Parametric finite element modeling of the thoracic spine. Geometry and mesh evaluations.

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Introduction

Vertebrae present a wide interindividual variability, with a shape strongly dependent on the vertebral level. Based on a previous validated "parametric and subject-specific modeling" (PSSM) method (Laville et al. 2009), the aim of this study is to develop and evaluate a parametric finite element model of the human thoracic spine.

Materials and methods

Both 3D reconstructions and geometric parameters of 12 spines were extracted from bi-planar X-rays (EOS system, EOS imaging©) of 6 men (mean: 29yo, 1.79m, 81kg) and 6 women (mean: 39.5yo, 1.61m, 54.6kg). In order to validate each vertebra modeling on Matlab, a thorough geometric and mesh analysis has been performed. The geometry of each generated model has been compared to the reconstructed geometry: the mean distance between the points of the reconstructed vertebra and the outer surface of the model was calculated. The mesh analysis consisted to calculate aspect ratios, parallel deviations, maximum corner angles, Jacobian ratios and warping factors and to know the warning ratio and error ratio for each vertebra.

Results and discussion

Automatic mesh generation was obtained from geometric parameters for the 12 subjects (Figure1). The mean point-surface distance was 0.87mm (RMS=1.16mm), close to the one previously obtained on the cervical spine. On average, 2.16% of the elements resulted in a warning. Most warned elements were in the lower thoracic vertebrae because the geometry changes as these vertebrae are transitional ones. Indeed, for T1 to T9, 0.7% of elements were with warning and for T10 3.6% (less than 5%). The vertebrae T11 and T12 had more than 5% of elements with warning, respectively 5.3% and 10.6%.

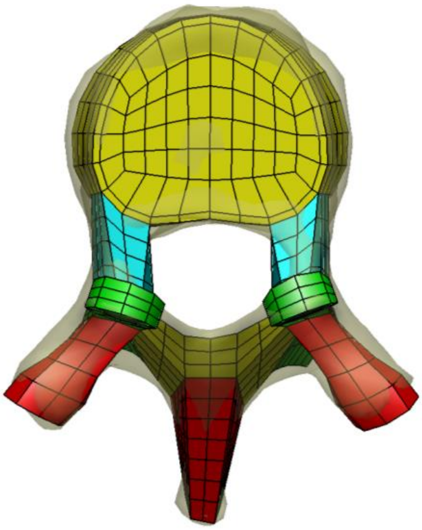

Figure 1: Example of reconstructed vertebra compared with its model

Conclusion

Automated generation of parametric finite element models provides new possibilities for efficiently studying the influence of geometric parameters. Preliminary evaluations have been performed to validate the coherence of the model. In order to enhance the validation of the models, kinematic simulation will be performed, followed by a stress study. The parametric subject-specific modeling method has been applied to the thoracic spine, and paved the way for large-scale clinical studies or dynamic safety applications.

Key reference

Laville A, Laporte S, Skalli W, 2009, Parametric and subject-specific finite element modeling of the lower cervical spine. Influence of geometrical parameters on the motion patterns, J Biomech, 42:1409-1415.