Confirmation Review "Mini-Thesis" - Summary
Medical School
Name of Candidate:

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Project Title:

Biomechanical assessment of spine fixation using patient-specific finite element models

Name of Supervisor:
Enrico Dall'Ara

Name of Co-Supervisor:
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Statement of Probity

I confirm that I shall abide by the University of Sheffield's regulations on plagiarism and that all written work shall be my own and will not have been PLAGIARISED from other paper-based or electronic sources. Where used, material gathered from other sources will be clearly cited in the text.

Signature: Marco Sensale **Date:** 30/07/19

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Summary

Introduction

Musculoskeletal diseases of the spine, as vertebral fractures, are commonly treated by surgery (Magerl et al., 1994). In recent years, minimally invasive (MI) techniques improved the efficiency of hospital care by reducing costs thanks to potential less complications and shorter intervening time (Kumar et al., 2015). A well-established MI surgery is percutaneous pedicle screw fixation: screws are inserted bilaterally a level above and a level below the fractured vertebra and tightened by a rod (Blondel et al., 2011). However, it is still not clear in the literature how to determine the best size of screws for each individual case. As a result, surgeons decide diameter and length of pedicle screws mainly based on radiographic measurements of pedicle size and among available commercial sizes. In most cases the outcomes of this choice can not be predicted systematically, because parameters of different patients are not considered quantitatively.

Goal of the project

In this research project, we aim at developing a computational patient-specific pipeline to simulate the outcomes of MI fixation of thoracolumbar fractures in order to help the decision process of surgeons.

First year project

During the first year of the project, we aimed at developing the finite element (FE) modelling pipeline to generate a single vertebra model starting from Computed tomography (CT)-scan images of a patient suffering from a burst fracture. The lower vertebra adjacent to the fractured one was segmented, and two screws were virtually implanted in a 3D modelling software (Figure 1).

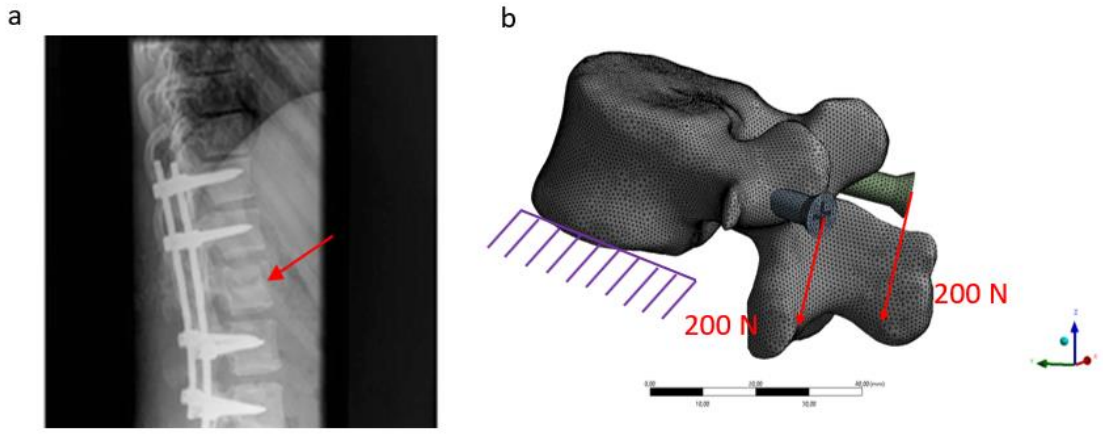

Figure 1: a) Lateral radiograph of a stabilised fracture through posterior pedicle screw fixation. The arrow indicates the fractured vertebra. Adapted from Kumar et al. 2015, open-access material. b) Mesh of the single vertebra model with implanted pedicle screws and applied boundary conditions.

Heterogeneous bone material properties were obtained by CT attenuation levels. The model was tested under a compressive load virtually transmitted through the rod to the head of screws. A mesh convergence study based on metrics of biomechanical relevance as the stress in implants and the strain in the bone was conducted. A maximum element size of 1.5 mm, providing a relative difference of approximately 12 % for the peak strain and 5 % for the peak stress with respect to the finest tested mesh, was chosen for sensitivity analysis. The effect of varying the diameter and the length of screws on output metrics was analysed. The model presented a higher sensitivity to changes in the diameter than in length. Specifically, as the diameter increased, the stress in implants was reduced as well as the strain in the vertebra (Figure 2).

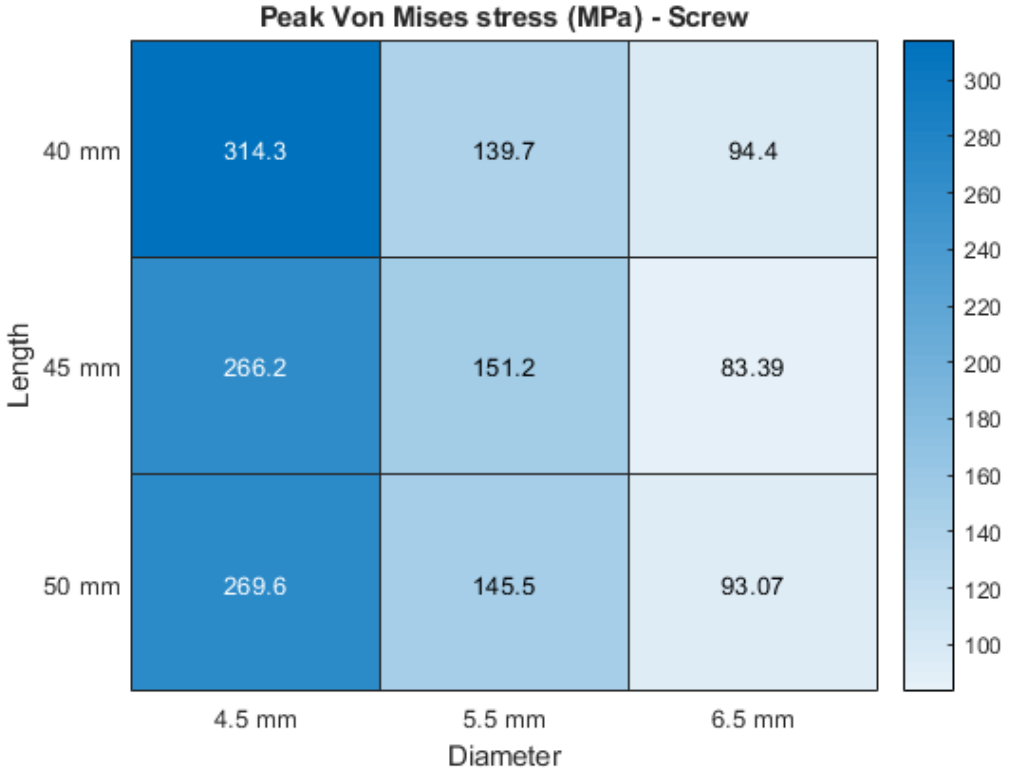

Figure 2: Maximum Von Mises stress in the screws vs. length and diameters of screws

Work plan

In the next years we will focus on improving the precision and the specificity of the 3D model by adding the fractured vertebra and the level-above one to the model, together with the remaining upper part of implants (two superior screws and connecting rods). Then, we will accelerate the workflow and the time of computation by using mesh morphing techniques and sophisticated reduced order modelling methods.

References

Blondel, B., Fuentes, S., Pech-gourg, G., Adetchessi, T., Tropiano, P., and Dufour, H. 2011. “Percutaneous Management of Thoracolumbar Burst Fractures: Evolution of Techniques and Strategy.” Orthopaedics & Traumatology: Surgery & Research 97 (5): 527–32. https://doi.org/10.1016/j.otsr.2011.03.020.

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