Biomedical Engineering IV
Recent Developments

Proceedings of the Fourth Southern Biomedical Engineering Conference

Barry W. Sauer

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PREFACE

The Fourth Southern Biomedical Engineering Conference was held in Jackson, Mississippi, October 11-12, 1985. Co-hosts were the University of Mississippi School of Medicine and the Mississippi Institute for Technology Development. The purpose of this annual conference was to bring together scientists, engineers, veterinarians, dental and medical personnel, and graduate and undergraduate students of the southern states for the dissemination of recent advances in biomedical engineering research.

Appreciation is expressed for the assistance and timely advice from organizers of the preceeding conferences. The chairman is especially grateful to the staff of the University of Mississippi Medical Center Division of Continuing Health Professional Education without whose assistance this conference would not have been possible. Last, but not least, the chairman wishes to acknowledge financial support from the Mississippi Institute for Technology Development and the individual sponsors whose contributions were essential to the success of the conference.

October, 1985
University of Mississippi School of Medicine
Jackson, Mississippi

Barry W. Sauer
Program Chairman

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Session 12: CLINICAL ENGINEERING

Session 1
BIOMATERIALS I

EFFECT OF STORAGE ON THE ELECTRICAL PROPERTIES OF BONE

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ABSTRACT

In this study the effects of various storage environments on the electrical properties of bone were evaluated. Cortical bone specimens from canine femora and tibiae were prepared and divided into three groups with one group maintained at room temperature (24°C), a second group stored in a refrigerator at 3°C, and the third group stored in a freezer at -10°C to -20°C. In each group, both the resistance and the capacitance decreased with time, the percentage of change being maximum for the samples stored in the freezer. This suggests that storage of bone specimens in a refrigerator or freezer with repeated thawing at room temperture does effect the electrical properties of bone, with the effect being dependent on the method of storage.

KEYWORDS

Electrical Properties; Bone; Storage Medium; Resistance; Capacitance.

INTRODUCTION

Although Orthopaedic surgeons are increasingly using electrical stimulation to treat non-unions and congenital pseudoarthrosis, the mechanism of action of bioelectricity is still unknown. For a better understanding of the role of electrical stimulation in bone remodeling and for an analysis of the distribution of direct or induced current in bone, we need accurate data on the electrical properties of bone. Although some investigators have measured electrical properties *in vivo*, this creates uncertainties regarding the current paths between a pair of electrodes placed in such a material and the nature of the tissue-electrode interface (Singh and Saha, 1984). Therefore, *in vitro* measurement techniques on standardized bone specimens have been utilized to characterize the electrical properties of bone.

With *in vitro* measurement methods it is important to know how various factors and parameters effect the measured value. Previously, Reddy and Saha (1984) have shown that the electrical properties of bone are anisotropic in nature and frequency dependent. Saha, Reddy, and Albright (1984) have shown that the electrical properties of bone are dependent on the moisture content, temperature, pH, time of exposure to the air, and measurement procedures. Other authors (Kosterich, Foster, Pollack, 1984; Singh and Saha, 1984) have shown that the

electrical properties of bone are dependent on the conductivity of the immersion fluid, perserving solution, principles and techniques of measurement, and others. However, the effect of the environment in which the bone sample is stored, when not being measured, has not been properly investigated.

The fact that in most studies the bones are stored frozen or refrigerated prior to testing indicates a need to know the effect of this type of storage on the electrical properties of bone. The objective of this study was to evaluate and determine if such storage changes the electrical properties of bone, and to compare this with other type of storage environments. Three storage environments were chosen which were room temperature, a refrigerator, and a freezer.

METHODS AND PROCEDURES

Canine femora and tibiae were used in the study. The bones were removed soon after the sacrifice of the animal and wrapped in towels soaked in lactated Ringer's solution to prevent the bones from drying. Two to three centimeter long specimens were then machined from the mid-diaphysis of each bone. Each specimen was then further machined in the axial direction to produce two to four matched specimens from each bone. During the entire machining process the bone were kept moist at all times. After machining, a total number of eleven bone specimens were individually placed into containers with lactated Ringer's solution and an added bacteriostatic agent.

After the specimens were prepared, the resistance and capacitance were measured using a LCR meter (HP model 4262A), as described before (Saha, Reddy, and Albright, 1984). All measurements were made at 1 kHz. This initial measurment was made approximately two and a half hours after the sacrifice of the animal. The measurments were repeated throughout the day. At the end of the first day the samples were divided into three groups. The first group was maintained at room temperature ($24^{o}C$); the second group was stored in a refrigerator at $3^{o}C$; and the third group was stored at -10^{o} to $-20^{o}C$. The next day the samples were removed from their storage environment and allowed to thaw and equilibrate to room temperature. Then the resistance and capacitance were measured repeatedly through the course of the day, being placed back into their respective storage environments at the end of the day. The procedure was repeated for upto four days with the times in which the bone specimens were removed from their environments and placed back being the same.

The electrical properties were measured using chlorided silver-metal electrodes. Surface moisture was removed from the bone prior to the measurement and a layer of conductive gel (Aquasonic^{R} 100, Parker lab) was applied to the bone surface and to the electrodes. The amount of time between the removal of the sample from the solution and the measurement was kept constant for each measurement due to the effect of exposure time (Saha, Reddy, and Albright, 1984).

RESULTS

Figure 1 shows the change in resistance for the three groups. The values for each day were calculated as the mean for the hourly readings for that day. As is shown, the resistance of the samples maintained at room temperature decreased slightly, similar to that of the specimens stored at refrigerator temperature. The resistance of the frozen specimens decreased at a noticeably faster rate than those stored at room temperature or in the refrigerator. The resistance of one sample at room temperature began to increase at day 5 while that of other specimens continued to decrease which was the reason for the large standard deviation noted. The reason for this increase is still unknown.

Figure 2 shows the change in capacitance versus time for the three groups of specimens. The values for each day were calculated by the same method as those for the resistance. The capacitance of the refrigerated specimens decreased at a slower rate than did the capacitance of those stored at room temperature or those in the freezer. The capacitance of the frozen specimens decreased by approximately 50% after the first night of storage and then it did not change to any noticeable extent. The capacitance of the room temperature specimens decreased until they reached approximately 50% of their original values and then the values paralleled those for the frozen specimens.

DISCUSSION

Previously, other authors have reported changes in other physical properties of bone over time, when preserved in various ways. Steinberg and coworkers (1976) found decreases in strain related potentials in adult rat femora for 4-7 days, after the bone had been excised. Elwood and Smith (1984) have reported decreases in the zeta-potentials of bone during storage.

Although we have reported our results at one frequency (1KHz), it is possible that the nature of change in resistance and capacitance at other frequencies may be different. Also, Elwood and Smith (1984) found that different storage methods utilizing different fluids in which the bone is stored in, minimized the effect of storage.

From our study we have shown that the resistance and capacitance of bone is effected by the method in which it is stored and the rate of change is dependent on the storage method. Further studies are in progress to evaluate if the change in electrical properties can be minimized by different storage methods, other than those reported here. We also plan to study the effect of storage methods on frequency dependence of the electrical properties of bone.

ACKNOWLEDGMENT

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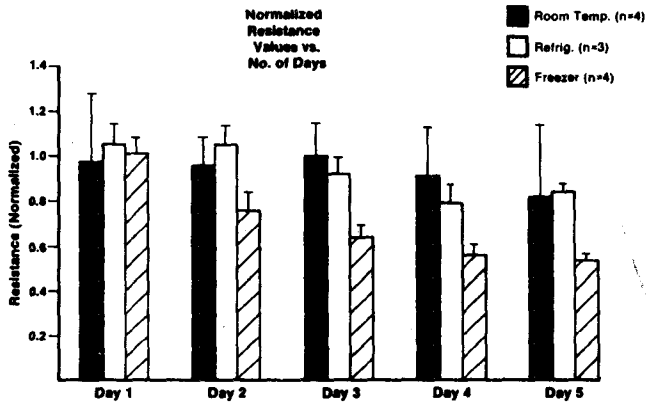

Fig. 1: Change in resistance with time for bone specimens stored in different environment.

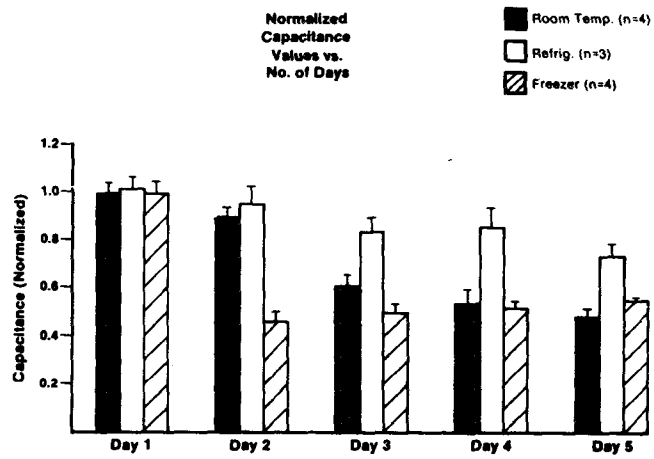

Fig. 2: Change in capacitance with time for bone specimens stored in different environment.

EFFECTS OF PLA SURFACE MICRO COATINGS ON BONE INGROWTH INTO POROUS CORALLINE HYDROXYAPATITE

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Abstract

In this study, a porous synthetic hydroxyapatite was microcoated with three different thicknesses of PLA and compared to uncoated samples in an in vivo model to determine the effect of coating on bone ingrowth. Coatings were mixtures of chloroform and DL-polylactic acid in ratios of 3:1, 10:1, and 30:1. These coated specimens, along with uncoated specimens, were implanted transcortically into the tibiae of New Zealand White rabbits. At 12 weeks the specimens with 3:1 and 10:1 coatings seemed to inhibit bone ingrowth as measured from interface shear tests ($p < .025$), and to a lesser degree so did 30:1. However, at 24 weeks, possibly due to degradation of the coating, interface shear strength in specimens with all coating thicknesses was not statistically different from the shear strength in uncoated specimens.

Key Words: Bone graft, coated ceramic, in-vivo bone regeneration

Introduction

For many years there has been a search for bone grafting materials as effective as cancellous autograft but available in larger quantities and without the additional trauma to the patient in harvesting the materials. Xenogenic materials (Salama and Grazit, 1978) and ceramics (Groves and co-workers, 1971; White and co-workers, 1975) have been suggested as alternatives to iliac crest autograft. White and co-workers (1975) described the replamineform process for conversion of the calcium carbonate material of various corals into pure hydroxyapatite without altering the pore structure. Because of its pore structure, the coral genus Goniopora (CHAG) after conversion has been used successfully as a bone defect filler in dogs (White and co-workers, 1975) and in humans (Holmes and co-workers, 1984). However, this material exhibits low compressive strength and is prone to brittle failure (Tencer and co-workers, 1984). Internal microcoating with polymers has been shown to improve the mechanical properties of CHAG while maintaining its pore dimensions (Tencer and co-workers, 1984). Our objective in this study was to determine if polymer coating of CHAG affected bone ingrowth into the implant in vivo.