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Research paper

Comparison of four methods to simulate swelling in poroelastic finite element models of intervertebral discs

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ABSTRACT

Osmotic phenomena influence the intervertebral disc biomechanics. Their simulation is challenging and can be undertaken at different levels of complexity. Four distinct approaches to simulate the osmotic behaviour of the intervertebral disc (a fixed boundary pore pressure model, a fixed osmotic pressure gradient model in the whole disc or only in the nucleus pulposus, and a swelling model with strain-dependent osmotic pressure) were analysed. Predictions were compared using a 3D poroelastic finite element model of a L4–L5 spinal unit under three different loading conditions: free swelling for 8 h and two daily loading cycles: (i) 200 N compression for 8 h followed by 500 N compression for 16 h; (ii) 500 N for 8 h followed by 1000 N for 16 h. Overall, all swelling models calculated comparable results, with differences decreasing under greater loads. Results predicted with the fixed boundary pore pressure and the fixed osmotic pressure in the whole disc models were nearly identical. The boundary pore pressure model, however, cannot simulate differential osmotic pressures in disc regions. The swelling model offered the best potential to provide more accurate results, conditional upon availability of reliable values for the required coefficients and material properties. Possible fields of application include mechanobiology investigations and crack opening and propagation. However, the other approaches are a good compromise between the ease of implementation and the reliability of results, especially when considering higher loads or when the focus is on global results such as spinal kinematics.

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