The fatigue properties of the pig mandible compact bone tissue

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1. Introduction

Investigations of compact bone tissue mechanical behaviour under cyclic loading provide the important information for oral implantology and orthodontics. The problem of jaw bone-dental implant interaction regards, in particular, the effects induced in the surrounding bone tissue under the application of functional cyclic loading. The evaluation of stresses in bone can be the basis of an analysis of the efficiency and reliability of the shape or dimensions of endosseous implants. This is a crucial aspect in determining the possible risk of implant failure. The analysis of the results obtained by various researchers showed that there is no data concerning the behavior of mandibular compact bone tissue under cyclic loading. The objective of this investigation was to study the fatigue behaviour of pig jaw compact bone specimens subjected to cyclic compression loads.

2. Methods

Samples for experiments were prepared from three 2 years old pig lower jaws. Specimens were tested under cyclic load with peak load levels that were 60%, 70%, 80%, and 90% of the compressive yield strength with a frequency of 2 Hz. For all specimens the density was measured using hydrostatic weighing method. Twenty six specimens were loaded to fracture to determine the ultimate compressive stresses and to find a correlation and regression between density and yield strength. The level of loading for 30 specimens was calculated using regression equation obtained in previous step.

3. Results

Fatigue tests of pig jaw cortical bone in compression were conducted and results were summarized as peak stress versus cycles. Experimental data were approximated using reversed power function. Compressive cyclic loading and time to failure were predicted, according to the cumulative damage model [1], by the accumulation of cycle-dependent damage only:

\[ D_F(t) = \omega t / F\Delta \sigma - G \]  

where \( \Delta \sigma \) is cyclic stress range (MPa); \( \omega \) is the loading frequency (Hz); \( t \) is time (s), \( F \) and \( G \) are empirical constants. The expression was solved for the time to fracture \( t_b \), by setting \( D_F(t_b) =1 \). This component is shown as the line in Fig. 1.

![Fig. 1](image)

Fig. 1 The effect of stress range on time to failure for zero-compression fatigue specimens of the pig mandible compact bone tissue. Model prediction is compared to experimental results.
The fatigue properties of cortical bone determined in this study were compared with previous studies from the literature [2, 3, 4]. The fatigue life of pig jaw cortical bone for a given compression stress magnitude was considerably less than fatigue life at similar stress magnitudes, determined in other investigations using compression loading [2, 3]. The results of this study agreed well with measurements of cortical bone fatigue life in shear that can be explained by the similar strengths measured in our study (68 MPa) and measured for shear test (51.6 MPa) [4].

4. Conclusion

- From compression tests of jaw compact bone tissue samples the fatigue stress-life data were obtained which characterise the material behavior in a cyclic stress range from 30.82 to 57.56 MPa.
- The experimental S/N curves of pig mandible compact bone material were approximated with reversed power function \(r^2 = 0.80\).
- Obtained results may aid in understanding of mechanism of cortical bone fatigue, should be taken into account in treatment programs designing and in improvement of mechanical parameters of endosseous implants.

References