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REPLICABILITY OF A FINITE ELEMENT MODEL TO QUANTIFY HUMAN FEMUR FAILURE LOAD

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Introduction

Femur metastases may affect femur strength. Currently, the clinical gold standard for failure risk estimation is the Mirels' score [1]. However, as pointed out several times [2], this score does not allow enough reliability to make an accurate prediction. Recent studies suggest that finite element (FE) methods may provide better estimations when it comes to fracture risk assessment [3, 4]. To our knowledge, none of the currently available FE models were reproduced outside of their original laboratory, thus, none were tested for their replicability. Therefore, the aim of this study is to evaluate the replication of one of the most promising FE models from the literature [5].

Material and methods

Two ex-vivo femur datasets were used. The KU Leuven dataset (8 femurs with lesions), and the Lyon dataset (16 intact + 6 femurs with lesions). All femurs were scanned with a clinical CT-scanner following similar protocols and reconstructed with resolutions of $0.5 \times 0.5 \times 0.2 \text{ mm}^3$ (Leuven) & $0.7 \times 0.7 \times 1.2 \text{ mm}^3$ (Lyon). Femurs underwent compressive tests to measure the failure load [6]. CT-scans were used to create a non-linear FE model [5]. Firstly, the reproducibility (*i.e.*, replication with the same dataset) of the model was tested. The FE analyses of the Leuven dataset were done by the original author of the model (Leuven operator) and an operator from Lyon, who transcribed the model from the original paper (same methodology but different tools). The results from both operators were then compared, which hints at the inter-operator and model transcription variabilities. Secondly, the model was tested for replicability. The Lyon operator did the FE analysis on the Lyon samples. The resulting accuracy was compared with those of the same operator on the Leuven samples to assess the influence of the experimental dataset.

Results

With the Leuven dataset, the difference between simulated and experimental failure loads (cf. Fig. 1A) averages to 549 N (RMSE = 881 N, $r^2 = 0.96$) for the Leuven operator and 978 N (RMSE = 1118 N, $r^2 = 0.98$) for the Lyon operator. A high correlation was found between operators (slope = 1.08, $r^2 = 0.95$). The accuracy of the model on the Lyon dataset (cf. Fig. 1B) averages to -978 N (RMSE = 1666 N, $r^2 = 0.3$) for

lesioned femurs and -3989 N (RMSE = 4487 N, $r^2 = 0.67$) for intact femurs. One of the FE analyses of the Lyon lesioned femurs did not converge; thus, the results are based on five femurs out of six.

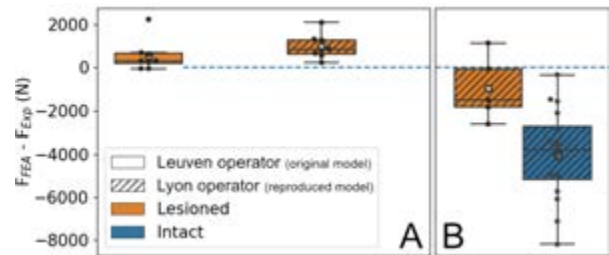


Figure 1: Accuracy of the FE analyses (Failure loads diff.: $F_{FEA} - F_{Exp}$). (A) Leuven dataset. (B) Lyon dataset.

Discussion

When using the Leuven dataset, both operators displayed similar results. Differences could be explained by inter-operator variabilities induced by segmentation or orientation [7], and by different pre-processing algorithms and FE software used. When applied to the Lyon dataset, the Lyon operator obtained an average accuracy 7 times worse than the original paper [5] on intact femurs, and 2 times worse on femurs with lesions. In addition to the aforementioned causes of variabilities, the lack of replicability questions the influence of the experimental setup, scan parameters, and possible divergences of physiologic femur characteristics between datasets. Overall, this replication study emphasizes the need to have clear and rigorous guidelines for bone FE models [8] and experiments, and assert the importance of model assessment on large datasets.

References

1. H. Mirels, *Clin. Orthop. Relat. Res.*, 249:256-264, 1989.
2. C. Confavreux *et al.*, *CSEA*, 13:5711, 2021.
3. F. Eggermont *et al.*, *Bone Joint Res.*, 7:430-439, 2018.
4. A. Sas *et al.*, *Bone Reports*, 12:100286, 2020.
5. A. Sas *et al.*, *Bone Reports*, 12:100263, 2020.
6. A. Sas *et al.*, *J. Mech. Behav. Biomed.*, 104:103648, 2020.
7. A. Levillain *et al.*, *ESB 2021*, 2021
8. M. Viceconti *et al.*, *Methods*, 185:120-127, 2021.

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