Therapeutic treatment of osteoporotic femur: Poroelastic approach

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INTRODUCTION: Osteoporotic femoral neck fracture is critical for elders. It is a life-threatening fracture. However, it is not easy to prevent them from osteoporotic fractures. Currently, the best way to prevent osteoporosis is to take pills. Ultrasound is a medical device that poses no harm to elderly patients, and it promotes the bone remodeling process. Thus, we suggest a possible method to treat osteoporotic patients who have a high risk of having femoral neck fractures.

METHODS: Poroelastic governing equations are derived for cancellous bone, and those are solved assuming the wave forms of ultrasound have a harmonic function because the pulsed wave or sine waves of ultrasound can be expressed by the harmonic function using the Fourier series. The wave harmonic function can be replaced by locomotion if the magnitude of displacement is greater and the frequency of the harmonic function is less than that of ultrasound waves, because the ultrasound waves also cause a small amount of displacement or vibration. After forming poroelastic governing equations, we solve them numerically using the mechanical properties of human cancellous bone. Poroelastic governing equations are composed of two relative motions: (a) the force equilibrium for the solid bone matrix and (b) the force equilibrium for the bone interstitial fluid. The first governing equation, (a) is formed by two forces, the force acting on the solid bone matrix and the force caused by the relative motion between the solid bone matrix and interstitial bone fluid, and the second governing equation (b) is formed by two forces, the force acting on the interstitial fluid and the force caused by the relative motion between the solid bone matrix and interstitial bone fluid. The harmonic function of solid bone matrix displacement and interstitial displacement has frequency and wave number. The governing equations have terms, mechanical properties of cancellous bone, such as solid bone matrix density, interstitial fluid density, the relative density between the solid bone matrix and interstitial fluid, the bulk moduli of solid bone matrix, interstitial fluid, drained bone matrix, and structural properties, such as tortuosity and porosity. The tortuosity is a structural parameter that determines how trabecular struts are formed. If trabecular struts are straightly aligned cylindrical rods, the tortuosity of trabecular struts is one. If trabecular struts are twisted or the actual length is greater than that of straightly aligned cylindrical rods, the tortuosity is greater than one.

RESULTS SECTION: Figure 1 shows the relative motion against tortuosity. If waves of ultrasound are closely aligned with trabecular struts, or the tortuosity is near 1.008, the relative ratio between the solid bone matrix displacement and interstitial bone fluid displacement in harmonic wave functions of ultrasound is maximized. In other words, the relative displacement induced by ultrasound waves along with trabecular struts is maximum, and bone cells on the trabecular struts' surface have the maximum shear stress on the bone cell membrane. Thus, the adjustment of ultrasound wave direction along with the main trabecular struts stimulates the bone cells' membrane by generating the maximum shear stress on the bone cell membrane surface.

DISCUSSION: We need clinical trials to demonstrate the actual reduction in osteoporotic femoral neck fractures. The applied patents show that a solid gel pad sets the ultrasound probe direction aligned with the main orientation of the femoral trabecular struts. Osteoporotic patients undergo daily ultrasound treatment to reduce their risk of osteoporotic fractures.

SIGNIFICANCE/CLINICAL RELEVANCE: (1-2 sentences): Treating osteoporosis femoral neck patients using ultrasound is clinically important. These results suggest the best way to reduce osteoporotic femoral neck fracture risk is using ultrasound treatment.

ACKNOWLEDGEMENTS: This result is a part of applied patents in Korea and the US.

IMAGES AND TABLES:

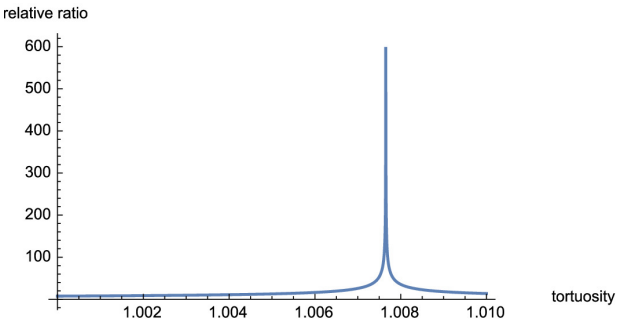

Figure 1. The relative motion of the solid trabecular solid bone matrix and interstitial fluid in ultrasound wave stimulation against tortuosity