EFFECT OF SR-MICROCT EXPOSURE TIME ON THE DAMAGE INDUCED ON TRABECULAR BONE USING DIGITAL VOLUME CORRELATION

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Introduction

The use of high-energy synchrotron radiation micro-computed tomography (SR-microCT) is becoming increasingly popular for studying the micro-architecture and micro-deformation of bone under *in situ* mechanical testing [1]. However, it is also known that the effect of X-ray irradiation can considerably alter the mechanical properties of the bone tissue [2]. Digital Volume Correlation (DVC) has been extensively used to compute the strain distribution inside bone specimens subjected to step-wise mechanical loading [3]. This study presents the first use of DVC on SR-microCT images to investigate the influence of irradiation-induced tissue damage on the apparent elastic properties of trabecular bone in situ at variable exposure times.

Materials and methods

SR-microCT imaging of cylindrical samples (D: 4mm, L: 8mm) of ovine trabecular bone was performed at the I13-2 beamline (Diamond Light Source, UK). The effective voxel size was 2.6µm. Tomographic datasets were obtained with a pco.edge 5.5 detector. Each sample was imaged at a different exposure time (512, 256, 128 and 64 ms/projection) and 1800 projections were collected for each tomography over an angular interval of 180 degrees. *In situ* mechanical testing was carried out (CT5000, Deben Ltd, UK) on samples immersed in saline solution. After preconditioning (10 cycles) each bone specimen was subjected to seven loading cycles in the apparent elastic range (0.5% global strain) and images acquired under load after each loading cycle. DVC (DaVis 8.3, LaVision, Germany) was used to couple irradiation-induced microdamage with the full-field strain developed in the bone. Three methodologies were considered: analyzing the raw images, masking out only the bone tissue and shading in black the bone marrow. Images after the first two cycles of load were used to compute strain uncertainties. A multipass approach with a final sub-volume of 64 voxels was found to minimize the errors with a reasonable spatial resolution.

Results

Samples imaged using high exposure times (512-256 ms/projection) showed the development of multiple microcracks in the tissue that started to be visible from the 6th cyclic step, although the stress-strain curve did not show any notable changes in the apparent elastic properties, particularly for the 512 ms/projection (Fig. 1). DVC applied to the raw images was highly influenced by bone marrow and fluid. However, masking/shading the bone marrow and setting a threshold on the correlation coefficient for the raw images helped DVC to couple visible microdamage in the bone tissue with principal compressive strains up tp approximate 8000 µε. As for the lower exposures (i.e. 64 ms/projection) no apparent damage was visible at both tissue and apparent level.

Discussion

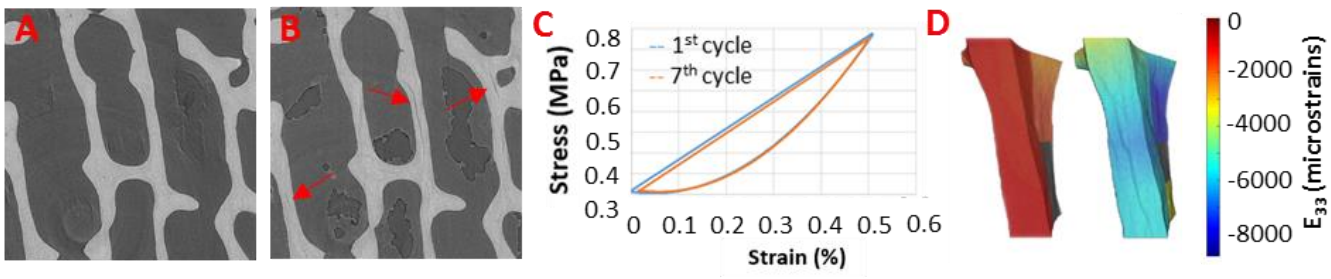

Figure 1. (A) and (B) SR-microCT images of trabecular bone (512 ms/projection) after the second (A) and last (B) loading cycles (arrows indicate visible microdamage). (C) Stress-strain curves for loading cycles (1st and 7th). (D) Minimum principal strain in the same trabecula after the second (left) and last (right) loading cycles.

This is the first study that uses DVC to quantify the damage induced at tissue level and in situ by X-ray irradiation on SR-microCT images. The development of microcracks in the tissue did not always correspond

to significant changes in the apparent elastic properties of bone. However, DVC successfully correlated the visual microdamage to high levels of compressive strains typical of trabecular bone yielding (8300 ± 1500με [4]). No visible damage was observed for lower exposures, which produced noisy images that could affect DVC at tissue level. Further work needs to be conducted to investigate the origin of this induced damage, establishing reliable protocols for in situ SR-microCT analysis of biological tissues.

References

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