Mapping of the Magnetic Field in a Prototype Developed for Magnetic Stimulation of Bone Fractures in Animal Models

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Abstract— **Biological tissue healing has been developed in many research protocols, once the use of biomaterials and technologic devices during postoperative period may enhance functional and aesthetic rehabilitation. The objective of this paper was to map the magnetic field in a prototype developed for bone healing stimulation in animal models. The prototype was developed with two parallel magnets positioned in attraction to each other. The magnets were fixed and allowed to move in all directions through 3 screws. The animal model chosen was Wistar rat and the fracture model was an incomplete femur osteotomy gap. The animals were divided in 4 groups of magnetic stimulation. The experimental times were 7, 14, 21 and 28 postoperative days. The field's intensity perpendicular to the osteotomy gap was ranged from -101 to -216 mT in the center of the magnetic prototype. During the postoperative stimulation, the osteotomy gap was positioned perpendicular to the center of the field. The project was submitted to the Ethical Research Committee of Positivo University and was approved under the protocol 006/2009. To the result analysis, it was measured the field intensity with a gaussimeter in 60 positions. The data were showed in graphics. Further histological and mechanical analysis will be performed on the bone specimens. As unpublished results it is expected to be possible to develop an experimental protocol to be used in future animal researches and bone fracture's models.**

Keywords— **bone healing, magnetic field, functional rehabilitation, prototype development, magnetic field measurement.**

I. INTRODUCTION

Magnetic and electromagnetic fields have been studied by many authors with their uses in many biological tissues and organelles [1,2,3,4,5]. Despite the great number of researches, there are no conclusive results about the effects of this type of stimulation on different tissues. However, the results tend to a good prognosis for future clinical applications [3,4,5,6,7,8].

The human body is composed of eukaryotic cells with electric charges and currents that occur inside them, due to the presence of ions. The external and central regions of the cell present negative charges due to the presence of amino acids, proteins and glycolipids molecules. The positive charges are located close to the cellular membrane, which contains sodium, potassium and calcium ions. These regions, at each side of the membrane, determine and maintain the electrical behavior of the cells. Although these molecules may not induce or generate currents by itself, it is reported in the literature that they answer physical stimulations. One example is the healing process mediated by low level laser therapy [2,8,9].

Another example of the electricity generated by the human body is the piezoelectric effect that occurs in bone tissues. When submitted to mechanical deformation, the bone generates an electric charge proportional to the deformation [3,5,9]. Moreover, the areas of active bone growth, as in the healing process, are also negatively charged. These observations have been conducted to the use of external electromagnetic stimulation to induce bone neoformation.

The above mentioned paragraphs clear the motivation to use magnetic fields to communicate charges. Once the bone cells have charged molecules and, also, change their behavior under physical stimulation, the use of magnetic fields may enhance bone healing response.

Thus, the objective of this paper was to map the magnetic field in a prototype developed for magnetic stimulation of bone fractures in animal models.

II. MATERIALS AND METHODS

A. Prototype Development

The prototype proposed was first developed in 2010, aiming to expose cultures of bacteria and fungus in broth to a static magnetic field [6]. For these purposes, 2 magnets were positioned in attraction to each other and fixed by acrylic plates. On the top, it was prepared 2 hollows to receive the tubes of broth.

Following the development, the prototype was allowed to move in the 3 directions: x, y and z. For that, screws were positioned at its base and it was fixed to an aluminum surgical table (Figure 1).

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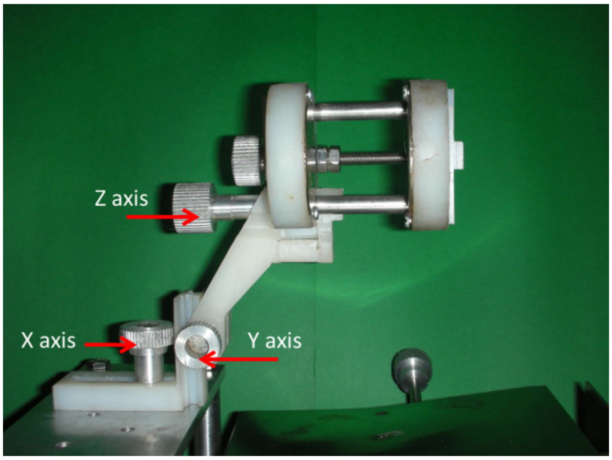


Fig. 1 Second prototype development. The red arrows shows the 3 axis, “x”, “y”, and “z”. The prototype is allowed to move within those axes.

To finish the prototype, the ruler was changed for a screw. Thus, the magnets were allowed to change its position through the “x” axis. With the shortening or increasing of the distance between them, the magnetic field would possibly be changed (Figure 2).

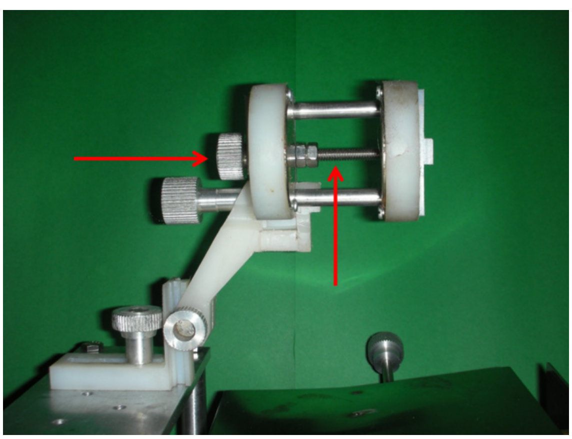


Fig. 2 The screw that replaced the ruler and the mechanism to shorten or increase the distance between the magnets (arrows).

B. Magnetic Field Measurement

After the development of the prototype, a gaussmeter was used to measure and map the magnetic field created between the magnets. The gaussmeter has 2 probes, one for AC field and one for DC field (Figure 3).

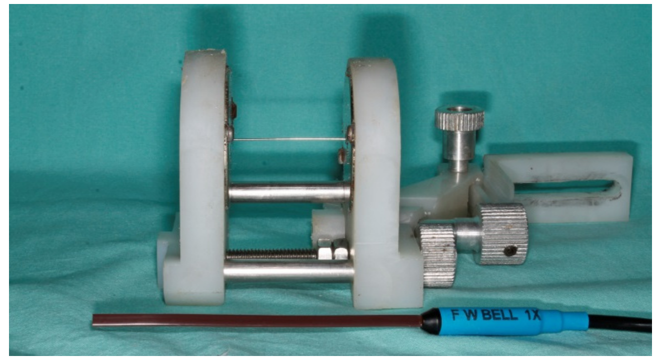
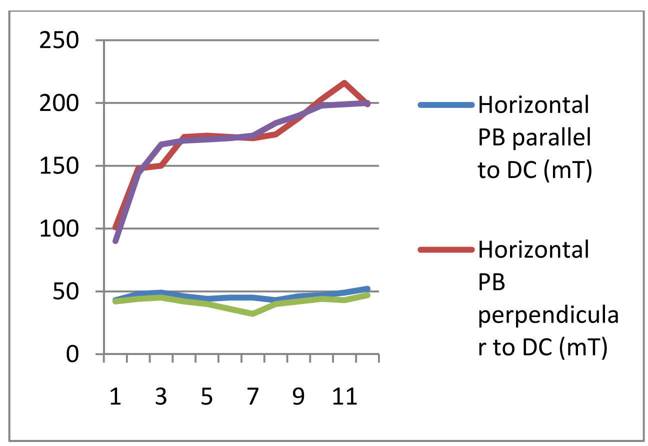


Fig. 3 Gaussmeter and its probe for the measurement of DC magnetic field.

In addition, to map the magnetic field, 60 measurements were made through a line that corresponds to the central diameter of the magnets (Figure 6). They are positioned 40 mm apart from each other, because this is the exact distance to the rat femur correct positioning during stimulation.

For the first and the second measurements, the probe was positioned horizontally with the sensor parallel and perpendicular, respectively, to the field lines. For the third and the fourth measurements, the probe was positioned vertically with the sensor parallel and perpendicular, respectively, to the field lines. The values of the central magnetic field are shown in Graphic 1.



Graphic 1: The four measurements of the magnetic field, shown in mT. Each probe measured the field 12 times. PB (DC probe); DC (magnetic field).

C. Animal Experiment

Twenty-four Wistar rats, average weight 300 g, were submitted to an incomplete femur osteotomy gap in its long axis. After the surgery, each femur was stimulated during

15 minutes, daily, until the end of the experimental period. The animals were divided in 4 groups of magnetic stimulation. The experimental times were 7, 14, 21 and 28 post-operative.

The procedures were performed in accordance with the ethical standards of the responsible committee on human experimentation, under protocol 006/2009 from Positivo University and with the Helsinki Declaration of 1975, as revised in 2000 and 2008.

III. DISCUSSION

The creation of this prototype aimed to achieve a methodological standardization of the magnetic stimulation, in order to make clear to the scientific community the biological processes not yet clearly understood. The developed prototype makes possible the study of the effects caused by magnetic fields in unicellular and multicellular organisms.

For each prototype, cylindrical neodymium magnets were employed, with 48 mm in diameter and 10 mm in width. The advantage of this material is that the magnetism is permanent, independent of electric current application. The permanent magnets have the property to create constant and steady magnetic fields. The two magnets were positioned vertically from each other, with a north pole facing a south pole. Nevertheless, the construction set allows that one of the magnets be inverted in position, in order to enable future studies inside repulsion fields. That could be obtained with the two north poles or the two south poles facing each other in the center of the prototype.

The intensity of the magnetic field varies with the distance between the magnets. The results from previous studies have shown that the growth of intensity of the magnetic field alters the results on the biological tissues. Aiming these field intensity changes, the prototype allows a regulation in the distance between the magnets, due to the screw positioned in its base, thus altering the field intensity.

The values of measurement are similar when concerning the position of the probe in relation to the field. Thus, probes positioned parallel to the field have shown minor values of measurement. On the other hand, probes positioned parallel to the field lines, showed higher values.

The values of interest ranged from -101 to -216 mT. These are the values of the field with the probe horizontally positioned to the prototype and perpendicular to the field. It reproduces the position of the femur during experiment. The mean value is -158mT. A value of 150mT was the value chosen by the authors as their hypothesis of the best bone tissue stimulation.

Further histological and mechanical analysis should be made to compare and interpret the results shown.

IV. CONCLUSIONS

Based on the methodology of this paper, it was possible to conclude that:

1. The prototype have been developed and improved to be used as a magnet stimulator for unicellular microorganisms and for biological tissues.
2. The mapping of the magnetic field corresponded to the objective of the study and its values ranged within the limits chosen for bone stimulation, namely, 50 to 150 mT.
3. The animal model of bone fracture was fully adaptable to the prototype developed and to the magnetic field generated.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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