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ON THE DETERMINATION OF DIFFUSION COEFFICIENTS IN BONE

Doctoral Thesis by

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Abstract

Diffusion in bone is needed for bone remodeling and bone healing. Understanding the phenomenon is often important for comprehension bone diseases. Mathematical modeling of the diffusion processes is a required prerequisite in the study of this important physical process in living bone tissue. A proper model is crucial in order to obtain realistic results. An easily accessible method to measure the diffusion coefficients in bovine bone is used in this work. In short, cortical bovine bone samples, that are saturated with potassium chloride are put in distilled water. The escaping chloride and potassium ions increase the conductivity of the water and the increase is registered over time.

In a first model, for simplicity, bone is regarded as a homogeneous material with position independent diffusion properties. However, it is well known that the bone structure in the shafts of the long bones is an in-homogeneous material with higher porosity closer to the medullary cavity and becomes denser closer to the outer surface. Because of this, a position dependent diffusion parameter is introduced in a second model. This improves the simulation model, and provides more realistic results. To determine the diffusion coefficients with good accuracy, an inverse method, a Kalman filter, is used to extract the diffusion coefficients from experiments for both constant diffusion and position dependent diffusion. The Kalman filter takes both measurement noise and material parameters noise into account. The results from the Kalman filter process are sensitive to the selection of initiation parameters, that have to be chosen carefully to avoid false local attractors or divergence. In this context, a method to determine diffusion coefficients is suggested together with recommendations on how to select the initiation parameters. To qualify the method a Kalman filter is applied on generated measurements with added noise. Finally, a method to determine the diffusion coefficients and the elastic properties of porous bone samples is derived. The method is based on a superposition principle, that employed dimensional scaling and established shape factors. The latter are found using finite element calculations for a few classes of characteristic pore shapes. The method is evaluated regarding both diffusion and mechanical behaviour on two real cases.