

Design and Fabrication of Helmholtz Coils to Study the Effects of Pulsed Electromagnetic Fields on the Healing Process in Periodontitis: Preliminary Animal Results

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ABSTRACT

Background: Effects of electromagnetic fields on healing have been investigated for centuries. Substantial data indicate that exposure to electromagnetic field can lead to enhanced healing in both soft and hard tissues. Helmholtz coils are devices that generate pulsed electromagnetic fields (PEMF).

Objective: In this work, a pair of Helmholtz coils for enhancing the healing process in periodontitis was designed and fabricated.

Method: An identical pair of square Helmholtz coils generated the 50 Hz magnetic field. This device was made up of two parallel coaxial circular coils (100 turns in each loop, wound in series) which were separated from each other by a distance equal to the radius of one coil (12.5 cm). The windings of our Helmholtz coil was made of standard 0.95mm wire to provide the maximum possible current. The coil was powered by a function generator.

Results: The Helmholtz Coils generated a uniform magnetic field between its coils. The magnetic field strength at the center of the space between two coils was 97.6 μ T. Preliminary biological studies performed on rats show that exposure of laboratory animals to pulsed electromagnetic fields enhanced the healing of periodontitis.

Conclusion: Exposure to PEMFs can lead to stimulatory physiological effects on cells and tissues such as enhanced healing of periodontitis.

Keywords

Design, Production, Non-ionizing Radiation, Pulsed Electromagnetic Fields, Healing, Periodontitis, Helmholtz Coils

Introduction

Periodontitis, a common inflammatory disease, is highly prevalent among adults [1]. Periodontitis can be defined as the perpetuating inflammation and tissue damage into the tooth supporting structures [2]. There are several types of periodontitis such as aggressive and necrotizing but the adult periodontitis is the most common form [3]. This disease, mostly caused by gram negative bacteria, is known to be a risk factor for many systemic diseases [2, 4]. Many studies have shown a clear relationship between periodontitis and low birth weight, preterm labor, pulmonary diseases and diabe-

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tes[4-7]. There are also some studies showing the inter relationship between this disorder and cardiovascular diseases [4, 8, 9].

The main goal of periodontitis treatment is to remove infection and prevention of the disease progression. Most forms of periodontitis are currently treated by nonsurgical methods such as scaling and root planing which can lead to healthy periodontium for a long time. However, recurrence is not uncommon [3, 10].

Over the past decade, new treatment methods have been introduced to the dentistry community. Antibiotic administration has been shown to have synergistic therapeutic effects in some types of periodontitis in combination with mechanical debriment [11, 12]. Host modulation is another method which has been widely studied recently [13]. Some other studies manifest effectiveness of alternative methods such as using lasers, interdisciplinary treatments and neuromuscular stimulation. However, none of the aforementioned methods can thoroughly remove the infective agents [14-17].

Over the past years, our laboratory has focused on studying the health effects of exposure to some common and/or occupational sources of electromagnetic fields such as mobile phones [18-25] and their base stations [26], mobile phone jammers [27], laptop computers [28], radars [19], dentistry cavitrans [29] and MRI [30, 31]. In this work, we designed and produced Helmholtz coils for enhancing the healing process in periodontitis.

Effects of electromagnetic fields on healing have been investigated for centuries. These fields can be either pulsed or static [32]. Magnetic fields can be demonstrated by lines of force and these fields are produced by electric current flow. Static magnetic fields (SMF) are formed around a permanent magnet or by direct current (DC)

flow, while time-varying magnetic fields are produced by alternating currents (AC) with a frequency above zero. A wide variety of biological phenomena are based on electrical functions. We know that all living cells preserve a membrane potential in the order of tens of mV across their plasma membrane. On the other hand, the energy transduction in mitochondria are electrically controlled. Furthermore, the action potentials generated in excitable cells along their membranes are in the order of -70 mV and the frequency modulation of nerve impulses plays a very basic role in conveying information along neural networks [33].

Some studies indicated the adverse biological effects of electromagnetic fields [34-36] while numerous studies showed the beneficial effects of these fields on both hard and soft tissues [37-39]. Many studies show positive effects of PEMF on healing both soft and hard tissues [40-43]. Enhanced healing of anastomoses and wounds by static electromagnetic fields has been reported by different investigators. Cheing *et al.* have recently shown that pulsed electromagnetic fields significantly enhanced wound closure and re-epithelialization [44]. The authors of this report hypothesized that PEMF can increase the myofibroblast population, contributing to wound closure during diabetic wound healing. Nayci *et al.* also hypothesized that EMF stimulation highly strengthen the colonic anastomoses [45]. Furthermore, Henry *et al.* and Shen *et al.* postulated that SMF may induce wound healing [46, 47]. There are also studies indicating positive effect of PEMFs in treatment of osteoarthritis and ulcers [48-51]. A study conducted by Girgin *et al.* suggested that PEMF will improve all physical features of the colonic anastomoses [49]. In this study, we designed and produced Helmholtz coils for enhancing the healing process in periodontitis in rodents. Helmholtz coils

devices that generate pulsed electromagnetic fields. This device is made up of two parallel coaxial circular coils that are separated from each other by a distance equal to the radius of one coil for producing an approximately uniform magnetic field in the space between the coils.

In a pair of Helmholtz coils consisting of two current loops (figure 1), each with N turns and radius R , which are separated by a distance R , the magnetic field at any point along the axis of the coils (z) can be calculated by summing the individual magnetic fields of the coils using the superposition principle. In this configuration, Biot-Savart law can be used to calculate the magnetic field at the center of this system when $z=0$ (point O on figure 1) as follows:

$$B(z = 0) = \frac{8}{5\sqrt{5}} \frac{\mu_0 IN}{R}$$

Where:

B is the magnitude of the magnetic field

R is the radius of the loop

N is the number of turns in the current loop.

μ_0 is the permeability of free space

I is current

Material and Methods

Animals

In this preliminary study, 10 male Wistar rats (200-250 g) were purchased from the SUMS animal Laboratory. All ethical codes of the SUMS regarding the use of animal models were applied. To induce periodontitis, 3-0 multi-filament braided silk suture (Supasil, SUPA medical devices, Iran) thread was placed at the cervical region of second maxillary molars and was knotted at the palatal side (right side was considered as a positive control). Later, the knot was transferred to the subgingival palatal region of the second molars. The thread was kept in the place for 21 days including 7 days of

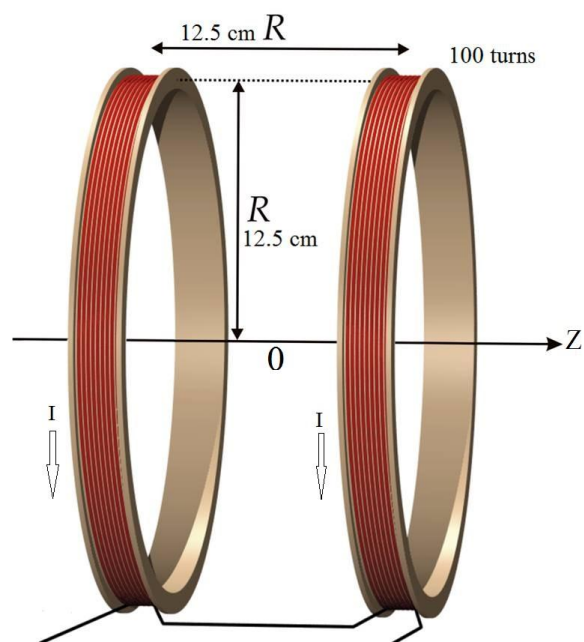


Figure 1: Schematic diagram of the Helmholtz coil manufactured in this study. This coil has 100 turns in each loop. The diameter of each loop was 25 cm and the distance between the two loops was 12.5 cm. The peak to peak voltage was set at 2.1 V (50 Hz, AC).

irradiation. The ligature was not removed during exposure to PEMF. Figure 2 shows the irradiation protocol used in this study.

Exposure System

Two pairs of identical Helmholtz coils were designed and manufactured in the Ionizing and Non-ionizing Radiation Protection Research Center (INIRPRC) at Shiraz University of Medical Sciences, Shiraz, Iran. As shown in figure 1, the Helmholtz coils, framed on Teflon, have 100 turns in each loop. The distance between the coils is 12.5 cm (the coils are spaced apart at a distance equal to their radii). These coils have an inner diameter of 12.5 cm and an outer diameter of 13.5 cm. The coils are driven by a sinusoidal signal from a function generator (GFG-8020H, GW Instrument Co., Ltd). The magnetic field (B) at the center, between

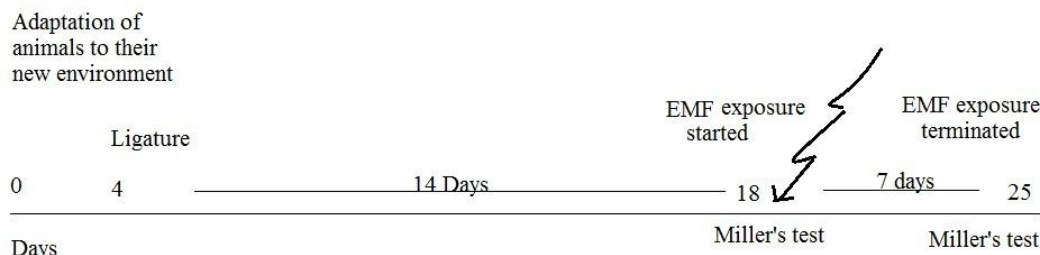


Figure 2: The ligature and irradiation protocol used in this study.

the coils, was measured with a Gaussmeter (Lutron 828, Taiwan). The magnetic field was relatively uniform (alterations less than 5%) in the central area of the coils. The earth magnetic field was not shielded in this exposure device. The windings of our Helmholtz coil were made of standard 0.95mm wire to provide the maximum possible current. The coil was powered by a function generator. The peak to peak voltage was set at 2.1 V (50 Hz, AC). An oscilloscope (GDS – 2202, GW Instrument Co., Ltd) was coupled to the system for monitoring the 50 Hz sinusoidal MF waveform. The strength of the magnetic field that is dependent on factors such as the number of turns in the Helmholtz coil and the current applied to the coils was measured by a recently calibrated EMF meter (Lutron 828, Taiwan).

Rats were exposed to PEMF 4h/day for 7 days. During the exposure rats were immobilized by using standard Plexiglas restrainers. The temperature inside the coil was monitored by a thermometer continuously during the experiment. In all animals, the left side was considered as experimental periodontitis side and the right side as the control (no intervention).

Results

Helmholtz Coils generated a uniform magnetic field between its coils which provided

a highly homogenous field ($\pm 5\%$). The magnetic field strength at the center of the space between two coils was 97.6 μT (figure 3).

The purpose of this preliminary study was to compare tooth mobility at different time periods before and after the exposure phase. According to the American Academy of Periodontology (AAP) tooth mobility can be defined as “The movement of a tooth in its socket resulting from an applied force”. A modified version of Miller’s mobility index (modified for rats) was used for assessing and scoring the mobility of the teeth [52]. Considering Miller’s mobility index, tooth mobility is divided into three classes; Score I- mobility up to 1mm, Score II- mobility of 1–2mm and finally Score III- mobility over 2 mm and/or rotation or depression.

Our preliminary results showed that exposure to EMF could significantly decrease the inflammation and mobility of the animals’ teeth.

Discussion and Conclusion

These findings are generally in line with those of other investigators who reported the healing effects of exposure to magnetic fields in cases such as fractures [53, 54]. Our findings are especially in line with the results obtained by Turk in 2001. He exposed rabbits after osteotomy of the femur to low-frequency magnetic field produced by a pair



(a)



(b)

Figure 3: a. The Helmholtz Coils manufactured in this study generated a uniform magnetic field between its coils which provided a highly homogenous field ($\pm 5\%$). b. The magnetic field strength at the center of the space between two coils was $97.6 \mu\text{T}$.

of Helmholtz-coils. He came to this conclusion that magnetic fields have significant positive effects on fracture healing. However, he stated that the mechanisms of interaction of magnetic field and bone fracture healing should be clarified by further studies [53]. It is worth mentioning that there are reports indicating that electromagnetic fields used clinically for accelerating bone healing also affect the proliferation of lymphocytes in vitro. Johnson have previously shown that T-cell proliferation can be modulated by in vitro exposure to electromagnetic fields [54]. Based on the preliminary findings of this study, exposure of laboratory animals to PEMF enhances the healing of periodontitis. Although we cannot directly extrapolate our findings on laboratory animals to humans, our results prompt us to perform further experiments on this issue.

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Conflict of Interest

None Declared

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