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Research paper

Study of the behavior of the trabecular bone under cyclic compression with stepwise increasing amplitude

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ABSTRACT

This paper presents the results of a study of 61 trabecular bone samples exposed to a cyclic (1 Hz) compression load. The load was increased stepwise. Characteristic patterns of the hysteresis loop for the middle cycles of successive steps of load and for respective steps of load are presented. Characteristic patterns of secant modulus were also determined. The fatigue life results recorded were compared with the indices of bone architecture determined using micro-CT. Using Pearson's correlation, the best relationship between fatigue life and bone volume ratio (BV/TV) and the maximum load for which there was also reported a maximal value secant stiffness were identified. Based on these findings, it was determined that it is possible to use stepwise increasing load for analysis of the fatigue behavior of trabecular bone.

1. Introduction

The structure of human trabecular bone changes with age. Beginning at 20–30 years of age, a gradual process of bone loss and a concomitant decrease in bone strength (Biewener, 1993; Taylor and Tanner, 1997; Warden et al., 2006) begin to occur. This loss and decrease is a slow process that is dependent on many individual and external factors (Warden et al., 2006; Martin, 2007). The process becomes obvious when it is accompanied by metabolic disorders, mainly osteoporosis (Rapillard et al., 2006; Oakland et al., 2009). At that point, there is a clear decrease in strength and in Young's modulus as a result of significant disturbances in bone structure that include a decrease in the number of trabeculae and their thickness. Decreases in the values of most indices of bone architecture, including apparent density (BMD), can also be noted at this time (Urlich et al., 1998; Rapillard et al., 2006; Mazurkiewicz and Topoliński, 2007; Brouwers et al., 2009).

A typical loading for bone is cyclic loading that is variable in time; behaviors under such loading can be termed 'fatigue behaviors' (Keaveny et al., 1993; Taylor and Tanner, 1997; Martin, 2003). In the estimation of the properties of materials, research is commonly based on methods that use constant amplitude loads rather than loads with stepwise increases in amplitude. In the case of bones, research carried out using constant amplitude loading covers cortical (Evens and Riolo, 1970; Zioupos and Casinos, 1998; Cotton et al., 2005) and trabecular bone parts (Ding et al., 2003; Bevill et al., 2009) in humans (Winwood et al., 2006; Zioupos et al., 2008) and in animals (Ganguly et al., 2004; Dendorfer et al.,

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