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# IN VIVO COMPARISON OF TWO FINITE ELEMENT MODELS PREDICTIVE OF THE FRACTURE OF METASTASIZED FEMUR

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## Introduction

Clinicians need to precisely assess the risk of fracture of metastasized femur to treat femurs at high risk. Quantitative computed tomography (CT) used in clinical routine allows to assess the personalized geometry and bone density distribution of the patient's femur. Using this data, finite element models may predict the femur behavior under load and compute its failure load. In association with the bone strength (BOS) score [1], these models could evaluate the risk of fracture. The BOS score is defined as the ratio of the failure load by the weight of the patient. If the score is below 8.9, the risk of failure is deemed high [2]. Nonlinear models were tested with a model-specific BOS score threshold to assess the risk of patients with metastasized femurs [2, 3]. A linear model might be better suited for clinical use due to its shorter computation time. The aim of this study was to compare the predicted failure loads of a linear and a nonlinear model using *in vivo* CT-scans and assess patients' risk of fracture using the BOS score.

## Material and methods

Two previously published models were reproduced and extensively tested in Lyon's laboratory [4]: the Lyon's model with a tetrahedral mesh, linear constitutive law and a failure criterion based on a volume of contiguous failed elements; and the Leuven's model with a voxel-based cubic mesh, and a nonlinear constitutive law. The mechanical parameters were defined in function of the bone density of each element extracted from the CT volume. The *in vivo* evaluation of the models was done using 9 metastasized patient's hip CT scans from Lyon. The failure load of both femurs of each patient was predicted using the boundary conditions used to validate the models [4].

Two patients presented metastases on both femurs. Failure risk was evaluated using the BOS score associated with the predicted failure load of each model.

## Results and discussion

For most patients, both models predict a lower failure load for the metastasized than the contralateral (without metastases) femurs (Figure 1). The Lyon's model predicts systematically higher failure loads than the Leuven's model (average differences: 1384 N (SD: 1370 N)), except for both femurs of one patient. The increase of failure load between the contralateral and metastasized femur in two femurs might be due to their location in a non-critical area of the femur. The BOS

scores obtained with the predictions of the Lyon and Leuven's models are highly correlated (Figure 2). Three patients are at high risk of fracture when using the BOS score with the Leuven's model.

The BOS score using Lyon's model predictions gives low risks of fracture for every patient. The BOS score threshold segregating low and high risks was shown to be model-specific [2, 3]. The linear (Lyon) and nonlinear (Leuven) models give correlated prognostics. This result suggests that an adapted threshold specific to the linear model might predict similar prognostics as the nonlinear model. A longitudinal study is currently in progress to evaluate the accuracy of the prognostics using different methods.

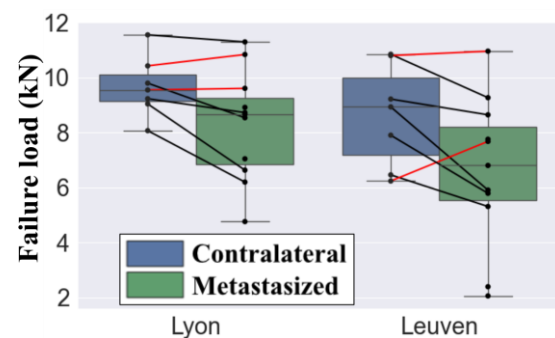


Figure 1: Predicted failure load of metastasized and contralateral (without visible metastasis) femurs for Lyon and Leuven's models. Straight lines link pairs of femurs from the same patient. Red lines mean an increase of strength for the metastasized femur.

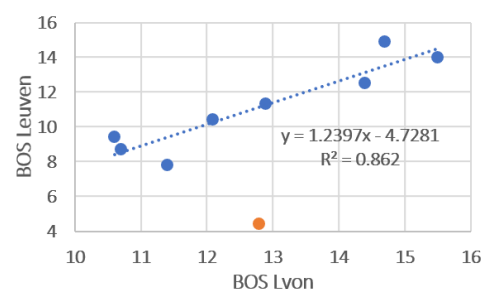


Figure 2: Correlation between the BOS scores obtained with the predictions of the linear Lyon and nonlinear Leuven models. One femur (in orange) was found to be osteoporotic and was not included in the correlation.

## References

1. Eggermont, F. et al. *Cancers (Basel)*, 14:5904, 2022.
2. Sas, A. et al. *J Orthop Res*, 41:225–234, 2022.
3. Ataei, A. et al. *Bone*, 179:116987, 2024.
4. Gardegaront, M. et al. *JMBBM*, submitted.

