3D PARAMETRIC FINITE ELEMENT MODEL FOR THE MECHANICAL SIMULATION OF VERTEBRAE WITH METASTATIC LESIONS

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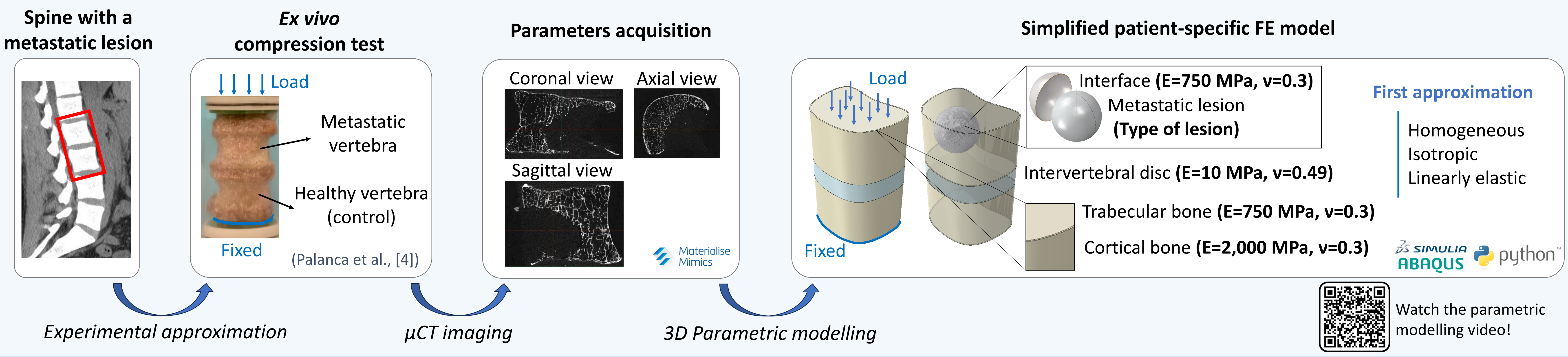
INTRODUCTION

- **Bones are frequently affected by metastatic lesions**, particularly by high incidence prostate, lung, and breast cancers [1].
- Bone metastases in the spine occur in 70% of cases, posing a significant **risk of vertebral fracture** [2].
- **Clinical soring systems** are used but are **not sensitive and specific** enough [3].
- **Computational modelling** offers a **valuable tool** for investigating of how metastatic lesions affects the mechanical stability of the spine.
- **The aim of this work** is to study the mechanical behaviour of vertebrae under the **influence of vertebral metastases**, specifically focusing on lytic and blastic lesions, and to determine if the **bone-tumour interface** influences this behaviour. For this aim, a **3D parametric model** for patient-specific analyses has been built. Additionally, experimental *ex vivo* data from [4] are used to validate the model.

MATERIAL AND METHODS



RESULTS

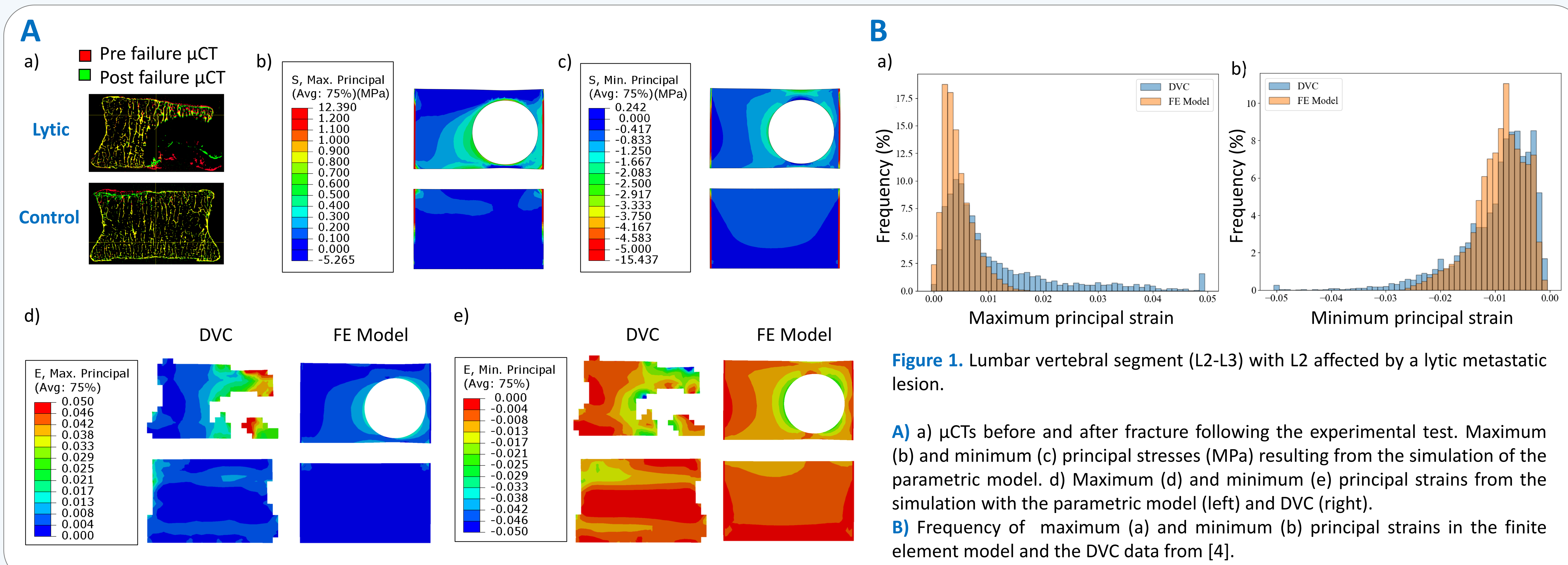


Figure 1. Lumbar vertebral segment (L2-L3) with L2 affected by a lytic metastatic lesion.

A) a) μCTs before and after fracture following the experimental test. Maximum (b) and minimum (c) principal stresses (MPa) resulting from the simulation of the parametric model. d) Maximum (d) and minimum (e) principal strains from the simulation with the parametric model (left) and DVC (right).
B) Frequency of maximum (a) and minimum (b) principal strains in the finite element model and the DVC data from [4].

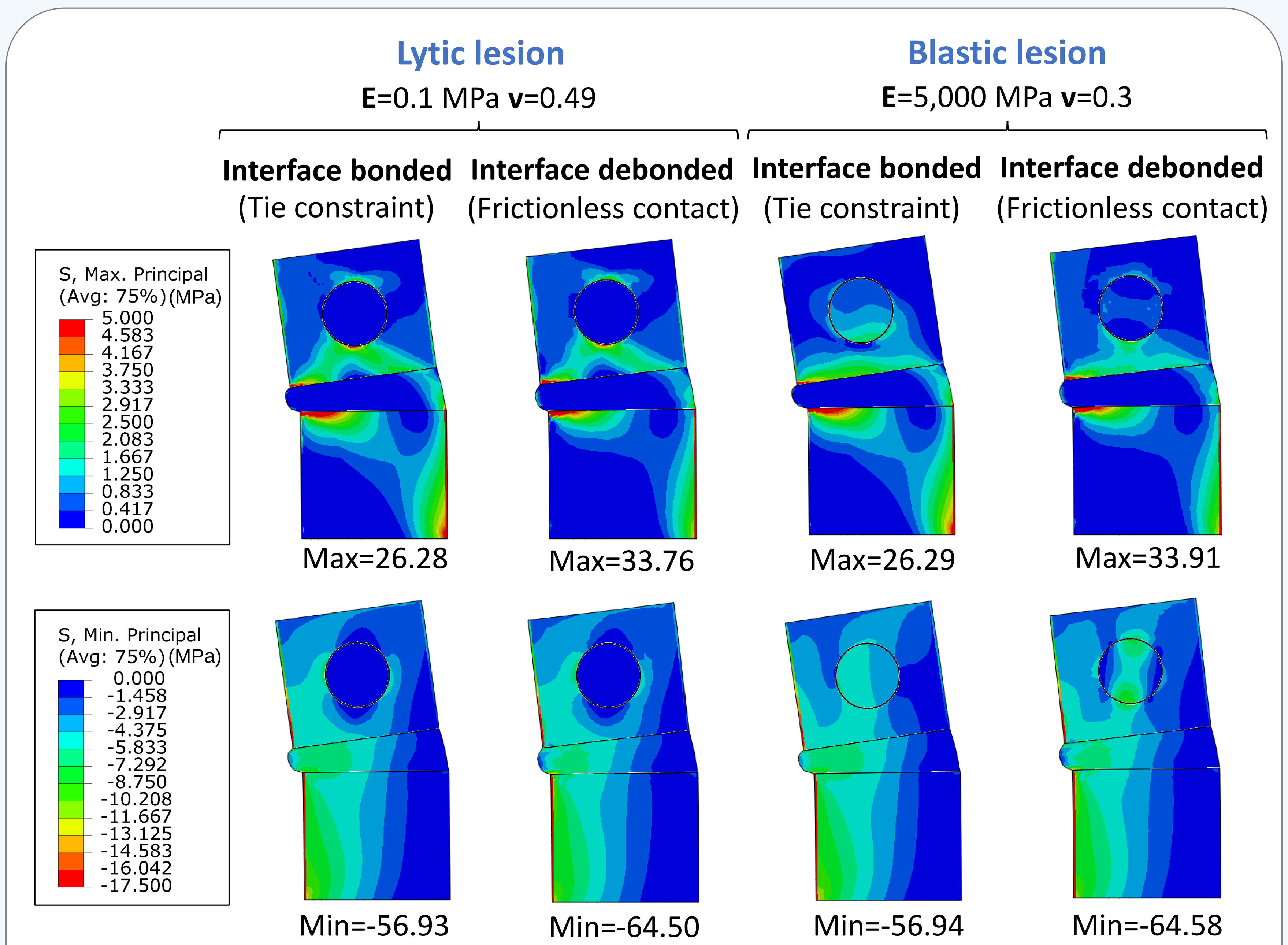


Figure 2. Maximum and minimum principal stresses (MPa) from simulations with the interface bone-tumour bonded using a tie constraint and debonded with contact for vertebrae with lytic (lytic) and blastic (right) lesions.

CONCLUSIONS

- The proposed methodology **facilitates patient-specific FE modelling of metastatic vertebrae**, bypassing the need of manual or semi-automatic bone segmentation.
- The developed parametric model **successfully reproduced** the results from two ***ex vivo* compression test**.
- Different **types of lesions significantly influence vertebral responses**.
- The hypothesis regarding the **quasi-incompressible behaviour of lytic lesions** was validated.
- The **bone-tumour interface modulates vertebral behaviour in blastic lesions** depending on bonding conditions. As the bond loosens, it adopts a behaviour similar to that observed in lytic lesions.

The parametric model allows for **patient-specific simulations**, providing **insights** into the interactions at the **bone-tumour interface** and the **types** of **metastatic lesion**. This approach serves as a foundation for studying vertebral biomechanics and the bone-tumour interface in different scenarios.

REFERENCES

[1] Ryan et al., Bone, 158, 2022.
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ACKNOWLEDGEMENTS

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