Time-dependent material growth applied to a finite viscoelastic continuum model for hard and soft tissue

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ABSTRACT

Growth and remodeling are time-dependent processes by which biological tissue adapt their shape and internal structure to external stimuli [1]. The phenomenon of growth becomes instrumental in any typical investigation pertaining to healing and recovery processes. The biological process of growth is specific to the biomaterial and has to be treated separately. The intercommunication between adjacent bone cells leads to growth and resorption of skeletal bone, for instance. Osteocytes have the ability to communicate with osteoblasts and osteoclasts to either form or remove bone matrix on the inner or outer surface of the bone [1]. Skeletal muscle, on the contrary, consists of long muscle fibers which enclose a large amount of myofibrils, respectively. The process of hypertrophy leads, inter alia, to an increase in the amount of myofibrils, so that the skeletal muscle grow in primarily perpendicular to the longitudinal axis. The initiating factors triggering growth or resorption in biomaterials are often still unknown.

A common approach for modeling stress-induced growth with a continuum formulation is to define a threshold level which allows to distinguish between the activation of growth and pure passive material behavior [2]. In this context, it is worth highlighting that most of biological tissue show a viscoelastic material behavior. Therefore, the coupling of a time-dependent material growth model with a viscoelastic material model would allow to investigate on the effects of different nonlinear mechanisms and to obtain a more reliable quantitative description of the mechanical response of biological tissue.

The objective of this work is the extension of a continuum material time-dependent growth model [2] with a viscoelastic material model [2] addressing both hard and soft tissues. The computational implementation is performed within the framework of finite thermoelastic-viscoplasticity. For this purpose, the governing differential equations of the finite element framework are rewritten in terms of the Perzyna-regulation which ensures time-dependent growth. Furthermore, a viscoelastic material model is coupled with the growth model by using a multiplicative split of the deformation gradient. Finally, the combined material model is applied and specified to a simplified geometrical model of skeletal muscle, as well as, to realistic bone trabecular reconstructed via microCT.

REFERENCES

