3Pb5-7

# Axial Transmission technique for evaluation of bone with mild periostitis.

Axial Transmission 法による軽度の炎症骨中の音速評価

Kazuki Miyashita[1†], Hidehisa Suzuyama[1], Ko Chiba[2], Hiroshi Mita[2], Norihisa Tamura[2], and Mami Matsukawa[1]
([1]Doshisha Univ., [2]Nagasaki Univ. , [3]JRA Equine Research Institute.)
宮下和輝 [1†], 鈴山英寿 [1], 千葉恒 [2], 三田宇宙 [3], 田村周久 [3], 松川真美 [1]
([1] 同志社大, [2] 長崎大, [3]JRA 競走馬
総合研究所)

## 1. Introduction

Evaluation of bone inflammation is very important for racehorses. The present mainstream of bone evaluation is X-ray techniques, which however, have problems to diagnose large animals. Therefore, development of safe and inexpensive quantitative ultrasound (QUS) techniques is expected [1]. Because the cortical bone of legs supports the body load, fractures of this bone decrease the quality of life. One of the QUS methods, the Axial Transmission (AT) technique, offers the potential to estimate elastic properties of cortical bone in long bones [2]. An AT technique measures the first arriving signal (FAS) which is a leaky wave from the bone surface. However, the velocity is dependent on the cortical bone thickness and the shape of surface. Therefore, we next focused on the subsequent waves which are observed after FAS.

In this study, we investigated the applicability of an AT technique for evaluation of the horse leg bone with mild periostitis. Additionally, 2D FDTD simulations of the wave propagation were also implemented.

## 2. Sample and experiments

A cortical bone cylinder was obtained from an equine third metatarsal bone with small surface changes due to inflammation (racehorse, 100-month-old). Experiments using an AT technique were performed at incident angles ($\theta$) of 15º and 60º, keeping the same geometries shown in Fig. 2 [3]. One cycle of sinusoidal electrical signal at 1 MHz was applied to a composite flat ultrasound transducer (diameter: 13 mm, Japan Probe). Ultrasonic wave penetrates into bone and leaky waves were received by a PVDF flat transducer (diameter: 10 mm). The receiver scanned the distance of 25 mm along the axial direction of the bone tube with a step of 1.0 mm. A spongy block was placed between the transducers to avoid direct waves.

----------------------------------------
ctwf0335@mail4.doshisha.ac.jp

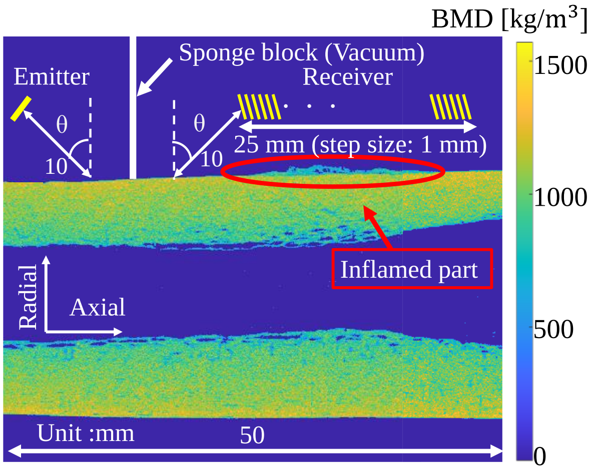


Fig. 1 Experiment and simulation conditions. (cross section view)

## 3. 2D simulations

Wave propagation was simulated using the elastic FDTD method [4]. A 2D digital equine bone model was created from High Resolution - peripheral Quantitative Computerized Tomography (HR-pQCT) images. The local bone mineral densities were in the range from 750 to 1590 kg/ $m^3$. The mass densities in bone were in the range from 1300 to 2760 kg/$m^3$. The densities in the inflamed part were lower than those in the normal part. The spatial resolution of the model was 61 µm. In bone, longitudinal wave velocity was assumed 4000 m/s, whereas shear wave velocity in bone was 1800 m/s. Longitudinal wave velocity and density in water were 1500 m/s and 1000 kg/$m^3$, respectively. Vacuum layer was set instead of spongy. In the simulation, the input signal was one cycle of sinusoidal wave at 1 MHz with Hann window. The wave propagation at an incident angle of 60º was simulated and the particle velocities in the axial and radial directions were also observed.

## 4. Results and discussion

Figure 2 shows simulated particle velocity in each direction (simulation at 60º). The 2-dimensional changes in particle velocities around areas I and II are shown in Fig.3. The particle velocities of area I were mostly oscillating in the axial direction. Considering the velocity, these waves may be longitudinal wave. The particle velocities of the area II in Fig.2 were mostly oscillating in the radial direction. Considering the velocity, waves around II were likely to be a shear wave. In the inflamed area (D), it might be difficult for shear waves to propagate, because the particle velocity in the radial direction was small. In area II near the surface, velocities often seem to show behaviors like Rayleigh wave.

The signals obtained at all receivers in the simulation were stacked and shown as the B-scan image in Fig. 4. Figure 5 shows wave velocities estimated from the arrival time differences between adjacent receivers. Strong FAS were observed at incident angle of 15º, whereas strong slow waves were observed at 60º. The behaviors of particle velocities show that fast and slow waves seem to be mainly longitudinal and shear waves, respectively. The estimated velocities were in good accordance with these velocities. Here, longitudinal wave velocity dispersion (standard deviation) was 820 m/s, whereas shear wave velocity dispersion was 140 m/s. Longitudinal wave velocities changed due to the shape of bone surface. However, the shear wave velocities did not show clear dispersion.

## 5. Conclusion

We investigated the applicability of the AT technique for wave evaluation in the horse leg bone with mild periostitis. The wave near FAS had velocities similar to longitudinal wave and showed the oscillating of particle velocities in the axial direction. The slow wave was probably the shear wave, but near the surface often shows behaviors like Rayleigh wave. Longitudinal wave velocity changed due to the surface fluctuation of inflamed bone, whereas the changes of shear wave velocity were small. The different behaviors of longitudinal and shear wave velocities may become good parameters for the initial screening of bone inflammation in vivo.

**Acknowledgment**

This study was partly supported by JST-ATEP.

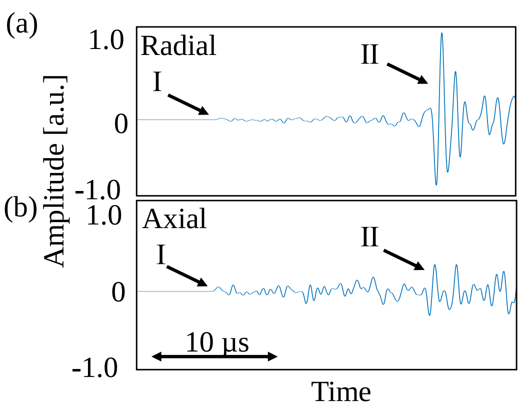


Fig. 2 Particle velocities estimed by the simulation (a) Radial direction. (b) Axial direction.

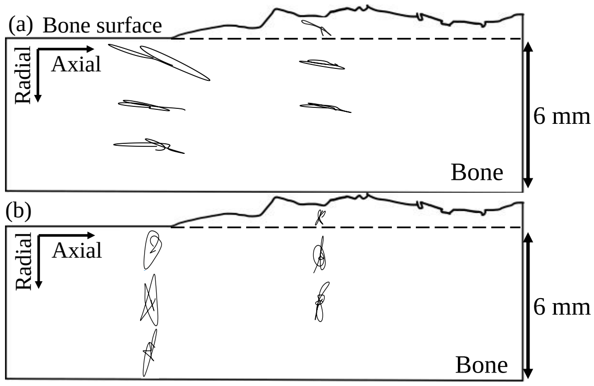


Fig. 3 Images of 2-dimensional particle velocity behaviors (Amplitudes were normalized) around (a) area I and (b) II.

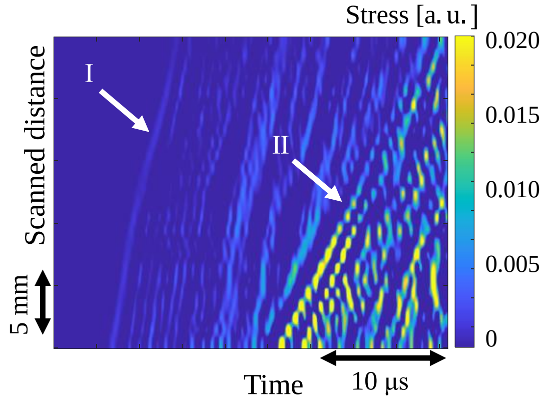


Fig. 4 A B-scan image in the simulation at 60º.

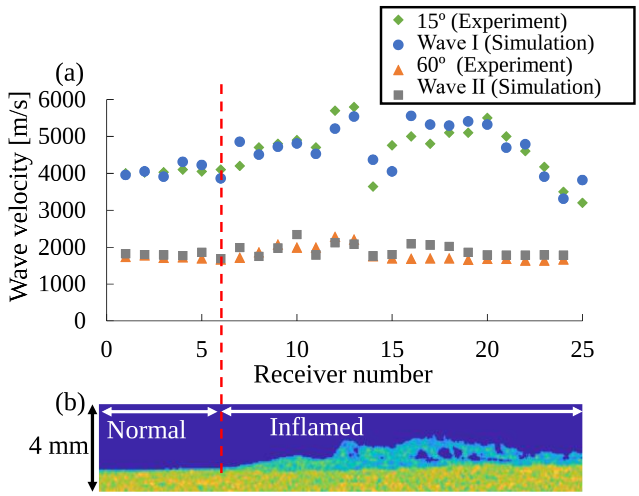


Fig. 5 (a) Wave velocities between adjacent receivers. (b) The surface at the measurement site.

## Reference

1. P. Laugier and G. Haiat eds., Bone Quantitative Ultrasound, Springer (2011).

2. M. Talmant, et al., Ultrasound Med. Biol., **35** (2009).

3. L.Bustamante et al:Jpn.J. Appl. Phys ., **58** , SGGE20 (2019).

4. Y.Nagatani,et al, Jpn. J. Appl. Phys., **45** , 7186 (2006).