REGIONAL VARIATION OF BONE STRAIN CREEP OF VERTEBRAL BODY DURING REPETITIVE LOADING – AN IN VITRO PORCINE BIOMECHANICAL MODEL

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INTRODUCTION

The compressive fracture of osteoporotic vertebra is the consequence of accumulated micro fracture caused by the mechanical repetitive loading. However, how the micro fracture or strain accumulated during repetitive loading within the vertebra is not well understood yet. The purpose of this study is to explore the distribution and progression of strain and strain field of vertebral body during repetitive loading.

METHODS

Seven fresh-frozen thoracic porcine spinal motion segments (T10/T11/T12) were used in the experiments. All ligamentous, capsular, and intracapsular structures were preserved. The T10 and T12 were mounted in polyester resin casts with the T11 vertebral body aligned. The surface of vertebral body was cleaned with alcohol. Two 3-axial strain gages rosettes (Kyowa KFG-1-120-D17-11N50C2, Kyowa Electronics Instruments Co., Ltd., Tokyo, Japan) were mounted at the anterior and posterior sites of T11 vertebral body.

A "drop-tower type" impact testing apparatus was used for the testing (Figure 1). The vibrator was guided by two rods to give a vertical motion. The energy of the vibration was produced with the two eccentric rotors droved by a motor. The energy was transmitted to the specimen through the impounder. The fixed frame, which is fixed to the guiding rode, is used to align the vertical movement of impounder. The specimen was mounted vertically below the impounder with a uni-axial load cell (Kistler 9021, Kistler Instrumente, Winterthur, Switzerland).

The magnitude of external loading was 200N compression and 100N tension from peak to peak. The loading frequency was 5 Hz, and the loading period was five hours; hence 90,000 cycles in total were applied. We recorded one second data every 5 minutes. Sixty sets of data were collected through the loading period. Signals of two strain gages rosettes and axial forces were recorded at 10 kHz sampling frequency. The signals were then low pass filtered at 250 Hz frequency using Butterworth filtering algorithm. The two principal strains at anterior and posterior sites of vertebral body were calculated from the measurement of two strain gage rosettes.

RESULTS AND DISCUSSION

The tensile strain of anterior site reached equilibrium after 30,000 cycles (1500 $\mu\varepsilon$), while the compressive strain kept progression through out the loading period (820 $\mu\varepsilon$ max) (Figure 2a). The tensile strain of posterior site reached equilibrium after 30,000 cycles (200 $\mu\varepsilon$), while the compressive strain did not reach steady state even after 90,000 cycles loading (850 $\mu\varepsilon$ max) (Figure 2b). We found that the compressive principle strain of both site of vertebral body did not reach the steady state even after 90,000 cycles of loading, while the tensile strain reached steady state at about 30,000 cycles of loading. The magnitude of the tensile principle strain is two times as large as the magnitude of the compressive principle strain at anterior site of vertebral body. It showed that tensile strain induced by the long-time fatigue loading maybe the reason for the wedge compressive fracture of vertebral body (Figure 3).

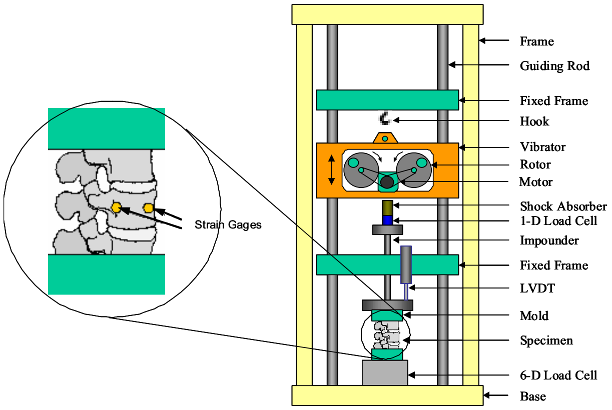
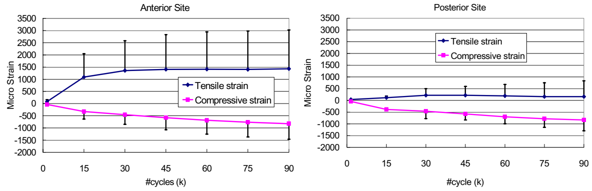


Figure 1: The schematic plot of testing apparatus.



(a) (b)

Figure 2: Principal strain of vertebral body at (a) anterior site, and (b) posterior site.

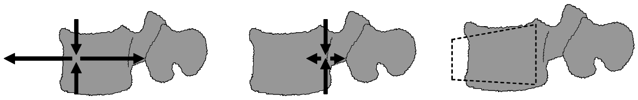


Figure 3: Schematic plot of principal strain of vertebral body.

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