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Ultrasound Backscatter Measurement in Cancellous Bone Using a Membrane Hydrophone

Membrane 型ハイドロホンを利用した海綿骨における後方散乱超音波の測定

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1. Introduction

Cancellous bone with a porous trabecular network can scatter an ultrasound wave, and the degree of the scattering can depend on the trabecular microstructure.[1] Then, ultrasound backscatter measurements in cancellous bone are attempted to use for clinical assessment of osteoporosis because of the applicability to skeletal sites where the through-transmission measurements are difficult. In general, the backscattered waves are measured using only one transducer with both roles of transmitter and receiver in pulse-echo mode. In this method, the transmitting and receiving areas cannot be separatly selected, but the receiving area is desired to be larger in order to detect the widespread backscattered waves.

A membrane-type hydrophone made of a piezoelectric film mounting on an annular frame[2] allows an incident ultrasound wave to pass through its aperture because of no backing material. In the present study, using this membrane hydrophone, the measurement of the backscattered waves from cancellous bone was attempted.

2. Methods

A handmade membrane hydrophone[3] was used to measure ultrasound backscattered waves from cancellous bone, and its schematic construction is shown in **Fig. 1**. A piezoelectric film of poly(vinylidene fluoride) (PVDF) was stretched to adhere on an annular frame with an inner diameter of 40 mm, and silver electrodes were deposited on the PVDF film. As the circular electrodes on either surface were overlapped but the linear electrodes were separated, ultrasound waves could be received only in the circular area. The diameter of this receiving area was set 10 or 20 mm.

Figure 2 illustrates the receiving method of the backscattered waves from cancellous bone. An ultrasound pulse wave was transmitted from a PVDF needle-type transmitter in water. The transmitted wave, which could pass through the PVDF film of the membrane hydrophone owing to the acoustic matching to water, was incident to a bovine cancellous bone specimen saturated with water. The porosity of the used cancellous bone specimen was about 0.8 (80%) and the major orientation of the trabecular network was parallel to the incident direction. The distance between the

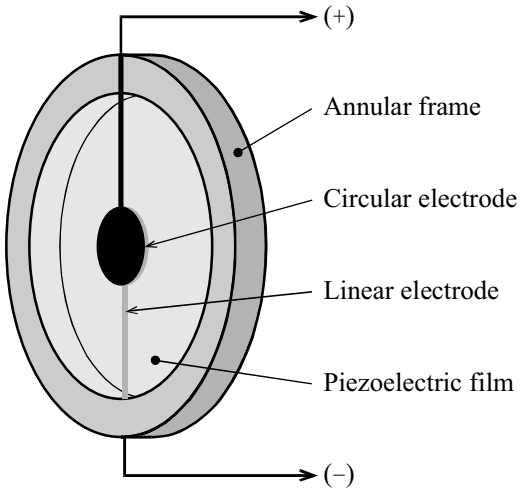

Fig. 1 Schematic construction of membrane hydrophone with a circular receiving area.

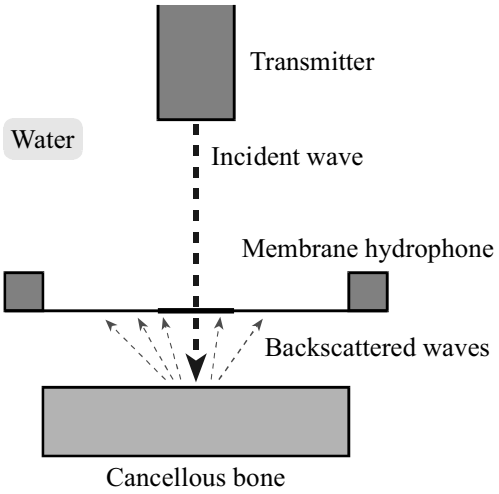

Fig. 2 Receiving method of backscattered waves from cancellous bone using a membrane hydrophone.

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membrane hydrophone and the cancellous bone specimen was 10 mm. The backscattered waves from the cancellous bone specimen were received by the membrane hydrophone, and the received signal was observed with a digital oscilloscope.

3. Results and discussion

Figure 3 shows the observed waveform obtained using the membrane hydrophone with the receiving area of ϕ 10 mm. In Fig. 3, the wave that first appeared with an arrival time of 7 μs was the incident wave, and the waves from 20 μs onward were the backscattered waves (including the reflected wave) from the cancellous bone specimen. Using the membrane hydrophone, the incident and backscattered waves could be observed together.

Figure 4 shows the comparison between the backscattered waves received by the membrane hydrophones with the receiving areas of ϕ 10 and ϕ 20 mm. In Fig. 4, the amplitudes of these backscattered waves were normalized by dividing by those of the respective incident waves. The maximum amplitude of the backscattered waves received in the area of ϕ 10 mm was larger than that in the area of ϕ 20 mm. This is considered to be due to the widely spreading of the backscatter waves. It is expected that the trabecular microstructure in cancellous bone can be estimated from the properties of the widespread backscattered waves. Using the membrane hydrophone with an annular receiving area, as shown in **Fig. 5**, only the widespread backscattered waves can be measured.

4. Conclusions

In the present study, the observation of the ultrasound backscattered waves from cancellous bone could be performed using a membrane hydrophone. Moreover, a new method for measuring only the widespread backscattered waves was proposed. In a further study, the trabecular microstructure in cancellous bone will be attempted to estimate using this backscatter measurement.

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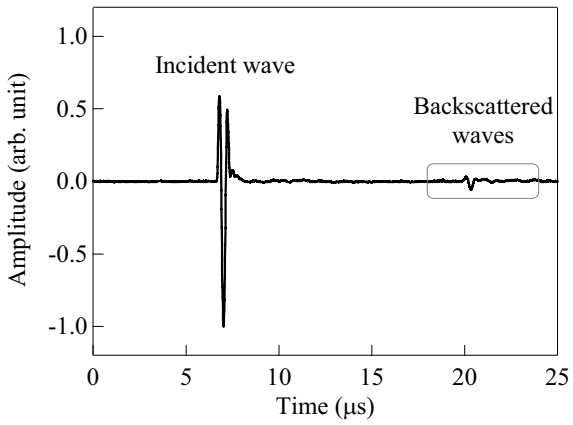

Fig. 3 Observed waveform obtained using the membrane hydrophone with the receiving area of ϕ 10 mm.

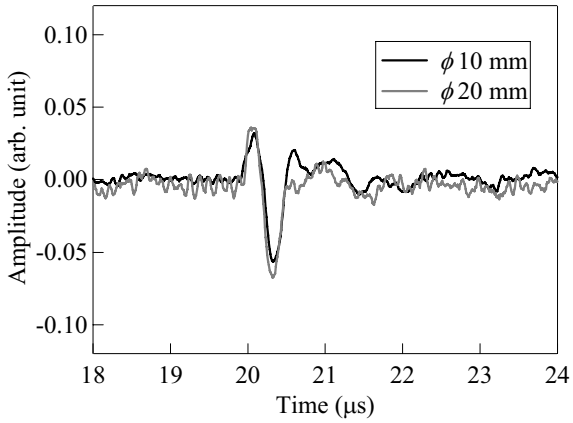

Fig. 4 Comparison between backscattered waves received by the membrane hydrophones with the receiving areas of ϕ 10 and ϕ 20 mm.

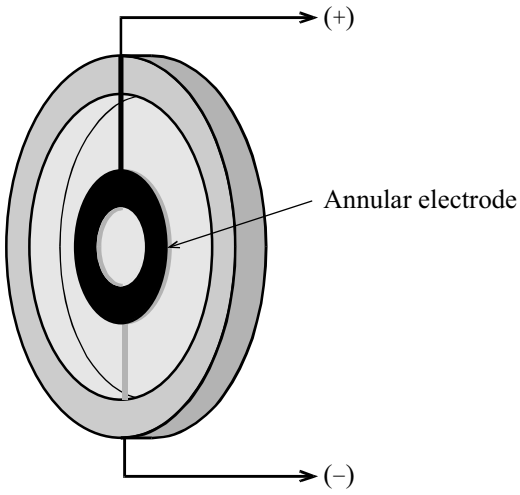

Fig. 5 Schematic construction of membrane hydrophone with an annular receiving area.