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INFLUENCE OF INTERINDIVIDUAL GEOMETRIC VARIABILITY ON THE BIOMECHANICS OF THE INTACT AND INSTRUMENTED SPINE.

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Introduction

The lumbar spine exhibits geometric variability among individuals [1,2]. This variability may impact the mechanical behaviour in terms of both load-displacement curves and internal loads in instrumented spines. Better understanding of such impact is important when considering post-arthrodesis complications. Despite the wide use of spine finite element models (FEM), subject specificity is rarely considered. This study aims to explore the influence of geometric variability on the biomechanics of both intact and instrumented lumbar spines using subject-specific FEM.

Methods

A previously validated mean 3D L1-L5 FEM was used, including vertebrae, intervertebral discs, ligaments and facet joints with surface contacts. Data from an existing database of biplanar calibrated X-rays from 53 asymptomatic subjects (26 females; mean age 39.3 ± 11.4 years) were used. The biplanar X-rays were processed to extract 3D coordinates of control points that were used to personalize the FE mesh through a kriging algorithm, followed by a mesh regularization process. Material properties were kept identical for all subjects. For each of the 53 subject-specific intact spine models, screw-rod instrumentation was added at the L4-L5 level, creating an additional set of 53 instrumented models. (Fig.1).

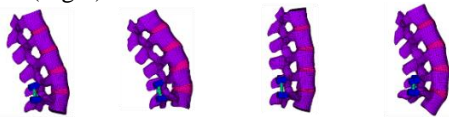


Figure 1: 4 out of the 53 instrumented FEM.

For each model and configuration (intact and instrumented), simulations were performed with the following boundary conditions: L5 was fixed, and a 10 Nm pure moment was applied on L1 in flexion, extension, lateral bending, and torsion. In the intact configuration, numerical load-displacement curves of L4-L5 and adjacent L3-L4 segments were compared to experimental corridors [3]. Then, instrumented spine Range Of Motion (ROM) was computed, as well as generalized forces in the screws.

Results

In the intact models, 412 out of 424 resulting curves fell within the experimental corridors (less than 3%

outliers). The experimental corridors were covered with percentages ranging from 46% to 96% depending on the load case and vertebral level. Instrumentation reduced the ROM of the instrumented segment in the four load cases with a mean value of 1° and a range (± 2 standard deviations (SD)) lower than 0.5° (Fig. 2A). The shear force in the screws exhibited higher variability, with a mean ± 2 SD of 92–127 N in flexion and 67–225 N in torsion (Fig. 2B).

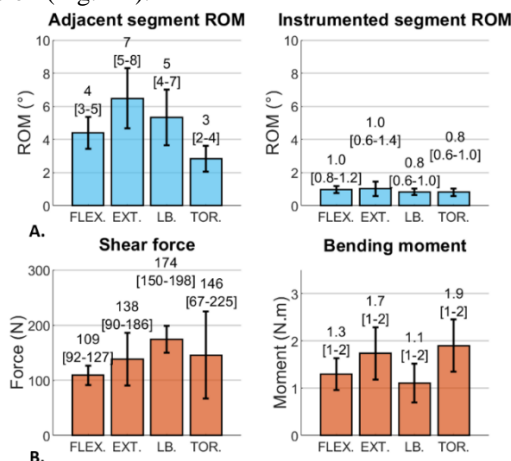


Figure 2: Bar plots of the quantities of interest of the 53 instrumented FEM (Mean [Mean ± 2 SD]).

Discussion

The FE results show that subject-specific geometry accounts for a large part of the variability of load displacement curves, while material properties could also play a role, especially in torsion. The main finding is that while rigid instrumentation reduced systematically the instrumented level ROM (which is its main objective), the resulting shear force in the instrumentation is highly variable among individuals. This study highlights the influence of geometric variability on the biomechanics of both intact and instrumented lumbar spines and its importance to better understand mechanical complications occurrence.

References

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