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A Multiscale Patient-specific Finite Element Analysis of Disc Degeneration in the Lumbar Spine

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Abstract

Treatment and prognosis of lumbar spinal disc degeneration are still based on the subjective experience of the orthopaedic surgeon and still lead to long-term complications and eventual morbidity. With this in mind, a predictive numerical tool able to simulate the different treatments of disc degeneration would enable to guide clinicians and improve clinical outcomes. Specifically, the aim of this study was two-fold: i) to develop accurate finite element models able to simulate the three most common options for spinal treatment (conservative treatment, discectomy and spinal fusion) and ii) to implement a patient-specific automated workflow within a clinical environment.

CT and MRI imaging data are registered together and processed with mesh morphing techniques to generate patient specific discretization of L1-S1 levels of each patient. Personalized material properties are defined considering QCT grey values to tune the trabecular bone's properties and Pfirrmann grade for disc constituents. Muscle and ligaments models have been chosen considering literature data. [1] Discectomy and spinal fusion are simulated either removing the protruding elements of the treated disc or including a standard spinal fusion system in the analysis by means of embedded elements. Reference points are identified on each patient's spine to guarantee correct positioning of the devices. Both spine extension and axial loading simulations have been analysed resulting in a total of six simulations per patient.

The preparation, running and post-processing of these analyses have been automated by means of a Python script which has been included in the MySPine clinical platform embedded in a user-friendly Gimias software.

In conclusion, advanced modelling strategies and software development techniques have been exploited to develop a user-friendly numerical tool able to simulate different spinal treatments and help clinicians in the surgical planning. In the next months, this numerical approach will be tested to investigate the 200 patients included in the MySpine clinical prospective study. Numerical results will be compared with the two-year clinical follow-up to validate the approach and foster its clinical translation.

References

1. FP7-ICT-2010-269909: Functional prognosis simulation of patient-specific spinal treatment for clinical use.

Keywords Disc degeneration; Finite Element Modelling; Spine