**FATIGUE BEHAVIOR OF HUMAN VERTEBRAL TRABECULAR BONE**

**Methods** Seven cylindrical cores of human vertebral trabecular bone (three male; four female, ages 37–85 years), cores were taken from L1-L5 (dimensions 8.3mm diameter x 40 mm length) and prepared with their principal trabecular orientation parallel to the long axis of the cylinder. Specimens were first preconditioned to 0.2% strain for 10 cycles at a rate of 0.1% strain/sec, and Young’s modulus was determined from the final cycle. The specimens were then randomly divided into two groups with a normalized stress (stress/initial Young's modulus) of 0.4% (n=3) or 0.5% (n=4). Since the reported monotonic yield strain for human vertebral trabecular bone is 0.80% strain (7), these loading conditions were expected to produce fatigue failure in a relatively small number of cycles (< 10,000). The fatigue experiments were performed at room temperature, with the specimens kept fully hydrated. Loading of the specimens was performed at 0.1% strain per second and was bounded by load limits between 0 N and that force corresponding to the reported monotonic yield strain for human vertebral trabecular bone, and that strain accumulation from creep may dominate those from fatigue. It remains to be shown, however, if any of these trends can be extended to human vertebral trabecular bone, and if so, to what extent.

The overall goal of this study was to investigate the fatigue behavior of human vertebral trabecular bone using in vitro mechanical test methods. Our specific objectives were to: 1) measure the cycles-to-failure, modulus reductions, and strains at failure for high-stress, low-cycle fatigue loading conditions; and 2) explore the sensitivity of the resulting behavior to specimen stiffness. The results provide a first glimpse at the fatigue behavior of human vertebral trabecular bone, and provide insight into possible mechanisms of progressive age-related vertebral fracture.

**Results** The specimens showed characteristics similar to those reported previously for trabecular and cortical bone. At the relatively high normalized stress levels used, there were modulus reductions from the onset of loading, which continued until overt fracture (Figure 1). At the higher load level (fewer cycles to failure), there was an approximately linear form to the modulus reduction-number of cycles curve. For the lower load level group (more cycles to failure), there tended to be a steeper drop in modulus at the start and end of the fatigue life, with a more gradual modulus loss in between. Modulus reductions at final fracture were higher in the low load level group, indicating that these specimens could sustain more mechanical damage (i.e. a larger modulus reduction) before final fracture (Figure 2). Specimens with high values of (intact) Young’s modulus exhibited higher modulus reductions at fracture than less stiff specimens. Analysis of the creep vs. damage strains indicated that the strain accumulation during the tests had similar components for creep and damage. Strains at failure ranged from 1.58–2.65% strain. They were higher for higher stiffness specimens and for the lower load level group.

**Discussion** The overall goal of this study was to investigate a number of aspects of the fatigue behavior of human vertebral trabecular bone, with a focus on the high load, low cycle regime. Our results show that human vertebral trabecular bone exhibits behavior consistent with what has been reported for bovine trabecular (4) and human cortical bone (8), but with some unique characteristics. For example, failure occurred at fewer cycles, when loaded to the same load levels, for the human vertebral compared to the bovine trabecular bone.

In the context of understanding age-related vertebral fractures, one notable finding was that more damage can be sustained before overt fracture if the bone density is high and the load level is low. Our results suggest that individuals with low bone density who are subjected to relatively high levels of repetitive load are most susceptible to developing overt trabecular fracture from repetitive loading. However, the strain levels at final fatigue fracture observed here are too low to constitute a clinical osteoporotic vertebral fracture. This suggests that vertebral fractures do not simply represent trabecular bone that has reached the end of its fatigue life, and that other factors such as isolated overloads may be required.

**References**

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**Figure 1.** Life fraction vs. normalized modulus for specimens tested to 0.4%E (low) and 0.5%E (high) load levels.

**Figure 2.** Modulus vs. percent modulus reduction for the high (0.5%E) and low (0.4%E) loading groups.

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