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A MULTI RIGID BODY MODEL OF THE SPINE EVALUATED WITH AND WITHOUT INSTRUMENTATION

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Introduction

The standard corrective surgical technique of early-onset-scoliosis is based on growing rod systems (GR), and leads to discs degeneration [1]. Recent studies pointed that flexible implants could preserve discs [2]. To help in understanding the implant effect on discs, numerical models of the spine have been developed since the 70's [3]. However, their behavior is rarely validated, especially according to instrumented spine. This study presents a multi-body model of the spine whose mechanical behavior was evaluated with and without posterior implant.

Methods

The T1-L5 model was developed with Solidworks®. Vertebrae were modeled as rigid bodies, their geometries being issued from MRI segmentation. Each intervertebral joint was represented by two linear diagonal stiffness matrices (3D translations and 3D rotations), at a mid-sagittal position, on the superior endplate level of the inferior vertebra. The mechanical properties have been defined from published *in vitro* data [3], [4], [5]. A follower load going through the rotation centers was added for gravity loading.

In vitro studies on spinal levels were simulated to evaluate the mechanical behavior of the model for intact spine, by applying various magnitudes (4, 7.5, and 10Nm) for the proximal torques (flexion/extension, lateral bending and axial rotation) as well as for the follower load (280 and 800N) [6], [7], [8], [9], [10].

Two *in vitro* studies on intact and then instrumented spines were also simulated. The modeling posterior instrumentations were respectively a T7-T11 titanium rod [11], and a specific implant from L2 to L3 [12]. The screw/rod joints were modelled by using two diagonal stiffness matrices.

Both segmental and global T1-T12 ranges of motion (ROM) were compared to published data. For studies with instrumentation, ROM of instrumented segments were compared relatively to intact ROM.

Results

For both the intact spine and segments, ROM of the modeling thoracic spinal levels (which integrated the rib cage stiffening) were in good agreement with literature data, for all torque values as well as for all follower loadings (cf. Figure 1). Note that for the lumbar levels, the model was stiffer for torque under 10N.m, but in the confidence interval.

The model with instrumentation presented relative ROM similar to *in vitro* data (cf. Figure 2).

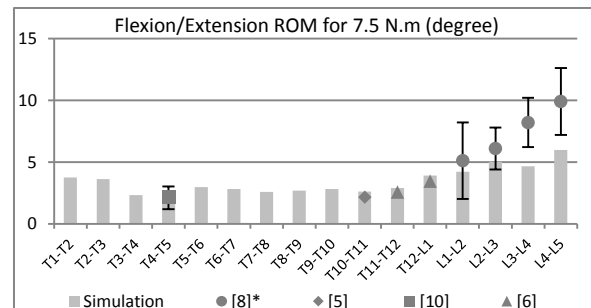


Figure 1: Flexion/Extension ROM for 7.5N.m, simulation of studies without instrumentation.

*: Torque 8 N.m and follower load 800 N

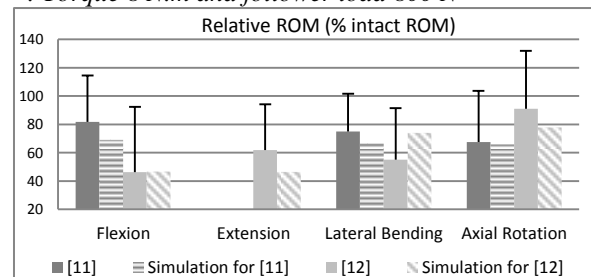


Figure 2: ROM relatively to intact ROM for the simulations of studies with instrumentation.

Discussion

The proposed model successfully reproduced the mechanical behavior of the spine, with and without posterior instrumentation.

Several limits could be underlined. Each intervertebral segment was globally represented by a linear 6 d.o.f. joint, without modeling independently biological structures. The model was evaluated on few *in vitro* (not on *in vivo*) experiments, with 19-81yo specimens. The geometry of the model was generic, related data being never reported in literature. A sensitivity study could be conducted to underline the critical parameters of the model.

CAO software should greatly simplify designing future implants for corrective spinal surgery.

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