3P5-29

Proceedings of Symposium on Ultrasonic Electronics, Vol. 30 (2009) pp. 579-580
18-20 November, 2009

Longitudinal wave properties in swine cortical bone.

ブタ皮質骨中の超音波伝搬特性について

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1. Introduction

The cortical bone has heterogeneous and anisotropic elasticity. It mainly consists of hexagonal hydroxyapatite (HAp) crystallites and type I collagen. Elastic properties are then strongly affected by the preference of HAp crystallites, because elastic modulus of HAp crystallites is more than 80 times larger than that of type I collagen. Previously, we have investigated distribution of speed of sound (SOS) and crystallites preference in bovine cortical bone, using a conventional pulse technique and X-ray diffractometer (XRD). The characteristic distribution of velocity and crystallites preference showed interesting tendency in the plexiform structure. The velocity values were significantly correlated with amount of HAp crystallites aligned in the axial direction [1-3].

In this study, we have investigated the longitudinal wave properties in swine cortical bone, which has complex structure similar to the human bone. We also investigate the relationship between the wave properties, HAp orientation and bone structure.

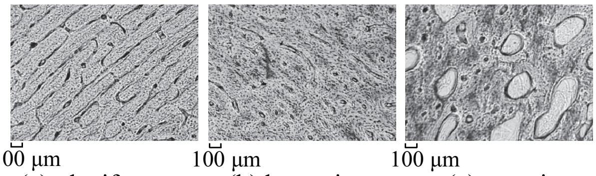
2. Material and Methods

2.1. Samples

A left femur was obtained from two swines. Ring-shaped bones about 5~7mm thickness were obtained from the mid, 15mm proximal and 15mm distal shaft of the swine femur. The top and bottom surfaces of the ring-shaped bone were polished and accurately parallel.

2.2. Microstructure of bovine cortical bone

The microstructures were observed by an optical microscope using undecalcified bone sections. The plexiform structure was the vascular plexus sandwiched within the laminar tissues. The haversian structure contained blood vessels surrounded by a concentric ring structure called osteon. The porotic structure had larger pores comparing with another structure. In Fig 1, each structure is shown.



(a) plexiform (b) haversian (c) porotic

Fig. 1 Microstructures of swine cortical bone

2.2. Velocity and Attenuation measurements

Measurement of longitudinal wave velocity was performed by a conventional ultrasonic pulse technique. A couple of PVDF transducers with diameter of 3mm were used. A single period of sinusoidal wave (5 MHz, 16 V) was applied to one transducer. After passing through the sample, the wave was received by the other transducer. The measurement point on the ring-shaped sample was changed using a precision stage.

2.3. X-ray measurement

X-ray diffraction profile was obtained by X-ray diffractometer (Philips, X-Pert Pro MRD). X-ray (Cu-Kα, 45 kV, 40 mA) irradiated the sample surface through the parallel beam optics with 1mm x 0.1mm slit. The X-ray irradiated area was always smaller than the sample surface area in this optics. An intense peak was observed at 25.8°, corresponding to the (0002) plane of HAp. The amount of c-axis oriented crystallites was estimated by the integrated (0002) peak intensity.

BMD was measured by DXA (Dual-energy X-ray absorptiometry, Hologic, QDR-1000).

3. Results and Discussions

Figure 3 shows the distribution of longitudinal SOS, integrated (0002) peak intensity (HAp orientation), BMD, and microstructure of the mid shaft sample. In the posterior part, SOS and BMD were lower than the other parts, and the microstructure was haversian or porotic. These characteristics are similar to those in bovine and human bone. However, the plexiform structure often contains heversian, which was different from bovine bone.

Figure 4 shows relationship between SOS and the integrated (0002) peak intensity. SOS does not seem to correlate with integrated intensities. SOS in the plexiform structure was usually higher than those in other structures.

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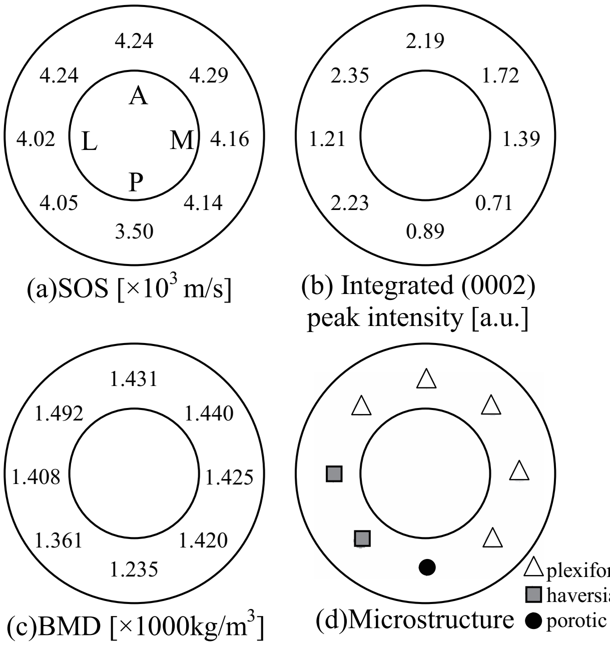

Fig.3 Distribution of SOS, integrated (0002) peak intensity, BMD and microstructure in the mid-shaft of swine femur. P, A, M and L indicate Posterior, Anterior, Medial, and Lateral parts of the sample.

Figure 5 shows relationship between the velocity and the BMD. We can find comparatively moderate correlation between SOS and BMD

Figure 6 shows relationship between attenuation and the integrated (0002) peak intensity. Attenuation does not seem to correlate with integrated intensities. However, we can find relationship between attenuation and BMD (Fig. 7). Those data tell us that attenuation does not depend on the crystal orientation but on BMD and microstructure in swine bone.

4. Conclusion

We have investigated the relation among SOS and the HAp orientation, BMD, and microstructure in swine cortical bone. We could not find the clear effect of HAp orientation on SOS and attenuation. However, they depended on the BMD and microstructure.

Acknowledgment

Part of this work was supported by a Grant in Aid for Scientific Research (B) from JSPS, and Bilateral joint project between JSPS and CNRS.

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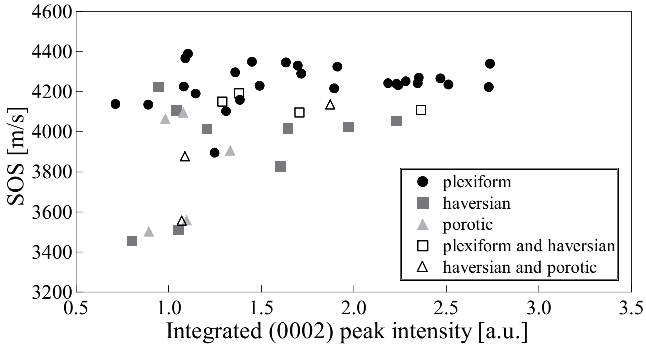

Fig. 4 Relationship between HAp orientation and velocity.

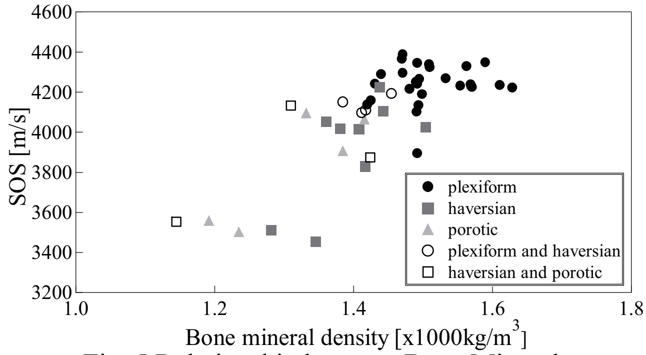

Fig. 5 Relationship between Bone Mineral density and velocity.

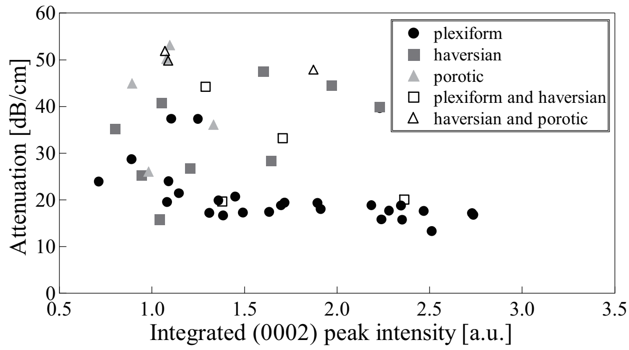

Fig. 6 Relationship between HAp orientation and attenuation.

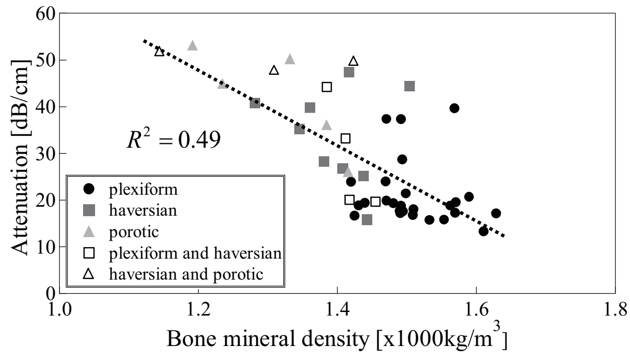

Fig. 7 Relationship between bone mineral density and attenuation.

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