EFFECT OF THE LOADING DIRECTION ON THE PREDICTED MECHANICAL PROPERTIES OF THE MOUSE TIBIA

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Introduction

Understanding how bone responds to mechanical loading is fundamental for the development of new biomechanical treatments for musculoskeletal diseases [1,2]. The *in vivo* tibial loading model is used to investigate the effect of passive mechanical loading on the mouse tibia [1,3]. While a nominal axial load is applied to the tibia through the knee and the ankle joints, the real loading direction in the experimental setup may induce out-of-axis loads on the tibia. These loads may dramatically alter the local strain distributions which affect the bone remodeling [4]. The aim of this study was to evaluate the effect of the loading direction on the predicted local mechanical properties of the mouse tibia before and after passive mechanical loading.

Methods

Six female C57BL/6 mice were ovariectomized (OVX) at week 14 of age. At weeks 18 and 20, the right tibiae were scanned using *in vivo* micro-tomography (micro-CT; 10.4µm/voxel). The mice underwent mechanical loading (ML) treatment at week 19 (12N peak load, 40 cycles/day, 3 days/week on alternate days). This data was acquired from a previous study [1].

Micro-CT based finite element models were generated from the segmented images (hexahedral elements; isotropic linear elastic material properties) for the mice at weeks 18 and 20 [5]. Three independent unitary load cases were applied along the axial, medio-lateral or anterior-posterior directions for each mouse at each timepoint. The components of the strain and stress, principal strains, principal stresses and strain energy density (SED) were recorded at the Gauss points.

Using scaling and the superimposition of the effects, the results were combined to calculate the local properties for different loading directions resulting from a 12N axial load (typical load controlled in the *in vivo* tibial loading model to induce osteogenic effects). Calculations were performed as a function of the angle from the inferior-superior axis (θ, 0-30° range, 5° steps) and the angle from the posterior-anterior axis (ϕ, 0°: anterior axis, positive anticlockwise, 0-355° range, 5° steps) (Figure 1). The SED distributions were calculated for each loading direction.

Results and Discussion

Results confirmed a higher sensitivity to a change in θ compared to a change in ϕ at both timepoints (results reported here only for SED, Figure 1). Lower SED values were found for different loading directions after mechanical loading, highlighting adaptation of the bone also for loading directions far from the nominal one. The difference in variability between week 18 and 20 may be due to the mice responding differently to OVX, and ML having higher effect on the cortical bone compared to OVX.

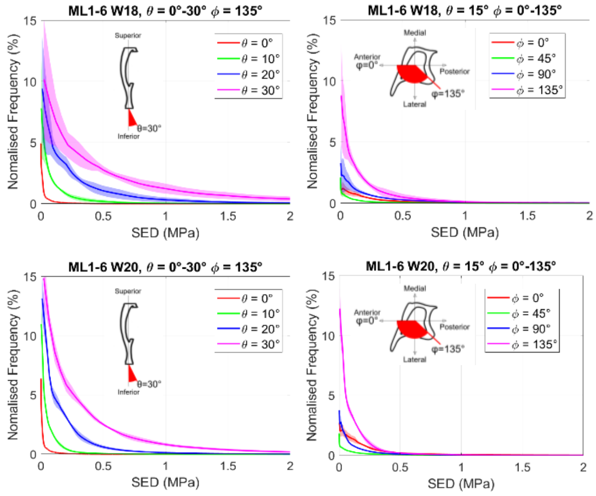

Figure 1: The frequency plots showing the mean and standard deviation for the SED for mice 1-6 for different loading directions with a 12N axial load, for (left) varying θ and fixed ϕ, (right) varying ϕ and fixed θ, (top) mice at week 18 of age, (bottom) mice at week 20 of age.

Conclusion

These results suggest that in studies which use the *in vivo* tibial loading model, repositioning of the tibia in the loading device may impact the distribution of local deformation and therefore of bone remodeling [3], and thus should be better controlled during the experiment.

References

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