Centre for Doctoral Training in Medical and Biological Engineering

Ruth H. Coe, Sebastien N.F. Sikora, David C. Barton, Ruth K. Wilcox
iMBE, School of Mechanical Engineering, University of Leeds, LS2 9JT
mn09r2c@leeds.ac.uk

UNIVERSITY OF LEEDS

Development of a Fatigue Testing Method for Vertebral Fracture Therapies

Introduction

Vertebral Fracture
- Over 27% of post menopausal women will suffer an osteoporotic vertebral fracture [1].
- This leads to pain and reduced quality of life.

Fig 1, Osteoporotic compression fracture [2].

Vertebroplasty
- Vertebroplasty is a surgical intervention for vertebral fractures involving the injection of bone cement into the fracture.

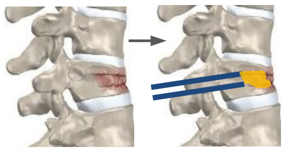


Fig 2, Bone cement injected through a biopsy needle through the pedicle.

- Large variations have been seen in patient outcomes, and the procedures and materials can still need to be optimised.
- Better understanding of the treatment could be gained by improved pre-clinical testing, specifically predicting long term outcomes.

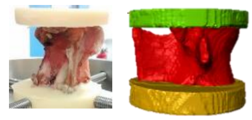


Fig 3, Improved In Vitro *and computational simulation can improve treatments.*

Aims

- Understand how damaged vertebrae perform under cyclic loading as a reference for testing vertebroplasty treated vertebrae.
- Develop a fracture method in animal vertebrae and fatigue test damaged vertebrae.
- Determine location and extent of damage as a function of applied load using physical measurements and microCT data.

Methods

Use of a Bovine Tail Model
- Relative consistency in size, geometry and trabecular morphology between vertebrae.
- Suitable geometry and size compared to human vertebrae for testing spinal therapies.

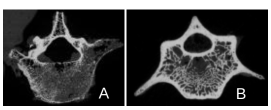


Fig 5, MicroCT scan of A) human vertebra and B) bovine tail vertebra.

Initial Fracture Creation
- 20 specimens were dissected and set up in the materials testing machine, see figure 6.
- All specimens were loaded axially up to 9.5kN or until failure was seen on the force-displacement curve.
- All microCT scanned at 82µm resolution before and after testing.

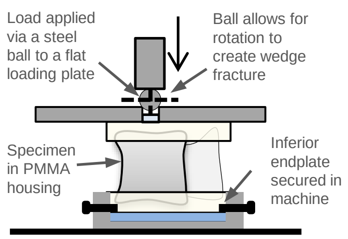
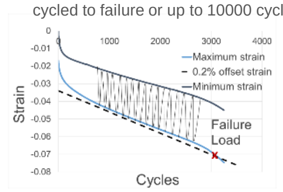


Fig 6, Axial compression test set up.

Fatigue Tests
- Pre-fractured specimens were split into 4 groups and tested at either 60%, 70%, 80% or 90% of the failure load.
- Tests were run at 1Hz with a pre-load of 50N and cycled to failure or up to 10000 cycles.



Failure point was defined using a 0.2% offset strain on the peak strain vs number of cycles graph, see figure 7.

Fig 7, Determining failure point.

Results

Fatigue performance
The 60% group showed significantly higher cycles to failure than the other groups (P<0.05), between which there was no significant difference.

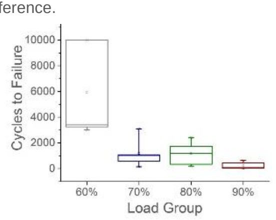


Fig 8, Cycles to failure for each load group, showing median, 25th & 75th percentile and range.

Reduction in mechanical properties
A similar reduction in mechanical stiffness was seen across all groups, with an average of 38%.

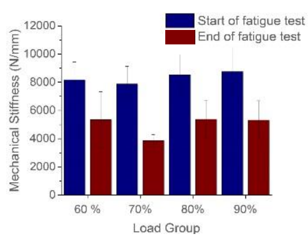
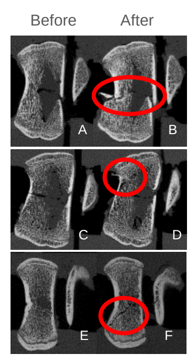


Fig 9, The reduction in mechanical stiffness for each load group after cyclic axial loading.



MicroCT scans
- Predominantly anterior wedge fractures, typically nearer the inferior endplate, figs 10B and 10F.
- Most failure was seen within the trabecular bone, rather than cortical.
- No distinction was seen between groups regarding the location or severity of the fracture.

Fig 10, MicroCT scans from before and after fatigue testing for vertebrae from the 70% (A,B,E,F) and the 90% (C,D) groups. Red highlights fractures.

Discussion

- Pre-fractured specimens tested at 70% ultimate load or above failed before 3100 cycles. At 60% ultimate load two specimens had not failed after 10000 cycles.
- All cyclic tests for specimens that failed an accumulation of residual strain.
- Large variations may in part be caused by the varying degrees of pre-damage experienced by the vertebrae during static testing, as well as the natural variations seen in animal tissue.
- Statistically significant differences were seen between the 60% load group and those tested at higher loads. Testing more specimens may highlight further differences.
- This study provides essential baseline data for the future comparison of different treatments such as the materials and techniques used in vertebroplasty and a basis for further testing on human vertebrae.

Future Work

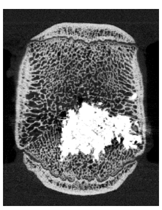


Fig 11, MicroCT scan of a bovine vertebra augmented with PMMA cement.

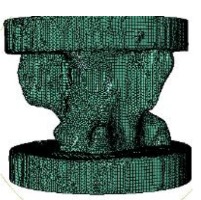


Fig 12, Specimen specific finite element model of a bovine tail vertebra, from microCT data.

- Use developed methods to test vertebrae treated with vertebroplasty, fig11.
- Repeat tests with human tissue.
- Develop specimen-specific finite element models of fatigue loading scenarios to investigate parameters affecting fatigue life of vertebroplasty treated vertebrae, fig12.

References
[1] Melton et. al, *Epidemiology of vertebral fractures in women,* 1989.
[2] http://www.osseon.com/vertebral-compression-fractures-information/

EPSRC
Engineering and Physical Sciences Research Council