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A METHOD FOR VALIDATION OF FINITE ELEMENT MODELS IN SCOLIOSIS BRACING SIMULATION

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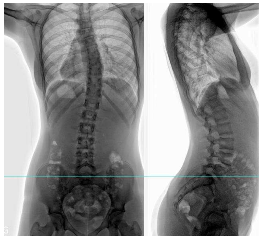
INTRODUCTION



Adolescent idiopathic scoliosis is a 3D deformation of the spinal column that can lead to functional impairment.

Several finite element models (FEMs) of the spine have been described in the literature to simulate bracing of the scoliotic spine. Validation of these models was often based on an incomplete set of reference parameters (Table 1).

Aims:

- Propose a clinically relevant validation method FEMs and
- Apply it to test a previously described model.

Table 1. Validation of FE models of the spine in the literature

Authors, journal	Number of clinical indices	Number of subjects
Gignac *et al.* Eur Spine J 2000	0	0
D. Périé *et al*. Spine 2003	0	12
D.Perie *et al.* Clin Biomech 2004	1	3
D. Perie *et al.* J Med Biol Eng Comput 2004	2	1
Nie *et al.* J Biomed Eng 2009	0	1
J. Clin *et al.* Eur Spine J 2010	0	3
Desbiens-Blais *et al.* Clin Biomech 2012	3	6

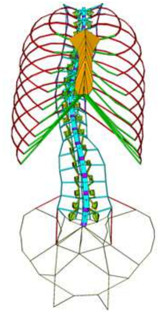


Figure 1. Personalized finite element model of a scoliotic patient

MATERIAL & METHODS

- Ten subjects (25 ± 13°, range 13° - 54°) treated by **brace or cast** were included.
- Bi-planar radiographs (EOS system) were acquired before treatment and in-brace.
- Three-dimensional geometry of **pelvis, spine and ribcage** was reconstructed in both conditions (Humbert *et al*. 2009). A personalized FEM was build from these 3D reconstructions (Figure 1, Descrimes *et al.*, 1995; Drevelle *et al.*, 2010),
- Orthosis action was simulated by applying the **displacements induced by the pads**, which were measured in vivo in the 3D reconstructions.
- **Clinical indices** (Table 2), vertebral positions and orientations were measured in the simulated geometry and compared to the in-brace reconstruction. RMS errors were compared to the measurement uncertainty.

RESULTS

Figure 2. Patient #4 out of brace (a), in brace (b) and simulated (c)

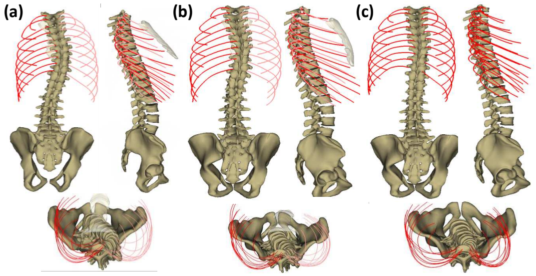


Figure 2 shows an example of an actual and simulated brace action. Differences between radiological and simulated clinical indices are presented in Table 2; **77 % of the simulated values were in the tolerance error interval**, while all values are of the same order of magnitude as the tolerance.

Table 2. Validation of the FEM of the present study

Clinical indices	RMS error between FEM and *in-vivo* measurements (range)	Uncertainty of in-vivo measurements (Humbert et al. 2009)
Kyphosis T1/T12	3.7 ° (0.5 - 6.7)	5.5 °
Kyphosis T4/T12	3.5 ° (1.0 – 5.1)	3.8 °
Lordosis L1/L5	4.9 ° (0.4- 9.6)	4.6 °
Cobb angle	5.7 ° (0.5- 10.8)	3.1 °
Apical axial rotation	7.0 ° (0.1 – 11.1)	3.4 °
Torsion index	6.2 ° (0.7 – 12.8)	4.0 °
Rib hump	6.4 ° (1.0 – 11.8)	5.0 °
Vertebral position	2.2 mm	1.0 mm
Vertebral orientation	2.9°	2.9 °

DISCUSSION

The FEM utilized in this study could reproduce the brace effect on the trunk to within acceptable error limits, both in terms of clinical indices and spine geometry.

In this study we propose a method to evaluate FE simulation of orthotic action. Clinically-relevant parameters were evaluated in the simulated in-brace geometry and compared to the actual in-brace 3D reconstruction. This allowed **objective evaluation of FEM predictions**, which provides a basis for the development of validated subject specific brace simulations.

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