicators for early OA. In healthy cartilage, the collagen matrix effectively captures and holds water protons, resulting in low signal intensity on T2-weighted images. During the early stages of OA, the matrix starts to deteriorate and becomes more susceptible to water, resulting in an increase in T2 relaxation times.

The purpose of this study was to examine the progression of cartilage degeneration in knees affected by symptomatic OA and determine its relationship with X-ray and T2 map MRI.

METHODS

This study was conducted at a Tertiary Care Teaching Institute in India, using an observational approach. The study received approval from the

Ethical Committee. Upon the patients' arrival at the OPD, a thorough survey was conducted to document any additional notable complaints.

In order for subjects to be classified as having "knee pain," they needed to provide a positive response to both parts of the question: Do you experience persistent knee pain for a month or longer?

a. "Have you ever had pain in or around the knee on most days for at least a month?
b. If so, have you experienced any pain during the last year?"

The response to both parts of the question was classified as "negative" due to knee pain. In this study, a total of 33 cases (40 knees) were included, consisting of both males and females. After obtaining informed consent, a thorough clinical and radiological examination was conducted over a period of 12 months.

For our assessment, we utilized the Western Ontario and McMaster University (WOMAC) osteoarthrosis index to evaluate factors such as function, quality of life, and joint pain [5]. The WOMAC OA index is a widely recognized tool for assessing the clinical symptoms of knee OA. It measures pain, stiffness, and physical function experienced over the past week. Extensive research has been conducted to validate the WOMAC index in relation to assessing function and quality of life in patients with OA [5]. On the day, knee radiographs and MR images were acquired, and all subjects were asked to complete the WOMAC questionnaire for the affected knee. This questionnaire is a self-administered tool that includes 24 items divided into three subscales. These subscales cover various aspects such as pain, stiffness, and physical function. Each question response is given a score ranging from 0 (none) to 4 (extreme). The scores for each question are added together to create a total score that can range from 0 to 96. After all is said and done, the raw scores undergo normalization by being multiplied by 100/96. After all is said and done, the raw scores undergo normalization by being multiplied by 100/96 with the help of WOMAC score and an X-ray [6]. An AP view of the knee joint was taken while the patient was standing, putting weight on the joint. Once the X-rays were obtained, they were assessed using the Kellgren–Lawrence classification, which grades them on a scale of 0 to 4. In Grade 0, there are no signs of OA on the radiograph. Grade 1 shows some doubt regarding joint space narrowing and the possibility of osteophytic lipping. Grade 2 indicates the presence of definite osteophytes and the potential for joint space narrowing on an AP weight-bearing radiograph. Grade 3 shows that there are multiple osteophytes, clear joint space narrowing, sclerosis, and a potential bony deformity. In Grade 4, there are large osteophytes, marked joint space narrowing, severe sclerosis, and definitive bony deformity.

A new X-ray was performed to visualize patellofemoral arthritis from a 45° skyline (Merchant) view. The grading was based on merchant classification, indicating Stage 1: Mild with joint space measuring over 3 mm, Stage 2: The joint space is moderately affected, with less than 3 mm remaining and no contact between the bones, and Stage 3: The condition is quite severe, with the bony surfaces in contact over less than one-quarter of the joint surface. The fourth stage is characterized by a significant level of severity, with direct contact between the bones across the entire joint surface.

The MRI was conducted using a SIEMENS AMIRA SYSTEM, specifically with a customized 16 element knee coil designed for the knee joint.

The cartilage's articular surfaces were categorized into six regions: Patella, trochlea, medial and lateral femoral condyles, and medial and lateral tibial surface. Precise location of the lesion was determined using the "ICRS-knee cartilage mapping system." The femur's cartilage was divided into different sections, including the Medial Trochlea, Central Trochlea, and Lateral Trochlea. The condyles were also categorized as Condyle Medial Anterior (CMA), Condyle Medial Central (CMC), and Condyle Medial Posterior (CMP) for the medial side and Condyle Lateral Anterior, Condyle Lateral Central (CLC) and Condyle Lateral Posterior for the lateral side.

The tibia is divided into different sections: Plateau Medial Anterior (PMA), Plateau Medial Central (PMC), Plateau Medial Posterior (PMP), Plateau Lateral Anterior (PLA), Plateau Lateral Central (PLC), and Plateau Lateral Posterior (PLP). The data were compiled and entered into a spreadsheet computer program (Microsoft Excel 2019) and then exported to the data editor page of SPSS version 15 (SPSS Inc., Chicago, Illinois, USA). Quantitative variables were reported using measures such as means and standard deviations or median and interquartile range, depending on their distribution. The presentation of qualitative variables was in the form of counts and percentages. Confidence level and level of significance were set at 95% and 5%, respectively, for all tests.

RESULTS

The present study included all cases of knee OA in individuals above the age of 30. In the study, there were patients across a range of age groups. A small percentage (6.0%) was under 40 years old, while a larger percentage (21.2%) fell between the ages of 41 and 50. The highest percentage (39.3%) was found in the 61–70 age range. The remaining patients were evenly distributed between the 51 and 60 and above 70 age groups. In this study, there were 21 females (63.6%) and 12 males (36.4%) (Tables 1 and 2).

In the present study, there was no difference between the side of the limb involved as both left and right were involved in 13 (39.39%) cases each and 7 (21.21%) cases had bilateral knee pain.

In the present study, according to Merchant Grade, 7 (17.5%) knees had Grade 0, 18 (45%) had Grade 1, 11 (27.5%) Grade 2, 4 (10%) knees had Grade 3, and none had Grade 4 (Table 3).

In this study, there was increase in mean T2 values with increasing grade of degeneration on X-Ray but it was not statistically significant in both the facets of patella (MF, LF; $p>0.05$) (Table 4).

In this study, a significant correlation was boas found between merchant grade and both facets of patella (MF, LF; $p<0.05$) with T2 map MRI (Table 5).

Table 1: Age distribution

Age (years)	Number	Percentage
≤40	2	6.06
41–50	7	21.21
51–60	9	27.27
61–70	13	39.39
>70	2	6.06
Total	33	100.0

Table 2: Gender distribution

Sex	Number	Percentage
Male	12	36.4
Female	21	63.6
Total	33	100

Table 3: Merchant grade distribution

Grade	Number	Percentage
Grade 0	7	17.5
Grade 1	18	45.0
Grade 2	11	27.5
Grade 3	4	10.0
Grade 4	0	0.0
Total	40	100.0

Table 4: Association between T2 map MRI and merchant grade

MRI	Mt Grade 0 n=7	Mt Grade 1 n=11	Mt Grade 2 n=16	Mt Grade 3 n=6	p-value
	Mean±SD	Mean±SD	Mean±SD	Mean±SD	
MF	33.21±9.32	36.11±7.03	39.77±9.04	45.00±6.45	0.092
LF	33.92±4.75	36.11±11.08	40.68±8.44	43.73±2.50	0.211

Table 5: Correlation between T2 map MRI and merchant grade

MRI	Merchant grade	
	Correlation coefficient	p-value
MF	0.381	0.015*
LF	0.457	0.003*

DISCUSSION

Recent MRI studies have examined various properties of cartilage, including its biomechanical and biochemical characteristics. These studies have measured the GAG and water content, as well as the organization and content of collagen [9]. Quantitative T2 mapping is a technique that has been used to measure cartilage water content and collagen fiber orientation. There is a connection between a focal increase in T2 relaxation time and damage to the cartilage matrix. Specifically, it leads to a loss of collagen integrity and an increase in water content [10].

In the present study, it was found that OA of the knee was more prevalent in females (63.6%) compared to males (36.3%). This finding is consistent with a previous study conducted by Bhandarkar *et al*. (2016) [11], which also reported a higher percentage of female cases (63%) compared to males (37%).

Based on the findings from merchant grade, Grade 0 was detected in 7 cases, Grade 1 in 18 cases, Grade 2 in 11 cases, Grade 3 in 4 cases, and no cases of Grade 4 were identified. The majority of these cases were classified as Grade 1. There was a significant increase in mean T2 values with increasing grade of OA according to K-L grade in all the compartments of cartilage of the tibia. There were several areas of interest in the study, including PLC, PLP, PMA, PMC, PMP, and the trochlea of the femur. The grade of the LT and the medial posterior condyle of the femur showed a significant increase in the medial anterior and central condyle of the femur (CMA, CMC). However, no statistical difference was found in the other compartments of the lateral condyle. These findings align with the results of Li *et al*. (2007) [12], which demonstrated an increase in mean T2 with KL scores (X-ray) and overall cartilage lesion grade. Unfortunately, the statistical significance of this relation could not be tested due to the small sample size of only 10 patients with OA.

In our study, we observed that the T2 value increased as the merchant grade increased in both the medial facet (MF) and lateral facet of the patella (LF). However, it is important to note that this increase was not found to be statistically significant ($p>0.05$). Unfortunately, we were unable to locate any research regarding the correlation between patellar cartilage T2 map MRI and merchant grade.

In the present study, there was a significant correlation ($p<0.05$) observed between the T2 map MRI and merchant grade for both the medial ($r=0.381$) and lateral facet ($r=0.457$) of the patella. Interestingly, the correlation was slightly stronger for the lateral facet compared to the MF.

The stiffness subscore showed a significant correlation ($p<0.05$) with various compartments including LT, CMP, CLC, PMA, PMC, PMP, PLA, and PLC. The T2 map MRI findings showed a significant correlation ($p<0.05$) with various segments, including MT, LT, CMP, CLC, PMA, PM, PMF, and LF, in terms of physical function. In a study conducted by Dunn *et al*. (2004) [13], it was found that there was a noteworthy ($p<0.05$) positive connection between the medial cartilage compartments of the femur and tibia and WOMAC pain scores, which aligns with our own findings.

In this study, a noteworthy correlation was observed between the WOMAC pain subscore and the Merchant Grade, with a slightly weaker correlation found with stiffness and physical function subscores.

We should note that our study had a limitation in terms of the number of patients with early OA (K-L Grade 0=3, Grade 1=8) that was included for analysis. This limited sample size was necessary to examine the normal distribution of cartilage T2 relaxation time and its correlation with severe OA of the knee joint. There were significant variations in T2 values when different acquisition methods were used and when the MRI scans were performed on different scanners [14].

CONCLUSION

T2 map of the articular cartilage correlates to morphologic imaging findings on X-ray with clinical symptoms of OA. The results of this study may indicate the potential of T2 map MRI to quantify pathologic cartilage changes in conditions that alter the biomechanical properties of the knee joint. The development of non-invasive methods to assess early cartilage matrix changes is potentially important to initiate early treatment, monitor disease progression, plan for operative procedure, and follow-up of operative cartilage repair.

CONFLICT OF INTEREST

None declared.

SOURCES OF FUNDING

Nil.

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