THE EFFECT OF PULSED ELECTROMAGNETIC FIELDS ON THE ACCELERATION OF TOOTH MOVEMENT

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***Aim**: Accelerating the speed of orthodontic tooth movement should contribute to the shortening of the treatment period. This study was designed to determine whether a pulsed electromagnetic field (PEMF) affects orthodontic tooth movement. **Methods**: The canines of one side of 10 patients (mean age 23.0 ± 3.3 years) who needed canine retraction were exposed to a PEMF; the canines on the contralateral sides of the same patients were not similarly exposed. After extraction of the maxillary first premolars, both canines were retracted with coil springs. A circuit and a watch battery were used to generate a PEMF (1 Hz). The generator was embedded in a removable appliance. Foil was used to obstruct the contol group from PEMF exposure. Patients were instructed to use the device from the commencement of canine retraction, and it was removed when Class I canine relationship was achieved in either of the canines after 5.0 ± 0.6 months. The changes in the space between the maxillary canine and first molar were measured to indicate the amount of tooth movement. The canine retraction distances were compared by paired* t *test. Afterward, the treatment plan was continued. **Results**: With exposure to a PEMF, canine retraction was 1.57 ± 0.83 mm more than the control group (*P *< .001). **Conclusion**: These findings suggest that application of a PEMF can accelerate orthodontic tooth movement. World J Orthod 2010;11:e52–e56.*

***Key words**: PEMF, tooth movement acceleration, orthodontic tooth movement, canine retraction*

Development of new methods for accelerating orthodontic tooth movement could shorten the period of active orthodontic treatment. Recently, magnets and pulsed electric magnetic fields (PEMFs) have been used as medicine, particularly in orthopedics. Great progress has been made in orthopedics by using PEMFs for the treatment of fractures in human long bones.[1] Despite the considerable amount of orthopedic research on PEMFs, their applications in dentistry and chiefly in orthodontics have been limited to the ability to increase the rate of orthodontic tooth movement.[2] The effect of electric currents in bone was examined by Fukada and Yasuda.[3] They hypothesized that electricity is produced when bone is stressed. This phenomenon, termed *piezoelectricity*, results from tension and compression in bone Tension and compression generate voltages of opposite polarity. The electric currents generated within the alveolar bone by orthodontic forces are thought to provide the signal for the directionality of the response[4] (that is, either resorption or deposition occurring during the remodeling process), whereas, the generalized enhancement of cellular activity is a function of the magnetic field strength.[5] It has been suggested that PEMF affects the activity of intracellular cyclic adenosine monophosphate and cyclic guanesine

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Fig 1 Electronic component on the dental cast before acrylic processing.

monophosphate by causing a change in membrane permeability, allowing increased flow of calcium, sodium, and potassium ions across the cell membrane.[6,7]

A study on the effects of PEMF on tooth movement through transmission electromicroscopy showed that tooth movement was accelerated as a result of increase in quantity of active cells without changing the cell structure.[8] Darendeliler et al[9] found that the application of either a PEMF or a static magnetic field were both quite successful in increasing the rate of orthodontic tooth movement in guinea pigs. In another study, Darendeliler et al[10] suggested that the PEMF-induced vibration may enhance the effect of mechanical and magnetic forces on tooth movement. Chang et al[11] also found a statistically significant increase and decrease of osteoclastogenesis and bone resorption areas when exposed to PEMFs of differing intensities. Besides, consistent correlation among osteoprotegerin (OPG), receptor activator of NFkappaB-ligand (RANKL), (macrophage colony-stimulating factor (M-CSF), osteoclast numbers, and bone resorption after exposure to intensities of PEMF were observed.

Since it has been hypothesized that PEMFs cause an increase in metabolic activity of bone, an increase is expected in the rate of orthodontic tooth movement. Therefore, the aim of this study was to determine whether PEMFs and mechanical forces affect orthodontic tooth movement.

METHODS

This study was a single blind sequential randomized clinical trial. Ten dental students (five men and five women) who required orthodontic treatment were selected randomly from the Orthodontic Department of the School of Dentistry. The mean age at the beginning of treatment was 23 ± 3.3 years. Five of the patients had Class I relationship and another five patients had Class II, Division I malocclusions. All of the patients had symmetrical crowding; therefore, they required maxillary premolar extraction to relieve crowding or reduce overjet. Patients did not take any vitamin D derivatives or anti-inflammatory and corticosteroid drugs during treatment. Intraoral photographs, lateral radiographs, and dental casts of the patients were obtained prior to canine retraction and after establishing Class I canine relationships on each side. The final records were obtained as soon as each side reached Class I relationship. The maxillary first premolars were extracted, and the distances from canines to maxillary first molars were measured with digital millimeter calipers (Orthopli Electronic Digital Calipers Model 50001) on dental casts. After banding, bonding, and leveling of the maxillary arch, the bilateral maxillary canines were retracted by 50 gram force of Dentaurum closed coil springs (Remanium Zugfeder No. 758-165-00). The maxillary canines of each patient were divided into control and

Fig 2 The combination of removable and fixed appliance during the retraction procedure.

experimental groups: Ten canines of one side of each patient were randomly assigned as control group, and the other 10 canines of the same patients were assigned to the experimental group. To apply the PEMF on humans, a new device was designed. This device was composed of an integrated circuit I.C. (Intersil, NE555) powered by a watch battery embedded in removable appliance (Figs 1 and 2). (The circuit was designed by an electrical engineering student.) The device was placed near the experimental group canines. To avoid any stimulation of the control group canines, aluminum foil was placed in the midline of removable appliance. All of the device's components were embedded in an acrylic maxillary removable appliance. The circuit generated a weak PEMF of 0.5 mT (Tesla), 1Hz that was induced only to the nearby canine (see Figs 1 and 2).

All patients were aware of the circuit, and each had signed the consent form before the start of the treatment. However, they were not aware of the placement of the circuit. The patients were instructed to wear the appliance for 8 hours daily overnight. Tip back and molar stoppage were performed on the maxillary molars to save anchorage. Closed coil springs were used to retract the canines. The springs were activated every 21 days; in addition, the function of the electronic circuit was continually checked by a sensitive coil. Canine retraction was stopped in both sides as soon as the Class I canine relationship was achieved in each side (after a mean of 5 ± 0.6 months). Afterward, radiographs, photographs, and dental casts were taken from each patient. The distances from midpoint of maxillary canines to the most mesial cervical point of maxillary first molars were measured with digital millimeter calipers, and these measurements were compared with the initial records. Statistical analysis was performed using SPSS for Windows 16 (IBM). Normality of data distribution was tested using the Kolmogorov Smirnov test. Moreover, the paired *t* test was used to evaluate intragroup distance differences before and after treatment. The *t* test was used to compare experimental and control group distances. All the records were measured again in 3-week intervals to reduce error. No statistically significant differences were observed.

After the calculations were made, conventional treatment was continued on all patients.

RESULTS

The mean pretreatment distance between the maxillary canine and first molar was 21.5 ± 1.3 mm in the experimental group and 21.2 ± 1.2 mm in the control group. The same distance was measured after a Class I relationship was achieved in either of the sides. This mean distance was 16.5 ± 1.5 mm in the experimental group and 17.7 ± 1.7 mm in the control group. The differences between pre- and posttreatment distances in each side were 5 ± 1.3 mm and 3.5 ± 1.6 mm for the experimental and control groups, respectively. The amount achieved from the distance difference in the control and experimental group as subtracted from each other was used to determine the final difference. A 1.57 ± 0.83 mm of difference was seen between the amounts achieved from experimental and control group. The paired *t* test showed that this difference was statistically significant ($P < .001$).

DISCUSSION

By postulating that PEMFs have the potential to activate cells involved in both depository and resorptive aspects, we decided to use them with closed coil springs in humans. Therefore, in the present study, we demonstrated the effect of PEMFs on the acceleration of tooth movement. The tooth movement was greater in the canine that was exposed to the PEMF. The present study showed that the canine that was exposed to the PEMF moved 1.5 mm more than the control canine in 5 ± 0.6 months. This amount might seem little; however, it is noteworthy that each tooth can be moved 1 mm per month. Therefore, in this study, we were 1.5 months ahead of the normal treatment plan in experimental group.

Previous studies have also demonstrated that administration of bone-resorption factors, such as prostaglandin E, prostaglandin E2, and 1, 25(OH) 2-vitamin D3, with mechanical force led to more rapid bone turnover and faster orthodontic tooth movement.[12–17] It has also been shown that mechanical stimulation, in particular low-intensity pulsed ultrasound, improves the rate of bone healing via upregulation of cartilage formation.[18,19] Furthermore, high-frequency (30Hz), low magnitude vibrations have been found to induce increased anabolic activity.[20]

The effect of magnetic field on bone healing is well documented in the literature,[21] and it has also been mentioned that PEMFs significantly accelerate bone-fracture healing.[22,23] However, this mechanism of action is not clear. Davidovitch et al[6,7] suggested that membrane permeability will be changed by PEMF, increasing the flow of calcium sodium and potassium ions across the cell membrane. Satake et al[24] also found that PEMFs caused an increase in calcium concentration in human periodontal ligament fibroblast cells. Darendeliler et al[9] found that the application of PEMFs along with coil springs was successful in increasing the rate of tooth movement compared with that produced by the coil spring alone. The mechanism by which the magnetic field increases tooth movement appears to be by the reduction of the lag phase associated with orthodontic tooth movement.[9] Haas[25] suggested that the combination of unloading and electric currents at the condyle causes histomorphologic changes that indicate an increase of cellular activity. PEMF stimulation was reported to increase the osteoblast proliferation,[26–28] enhance osteoblast differentiation,[26,29] and increase bone formation.[26,30] More recently, it was also reported that the waveforms of EMF were the crucial parameters to induce the response of osteoblasts.[31]

The source of the PEMF in this study was a watch battery, which poses no threat to humans. However, all patients were dental students who were aware of the presence of the battery in their removable appliance.

CONCLUSION

This study showed that PEMFs of 1 Hz was quite successful in increasing the rate of orthodontic tooth movement when used in combination with closed coil springs.

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