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SIMULATION OF TISSUE FORMATION DURING FRACTURE HEALING USING INTERFACE CAPTURING TECHNIQUES

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Summary: Tissue formation during the fracture healing process is regulated non-trivially by biological and biomechanical factors. One way to increase our understanding is the development of computational methods that capture the healing process on different tissue scales. The numerical method we present is characterized by the usage of numerically well-established interface capturing techniques. In order to apply these techniques we combine the level-set and volume of fluid method to obtain the interfaces between different tissue types. In this way, osteogenesis, chondrogenesis and revascularization can be interpreted as tissue surface processes that are triggered via mechano-transduction according to the hypotheses of Claes and Heigele. Here, the mechanical stimulation is governed by a stress-strain equation that can be solved by standard finite-element methods. Subsequently, strain invariants corresponding to Pauwel's hypotheses are evaluated and the type of tissue formation is determined by them due to the tissue differentiation hypotheses. A benefit of this procedure is that tissue formation is modeled via an advection equation which provides the growth velocity related to the different types of genesis as a natural parameter. After analyzing the convergence behavior, we benchmark our model with the previous presented results of the Ulm healing model. Furthermore, we show that the predicted tissue distributions and the time-dependent behavior of the interfragmentary movement resemble observations of past animal experiments. Finally, we give an outlook on future extensions of the model to include osteoconductivity and osteoinductivity which play a major role in the simulation of implants.