FINITE ELEMENT ANALYSIS OF HUMAN TRABECULAR BONE RELAXATION RESPONSE

Brian Kunath[1], Sylvana Garcia-Rodriguez[2], Roshni Rainbow[1], Heidi-Lynn Ploeg[1]
[1]Queen's University, Kingston, ON, Canada, [2]University of Wisconsin, Madison, USA
Email: 14bak3@queensu.ca

INTRODUCTION: Trabecular bone's viscoelastic behaviour plays a significant role at the bone-implant interface [1, 2]. Previous studies have modelled relaxation and creep responses of bovine trabecular bone using empirical models to quantify the viscoelastic response in terms of stress and strain [1, 2]; however, human trabecular bone may behave differently than bovine bone. Combining analytical models with finite element analysis (FEA) may provide a better understanding of the viscoelastic response of trabecular bone and the bone-implant interface.

OBJECTIVE: The objective of this study was to combine analytical models with FEA to simulate the relaxation response of human trabecular bone.

METHODS: 5 mm x 10 mm (height x diameter) cylindrical trabecular bone samples (n = 76) were prepared from femoral heads donated by seven hip replacement recipients (five females; ages 66 – 87 years). This study was approved by the Queen's University Health Sciences and Affiliated Teaching Hospitals Research Ethics Board (MECH-029-05) and patient written consent was provided. Samples were individually tested in an *ex-vivo* bioreactor at room temperature and compressed for one minute at five strain loads (-2200 με, -3000 με, -3800 με, -4600 με, and -5400 με) with a 20-minute recovery period between each load. A 3-term generalized Kelvin-Voigt analytical model (R^2 = 0.99) was combined with ABAQUS 2017 FEA software to simulate the viscoelastic response of trabecular bone cores (n = 15) using linear-elastic and hyperfoam material models. The analytical model was used as a surrogate to analyze the significance of the FEA models.

RESULTS: The linear-elastic FEA (R^2 = 0.85) showed a stronger average coefficient of determination to the analytical model compared to the hyperfoam FEA (R^2 = 0.62), despite underestimating the early stress relaxation (Figure 1).

CONCLUSIONS: Despite using a linear-viscoelastic analytical model and bulk representations of the bone microstructure, the linear-elastic FEA was able to predict human trabecular bone relaxation.

REFERENCES:
[1] Manda, et al., *Biomech Model Mechanobiol*, 15(6): 1631-1640, 2016.
[2] Manda, et al., *Biomech Model Mechanobiol*, 16(1): 173-189, 2017.

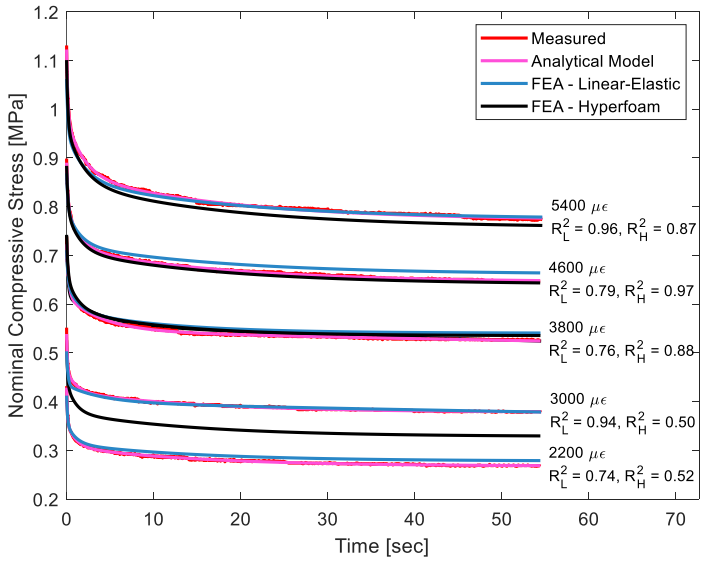

Figure 1. Relaxation response of a representative trabecular bone core for all loads. Coefficients of determination are shown for the linear-elastic FEA (R^2_L) and hyperfoam FEA (R^2_H) compared to the analytical model for each load.