BIOENGINEERING AND MEDICAL-SURGICAL SCIENCES

Ateneo - Development of in silico models of the spine across multiple scales to guide clinical and surgical decisions

Funded By	Politecnico di TORINO [P.iva/CF:00518460019]

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Context of the research activity	The lack of accurate clinical parameters for assessing vertebral fracture risk necessitates the development of in silico tools, able to simulate physiological loads, boundary conditions, and the impact of orthopedic devices on patient-specific models. The goal is to enhance clinical decision-making, guide treatments, and improve post-surgery outcomes, ultimately enhancing the healthcare system's effectiveness.

	According to the World Health Organization (WHO), by 2030, the number of people older than 60 will increase by 34% compared to 2020. Due to risk factors such as increased propensity to fall and deteriorated mechanical properties of the bone tissue, the elderly present a markedly increased bone fracture incidence, mainly at the hip, wrist, and spine. At the same time, the WHO has also reported that almost 20 million new cancer cases are diagnosed every year. In fact, the improved therapeutic protocols for cancer patients have significantly increased their average survival. In return, an increasing incidence of bone metastases has been observed, primarily located in the spine, which compromises the physiological mechanical competence of the vertebrae. The spine is already per se one of the most fracture-prone anatomical sites, and pathological vertebrae are exposed to an even higher risk of fracture. In this rapidly evolving and complex context, reliable in silico methodologies could turn out to be crucial to support a clinical or surgical decision. As a matter of fact, there are currently no clinical parameters able to provide an accurate risk of fracture at the vertebral level, which would be pivotal to guide clinical decisions (e.g., conservative preventive treatments) or surgical interventions. Hence, the possibility of having in silico tools able on the one hand to reproduce reliable physiological loads and boundary conditions, and, on the other, to explore the effect of orthopedic devices on subject-specific models would be extremely beneficial for the quality of the treatment, patients' post-surgery life and then, the effectiveness of the healthcare system. In this framework, the possibility of

Objectives	developing more complete multibody models might allow to establish the loads acting at the spine during numerous physiological activities. In parallel, these loads could be transferred to finite element models built from patient-specific clinical images which might be used to assess bone response. Because the spine is composed of multiple vertebrae with the intervertebral discs interposed between those, also modeling the disc as accurately as possible would be important. The research objectives of the PhD program will be: - The implementation of Musculo-skeletal models of the spine, including main active and passive spinal elements, able to replicate the most common or critical physiological loading conditions. - The implementation and validation of CT and MRI-based multi-level finite element models, able to accurately reproduce the deformation state experienced by the vertebrae. - The development of a workflow allowing to merge the two different kinds of models by transferring the output of the multi-body model to the finite element model as inputs. If feasible, some experimental activities might also be carried out in order to increase the data informing the models as well as to support the models' validation. The final aim of the research will be the implementation of a pipeline that, combining models of the spine at different scales, could be able to replicate physiological/pathological boundary conditions to obtain reliable predictions in terms of interplaying loads among the different structural elements, as well as deformation and stress state at the vertebral bone in physiological/pathological conditions. Such a modeling pipeline might be employed, for instance, to predict the onset of a fracture, to predict the outcomes of a surgery, and to test new fixation devices.

Skills and competencies for the development of the activity	We are looking for talented and motivated candidates, preferably with skills/experience in: Numerical modeling (finite element and/or multibody methodologies and software), Image and data processing, Computer programming, Technical drawing, and Experimental mechanical testing. We desire a candidate with a strong aptitude for teamwork and problem-solving, who is open and able to work in multidisciplinary teams and has good communication skills. We require a good proficiency level in both Written and Spoken English.