Benha Journal of Applied Sciences (BJAS) **print: ISSN 2356–9751**
Vol. (9) Issue (6) (2024), (29-35) **online: ISSN 2356–976x**
http://bjas.bu.edu.eg

Temporal Resolution of The Knee Articular Cartilage by T2 Mapping Technique on High Tesla MRI Compared with Conventional MRI Sequences

Nawres A. Majeed, Hesham E. Elsheikh and Ahmed E. Shaalan
Department of Radiodiagnosis, Faculty of Medicine, Benha University
E-mail: nawrasalrobiey@gmail.com

Abstract

Introduction: The introduction outlines the significance of early diagnosis of osteoarthritis and the limitations of conventional MRI in detecting early-stage cartilage abnormalities. It introduces T2 mapping as a promising technique for early detection and monitoring of cartilage changes. **Aim of the work:** The study aims to evaluate the temporal resolution of knee articular cartilage using T2 mapping on high Tesla MRI compared to traditional MRI sequences. **Subjects and methods:** Twenty patients undergoing 1.5 Tesla MRI of the knee were included in the study. The MRI protocol included standard sequences and T2 mapping. Demographic data, clinical complaints, and MRI findings were analyzed. **Results:** Demographic and clinical data showed no significant differences between the osteoarthritis and control groups. T2 mapping demonstrated potential in identifying cartilage abnormalities and correlating with age and cartilage thickness. **Discussion:** The discussion highlights the importance of accurate knee cartilage evaluation and introduces T2 mapping as a promising method. The study findings support the superiority of T2 mapping over traditional MRI sequences. **Conclusions:** The study concludes that T2 mapping offers superior temporal resolution of knee articular cartilage compared to traditional MRI sequences. It suggests T2 mapping as a quantitative indicator of osteoarthritis severity and advocates for its clinical use in evaluation and treatment monitoring. **Limitations and Recommendations:** Limitations include the small sample size and lack of histopathological testing. Recommendations include larger-scale studies, long-term follow-ups, and correlation with histological data to further validate T2 mapping.

Keywords: Knee articular cartilage, Osteoarthritis, T2 mapping, High Tesla MRI

Introduction

The chondrocytes that make up cartilage are encased in an extracellular matrix that mostly includes water, proteoglycans, and collagen fibers. According to [1], it is a crucial component of degenerative joint diseases such as osteoarthritis (OA).

Deterioration of the knee's articular cartilage over time is a hallmark of osteoarthritis. Individuals and society alike bear enormous financial costs due to this condition, which is thought to affect the majority of joints and is the primary reason for long-term impairment [2].

It is critical to diagnose osteoarthritis early in the clinical context so it can be stopped in its tracks. There is hope that new disease-modifying osteoarthritis drugs and advances in joint preservation strategies will one day change the trajectory of the illness and reduce the pace of joint deterioration [3].

Magnetic resonance imaging (MRI) is the gold standard for diagnosing articular cartilage pathologies due to its high contrast, capacity to acquire and reconstruct in many planes, and higher spatial resolution [4].

The knee's anatomy can be evaluated and any morphological changes can be detected using conventional magnetic resonance imaging (MRI) sequences. Neither morphologic MRI nor radiography of the knee can detect early stages of osteoarthritis (OA) or the response to treatment after cartilage repair procedures [5].

While there are a variety of treatments available for osteoarthritis [6], the effectiveness of these options—which aim to reduce or halt the disease's progression—depend on prompt and precise diagnosis of the disease's stage.

Degenerative cartilage changes associated with proteoglycan loss and collagen network degeneration characterize the early stages of osteoarthritis (OA) prior to morphological abnormalities. Reduced elasticity in the cartilage causes water to move more freely and, as a result, the proton concentration of H2O to rise [7].

Articular cartilage changes can be more accurately and earlier depicted with quantitative imaging techniques of the knee, such as the T2 mapping sequence. According to [8], these techniques are compositional evaluation tools that can reveal alterations in the collagen network, water content, and cartilage's three-dimensional ultrastructure.

T2 mapping, an MRI technique that is biochemically sensitive and can add strong indicators for disease onset and progression, could be a helpful diagnostic tool for identifying and tracking down cartilage abnormalities [3].

Previous studies have demonstrated that the T2 mapping sequence can be impacted by T2 prolongation, which is produced by cartilage deterioration in knee osteoarthritis [6]. T2 values may be associated with radiographic late-stage osteoarthritis in some studies, but not in others [9].

Aim of the work

In order to evaluate the temporal resolution of the knee articular cartilage, this study compares traditional MRI sequences with high tesla MRI using the T2 mapping approach.

Subjects and methods

Twenty patients out of sixty-three who were sent for 1.5 tesla magnetic resonance imaging (MRI) of the knee joint at the diagnostic radiology department of Benha University Hospitals between November 2022 and May 2023 made up this observational study.

The Benha University ethics committee gave their stamp of approval before any informed consents were signed. A secret code and an explanation of the study's goal were given to each patient.

Inclusion criteria:

• To patients of every age.
• People of all sexes were present.
• Patients affected by a variety of knee diseases, including OA and meniscus lesions, who needed 1.5 tesla MRI.

Exclusion criteria:

For example, if you have a pacemaker, cochlear implant, cerebral aneurysm clip, ocular metallic foreign body, a history of knee joint surgery, acute arthropathy, or are near any major arteries or organs, you should not get an MRI.

This was applied to all cases that were part of the study:

A. Thoroughly collecting medical history, including vital signs (such as age, sex, and illness history).
B. A comprehensive medical evaluation that takes into account all systems and monitors vital signs.
c. A full blood count, random blood sugar tests, and other routine laboratory evaluations
• The functioning of the kidneys and the liver.
d. Knee MRI scanner

MRI protocol

An MRI scan (Signa; GE Healthcare, USA) with a 1.5 Tesla motor was used for the procedure.

• The following were the standard MRI sequences: sagittal T2-WI (2 min 58 s; repetition time/echo time: 3000/81 ms), axial T2-weighted images (3 min 19 s), sagittal T1-weighted images (435/10 ms; duration: 2 min 55 s), sagittal proton density-WI (2440/40 ms; duration: 2 min 38 s), coronal proton density-weighted images with fat saturation (3890/40 ms; duration: 2 min 25 s), and axial merge (750/16 ms; duration: 2 min 27 s) with a knee coil. This device has the following specifications: a 10 by 10 mm viewing area, a 320 × 224 matrix, a 4 mm space between slices, and a 4 mm thickness between each slice. Three sets of axial data were analyzed via the knee using FSE with a 1000-repetition-time and eight echo times (8.4 ms, 16.8 ms, 25.2 ms, 33.5 ms, 41.9 ms, 50.3 ms, 58.7 ms, and 67.1 ms) to provide T2 mapping. The specifications include an optical field of view (FOV) ranging from 90 to 130 mm, a matrix of 256 × 256, a slice gap of 3.5 mm, and a slice thickness of 3 mm.

The entire T2 map took about four or seven minutes to obtain. To make a T2 colored map, we just used the program's basic features and settings. With default parameters ranging from 11 to 89 ms, the computed cut-off point for the T2 intensity is 50 ms. The color scale ranges from red to blue, with green or blue indicating a high T2 value on at least two consecutive slices. Once the MR images were transferred to a workstation, the T2 values and cartilage thickness were quantitatively measured offline for each patient. The average T2 value was determined by manually constructing and examining an elliptical ROI on the sequences. Areas of interest were delineated using a border of 0.5 to 1 mm from the bone's surface to exclude subchondral bone. Standard MRI and a related T2 map could be shown simultaneously on the PACS thanks to a multi-planar localization key.

Fig. (1) Normal medial and lateral menisci. Sagittal proton density- weighted (PDW) magnetic resonance (MR) image in a 41-year-old male with normal anterior and posterior horns of the medial meniscus.

Images acquired with SESE sequence as well as the T2 map result.

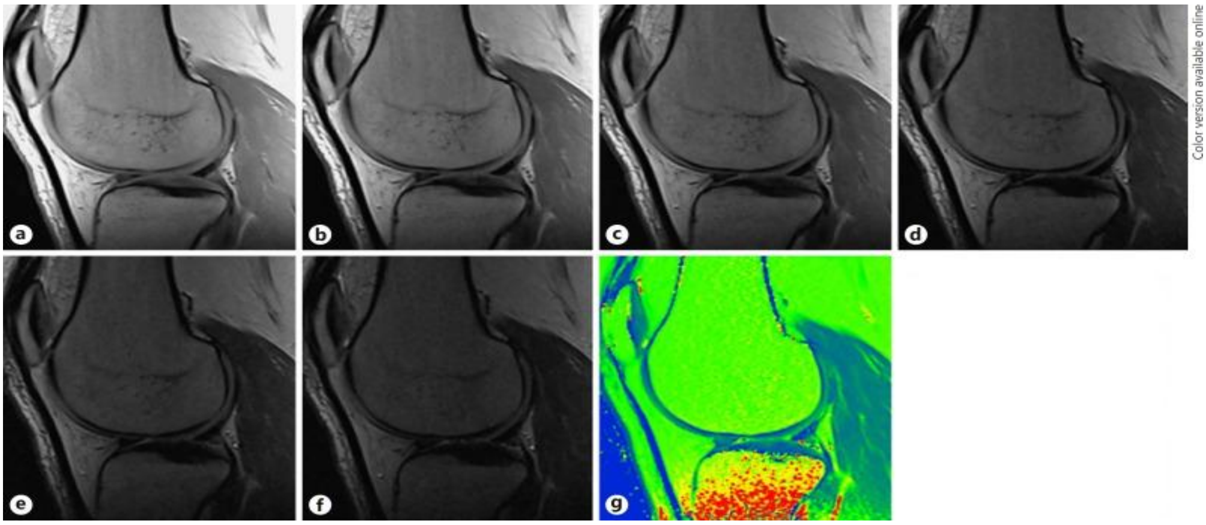

Fig. (2) Images from the SESE reference sequence acquired with different TEs as well as the resultant T2 map. **a** TE = 12 ms. **b** TE = 24 ms. **c** TE = 36 ms. **d** TE = 50 ms. **e** TE = 60 ms. **f** TE = 70 ms. **g** T2 map.

Statistical analysis:

Data was cleaned, processed, and put into tables using the Statistical Package for the Social Sciences (IBM Corp. Released 2017). IBM SPSS Statistics for Windows, Version 25.0, Armonk, New York, USA: IBM Corp. Data were presented and evaluated correctly for each parameter according to the type of data obtained.

• Data normalcy

To ensure that the data was distributed normally, the Shapiro-Wilk test was employed.

• Statistics for description:

• Numberal data mean and standard deviation (± SD).

• The percentage and frequency of data that is not numerical.

When comparing the means of the two groups, the analytical statistics tool known as the Student T Test was employed to determine whether the difference was statistically significant.

To determine if there was a statistically significant difference in a non-parametric variable between the two groups of participants, the Mann Whitney U test was utilized.

• Two qualitative variables were examined for their association using the Chi-Square test.

• A correlation analysis can be used to determine how strongly two quantitative variables are related to one another.

One helpful tool for assessing the specificity and sensitivity of quantitative diagnostic tests that classify cases into two categories is the receiver operating characteristic curve, or ROC Curve. Maximizing the area under the curve (AUC) value was used to establish the optimal cut off point. According to area under the curve (AUC), a test with a value higher than 0.9 is considered to have high accuracy, 0.7-0.9 stands for moderate accuracy, 0.5-0.7 for low accuracy, and 0.5 for a chance result.

• Results' likelihood

If the p-value is less than 0.05 with a 95% confidence interval, it is deemed significant.

Results

Demographic and clinical data

Table (1) Demographic data in the studied groups.

Variable		Osteoarthritis group n=53	Control group n=10	*test*	*p*
Age (years)	Mean ±SD	39.9 ± 12.8	41.3 ± 14.8	X^2=0.160	0.873
Gender, n (%)	Male	41(77.4%)	6(60%)	t=1.338	0.247
	Female	12(22.6%)	4(40%)		

t= t student test; X^2=Chi square test; *: Significant ≤0.05

The current study carried on 63 subjects divided into two groups:

- **Osteoarthritis group (n=53):** Cases with various knee pathologies, including osteoarthritis and meniscus lesions.
- **Control group (n=10):** Cases without knee pathologies.

According to demographic data, the mean age of osteoarthritis group was 39.9 ± 12.8 years and 41.3 ± 14.8 years in the control group. In terms of gender, the osteoarthritis group consisted of 41 males (77.4%) and 12 females (22.6%), while the control group consisted of 6 males (60%) and 4 females (40%). The difference in age and gender distribution between the two groups was not statistically significant.

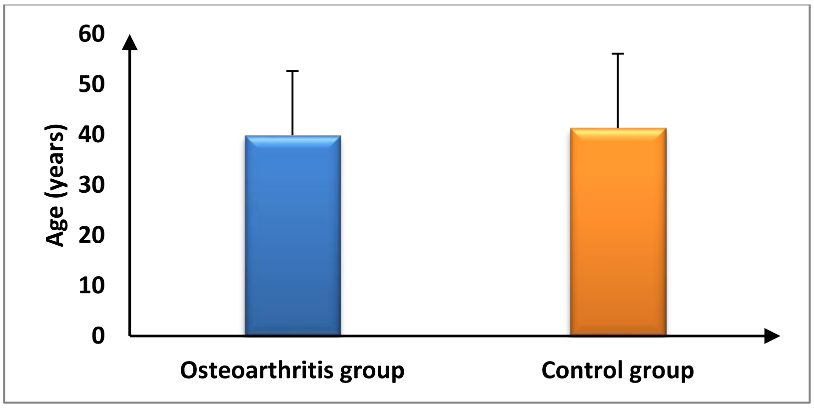

Fig. (3) Age in the studied groups.

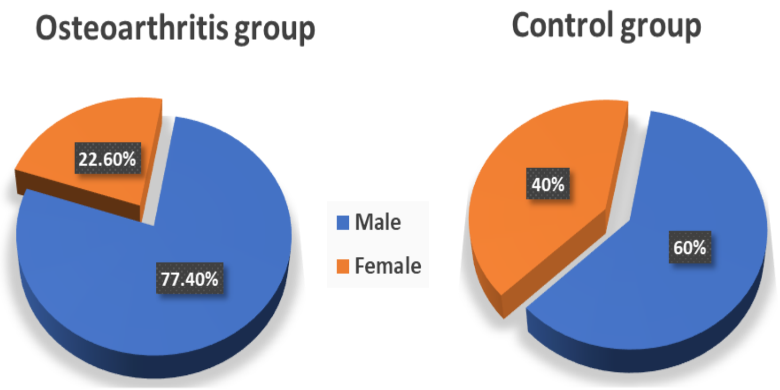

Fig. (4) Gender frequencies in the studied groups.

Table (2) Distribution of complaints in the osteoarthritis groups.

Variable		Osteoarthritis group n=53
Complaint, n (%)	Edema	10(18.9%)
	Knee Pain	29(54.7%)
	Limitation of movement	14(26.4%)

According to patient complaint in the osteoarthritis group, 10 individuals (18.9%) complained of knee swelling and edema, 29 individuals (54.7%) complained of knee pain, and 14 individuals (26.4%) complained of limitation of movement.

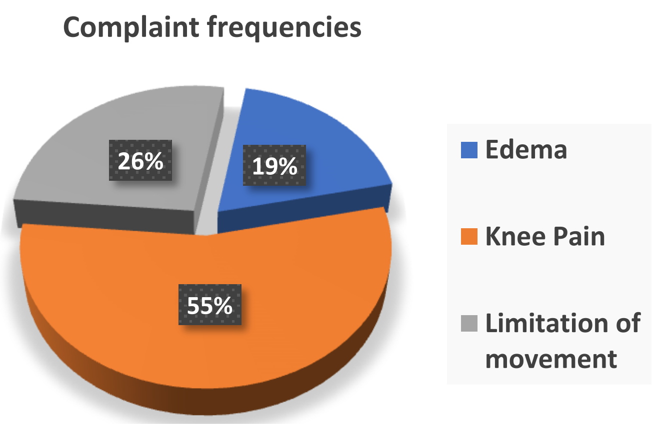

Fig. (5) Frequencies of complaint in osteoarthritis group

Case Presentation

Case 1

29 years old female, with left knee pain following a fall on the ground. No clinical signs of AO.

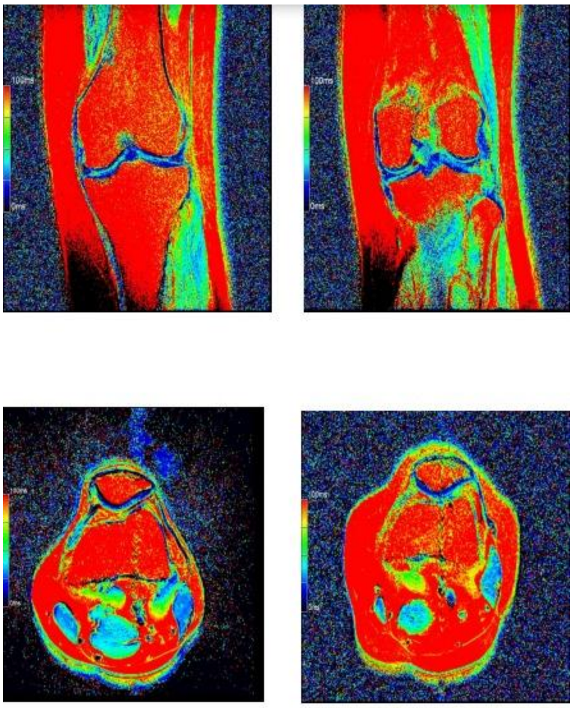

Fig. (6) Axial and coronal T2 mapping images shows no evidence of significant cartilage.

Discussion

As a weight-bearing joint, the knee is vulnerable to a number of diseases and conditions, such as osteoarthritis and meniscus tears. According to [10], those who suffer from these illnesses may have a decrease in quality of life, functional disability, and intense discomfort.

In order to diagnose, prepare for, and monitor these diseases, an accurate evaluation of the knee articular cartilage is essential. New imaging methods have become useful for assessing the knee joint and revealing specifics about the articular cartilage's structural health and functional alterations in the last several years [11].

Since traditional MRI has better soft tissue contrast and multiplanar capabilities, it has been extensively employed to evaluate the knee joint. It reveals important details regarding the anatomy and anomalies of the knee joint's articular cartilage, synovium, menisci, ligaments, and more. While it is essential to understand the severity and course of cartilage deterioration, traditional magnetic resonance imaging (MRI) sequences may not be able to adequately portray the knee articular cartilage's temporal resolution [12],[13].

Researchers have looked into new magnetic resonance imaging (MRI) methods that can evaluate the articular cartilage quantitatively and qualitatively to get beyond these constraints. Among these methods, T2 mapping has recently come to the forefront [8].

Measurements of T2 relaxation periods, made possible by T2 mapping, provide light on the cartilage's structural integrity and water content. It is feasible to learn about the cellular level microstructural changes in the articular cartilage by quantifying the T2 values. This method may help us better understand diseases of the knee cartilage, and it has already demonstrated promise in other musculoskeletal contexts [13].

The use of T2 mapping to evaluate the knee's articular cartilage has been the subject of multiple promising investigations. It has been shown that T2 mapping can detect early signs of cartilage deterioration, track the evolution of diseases, and assess the efficacy of treatments. In addition, it might be used as a non-invasive way to gauge how well cartilage restoration surgeries worked and as a biomarker to determine who is at risk of getting osteoarthritis. Additional study is required to confirm its practicality in the clinic, evaluate how well it performs in comparison to traditional MRI sequences, and develop uniform protocols for its application [9].

So, this study set out to compare traditional MRI sequences with high tesla MRI using the T2 mapping approach to see how well it evaluated the knee articular cartilage's temporal resolution.

In this observational study, 63 individuals were included who were scheduled for 1.5 tesla magnetic resonance imaging (MRI) of the knee. One group of patients had knee conditions such as osteoarthritis or meniscus lesions, while the other served as a control group for those without these conditions. Every individual who took part in the study had a thorough medical history, physical examination, and standard laboratory testing. The magnetic resonance imaging (MRI) procedure comprised standard MRI sequences such T2-weighted, proton density-weighted, and T1-weighted images, in addition to T2 mapping sequences. We measured cartilage thickness and T2 values from the obtained images.

The average age in the osteoarthritis group was 39.9 ± 12.8 years, while in the control group it was 41.3 ± 14.8 years, as seen in the demographic data. The gender breakdown of the participants was as follows: 41 men (77.4% of the total) and 12 females (22.6%) made up the osteoarthritis group, whilst 6 men (60%) and 4 females (40% of the total) made up the control group. There was no statistically significant variation in the distribution of age or gender between the two groups. In the group of patients with osteoarthritis, 10 people (18.9%) reported swelling and edema in their knees, 29 people (54.7%) reported discomfort in their knees, and 14 people (26.4%) had difficulty moving around due to their condition.

Conclusions

We conclude that T2 mapping on high tesla MRI, in comparison to traditional MRI sequences, offers superior temporal resolution of the knee articular cartilage and yields important insights. This method has the makings of a quantitative indicator of the severity of osteoarthritis, since it correlated strongly with both age and cartilage thickness in patients. When compared to traditional MRI, T2 mapping was more sensitive and accurate in identifying cartilage abnormalities and osteoarthritis. Additionally, it demonstrated potential in compartment-specific evaluation, which involves differentiating between various knee compartments. These results lend credence to T2 mapping's potential as a clinical tool for bettering the evaluation, tracking, and therapy of knee diseases, leading to more tailored approaches.

Limitations

• The statistical power and accuracy of the results were impacted by the study's small sample size of 63 cases, which may have limited the findings' generalizability.
• At one point in time, the study's primary objective was to measure how much the knee articular cartilage had healed.
• The study failed to incorporate histopathological testing of the knee articular cartilage.
• Additionally, T2 mapping was not compared to other established methods, including arthroscopy or histopathological investigation.

Recommendations

• To improve the results' generalizability, larger-scale prospective studies involving multi-center corporations are required.
• If we want to know how well T2 mapping predicts disease progression and treatment results, we need trials with long follow-up periods.
• To further understand the underlying tissue alterations, it would be helpful to correlate the MRI results with histological data.
• It is still not known whether T2 mapping can be used to evaluate other knee conditions, like synovial illnesses or ligament damage.
• T2 mapping results may not be reproducible or comparable among centers due to differences in imaging techniques and software settings.

References

[1] Mars, M., Chelli, M., Tbini, Z., Ladeb, F., & Gharbi, S. (2018). MRI T2 mapping of knee articular cartilage using different acquisition sequences and calculation methods at 1.5 Tesla. Medical Principles and Practice, vol :27(5), PP.443-450.

[2] Mobasheri, A., & Batt, M. (2016). An update on the pathophysiology of osteoarthritis. Annals of physical and rehabilitation medicine, vol: 59(5-6), pp.333-339.

[3] AlSayyad, A., Salah, F., Bardon, J., Hirchenhahn, P., Shihata, L., Houssiau, L., & Plapper, P. (2021). Laser ablation of titanium alloy (Ti64): effects of process parameters on performance of laser welded Ti64–polyamide 6.6 joints.

[4] Van Dyck, P., Vanhevel, F., Vanhoenacker, F. M., Wouters, K., Grodzki, D. M., Gielen, J. L., & Parizel, P. M. (2015). Morphological MR imaging of the articular cartilage of the knee at 3 T—comparison of standard and novel 3D sequences. Insights into imaging, vol:6, pp.285-293.

[5] Liebl, H., Joseph, G., Nevitt, M. C., Singh, N., Heilmeier, U., Subburaj, K., ... & Link, T. M. (2015). Early T2 changes predict onset of radiographic knee osteoarthritis: data from the

osteoarthritis initiative. Annals of the rheumatic diseases, vol:74(7), pp.1353-1359.

[6] Roos, E. M., & Arden, N. K. (2016). Strategies for the prevention of knee osteoarthritis. Nature Reviews Rheumatology, vol:12(2), pp.92-101.

[7] Ege, F. (2021). Pathogenesis, Pathology and Genetics of Osteoarthritis. In Rheumatoid Arthritis. IntechOpen.

[8] Banjar, M., Horiuchi, S., Gedeon, D. N., & Yoshioka, H. (2022). Review of quantitative knee articular cartilage MR imaging. Magnetic Resonance in Medical Sciences, vol:21(1), pp.29-40.

[9] Zhao, Y., Ou, Q., Cai, Y., Ruan, G., Zhang, Y., & Ding, C. (2022). Shedding light on experimental intra-articular drugs for treating knee osteoarthritis. Expert Opinion on Investigational Drugs, vol:32(6), pp.509-524.

[10] Ozeki, N., Koga, H., & Sekiya, I. (2022). Degenerative meniscus in knee osteoarthritis: from pathology to treatment. Life, vol:12(4),pp. 603.

[11] Karpiński, T. M., Ożarowski, M., & Stasiewicz, M. (2022, November). Carcinogenic microbiota and its role in colorectal cancer development. In Seminars in cancer biology (Vol. 86, pp. 420-430). Academic Press.

[12] Nacey, N. C., Geeslin, M. G., Miller, G. W., & Pierce, J. L. (2017). Magnetic resonance imaging of the knee: An overview and update of conventional and state of the art imaging. Journal of Magnetic Resonance Imaging, vol:45(5), pp.1257-1275.

[13] Florkow, M. C., Willemsen, K., Mascarenhas, V. V., Oei, E. H., van Stralen, M., & Seevinck, P. R. (2022). Magnetic resonance imaging versus computed tomography for three‐ dimensional bone imaging of musculoskeletal pathologies: a review. Journal of Magnetic Resonance Imaging,vol: 56(1), pp.11-34.

[14] Cao, S., Wei, Y., Yao, Z., Yue, Y., Deng, J., Xu, H., ... & Zeng, H. (2023). A bibliometric and visualized analysis of nanoparticles in musculoskeletal diseases (from 2013 to 2023). Computers in Biology and Medicine, vol:169, pp.107867.