# Towards a repository of patient-specific intervertebral discs finite element models

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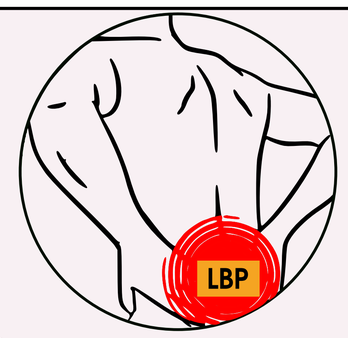
## BACKGROUND

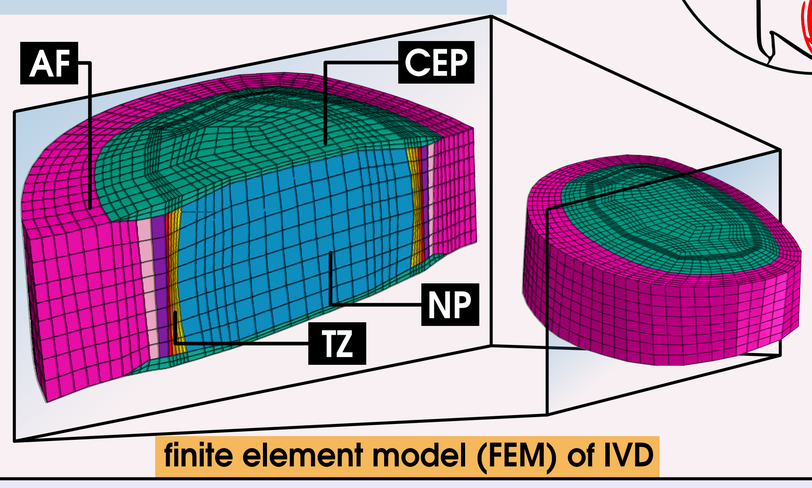
- 266 million individuals worldwide suffer degenerative disease of the spine [1]
- Intervertebral disc (IVD) degeneration (IDD) is a major risk factor of low back pain (LBP)
- Endplate anomalies are related to IDD and severe LBP, but mechanisms cannot be measured




Finite element (FE) simulations can determine the internal multiphysics mechanisms possibly involved in IDD

**but...** → Simulation results depend on IVD morphology [2] → **and**

there is no repository of different IVD morphologies to perform the numerical simulations

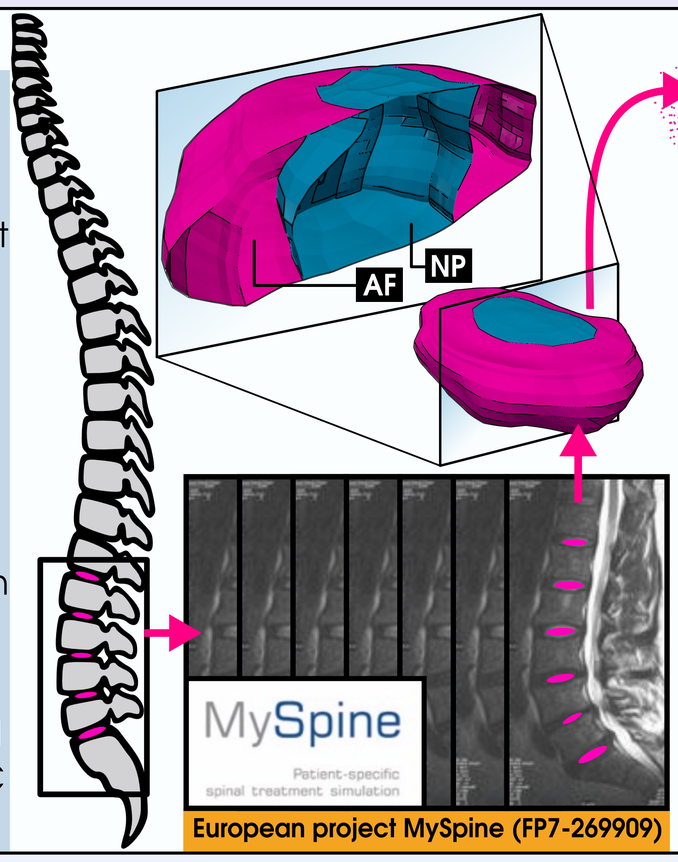



## OBJECTIVES

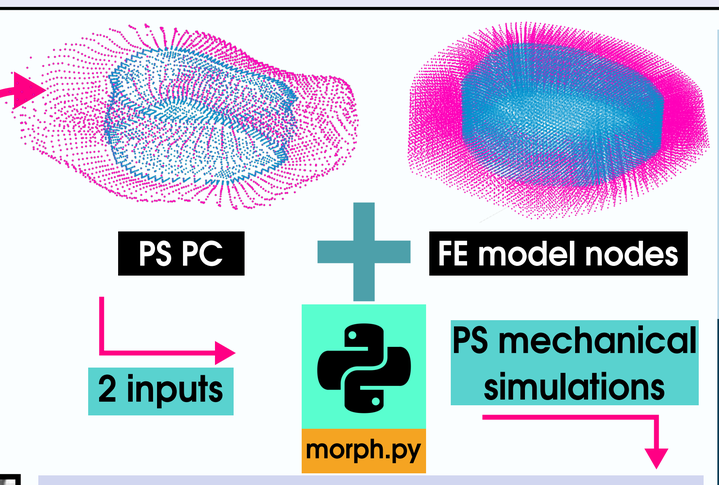
- Establish a procedure and agorithms to adapt a IVD structured FE mesh to patient-specific models
- Automatize the IVD morphing algorithm and create a free repository of PS FE models of the IVD for the scientific community

## METHODS

- 169 PS models of the lumbar spine IVD were obtained through MRIs from the MySpine project
- The surfaces of the AF and NP were used to generate a PS point cloud (PC).
- The BCPD [3] algorithm was used to morph the FEM to the PS PC through the morph.py code
- The mesh quality of the morphed PS models and the similarity to the PS PC models were assessed




European project MySpine (FP7-269909)




**Preliminary mechanical simulations:**

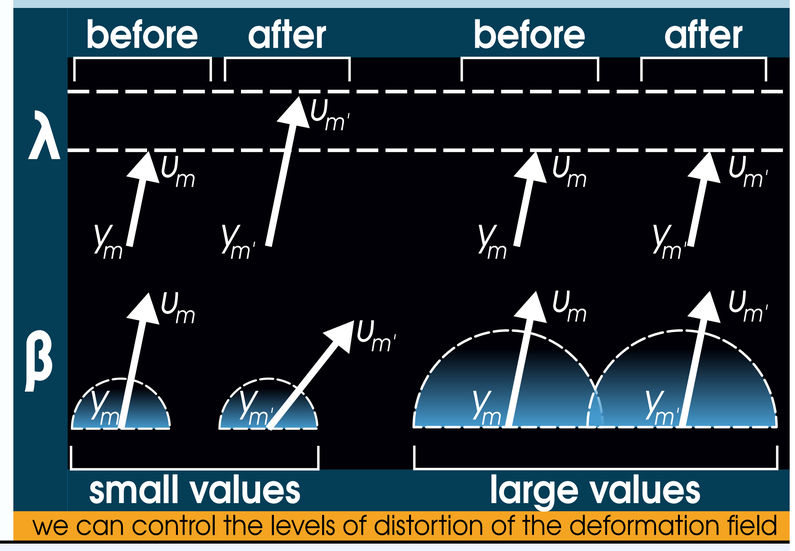
- FE simulations of physiological compressive loads defined in previous work [4] were simulated in ABAQUS on all the morphed IVDs
- Evaluated computational results:
  - Pore fluid effective velocity
  - Pore pressure

**BCPD: Bayesian Coherent Point Drift**

**Principal variables to consider:**

λ : Length of displacement vectors

β : Directional correlation of displacement vectors

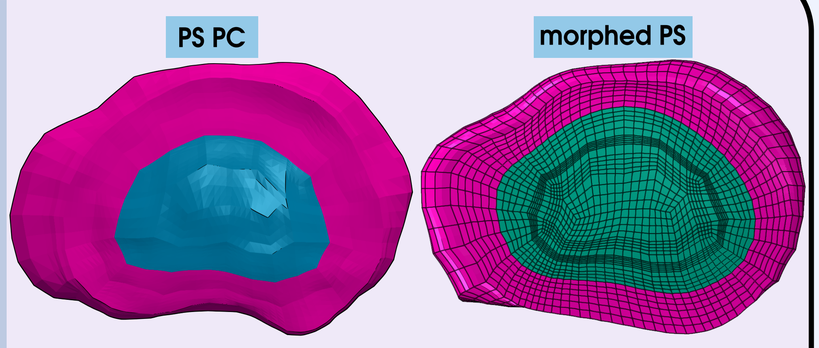


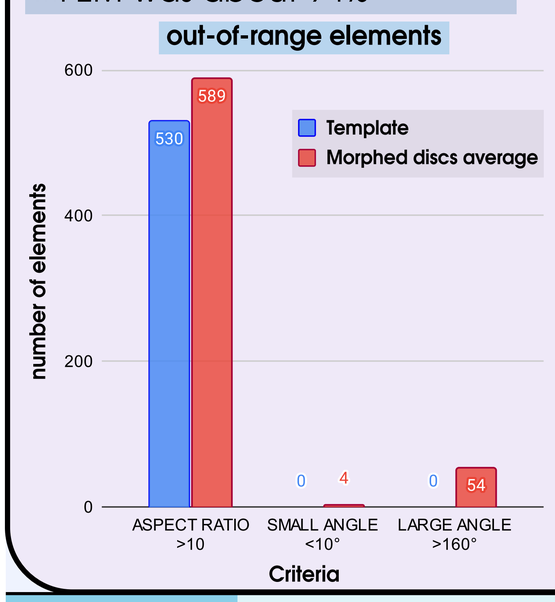

we can control the levels of distortion of the deformation field

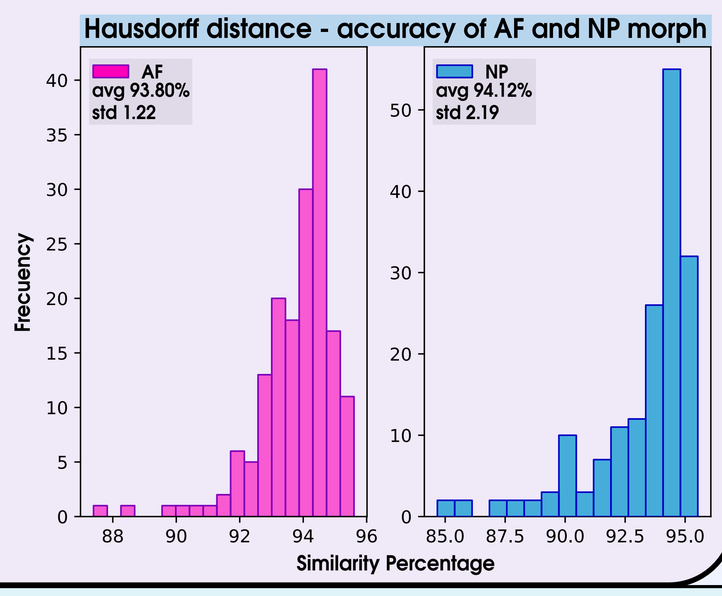
## RESULTS

### Morph process

- No significant differences were observed in mesh quality between the template and the PS models
- According to the Hausdorff distance, the similarity between the PC and the FEM was about 94%

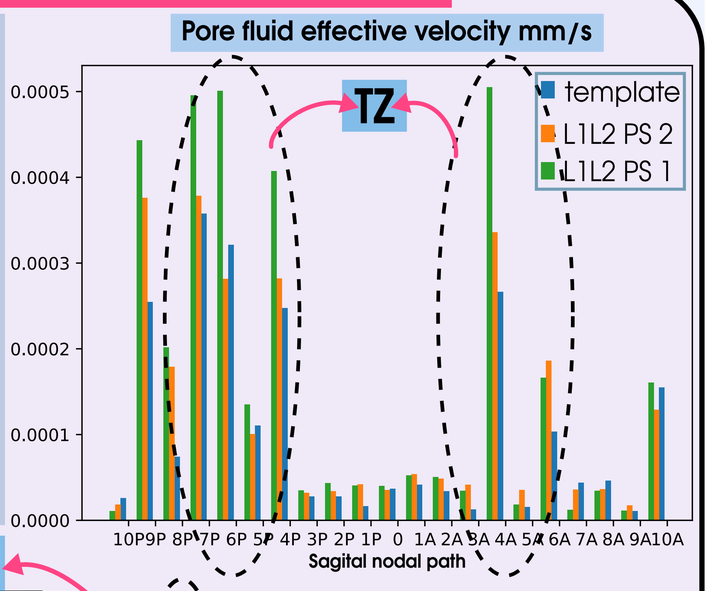


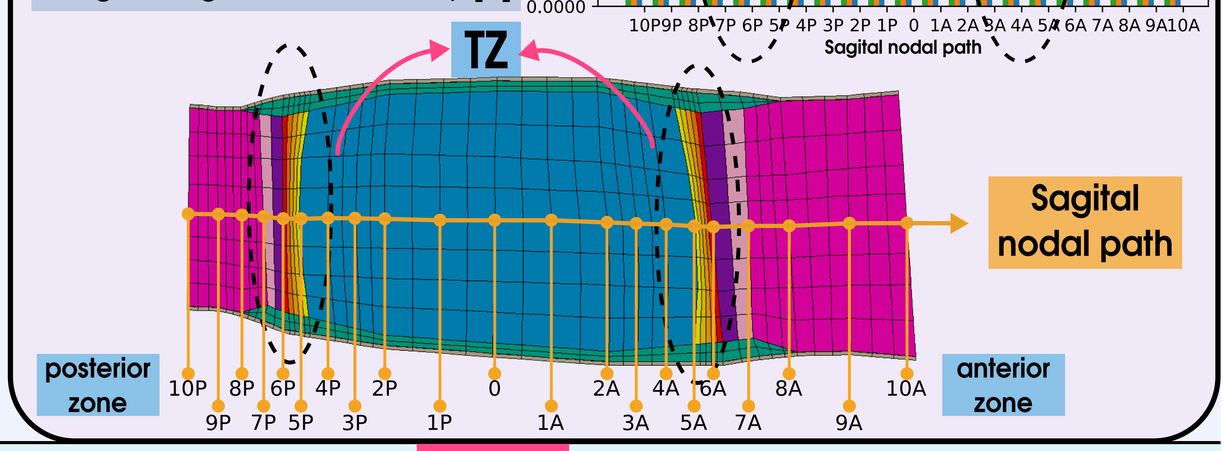




### Preliminary mechanical simulations results

- The transient pore fluid velocity differed strongly between the models in the TZ
- Alterations of the disc in early stage of IDD was observed in the same zone through clinical images [4]
- Mechanical variables affects the transport of metabolites and waste products, both regulating the cell viability [5]




## conclusions

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|---|---|---|---|---|
| The automatic tool that transforms the structured IVD mesh into PS FE models was successfully developed | PS FE simulations seem cornerstone to assess mechanoregulatory variables in critical regions such as the TZ | A repository of 169 IVD models was created, and all models have the same number of nodes, elements and connectivity, except for the nodal coordinates | **impact** Observe differences based on the morphology of the discs through statistical shape modeling | **impact** Perform nutrient PS transport simulations and assess cell viability |

## references

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

[2] Malandrino, A. et al. (2015). Frontiers in Bioengineering and Biotechnology

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

[4] Lachlan J. Smith et al. (2011). Disease Models & Mechanisms

[5] Malandrino, A. et al. (2014). Journal of Biomechanics

## acknowledgments

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