Electrical Properties and Bone Mineral Density Correlation on Canine Cadaveric Cortical Bone

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Abstract

In this study, the electrical properties of 19 segments of canine cadaveric bones were measured using an Impedance Analyzer E4990A using frequencies ranging from 20 Hz-20MHz with the purpose of identifying a correlation with the bone mineral density. The Impedance Analyzer was able to display ideal plots of the electrical properties for biological tissue. The conductivity also showed consistent behavior of the age of the bone sample with its bone mineral density thus, providing promising results of using bioimpedance to acquire this type of variable.

Introduction

Since the early 20th century, studies of electrical properties from biological tissue have been incrementing ever since the acquired data has been able to identify a relationship between disorders and the osseus health. Literature has shown that the electrical properties of this connective tissue may provide clinical information that can assess the overall bone health. Electrical characteristics of a biological tissue have encouraged various investigations to take initiative by using these properties for the development of methods for diagnostics and monitoring. Understanding these properties of the organism's system, in this case, canine skeletal system, could open a window of opportunities to use this knowledge to measure bone mineral density and other mechanical properties to determine the health of said system. Measuring the impedance can reveal the amount of electrical flow that the bone can absorb.

Objectives

- Identify the electrical properties of the dry bone sample: permittivity (ε), conductivity (σ) and loss factor ($\varepsilon'/\varepsilon''$).
- Identify the distinct patterns of the electrical properties on canine cadaveric cortical bone

Materials and Methods

1. **Sample acquisition** – 19 segments of canine cadaver bones (femur, tibia, radius, humerus, fibula and ulna)
2. **Storage** – The samples were stored in refrigerator for biological tissue in resealable plastic bags without a saline solution at a temperature of 37°F
3. **Sample Preparation** – Remove the muscle, tendons, bone marrow and blood from the cadaveric bone. Measure the dimensions and weight of the sample. Prior testing the electrical properties, samples were cut from the diaphysis (compact bone) into squares and rectangles.
4. **Testing** –The electrical properties were measured using the Impedance Analyzer E4990A (20Hz – 20MHz) with 16451B Dielectric Test Fixture.
5. **Analyze Data** - Using the Impedance Analyzer E4990A software. The following equations were used: permittivity, conductivity and loss factor.

$$\varepsilon = \varepsilon' - j\varepsilon'' \quad (1)$$

$$\sigma = w\varepsilon_o\varepsilon'' \quad (2)$$

$$\tan\delta = \frac{\varepsilon''}{\varepsilon'} \quad (3)$$

$$\frac{BV}{TV} = \frac{D_{app}}{D_{mat}} \quad (4)$$

6. **Compile Data** – The data was organized in tables and charts using Microsoft Excel
7. **Results** – Plot the electrical properties. Identify a relationship between the age of the canine cadaveric cortical bone to the electrical properties.

Results

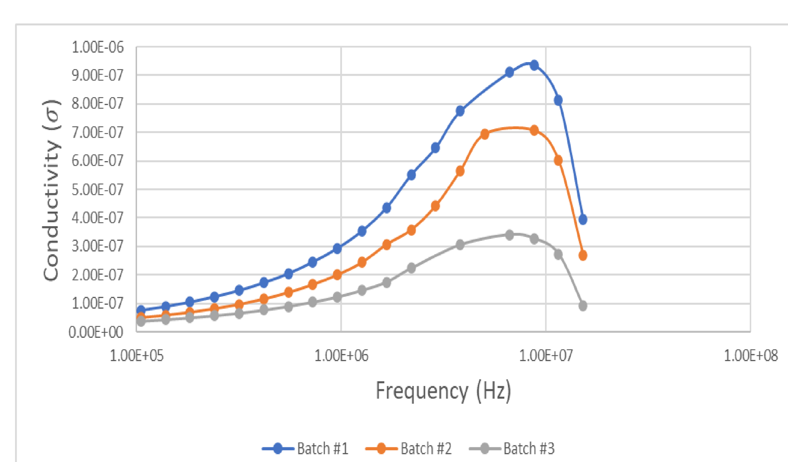

Figure 1: Conductivity vs Frequency

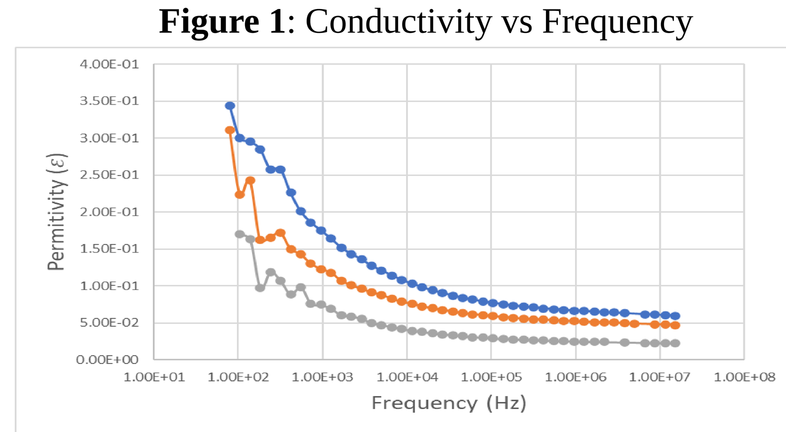

Figure 2: Permittivity vs Frequency

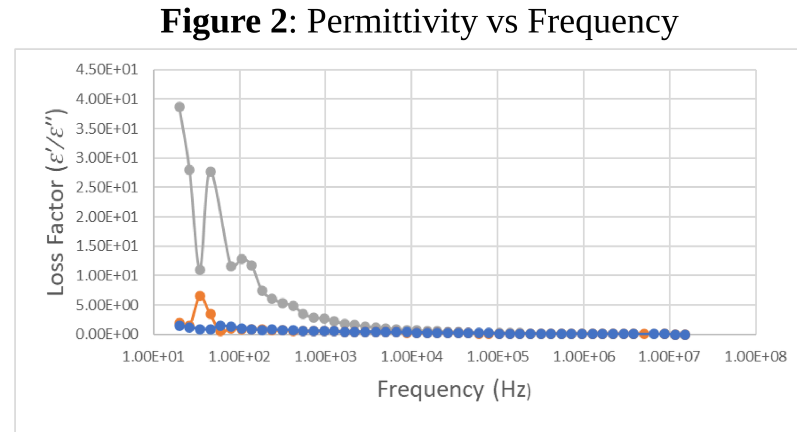

Figure 3: Loss Factor vs Frequency

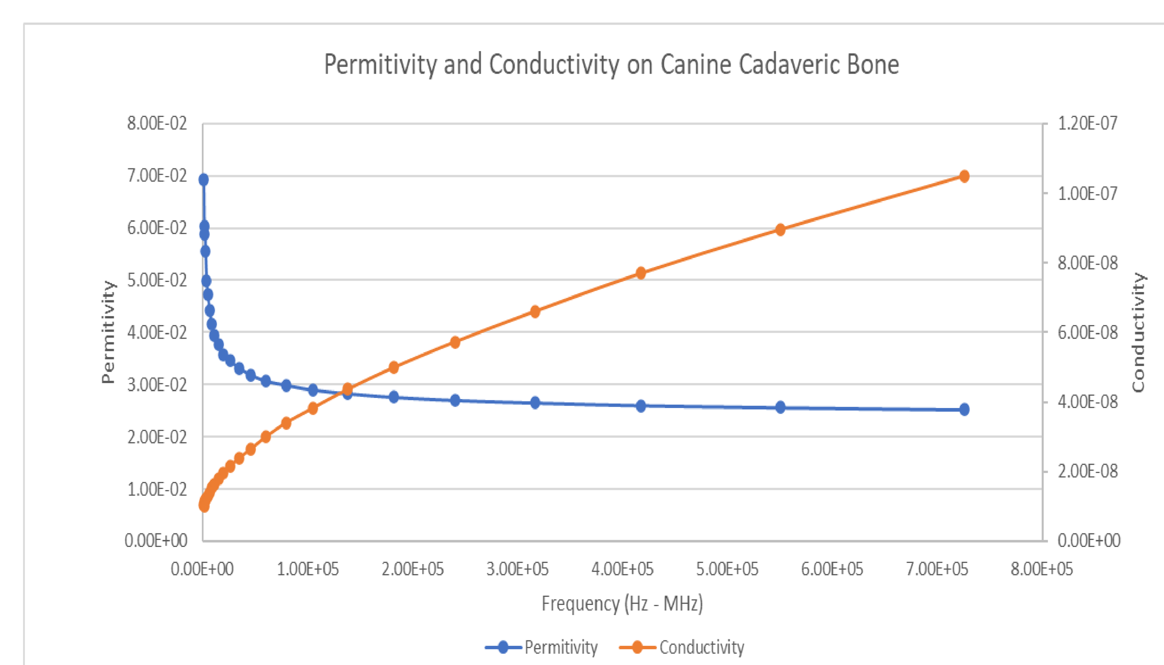

Figure 4: Permittivity and Conductivity for Canine Cadaveric Bone

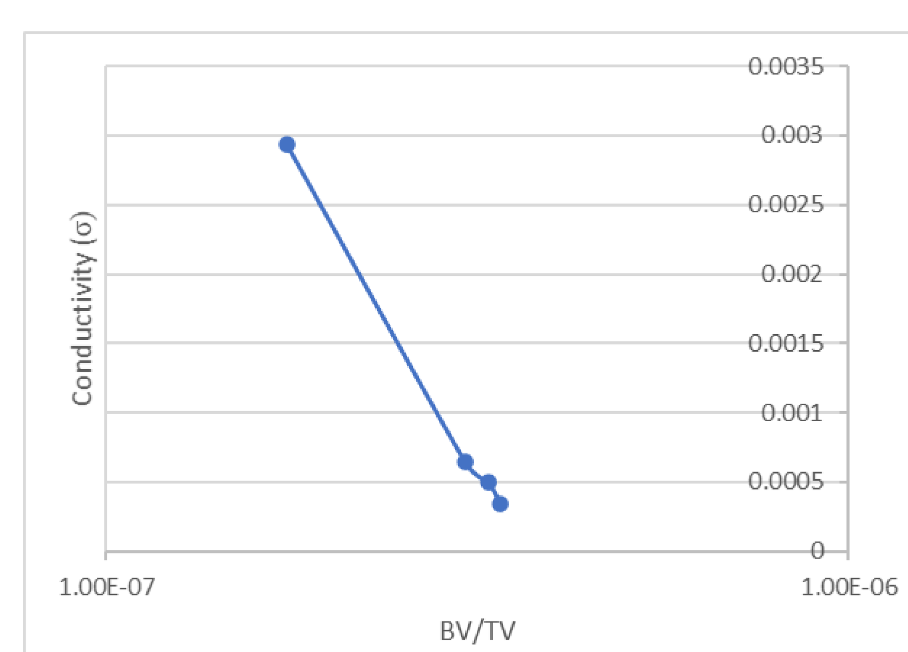

Figure 5: Conductivity vs BV/TV. (m =-1.26 x 10^-5)

Discussion

According to the data obtained and the analysis of the graph, the Impedance Analyzer was able to provide accurate results of bone mineral density from bones of ages: 3, 5 and 12. All the samples displayed characteristic plots of the electrical properties, which are shown in figure 1, figure 2 and figure 3. In figure 1, a relationship between the conductivity and the bone mineral density was identified since the bone samples from the batch #1 were younger than those from batch #3. The decrease of curvature presents the effect of the material's conductivity as the bone mineral density decreases throughout aging.

Conclusions

In this study, we can conclude that all canine cadaveric samples presented the ideal plots expected from biological tissue when measuring permittivity, conductivity, and loss factor. A relationship between the conductivity with the age of the canine sample. These promising results can be a window of opportunities for future research.

Recommendations

- To obtain a higher result of accuracy, it would be beneficial to use CT-scan for animals that provides bone mineral density.
- Experiment with different age groups of bones to identify any correlations

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References

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