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Research Article

The Effect of 9.4 Tesla Magnetic Resonance Imaging on Microleakage in Amalgam Fillings

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Abstract

Statement of the problem: In dentistry, while the bony structure can be observed perfectly through the X-ray based diagnostic techniques; imaging soft tissue fails to satisfy. In these cases, MRI becomes an alternative; however, the orofacial region which often contains restorations with miscellaneous metals causes major disadvantage for this imaging modality.

Objective: The aim of this study is to observe the effect of 9.4 Tesla (T) MRI on amalgam fillings within the frame of microleakage.

Materials & Methods: Class V cavities were prepared and filled with amalgam restorations with 3 different silver contents on 120 teeth which were extracted for various reasons. Whole tooth surface was covered with 2 layers of nail varnish, and cyanoacrylate-containing glue to prevent the basic fuchsine leakage. Equal numbers of teeth were randomly chosen from different silver content groups to create separated control groups. The case groups were exposed to magnetic field with a certain cranial imaging protocol in a 9.4T device. The teeth were bisected from the middle axis of the restorations after being held in a basic fuchsine solution for 24 hours. The microleakage was scored by 3 restorative dentistry specialists. The results were evaluated statistically.

Results: Using the intraclass correlation coefficient, the accordance among the evaluators was evaluated as perfect. No statically significant difference was found between the groups.

Conclusions: In context of microleakage, 9.4T MRI has no effect on the leakage between amalgam and tooth cavity.

Keywords: Amalgam, Class V Cavity, Microleakage, Magnetic Resonance Imaging, Tesla, Ultra-High Field Magnetic Resonance Devices, Projectile Effect, Biocompatibility

Introduction

In contemporary dentistry, new techniques and methods of magnetic resonance imaging (MRI), with which tomographic images can be acquired without using X-ray, are recommended. MRI allows insight of the high contrast resolution cross-sectional images of human body with a powerful magnet and radio waves.[1,2] Tesla (T) is the magnetic field unit used for magnetic resonance imaging.[3,4]

3T MR devices started to be put into clinical use in the 2000s, are called "High-Tesla MR Devices". 0.5T; 1.5T and 3T devices are in routine clinical use in our country for medical imaging. It was stated in 2016 that 50 High-Tesla MRI devices were globally being used actively at 40 medical centers.[5] Systems which have 7T and above magnetic field strength have been just put into clinical use from an experimental environment are called "Ultra-High Field Magnetic Resonance Devices" (UHF MRI).[6,7] FDA approved the convenience for clinical use of 7T devices in 2017. Beside the detailed anatomical imaging, high-T devices are capable of magnetic resonance spectroscopy (MRS) that shows the biochemical structure of the tissue and tissue and the functional magnetic resonance imaging (fMRI) where brain mechanism is mapped.5 It is stated that application of these sophisticated techniques to broad spectrum neurologic diseases such as epilepsy, brain tumors, psychiatric diseases, multiple sclerosis and Alzheimer, will provide detailed anatomical, functional and metabolic information.

The disadvantages of MRI are mainly derived from the magnetic field power of the device and the effects created by technique. The main components of MR system are magnet, gradient system and radiofrequency (RF) electromagnetic pulse chain.[6] Static magnetic field interacts with the human body in molecular, cellular, textural and visceral levels. The gradient system forms a weak magnetic field that superposes on static magnetic field.[6] RF transfers some part of electromagnetic pulse energy to tissue as heating. This energy transfer has been limited by the International Electrotechnical Commission (IEC) and the Food and Drug Administration (FDA).[8,9] In some studies, it was reported that some patients and employees talked about some subjective symptoms such as tingling, vertigo, muscle contraction, metallic taste in mouth and tinnitus.[6,7,10]

The main danger of magnetic field is derived from "the projectile effect" that pulls ferromagnetic objects rapidly into the MR device. It was reported that the objects, without mattering how big in size were (from hairclip to oxygen tube and stretcher), caused accidents by

being pulled into the device.[11] All the objects that get into the magnetic field show 3 types of magnetization, particularly ferromagnetic, paramagnetic and diamagnetic ones, at the rate of magnetic sensitivity.[12] Ferromagnetic objects are the substances that show strong gravity; contain iron, nickel, cobalt and alloys. Paramagnetic objects are pulled by the object that turns it into a magnet. As for the diamagnetic ones, when exposed to magnetic field, tiny electron activation occurs and affected weakly. Copper, silver, gold, water and hydrogen are in this group.[12]

Orofacial region is an area occupied by lots of metals. Among these metals there are crown-bridges, inlay-onlay restorations, fillings with metal contents, splints and orthodontic wires.[12] These materials contain mostly precious (Au, Ag, Pt) and non-precious alloys (Cr, Co, Mo, Ni), amalgam, pure gold, titanium and titanium alloys.[13] Dental implants and surgical reconstructive materials are made mostly with titanium, stainless steel and vitallium.[12] The studies that were done in order to determine MR features of these materials are performed through in-vitro test methods.[12,14,15]

Amalgam, which is among the oldest filling material that have been used in dentistry in order to restructure the missing tooth tissue, formed %75 of the restorations until the 70s.[16,17] Amalgam cannot be attached chemically to the cavity walls and it holds on the tooth mechanically. Mercury and copper inside amalgam are diamagnetic. There are numerous studies that analyze the interaction between magnetic field and human body and in which different methods are used.[18-20]

Even though the security records of UHF MRI have been pretty satisfactory over the last decade, it is still classified among investigational new devices.[7] In the literature there are studies in which the teeth with amalgam filling viewed through MRI are analyzed in regard to microleakage.[15,20] The translational interaction and the heating rates of dental materials in magnetic field have been analyzed with MRI.[21,22] The aim of this study is to investigate whether UHF MRI causes microleakage in amalgam fillings or not.

Materials & Methods

In this study, the presence of microleakage into the teeth with amalgam fillings that were exposed to 9.4T magnetic field has been evaluated in-vitro with the approval of Kırıkkale University, Clinical Researches Ethics Committee.

-Preparation of the Samples

120 molar and premolar teeth without decay were put into isotonic saline solution after the extraction process on condition that it wouldn't last more than 3 months. Each tooth after surface debridement, was polished with pumice and rubber drill. With mesiodistally 4 mm, occlusogingivally 3 mm widths, 2 mm deep class V cavities were prepared on the buccal and lingual surfaces of the sample teeth, with a high-speed handpiece using a diamond burr under water cooling. Cavities were filled with amalgam with 3 different silver contents (Group A: 45%, Group B: 55%, Group C: 68% Ag) under standard conditions. Whole crown surface excluding a 1 mm distance to the filling peripherally was covered with 2 layers of nail varnish and roots with additional cyanoacrylate-containing glue in order to prevent the basic fuchsine leakage. Teeth for control groups with equal numbers were randomly chosen and separated as (A*, B*, C*). 3 control and 3 study groups, each with 20 teeth, were established.

-Ultra-High Field Magnetic Resonance Imaging

MRI group was sent to ultra-high field magnetic resonance center abroad (Scannexus, Maastricht, Nederland). The applications in other groups were performed 1 week later following the filling process since the transportation of the teeth and the researcher to imaging center took 1 week. Magnetic resonance imaging executed with exposing samples to static and transitional magnetic field nearly 20 minutes in 9.4T device (Siemens MAGNETOM system) by applying a specific head imaging protocol (Thin slice T1 axial precontrast/postcontrast, T1 axial fast spin echo, T2 axial fast spin echo, T1, MPRAGE, T2*, T2 FLAIR, T2 coronal and sagittal fast spin echo). The teeth in control group at the end of the 9th day; following the imaging of the teeth in experimental group, remained in %2 basic fuchsine solution for 24 hours. Afterward, the teeth were washed and dried (Figure 1).

Figure 1. Class V amalgam filled teeth that were imaged through MRI, were held in fuchsine solution, washed and prepared.

-Cutting the teeth

Each tooth was embedded into a self-cured acrylic block to the 2/3 of its roots. Each sample was bisected buccolingually along the line passing in the middle of the fillings with a sensitive low speed cutting device MICRACUT -125 (Metkon Instruments Ltd, Bursa, Turkey). The cutting process was made under lubricant liquid and water cooling. The diamond cutting wheels were changed after each 15 sample as they lost their sharpness.

-The scoring of microleakage

The teeth broken and teeth with fillings dislodged during the bisection were excluded from the study. The teeth that show faulty coloration leaking out of the cavity were excluded from scoring. The axial and gingival margins of the restorations of all the pieces acquired were evaluated and scored under a dental microscope (OPMI pico, Dental Microscope, Carl Zeiss, Germany) by three specialists who were not given the knowledge of the groups the samples belong.

The coloring scoring between tooth and filling was made as follows (Figure 1 and Figure 2);

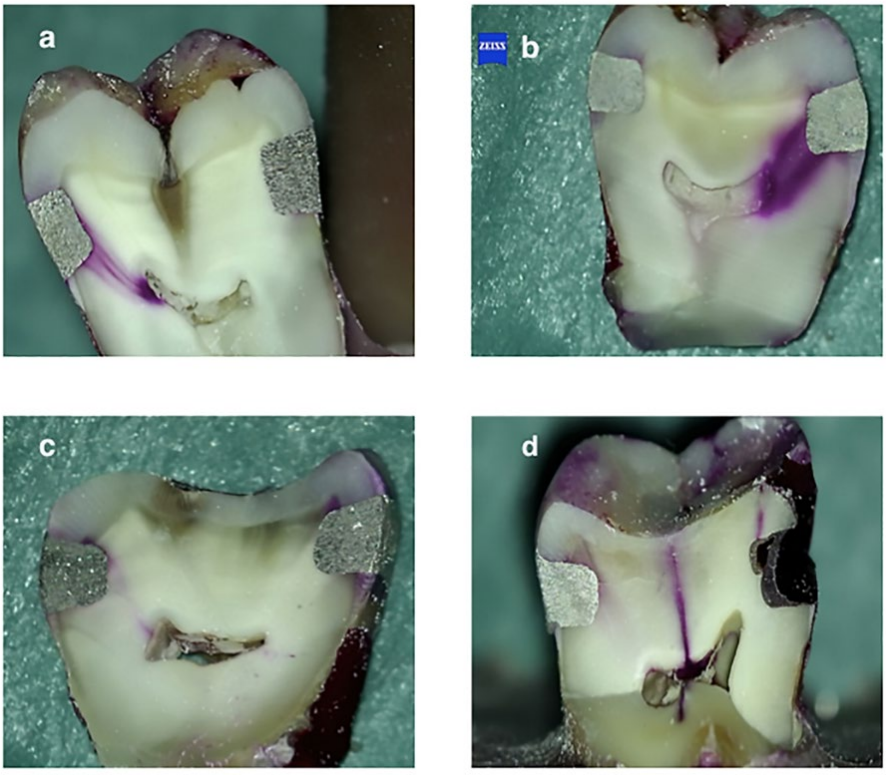
0: There is no color penetration

1: There is coloring along the enamel

2: There is penetration along the dentine and enamel junction but there is no coloring on the axial wall

3: There is coloring including axial Wall

Figure 2. Microleakage scores: a- While the score is 0 on the right, it is 3 on the left; b- Score 1 leakage on the left and score 3 on the right; c-Second-degree leakage; d- Inappropirate coloring and dislogging of filling from cavity (the teeth that were excluded from the evaluation)



-Statistical Analysis

Interclass correlation coefficient and % 95 confidence intervals were calculated to evaluate the accordance between the evaluators. Saphiro Wilk test was used in eligibility check of numeric variables to normal distribution. During the comparing of non-normally distributed

variables in two independent groups Mann whitney U test and for the comparing in more than 2 independent groups Kruskal Wallis tests were used. A package software was used for statistical analysis (SPSS for Windows version 24.0) and P > 0.05 was accepted significant statistically.

Results

Accordance between the evaluators has been tested by employing Interclass correlation coefficient. It was observed that the ICC value was generally above 0.95 and the accordance among the observers was commented as perfect (Table 1).

Table 1. The accordance among observers.

Group	Intraclass Correlation	95% Confidence Interval		P
		Threshold	Majorant	
Group A	0.982	0.972	0.988	0.001
Group B	0.995	0.992	0.996	0.001
Group C	0.965	0.948	0.977	0.001

When the fillings with 3 different contents were evaluated among themselves with Kruskal Wallis test, no statistically significant difference was detected between A, B and C groups (P = 0.193) (Table 2).

Table 2. Microleakage scores of different silver contents which imaged with 9.4T MRI. When A, B, and C groups were compared among them, no statistically significant difference was detected among the groups (P = 0.193).

Test: Kruskal Wallis			Measuring				
		n	Average	Std deflection	Median	25%	75%
Group	Group A	61	2.07	1.25	3.00	1.00	3.00
	Group B	71	1.92	1.29	3.00	0.00	3.00
	Group C	71	2.35	0.99	3.00	2.00	3.00

When A, B, and C groups that were viewed through magnetic resonance imaging were compared through controls (A* B* C*), no statistically significant difference was detected between the groups (Table 3).

Table 3. The comparing of microleakage values among Case and Control groups: When A, B, and C groups were compared through controls (A* B* C*), no statistically significant difference was detected among the groups.

Comparison of control case group		P value
Group A*	Group A	0.246
Group B*	Group B	0.061
Group C*	Group C	0.884

Discussion

Dental amalgam is a material which is used clinically for over 200 years and today, criticism about this material has been increased after the development of alternative filling materials. However, FDA announced in its report published in 2009 that no scientific evidence was found to affect the usage of amalgam negatively.[15,16] In this study, we tested whether the magnetic resonance imaging with an ultra-high magnetic field had an effect of microleakage between the teeth and the filling in the amalgam filled teeth.

For the dental restorations to last long and maintain the pulp health, the adaptation of the filling to the cavity walls has a critical importance. There are various in vivo and in vitro methods for examining the microleakage. These are: penetration tests of the coloring agent, chemical markers, bacterial studies, air pressure method, neutron activation analyses, electrochemical studies, autoradiographic method, electron microscope and the examination done with the microtomography (micro-CT) devices.[23,24] In our study, we evaluated the microleakage under dental microscope with basic fuchsine infusion to dentin tubules thanks to its easiness of accessibility, clinical application and enabling to fast and direct measurements. During the study, we also tested to observe the microleakage with a micro-CT scan on 2 sample however, because of the artifact formation originated from the amalgam no evaluable images could be obtained.

To be able to test the microleakage, the coloring agent should diffuse only through the cavity borders. Applying the nail varnish only a single layer falls short of amount as we experienced in our previous study in 2013. Therefore, 2 layers of nail varnish were applied to the crown of the tooth and cyanoacrylate-based glue to the root surface, to isolate apical openings

and possible cracked areas. The samples with undesired coloring leakages from the cracks despite the isolation procedure and from the surfaces which were not covered with enamel were excluded from the study.

Previous studies on the effects of high magnetic fields up to 19T-30 on various metallic alloys, it was reported that they influenced the phase transformations, recrystallizations, and the distribution of the particle structures.[25,26] In their research with low magnetic field of 0.2 T and 1.5 T, Alkurt et al[27] couldn't detect any phase transformations in dental amalgam.

Amalgam is a dynamic biomaterial that contains different phases according to its content ratios and during its hardening. Not researching the phase transformation between different silver contents could be considered as one of the limitations of this study. Nevertheless, putting into consideration the magnetic features of silver, we aimed to compare the different ratios of silver in terms of microleakage.

There are 3 studies to the authors' knowledge in which microleakage, and magnetic field interactions were evaluated. First of them is the study that was done with 1.5T magnetic field by Shaidi[28] and his colleagues in 2009. In this study, the researchers have used 3 different brands of amalgam. The second study found study was the microleakage research that was performed by the authors of the current study with a 3T MRI device in 2013.[29] In our study like the previous one, we used 3 different amalgam restoration materials which included 45%, 55% and 68% Ag (İnci Dental, İstanbul, Turkey) and tested them on a 9.4T device. The third study evaluated the microleakage of amalgam bonding procedure which was also performed with a 1,5 T MRI device, and no significant differences were detected between the microleakage scores.[29] While Shaidi et al[28] couldn't find significant differences regarding microleakage between the control and the MR application groups of Cinalux, they observed significant differences of microleakage between GS-80 and Vivacap groups. Selmi et al[29] couldn't find any significant differences between fillings with various silver contents which were imaged in a magnetic field with a 3T machine, although found significant differences between all of the MRI and control groups in terms of microleakage values though. However, we couldn't detect an important variation between the MRI groups and the control group in our study with 9.4T. These experiments performed with magnets of various powers are the first studies in the literature and they need to be tested again with different experiments.

While the numbers are increasing every day, there are more than 60 7T or above magnetic resonance imaging devices being used all over the world.[30] With their very high field

power, these systems cause storage of more radiofrequency energy in comparison with the 1.5T MR systems.[30] The doubling of the field power (i.e. 1.5T and 3T) will lead to the storage of 4 times more RF energy in the same pulse sequence.[31] With the result of resistive losses, a big amount of this energy is transformed to thermal energy within the patient's tissues.[32,33] There have been studies on the security of the 7 T devices in the clinical practice with the implants in the human body and the metals used in the dental medicine.[34,35] In their study in which 28 implants and foreign objects in the cranial region were tested, Dula and colleagues[34] reported that 8 of the objects that were found to be safe for the 7 T were posing a potential risk. Oriso et al[35] evaluated full metal crowns, attachment holders, implants and abutments from the point of their heating up in a 7T MR device. However, the dental restorations mentioned in this study are not the amalgam fillings; they are the gold, platinum-gold, silver, chromium-cobalt and nickel-chromium alloys used in full metal crowns. In some studies, it was stated that external magnetic fields might affect some metallurgic reactions such as recrystallizations, particle border migrations and phase transformations in alloys.[36,37] Selmi and colleagues[38] stated that by the effect of 7T MR imaging a quite higher value than the WHO threshold values of mercury intake was leaked from amalgam filled teeth after 24h of imaging. The mercury release from the filling results with the structural changes in the amalgam.

To the authors' knowledge, the current study is the first research that evaluated the effect of these changes to the microleakage occurred by the result of an ultra-high field magnetic resonance imaging.

Conclusion

Although restorations containing metals like amalgams, orthodontic brackets and braces, implants and many fixed prosthodontic restorations which exist in the majority of the population are not classified as contraindications for MRI, more studies should be conducted on the effects of relatively new developed ultra-high magnetic fields on dental restorations.

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