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Axial Transmission technique for screening bucked shin in a horse leg.

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1. Introduction

The leg bones of a horse show high strength in the axial (bodyweight) direction to withstand heavy loads. However, heavy exercise, infections, and overload often cause bucked shin in the metacarpals and metatarsals without inflammatory cells[1)]. If the heavy bodyweight cannot be supported due to the leg problem, it may endanger horses' lives.

The present main diagnosis of the bone disease is a radiography. The X ray computed tomography (CT) can also detect initial lesion of bone disease. However, they have problems of radiation exposure and require bulky and expensive systems, which are difficult to carry and use in the field. Therefore, a safe, inexpensive, and easy technique for bone evaluation in the field must be developed for horses. For this purpose, the quantitative ultrasound (QUS) is a promising candidate[2)]. One of the QUS methods, the Axial Transmission (AT) technique, offers the potential to estimate elastic properties of long bones[3)]. The AT technique measures the waves which propagate along the long bone axis and leak from the bone surface.

In this study, we experimentally measured ultrasonic wave velocities in the axial direction of the bone with the bucked shin. The results were compared with the simulation obtained using the bone digital model.

2. Sample and experiments

A 150 mm cortical bone cylinder was obtained from a third metatarsal bone of a 100-month-old racehorse (Thoroughbred). It has small surface irregularities due to the bucked shin (Fig. 1). The AT experiments were performed at ultrasound incident angles (θ) of 15º to the bone surface. One cycle of the sinusoidal electrical signal at 1 MHz was applied to a composite flat ultrasound transmitter (diameter: 13 mm Toray Engineering). Ultrasonic wave penetrates into the bone and leaky waves were received by a PVDF flat transducer (diameter: 10 mm, self-made). The receiver scanned the distance of 35 mm along the axial direction of the bone with a step of 1.0 mm. A spongy block was placed between the transducers to avoid direct waves. As shown in Fig. 2, the experimental system includes a function generator (Agilent Technologies, 33250A) and an amplifier (NF, HSA4055). In the receiving part, a pre-amplifier (NF, BX-31A) was used for the amplification of the detected signals by 40 dB. The signals were finally observed by an oscilloscope (Tektronix, DPO7054).

3. 2D model construction

A 2D digital equine bone model was created from the high-resolution peripheral quantitative computed tomography (HR-pQCT) images of bone mineral density in the sample. The voxel size of the model was 61 µm. The model was heterogeneous and uniaxially anistropic. The elastic constants along the bone axis direction were estimated from the density and measured wave velocities of the bone by the ultrasonic pulse technique in the MHz range. Using an interpolation technique[4)] and Poisson's ratio of 0.33 [5)], we estimated all constants in all voxels following studies of Nakatsuji and Yamato [6,7)].

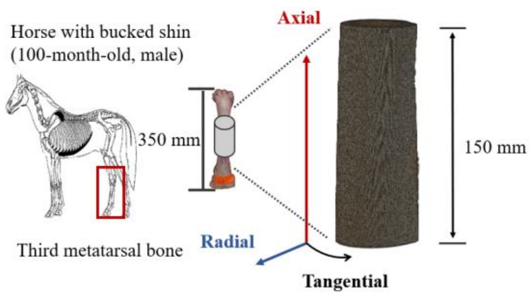

Fig.1 The sample of the metatarsals bone.

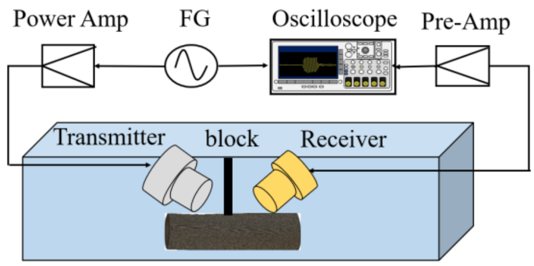

Fig. 2 Experimental set up.

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4. FDTD Simulation

A 2D elastic finite-difference time-domain (FDTD) method was used [4]. Transducers were set at incident angles of 15º (Fig. 3). A vacuum area was set between the transducers to avoid direct waves. The bone model was set in a water to realize the same condition as in the experiment. Longitudinal wave velocity and density in water were 1500 m/s and 1000 kg/m^3, respectively. The Higdon's second order absorbing boundary condition was used. The input signal to the emitter was one cycle of sinusoidal wave at 1 MHz with Hann window.

5. Results and discussion

The apparent wave velocity of the wavefront was estimated from the arrival time difference of waves observed by adjacent receivers in the experiment and simulation. As shown in Fig.4, the arrival time was decided from the 10% of the first peak of the observed waveform. Figure 5 shows the observed apparent wave velocities. These velocities were around 4000 m/s, then, the waves may be longitudinal waves. The apparent velocities were almost constant in the normal part, however, fluctuated in the area of the bucked shin, due to the small surface irregularities. The standard deviations (SD) of velocities in the bucked shin part were 630 m/s (experimental), and 690 m/s (simulation). These data indicate that bucked shin may be detected clinically by the simple evaluation of apparent wave velocity fluctuation measured by the AT technique.

6. Conclusion

The applicability of the AT technique for wave evaluation of the bucked shin in a horse leg was investigated. The observed wave velocity showed changes due to the small surface irregularities of the bucked shin. Experiment and simulation showed similar SD values of velocity. These data indicate that first arriving wave velocities observed by the AT technique may become good parameters for the initial screening of the bucked shin in vivo.

Acknowledgment
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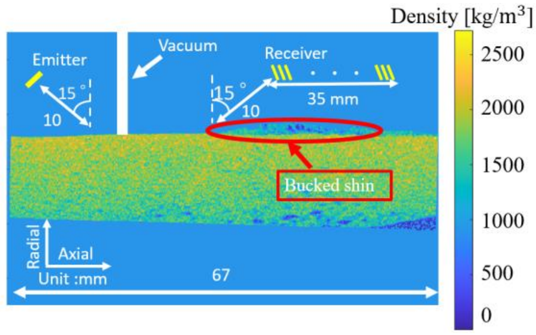

Fig. 3 FDTD Simulation condition.

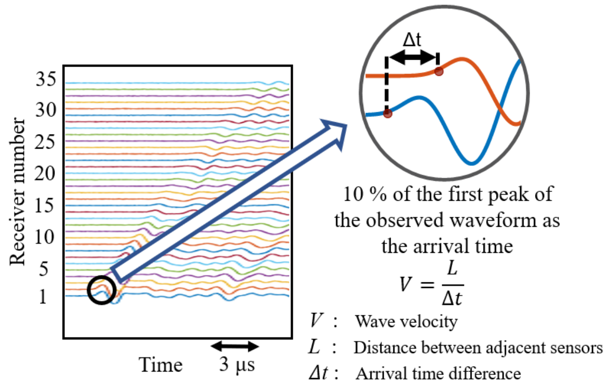

Fig. 4 Observed waveforms

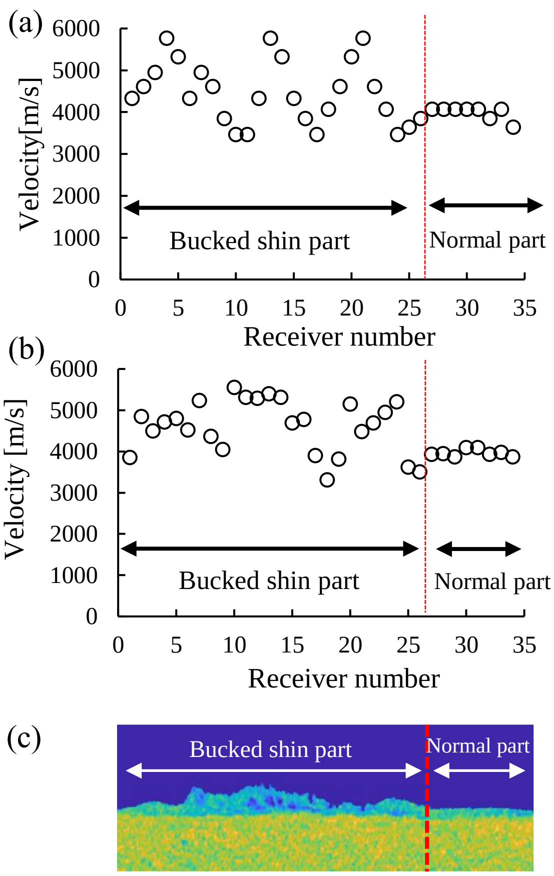

Fig.5 Observed longitudinal wave velocity
(a) Results from simulation
(b) Results from experiment
(c) The surface near the measurement site.