# The Effect of Extremely Low Frequency Pulsing Magnetic Fields on Pain Threshold of Human Frontal Teeth

*Ruben Hovhannisyan[1], Sinerik Ayrapetyan[1]**

1. UNESCO Chair-Life Sciences International Postgraduate Educational Center, 31 Acharyan st. Yerevan, 375040 Armenia.

**Abstract**

The purpose of this work was to study the effect of Extremely Low Frequency Pulsing Magnetic Fields (ELF PMF) on pain threshold of human frontal teeth by means of algesimetric method.

For the determination of pain threshold an electric current generated by electroodontometer “Biophys-odontometr -1” (production of Armenian Radiophysics institute) was passed through the tooth. The application of PMF was performed with the help of ELF EMF source “Magniter--02” (frequency-50Hz, intensity-30mT) using in magnetotherapy (production of NPO “Polet” Nijni Novgorod, Russia). In total 720 measurements were performed: 360-control and 360-experiments.

The obtained data have shown that teeth had different pain thresholds and sensitivity to PMF. The differences were also observed in male and female teeth. The pain threshold in female was lower (about 31%), while the sensitivity to PMF was higher (about 20%) than in male. In female the PMF had significant elevating effect on pain threshold, while in male this effect was varied depending on their location in oral cavity.

It is suggested that the more detailed characterization of PMF-sensitivity of each tooth, i.e. pain threshold-dependency on PMF intensity and exposure time, would allow us to use the ELF PMF in dentistry as a pain releasing method.

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## Introduction

The orofacial region very often serves as a pain source for human beings and this pain could have physical and psychological natures. Physical pain could be generated by external or internal factors (acute pain) or could have a neuropathological nature (chronic pain). Tooth pain can be generated upon the effect of different factors on pain receptors (nociceptors).

They are concentrated in tooth tissues (15000-30000 nociceptors are located in 1 $cm^2$ of dentin, while in the border of dentine-enamel this number is about 75000). It is considered that 25-40% of receptors in orofacial region are nociceptors, which could be stimulated by mechanical, thermal and chemical factors.

There are also polimodal receptors, which are sensitive to all these three factors. As the functions of all these receptors are realized through the activation of potential-dependent ionic channels (responsible for generation of action potentials) in the membrane of nerve endings, the minimal intensity of electric current passing through the tooth, able to generate the pain sense, could be considered as a pain threshold for each tooth.

There is a wide variability between pain thresholds of different teeth as well between the same teeth of different patients. The opiate receptors and endorphins, enkephalin release in nervous system form the antinociceptive system of organism. So, the determination of tooth pain threshold by odontometric method could be considered as an integrative response of nociceptive and antinociceptive networks of nervous system.

The early works have shown that abnormal hydration (cell swelling) of neurons led to its abnormal excitation (nociceptive signals) as a result of the increase of the number of functionally active protein molecules in membrane, having enzymatic, chemoreceptive and channel-forming properties, while cell dehydration had opposite (antinociceptive) effect on membrane excitation (Ayrapetyan et al., 1984; Ayrapetyan 1998). Thus, from the point of this

***Corresponding author:**
*Prof. Sinerik Ayrapetyan,*
*UNESCO Chair-Life Sciences International Postgraduate Educational Center*
*31 Acharyan str.*
*Yerevan, 375040, Armenia*

***E-mail:** info@biophys.am*

hypothesis the nerve ending hydration is considered as a cell marker for determining the pain threshold. At the same time it was shown that static and pulsing magnetic fields (**SMF, PMF**) have dehydration effect on different tissues (Danielyan et al., 1999; Ayrapetyan 2006). On the basis of these data it is predicted that magnetic field (**MF**)-induced cell dehydration could have pain-releasing effect, which agree with well documented literature data on analgesic effect of SMF and PMF (Ayrapetyan 1996; Markov 2004; Hazlewood et al., 2006).

Although, at present the Electromagnetic Fields (**EMF**) are widely used for the treatment of various deceases and for pain releasing purposes (Bistolfi 1990; McLean et al., 2003), their application in dentistry is rather limited. Such limitation is due to our weak knowledge on the molecular and cellular mechanisms of generation of nociceptive signals as well as on metabolic nature of pain releasing effect of MF.

The recent our data on metabolic nature of MF-induced cell dehydration which is realized through the activation of cGMP-dependent $Na^+/Ca^{2+}$ exchanger leading to the reactivation of electrogenic Na-K pump (Ayrapetytan et al., 2005), allow us to predict that MF could serve as a universal pain releasing factor in dentistry, too. For testing this hypothesis the effect of 20 minutes 50 Hz PMF (intensity-30 mT) exposure on tooth pain threshold, determined by an electric current passing through it, was studied.

## Methods

The studies described in the present work were carried out according the Institutional Review Board (**IRB**) approval and comply with all state and local regulations.

The measurements of pain threshold of each frontal tooth of 6 male and 4 female patients were performed. The patients were chosen from 15-45-year-old 28 voluntaries having healthy medical conditions, nonsmoking, without any dental problems and they did not serve as volunteers for any other medical experiments. They were asked to ensure the eight-hour roosting time before the date of experiment and do not use any analgesics and tranquilizers.

For determination of pain threshold an electric current generated by electroodontometer “Biophys-odontometr -1” (production of Armenian Radiophysics institute) was passed through the tooth. The device has active and passive copper electrodes having cylindrical (1.5 cm length) and hooked (3 cm length) forms, accordingly. The diameter of both of electrodes is 1 $mm^2$. The passive electrode was fixed to the lower lip, while the active electrode was placed on the middle point of the cutting edges of the tooth. The testing current was in range of 1-100 mA. The threshold of pain sense was determined by the patient’s voice answer signal. Before each measurement the calibration of equipment was performed by passing 10 mA current through 500 kOhm electric demand.

The both, equipment and operator were beyond the vision of the patients and their voice answer signal was the reflection to the passing current through electrodes.

Because of wide variation of pain thresholds of each individual, the estimation of PMF-sensitivity of tooth pain threshold was performed by comparing the pain threshold before (control) and after PMF exposure (experiment) of the same patient. The electroalgesimetric data for each frontal tooth of upper and lower jaws of all volunteer participants were measured 3 times. The intervals between each measurement were 10 min. The mean value of the obtained data was considered as control. The intervals between control measurements and PMF exposure were 30 min. The application of PMF was performed with the help of ELF EMF source “Magniter--02” (frequency-50Hz, intensity-30mT) using in magnetotherapy (production of NPO “Polet” Nijni Novgorod, Russia). “Magniter--02” was applied on level of rima oris during 20 minutes. The measurements of pain threshold of each tooth after PMF exposure were carried out by the similar method as before the exposure. The PMF effect on pain thresholds was expressed in % to the initial value (control) of pain threshold.

In order to have a stable electrical contact between the active electrode and dental tissue, toothpaste was used. The tooth surface was dried by a cotton tampon in apical direction and the dried tooth was isolated with the tampons. In total 720 measurements were performed: 360-control and 360-experiments. The mean value, standard deviations, and the statistical probability, determined by Student T-Test were calculated with the help of computer program Sigma Plot (Version 8.02A).

## Results

Figure 1 presents the formula of frontal teeth (according to WHO classification) on which the odontometric studies of pain thresholds of teeth in female and male patients were performed. As it was predicted, because of the different anatomical and morphological properties, each tooth had its own pain threshold to the testing current passing through it. The significant differences between pain thresholds of teeth in female and male patients were demonstrated: in female it was lower than in male (about 31%) (Figure 2 A, B).


Fig.1 The formula of frontal teeth (according to WHO classification).

The control population did not feel pain in case of absence of testing signal (current), i.e. when current between electrodes was absent. The studies of the effect of 20 minutes PMF exposure on level of rima oris have shown the changes of pain threshold of the teeth. The character of these changes (qualitative and quantitative) was specific for each tooth depending on their location in oral cavity (Figure 3 A, B). Significant differences between PMF-sensitivity of pain threshold in female (A) and male (B) were observed. In female patients 20-minute-PMF-exposure led to the elevation of pain threshold for all teeth (Figure 3A). In male patients the pain thresholds of the major part of the teeth (13,12,11,23,43,42,41,31) were less sensitive to PMF-exposure than in female: in teeth No 13,12,11,21,23,43,41,31,32 and 33 PMF had elevating, while in teeth No 22,23 and 42 -- depressing effect on pain threshold.

Thus, in female, having comparatively lower tooth pain threshold, PMF mainly had significant pain releasing effect on it, while in male with comparatively higher tooth pain threshold, only in same teeth PMF-induced releasing effect was not pronounced.

## Discussion

Although the pain releasing effect of PMF is a well documented fact (Markov 2004), its cellular and molecular mechanisms still remain unclear. On the basis of previous work of our laboratory the pain (nociceptive) signal was considered an abnormal membrane excitability of nerve endings as a result of overhydration (Ayrapetyan 1995).

This suggestion is based on the experimental data that cell membrane protein molecules, determining membrane function (enzymes, receptors and ionic channels), in normal living state, are in functionally active and inactive states and the ratio of active and inactive molecules is changed depending on the size of active membrane surface (membrane packing) (Ayrapetyan 1980).

The cell swelling led to the increase of membrane excitability as a result of the increase of the number of functionally active potential-dependent ionic channels , while the shrinkage has the opposite effect on it (Ayrapetyan et al., 1988). It is known that the dysfunction of the Na/K pump which is the consequence of cell pathology, causes the elevation of intracellular Ca and cAMP contents having a promotional role in the generation of nociceptive signals (Kostyuk and Lukyanetz 2006, Julius & Basbaum 2001).

On the other hand it was shown that magnetic field has a dehydrating effect on nerve tissue, the decrease of the number of functionally active protein molecules in membrane, (Danielyan et al., 1999 a, b,), the decrease of intracellular cAMP and Ca ions and the increase of intracellular cGMP content (Ayrapetyan et al. 1994, 2005) causing the decrease of neuromembrane chemosensitivity and excitability (Ayrapetyan et al 2004 ). Thus, on the basis of presented data it was suggested that PMF could also serve as a novel therapeutic pain relief tool.

The preliminary data obtained in the present work on the modulation effect of PMF on teeth pain thresholds could be considered as convincing data on teeth pain relief effect of PMF. However, different sensitivity of each tooth depending on its location in oral cavity, as well as on sex differences of the patients serve as a main barrier for application of PMF as tooth pain relieving factor. Such variability of individual teeth to PMF from the point of view of our hypothesis can be explained by different initial levels of nerve ending hydration. (Ayrapetyan 1998).

Therefore, to use PMF as a novel tool for teeth pain relief therapy it is necessary to continue the study of the correlation between PMF-induced pain relief effect and impendence- metric parameters (marker for tissue hydration) of individual tooth, which is the subject of our current investigations.

## Conclusions

The obtained data have shown that the teeth had different pain thresholds and sensitivity to PMF. The differences were also observed in male and female teeth. The pain threshold in female was lower (about 31%), while the sensitivity to PMF was higher in female (about 20%) as compared with male.

In female the PMF had significant elevating effect on pain threshold, while in male this effect varied depending on their location in oral cavity.

It is suggested that more detailed characterization of PMF-sensitivity of each tooth, i.e. pain threshold-dependency on PMF intensity and on the exposure time, would allow us to use the PMF in dentistry as a pain releasing therapeutic tool.

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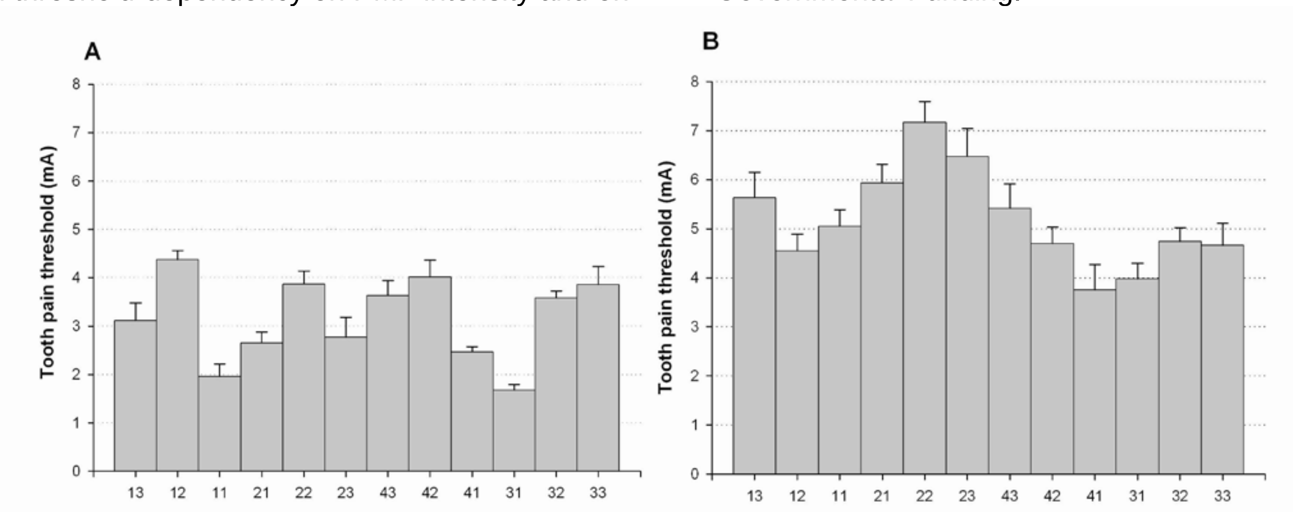
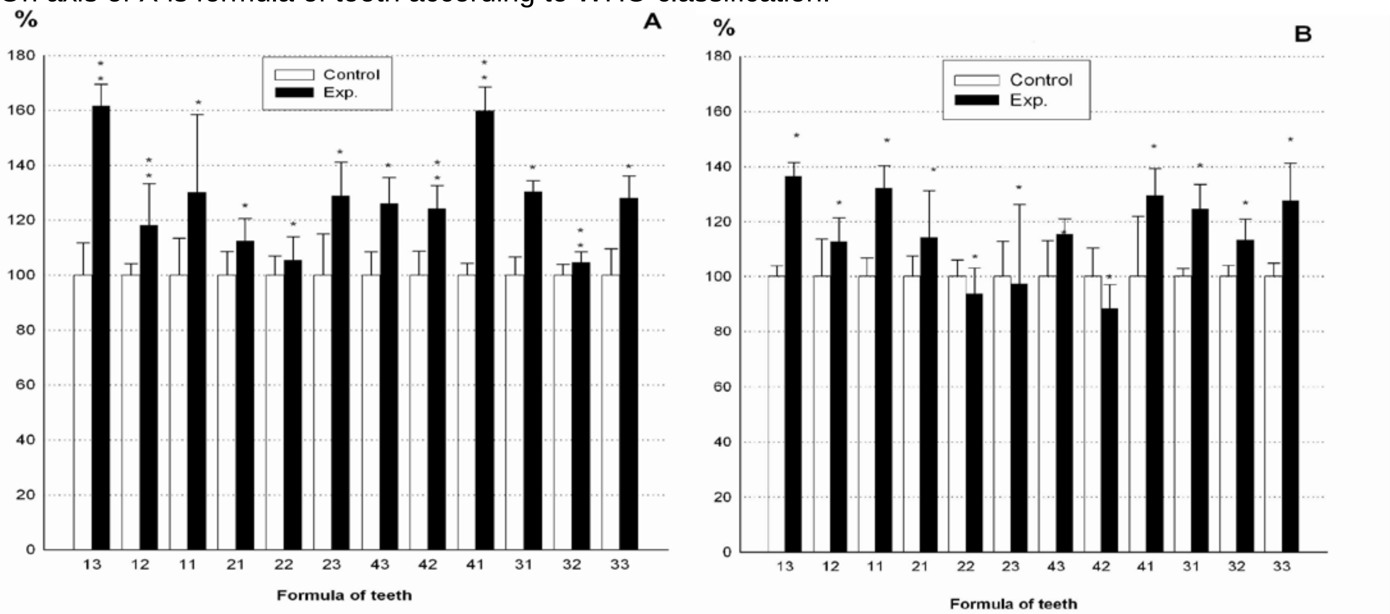



**Fig.2** The mean value of pain thresholds of frontal teeth in female (A) and male (B) patients. The electroalgesimetric data for each frontal tooth of upper and lower jaws of female and male participants were measured 3 times. Each column represents the mean value of 12 measurements for 4 female (A), 18 measurements for 6 male (B) patients. The range of variations is not observed, because the values were so small as to be observed as symbol mark. On axis of Y is pain threshold measured by milliampere (mA). On axis of X is formula of tooth according to WHO classification.




| Female (formula of teeth) | Mean of Control (mA) | Mean of Exp. (mA) | Control (%) | Exp. (%) | P value |
|---|---|---|---|---|---|
| 13 | 3.11±0.37 | 4.71±0.23 | 100±11.76% | 161.63±7.86% | 0.06 |
| 12 | 4.37±0.19 | 4.47±0.58 | 100±4.24% | 118.09±15.22% | 0.06 |
| 11 | 1.95±0.26 | 2.22±0.48 | 100±13.43% | 130.14±28.31% | 0.40 |
| 21 | 2.64±0.23 | 2.6±0.19 | 100±8.61% | 112.44±8.25% | 0.33 |
| 22 | 3.86±0.27 | 3.84±0.31 | 100±6.90% | 105.5±8.43% | 0.48 |
| 23 | 2.76±0.42 | 3.47±0.33 | 100±15.02% | 128.88±12.29% | 0.26 |
| 43 | 3.63±0.31 | 2.56±0.19 | 100±8.48% | 126.07±9.39% | 0.11 |
| 42 | 4.01±0.35 | 3.36±0.23 | 100±8.79% | 124.29±8.36% | 0.03 |
| 41 | 2.46±0.11 | 2.71±0.26 | 100±4.32% | 159.91±8.67% | 0.19 |
| 31 | 1.68±0.11 | 2.44±0.16 | 100±6.64% | 130.40±3.89% | 0.19 |
| 32 | 3.58±0.14 | 3.88±0.14 | 100±3.97% | 104.64±3.89% | 0.02 |
| 33 | 3.86±0.37 | 4.44±0.28 | 100±9.55% | 128.13±7.96% | 0.35 |

| Male (formula of teeth) | Mean of Control (mA) | Mean of Exp. (mA) | Control ( %) | Exp. ( %) | P value |
|---|---|---|---|---|---|
| 13 | 5.62±0.52 | 5.96±0.29 | 100±3.95% | 136.42±5.08% | 0.19 |
| 12 | 4.55±0.34 | 4.31±0.26 | 100±13.71% | 112.69±8.70% | 0.33 |
| 11 | 5.05±0.34 | 5.77±0.23 | 100±6.54% | 132.18±8.11% | 0.33 |
| 21 | 5.92±0.39 | 6.20±0.43 | 100±7.28% | 114.24±16.9%1 | 0.43 |
| 22 | 7.16±0.42 | 4.71±0.47 | 100±5.84% | 93.86±9.22% | 0.15 |
| 23 | 6.47±0.57 | 5.75±0.87 | 100±12.84% | 97.49±28.77% | 0.29 |
| 43 | 5.41±0.49 | 6.22±0.40 | 100±13.09% | 115.58±5.55% | 0.21 |
| 42 | 4.7±0.33 | 3.96±0.27 | 100±10.37% | 88.29±8.73% | 0.26 |
| 41 | 3.75±0.52 | 4.98±0.40 | 100±22.06% | 129.65±9.50% | 0.28 |
| 31 | 3.97±0.32 | 5.03±0.25 | 100±2.86% | 124.58±8.91% | 0.18 |
| 32 | 4.73±0.28 | 4.70±0.25 | 100±4.05% | 113.27±7.75% | 0.14 |
| 33 | 4.66±0.45 | 5.48±0.56 | 100±4.92% | 127.62±13.67% | 0.38 |

**Fig 3.** The effect of 20 min. oral cavity exposure by 50 Hz, 30 mT Pulsing Magnetic Fields on pain

thresholds of frontal teeth in female (A) and male (B) patients. PMF effect is expressed in % compared to the pain threshold of non-exposed (control) teeth (100%).
On axis of X is formula of tooth according to WHO classification.
On axis of Y is change of pain threshold calculated by percent according to the Control (100%).
Symbols denote significance of the treatment effect evaluated across all experiments; P< 0.5(*), P< 0.05(**).

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