# ASSESSING THE EFFECT OF FIXATION LENGTH IN LUMBAR SPINE COMBINING RIGID AND FLEXIBLE BODY MODELING

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## Introduction

The growing incidence of degenerative spine diseases necessitating a segment fixation to solve spinal instability is dramatically increasing. At present, reducing the number of fixed vertebral levels is topic of heated clinical debate, but long fixations are still preferred as more stabilizing, and in case of pedicle screw failure, permit a more conservative revision treatment [1]. The study intends to explore this controversy, through a combined finite elements - rigid bodies approach, by investigating whether fixation length is a risk factor for the failure of the implant itself.

## Methods

An experimental campaign was conducted recurring to a T12-S1 biomimetic phantom (Sawbones SKU3430) to characterize (i) a pathological condition of an osteolytic lesion in L3 combined with a posterior decompression, and (ii) a long fixation (*L*) involving two levels above and below the lesion and (iii) a short fixation (*S*) connecting only the L3 adjacent levels in carbon-fiber reinforced PEEK (Fig. 1A). Concurrently, a T12-S1 rigid body spinal segment was designed recurring to the vertebral geometry of the phantom, consistent with an average human adult male anatomy. The intervertebral discs behaviour was characterized by eq. 1,2.

$$\vec{F} = [K]\,\Delta\vec{s} + [C]\,\Delta\dot{\vec{s}} \qquad (1)$$

$$\vec{M} = \sum_{p=0}^{3}[k_p] \circ \Delta\vec{\vartheta^p} + [C_T]\,\Delta\dot{\vec{\vartheta}} \qquad (2)$$

With $K, C, C_T$, respectively the translational stiffness, and translational and rotational damping diagonal matrices; $\Delta\vec{s}$ and $\Delta\vec{\vartheta}$ describe the relative displacements and rotations of two adjacent vertebrae in the space. Ligaments were modelled as non-linear pre-stressed tension-only spring dampers and validated through backward stepwise reduction strategy [2]. Concerning the surgical outcomes, FEM was adopted to simulate the implants which were simulated fixed to the bones (Fig. 1B). The Young's modulus was estimated through a four-point bending test on rods provided by CarboFix Orthopedics Ltd. The *in vitro* data permitted to fully validate the numerical surgical outcomes (Fig. 1C). From a mechanical perspective, the most severe internal loads occurring at the fixation joints are shear forces and bending moments [3]; hence, these loads, and the resulting Von Mises stresses along the rods, were compared between *L* and *S* outcomes in flexion-extension, lateral bending and axial rotation (Fig. 1D).

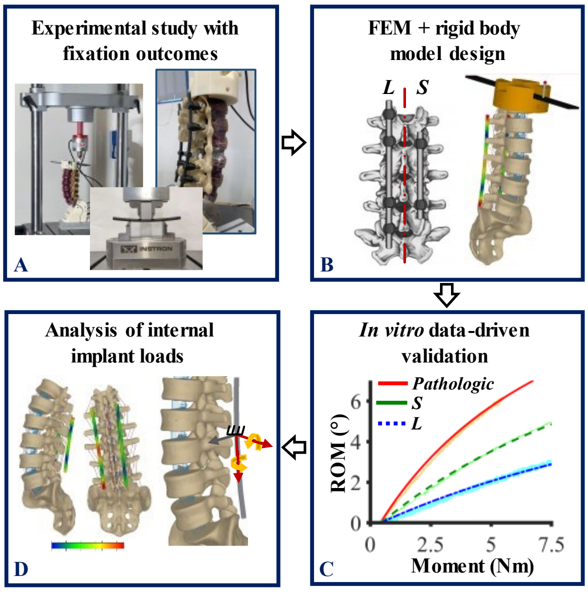


*Figure 1: Workflow adopted in this study.*

## Results

By simulating a hybrid protocol at 5Nm [4], a clear fixation-length dependence of the internal loads in the implants emerged, with *L* presenting up to 10 times higher moments in 2.5° axial rotation and in 10° extension, and generating more severe shear forces, like in 15° lateral bending where the most caudal fixation was subjected to ~1700N against ~300N. Reducing the fixed levels also permitted to contain Von Mises stresses ($\sigma_{max}$< 40% at least) and to guarantee their uniform distribution: indeed, the central fixations of *L* always revealed shielded by the hence overloaded distal ones.

## Discussion

Fixation length resulted strongly associated with implants internal loads in all the studied poses (consistent with patients' post operative mobility). This calls the attention that the surgical practice of lengthening fixation should be reconsidered; indeed, the study demonstrated that the insertion of a larger number of pedicle screws don't entail a more favorable load sharing, but, conversely, an hyperstatic construct with overloaded joints and shielded ones, making the *L* outcome more prone to failure.

## References

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2. Heuer et al, J Biomech., 40(2):271-280, 2007.
3. Song et al, Sci Rep 11 :12968, 2021.
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