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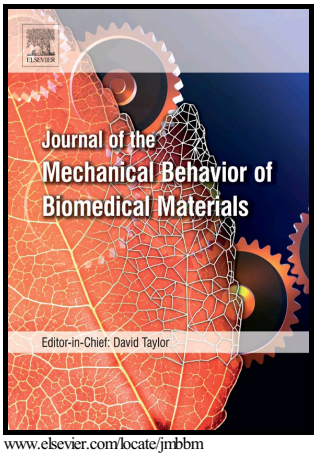

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Nondestructive mechanical characterization of developing biological tissues using inflation testing

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Abstract

One of the hallmarks of biological soft tissues is their capacity to grow and remodel in response to changes in their environment. Although it is well-accepted that these processes occur at least partly to maintain a mechanical homeostasis, it remains unclear which mechanical constituent(s) determine(s) mechanical homeostasis. In the current study a nondestructive mechanical test and a two-step inverse analysis method were developed and validated to nondestructively estimate the mechanical properties of biological tissue during tissue culture. Nondestructive mechanical testing was achieved by performing an inflation test on tissues that were cultured inside a bioreactor, while the tissue displacement and thickness were nondestructively measured using ultrasound. The material parameters were estimated by an inverse finite element scheme, which was preceded by an analytical estimation step to rapidly obtain an initial estimate that already approximated the final solution. The efficiency and accuracy of the two-step inverse method was demonstrated on virtual experiments of several material types with known parameters. PDMS samples were used to demonstrate the method's feasibility, where it was shown that the proposed method yielded similar results to tensile testing. Finally, the method was applied to estimate the material properties of tissue-engineered constructs. Via this method, the evolution of mechanical properties during tissue growth and remodeling can now be monitored in a well-controlled system. The outcomes can be used to determine various mechanical constituents and to assess their contribution to mechanical homeostasis.

Keywords: soft tissues, growth and remodeling, mechanical characterization, inverse analysis, ultrasound

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