INTRA-OPERATOR COMPARISON OF TWO MODELS TO PREDICT VERTEBRAL FAILURE ON THE SAME EXPERIMENTAL DATASET

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Introduction

Clinical use of finite element analysis requires a well-defined process and the evaluation of uncertainties. Literature models have rarely been compared on the same experimental dataset and the influence of operator have not been evaluated either. Therefore, this study compared two models of vertebral bodies including endplates, on the same experimental dataset, and evaluated the influence of the operator on the failure load.

Material and methods

The experiments were obtained in a previous study [1]. Twenty-eight vertebrae were extracted from eleven donors (5 males and 6 females, 61-87 y.o.). L1-L3 vertebral bodies with endplates were resected at the pedicles, loaded to failure on the anterior part with PMMA embedded supports. Samples were scanned with a QCT scanner ICT 256 (Philips Healthcare; 120 kV, 1489 mA/s), at 0.39 x 0.39 x 0.33 mm resolution with a calibration phantom (QRM-ESP, QRM GmbH, Germany).

Two FE models were considered in this study:
ENSAM's model [1]: linear hexahedron mesh was created by semi-automatic segmentation of the scan (1-1.5 mm). Each element was assigned an averaged density, which was then converted into Young's modulus via the relationship from [3]. The mesh is constrained in Ansys with a linear resolution and the results are post-processed to find the failure load for which 1 cm^3 of contiguous elements reach a 1.5% yield strain.
Lyon's model developed by LYOS and LBMC [2]: A 1 mm3 quadratic tetrahedron mesh was created after manual segmentation. Specific densities for each element were assigned to each element and converted to Young's modulus using the relationship from [3]. Specific yield stress was computed using a constant yield strain of 0.7%. Perfect plasticity was given to each element. Each resulting vertebral model was compressed to reach 1.9% of total strain. Non-linear analysis was performed with Ansys to acquire failure load.

The influence of the operator was assessed for each model by evaluating the model twice by the same operator, especially the segmentation which is the only semi-automatic step.

Intra-operator relative difference (%) =

$$\left|\frac{Trial_2 - Trial_1}{(Trial_1 + Trial_2)/2} \times 100\right|$$

Results

Experimental failure loads are 3120 ± 1595 N (m ± SD). Comparisons to the experiments (model) and between trials by the same operator (intra-operator) are given in (Table 1), in terms of accuracy (mean of the difference between the average of simulated trials and experimental failure load) precision (SD of this difference) and determination coefficient. Both models' results are strongly correlated (R^2=0.91). Each model's results are close to the experiments (Table 1).

	Mean	SD	R^2
ENSAM's model	165 N	331 N	0.96
ENSAM intra-operator	103 N	298 N	0.96
Lyon's model	563 N	489 N	0.92
Lyon intra-operator	80 N	123 N	0.99

***Table 1**: Differences between simulated and experimental failure load for each model and differences between simulated failure loads for the same operator (intra-operator) expressed in mean, standard deviation, and determination coefficient*

Results between trials are highly correlated (Table 1). Intra-operator differences are low (ENSAM: 6.4 ± 6.2 %; Lyon: 3.5 ± 2.1 %).

Discussion and Conclusion

Differences between models may be the consequence of differences in segmentation process, meshing and material attribution. Furthermore, differences due to the operator may also result from segmentation process and the sensitivity of the model to segmentation variation close to boundaries of the model.
Comparison of models on the same dataset and operator influence are steps needed to assess the credibility of models.

References

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