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Anisotropy of ultrasonically induced electric potentials in bone

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Background, Motivation and Objective

The mechanism of bone fracture healing by the low intensity pulsed ultrasound technique has not been perfectly understood yet. One possible initial mechanism is the piezoelectricity in the MHz range. The ultrasonically induced electrical potentials in bone were successfully measured by the bone transducer [1]. Bone is composed of collagen and hydroxyapatite, and has strong anisotropy. The purpose of this study is to observe the effects of bone anisotropy on the ultrasonically induced electrical potentials.

Methods

Three kinds of cortical bone samples (diameter; 11 mm, thickness; 5.00 ± 0.01 mm, normal directions of the plates; radial, tangential or bone axis directions) were extracted from a 29 month-old bovine femur. They were processed into cylindrical samples which have electrodes on the inside and the outside surfaces. Using these cylinders as piezoelectric materials, we fabricated bone transducers for ultrasound reception. For the experiments, a transmitter (PVDF focus transducer; focal length, 40 mm) and a receiver were set to be crossed at right angles in water. A short ultrasound pulse (main frequency; 760 kHz, 7.4 $kPa_{peak\text{-}peak}$) was irradiated to the side of bone cylinder as shown in Fig.1 (a). The ultrasonically induced electrical potentials in bone were observed by an oscilloscope after amplification. The bone transducer was rotated at each 10 degrees to check anisotropy.

Results/Discussion

Figure 1 (b) shows observed waveforms by a bone transducer (tangential) and Fig. 1 (c) shows relationships between the amplitudes of induced electrical potentials and ultrasound propagation directions. The amplitudes became maximum around 45, 135, 225 and 315 degrees, whereas they showed minimum in the radial and axial directions. The polarities and amplitudes of the induced electrical potentials by another bone transducer (radial) showed a similar tendency. The amplitudes of the induced electrical potentials observed by the other bone transducer (axial) did not show clear angle dependence, whereas the polarity changed due to the angle. These data tell us there are optimum radiation angles to induce electrical potentials in bone.

[1] M. Okino et al., *Appl. Phys. Lett.* **103**, 103701 (2013).

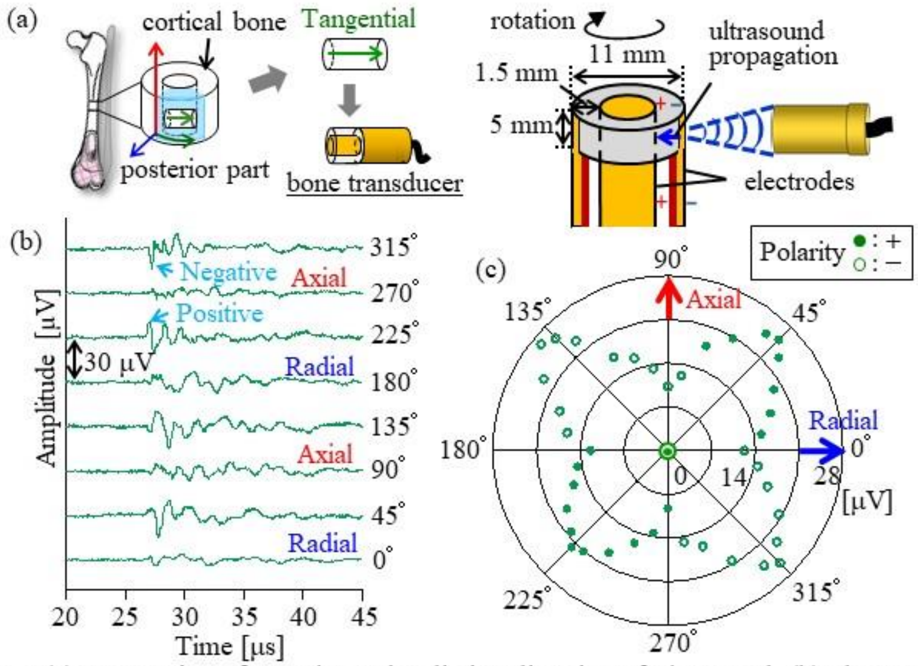

Fig. 1 (a) Preparation of samples and radiation direction of ultrasound, (b) observed waveforms, (c) relationships between induced electrical potentials and ultrasound radiation directions.