INTRODUCTION: Cement augmentation techniques, such as vertebroplasty, are increasingly being used in the treatment of bony fractures. The rise of such procedures, along with the continued use of cement in total joint replacement, has led to increased interest in the behavior of the bone-cement interface. This region is critical in the performance of joint replacement devices and the load transfer through the spinal segment after vertebroplasty.

In previous finite element (FE) studies of joint replacement, the bone-cement interface has been represented in a simplified form by the properties of the bone and pure bulk cement respectively. The stem-cement-bone interface has been modeled as either perfectly bonded or perfectly un-bonded, and the actual interdigitated bone-cement interface has not been fully represented. In previous studies of vertebroplasty, the augmentation region has also often been represented as pure cement, but a recent study has shown this to lead to a large overestimation in the predicted stiffness of the augmented vertebra [1].

The aim of this study was to compare different methodologies for representing the cement-bone interface using subject-specific models of a trabecular-like foam material augmented with cement. Direct comparisons were made between the model predictions and corresponding experimental tests. The effects on the apparent elastic modulus and the stress due to the relative properties of the cement and foam were also investigated.

METHODS: Three sets of six specimens (24 mm diameter, 19 mm height) were cut from an open cell polyurethane foam (Sawbone, Sweden). The first set were not augmented, the second were fully augmented with cement and the third were partially augmented by injecting cement into the centre of the specimen. The cement used in all cases was Cranioplastic (Type 1 Slow set, Codman, UK). All specimens were scanned using micro-computed tomography (Scanco μCT80, Switzerland). The specimens were then press-fitted between steel endcaps and tested under axial compression.

Based on a previous convergence study [2], finite element (FE) models were built with a maximum element size of 1.5 mm using the μCT image grey-scale data. From the first two sets, factors converting the grey-scale to elastic modulus for each element of the pure sawbone and the cement-sawbone composite were determined by comparison with the compression tests. For the final set, FE models with the same mesh density were generated by three different methods. Method I: both sawbone and cement regions were assigned single homogenous properties; Method II: the elements in the sawbone region were assigned element-specific properties based on the image grey-scale, whilst the cement region was defined with a single homogenous property; Method III: elements in both the sawbone and cement regions were assigned element-specific properties based on the image grey-scale using the factors determined from the first two sets.

For both Method I and II, different properties of the cement region were defined and compared. Firstly, the properties of the cement region were defined as the same as those of pure cement (2500 MPa), as has been used previously [3]. Secondly an average elastic modulus was defined based on the average grey-scale value and the selected conversion factor (giving a value of 285 MPa).

To examine the relative effects of the difference in the elastic modulus of the cement and bone, two groups of models were built based on the homogenous models in Methods I. In these groups, the elastic modulus of the sawbone region and cement region were respectively increased to twice of their original values. Both the predicted specimen stiffness and maximum von Mises stress were compared with the experimental results of these models.

RESULTS: For the partially cemented computational models, the comparison between the predicted stiffness and that of the experimental values is shown in Figure 1 and the average absolute errors in Table 1.

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REFERENCES:

FIGURES:
Figure 1: Agreement between FE-predicted and experimentally-measured stiffness
Figure 2: The maximum stress in the homogenous models with different elastic moduli of the Sawbone (Es) and cement (Ec)