Mechanical Evaluation of Bone Graft Enhanced Ovine Tibia Bone Defect Using Digital Volume Correlation

A. Karali[1], A. DeMori[3], R. Kallala[2], G. Blunn[3]

1. School of Mechanical and Design Engineering. University of Portsmouth, UK; 2. School of Pharmacy and Biomedical Sciences, University of Portsmouth, UK; 3. Corthotec Ltd, UK

Introduction

The mechanical behaviour of newly formed bone under compression has been examined using *in situ* X-ray computed tomography (XCT) and digital volume correlation (DVC) in femoral condyles [1]. Previously, four point bending has been employed in sheep models to assess the healing of fractures in long bones [2]. The aim of this study is to use *ex situ* XCT four-point bending to examine the 3D full-field residual strain distribution of newly formed bone treated with calcium sulphate based synthetic bone graft material in a tibia mid-shaft osteotomy, using DVC.

Methods

Sheep tibia bones with an osteotomy defect of 2 cm, were stabilised using an external titanium mono-fixator with half pins and retrieved 12 weeks post-operative. Three of the bone defects were packed with calcium sulphate pellets containing varying levels of parathyroid hormone (PTH) of 1, 2 and 5 ng/ml, and one was used as control. Two consecutive tomograms were acquired (Versa 520, Zeiss) for the calculation of the strain uncertainties (≤ 300 με) [3]. *Ex situ* four-point bending was used to measure the mechanical response of the regenerated tissue, within the apparent elastic region, max load 300 N (i.e. normal walking load). DVC analysis (DaVis10, LaVision, UK) was conducted using a single-step pass processing scheme (48 voxels) and 0% overlap to compute the strain distribution through the newly formed bone. Histology was also performed on the tissue using haematoxylin and eosin staining subsequent to the mechanical testing.

Results

All four specimens showed similar response to the load with the control specimen presenting the highest displacement (4.2 mm) (Fig1). DVC analysis shows higher compressive strain (ε_{p3}) at the inferior part of the osteotomy (approximately -2800 με). Similarly, the shear strain (γ) has a maximum value of 9000 με in the same region, whereas in the middle on the osteotomy is reaching a maximum value 4000 με (Fig.2). Histology shows callus formation and mineralisation of the regenerated tissue.

Discussion

This study explored the strain distribution in the newly formed bone treated with calcium sulphate pellets containing PTH. The XCT images showed that bone formation is uniform for all the different levels of PTH and therefore the strain distribution is dependent on both the growth and morphology of the tissue. Work is in progress to investigate the effect of PTH levels in the healing fracture, using energy dispersive X-ray spectroscopy (EDS).

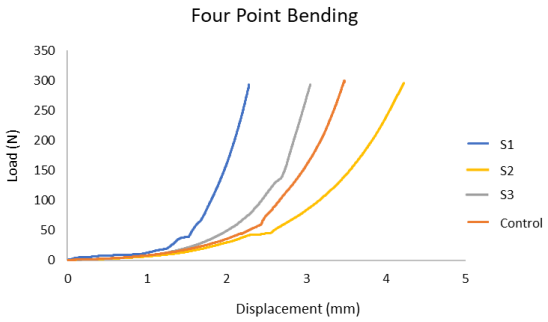

Figure 1: Load displacement curve of sheep tibia under four-point bending.

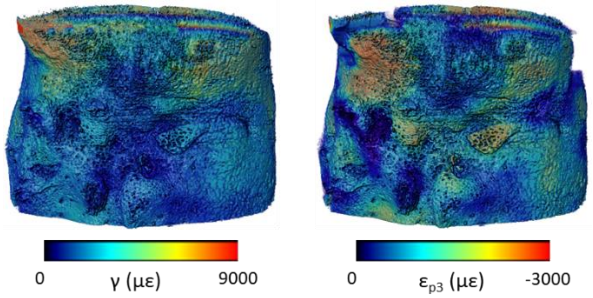

Figure 2: Sheep tibia osteotomy region with 5ng/ml. DVC analysis of the of the newly formed bone illustrating the 3D full-field residual strain

References

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