THE EFFECT OF LOW-INTENSITY PULSED ULTRASOUND STIMULI ON OSTEOPOROTIC TRABECULAR BONE
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Introduction: Ultrasound is a form of mechanical energy that is transmitted through and into biological tissues as an acoustic pressure wave. Currently, the ultrasound is used widely in medicine as a therapeutic, operative, and diagnostic tool. Recently, low-intensity pulsed ultrasound has been tried to be used as a potential nonpharmacological intervention for treatment of osteoporosis [1-3]. Duncan and Turner (1995) [1], Warden et al. (2001) [2], and Carvalho and Cliquet [3] investigated whether or not mechanical stimuli, which were produced by the low-intensity pulsed ultrasound, initiate a modeling/remodeling process on the osteoporotic trabecular bone. There were, however, still conflicting conclusions in explaining the effects of the low-intensity ultrasound on the osteoporotic trabecular bone. The aim of the current study is, therefore, to quantify obviously the effects of the low-intensity ultrasound on the osteoporotic trabecular bone, in terms of various morphological characteristics of the trabecular bone.

Materials and Methods: Four virgin Sprague-Dawley (SD) rats (13-week-old, approximate weight 250g) were housed in individually ventilated cages under vivarium conditions. All rats were ovariectomized (OVX) to induce osteoporosis on the trabecular bone and a degree of occurrence of the osteoporosis for each rat was confirmed morphologically through in-vivo micro-CT images with 18μm resolution. All rats were restrained by a customized device for all tests. One hindlimb (right limb) for each rat was then treated with active low-intensity pulsed ultrasound. Here, the contralateral hindlimb (left limb) for each rat was not treated and served as an internal control. In the current study, the efficiency of the low-intensity pulsed ultrasound with 30mW/cm2 and 200μs burst of 1.5MHz sine waves repeated at 1.0kHz was evaluated for the osteoporotic trabecular bone of the tibia induced by OVX. Here, the application of the low-intensity pulsed ultrasound was introduced for 20 minutes per day and 5 days per week over a 4-week period. For analysis, morphological characteristics were calculated through the in-vivo micro-CT images with 18μm resolution, which were acquired at both 0 (before treatment) and 4th week (after treatment). In the current study, bone volume fraction (BV/TV, %), trabecular thickness (Tb.Th, μm), trabecular separation (Tb.Sp, μm), trabecular number (Tb.N, 1/mm) and structure model index (SMI) were computed for the evaluation. A paired t-test was used to identify whether or not the morphological characteristics for the treated and the non-treated osteoporotic trabecular bones at the initial stage (before the treatment) were similar to each other. Additionally, a paired t-test was used one more to identify a significant difference between the morphological characteristics for 0 and 4th week in the treated (right hindlimb) or the non-treated (left hindlimb) osteoporotic trabecular bone. Here, the significance level for the paired t-test (p) was set at 0.05. All procedures for specimen preparation were in accordance with the approved National Institutes of Health (NIH) Guide for Care and Use of Laboratory Animals

Results: The morphological characteristics for the treated and the non-treated osteoporotic trabecular bones were summarized in Table 1. There are no significant differences between the morphological characteristics for the treated and the non-treated osteoporotic trabecular bones at 0 week (p>0.05). The bone volume fraction and trabecular number of the morphological characteristics were, however, changed at 4th week. For the non-treated osteoporotic bone, bone volume fraction and trabecular thickness at 4th week were decreased successively to average 67.7% and 73.7%, respectively, relative to those at the 0 week (p<0.05 for all cases). For the treated osteoporotic bone, only trabecular thickness at 4th week was decreased to 52.9% averagely, compared with that at the 0 week (p<0.05). Other morphological characteristics (trabecular thickness, trabecular separation, and structure model index) were not significantly changed for all cases considered in the current study (p>0.05).

Discussion: In the current study, the effects of the low-intensity ultrasound applied on the osteoporotic trabecular bone were not clearly shown. Warden et al. (2001) [2], and Carvalho and Cliquet [3] advocated that most of the low-intensity ultrasound energy was generally attenuated at the soft-tissue and the bone interface. This fact indicates that the effect of the low-intensity ultrasound may be primarily concentrated on the cortical bone, not the trabecular bone. That is, the mechanical strain generated by the low-intensity ultrasound energy may be insufficient to initiate the trabecular bone modeling/remodeling process. These may explain why the effects of the low-intensity ultrasound applied on the osteoporotic trabecular bone were not obviously appeared in the current study. Additionally, in the current study, a number of trabeculae were decreased extremely after OVX, compared with those before OVX (p<0.05). This fact also may make it difficult to identify clearly the treatment effects of the low-intensity ultrasound. However, the current study showed the potential evidences related to the prevention of the continuous bone-loss in terms of some of the morphological characteristics. That is, the low-intensity ultrasound under a well-controlled configuration may have a potential benefit in the treatment of the osteoporotic trabecular bone. The current study may be, therefore, valuable as a quantified demonstration of the effect of the low-intensity ultrasound for the osteoporotic trabecular bone.

References: 1. Duncan and Turner, Calciit Tissue Int, 57, 1995,
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