Effect of extremely low frequency magnetic field on enamel microhardness in rats

ABSTRACT

The potential effects on human health of extremely low frequency magnetic field (ELF-MF) are of considerable concern. In the present study, it was investigated the effect of long term ELF-MF exposure on microhardness of rat teeth.

Materials and methods

Thirty male Sprague-Dawley rats were divided into three groups. The first and second experimental groups (n=10) were exposed to 100 µT and 500 µT ELF-MF during 10 months, 2 hours a day respectively. For the control group, nothing was applied to the rats and they completed their life cycle in the cage during the study period. After ELF-MF exposure, microhardness of enamel surface was determined for each group.

Results

The decrease in microhardness in the second experimental group was found to be statistically significant compared to the control group (P<0.05). However, no statistical difference was found between the first and second experimental groups (P>0.05).

Conclusion

From the results it can be concluded that 500 µT level of magnetic field strengths may have a certain negative effect on enamel mineralisation. Further investigations are necessary to analyse the effect of ELF-MF on teeth.

Keywords: Magnetic field; Enamel; Microhardness.

Introduction

Numerous sources of electromagnetic fields exist in nature and in the occupational and residential environments. In nearly all instances, these fields pose no obvious threat to human health or safety and are generally discussed as an inevitable by-product of modern technology. In fact, the ability of extremely low-frequency magnetic fields (ELF-MFs) to produce effects on living systems is still a matter of debate, and contradictory results are available in the literature [Tenforde et al., 1987; Knave, 2001].

In many studies, ELF-MFs have been used to help fresh fracture healing, prevention and treatment of osteoporosis, heal ununited congenital pseudoarthrosis of the tibia and surgically resistant nonunions in adults [Grace et al., 1998; Tabrah et al., 1990; Chang et al., 2003; Tabrah et al., 1998]. Some investigators reported that ELF-MF may affect the behaviours of osteoblast-like cells, stimulate the osteoblasts in the early stages of culture and accelerate cellular proliferation of osteoblasts [Chang et al., 2004; Jonathan et al., 2000; Diniz et al., 2002]. In some studies, ELF-MFs have also been used for the treatment of arthritic patients [Jacobson et al., 2001; Poornapriya et al., 1998]. Vera et al. [1999] investigated possible mass and bone density alterations in second-generation OF1 mice exposed chronically since birth to a magnetic field of 50 Hz and 15 µT. In this study, no significant differences were observed in relation to densitometric parameters such as total mass, total density and mechanical parameters like periosteal and endosteal circumferences, etc. Chang et al. demonstrated that extremely low intensity, low frequency, single PEMFs significantly suppressed the trabecular bone loss and restored the trabecular bone structure in bilateral ovariectomised rats [Chang et al., 2003]. Hanafy et al. [2008] found that the generated magnetic field can cause biological effects on bone cells. But magnetic responses of biological systems have not been well characterised. There are many studies in relation to the effect of ELF-MF on bone fractures, osteoporosis, osteoarthritis, osteoblast and osteoclast cells. Some authors also investigated the effects of ELF-MF and ovariectomy on biomechanical properties of rat bone [Gurgul et al., 2008; Comelekoglu et al., 2007]. However, no data have been reported in the literature considering histopathologic studies focused on the effects on teeth and the effects of ELF-MF on microhardness alterations of rat teeth.

The objective of this study was to analyse the effects of exposure to 100 µT and 500 µT ELF-MFs exposure on microhardness alteration of enamel surface in rats.

Materials and methods

Animal care

The experiments were performed on 30 male Sprague-Dawley rats obtained from the Medical Science Application and Research Center of Dicle University, aged 4 months at the beginning of the study, weighing 300-390g, and fed with standard pelleted food (TAVAS Inc. Adana, Turkey). The animals were kept in 14/10h light/dark environment at constant temperature of 22 ± 3°C, 45 ± 10% humidity. The rats were separated into three groups in this study (control: 10 and two experimental groups: 20). The first and second experimental group (n=10) were exposed to 100 µT and 500 µT ELF-MF respectively during 10 months, 2 hours a day. For the control, nothing was applied to the rats in this group and they completed their life cycle in the cage during the study period. This protocol was approved by the Scientific and Ethics Committee of Dicle University Health Research Center.

Magnetic field generation and exposure of rat to magnetic field

The MF was generated in a device designed by us that had one pair of Helmholtz coils of 25 cm in diameter in a...
Faraday cage (130x65x80 cm) that earthed shielding against the electric component. This magnet was constructed by winding 225 turns of insulated soft copper wire with a diameter of 1.0 mm. Coils were placed horizontally as facing one another. The distance between coils was 25 cm. An AC current produced by an AC power supply (DAYM, Turkey) was passed through the device. The distance in the wires of the energised exposure solenoid was 0.12 A for 100 µT and 0.50 A for 500 µT, which resulted 50 Hz MF.

The MF intensities were measured once per week as 100 µT and 500 µT in different 15 points of the methacrylate cage by using digital teslaimeter (Phywe, 209101074, Göttingen, Germany) to ensure homogeneity of the field during the course of the experiment. Magnetic field measurements showed that, at the conditions of the experiment, the magnetic field exposure system produced a stable flux density of 100 µT, 500 µT and stable frequency of 50 Hz with negligible harmonics and no transients. The static earth magnetic field was measured with a Bell 7030 Gauss/Teslaimeter (F.W. Bell, Inc., Orlando, FL). The component parallel to the exposure field was 14 µT and the component perpendicular to the exposed field was 34 µT. All field measurements were performed by operators not involved in the animal experiments. Observers were not aware of which group of rats was ELF Magnetic Field-or control, i.e. the whole study was done blind. No temperature differences were observed between exposure and control coils during the exposure. After 10 months of MF exposure, the study was terminated. Immediately after the last exposure, teeth were extracted under ketamine anaesthesia (100 mg/kg, intramuscularly) and kept in sterile solution for the microhardness test.

Preparation of specimens for microhardness testing

The 10 enamel samples were obtained from the three study groups from the buccal surface of each extracted tooth. Only intact enamel areas on the buccal surface were used in this study. The buccal side was sectioned with a diamond saw and enamel pieces were embedded in epoxy resin. The top surface of each specimen was ground flat and polished with water-cooled carborundum discs 1200 grit waterproof silicon carbide paper, thereby removing about 200 µm of enamel. The enamel samples were then stored in tap water prior to investigation.

Surface microhardness analysis

Digital Micro-Vickers Hardness Tester (Wilson Wolpert Europe BV, 401 MVD, Nederland) fitted with a Vickers diamond and a 200 N load was used to make indentations in the enamel surface. The loaded diamond was allowed to rest on the surface for 15s. Microhardness of enamel surface was determined for each group (control, 100 µT, 500 µT exposure). Five indentations spaced 100 µm, from the study and control groups were made. The mean values of all five measurements at the three groups were then compared.

Statistical analysis

Data were computerised and analysed using SPSS 16.0 software (Chigago, IL). Kruskal-Wallis Statistic and one-way analysis of variance (ANOVA) were used to compare surface microhardness among exposure level.
content. Adiguzel et al. [2008] also reported that long-term GSM-modulated 900 MHz radiofrequency radiation exposure can be a factor in the alteration of teeth trace elements density. Kaya et al. [2009] suggested that the mineral amount of rat teeth can change after overvaccelony and ELF-MF exposure, even strontium ranetate treatments cannot increase the mineral content of teeth.

The direct comparison of the results of this research with previous studies is complex because no data have been found related to the interaction of ELF-MF and biomechanical properties of teeth. However, Gurgul et al. [2008] investigated the effect of ELF-MF exposure on biomechanical parameters on rats' bone. In this study, the authors concluded that the bone quality of rats was decreased by magnetic field exposure. The results of the present study are indirectly consistent with the results of Gurgul study.

However, there is a limited literature in dental sciences, and one study reports that the ELF-MF treatment not only appears to increase bone formation, as previously reported in the literature, but, acting on osteoclast activity, it also seems to improve bone quality during orthodontic treatment [Stephen, 1998].

Enamel is the hardest and most highly mineralised substance of the body: it consists for 96% of minerals, with 4% of water and organic material. Dentin is made up of 70% inorganic materials, 20% organic materials and 10% water by weight; 90% of the organic material is collagen type 1 and the remaining 10% ground substance which includes dentin-specific proteins [Ten Cate, 1998]. One possible explanation as to why the trace elements of enamel and dentin were affected by ELF treatment is that ion transports can be altered by the ELF magnetic field. In the present study, the decrease in enamel microhardness of rat teeth can stem from the alteration of mineral contents in teeth of rats exposed to ELF-MF [Yavuz et al., 2008; Adiguzel et al., 2008; Kaya et al., 2009]. Mineral changes in surface layers of enamel are directly related to microhardness alterations, i.e. remineralisation of enamel carious lesions is associated with an increase of enamel surface microhardness [Feagin et al., 1969; White et al., 1988]. There are several methods for the measurement of surface alterations of dental enamel, some of them are quantitative. Microhardness testing permits the measurement of the degree of softening of the surface, since dental enamel can be softened (altering its microhardness) in association with dental wear [Risot et al., 2006].

From the results it can be concluded that a 500 μT magnetic field may have a negative effect on enamel mineralisation. Further investigations are necessary to analyse the effect of ELF-MF on teeth. Because of differences in body size, geometry and physiological responses, extrapolation of these results to humans is not straightforward, and any such comparison should be made with caution. Particular attention should be directed toward long-term, ELF-MF exposure on humans. In vivo studies should focus on the potential for possible synergistic, genotoxic, immunological, and carcinogenic effects in combination with appropriate chemical agents, such as hormones, bisphosphonates, calcium, and Vitamin D associated with prolonged exposure to ELF-MF.

References


