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Effects of circumferential wave on fast and slow wave propagation in the human radius model.

ヒト橈骨遠位モデルにおいて周回波が高速波と低速波に及ぼす影響

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1. Introduction

Osteoporosis is a serious skeletal disease which decreases bone density. Patients of osteoporosis have high risk of bone fracture. Therefore, it is important to detect it earlier. QUS (Quantitative Ultrasound) method is suitable for mass screening of osteoporosis, because it is simple, easy to use, and without radiation [1]. One of the QUS methods utilizes two wave phenomenon. This is a phenomenon that ultrasound in cancellous bone separates fast wave (mainly propagates along trabeculae) and slow wave (mainly propagates in bone marrow). Characteristics of these waves reflect bone density and quality [2].

The new QUS system LD100 (OYO) is expected to evaluate bone strength by utilizing this two wave phenomenon. The measuring point of LD100 is distal radius. However, in the distal radius, cancellous bone is surrounded by cortical bone. The radiated ultrasound wave to this area includes circumferential wave (propagates circumferentially along cortical bone) in addition to the two waves. These waves may overlap, especially when the bone is small.

In this study, we prepared a human distal radius model, and studied ultrasound wave propagation in this model experimentally.

2. Sample

Referring to pQCT image of an adult human male distal radius, we fabricated a radius model using a bovine bone. The radius model is composed of cancellous bone and cortical bone layer (Figure 1). To observe the circumferential waves, we prepared not only the human radius model but also the cortical bone layer model without inside cancellous bone. In this cortical layer model, the inside was filled with air. 3D images of the samples were obtained using an X-ray micro-CT (Shimadzu, SMX-160CTS) and, Bone Volume / Total tissue Volume (BV/TV) was analyzed using a software (Ratoc, 3D BON).

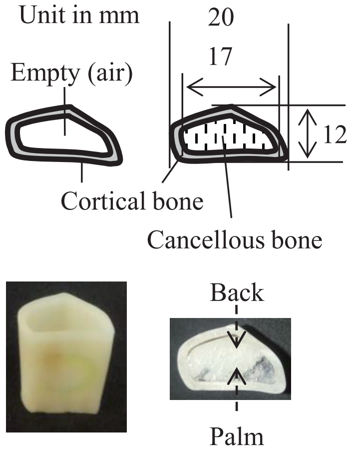

Figure 1 Prepared samples.

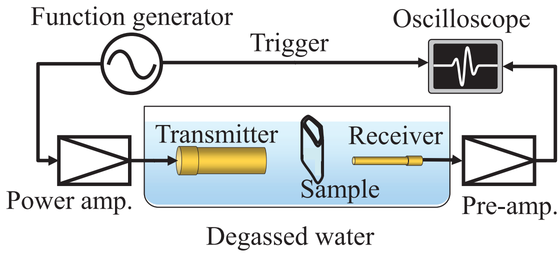

Figure 2 Experimental system.

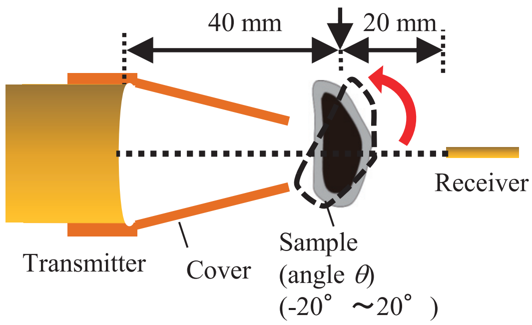

Figure 3 Location of transducers and specimen.

3. Experimental method

Figure 2 shows the experimental system used. A single sinusoidal wave at 1 MHz, with amplitude of 5 Vp-p from a function generator (Agilent Technologies, 33250A) was amplified 20 dB by a power amplifier (NF, HSA 4101), and applied to the transmitter. The transmitter was a PVDF focus transmitter (Custom made, Toray, 20 mm in diameter with a focal length of 40 mm). The waves that passed through the sample were converted into electrical signals by the receiver (handmade, 3 mm in diameter) and investigated by a digital oscilloscope (Tektronix, TDS 524A) with 20 dB preamplifier (NF, BX-31). We set the focal point of wave on the center of the specimen, and the transmitter was prepared to be 60 mm away from the receiver. By changing the incident angle of wave to the specimen (the range was from -20 to 20 degrees, where 0 degree is the direction of minor axis of the specimen), ultrasonic wave passed through the specimen was observed (Fig.3).

4. Results and Discussion

BV / TV of the cancellous bone used was 26.4 %. This value was a little higher than the average value of healthy human.

Figure 4 shows typical observed waveforms (dot lines show waves in cortical layer model, and solid lines show waves in human radius model). At any incident angles, circumferential wave seemed to overlap with slow wave (Fig.5). However, the amplitude of circumferential wave was too small and almost one eights of the slow wave. In case of *in vivo* measurements, slow wave is expected to be larger, because BV / TV of osteoporotic cancellous bone is lower than this human radius model [3].

Moreover, the circumferential wave through osteoporosis bone may also be smaller. There are two reasons. First, the cortical bone of osteoporosis patients is usually thinner than this human radius bone. Second, the circumferential waves in this experiment were observed by using a cortical layer model (the inside was filled with air), and the all ultrasound irradiated into the sample was expected to propagate as circumferential wave. However, the cortical bone *in vivo* covers cancellous bone, so the circumferential wave *in vivo* seems to be smaller than the circumferential wave in this study. Therefore, under *in vivo* situation, the effect of circumferential wave seems weaker.

5. Conclusion

In this study, we investigated the influence of circumferential wave on fast and slow waves. As the result, circumferential wave overlapped with slow wave when the incident angles are in the range of -20 to 20 degrees. However, circumferential wave was so small that it does not influence strongly on the slow wave. In case of LD100, the incident angle is almost kept in the range of -20 and 20 degrees, then the effect of circumferential wave seems negligible.

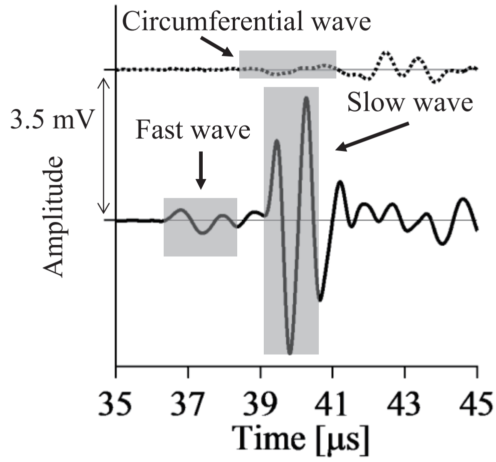

Figure 4 Typical waveform.

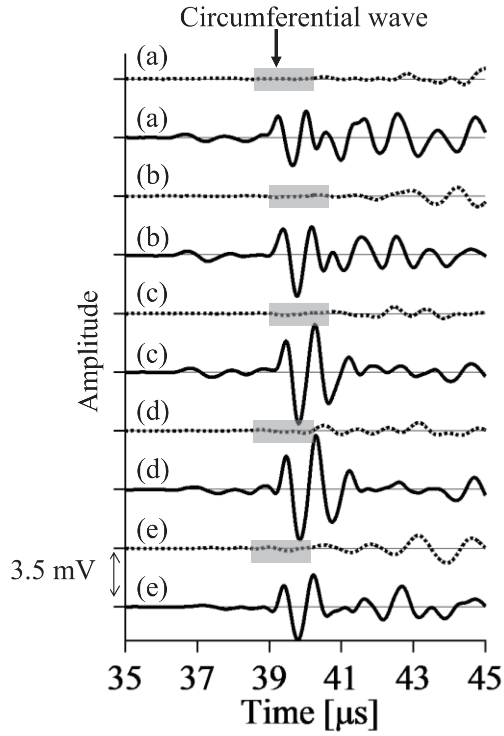

Figure 5 Waveform ((a) -20 degree, (b) -10 degree, (c) 0 degree, (d) 10 degree, (d) 20 degree)

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