

Monotonic and Cyclic Behavior of Trabecular Bone Under Uniaxial and Multiaxial Loading

Ardiyansyah Syahrom¹

¹Universiti Teknologi Malaysia, Malaysia

Abstract

Biomechanics of bone has drawn major concern in research due to social and economic demand. In real life, trabecular bone is subjected to multiaxial stresses during routine physiological loading. Fatigue failure of the bone accounts for various clinical implications, thus studies and research to better understand the fatigue failure of the bone are needed. The overall aim of this study is to investigate the effect of torsional loading towards trabecular behaviour under compression in both monotonic and fatigue loading. Samples from femoral bovine trabecular bone were subjected to a series of monotonic and cyclic tests. Hill's criterion was selected to determine the five combined stress ratio of compressive to shear stress for fatigue test. For finite element simulation, effect of morphology and orientation were investigated to predict fatigue life and plastic strain. The ultimate stress of the trabecular bone in monotonic compression and torsion were 14.22 and 8.95 MPa, respectively. In monotonic multiaxial loading, the ultimate stress was reduced to 2.5 MPa in compression and 3.8 MPa in torsion. Under fatigue compression, an endurance limit was found approximately at 25 % of ultimate compressive stress. Under multiaxial fatigue, the ability of the sample to retain shear stiffness with increased number of cycles is strongly correlated to the stress ratio. Fatigue life reduction was significant when the maximum shear stress is at least 24 % of the maximum compression stress. From the computational analysis, it was demonstrated that lower bone volume fraction (BV/TV), trabecular thickness (Tb.Th), and connectivity density (Conn.D) resulted in lower number of cycles to failure, regardless to the loading conditions. However, the number of cycles to failure was found to be negatively correlated to the value of structural model index (SMI). Off-axis orientation effect on the fatigue life of the trabecular bone was demonstrated the worst in horizontal trabecular bone model. In conclusion, the effect of torsional loading onto the mechanical behaviour of bovine trabecular bone was demonstrated throughout this study. It is apparent that torsional forces are the major factor that needs to be considered since these can lead to fatigue fractures. This research is expected to improve the knowledge base for the development of trabecular bone analogous materials.