THE USE OF ELECTROTHERAPY TO ENHANCE OSTEOGENESIS

Essay

SUBMITTED IN PARTIAL FULFILMENT

OF MASTER DEGREE IN

ORTHOPAEDIC SURGERY

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(CAIRO)

1987

بسم الله الرحمن الرحيم

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ACKNOWLEDGEMENT

"First and foremost, thanks are due to GOD
the beneficient and merciful"

I feel greatly indebted to **Prof. Dr. FAROUK BORG,** Professor of Orthopaedics, Ain Shams University for his advices, kindness and masterly teaching.

I would like to express my appreciation to **Dr. MOSTAFA BADAWI,** Lecturer of Orthopaedics, Ain Shams University for his encouragement, generous help, and guidance.

I should pay much gratitude and respect to my professors and teachers of Orthopaedics, they taught me all over years, their attitude that created me have interest in Orthopaedics.

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I N T R O D U C T I O N

INTRODUCTION

Orthopaedic surgery has entered the era of biophysics or that discipline of science concerned with the action of physical forces upon or within living cells. **Kuntscher (1941)** and others, proved several years ago that callus formation could be induced by mechanical, thermal, or chemical irritation. Of the several physical forces, only electricity has been studied extensively. Yet, the mass of evidence collected to date, even though it is largely circumstantial in nature, points to electricity as the signal which directs the physiological response of the bone cell to changes in its physical environment **(Brighton, 1977).**

This essay aims at collections of the articles and data about the origin of electrical signals and the bio-electrical characteristics in the bone. Also, this essay purposes to delineate the different electrical systems used for treating the different osteogenic problems and to describe what little is known about the mechanisms of action of electrically induced osteogenesis.

Time and more quantifiable studies will tell, which form of electricity, and which technique of applying electricity to bone, are most efficient in promoting osteogenesis and are most practical for clinical use.

HISTORICAL REVIEW

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The concept of utilizing electricity to heal ununited fractures or non-unions is not new. In **1841, Hartshorne** reported the case of a patient with non-union of the tibia who, in 1812, was treated with "shocks of electric fluid passed daily through the space between the ends of the bones" for six weeks. As far as is known, this was the first attempt at treating non-union with electricity. In, **1850, Lente** reported on three additional cases of delayed union or non-union treated with galvanic current for ten minutes, three times a week, for several weeks. Apparently these lesions healed successfully under the influence of the electric treatment. For reasons that are not completely clear today, further attempts at using electricity to treat non-union were abandoned, a relatively silent period of 103 years ensued.

Interest in electrically induced osteogenesis was reawakened in **1953 when Yasuda and Fukada** demonstrated the appearance of new-bone formation in the vicinity of the cathode (negative electrode) when a current in the microampere range was applied continuously for three weeks in the rabbit femur. They also described stress-generated potentials in bone in which the site of the bone under mechanical compression became electronegative and the site under tension became electropositive. Similar experiments were reported independently in the United States by **Bassett and Becker (1963)** and by **Shamos et al. (1963). Friedenberg and Brighton (1966)**, reported another kind of electrical potential in bone, the bio-electric or steady-state potential. In living, non-stressed bone, areas of active growth and repair were electronegative when compared with less active areas.

Based on the cited findings, many laboratories around the world began studying the effects of electricity on bone and cartilage. In **1971, Fridenberg et al.** were the first in modern times to report the healing of a non-union with direct current. In **1974, Bassett et al.** reported for the first time on the use of electromagnetic stimulation in treating non-union. By 1976, articles had appeared in the world literature describing the effects of various forms of electricity on bone growth and repair in laboratory animals and in humans **(Spadaro, 1977)**.

Now, electricity can be applied to bone in three different commercially available electrical systems (approved by Food and Drug Administration in USA 1979): the semi-invasive system, the totally invasive system and the non-invasive system. All three systems seem to give the same results in treating different osteogenic problems, results that are comparable to those of bone graft surgery **(Brighton, 1984)**.

THE BIOELECTRICAL CHARACTERISTICS OF BONE

* Introduction
* Piezoelectricity
* Electrokinetics
* Experimental findings in fluid-filled bone
* Experimental findings in fluid-filled cartilage
* Bioelectrical potentials in bone

INTRODUCTION

The appearance of an electrical potential difference between one region of bone and another in the presence of applied stress indicates that electrical charges within the bone undergo some relative displacement due to the presence of the stress. Such potentials were observed in dry bone by **Fukada and Yasuda** as early as **1957** and since that time numerous investigators around the world have observed this effect.

Considerable controversy existed as to the origin of these endogenous stress-generated potentials in bone. Researches are concentrating upon demonstrating that either piezoelectricity or electrokinetic effects were the responsible mechanism(s) for the observed potential.

This chapter sough to define the piezoelectricity and electrokinetic effects in bone and also to determine the bioelectrical potentials in bone.

PIEZOELECTRICITY

The following experiment was performed by **Yasuda (1953),** one end of a long tubular bone was fixed to a stationary stand while a weight was placed on the other end to bend the bone (Fig. 1).

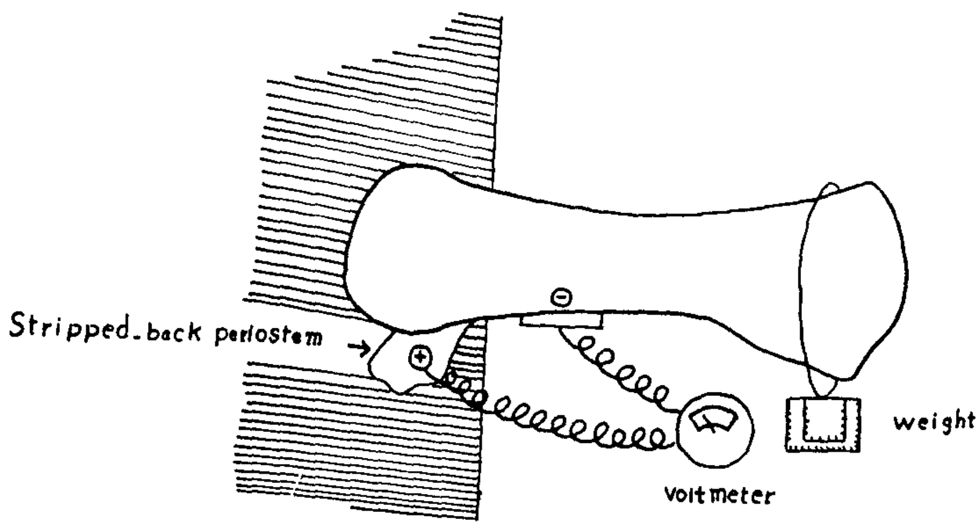

Fig. (1) Drawing depicting bone fixed on one end with weight applied to the other end. Region under compression is electronegative (Yasuda, 1953).

The potential (voltage) was measured at the portion where the largest forçe was applied, and was compared to the potential of the periosteum which was peeled back. As was speculated, the region under compression was electronegative as compared to the non-stressed portion. In contrast, regions under tension were electropositive. Therefore, it can be said in a simple way that if bone is stressed, electricity is produced. This phenomenon has been called "Piezoelectricity of bone".

Now, piezoelectricity is a term generally used to describe the appearance of electrical potentials in certain materials when stress or external forces are present. These potentials arise from the stress-induced orientation of electric dipoles in the material, the stress-induced formation of dipoles, or from charge separation in materials whose structure lacks a center of symmetry **(Pollack, 1984).** The electrical potentials can be taken to increase linearly with the magnitude of the applied stress; however, in the case of dry bone the actual mathematical relationships are more complex **(Johnson et al., 1980).** When stress is applied, either a net charge separation results wherein the positive charges are spatially separated from the negative charges or the dipoles within the material are oriented by the stress, resulting in a net charge difference at the surface of the material (Fig. 2) **(Pollack, 1984).**

It is generally agreed that in dry bone, the collagen fraction accounts for the observed piezoelectric properties. **Marino et al. (1975),** measured the piezoelectric effect as a function of the angle between the applied pressure direction and the long axis of bone specimens. They found that the potentials exhibited by bone could be accounted for by the collagen and that the mineral phase produced little or no potentials. Such piezoelectric properties are exhibited by a wide range of tissues and are most probably due to their polar molecular structure **(Marino et al., 1975).**

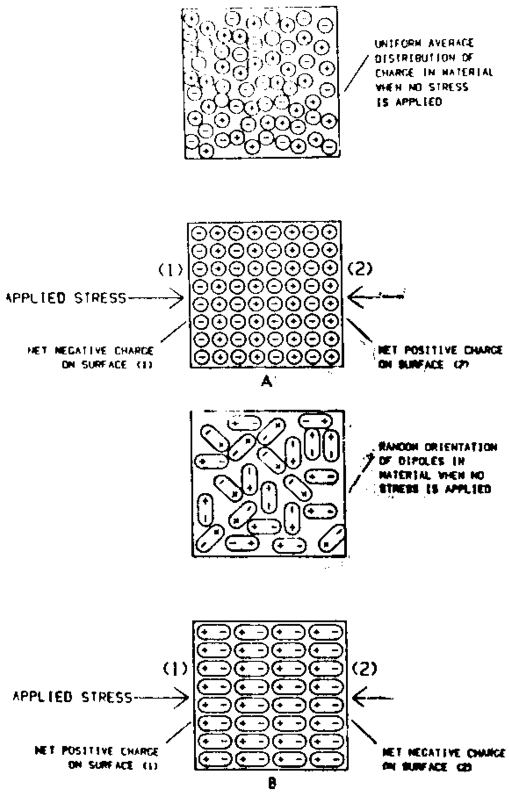

Fig. (2) This schematic representation shows the formation of a piezoelectric signal (Pollack, 1984).