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Bone Growth by Electrical Stimulation

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ABSTRACT: When a bone in our body experiences an injury, the natural process of regeneration is considered to regenerate and heal itself. But the procedure was interrupted in some patients leads to delays in the healing of bones and unions. Bone growth by electrical stimulation is a therapeutic way to promote bone growth it is difficult to heal cracks by using low electrical energy in a fractured area. Potential or non-destructive bone growth stimulants can be used instead, or in addition to other methods to promote bone healing. Invasive stimulation involves the insertion of a cathode implant into a crack with the production of Direct Current (DC) electrical stimulation. Non-invasive bone growth simulators introduce weak electricity into the target area using electromagnetic pulsed fields, capacitive coupling or combined magnetic field.

KEYWORDS: Electrical stimulation, DC stimulation, Capacitive Coupling, Inductive Coupling.

I.INTRODUCTION

Bone is a tissue or organ that is found in almost all mammals, including humans. The primary function of the bones in our body is to provide support and structure and to protect the internal organs from external injuries. About 8% of fractures are treated with invasive methods, which usually mean surgical intervention to prevent, restore, or replace a damaged bone. Unsuccessful osteoporosis and delayed healing are reported complications reported after fractures, joint fractures, and bone grafting procedures. The incidence of reduced healing or non-healing after spinal fusion may range from 5% to 35%, with long bone fractures ranging from 5% to 10%. The reason for the non-union and the healing of the delay in the split is often unknown. Known causes of delayed or dysfunctional unions include problems with functional and non-functional interventions, including insufficient fracture stimulation, disruption of fracture fragments with repair or pulling devices, repetitive strain or excessive early fracture movements, periosteal rupture, and other soft tissue injuries during functional exposure. The ability to heal a fracture to improve the percentage of patients with non-traumatic cures will have a significant impact on the economy, as well as improve the physical and mental well-being of these patients. There are a variety of biological, mechanical, and physical interventions designed to improve the healing of fractures. In the early 1950's, Fukada and Yasuda showed that when pressure was applied to the bone, in areas of tension the bone was strong and regenerated, while areas of compression were tilted and caused resorption. The built-in electric field varies in size due to the type of tissue in the fracture and the magnetic properties used. Electromagnetic fields ranging from 0.1 to 20 G were used to create an electric field in an area of 1 to 100 mV / cm. Electrical stimulation has been shown to be effective in assisting bone healing in various bone conditions such as assisting internal and external repair, increasing delayed or non-union delays with osteotomies, improving bone function, treating new fractures, and assisting osteonecrosis.

II.WORKING PRINCIPLE

The mechanical pressure applied to the bones results in the production of electrical energy. Electronegative energy is produced by pressure and electropositive energy is produced by resistance. The piezoelectric structures of the collagen matrix and the electro kinetic effects cause this electrical energy to respond to the mechanical environment. It has been shown that bone is formed under electronegative power and regenerated under electropositive energy. It is thought that this energy boost is the way bones are built in response to the load used. Electric and electrical compounds are thought to play a role in orthopedic treatment using the same principles as mechanical stress applications. Follow the dispersion process. The use of Electromagnetic fields aids in fractures is intended to mimic the effect of mechanical stress on the bone. Electrical resuscitation methods have been used for severe fractures, delayed unions and non unions. Incompatibility of electrical stimulation includes dislocated bone loss in the fracture site, synovial pseudoarthrosis, congenital pseudoarthrosis, non-infectious unions, and improper stability of local fracture equipment. In these clinical situations, surgical management of a bone marrow transplant, to eliminate infection, or to stabilize a fracture with internal correction is required prior to electrical considerations.

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III.INVASIVE AND NON INVASIVE STIMULATION

Bone formation is influenced by a variety of local and systemic factors. The first includes the rate of bone loss, trauma, and the type of bone affected, the degree of disability, infection, spinal cord injury, vascular and other conditions. The latter include the patient's age, duration from injury, hormones, corticosteroids, exercise and local pressure regarding fractures. Electrical growth stimulators can be divided into two general categories, based on clinical practice.

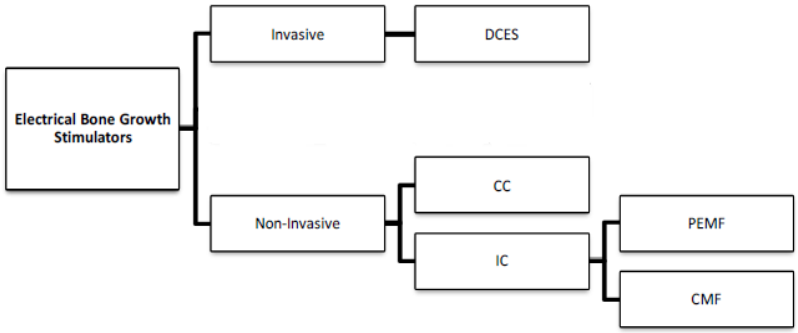

Fig. 1 Classes of electrical bone growth stimulators by their methods of administration and electrical signals. (CC: capacitive coupling, CMF: combined magnetic field, DCES: DC electrical stimulation, IC: inductive coupling, PEMF: pulsed electromagnetic field)

The invasive method uses a built-in plug-in device that delivers direct electric current stimulation (DCES) to the region of interest. The device itself consists of a short-lived current generator that transmits current with metal lead and electrodes directed to the appropriate locations. The cathode (non-constructive electrode) is the site of osteogenesis, and is therefore embedded in the bone graft; and the anode (constructive electrode) must be placed on nearby soft tissues, otherwise it will produce the opposite effect to the desired effect. The current generator is usually surgically removed after 6 to 9 months or until treatment occurs, while the track and electrodes can be tested or inspected.

In contrast to DCES, non-invasive stimulation involves the delivery of weak, time varied electromagnetic fields to the infected bone tissue, using inductive coupling (IC) or capacitive coupling methods (CC). In both cases, the device's tools are fully external, and this method is painless to a certain extend. While these methods exist often found to be well tolerated, patients still need to actively operate and wear .Low patient adherence to a treatment plan can hinder the effective implementation of non-invasive strategies .A 2006 safety analysis of the six bone growth stimulants on sale at that time identified 47 serious incidents during the 18-year period. Problems included: hot flashes, electric shocks, device malfunctions, skin irritation, and excessive reaction. While non-invasive bone growth stimulants are generally considered to be safe, the existing studies are inconsistent with the biological hazards (teratogenicity, mutagenicity), and simultaneous communication by these devices (pacemakers, ventricular help devices, defibrillators), or metallic fixation devices. Similar to DCES, non-invasive stimulation indicates a dose-dependent response to treatment time. 1-10V power in a20-200 kHz frequency for CC devices, with electromagnetic fields ranging from 0.1 to 20 G for IC devices, they are needed to achieve the desired momentum. Effect of electric fields for a thickness of 1-100mV / cm at the target site has been shown to promote bone formation.

Inductive coupling is further divided into pulsed electromagnetic fields (PEMF) and combined magnetic fields (CMF).Both are actually the same, but CMF is different from PEMF that it superimposes an additional magnetic field to the existing field. As a result, CMF is faster than PEMF. That is, instead of wearing a PEMF device for 3 to 8 hours daily for 3 months, the patient need to wear CMF device 30 minutes a day for 3 months to obtain the same result.

IV.COMMONLY USED BONE GROWTH STIMULATORS

OsteoGen bone growth stimulator: The OsteoGen surgically implanted bone growth stimulator is a useful adjunct for the treatment of non-unions when surgery is already planned or when patient compliance may be a concern. Because the OsteoGen is totally surgically implanted, patients are assured of therapeutic treatment directly at the non-union site 24 hours a day for at least 6 months. The OsteoGen bone growth stimulator is compatible with bone graft surgery in the surgical treatments (internal and external fixation) commonly used for the management of non-unions.The Mesh Cathode provides the same current density to the connection site as a straight cathode, but with more contact the cathode goes to connecting and holding the bone. To achieve this, the mesh cathode of OsteoGen-M is made of the same titanium thread as a triple wire cathode of OsteoGen straight titanium wire. Although the dimensions of the mesh cathode and the straight cathode appear differently (grid 1x8 cm vs. 25 cm straight cathode), the visible area of both cathodes remains exactly the same. By maintaining the same transparency area between the mesh and the vertical suspension, the same current density is maintained at the cathode coupling site. The mesh configuration increases the

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number of points to identify contacts for the cathode travels to these sensitive areas, thereby increasing the surface area of the membrane bones.

Fig.2 OsteoGen bone growth stimulator

Orthologic 1000 single coil bone growth stimulator:The OL1000 SC is a portable, battery powered, microprocessor controlled, bone growth stimulator. The device is worn by the patient for 30 minutes a day as well provides local electric treatment with non-invasive splits. The device generates the lowest energy consists of static fields. The device has a pressure button that starts treatment with an audible voice input. Liquid crystal display (LCD) used to display device status, e.g., medical record, daily treatment time count down.

Fig.3 OL1000 SC size 2.

V. COMPARATIVE STUDY

TECHNIQUE	METHOD OF APPLICATION	ADVANTAGES	DISADVANTAGES
Direct electrical stimulation	One or multiple surgically implanted cathode with one cutaneous electrode.	▪ Increased patient compliance. ▪ Constant stimulation of the bone directly at the fracture site.	▪ Poses threats like lead breakage and battery malfunction. ▪ Risk of infection and soft tissue discomfort since the technique is invasive.

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Capacitive coupling	Two cutaneous electrodes.	▪ Non-invasive and painless. ▪ No potential problems such as electrochemical reactions and injuries. ▪ Can be used by the patient conveniently at home	▪ Requires constant monitoring to ensure adequate battery level. ▪ Patients must change the batteries daily.
Inductive coupling	Cutaneous electromagnetic coil.	▪ Non-invasive and hence painless. ▪ No electrochemical effect on tissues.	▪ Therapy success greatly depends on patient compliance. ▪ The non-localised of inductive stimulation affects multiple tissues surrounding the injury site.

Table.1 A comparative study on different bone growth stimulation techniques.

VI. CONCLUSION

Summarizing, in vitro experiments that expose cells to Electrical Stimulation, generally show positive results, although, a lack of standardization of cell types, models and protocols make it difficult to draw realistic conclusions. Additional studies are needed to develop strategies for transferring these encouraging in vitro findings into meaningful in vivo BTE applications. In addition, the logistics of combining Electrical Stimulation and BTE treatments in practical, cost effective ways in clinical settings must be considered. Recent advancements in polymer science, using "smart" biomaterials, that enable built-in stimulus/response behavior capabilities, have tremendous potential. Electro active smart polymeric biomaterials could be used to build bone tissues that offer precise control over the amount, duration, and localization of the electrical stimulus, thus obviating the need for bone stimulators. These materials have already been tested in vitro, where they have demonstrated the ability to improve cell proliferation and differentiation. If in addition to promoting these pro-osteogenic activities, these smart biomaterials can also be designed to biodegrade after a given useful time period, this would be yet another benefit.

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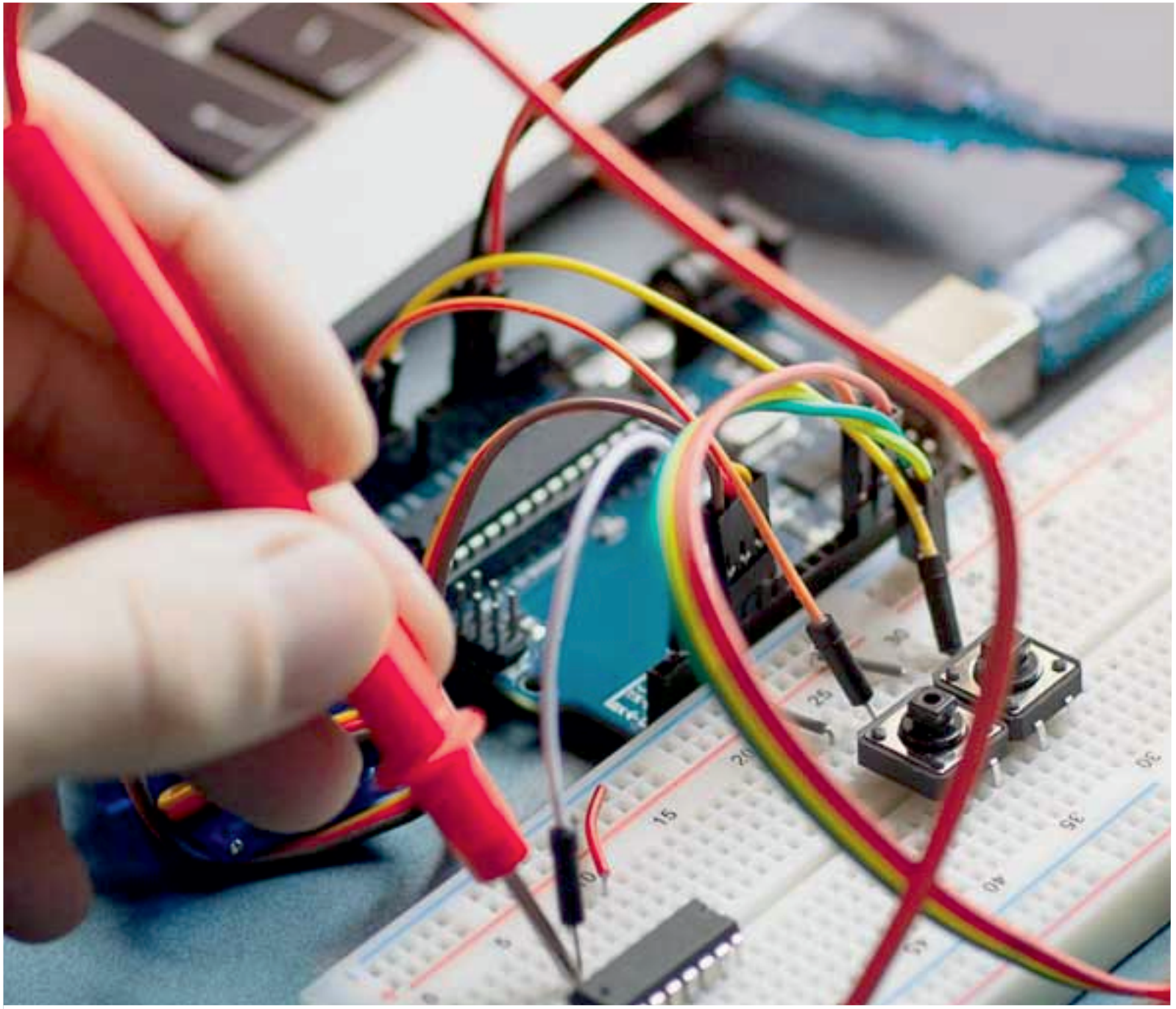

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