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ORIGINAL ARTICLE

Occupational exposure to electromagnetic fields from dental devices: A descriptive study

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Abstract

Objective: Electromagnetic Field sources, which are widely used as part of the operating mechanism, cause occupational exposure when electricity is generated, distributed, or usage in the everyday environment. We aimed to obtain the Extremely Low Frequency-Magnetic Field exposure profile for dental health workers from electrical devices used in dentistry.

Method: Measurements were performed while appliances were under working conditions at a 10 cm distance from the device for 6 minutes and for 7 days. The highest measured value in every 10 second was recorded. The mean ± SD of the minimum and maximum Extremely Low Frequency-Magnetic Field for high-speed dental handpiece with LED, low-speed dental handpiece, model-trimming machine, automatic boil-out unit, steam machine, vacuum device, and polishing machine were recorded in milliGauss.

Results: The values obtains from model-trimming machine and polishing machine were remarkable (809.1 ± 37.7 / 975.0 ± 10.2, 649.3 ± 201.3 / 1367.0 ± 32.1, respectively).

Conclusion: The results show that periodic Electromagnetic Field exposure measurements should be conducted to obtain more detailed information about workplace exposures and sources.

Keywords: Health, Electromagnetic Field, Extremely Low-Frequency Field, Exposure, Occupational

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INTRODUCTION

Electromagnetic Field (EMF) sources, which are widely used as part of the operating mechanism, cause occupational exposure when electricity is produced, emitted, or used in the daily working area. EMF can be defined by its frequency fields and the electric and magnetic field magnitudes. The sufficient frequency of the EMF source can have biological effects, and the electric or magnetic field magnitude determines the potential biological response.[1] Recent studies have shown an association between exposure to EMF and conditions such as childhood leukemia, cancer, fatigue, and depression. In addition, sensory organs and nerve damage, vestibular disorders, tingling sensations, pain, or muscle contractions may occur depending on the strength of the fields.[1-4] Due to the increasing number of technologic devices, personnel are exposed to more EMF sources in the working area, and thus occupational safety questions are increased. Extremely low-frequency (ELF) fields contain alternating current (AC) fields used by home and office devices and industrial and commercial instruments. Micro-Tesla (μT) or milli-Gauss (1mG = 0.1 μT) are ELF magnetic field units in the International System of Units (SI).[5] In measuring radiofrequency magnetic fields, volt per meter (V/m) for electric fields or ampere per meter (A/m) for magnetic fields are used.[6]

A guideline has been published by the International Committee on Non-Ionizing Radiation Protection (ICNIRP 2010) to limit exposure to EMF.[7] In 2002, the International Society for Research on Cancer (IARC) classified ELF-MF (Extreme Low Frequency Magnetic Fields) as possible carcinogens.[8] In the literature, the risk limit for long-term exposure is accepted as 2 mG (0.2 μT, 50 Hz).[6]

The magnitude of a magnetic field (MF), which is generated by an electric current, is directly changed by the current flow, where the frequency range is between 0-300 Hz, including power frequencies (50/60 Hz).[4] EMF formed by medical sources can be divided into two categories: sources of static and low-frequency fields (0 Hz-100 kHz) and sources of high-frequency fields (100 kHz - 300 GHz). A sufficiently strong low frequency EMF can stimulate sensory organs and nervous or muscle tissue via magnetic induction of internal electric fields. It can also cause overheating and tissue damage with sufficiently strong, high-frequency EMF.[3]

Dental instruments are devices connected to the electrical network that generate ELF in the 50 or 60 Hz power frequency range.[3,9] Exposure to ELF-MF during dental training can be defined as workplace exposure, which has been reported to be overexposure on a given day.[9,10]

The magnetic fields associated with various clinical and laboratory equipments should be measured to define the profiles of ELF-MF exposure of dental students, technicians, and trainers. With the study, we aimed to obtain the ELF-MF exposure profile for dental students, dental laboratory technicians, and trainers in prosthetic laboratuary and clinical applications. Dental students usually practice in either laboratories or clinics, and these two enviroments are very different in academic institutes. We separately measured ELF-MF values in those working areas, which can be useful for addressing overall occupational exposure to ELF-MF.

METHODS

In the current study, ELF-MF values of the frequently used equipment in the prosthetic laboratory and dental clinics, such as low-speed dental handpiece/contra-angle (NSK/Nakanishi INC., Tochigi, Japan), high-speed dental handpiece with LED (Ekemed, Aymeray Ltd., NCTR), model-trimming machine (Rotaks-Dent, Plaster Cutting Machine, İstanbul, Türkiye), automatic boil-out unit (Ermetal, Ankara, Türkiye), steam machine (Gazella, Gold Dental, Steam Cleaning Robot, Türkiye), vacuum device (Ermetal, Ankara, Türkiye), polishing machine (Universal, İstanbul, Türkiye), and dental vibrator (Rotaks-Dent, Pulse 4 Type Vibrator, İstanbul, Türkiye) were investigated. The fields were evaluated with an manual magnetic field meter device (Tenmars Electronics Co.Ltd., Taipei City, Taiwan). The TENMARS TM-191 Magnetic Field Meter is designed for measuring electromagnetic fields of extra low frequency (ELF) of 30/300 Hz ranging of 200/2000 mG or 20/200 μT, with a resolution of 0.1/1 mG or 0.01/0.1 μT and accuracy of ± (3% + 3 dgt) at 50/60 Hz.

The devices were measured in the most commonly used places: dental clinics, prosthetic laboratories, and clinical education areas. All nearby tools except the measuring device were powered off to minimize background intervention. "Spot" measurements were performed every day at the same time (between 08:00-09:00 a.m.). Measurements of the low-speed dental handpiece/contra-angle, high-speed dental handpiece with LED, model-trimming machine (one device and two devices), and polishing machine (one device), were made at a distance of 10 cm from the device for 6 minutes each day for 7 days. The polishing machine measurements (three devices) were performed at a distance of 10 cm from the device for 3 minutes each day for 7 days. The measurements of the steam machine and vacuum device from a distance of 10 cm were carried out for 1 minute each day for 7 days. In addition, ELF-EMF intensity was measured at a 10 cm distance for one minute each day for 7 days when the automatic boil-out unit was started up and its temperature reached 55^{0}C. The highest measured value for each device was recorded every 10 seconds under operating conditions. In addition, dental vibrator (one device and two devices) and a high-speed dental handpiece without LED were also measured. However, since the values of the dental vibrator ELF-MF intensity were overload and the values of the high-speed dental handpiece without LED values were about zero (between 0-0.2 mG), they were not taken into consideration. A total of 1554 measurements were performed for the nine devices that were evaluated during the runtime. Data are presented as average magnetic field strength ± standard deviations (SDs).

RESULTS

Table 1 shows ELF-EMF intensity of the high-speed dental handpiece with LED, low-speed dental handpiece, the model-trimming machine, the automatic boil-out unit, the steam machine, the vacuum device, and the polishing machine.

ELF-MFs in milliGauss plotted with respect to time produced by devices used in dental clinics (high-speed dental handpiece with LED and low-speed dental handpiece) are shown in Figure 1.

Table 1. Average magnetic field strength of the devices used in dentistry.

Devices	Usage area	Average Magnetic Fields Strength ± SD (milliGauss)						
		1st day	2nd day	3rd day	4th day	5th day	6th day	7th day
High-Speed Dental Handpiece with LED	clinical area	547.4 ± 43.9	593.5 ± 47.4	570.3 ± 41.8	566.3 ± 79.9	631.8 ± 13.7	584.0 ± 39.1	603.5 ± 68.2
Low-Speed Dental Handpiece	clinical area	5.5 ± 0.5	5.4 ± 0.3	6.7 ± 0.2	5.8 ± 0.9	5.6 ± 0.9	6.0 ± 0.4	6.1 ± 0.3
Model-Trimming Machine (One device)	prosthetic laboratory	839.7 ± 9.6	906.6 ± 17.5	838.8 ± 7.3	809.1 ± 37.7	860.5 ± 53.5	975.00 ± 10.2	932.5 ± 13.5
Model-Trimming Machine (Two devices)	prosthetic laboratory	863.0 ± 9.9	977.0 ± 8.6	867.6 ± 14.2	818.0 ± 16.7	935.6 ± 8.8	990.3 ± 10.2	1015.8 ± 13.5
Automatic Boil-Out Unit	prosthetic laboratory	9.4 ± 0.8	68.4 ± 3.1	46.2 ± 2.6	46.8 ± 0.04	52.6 ± 3.4	48.9 ± 5.7	46.9 ± 2.1
Steam Machine	prosthetic laboratory	42.5 ± 4.7	60.9 ± 3.9	53.1 ± 7.1	45.1 ± 5.8	41.0 ± 1.0	58.5 ± 0.5	42.4 ± 1.1
Vacuum Device	prosthetic laboratory	90.7 ± 40.2	68.1 ± 13.6	66.4 ± 3.6	79.4 ± 2.7	83.3 ± 0.8	99.7 ± 1.1	105.6 ± 1.0
Polishing Machine (One device)	prosthetic laboratory	1046.6 ± 36.7	1225.6 ± 55.4	1048.3 ± 52.6	1099.3 ± 48.4	649.3 ± 201.3	1367.0 ± 32.1	1076.8 ± 77.7
Polishing Machine (Three devices)	prosthetic laboratory	1653.0 ± 45.8	1715.3 ± 35.8	1466.3 ± 205.3	1420.6 ± 72.6	1606.6 ± 122.1	1727.3 ± 14.0	1696.6 ± 23.4

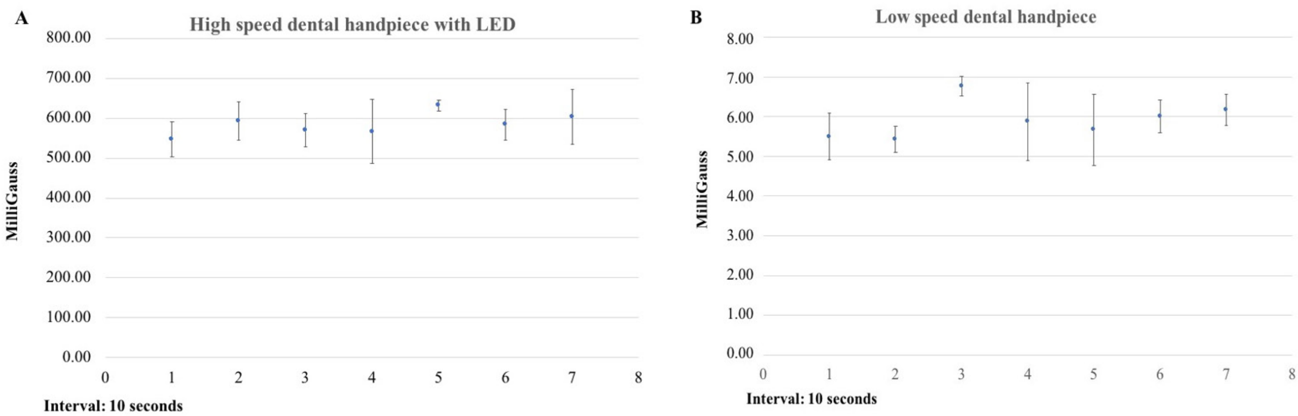

Fig. 1. ELF-MFs in milliGauss plotted with respect to time produced by devices used in dental clinics
A: High speed dental handpiece with LED; **B:** Low speed dental handpiece.

Also, ELF-MFs in milliGauss plotted with respect to time produced by devices used in prosthetic laboratories (model trimming machine, polishing machine, automatic boil-out unit, steam machine and vacuum device) are shown in Figure 2.

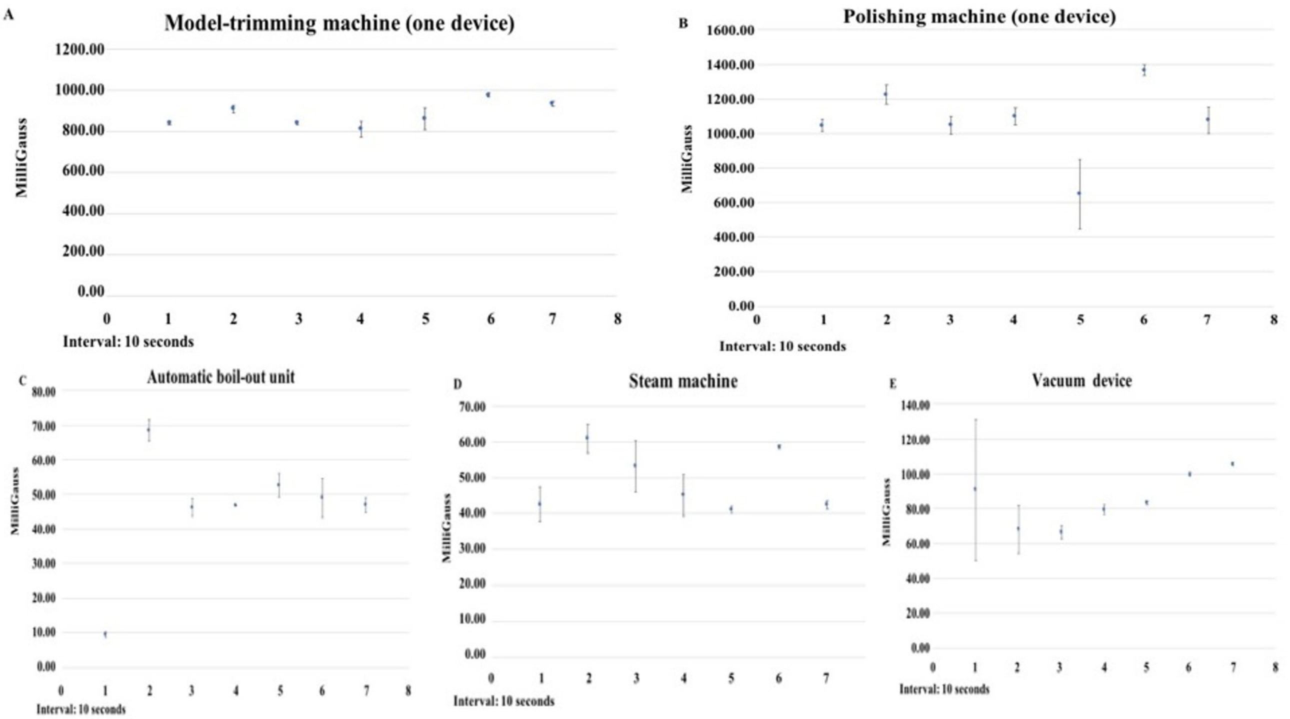

Fig. 2. ELF-MFs in milliGauss plotted with respect to time produced by devices used in prosthetic laboratory

A: Model-trimming machine (one device); **B:** Polishing machine (one device); **C:** Automatic boil-out unit; **D:** Steam machine; **E:** Vacuum device.

DISCUSSION

Dental equipments are used in undergraduate dental education programs at universities for both clinical and educational purposes. Dental staff and students in both dental clinics and prosthetic laboratories may be exposed to EMF from more than one source simultaneously, potentially resulting in higher exposure in dental laboratories and clinical education areas.

In this study, we aimed to measure the ELF-MF values of some selected devices used in the dental clinic and prosthetic laboratory and to evaluate the exposure levels of dental staff.

The minimum and maximum mean magnetic field strength ± SD values for the devices used in the clinic were found te be 5.4 ± 0.3 and 631.8 ± 13.7 mG, respectively. Mean magnetic field strength ± SD values for the devices used in the prosthetic laboratory varied between 9.4 ± 0.8 and 1727.3 ± 14.0 mG. The maximum ELF-MFs were measured in polishing machine (one device; between 649.3 ± 201.3 and 1367.0 ± 32.1 mG; three devices; between 1420.6 ± 72.6 and 1727.3 ± 14.0 mG). And also, the minimum ELF-MFs were measured in low-speed dental handpiece (between 5.4 ± 0.3 and 6.7 ± 0.2 mG).

In current study, since the values of the dental vibrator device were too high, they could not be measured. ELF-MF measurements of high-speed dental handpiece without LED remained below the risk limit for long-term exposure. These devices were therefore not included in the assessment.

According to the results of this study, we observed that ELF-MF measurements of all devices were higher than the risk limit of 2 mG (0.2 μT, 50 Hz) for long-term exposure.

Besides, the current analysis shows that there is a considerable potential that increasing the number of the devices may increase the level of exposure. Dental staff and dental students may have simultaneous exposure to EMF from multiple sources, potentially resulting in higher exposure in clinical education areas.

Newton et al. reported that dentists spend an average of 44 hours per week in their clinics.[11] In addition, it has been reported that while dental students spend one hundred and ten hours in class laboratory, they practice for an average of eighty-three hours outside the classroom in an eight-month period.[12] According to these reports, dental students spend quite a long time working with various dental devices throughout the year in the classroom laboratory and outside of the classroom, and ELF-MF exposure values of the dental students may increase because they work simultaneously with other students in the dental clinic and prosthetic laboratory. Additionally, dentists may have long-term ELF-MF exposure both in their clinics and during training.

van Tongeren et al. found that dental practitioners had the third highest average exposure (arithmetic mean, AM: 0.4 μT) among various job titles, and dental nurses (0.3 μT) had mean exposures higher than 0.2 μT.[13] Huang et al. showed that the average environmental ELF-MF exposure was 0.55 μT in dental clinic offices, and ELF-MF was above than 0.4 μT at 30 cm from the selected equipments in their study. They also reported that dentists worked in their clinics 35.7 and 19.3% of their time. They suggested that dentists, when treating their patients, may over-exposure themselves to ELF-MF. ELF-MF levels produced by dental equipment were consistent with the present study.[10] Contrary to their hypotheses, Kim et al. reported that dental staff working in endodontic clinics were not exposed to high electric and magnetic fields in their findings. They attributed this to the distance between the measuring device on the left upper arm and the equipment used. The researchers observed that the effect decreased as the distance increased.[9]

In a study conducted by Green et al in Canada investigating the relationship between magnetic field exposures and childhood leukemia, information was obtained that occupational exposure level and duration increase the risk of acute non-lymphocytic leukemia, particularly acute myelogenous leukemia.[14]

In the current study, it was observed that the selected devices used in the prosthetic laboratory had a higher level of ELF-MF intensity than the dental handpieces used in the clinic. However, no reports of ELF-MF levels in laboratory devices could be found to compare the results.

The literature on exposure contains several limitations. Measurements listed in the study by Mair et al. were carried out in a limited number of locations and workplaces.[15] In our study, some measurements were carried out at a standard 10 cm distance from the source. Therefore, exposure may be higher for measured sources.

Simultaneous exposure to different frequencies of sources can increase overall exposure. These exposures contribute to their effects.[7] Another important limitation is that measurement uncertainty such as methodological variability and inter-individual, inter-species, and inter-strain differences is not taken into account. These pathways have different implications for the number of businesses that need to take action. For these reasons, further specification or guidance on uncertainty management is important.[16,17] Some studies have taken measurement uncertainties into account in their exposure assessments.[4,9]

The main limitation of this study is that it is a descriptive study, so there is no comparison group. Therefore, the relationship between a risk factor and disease was not identified in this study to support a hypothesis.

Exposure to ELF-MF during dental training can be defined as workplace exposure reported to be one of the highest in daily exposure. In addition, dentists work for a long time with devices that produce ELF-MF in their own clinics. In this study, ELF-MF values were measured separately at working areas to address occupational exposure to ELF-MF. The results of the current study indicated that the occupational exposure limit values to EMF in the revised European Directive can be exceeded in some of the prosthetic laboratory and clinical devices. This result suggests that exposure to dental devices may cause long-term advers health effects as well as short-term effects. The present study serves this purpose and is valuable in this respect.

When all possible technical and organizational precautions are taken for dental staff, they will be protected against safety risks and adverse health effects. Guidance on security measures at the national or European level will help in this regard. It is clear that a more comprehensive and widespread risk assessment is needed in dental sector. Few studies have evaluated occupational EMF exposure due to dental equipment and dental clinics.[6,9,10,12,18]

First of all, mitigation measures can be taken to reduce exposure below reference levels. If this possibility is implemented, exposure reduction measures will be necessary in dental clinics, prosthetic laboratories, and clinical education areas. Alternatively, expert advice on the electric field can be sought. Numerical dosimetry specialists can usually perform the necessary calculations and computer simulations.[15,17]

In the event that all possible precautions are taken in dentistry and protection against safety risks and adverse health effects continues, the exposure limit values in the Annexes of the Revised Directive will not be valid.[19]

As a result, periodic measurements should be made to obtain more detailed information about workplace exposures and resources in dentistry, and dental staff and students should be aware of the critical EMF level to protect their health. In addition, one of the responsible authorities, such as World Health Organization (WHO) or the International Labor Organization (ILO), should inform workers that EMF levels are important for maintaining health.

CONCLUSIONS

Dentists, trainers, prosthetic technicians, and dental students are likely to be overexposed to ELF-MF during the treatment of patients and the training. Despite the controversy about the potential adverse health effects of ELF-MF exposure on adults, it is important to reduce dentists' occupational exposure to ELF-MF as their daily exposure is high.

The size of the ELF-MF has been found to differ between different models and types of dental instruments. An appropriate way to limit exposure to low-frequency electromagnetic fields is thought to be to eliminate their occurrence with dental devices. For this reason, MF levels generated by dental devices can be reduced by removing devices that generate MFs or by developing dental devices with low MF production.

In conjunction with existing conventional EMC (electromagnetic compatibility) standards such as ISO standards, new regulatory standards specific to human health are also needed.

Periodic exposure measurements are required to obtain more detailed information about EMF sources and exposures resulting from these sources. Measures against exposure can be taken by carrying out these measurements regularly. Dental sector employees should be aware of their EMF levels to maintain their health.

In conclusion, a broader risk assessment is clearly needed to provide methods of EMF protection in dentistry, to effectively exploit these effects, and to explore whether counter measures can be developed.

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Author Contributions: Concept: BA, FA Design: FA, BA Supervising: FA, BA Data collection and entry: FA, BA Analysis and interpretation: FA, BA, KN Literature search: FA, BA, KN.

Data Ailability

Information on the approval processes involved to access data from this study is available from the corresponding author.

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