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Microleakage of amalgam restorations after exposure to electromagnetic fields from common Wi-Fi routers, LTE mobile network and 3T MRI

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Abstract
Objectives: To evaluate the effect of exposure to Wi-Fi signals, LTE mobile networks and MRI on the microleakage of amalgam.
Method: Standard class V cavities were prepared on the buccal surfaces of 40 extracted human premolar teeth. The samples were divided into three exposure groups and one non-exposed control group of 10 teeth each. The specimens in the experimental groups were exposed to a radiofrequency (RF) radiation emitted from a commercial 2.4 GHz Wi Fi router (group I), LTE mobile network (group II) and a magnetic field of 3 T for 20 min (group III).The distance between the Wi-Fi router, LTE mobile network and samples was 30 cm and the router was exchanging data with a laptop computer that was placed 20 m away from the router. Teeth samples in exposure group (group A and B) were exposed to RF for 3 days. Then the teeth were sectioned and scored for microleakage under a stereomicroscope.
Results: The result showed that the score of microleakage (percentage taken) was significantly higher in the exposure group I, II and III than that of control group. The scores of microleakage were not significantly different between the exposure group I and II. The scores of microleakage were significantly higher in group III as compared to other experimental groups.
Conclusion: Exposure of patients with amalgam restorations to radiofrequency radiation emitted from conventional Wi-Fi devices, mobile networks and 3T MRI can increase mercury release from amalgam restorations.

Keywords: Amalgam, Wi-Fi, MRI, mercury release, radiofrequency, electromagnetic fields

1. Introduction
Dental amalgam has been used widely for more than 150 years for restoring posterior teeth. The first use of a room-temperature mixed amalgam as a restorative material are attributed to Bell in England (1819) and Taveau in France (1826), who advocated a mixture of silver and mercury as a filling material [1, 2]. Dental amalgam is an alloy comprised of 50 % elemental mercury and a mixture of other metals such as silver, tin, copper, and sometimes palladium, indium and zinc [3-5]. Dental amalgam has many advantages such as low technique sensitivity, highly wear resistance, low cost, durability [6-8]. However, one of the drawbacks of amalgam restorations is lack of chemical adhesion to the tooth structure which can result to microleakage of amalgam.

Wi-Fi is a local are Wi-Fi is a local area wireless computer networking technology and has been used in houses and public places such as schools and hospitals during recent years [9]. It allows electronic devices such as personal computers, video-game consoles, smart phones, and tablets to network. The standards mainly use the 2.5 gigahertz (12 cm) UHF and 5 gigahertz (6 cm) SHF ISM radio bands [10]. The lower cost of these devices than wired computer networks lead to rapid increase of Wi-Fi devices [11]. However, this also raised public concern about the adverse effects of exposure to electromagnetic fields (EMFs) emitted from these devices [12]**.** LTE is a 4G wireless communications standard developed by the 3rd Generation Partnership Project (3GPP) that's designed to provide up to 10x the speeds of 3G networks for mobile devices such as smartphones, tablets, notebooks, and wireless hotspots.

Various methods are used in the diagnosis and treatment of oral and maxillofacial pathologies, and there is a lot of literature on the benefits of intraoral radiographs, orthopantomograms, CT, cone beam CT, MRI, ultrasonography [13, 14]. MRI is often preferred as a fast and non-invasive diagnostic modality for use on the entire human body, especially for the central nervous system, musculoskeletal system, head and neck region and abdominal and pelvic examinations [15, 16]. Although 1.5 T MRI systems are common, 3 T MRI systems exert a stronger static magnetic field and faster gradient fields. Therefore, 3 T magnetic fields were used in this study.

Materials and Methods
Teeth Samples
The present study was approved by the Ethics Committee of National Dental College and Hospital, Derabassi. Forty non-carious extracted premolar teeth were selected for this study. The teeth were stored in saline solution for up to 2 months after cleaning and surface debridement. The teeth with fractures or structural defects were excluded. Standardized class V cavities (3 mm length, 5 mm wide, 2 mm deep) were prepared on the buccal surface at the cementoenamel junction using carbide burs (SS White Burs, Lakewood, NJ) and a high speed turbine with air-water spray using a template. The cavities were restored with DPI (non-gama-2, spherical amalgam) amalgam. The amalgams were triturated according to manufacturers' directions, and then they were condensed incrementally towards the cavity walls using small condensers. All the procedures for restoration of the cavities including cavity preparation, burnishing, and polishing were performed by the same clinician. The restored teeth were placed in saline solution at 37°C until they were exposed. The teeth were randomly divided into 4 groups each containing 10 teeth.

Exposure Setup
The specimens in the exposure groups were exposed to radiofrequency radiation emitted from a commercial 2.4 GHz Wi-Fi router (TP-Link Archer C60 AC1350 Wireless Dual Band Router). The distance between the Wi-Fi router and samples was 30 cm and the router was exchanging data with a laptop computer that was placed 20 m away from the router during the whole exposure phase. The exposure group I was exposed to radiofrequency radiation emitted from standard Wi-Fi devices for 3 days. The second exposure group (II) was exposed to LTE mobile network that was placed at a distance of 20 m for 3 days. The exposure group (III) was exposed to 3 T MRI (Philips Ingenia 3.0 T). The specimens were placed in gantry and 20 min of MRI was performed. The control group (IV) was kept outside the experimental rooms.

Microleakage evaluation
Two layers of nail varnish were applied to the entire teeth surfaces except for the restorations and 1 mm around them. The specimens were immersed in 2% methylene blue dye solution at the room temperature for 24 hours and then they were rinsed in tap water and dried. A slow speed water cooled saw was used to section each tooth buccolingually. The section corresponding to the central portion of the tooth restoration was examined at the gingival, axial and occlusal margins under a stereomicroscope (Nikon, SMZ 745, Japan) at 80× magnification by the examiner who was blinded to the groups. The degree of microleakage was evaluated according to a standard ranking in which [32] 0= No dye penetration; 1= Dye penetration along the enamel; 2= Dye penetration along the dentine-enamel junction (DEJ) but not including the axial wall and 3= Dye penetration along the axial wall (Figure 1 and 2).

The data were analyzed using the Kruskal-Wallis test and the NPAR tests to compare microleakage in the case and control groups to identify any statistically significant differences at the significance level of 0.95 (p <0.05).

Results
The distribution of the scores of microleakage in each group is presented in Table 1 and 2. The score of microleakage was significantly higher in the exposure group (I, II, III) than that of the control group (IV) (p =0.03). The scores of microleakage were not significantly different between the exposure group I and II. The scores of microleakage were significantly higher in the exposure group III than the experimental groups I and II (p =0.04). The mean (±SD) was highest in group III and lowest in control group (group IV). Descriptive statistics in NPAR tests show highest mean value for group III. Therefore, the microleakage of mercury in the 3T MRI group was about twice of the control group.

Fig 1: Dye peneteration through enamel, passing DEJ to dentin (score 3).

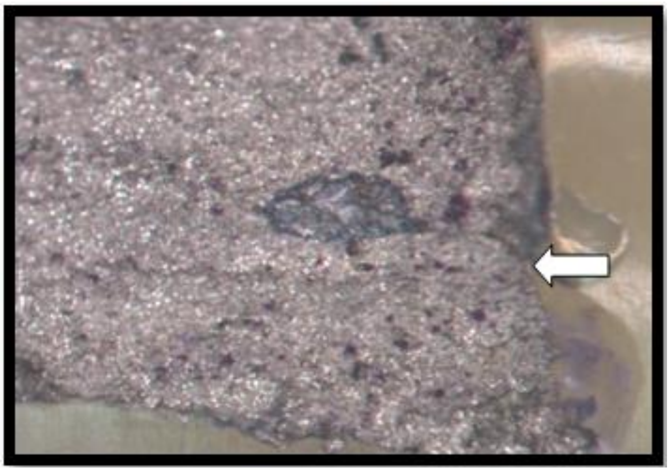

Fig 2: No Dye leakage (score 0) in a control tooth.

Table 1: Kruskal-Wallis Test (% of scores)

Groups	N	Mean Rank
I	10	20.60
II	10	21.25
III	10	22.30
IV	10	17.85

Table 2: Descriptive Statistics

	N	Mean	Std. Deviation	Minimum	Maximum	Percentiles		
						25th	50th (Median)	75th
%of Scores	10	.70	1.059	0	3	.00	.00	1.25
Group I	10	1.00	.000	1	1	1.00	1.00	1.00
%of Scores	10	.60	.699	0	2	.00	.50	1.00
Group II	10	2.00	.000	3	3	3.00	3.00	3.00
%of Scores	10	.80	1.033	0	3	.00	.50	1.25
Group III	10	3.00	.000	2	2	2.00	2.00	2.00
%of Scores	10	.40	.699	0	2	.00	.00	1.00
Group IV	10	4.00	.000	4	4	4.00	4.00	4.00

Discussion

The present study suggested that exposure radiofrequency radiation emitted from commercial Wi-Fi devices and LTE mobile network can increase the microleakage of amalgam restorations. Also, magnetic fields from 3T MRI increased microleakage of amalgam restorations. The score of microleakage was significantly higher in the exposure group III compared to that of group I, II and the control group and the score of microleakage in the exposure group III was also significantly higher than that of the exposure groups I and II.

Public concern about the possible adverse health effects of using Wi-Fi technology is increasing because of the widespread use of wireless communication systems [17]. Moreover, increased number of mobile phone users during recent years has generated great concern too. The electric circuit powers generate low-frequency electromagnetic waves that can induce electric currents in metallic objects in the oral cavity. Thus, the effects of these induced currents on human health have been of concern particularly because of their great proximity to the brain. Mortazavi *et al*. reported that radiofrequency radiation emitted from mobile phones significantly increased mercury release from amalgam restorations [18].

Mercury is a toxic element which has adverse biological effects even at low doses [19]. The mercury release from dental amalgam into saliva has been previously evaluated in both in vitro and *in vivo* conditions [20-23]. There are few studies which evaluated the effects of electromagnetic radiations on microleakage of amalgam restorations [24-26]. Many studies successfully showed that the electromagnetic fields were capable of increasing the microleakage of amalgam restorations [25-26]. Moreover, it is found that X-ray exposure can increase the microleakage of amalgam restorations [27]. Kursun *et al*. in 2014 showed that exposure to X-rays, a high energy ionizing component of the wide spectrum of electromagnetic radiation, can increase the release of mercury from dental amalgam fillings [28]. Shahidi *et al*. have suggested that the increase in microleakage following MRI might be attributed to the thermoelectromagnetic convection induced by exposure to EMFs that was supposed to be responsible for the enhancement of the diffusion process and vacancy formation resulting in microleakage [31].

“Triple M” effect is proposed by Mehdizadeh AR, Mortazavi G and Mortazavi SAR. The “Triple M” effect is based on these physical facts:

1. Due to shrinkage, there are spaces between amalgam and the tooth, a phenomenon which is usually called “marginal micro leakage”.
2. These small spaces are filled with very small amounts of saliva
3. Exposure of oral cavity to RF-EMFs (MRI or mobile phone radiation), raises the energy of these small amounts of saliva.
4. Reflection of the radiofrequency radiation on the inner walls of the above-mentioned small spaces causes interference which in turn produces some “hot spots” in these spaces. It is worth mentioning that this effect is similar to the issue of in homogeneity of radiation intensity and formation of hot spots in commercial microwave ovens (manufacturers of microwave ovens have solved this problem by using a rotating glass plate in the oven) [29]. It should be noted that bone (or tooth) reflects microwave and this reflection is reported to cause overheating in the adjacent regions [30].
5. Formation of gas bubbles in response to increased temperature and rapid expansion of these bubbles will accelerate the microleakage of amalgam.

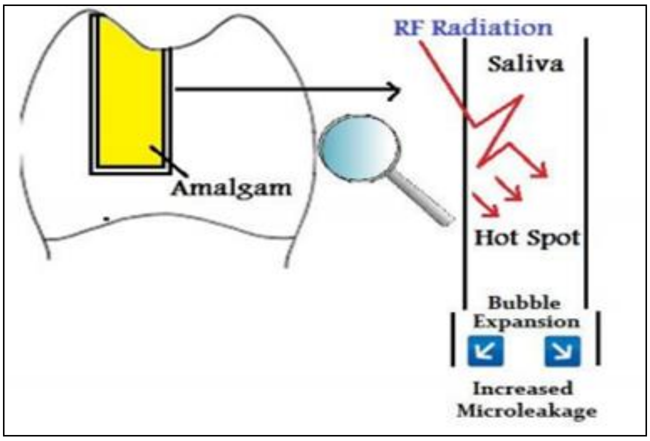

Fig 3: Reflection of radiofrequency radiation on the inner walls of small spaces between the amalgam and tooth surface causes interference which produces “hot spots”. Then, formation of gas bubbles takes place in response to increased temperature and expansion of these gas bubbles increases the microleakage of amalgam restoration.

Methylene blue is inexpensive and has better penetration than eosin and other radioisotope traces. Therefore, methylene blue was used in the present study for dye penetration test. Two layers of varnish coating were applied around restoration margins and the pulpal surfaces as a barrier to decrease microleakage around amalgam restoration and prevent any undesirable dye penetration because varnishes do not bond to the tooth structure or amalgam restoration and they only perform as the mechanical barriers.

Conclusion

In conclusion, the present study found high levels of microleakage in amalgam restorations exposed to wifi, mobile network and MRI compared to those of unexposed control group. Therefore, these exposures may threaten the durability of amalgam restorations. 3 T MRI is not contraindicated for patients who have amalgam restorations; however, it needs to be evaluated more from different perspectives Considering the importance of this challenging issue, further investigations are required to fully identify different aspects of the effect of exposure to electromagnetic fields on the microleakage and release of mercury from dental amalgam restorations.

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