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Ultrasonic longitudinal wave velocity in equine cortical bone with periosteum inflammation

骨膜炎が皮質骨の超音波音速に及ぼす影響

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1. Introduction

The bone inflammation of a racehorse is a very severe probrem. It is better to prevent bone periosteitis in advance[1]. Currently, computed tomography (CT) is used for human bone diagnosis. This method can accurately evaluate the microstructure of bone. However, it is difficult to diagnose large animals by the X-ray system. On the other hand, bone diagnosis using ultrasound enables easy and safe measurements of bone elasticity of human and even large animals [2,3]. For precise evaluation, a lot of basic data of wave velocity are necessary.

In this study, we studied the longitudinal wave velocity and orientations of HAp crystallites in bone, which are expected to align along collagen fibrils[4], in addition to the bone mineral density (BMD). The effects of the orientations of HAp crystallites and BMD on the wave velocity were then examined.

2. Materials and Methods

Figure 1 shows the specimen preparation. Cortical bones were obtained from the midshaft of an equine right third metatarsal bone (racehorse, 100-month-old). Then, it was processed into a ring bone sample with the thickness of 10.00 ± 0.02 mm. Eight rectangular specimens (anterior [A], posterior [P], medial [M], lateral [L], and five oblique parts) whose sides were perpendicular to the three orthogonal axes (axial, radial, and tangential) were obtained from the ring-shaped bones. Especially bone specimen I was cut from the inflammation area.

Figure 2 shows the system of the wave velocity experiment. A focus PVDF transducer (diameter 20 mm, focal length 40 mm) was used as the transmitter, and an input signal of 70 Vp-p, one sinusoidal wave at 2.0 MHz were applied to the transmitter. Longitudinal waves transmitted through the bone specimen were received by a PVDF transducer with a diameter of 3.0 mm. The signal was then amplified by 20 dB with a preamplifier, and observed by an oscilloscope. The wave velocity of the bone was calculated from the difference of arrival times Δt between the observed waveform that passed through the degased water only and that passed through the water and the bone specimen.

Next, in order to measure the orientations of the HAp crystallites, 2θ-ω scan measurements were performed using an X-ray diffractometer (X'Pert PRO MRD; PANalytical). Then, the (0002) peak intensities of hexgonal HAp crystallites were obtained. In addition, high Resolution peripheral CT (HR-pQCT, Scanco Medical) was used for BMD measurement.

3. Results and Discussion

Figure 3 shows observed waveforms of longitudinal wave which propagated only in water, and propagated in water and the bone specimen. **Figure 4** shows the wave velocities of bone specimens.

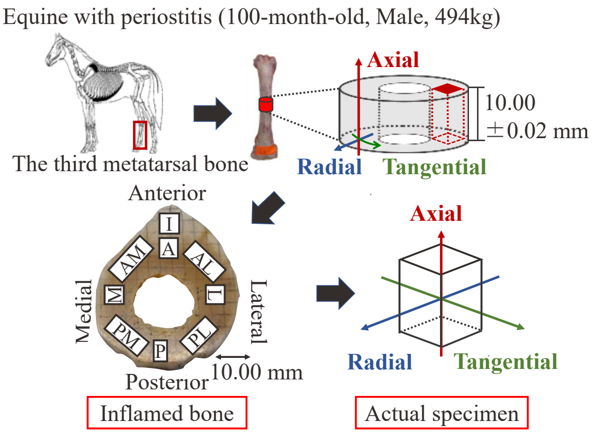

Fig. 1 Preparation of bone specimens.

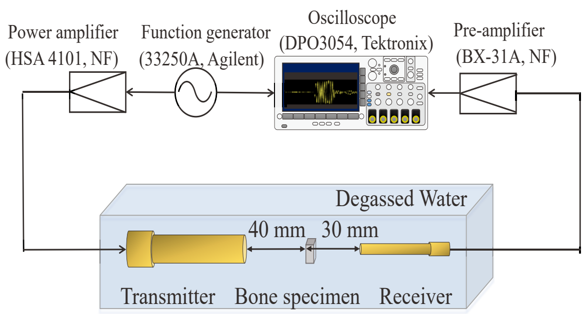

Fig.2 Experimental set up.

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In the healthy area of inflamed bone, wave velocities were the highest in the axial direction and in the range from 4040 to 4180 m/s. Velocities in the radial direction varied from 3210 to 3400 m/s. In the tangential direction, they varied from 3250 to 3370 m/s. Then, almost uniaxial anisotropy was confirmed.

On the other hand, in the inflamed area, wave velocities were 3580 m/s in the axial direction, 2990 m/s in the radial direction and 3050 m/s in the tangential direction. In the inflamed area, the velocity anisotropy was weak.

Figure 5 shows a result of $2\theta - \omega$ scan by the X-ray diffraction technique. The (0002) peak indicates that the hexagonal HAp crystallites are oriented along the bone axis. We can also find strong peak near $(11\bar{2}2)$, however, because of overlaps with other $(21\bar{3}1)$ and $(20\bar{2}2)$ peaks, actual $(11\bar{2}2)$ peaks are not very strong.

Figure 6 shows the relationship between wave velocities and integrated intensity of (0002) peaks, which indicate the amount of HAp crystallites aligning perpendicular to the specimen surface. The intensity showed good correlation with velocity. However, in the inflamed area, the velocity and intensity values were lower than those in the healthy area. One reason of this difference may come from the porosity in the inflamed area. Actually, we found small pores and low BMD in this area.

4. Conclusion

The effect of periostitis on the wave velocity in the equine cortical bone was investigated. Wave velocities and BMD values were low in inflamed area. In this area, (0002) peak intensities were low, telling that HAp crystallites do not align along the bone axis, which is a similar character to newly bones.

Acknowledgment

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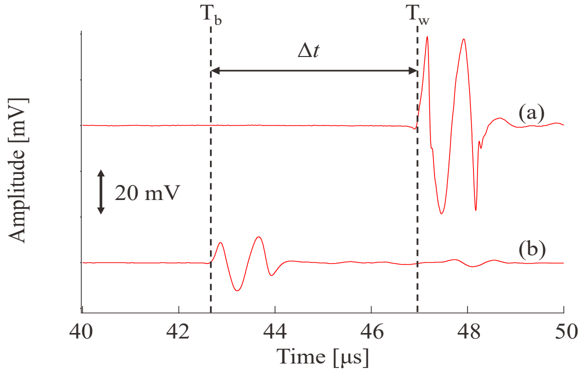

Fig. 3 Observed waveforms which passed through water and bone.

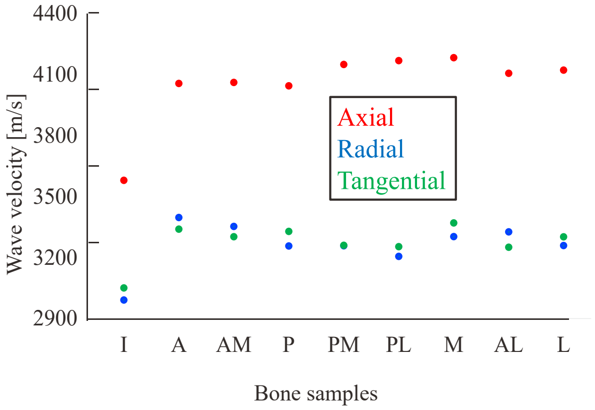

Fig. 4 Wave velocities in an equine bone in three orthgonal directions.

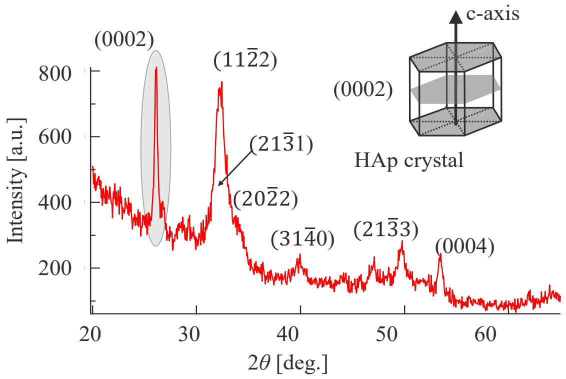

Fig. 5 2θ-ω scanning X-ray diffraction result of bone specimen A.

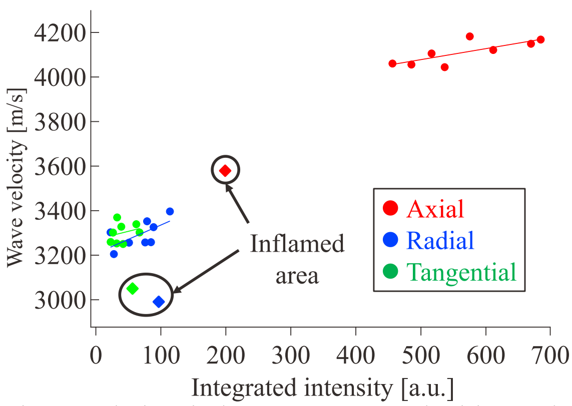

Fig. 6 Relationsip between wave velocities and the (0002) peak integrated intensity of HAp crystallites in three orthgonal directions.