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The influence of bone medullary in cancellous bone on two phenomenon
二波伝搬現象に海綿骨中の髄腔が及ぼす影響

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1. Background

Early detection of osteoporosis is very important because osteoporosis is a skeletal disease where decreasing bone density increases the risk of bone fracture[1)]. The X-ray techniques are utilized widely for the evaluation. However, the techniques have several problems including X-ray irradiation, expensive technical facilities and experts, and large system. On the other hand, the QUS (Quantitative Ultrasound) method is suitable for mass-screening because it can be used simply and reasonably without X-ray irradiation[2)].

Two wave phenomenon can be observed when ultrasound is irradiated into cancellous bone. Ultrasound passing through cancellous bone separates into fast wave (propagating mainly along trabeculae) and slow wave (propagating mainly into bone marrow). The characteristics of these waves can give us information about the bone strength, and two wave phenomenon is now used for diagnosis of osteoporosis[3)].

Osteoporotic patients have larger bone medullary in their cancellous bones (**Fig. 1**). However many studies have mainly reported the relationship between two wave phenomenon and bone volume fraction and anisotropy. There is no study on the bone medullary. In this study, the ultrasound passing through an artificial bone model with medullary is experimentally investigated to check the influence on two wave phenomenon.

2. Experimental method

Cancellous bone was cut from a bovine bone (29 month old, female). A elliptic cylinder model (9 × 12 × 25 mm) was then fabricated. At the center of the model, a hole (diameter: 0, 2.3, 3.4, 4.2, 5.2, or 5.9 mm) was drilled (**Fig. 2**). Using X-ray micro CT (Shimadzu, SMX-160CTS), 3D image of the model was obtained, and BV/TV (Bone Volume / Total tissue Volume) was analyzed by commercial software (Ratoc, 3D BON).

Figure 3 shows the experimental system used. A single sinusoidal wave at 1 MHz with amplitude of 7 V_{pp} was generated by a function generator (Agilent Technologies, 33250A), and was amplified 20 dB by a power amplifier (NF, HSA 4101). The signal was applied to a PVDF focus transmitter (Custom made, Toray Engineering, 20 mm in diameter with a focal length of 40 mm). The transmitter converted the signal into ultrasound wave, and irradiated it to the model along the

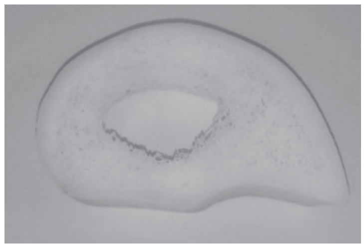

Fig. 1 Bone medullary.

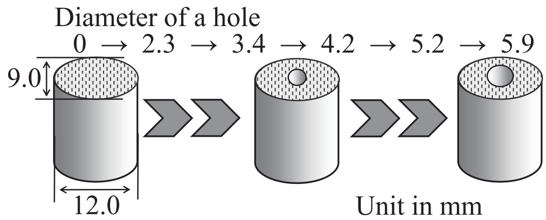

Fig. 2 Experimental model.

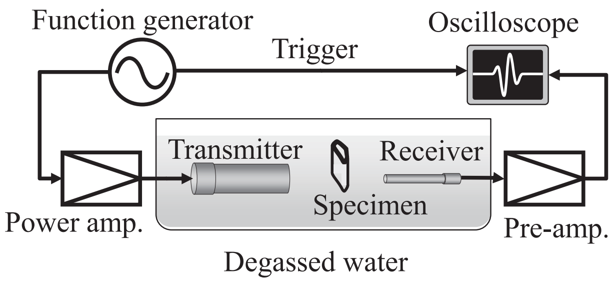

Fig. 3 Experimental system used.

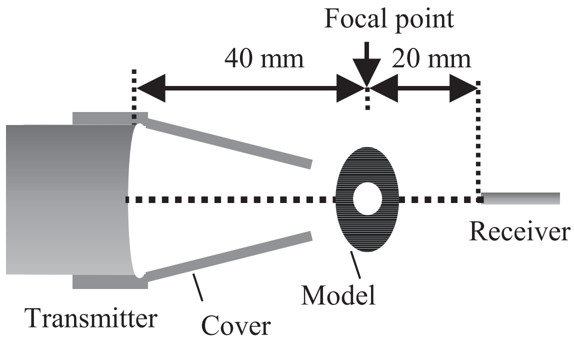

Fig. 4 The location of transducers and the model.

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oriental direction of trabeculae. The ultrasonic wave which passed through the model was converted into electrical signal by a PVDF flat receiver. The obtained electrical signal was investigated by a digital oscilloscope after 20 dB amplification by a preamplifier. **Figure 4** shows the location of the model and transducers. The distance of the transducers was 60 mm, and the axes of transducers and ultrasound were matched. The focal point of the transmitter was set on the center of the bone model.

3. Result

As the result of the X-ray micro CT analysis, BV/TV was 23.8 %, which was near the value of healthy people. **Figure 5** shows the observed waveforms passing through the models. Two waves were clearly observed in the waveforms passing through the model without the hole. With the increase of the diameter, the fast waves became smaller. Then the fast waves passing through the model with larger holes (more than 3.4 mm) were difficult to observe. On the other hand, the slow waves became larger with the increase of the diameter of the hole. These tendencies are due to the decrease of the fast-wave path in the trabeculae and the increase of the slow-wave path. **Figure 6** shows the relationship between the peak-to peak amplitude values of fast and slow waves and the diameter of the hole. As can be seen, the amplitude of two waves is useful to evaluate the size of the hole.

The diameter of focusing ultrasound spot was 3 mm. Then it is amazing to observe the fast waves passing through the model with more than 3 mm hole. These fast waves are expected to have propagated along trabeculae around hole circumferentially, because cancellous bone has complicated trabecular connections in addition to the main orientation. In Fig.4, we can find waves around 40 μs between the fast and slow waves. One possible explanation of the wave is the mixed wave, which propagates through the trabeculae in part. The wave overlapped with the initial part of the slow wave and changes the slow waveform.

4. Conclusions

In this study, we investigated how two wave phenomenon changes with the increase of hole of bone like medullary. As the result, the amplitude of fast waves became smaller with the diameter increase of the hole, whereas the amplitude of slow waves became larger. Then two wave phenomenon, in particular the amplitude of the slow wave, seems to be useful to diagnose the advance of osteoporosis.

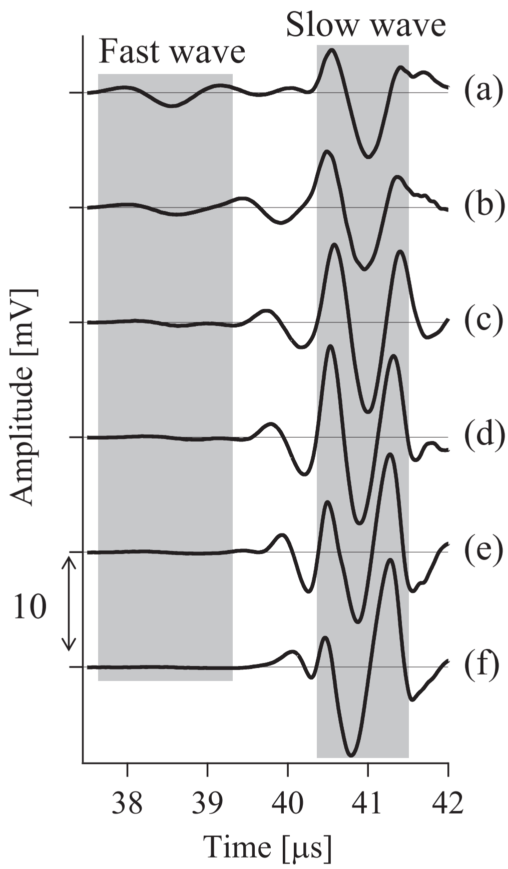

Fig. 5 Observed waveforms (diameter of hole (a) 0, (b) 2.3, (c) 3.4, (d) 4.2, (e) 5.2, (f) 5.9 mm).

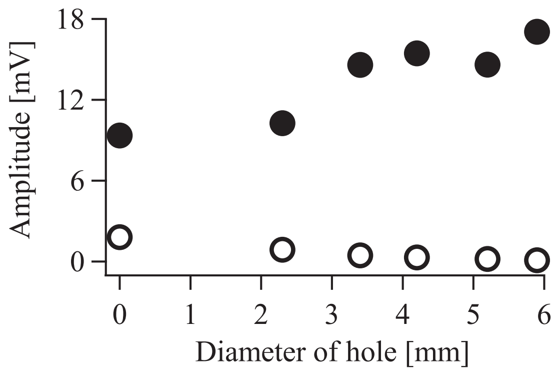

Fig. 6 The relationship between fast and slow wave amplitudes and diameter of hole (○ fast wave, ● slow wave).

Reference

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