The effect of pulsed magnetic field on bone healing and osseointegration of intraosseous implant

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ABSTRACT

Background: In most types of dental implant at least three month it was advisable before loading for allowing time for osseointegration to be formed. Many researches and clinical studies have clearly shown a positive effect of pulsed electromagnetic field on the rate of osseous repair and acceleration of bone fracture healing. This in vivo study was conducted to evaluate the effect of pulsed magnetic field on bone healing and osseointegration around dental implant.

Materials and Methods: Twenty four mini implant types (Senax MDI) were inserted in the tibia of 24 oryctologus cuniculus male rabbits, they were divided into two groups each group consist of 12 animals. The 1st was control group for titanium implant without magnetic field, 2nd experimental group with (50 Gauss) pulsed magnetic field. 3 animals from each group were sacrificed at (2, 4, 6 and 8 weeks) period for histomorphological examination, eye pieces reticle and ruler were used for morphometrical studies, which were includes number of osteocytes, trabecular and periosteal thickness in the bone threads, statistical analysis by t-test and stander error were performed to compare between the two groups.

Results: It was revealed that the pulsed magnetic field showed stimulatory effects on bone healing and reduced the time of osseointegration, bone formation and bone maturation around titanium implant in the experimental animals when compared with animals of the control group.

Conclusion: The use of pulsed magnetic field (50 Gauss) with titanium implant showed stimulating effect on bone healing and osseointegration, leading to shorter healing period than non magnetic field titanium implant.

Keyword: Dental implant, pulsed magnetic field, osseointegration.

INTRODUCTION

Most of dental researches indicated that the most important factors for success of the dental implant depend on the success of fixation of the implant by osseointegration (1 to 4). One of the goals of dental implantology is to achieve good and fast osseointegration (5). Times about three month it was advisable in most types of dental implant before loading for allowing time for osseointegration to be formed (4, 6, 7). Other researcher (3) concluded in their study that dental implant need at least 3-6 months unloading period to obtain a complete osteointegration. Magnetic fields are widely used to promote bone healing of orthopedics and many researches and clinical studies have clearly shown a positive effect of pulsed electromagnetic field on the rate of osseous repair and acceleration of bone fracture healing (8 to 11). Many studies showed that proliferation and differentiation of osteoblasts, which are normally responsible for the growth of the bones, are modulated by several extra cellular factors, such as cytokines and hormones and are affected by pulsed electromagnetic fields (10, 12, 13).

Few studies have investigated the effect of magnetic field on stimulation of bone healing around dental implant and their results showed different degree of stimulatory effects on healing process in oral implantology (5, 11, 14).

MATERIALS AND METHODS

The experimental animals were divided into two groups, 5mm length of IMTEC Sendax implants were inserted at 2 cm away from proximal end of lateral surface of left tibia.

Group A: - Consist of twelve animals, with titanium implant and this group not exposed to magnetic field and this group considered as control titanium group.

Group B: - Consist of twelve animals, with titanium implant and this group exposed to pulsed magnetic field at the implant site and this group considered as experimental group.

After preparation of the animals an I.M. injection of 0.5ml/ kg of phenobarbetal was given for sedation and hypnosis followed by an intramuscular injection of 0.5 ml/kg, (50 mg for kilograms weight). Ketamine hydrochloride for anesthetic and muscle relaxant. The lateral surface of the tibia was chosen as site of operation, so the skin of this area was shaven and the area were wiped by Betadine solution and alcohol 70% for 10 minutes, and then a sterilized towel was draped over the animal. One cc of Lidocain hydrochloride
was removed after 7 days.

**Surgical procedure:-** Skin incision of 3cm in length was carried along the lateral surface of the tibia, the muscles were dissected to expose the tibia bone. A hole was made in the bone using an bur of implant till reach the master bur which is the same size 5mm in length and 1.7mm in diameter, than the implant was inserted after making a cut at 5mm distances from the tip of the implant final cutting was done for the excess of the implant by the surgical disc.

The surgical region was irrigated by normal saline and the muscles layers were sutured by absorbable chromic catgut suture, while the skin was suture with 3/0 black silk. The area of surgical site clean by wet sterilized gauss, then the skin sprayed with an antiseptic solution (povidone iodine 4%) and then dressed by sterilized gauss. The animal was injected by 0.3ml/kg Analgimed intramuscularly to reduce post operative pain and systemic antibiotic (penicillin G + procaine penicillin 800.000 I.U.) with dose 100 I.U. /kg B.W. was given as intramuscular injection once daily for 5 days postoperatively. The wound was carefully observed and the dressing was changed every day for 3 days postoperatively. The wound was carefully observed and the dressing was changed every day for the surgical area was covered by tetracycline eye ointment for one week post operatively, the suture of the surgical area was covered by tetracycline eye ointment for one week post operatively.

The stimulator is attached in series to a pair of coils with a total nominal inductance of 2.4 mH. The diameter of the coils was determined by the size of the tibias bone at the surgical site of the animal. The coils are wound from 0.060mm diameter insulated copper and attached to the stimulating device by (2 meter) long of 0.7mm² cross-section of cable. The coil was placed directly above the surgical site and fixed to this area by using special surgical plaster, which can be replaced without any complication, a current set at range (0-2 A) producing a field of (0-10mT) at its center it was checked by Teslameter. The pulses of the voltage train were applied for 28µs followed by a 200µs gap before repetition. To obtain the wanted field (50 Gauss), coils made up to 3 cm in diameter with 250turns of a maximum current of roughly 1 Ampere, maximum voltage across the coils of about 25V are required.

**Biopsy:-** Three animals were sacrificed by Islamic slaughtering from each group in the following interval of times (2, 4, 6, 8 weeks). The excisional bone biopsies were taken from the tibia. Morphometrical studies were performed by using eye piece WF 10×/18, it contain ruler from (0 to 10mm) length distances which used for determining the thickness of object. Periosteal thickness, trabecular thickness, and osteocyte counting were measured by using the eye piece reticles, in same manner of measurement done by Hassan(16) for assessment of bone healing process. Periosteal thickness measurement was done on each side of bone edge which contacts the implant surface and fined the mean. While trabecular thickness was measured in all bone thread on each side of the implant by taking the thickest and the thinnest parts of the trabecule and fined the mean. Osteocytes counting were performed by measuring the numbers of the osteocyte cells in the bone threads of the implant and then the means were taken.

**RESULTS**

The histological view in the control and experimental groups at (2 weeks) illustrates primitive new bone formation. The osteoblasts formed one raw on the bone surface, some of them change to preosteocyte cells figures (2) woven bone was noticed in the thread area and it following the screw shape, this type of bone is characterized by presences of osteocyte cell scattered randomly, numerous in number, new capillaries formation. The periosteum was thickened at implant region. The differences at (2weeks) between the two groups from histological examination which can be noticed from the figures (2 and 3) indicated that in magnetic field group of titanium implant was showed larger amounts of newly formed bone trabeculaes than control group, the same results have been shown for the periostium thickness, in magnetic groups which was thicker than non magnetic groups. In the bone marrow region, apparently normal marrow tissue with endothelial cells, fibers, fibroblast and fat cells could be seen. The experimental rabbits in titanium group (B) showed increases in the osteocytes numbers at period (2, 4, 6 weeks) when compared with control group (A), while at 8week the control group showed higher cells numbers and the differences was significant for all period (p<0.01) as shown in table 1. Table 2 and figure 1 indicated that bone trabeculae thickness was higher in magnetic titanium group (B) than control group (A) for all periods and these differences statistically was showed high significant differences at (6 and 8 weeks) period. There were slight greater thickness of the periostium in experimental groups than control groups at period (2, 6 and 8 week) and this differences statistically was non significant, but at (4 weeks) period it showed high significant differences in periosteum thickness between the two groups. The microscopic view for the sections of the tibia...
bones (figures 4 and 5) for 4 weeks showed bone trabeculae formation which is branching, anastomosing and harbors primitive marrow spaces, active osteoblast appears as a rim of cells surround the bone region. Newly formed blood vessels, the periosteum was thickened near the implant, from the figures 4 and 5 indicated that in magnetic field group of titanium implant showed larger amounts of newly formed bone trabeculae than control group.

Table 1: The statistical analysis by t-test for osteocytes numbers between control groups (A) and magnetic titanium groups (B) of the rabbit.

<table>
<thead>
<tr>
<th></th>
<th>Con. 2Weeks</th>
<th>Exp. 2Weeks</th>
<th>Con. 4Weeks</th>
<th>Exp. 4Weeks</th>
<th>Con. 6Weeks</th>
<th>Exp. 6Weeks</th>
<th>Con. 8Weeks</th>
<th>Exp. 8Weeks</th>
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<tr>
<td>Mean ± SE</td>
<td>14.3±0.5</td>
<td>19.9±0.6</td>
<td>16.7±0.4</td>
<td>26.1±0.7</td>
<td>23.5±1.0</td>
<td>27.7±0.8</td>
<td>26.7±0.6</td>
<td>23±0.5</td>
</tr>
<tr>
<td>Cal. t</td>
<td></td>
<td>t=6.8</td>
<td></td>
<td>t=8.6</td>
<td></td>
<td>t=3.2</td>
<td></td>
<td>t=4.5</td>
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<tr>
<td>P value</td>
<td>**P=0.0003</td>
<td>**P=0.0001</td>
<td></td>
<td>**P=0.009</td>
<td></td>
<td>**P=0.0001</td>
<td></td>
<td>*P=0.001</td>
</tr>
</tbody>
</table>

Significant at P < 0.01; Con: Control group; Exp: Experimental group (*P: Significant, **P: Highly significant).

Table 2: The statistical analysis by t-test for bone trabeculae thickness (µm) between control titanium groups (A) and magnetic groups (B) of the rabbit.

<table>
<thead>
<tr>
<th></th>
<th>Con. 2Weeks</th>
<th>Exp. 2Weeks</th>
<th>Con. 4Weeks</th>
<th>Exp. 4Weeks</th>
<th>Con. 6Weeks</th>
<th>Exp. 6Weeks</th>
<th>Con. 8Weeks</th>
<th>Exp. 8Weeks</th>
</tr>
</thead>
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<tr>
<td>Mean ± SE</td>
<td>11.4±1</td>
<td>19±3</td>
<td>20.5±3</td>
<td>31.5±5</td>
<td>20.3±1</td>
<td>44.5±3</td>
<td>32.5±2</td>
<td>57±5</td>
</tr>
<tr>
<td>Cal. t</td>
<td>t=2.2</td>
<td></td>
<td>t=1.3</td>
<td></td>
<td>t=6.7</td>
<td></td>
<td>t=6.0</td>
<td></td>
</tr>
<tr>
<td>P value</td>
<td>P=0.055</td>
<td></td>
<td>P=0.199</td>
<td></td>
<td>**P=0.0007</td>
<td></td>
<td>**P=0.0001</td>
<td></td>
</tr>
</tbody>
</table>

Significant at P < 0.01; Con: Control group; Exp: Experimental group (*P: Significant, **P: Highly significant).

Table 3: The statistical analysis by t-test for the differences in periosteum thickens (µm) between control titanium groups (A) and magnetic groups (B) of the rabbit.

<table>
<thead>
<tr>
<th></th>
<th>Con. 2Weeks</th>
<th>Exp. 2Weeks</th>
<th>Con. 4Weeks</th>
<th>Exp. 4Weeks</th>
<th>Con. 6Weeks</th>
<th>Exp. 6Weeks</th>
<th>Con. 8Weeks</th>
<th>Exp. 8Weeks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean ± SE</td>
<td>13.9±1</td>
<td>18.3±1</td>
<td>15.8±1</td>
<td>31.5±2</td>
<td>20.8±1</td>
<td>23.5±2</td>
<td>18.8±1</td>
<td>20.7±1</td>
</tr>
<tr>
<td>Cal. t</td>
<td>t=2.41</td>
<td></td>
<td>t=5.7</td>
<td></td>
<td>t=0.7</td>
<td></td>
<td>t=1.6</td>
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<tr>
<td>P value</td>
<td>P=0.038</td>
<td></td>
<td>**P=0.0002</td>
<td></td>
<td>P=0.49</td>
<td></td>
<td>P=0.013</td>
<td></td>
</tr>
</tbody>
</table>

Significant at P < 0.01; Con: Control group; Exp: Experimental group (*P: Significant, **P: Highly significant)
Figure 2: Microphotography illustrate the bone growth at two week for titanium implant with magnetic field, revealing the bone threads, BT: Bone trabeculae, PO: Periosteum, OST: Osteocyte. H&E stain x40.

Figure 3: Microphotography illustrates the bone growth at two weeks implant with out magnetic field, revealing the (bone marrow, x40), periostium and B: Bone tissue x20, H&E stain.

Figure 4: Microphotography illustrates the bone growth at four weeks for titanium implant with magnetic field, revealing the bone threads (trabeculae of newly formed bone), BT: Bone trabeculae, OST: Osteoblast cells. H&E stain x10.

Figure 5: Microphotography illustrate the bone growth at four week titanium implant with out magnetic field, revealing the bone trabeculae of newly formed bone at (arrow), H&E stain (x40).
The microscopic view for six weeks after implantation showed more bone trabeculae formation than four weeks, which is branching, anastomising and harbors primitive marrow spaces, active osteoblast appears as a rim of cells surround the bone region, the periosteum was thickened near the implant in general description for all groups, but the differences between two groups from histological examination which can be noticed from the figures (6 and 7) indicated that in magnetic field group of titanium implant was showed larger amounts of newly formed bone trabeculae than control group. In the bone marrow region, apparently normal marrow tissue with endothelial cells, fibers, fibroblast and fat cells could be seen.

![Bone thread](image1)

**Figure 6:** Microphotography illustrates the bone growth at six week titanium implant with magnetic field, revealing the newly bone thread formation at (arrows), H&E stain (x10).

![Bone thread](image2)

**Figure 7:** Microphotography illustrate the bone growth at six week titanium implant with out magnetic field control group, revealing the trabeculae of newly formed bone at (arrow), OSC: Osteocyte cell, BT: Bone trabeculae, H&E stain (x40).

Histological evaluation of the group (B) at eight week after implantation figure (8) indicated that the bone becomes nearly matured, the osteocytes distributed in the bone area and some time arranged around circles in concentric manner, the periosteum have active progenitor cells and the bone thread following the shape of screw. While histological evaluation of the group (A) figure (9) indicated that their were bone marrow spaces, osteocytes arranged in irregular trabeculae formation connected with each other and the bones showed more bone trabeculae formation than six weeks control groups, which is branching, anatomizing and harbors primitive pattern, the periosteum shows active progenitor cells, active osteoblast appears as a rim of cells surround the bone region, the periosteum was thickened near the implant.

![Bone thread](image3)

**Figure 8:** Microphotography illustrates the bone growth at eight week titanium implant with magnetic field, revealing the irregular pattern of osteocyte cell in newly formed bone thread at (arrow) OSC: Osteocyte cell, H&E stain (x40).
DISCUSSION

It was clear that the removal of haematoma was faster in group B that is mean it was faster in magnetic field groups than non magnetic groups and this could be due to the stimulatory effect of magnetic field as it causes vasodilatation and capillary dilatation and this may helping to speed up the process of bone formation also the magnetic field have stimulating effect on bone marrow cells, osteoblast cells and osteoprogenator cells and this result in faster bone healing .this results agrees with other researches Harki, Dennis which showed that electromagnetic field induced callus formation which enhances the healing of bone and this is may be due to changes in the intracellular cyclic adenosine monophosphate (cAMP) which is utilized by the osteoblast and osteocyte cells, while other studies attributed the stimulating effect of magnetic field on the osteoblast and inhibiting osteoclasts function which leads to bone matrix formation and calcification. Study by Laycock indicated that living cells within the body possess potentials between the inner and outer membranes of the cell, which are in normal condition, are fixed, different cells have different potentials. When cells are damaged, these potentials change such as the balance across the membrane changes, causing the attraction of positive ions into the cell and negative trace elements and proteins out of the cell. The net result is that liquid is attracted in to the interstitial area and swelling occurred. The pulsed magnetic field shown to help the body to restore normal potentials at an accelerated rate and this aiding in healing of most wounds and reducing swelling, and according to this effect the pulsed magnetic field stimulate bone healing at implant site which lead to faster healing in group B. The greater osteocyte cells numbers in magnetic field groups which indicated that the bone healing was faster in magnetic groups as the numbers of the osteocyte cells were greater than non magnetic groups which can considered as a good indicator about the osteoblastic proliferation activity in comparison to control groups and this result agree with other studies Victor and Ohy and The trabeculae thickness in group B indicated that bone healing was faster in magnetic group than control group and this finding agrees with other study as they indicated the stimulatory effect of magnetic field on bone healing, by enhancing early vascularization and new bone formation leading to faster bone maturation and ossification which is the induction of small eddy currents in the trace elements play apart in turn strengthen the formation of crystal structures of the bone and this results agrees with Edela and Harki.

REFERENCES

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