Electro-Mechanical Properties of Bones

Project Description

- The motivation of the model is to describe the flow of current through the piezoelectric bone when an external electrical field is applied to the bone.
- From [1] , fundamental constants (such as resistivity of the bone) as well as a basis of a model for the flow of current , can be extracted and utilized for the model.
- If one is trying to use the piezoelectric properties of bones for healing, the flow of current must be model so that the bone going under treatment will not be damaged in the process.
- The goal is to accurately model the flow of any current through a general bone.

Scientific Challenges

- Since the bone is anisotropic, describing the flow of current, and thus conductivity, becomes difficult to calculate using Ohm's law.

Potential Applications

- In medicine, by describing the overall conductivity of the bone, the maximal voltage that can be applied to a fractured bone can be used to increase the speed of bone recovery.

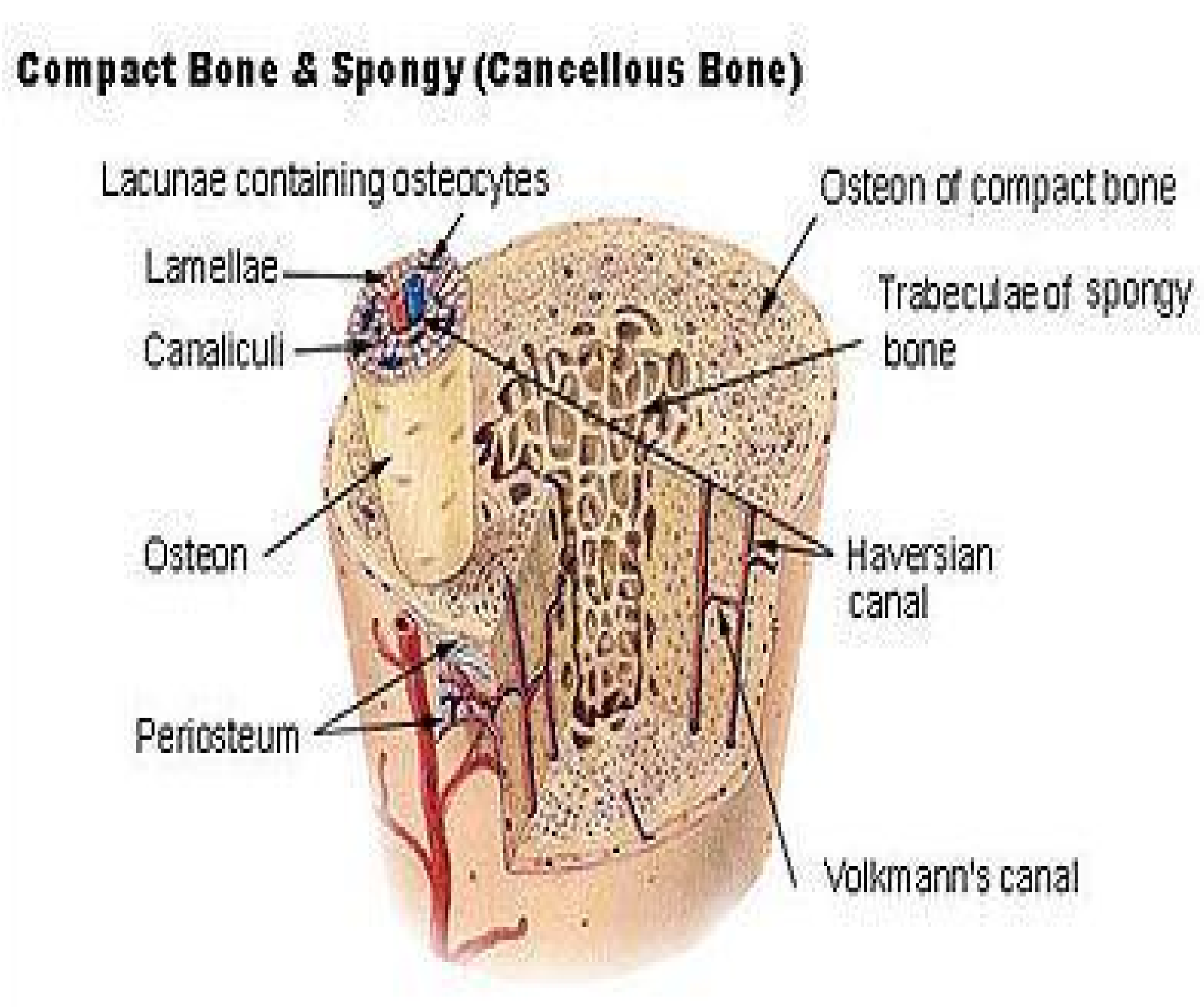

Fig 1) Image of compact bone and various canals.

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Methodology

1. General definition of resistance with respect to resistivity is used with respect to the resistance of the Haversian canals (vertical; r=25um, l=5mm) and Volkmann canals (horizontal; r=2.5um, l=0.5mm)
2. General definition is expanded for total effective resistivity in vertical and horizontal direction using known values of the bone.
3. General definition is solved for both horizontal and vertical contributions to the bone.
4. Values placed in conductivity tensor **k** and compared to results obtained in [1].

Results

1. Values for the effective conductivity of the Vertical and Horizontal directions of a bone are 0.013 and 0.034 $(\Omega m)^{-1}$, respectively.
2. Ratios of effective conductivity of Haversian canals to Volkmann canals from derivation of general definition of resistivity and [1] are 2.61 and 4.33, respectively.
3. Conductivity tensor **k** is described as shown.

$$\mathbf{k} = \begin{bmatrix} 0.034 & 0 & 0 \\ 0 & 0.034 & 0 \\ 0 & 0 & 0.013 \end{bmatrix}$$

Fig 3) Conductivity tensor **k** , in $(\Omega m)^{-1}$ derived from definition of resistivity.

Glossary of Technical Terms

Piezoelectricity: The production of electrical charge due to pressure on an object. Piezoelectric effect describes the formation of charge, or current due to stress, while the reverse piezoelectric effect it the result of stress on an object due to the accumulation of electric charge.
Anisotropic: Any property that is dependent upon direction
Haversian Canals: Canals in the bone matrix that travel along the length of the bone. Composed of nerve fibers with high conductivity per canal.
Volkmann Canals: Canals that run perpendicular to the long axis of bone composed of arteries. Smaller than Haversian canals but are more vast due to the same fill factor as Haversian canals.
Tensor: A multi-dimensional array that describes the flow of any physical property.

$$\rho_o = \frac{\rho_C \rho_B L_C L_B}{\rho_C L_C S_B + \rho_B L_B S_C} \frac{S_C}{(L_C + L_B)\kappa}$$

$$\int_0^l R(x) x dx = \frac{-1}{\pi l} \int_0^l \frac{x}{\sqrt{1 - \left(\frac{x}{l}\right)^2}} dx = \frac{2l}{\pi}$$

Fig 2) Resulting derivation for resistivity of bone in axial direction and average effective length of Volkmann Canals.

References

1. R. Casas, I. Sevostianov, *Electrical resistivity of cortical bone: Micromechanical modeling and experimental verification.* International Journal of Engineering Science **62,** 106–112 (2013).

Acknowledgments

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