ANALYSING FIXATION LENGTH AS A RISK FAILURE FACTOR VIA A COMBINED MUSCULOSKELETAL AND FLEXIBLE BODY MODELING

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Introduction

The growing incidence of degenerative spine diseases necessitating a segment fixation is dramatically increasing. At present, reducing the number of fixed vertebral levels is topic of 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]. This study explores, through a multi-level modeling, whether fixation length affects the loads exchanged in spine-implant construct, being a risk factor for the mechanical failure of the fixation itself.

Methods

From 25 upper-body healthy male subject-specific musculoskeletal models [2], postoperative outcomes were designed in OpenSim, simulating a long (L1-L5, *L*) and a short (L2-L4, *S*) lumbar fixations, rigidly connecting the vertebrae involved in the surgical implant. The altered kinematics of postoperative models was returned by compensating the null contribution of the fixed levels on the cranial and caudal adjacent free levels (75% and 25%, respectively) [3]. The muscular activity of the erector spinae, transversospinalis, psoas major, and quadratus lumborum was recorded for 30° flexion and 15° axial left rotation for each configuration (Fig. 1A). Then, the surgical implants were built on a T12-S1 multibody validated model [4] which incorporated ligaments, intervertebral discs and facet joints, all characterized by non-linear constitutive laws.

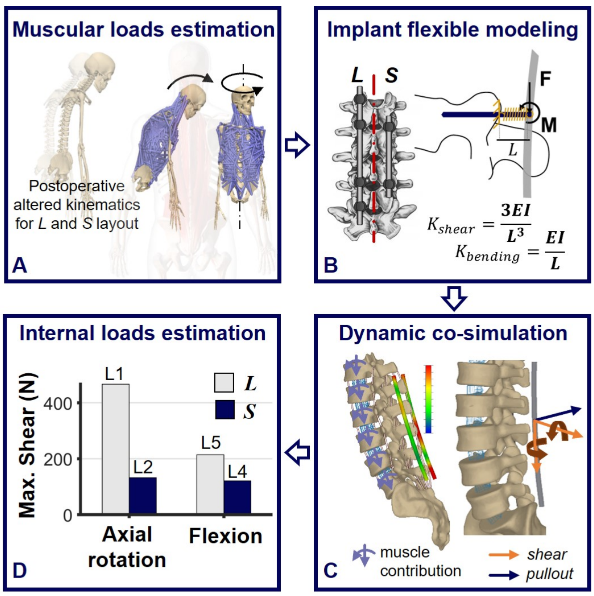

Figure 1: Workflow of this study

Modal theory was used to return the flexibility of CFR-PEEK rods. Conversely, pedicle screws were modelled as flexible connectors whose stiffness was evaluated assuming the screws as beams with one fixed extremity (i.e., their insertion point), and the other subjected to the loads transmitted by the rod (Fig. 1B). The computed muscular loads were applied in terms of concentrated forces and moments and added to the multibody-FEM co-simulation in MSC Adams (Fig. 1C). For both *L* and *S,* the pull-out and shear forces at the anchorages were estimated, together with the Von Mises stresses along the rods. These loads were deemed the most hazardous for the construct mechanical failure.

Results

The muscular recruitment in the T12-S1 region differed among the three configurations. At 30° flexion, the muscular compressive force acting on L5 was increased of +86% (*L*) and +48% (*S*) with respect to the intact model. Generally, at parity of task, *L* always resulted more loaded than *S*. Observing the reactions at the anchorages, during axial rotation the maximum shear force in *L* occurred in L1 and was 3.5 times higher than the maximum in *S* (Fig. 1D); moreover, bending moment reached 10Nm in L3, significantly stressing the whole construct. In flexion, cranial anchorages were subjected to pull out forces, and short rods limited them of 72% (~125N in *L*). Finally, *S* revealed more uniform Von Mises stresses, avoiding the load shielding emerged in the central anchorages of long rods.

Discussion

The impact of fixations on intervertebral joints has been extensively explored in literature, yet the stress that implants must endure during daily tasks is often overlooked. Delving in this direction, a significant dependency with fixation length emerged: long fixation appeared as hyperstatic construct and its altered kinematics provoked greater muscular recruitment and the production of heightened and severe reactions at the implant anchorages which could accelerate the dislodgment or the early fatigue of the screws. Then, the study suggests reconsidering lengthening fixation as a solution that risks to trigger the development of unfavorable loads, adverse for the implant lifetime.

References

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