An IGA approach to flexoelectricity-induced remodelling in cortical bone

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Abstract

Flexoelectricity, which couples electric polarisation with strain gradients, was found to be present in cortical bone and to take a key role within the bone remodelling. In this regard, experiments showed that flexoelectricity can induce osteocyte apoptosis in mechanically stimulated bones, (1), which is a starting point for targeted bone remodelling. This effect is most relevant on small scales due to the size-dependency intrinsic to felxoelectricity. Conceptually speaking, strain gradients in the vicinity of micro cracks in cortical bone induce an electric field that, if sufficiently large, results in osteocyte apoptosis. A related computational model has been proposed, see (2,3), which is the basis for this contribution. To cover higher gradient contributions as occurring in the resulting set of field equations to be solved, an isogeometric analysis is employed within the computational setting, (4), since the NURBS basis functions used satisfy the required continuity properties. In addition to the flexoelectric electro-mechanical coupling, a coupling to chemical fields is included so that the behaviour of different bone cells and biochemical signals, which drive the remodelling process, can be modelled. Specific types of bone cells considered are osteocytes, osteoclasts and osteoblasts. Moreover, signalling is performed by different types of messenger substances. All these bone cells and chemical substances are included via additional field variables, respectively diffusion type balance equations. A representative initial boundary value problem is discussed, which mimics healing of a micro crack in a small sample of cortical bone.

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