DYNAMIC MECHANICAL ANALYSIS OF CANCELLOUS BONE: THE EFFECT OF SPECIMEN GEOMETRY AND END BOUNDARY CONDITIONS

INTRODUCTION The viscoelastic properties of bone can play an important role in high-energy impact type fractures because the incidence of hip fractures in the elderly population depends on the magnitude of impact energy created by the fall and how bone would dissipate energy [1]. Using a dynamic mechanical analyzer (DMA), viscoelastic properties of cancellous bone can be studied non-destructively by applying small compressive loads to bone in a parallel plate measuring system [2]. However, there are known technical difficulties with compression testing of cancellous bone between platens. Foremost, initial non-linearity in the stress-strain behavior resulting from end-artifacts during platens testing of cancellous bone may have a significant influence on the measured Young’s modulus. As a result, glued end caps are used to eliminate the end-artifacts from the traditional platens testing method [3]. It is also recommended that specimens with a high aspect ratio (length-to-diameter) of 2:1 should be used for more accurate modulus measurements [4, 5]. On the other hand, the use of shorter specimens (up to 5 mm in length) is recommended in the standard for DMA measurement of viscoelastic properties of plastics in compression (ASTM D 5024-95a).

To our knowledge, no study has ever addressed the issues of specimen size and end boundary conditions for dynamic mechanical analysis of cancellous bone. Therefore, the purpose of the present study was to investigate the effects of specimen geometry and glue technique on viscoelastic properties of cancellous bone as measured by dynamic mechanical analysis.

METHODS Cylinders (8 mm in diameter) of cancellous bone were cored from bovine proximal radius using a diamond-tipped coring tool. In order to examine the effect of specimen geometry on dynamic mechanical properties of cancellous bone, four specimens with different length-to-diameter ratios (5/8 or 10/8) were cut from the cylindrical cores using a low speed diamond saw under constant irrigation. The exact dimensions were measured using a digital caliper and the average of three measurements was recorded.

The specimens were tested between parallel plates using a dynamic mechanical analyzer (DMA7e, Perkin-Elmer, Norwalk, CT). During the DMA test, the specimens were submerged in normal saline at 37°C. The loss tangent of each specimen was measured for a frequency range from 1 Hz to 20 Hz. Each sample was first tested using a range of static forces from 1 N to 7 N while the dynamic force was held constant value at 0.5 N.

In conclusion, the use of glued end conditions and long specimens will be sources of significant errors in DMA analysis of cancellous bone compressive viscoelastic properties. Therefore, unlike for mechanical testing, we recommend that short cancellous bone cylinders (with a length of 5 mm and a diameter of 8 mm) should be used without gluing in the dynamic mechanical analysis of cancellous bone.