World Congress of Biomechanics, Boston (USA), July 6-11, 2014

A Method for Validation of Finite Element Models in Scoliosis Bracing Simulation

C. Vergari[1], G. Ribes[1], B. Aubert[1], C. Adam[1], L. Miladi[2], B. Ilharreborde[3], K. Abelin-Genevois[4], P. Rouch[1], W. Skalli[1]

[1] *Arts et Metiers ParisTech, LBM, 151 bd de l'hopital, 75013, Paris, FRANCE,*
[2] *Department of Pediatric Orthopedics, Necker Enfants Malades Hospital, AP-HP, Paris, FRANCE*
[3] *Pediatric Orthopaedics Department, Robert Debré Hospital, AP-HP, Paris Diderot University, Paris, FRANCE*
[4] *Department of Paediatric Orthopaedics, Hospices Civils de Lyon, Claude Bernard Lyon 1 University, Lyon, FRANCE.*

Adolescent idiopathic scoliosis is a three-dimensional deformation of the spinal column that usually develops during adolescence and can lead to functional impairment. Early stage scoliosis is often treated conservatively with braces or casts, in an attempt to prevent or slow down curve progression which can lead to spine surgery.

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, however, was often only partial and based on an incomplete set of reference parameters; therefore validation methods could be improved and standardized. In this work we propose a clinically relevant method to validate FEMs and apply it to test a previously described model.

Nine subjects (average Cobb angle: 27 ± 13°, range 13-54°) who were prescribed brace or cast treatment were included retrospectively in this study. Bi-planar radiographs (EOS system) were acquired both before treatment and in-brace (< 3 months delay between the two scans). Three-dimensional geometry of pelvis, spine and ribcage was reconstructed in both conditions using previously described methods [1]. Orthosis action was simulated by applying the displacements induced by the orthosis, which were measured *in vivo* in the 3D reconstructions, to the pad regions of the model. Tissue mechanical properties were assigned to the model from literature values. Clinical indices (Table 1), vertebral positions and orientations were measured in the simulated geometry and compared to the in-brace reconstruction. Root mean square (RMS) errors were then compared to the 3D reconstruction uncertainties.

RMS errors between FEM and *in-vivo* measurements in-brace are reported in Table 1. Errors for clinical indices were of the same order of magnitude as in-vivo 3D reconstruction uncertainty. Apical axial rotation and vertebral positions were the only parameters that showed relatively higher error, although it remained acceptable for clinical purposes.

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.

[1] Humbert, L., De Guise, J. A., Aubert, B., Godbout, B., Skalli, W., 2009. 3D reconstruction of the spine from biplanar X-rays using parametric models based on transversal and longitudinal inferences. Med Eng Phys 31, 681-687.

Table 1

Clinical indices	RMS Error between FEM and *in-vivo* measurements	Uncertainty of *in-vivo* measurements [1]
Kyphosis T1/T12	6.0 ° (range: 0.5 - 9.7)	5.5 °
Kyphosis T4/T12	5.3 ° (range: 1 - 9.8)	3.8 °
Lordosis L1/L5	4.0 ° (range: 0.5 - 8)	4.6 °
Cobb angle	5.6 ° (range: 1.3 - 10.1)	3.1 °
Apical axial rotation	6.9 ° (range: 0.9 - 10.9)	3.4 °
Torsion index	4.8 ° (range: 0.9 - 10.3)	4.0 °
Rib hump	6.9 ° (range: 0.3 - 11.8)	5.0 °
Vertebral position	2.2 mm	1.0 mm
Vertebral orientation	4.2°	2.9 °