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TOWARDS A REPOSITORY OF PATIENT-SPECIFIC INTERVERTEBRAL DISCS FINITE ELEMENT MODELS

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Summary: Numerical analysis methods, such as Finite Element Analysis (FEA), have been widely used to study the biomechanics of human tissues and organs. However, patient-specific (PS) model creation usually requires complex procedures that are difficult to automatize in some instances. For example, in spine computational studies, intervertebral disc (IVD) modeling requires structural meshing, as the synchronized mechanical behavior of specific tissue domains needs to be explored under large deformations. Multiple studies related to IVD degeneration (DD) have been carried out using FEA, but a repository of IVD PS models has not yet been created to explore in-depth PS particularities. A significant challenge is the ability to map different tissue regions, such as the Cartilage Endplate (CEP), Annulus Fibrosus (AF), Nucleus Pulposus (NP), and the Transition Zone (TZ) in PS IVD shapes. Such mapping can provide further information about the influence of the CEP on DD combined with the effects of different sets of diffusion distances from the peripheral vasculature to the NP. This work aims to generate a repository of PS finite element meshes of IVD models with the same mesh connectivity and different geometries of the external surface and its internal components for systematic mass FEA. Using T2-weighted magnetic resonance images, 176 PS IVD models were obtained through 3D segmentation, acquired during the European project My Spine (FP7-269909). Segmentations included the AF and NP. The Bayesian coherent point drift (BCPD) algorithm was used to non-rigidly align the meshes. This code fits a point cloud of a source mesh (template) to a target mesh (segmentations). In this way, a pre-existing structural mesh of an IVD was adapted to the PS models. The external surfaces of the AF and NP were represented by point clouds, which were used as targets. The morphing process of the template was carried out in three stages. First, the AF and the NP surfaces were adapted. Then, the results were merged into a single point cloud, used as a target, for the final fitting of the complete volumetric mesh of the template. The CEPs, not visible in the images, were automatically recreated, with a thickness between 0.7 and 1 mm. The development of the second stage preserved the surface area initially covered in the IVD. Mesh quality of the morphed models and Euclidean distance between the morphed and the target were checked to ensure good quality elements. A repository of finite element meshes with the same connectivity was created following the abovementioned method. Regarding mesh quality, the average criteria limits of all morphed IVDs were: Min and Max angle on Quad Faces (<10 and >160) were less than 0.2 and 0.8 % of the total elements, respectively. The Hex elements that exceeded the Aspect Ratio criteria limit (>10) were less than 6%.This repository is a unique set of model collections to explore the effect of multiple geometrical variations on the IVD multiphysics and mechanobiology, including the likely substantial impact of the CEP. The algorithm can generate PS FE models from any segmented surfaces third parties provide.