A model of bone turnover in the framework of generalized continuum mechanics

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Abstract

We present here a framework for the description of bone remodeling based on the theory of material remodeling-an instance of generalized continuum mechanics aiming to model the adaptive behavior of living materials. The focus is set on bone turnover, i.e. the biological process through which bone tissue continuously renew and adapt to its prevailing mechanical and biochemical environment. Macroscopic bone turnover results from microscopic biological and biochemical processes, namely: (i) the concerted activity of bone-resorbing cells (osteoclasts) and bone-forming cells (osteoblasts); and (ii) the mineralization of the newly-formed bone matrix.

In the present model, the standard continuum description is enriched with new state variables describing the composition and organization of bone tissue at the microstructural scale. Accordingly, the balance structure of the enriched continuum is obtained through an extended statement of the virtual power principle. Eventually, evolution laws describing bone turnover are obtained in a thermodynamically consistent framework.

In the present study, we investigated the influence of the biochemical environment on bone remodeling. Different biological scenarios were explored highlighting the interplay between the different microscopic mechanisms governing the macroscopic bone turnover. Our preliminary results are physically sound despite the simplifying constitutive assumptions.

The proposed modeling approach lends itself nicely to introduce mechanobiology in a thermodynamically consistent mechanical framework and opens the way to a multiscale description of bone remodeling integrating mechanical modeling at the tissue scale and cell dynamics at the microstructural scale.

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