INFLUENCE OF METASTATIC LESIONS ON TWO MODELS ASSESSING VERTEBRAL FAILURE

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Introduction

Literature contains various finite element models in terms of meshing parameters, mechanical behaviour, or failure criteria. However, models have not been applied on the same experimental datasets making comparison difficult [1]. Furthermore, the influence of metastatic lesions on failure load assessment has not been studied. Hence, this study aims at comparing two models on the same experimental dataset and evaluate the influence of the type of lesions on the models' performances.

Material and Methods

Forty-five vertebrae with confirmed metastatic lesions were considered from eleven donors (8 males and 3 females, 49-71 y.o.). The vertebral bodies were resected at the pedicles and the endplates were removed resulting in parallel surfaces. Samples were scanned using a µCT (µCT100, Scanco Medical, Switzerland) at 24.5 µm isotropic voxel size. The samples were then tested to failure in compression using a servo-hydraulic testing machine [2].

Two FE models were considered in this study:
Bern's model developed by ARTORG [2]: A 0.98 mm linear hexahedron mesh was created from conversion of each voxel into elements. Computed mechanical properties gave to each element linear elasticity, yielding and plasticity with the accumulation of damage and irreversible strains. The non-linear FE model was run in Abaqus (V.6.13, Dassault Systems, France).
Lyon's model developed by LYOS and LBMC [3]: A 1 mm^3-quadratic tetrahedron mesh was created. Average grey levels for each element were assigned to each element using a custom Python script. Then, the relationship from [4] was used to attribute Young's modulus to each element. Specific yield stress was computed using a constant yield strain of 1.5%. Perfect plasticity was given to each element once they reached their yield stress. Each vertebral model was compressed to reach a total apparent strain of 1.9% [5]. Non-linear finite element analysis was performed with ANSYS (v21R1; Houston, USA).

Results

Bern's and Lyon's models show close results (R^2=0.91) with similar accuracy and precision (868 ± 1569 N for Bern and 656 ± 1683 N for Lyon). Accuracy and precision for both models show higher differences for blastic lesions compared to mixt and lytic lesions (Figure 1).

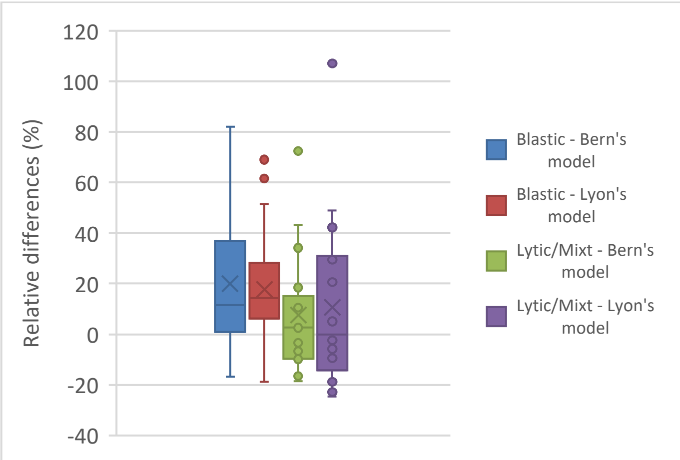

Figure 1: Relative differences between simulated and experimental failure loads for both models and for blastic and lytic/mixt lesions.

Discussion and conclusion

Models show similar performances even though their complexity are different: elasto-plastic perfect for Lyon and elasto-plastic with damage for Bern. However, when considering the type of lesions, blastic lesions show a significant overestimation compared to lytic/mixt lesions. This overestimation may be explained by the high density observed in blastic lesions [2].
A sensitivity study could be of interest to assess the impact of mineral density in metastatic lesions.

References

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