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# Longitudinal Wave Velocity and Crystal Orientation of HAp in Equine Cortical Bone

ウマ皮質骨における超音波縦波音速と HAp 結晶配向

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## 1. Introduction

The bone fracture of a racehorse is a very severe probrem. It is better to prevent bone fractures in advance. 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 using the X-ray system. On the other hand, bone diagnosis using ultrasound enables easy and safe measurements of bone elasticity even in large animals [1]. However, there are few date on the wave volocity of racehorse bones.

In this study, we measured the distribution of longitudinal wave velocity in equine cortical bone in the direction of bone axis. In addition, the orientations of HAp crystallites at the same parts were measured. The influence of the orientations of HAp crystallites on the wave velocity was then examined.

## 2. Materials and Methods

**Figure 1** shows the sample preparation method. Cortical bone was obtained from the center part of the diaphysis of equine right third metatarsal bone (racehorse, 53-month-old) [2]. Then, it was processed into an annular bone sample with the thickness of 10.00 ± 0.02 mm. The microstructure of the bone sample surface was observed by an optical microscope. In all areas, we found haversian stracture[3].

**Figure 2** shows the system of the wave velocity distribution 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 1.0 MHz were applied to the transmitter. Longitudinal waves transmitted through the bone sample 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 $\Delta t$ between the observed waveform that passed through the degased only water and the observed waveform that passed through the degased water and the bone sample.

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Next, in order to measure the orientations of the HAp crystallites, the $2\theta$-$\omega$ scan measurements were performed using an X-ray diffractometer (X'Pert PRO MRD; PANalytical). Then, the orientations of the HAp crystallites, which are hexagonal, were observed from the peak of the (0002) plane obtained by the measurement.

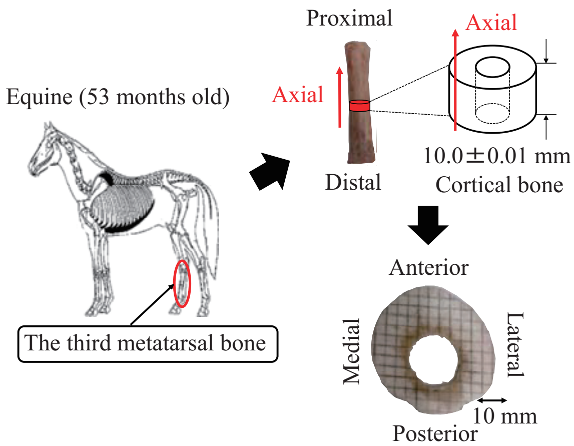


Fig. 1 Preparation of a bone sample.

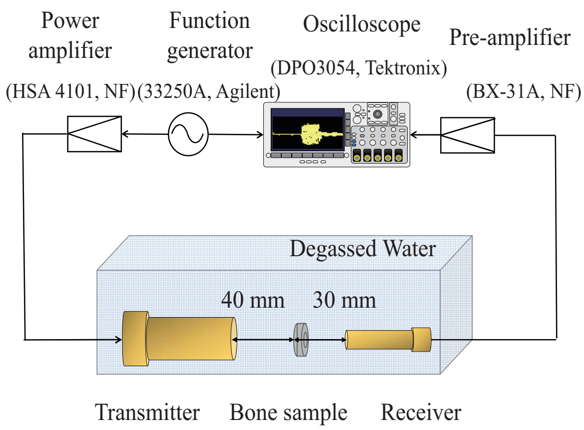


Fig.2 Experimental set up.

## 3. Results and Discussion

**Figure 3** (a) shows an observed waveform of longitudinal wave which propagated only in water. **Figure 3** (b) shows an observed waveform of longitudinal wave which propagated in water and the bone sample.

The maximum wave velocity was 4162 m/s and the minimum wave velocity was 3618 m/s. They were relatively high in the medial and lateral parts and relatively low in the posterior parts.

In a previous study using swine femur, the wave velocity was significantly higher in the lateral parts and relatively lower in the posterior parts, which was different tendency from the equine [4]. The wave velocity of swine bone was in the range of 3894 to 4459 m/s, which was higher than velocities in the equine bone.

**Figure 4** shows the result of HAp crystallites orientations in bone measured by X-ray diffraction technique.

**Figure 5** (a) shows the spatial distribution of the measured wave velocity. **Figure 5** (b) shows the spatial distribution of the measured HAp orientations. The tendencies of wave velocity and HAp orientations are similar.

In a previous study using swine femur, HAp crystallites orientations are higher in the lateral parts and lower in the posterior parts [4]. In swine bones, HAp crystallites orientations showed a similar tendency to wave velocity.

**Figure 6** shows the correlation function between wave velocity and HAp crystallites orientations. The correlation function, $R$, exceeded 0.90 at all parts. It is very interesting to find highest velocity in the medial parts where the correlation function was the lowest.

This suggests that there may exist other factors that affect the wave velocity in addition to the alignment of the HAp crystallites.

## 4. Conclusion

We investigated the wave velocity in the bone axis direction of equine cortical bone. The wave velocity values were in the range of 3618 to 4162 m/s and were relatively high at the medial and lateral parts. The wave velocity strongly depended on the orientations of the HAp crystallites.


## References

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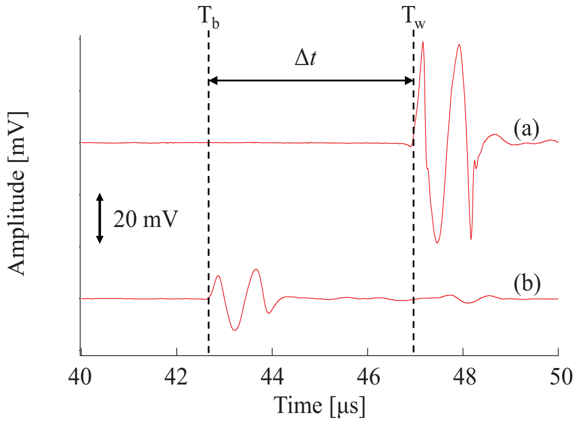


Fig. 3 Observed wave form of water and bone.

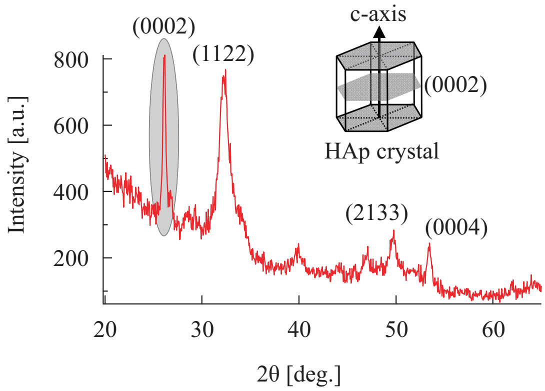


Fig. 4 Experimental results by 2$\theta$-$\omega$ scanning X-ray diffraction.

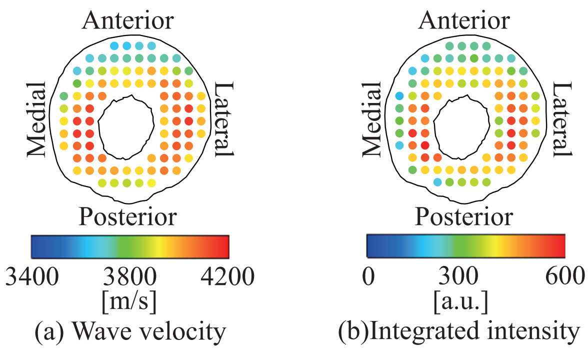


Fig. 5 Distributions of sound velocity and the orientations of the HAp crystallites.

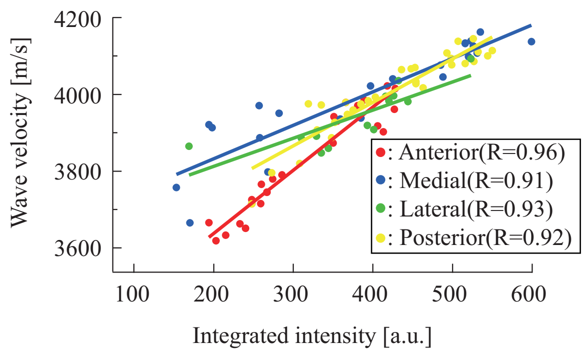


Fig. 6 Correlation of wave velocity and the orientations of the HAp crystallites.