

Effects of Radiofrequencies and Extremely Low Frequency Magnetic Fields Emitted from Mobile Phones and Other Equipment on Oral Tissues and Teeth

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Abstract

All the devices work by electricity produce extremely low frequency magnetic fields (ELFMF) in environment. Similarly, all the equipment work by wireless communication produces radiofrequency radiation (RF) in environment. Both of this environmental pollutant classified as 2B (Possible carcinogen) by World Health Organization in different time period. Most of the studies performed on RF or ELFMF and health focused on the brain tumors or childhood leukemia. No one pay attention to the potential health effects of this electromagnetic pollutant on oral tissues and teeth. Since there are limited numbers of studies that have been done in this topic, the purpose of this review is to summarize the results of the studies investigated until now. The studies performed in this field can be classified as; RF exposure studies; Continuous and Pulsed ELFMF exposure studies and Static magnetic field studies. In conclusion, the results of the studies investigated the effects of RF and ELFMF exposure on oral tissues and teeth indicated that such exposures have potential to cause some dental health problems. However, Static magnetic fields may have potential to help tooth movement. Finally, further studies including human studies are necessary to illuminate this topic.

Keywords: *Mobile Phones and Radiofrequencies; Extremely Low Frequency Magnetic Field; Static Magnetic Fields; Tooth Movement; Oral Tissues and Teeth*

Introduction

There are two omnipresent forces which play important roles in the functional activities of living organisms: gravity and electromagnetism. Living organisms have been exposed to natural electromagnetic waves inevitably. Therefore no one has chance to discuss natural electromagnetism that is not issue of this review. Whereas, everybody have an opportunity to discuss man-made sources produce magnetic or electromagnetic fields because of their hazards resulting from overexposure. Relation between some diseases and widespread using of manmade equipment emitted electric, magnetic and electromagnetic fields brought a new concept to the agenda: Electromagnetic pollution. In general, there are two types of radiation source to create electromagnetic pollution in environment: ionizing and non-ionizing radiation. It should be noted that this review will be focused on the effects of radiofrequencies and extremely low frequency magnetic fields, which are most popular today as a member of non-ionizing radiation.

All the devices work by electricity produce extremely low frequency magnetic fields in environment. Similarly, all the equipment work by wireless communication produces radiofrequency radiation in environment. Both of this environmental pollutant classified as 2B (Possible carcinogen) by World Health Organization in different time period [1-3].

In recent years, the number of studies regarding to the possible health effects of extremely low frequency-magnetic fields (ELF-MF) has increased considerably. Some epidemiologic and laboratory studies have suggested a possible association between exposure to ELF-MF

and reproductive toxic effects, immune suppression and cancer. However, the results of these studies have not been supported by some authors who suggest that there is not a dose-response relationship between ELF electromagnetic fields and cancer. Although availability of these contradictions ELF-MF have been classified as being possibly carcinogenic to humans in group 2B by the International Agency Research on Cancer (IARC 2002) reports, based on data pooled from epidemiological studies that show the risk of childhood leukemia doubles with exposure to ELF-MF. There is also strong evidence of associations of adult leukemia and adult brain cancer with exposure to ELF-MF [4].

Radiofrequencies had been mainly emitted from a few radio and television transmitters, located in remote areas and/or very high places until 1990's. Since the introduction of wireless telecommunication in the 1990's the rollout of mobile phones and wireless networks has caused an incredible increase in electromagnetic pollution in cities and the countryside [5]. Therefore, it can be stated that wireless technological equipment has led to a dramatic increase in electromagnetic pollution and man-made sources have by far exceeded those of natural origin. Based on the data released by the International Telecommunication Union (ITU 2014) the number of mobile-cellular subscriptions worldwide is approaching the number of people on earth and mobile-cellular subscriptions will reach almost 7 billion by end of 2014. Therefore, public opinion focused on the adverse effects of these technologies especially on mobile phones [6]. On the other hand, use of wireless technologies such as Wireless Fidelity (Wi-Fi) communication devices has been growing tremendously over the past years. Accessing Wireless Local Area Networks (WLAN) in houses, workplaces, public areas and schools has become a routine task in our daily lives. However, rapid development of wireless technologies has steadily increased the environmental electromagnetic field (EMF) levels. Therefore, public and scientific awareness that was previously focused on the adverse health effects of EMF emitted from mobile phones has shifted to the biological hazards of wireless equipment such as Wi-Fi [7].

As it is known living organism is a complex electrochemical system where electron transfer is recognized as one of the essential requirements for communication between molecules. Therefore, to be knowledgeable about operation of the system is very important to understand communication of cellular system [8]. The most widely accepted mechanism of interaction between radiofrequency radiation and biological systems is based on tissue heating that occurs when tissue or total body temperature increases for more than 1°C overloading cell thermoregulatory capacity. However, effects happening at non-thermal level have still to be investigated because of very little is known about their molecular mechanism [3].

The studies on the effects of extremely low frequency magnetic field and radiofrequency radiation focused on different organs in general. Whereas there is an important part of our body that runs away from the eye: Teeth. Meanwhile, it should be noted that some of wireless equipment such as mobile phones creates both ELF and RF in environment. Therefore, to investigate health effects of these environmental pollutants originated from the wireless tools used near the head is very important. Most of the studies that observed this topic focused on brain studies [9-14]. Although number of the studies performed on relation between ELF/RFR and teeth is very limited this review aimed to summarize results of the studies performed on the effects of ELF and RFR on teeth.

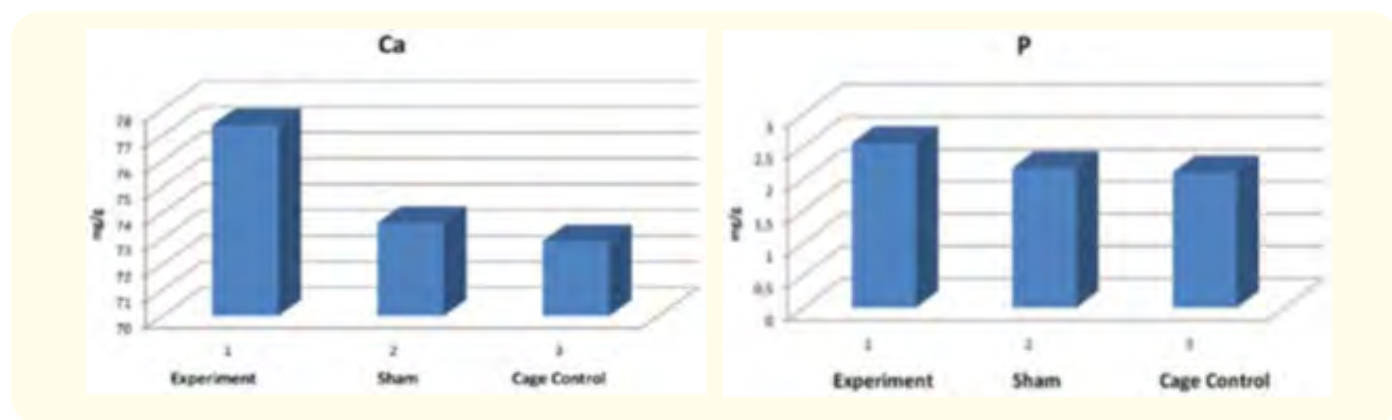
Studies performed on bone

Bone is composed of a mineral matrix reinforced by a network of collagen that governs the biomechanical functions of the skeletal system in the body. The studies investigate the relation between electromagnetic fields and bones have been especially focused on the continuous or pulsed magnetic fields because of its nature. In many studies, extremely low-frequency (ELF) magnetic fields (MF) were used to treat fresh fracture healing, prevent and reverse of osteoporosis, and heal ununited congenital pseudoarthrosis of the tibia and surgically resistant nonunions in adults. Some of the studies also stated that ELF-MF may affect the behaviors of osteoblast-like cells, stimulate the osteoblasts in the early stages of culture, accelerate cellular proliferation of osteoblasts, and stimulate increasing of total bone mineral content [15]. On the other hand, limited studies performed on the effects of radiofrequencies on bones. For instance, Sen et al. performed an experimental rat study to investigate the effects of 9.45 GHz microwave radiation on fracture healing in 1991. They formed a controlled incision in femur and exposed femur to microwave radiation. They did not observed positive healing effect on fracture healing. However, they stated that endochondrial ossification was retarded by the exposed microwave [16]. Akpolat., et al. investigated the effect of long

term ELF magnetic field on rat calvarian and mandibular bone mass. They exposed ovariectomized rats to 1.5 mT ELFMF for 4 h/day during 6 months. They compared pre and post exposure total cranial and mandibular bone mineral density (BMD) and bone mineral content (BMC) of rats. They observed greater BMD and BMC in the total cranial and mandibular bone of exposed rats [17]. However, Akdag, et al. investigated the effect of long-term ELFMF on geometric and biomechanical properties of rat bones. They exposed rats to 100 and 500 mT ELFMF 2h/day during ten months and compared pre and post exposure geometric and the biomechanical properties of rats' bone, such as cross-sectional area of the femoral shaft, length of the femur, cortical thickness of the femur, ultimate tensile strength (maximum load), displacement, stiffness, energy absorption capacity, elastic modulus, and toughness of bone. They finally stated that ELFMF alter the some biomechanical properties of rat bones, especially cortical bone quality and bone strength [15]. Durgun., *et al.* also evaluated effect of 2100 MHz electromagnetic radiation on the healing of mandibular fractures in rabbits. They exposed rabbits with mandibular fractures to 2100 MHz radiofrequency radiation three hours per day for twenty-eight days. They observed biomechanical parameters of mandibula following radiofrequency treatment and found that energy absorption capacity, toughness and maximum strength of the mandibular bone were increased. However, the histopathological examination revealed that the fracture healing score was higher in the exposed rabbits although any radiological differences was to observed between the exposed and control rabbit. They finally concluded that 2100 MHz RF radiation positively affected fracture healing [18].

Mobile Phone and Wi-Fi Exposure Performed on Oral Tissues and Teeth

Over the past two decades, wireless communication system has been widely used all over the world. The use of mobile phones has been rapidly increased. Therefore, public concerns have been focused on health effects of mobile phones after the studies, which are stated health risks of uncontrolled use of mobile phones and other wireless equipment. Although many of studies pointed out brain tumor effects of mobile phones very limited studies are still available. No one pay attention to the effects of radiofrequency radiation emitted from mobile phones on teeth or oral tissues although cheeks and teeth exposes radiation since mobile phones are attached to the ear during talking. Therefore, more attention and performance is necessary to understand the effects of radiofrequencies on oral tissues and teeth. As it is stated above, very limited study is available on the effects of radiofrequencies emitted from mobile phones. For instance, Kaya et al investigated the effects of long term exposure of 900 MHz radiofrequency radiation emitted from mobile phone on periodontal tissues and teeth of rats. They used a 900 MHz radiofrequency generator to standardize the RF exposure and simulate mobile phone exposure. Rats were exposed for 2h/day for ten months. The result of the study indicated that RF has potential to affect periodontal ligaments and alveolar bone. However, they stated that RF exposure may have caused abnormal histological changes such vasodilatation and focal bleeding in periodontal ligament, alveolar bone, gingiva and pulpa [19]. Adiguzel., *et al.* also investigated the long-term exposure effect of 900 MHz radiofrequency radiation on trace element content of rat teeth. They analyzed some of trace element content such as Ca, Mg, Zn, and P in teeth and found that. Results of the study showed that 900 MHz RF altered concentration of the measured trace elements. However, only Mg and Zn content in teeth of exposed rats were found statistically significant [20]. Results of the study summarized in the figure 1.



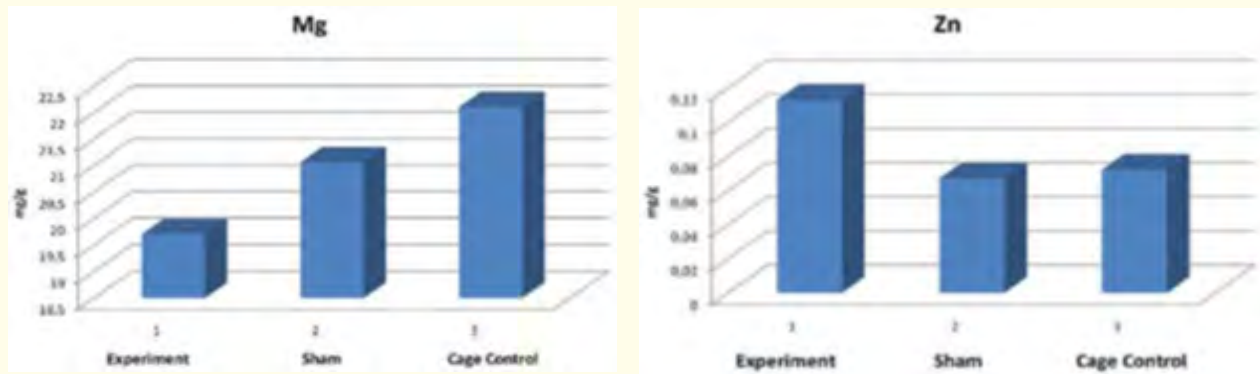


Figure 1: Effect of 900 MHz mobile radiofrequency exposure emitted from mobile phones on some teeth trace elements.

On the other hand, Dasdag, *et al.* investigated effect of long term 900 MHz radiofrequency radiation on enamel microhardness of rat's teeth. They also found that 900 MHz RF radiation do not alter the enamel micro hardness of rats' teeth [21]. However, Ciftci., *et al.* investigated effects of prenatal and postnatal exposure to 2.45 GHz radiofrequency radiation (Wi-Fi) on teeth and surrounding tissue development as well as trace element concentration in growing rats. They exposed rats to 2.45 GHz RF for 2h/day during the pregnancy (21 days) and lactation (21 days). They found no difference in terms of development and apoptotic activity in the exposed rats. However, trace elements such as iron and strontium concentrations were increased in the RF exposure group, whereas boron, copper, and zinc concentrations were decreased. They also did not find difference in calcium, cadmium, potassium, magnesium, sodium, or phosphorus values in the exposed rats. Additionally, they stated that short-term exposure to Wi-Fi-induced EMR may cause an imbalance in the oxidative stress condition in the teeth of growing rats [22].

Magnetic Field Studies Performed on Oral Tissues and Teeth

Number of the studies on the effect of magnetic fields on oral tissues of teeth is partially more than radiofrequency studies. It should be remembered that the equipment such as mobile phones also emit extremely low frequency magnetic fields because of their battery. Therefore, to have information related to the effects of magnetic fields on oral tissues or teeth is important point at least for dentists. However, biological effects of static and pulsed magnetic fields studied by some scientists. For instance, Stark and Sinclair investigated the effects of pulsed electromagnetic fields on the orthodontic tooth movement. They indicated that noninvasive pulsed electromagnetic fields increased orthodontic tooth movement rate and bone deposition [23]. However, another type of magnetic fields is static magnetic fields and very limited study available in this field. Bondemark, *et al.* examined effect of static magnetic field emitted from orthodontic samarium-cobalt magnets on human dental pulp and gingival tissues. The study was carried out on seven young subjects with age range of 11.5 - 17.5. The maxillary first premolars and immediately adjacent gingival tissues of the subjects were exposed to a static magnetic field by a bonded magnet. They did not observed any effect of the static magnetic field on human dental pulp and gingival tissue adjacent to the magnets [24]. Tengku., *et al.* investigated effects of static magnetic fields on orthodontic tooth movement in rats. They found that static magnetic field did not enhanced tooth movement and alter histopathological appearance of the periodontal ligament during tooth movement [25]. Yamamoto., *et al.* studied the effects of static magnetic field on osteoblastic differentiation, proliferation and bone nodule formation. They used rat calvaria cell culture. They found that static magnetic fields stimulated bone formation by promoting osteoblastic differentiation and activation [26].

On the other hand, some of the studies investigated the effects of extremely low frequency magnetic fields (ELFMF) on oral tissues or teeth. Kaya et al studied the effects of ELFMF on oral tissues. They found that ELFMF altered mineral content of jaw and cranial region of rats [27]. Yavuz., *et al.* performed a study on the effects of ELFMF on mineral and trace elements content of rat teeth. They indicated that

ELFMF increased some trace elements such as Ca, Mg, Zn and P in rat teeth [28]. Kaya, *et al.* investigated effect of ELF-EMFs and strontium ranelate on trace element such as Ca, Mg, P and Zn in teeth. They found that ELFMF increased Zn concentration and Mg decreased. Therefore, they stated that ELFMF have potential to alter concentration of some trace elements [29]. Kaya, *et al.* also investigated the effects of ELFMF on dental pulp of ovariectomized rats. They observed histological alteration in collagen fibrils, fibroblasts, blood vessels and odontoblast which create pulps. They finally stated that ELFMF exposure enhanced histopathology and did not resolve the histopathological effects developed depend on osteoporosis [30]. Kaya FA, *et al.* investigated the long-term effects of ELFMF exposure on periodontal tissues and teeth in rats. Their study is different than the studies summarized in this review since they observed the effects of 100 and 500 μ T ELFMF which were accepted by international Agencies as safety standards for public and workers respectively. They indicated that both ELFMF affected alveolar bone, pulp and gingiva and stated that safe limit of ELFMFs has potential to affect periodontological tissues and teeth [31]. Kargul, *et al.* investigated the effect of extremely low frequency magnetic field on enamel microhardness of rats. They also investigated the effects of 100 and 500 μ T ELFMF as the study of Kaya FA, *et al.* They concluded that 500 μ T ELFMF may have a certain negative effect on enamel mineralization [32]. The results of Kargul *et al* seen in figure 2.

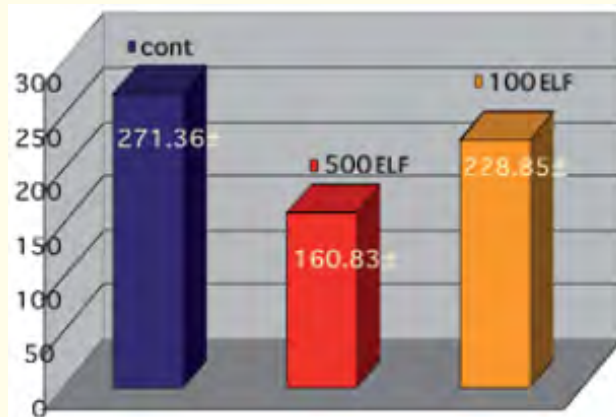


Figure 2: Mean \pm SD value of microhardness of the enamel specimens in the experimental groups.

Ulku, *et al.* studied the effects of long-term ELFMF exposure and hormonal changes produced by bilateral ovariectomy on the histologic and histomorphometric structure of rat mandibular condyle. They concluded that long-term ELF-MF exposure and ovariectomy application can cause some histopathological changes in the structure of the condyle but ELF-MF exposure cannot recover ovariectomy-induced changes [33].

Discussion

As it is understand from the studies discussed here, sufficient number of the studies performed on the relation between RF and ELFMF exposure and oral tissues including teeth is still not available. The studies on the effects of RF emitted from wireless equipment can be grouped under two headings such as mobile phones and Wi Fi. Three studies available on 900 MHz mobile phone exposure and oral tissues. We can summarize the results of these studies as [19-21]:

- 900 MHz RF exposure has potential to affect periodontal ligaments and alveolar bone. RF exposure may have causes some abnormal histological changes such as vasodilatation and focal bleeding in periodontal ligament, alveolar bone, gingiva and pulpa.
- 900 MHz RF exposure has also potential to alter the concentration of some trace elements.
- 900 MHz RF radiation has no potential to alter the enamel micro hardness of rats' teeth

The results of Wi Fi exposure study [22] can be summarized as:

- Short term 2.4 GHz RF exposure has potential to alter the concentration of some trace elements. However, Wi Fi exposure may cause an imbalance in the oxidative stress condition in the teeth of growing rats.

The result of Mg and Zn in 900 MHz RF exposure was not supported by the 2.4 GHz RF exposure study [20,22]. The contradiction between two frequencies may have originated from the difference of frequency, exposure duration, exposure setup and animals.

The results of the studies performed on tooth movement can be classified as:

- Noninvasive pulsed electromagnetic fields increased orthodontic tooth movement rate and bone deposition [23].
- Static magnetic field has no potential to alter human dental pulp and gingival tissue adjacent to the magnets [24].
- Static magnetic field has not potential to enhanced tooth movement and may alter histopathological appearance of the periodontal ligament during tooth movement [25].
- Static magnetic fields stimulate bone formation by promoting osteoblastic differentiation and activation [26].

The results of the studies performed on ELFMF can be ordered as:

- ELFMF has potential to alter trace element content of jaw and cranial region [27-30].
- ELFMF has potential to disturb histological structure of some oral tissues or teeth [30,31,33].
- ELFMF may have a certain negative effect on enamel mineralization [32].

If we generalize the result of the studies performed on RFs and ELFMFs, we can conclude that both physical exposure parameters have potential to alter histological structure of oral tissues and teeth. Therefore, dentists should not forget to ask their patient's wireless device usage habits when they face the complaints summarized in this review.

In conclusion, the results of the studies investigated the effects of RF and ELFMF exposure on oral tissues and teeth indicated that such exposures have potential to cause some complaints. However, further studies including human studies are necessary to illuminate this topic.

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