

Surgical reconstruction technique investigation after total en bloc sacrectomy with the use of the finite element method

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Mechanical Engineering Modelling MSc, Major in Solid Mechanics, 2019/2020/II.

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1. Introduction

Sacral tumours are rare pathologies, hence their management generates a complex medical problem. In silico medicine, including finite element (FE) analysis based methods, plays a crucial role in the realization of individualized treatments and surgeries in pre-surgical planning. My thesis aimed to develop a workflow for the FE investigation of different lumbopelvic reconstruction techniques after en-bloc sacrectomy due to sacral chordoma.



Figure 1.: Giant sacral chordoma. A photograph lateral view, B pre-op CT scan, C-D postoperative CT scan based reconstruction (Varga et al. 2009)

2. Methods

2.1. Development of the lumbar spine FE model

In the first part of my thesis, the geometry of a 24 years old male patient's lumbar spine was defined based on computed tomography (CT) images.

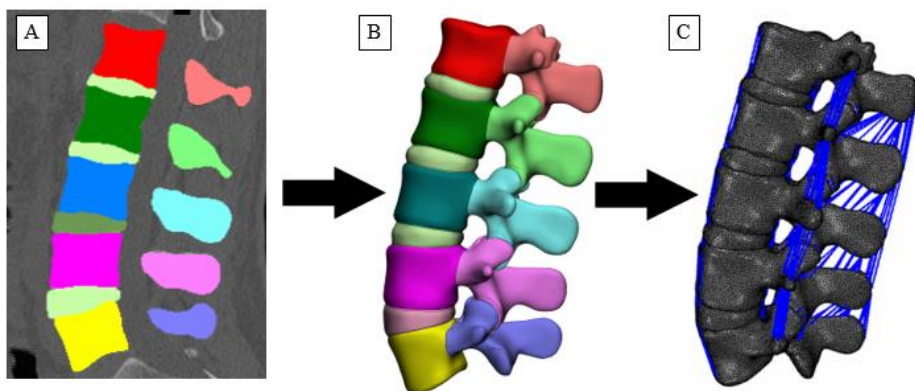


Figure 2.: Lumbar spine FE model development based on CT scans

The developed model consisted of separate cortical and cancellous bony structures, vertebral endplate and posterior elements. The intervertebral disc (IVD) was modelled with semi-automatic methods, since the soft tissues cannot be seen on the CT scans. The IVD consisted of the cartilaginous endplate, the nucleus pulposus and the annulus fibrosus. All seven spinal ligaments were added to the FE model. Materials were assigned according to the literature. The bony and soft tissues were modelled with ten-node tetrahedron elements, while the ligaments as two-node truss elements, with tension only properties. The load-displacement curve of the lumbar spine was obtained and compared to literature data.

2.2. Development of the lumbopelvic reconstruction FE models

In the second part of my thesis, two different lumbopelvic reconstruction technique was modelled and integrated to the lumbar spine model. The closed loop technique (CLT) and the sacral-rod reconstruction technique (SRR) were analysed. The models were loaded with pure moment in the three anatomical planes to simulate flexion/extension, lateral bending and axial torsion, while the standing was simulated with the follower load technique. The inferior surface of the most caudal vertebra was fixed; the moment

was applied on the superior endplate of the most cranial vertebra. These two systems were compared based on the range of motion and the maximal von Mises stress values.

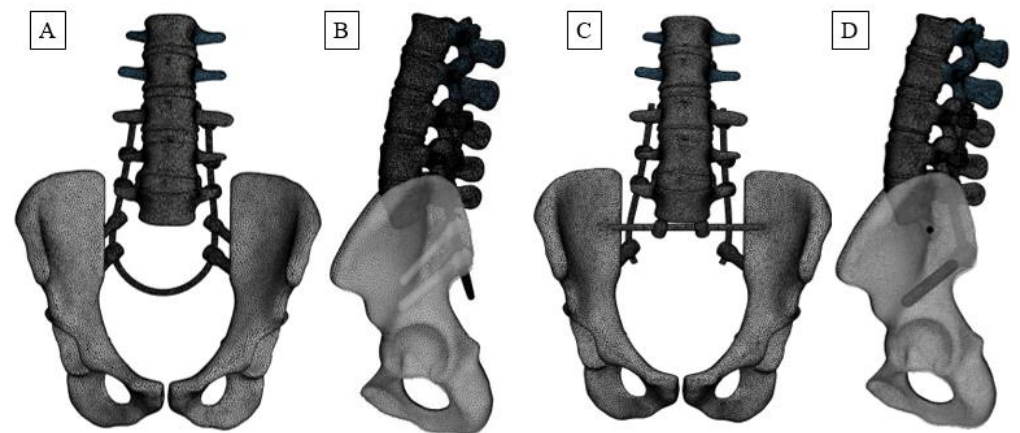


Figure 3.: The CLT and the SRR geometry model

3. Results

The results of the first part show that the characteristic of the load-displacement curve of this FE study is linear.

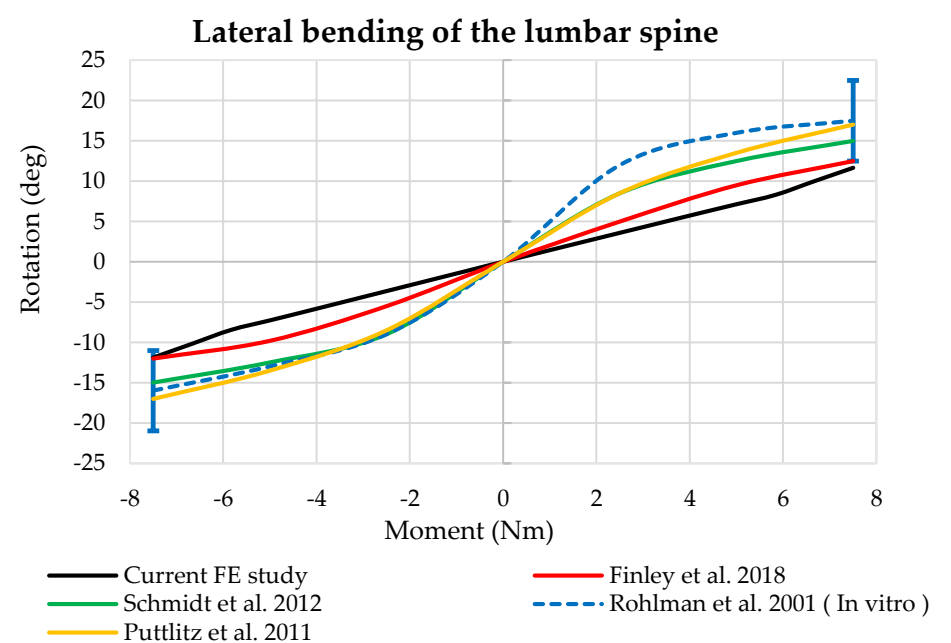


Figure 4.: The load-displacement curve against lateral bending

The speciality of the CLT system over the SRR is the application of a single U-shaped rod. Thus, the systems have more harmonic stress distribution and more ability to deform. The results of the second part show that the CLT induce higher deformation values and lower stress values.

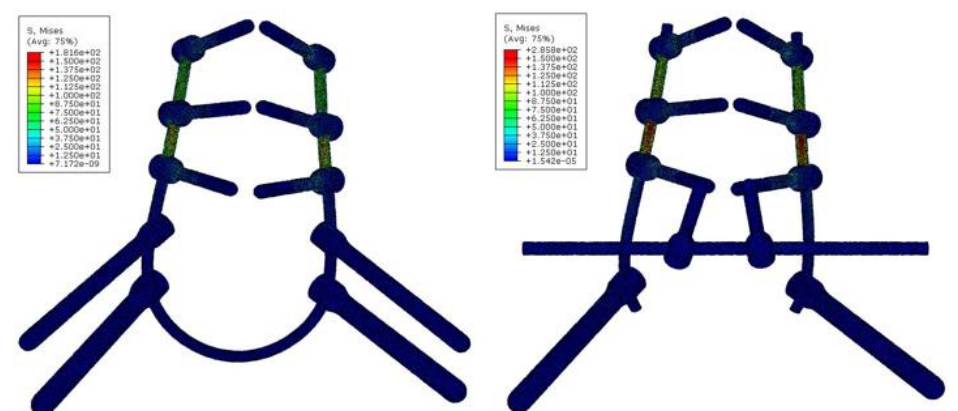


Figure 5.: The CLT and SRR against standing load

4. Summary

The developed lumbar spine model can be used for comparative FE studies, but to achieve a better fit of the curve the modelling approaches must reconsider. The two reconstruction systems were evaluated. We can state that the CLT was the more advantageous from the biomechanical point of view.