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# Ultrasonic transmission characteristics of in vitro human cancellous bone

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## 1. Introduction

The propagated ultrasonic signals through cancellous bone or through *in i o* measurement site containing cancellous bone are theoretically formulated for both the fast and slow waves.[1~4)] This formulation is applied to develop a new ultrasonic bone densitometer, prototype LD-100, using acoustic parameters of the fast and slow waves.[5)] The newly developed ultrasonic system measures the amplitudes of transmitted ultrasonic waves and the propagation speeds for both the fast and slow waves through cancellous bone and evaluates bone mass density in real unit (mg/cm$^3$ or kg/m$^3$, not in the form of ultrasonic parameters of BUA and SOS) and elasticity [GPa] of cancellous bone with a spatial resolution comparable to that of the pQCT (peripheral Quantitative Computed Tomography) system.[5)] The effect of trabecular structure on the ultrasonic characteristics of cancellous bone should be also investigated to realize the better estimation of the bone quality. We present here some experimental studies on the ultrasonic characteristics of *in itro* human cancellous bone and the effect of trabecular structure.

## 2. Experimental

Cancellous bone specimen was prepared with *in itro* femoral head of an 80-year-old female. The femoral head was sectioned 10 mm-thick slice perpendicularly to the femoral cervical axis. **Fig.1** shows the photograph of a sectioned specimen with soft tissue *in it* and with three drilled holes for positioning. The specimen was subjected to a modified system of LD-100. The original system, prototype LD-100 is designed and developed to assess the bone density at the distal end of radius for *in i o* clinical measurements.[5)] The modified LD-100 is adapted the transducer supporting and scanning mechanism for measuring *in itro* specimen in a water tank. A pair of focused ultrasonic transducers (a transmitter and a receiver) was arranged in the water tank and a specimen was set between the transmitter and the receiver. The ultrasonic beam was scanned on the specimen surface by a mechanical two-axis positioning system. The transmitted ultrasonic signals were taken and recorded at intervals of 1 mm over a scanned area in both X-Y directions (30×30mm). The transmitted signals through the specimen (cancellous bone) were observed by the receiving transducer and analyzed to obtain the amplitudes and the propagation speeds of the fast and slow waves. The local bone density corresponding to the measured point by the ultrasonic system was obtained using a microfocus X-ray CT system (MCT-12505MF, Hitachi Medico). The local bone density distribution of the specimen measured by the micro X-ray CT system is shown in **Fig.2**. The transmitted ultrasonic wave levels are shown for the fast wave in **Fig.3** and for the slow wave in **Fig.4**. The reference level (0[dB]) is set at the signal level transmitted through the reference medium (degassed water). The propagation speeds are shown for the fast wave in **Fig.5** and for the slow wave in **Fig.6**. All results are plotted as a function of the local bone density (bone volume fraction) measured by the microfocus X-ray CT system.

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## 3. Discussion and Conclusions

The measured specimen was removed from an 80-year-old osteoporotic female. Then, it is expected that trabeculae were seriously reduced and disconnected. The fast wave levels are too low (Fig.3) compared with the slow wave levels (Fig.4). This suggests that the fast wave paths were greatly reduced. Thus, measurable zone of the fast wave propagation speed are very limited as shown in **Fig.7** (zone A and B), as a result of too low level of the fast wave. In Fig.5, measured values of the propagation speed of fast wave in zone A are plotted by solid circles and in zone B by open triangles. Referring to the previous studies[1),3),4)], it is estimated that the trabecular alignment is well oriented to the propagation direction, and is also considered that the trabecular alignment in zone B is considerably angled to the propagation direction. Measured values outside zone A are considerably scattered as shown in Figs.4. These scattered values do not imply problems of instability in the ultrasonic method of bone characterization, but reflect that the ultrasonic characteristics of cancellous bone depend on both the bone density and the trabecular structure. This means that the ultrasonic method has the potential to evaluate both the density and the trabecular structure in cancellous bone characterization.

**References**

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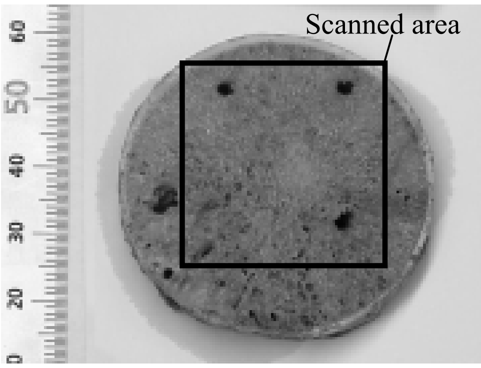


Fig.1 Sectioned femoral head of an 80-year-old female and scanned area.

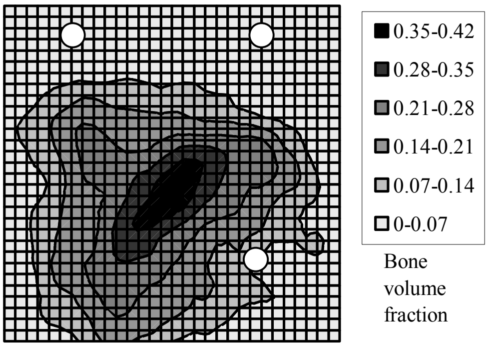


Fig.2 Mass density distribution of specimen, measured by micro X-ray CT.

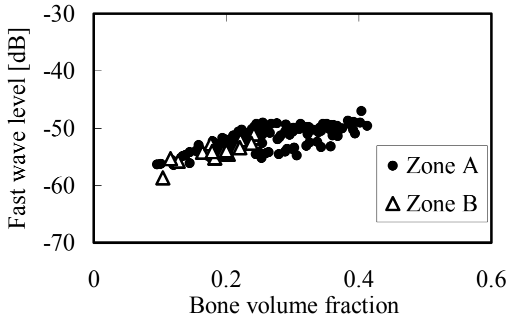


Fig.3 Fast wave level (as a function of bone volume fraction).

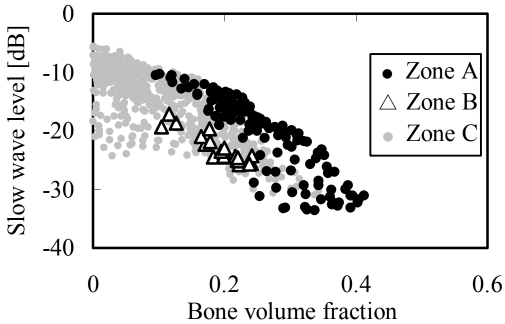


Fig.4 Slow wave level (as a function of bone volume fraction).

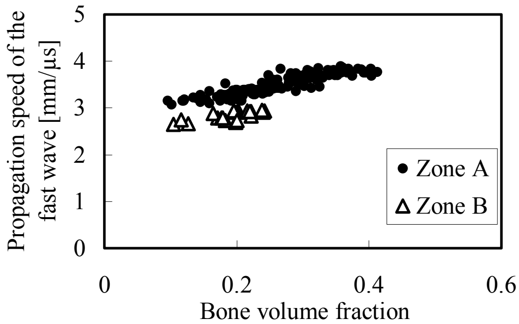


Fig.5 Propagation speed of fast wave (as a function of bone volume fraction).

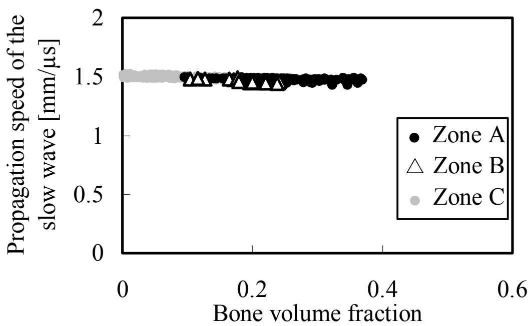


Fig.6 Propagation speed of slow wave (as a function of bone volume fraction).

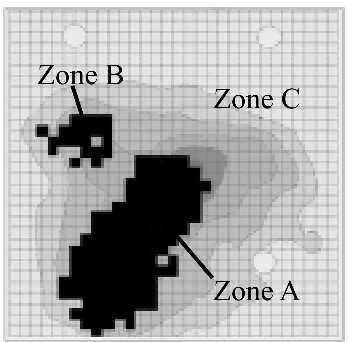


Fig.7 Measurable zone of fast wave propagation speed. Zone A and Zone B.