Towards a repository of patient-specific intervertebral disc finite element models

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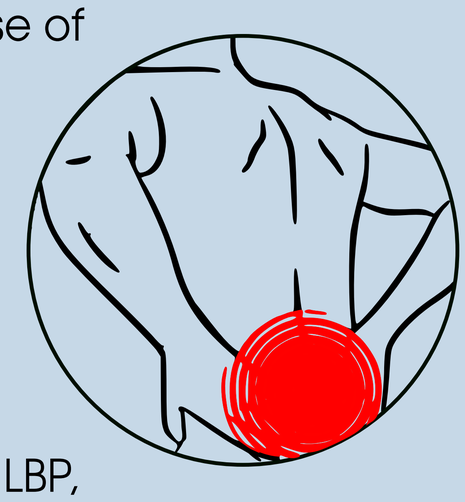
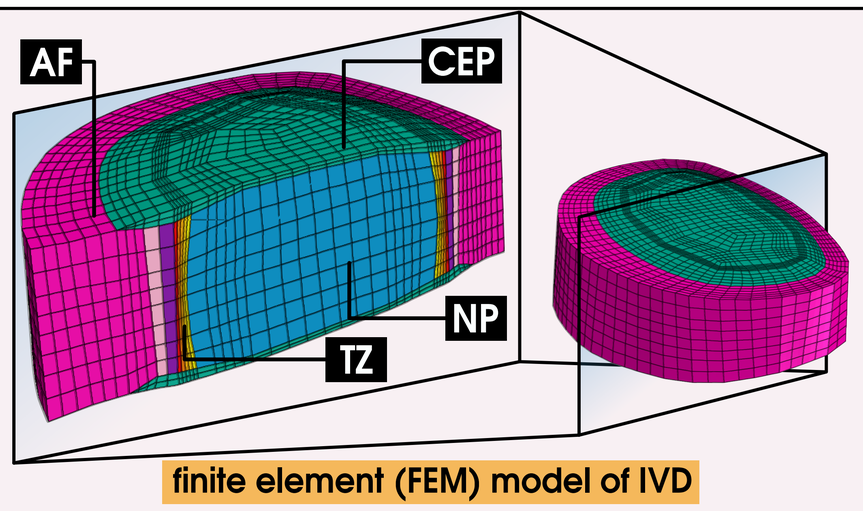
BACKGROUND

266 million individuals worldwide suffer degenerative disease of the spine [1]

intervertebral disc (IVD) degeneration (IDD) is a major risk factor of low back pain (LBP)

Endplate anomalies are related to IDD and severe LBP, but mechanisms cannot be measured





finite element (FEM) model of IVD

AF	anulus fibrosus	CEP	cartilage endplate
NP	nucleous pulposus	TZ	transition zone

numerical simulations determine the heterogeneous multiphysics field [2]

but... → IVD patient-specific (PS) is challenging → **and**

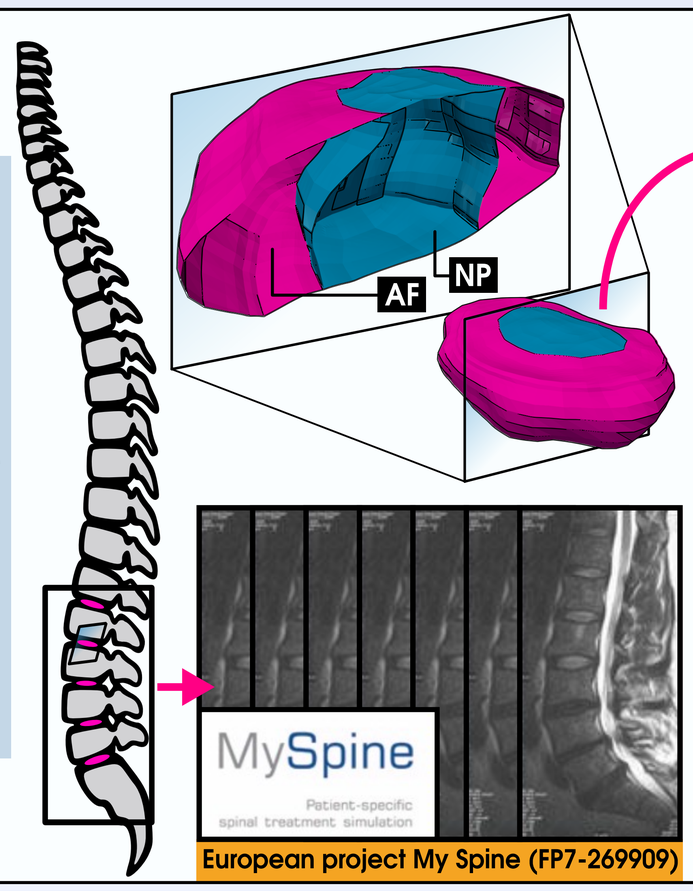
there are not enough FEM studies using a plethora of disc morphologies to determine a relation with IDD

OBJETIVES

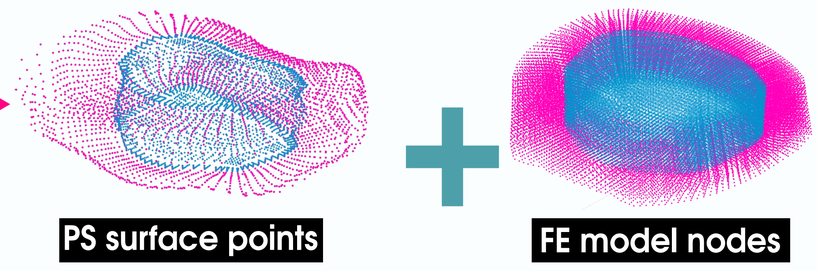
- establish a procedure and agorithms to adapt the IVD structured FEM mesh to patient-specific models
- systematize the algorithm and create a free repository for the scientific community
- perform tissue-level simulations to assess the role of morphological factors in disc degeneration

METHODS

- 174 IVD PS models of the lumbar spine obtained through T2-weighted MRI from the MySpine project
- only the surfaces of the AF and NP of the IVD can be obtained
- the BCPD [3] algorithm was used to morph the IVD



European project My Spine (FP7-269909)



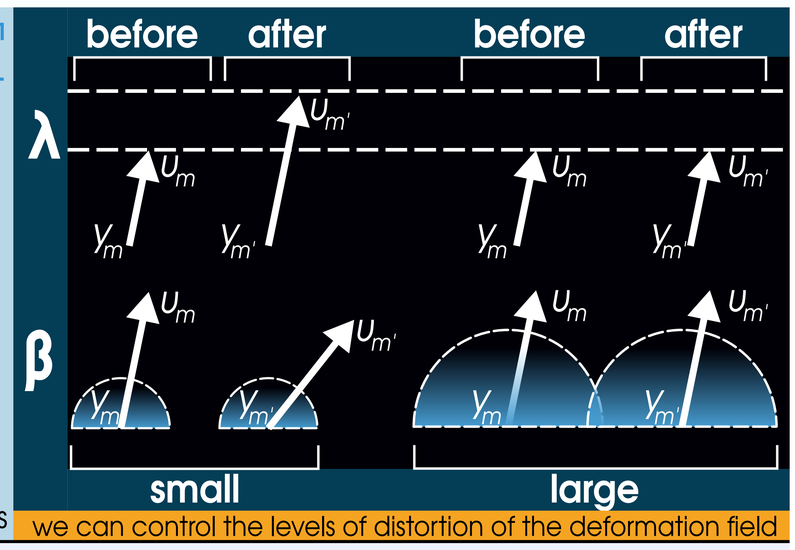
BCPD: Bayesian Coherent Point Drift

- adapts point clouds from a source to a target
- convergence guaranteed by variational Bayesian inference
- rigid and non-rigid registration in a single algorithm
- point-to-point correspondences are not assumed

principal variables:

λ : length of displacement vectors

β : directional correlation of displacement vectors

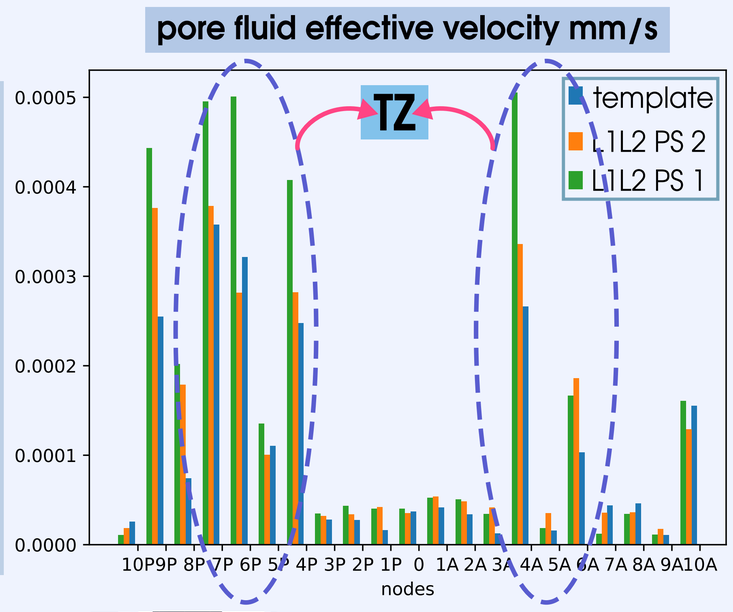


we can control the levels of distortion of the deformation field

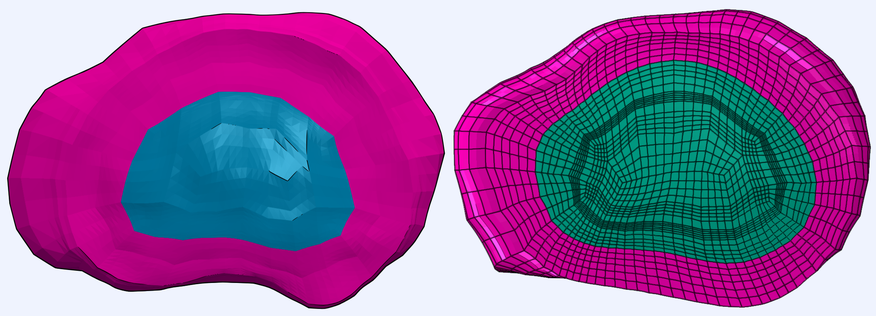
RESULTS

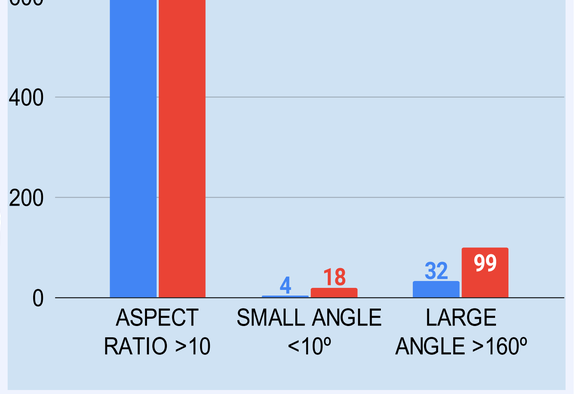
the pore fluid velocity has shown important differences between the models in TZ for mechanical simulations

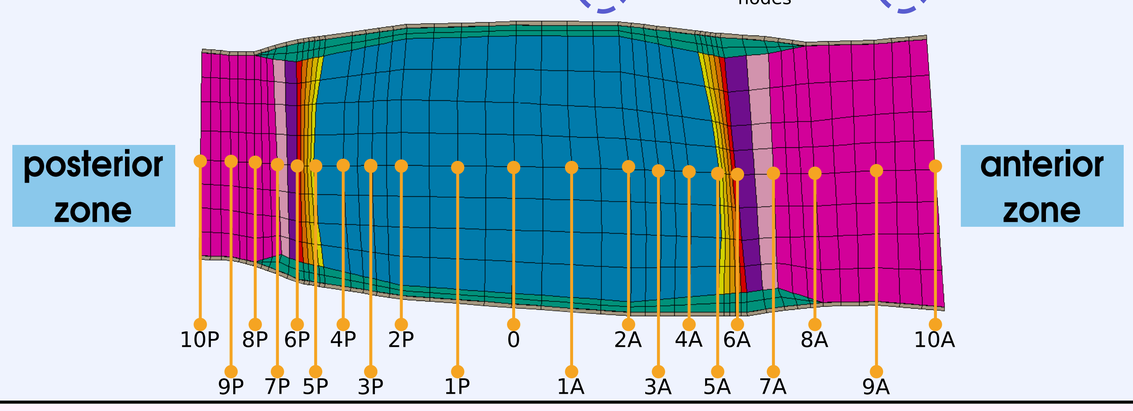
alterations of the disk in the structured mesh were observed in the same zone [4]



no major differences were observed in mesh quality between the template and the PS models







conclusions

- the automatic tool that adapts the structured IVD mesh was successfully developed
- significant differences were observed in preliminar numerical simulations of PS models

impact

- observe differences based on the morphology of the discs through statistical shape modeling
- perform nutrient transport simulations and assess cell viability

references

[1] Ravindra, V. M. et al. (2018). Global Spine

[2] Ruiz, C. et al. (2013). Journal of the Mechanical Behavior of Biomedical Materials

[3] Hirose, O. (2021). Institute of Electrical and Electronics Engineers (IEEE)

[4] Ruiz Wills, C. et al. (2018). Frontiers in Physiology

acknowledgments

MARIE SKŁODOWSKA-CURIE ACTIONS

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