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AN HPC APPLICATION OF PORO-ANISO-HYPERELASTIC MODEL FOR THE IN SILICO STUDY OF THE INTERVERTEBRAL DISC DEGENERATION

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Summary: Intervertebral Disc (IVD) degeneration is the leading cause of Lower Back Pain, affecting more than 10% of the global population. In silico modeling could contribute to the understanding of the dynamics of IVD degeneration. Patient specific medical solutions can be explored by exploiting the high scalability of supercomputers, regarding both the number of cases simulated and the refinement level of the finite element mesh. For that reason, finite element simulations are performed in Alya, the highly parallelizable finite element (FE) solver developed by Barcelona Supercomputing Center. IVDs are known to exhibit poro-aniso-hyper-elastic behavior. The mechanical hyperelastic model accounts for the compressibility of the total IVD matrix, while respecting the incompressibility of both the dry matrix and the surrounding solute. The presence of collagen (COL-I, COL-II) is related to the model's anisotropy, for which a modified Holzapfel-Gasser-Ogden model is used. Finally, the pressurization of the disc derives from both the mesh's deformation and the Donnan osmotic pressure. While Alya treats solid models considering a Total Lagrangian formulation, the simulation of both the porous medium and the solute transport are traditionally solved following an Eulerian formulation. To overcome this inconsistency and to account for the deformability of the mesh, a proper set of Piola-Kirchoff transformations regarding the porous model's permeability and the solute model's diffusivity, are employed. This setup allows for high scalability as well as the plug-in of Agent Based models designed for HPC.