# FINITE ELEMENT PREDICTION OF CORTICAL AND TRABECULAR BONE REMODELLING IN AN IN VIVO MODEL OF BONE ADAPTATION

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## INTRODUCTION

Bone remodelling is known to be a function of its mechanical environment. However the precise nature of the mechanical signal governing bone formation is poorly understood. As well as improving our understanding of bone formation and bone quality maintenance, a quantitative understanding may ultimately reveal novel approaches for the treatment or prevention of age related fractures and diseases such as osteoporosis. Several computational models have attempted to provide theoretical frameworks which explain load induced adaptations. Whilst these models are able to mimic bone adaptation qualitatively, they lack quantitative validation. Here, using an in vivo model for synchronous cortical and trabecular bone adaptation, we attempt to characterize more precisely the relationship between the mechanical environment and bone remodelling.

## METHODS

In a previous study we demonstrated appreciable 25.9% and 11% increases in both trabecular and cortical bone volume density, respectively when subjecting the fifth caudal vertebrae (C5) of C57/BL6 mice (15 weeks of age) to an acute loading regime (Amplitude of 8N, 3000 cycles, 10 Hz, 3 times a week for 4 weeks) [1]. We have also established a validated finite element (FE) model of age matched C5 vertebra using micro-computed tomography (μCT) [2]. To investigate the relationship between load-induced bone adaptation and mechanical strains, in vivo and in silico data sets were compared. We divided cortical and trabecular compartments into 15 sub-regions (figure 1) and determined, for each region, a bone formation parameter ΔBV/BS (a cross-sectional measure of the bone volume (BV) added to cortical and trabecular bone surfaces (BS) following the described loading regime). Linear regression was then used to correlate mean regional values of ΔBV/BS with mean regional values of strain energy density (SED), orthogonal strains and shear strains. All mechanical parameters were derived from the FE models, similarly compartmentalized. Furthermore, to investigate how the load induced bone was deposited mean regional values of ΔBV/BS were correlated with mean regional percentage increases in structural indices specific to both cortical and trabecular compartments.

## RESULTS AND DISCUSSION

For cortical regions regression analysis showed mean regional values of ΔBV/BS to correlate extremely well with strain energy density ($R^2$ = 0.82, figure 2). ΔBV/BS also correlated well with the percentage increase in both tissue volume ($R^2$ = 0.81) and marrow volume ($R^2$ = 0.64), inferring a load-induced radial expansion of the cortical shell. For trabecular regions ΔBV/BS significantly correlated with percentage increase in trabecular thickness ($R^2$ = 0.79) and trabecular number ($R^2$ = 0.26). However no correlation was observed with SED or any other mechanical parameter (figure 2).

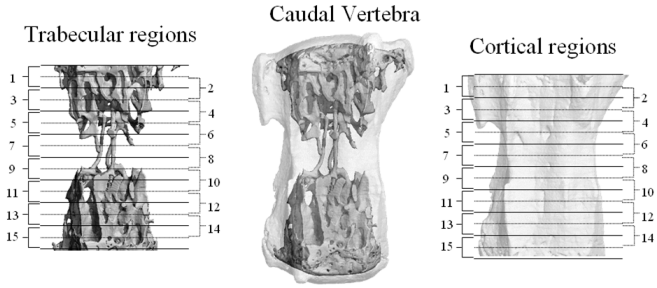


**Figure 1**: Digital image of a whole B6 vertebra (C5) showing cortical and trabecular compartments which are subdivided into 15 overlapping regions (1–15).

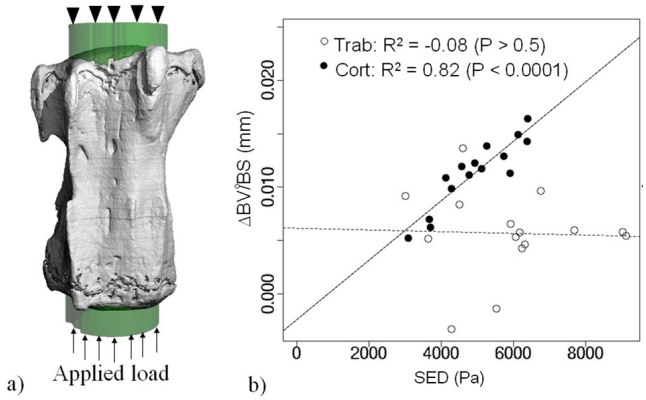


**Figure 2**: (a) Diagram showing the FE model. (b) Linear correlation of mean regional SED and mean regional ΔBV/BS for both trabecular and cortical bone.

## CONCLUSIONS

These results show that SED is able to predict the addition of cortical bone mass following an acute loading regime. The absence of any correlation for trabecular remodelling may be indicative of two distinct remodelling mechanisms. In this study we have established a combined experimental and computational approach which will provide further insight into bone remodelling mechanisms when implemented with in vivo imaging technologies.

## ACKNOWLEDGEMENTS

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## REFERENCES

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2. Webster DJ, et al., *Computer Methods Biomech Biomed Engin.* 2008 Oct;11(5):435.41.