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Shear Wave Measurements in Cortical Bone Tubes with Soft Tissue-mimicking layers: Experiments and 3D-simulations

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Background, Motivation and Objective

Shear waves in bone have not been extensively reported although, it is necessary for a complete bone evaluation. Shear waves are related to shear modulus, torsional strength and important factors in the prediction of bone fractures. Shear wave detection was demonstrated in bone plates[1)] and tubes. This study evaluates the impact of soft tissue in the shear wave measurement in cortical bone tubes. Using an ultrasonic axial transmission technique, longitudinal and shear waves velocities were obtained. A 3D-simulation of the wave propagation using the elastic FDTD method was implemented.

Methods

A tubular sample was fabricated from the cortical bone of bovine femur and covered by a soft tissue-mimicking layer (10% Agar and water, thicknesses: 2.2 – 7.0 mm), shown in Fig. 1. Transducers were set at incident angles of 15º, 30º, 45º and 60º. One cycle sinusoidal electrical signal at 1 MHz was excited. Using a time-of-flight technique, velocities were determined as the gradient of the line described by the point being detected at different time.

In the FDTD simulation, the bone model was considered as an isotropic and homogeneous material surrounded by soft tissue. The spatial resolution of the model, 74 µm and time resolution, 6.6 ns satisfied Courant's stability condition. A single sinusoidal wave at 1 MHz, was detected by fifty receivers.

Results and Discussion

Figure 1 b) - d), show the experimental wave velocities obtained with different soft tissue layers as a function of the incident angles. For angles smaller than 30º, longitudinal waves were obtained and for angles larger than 30º, shear waves were detected showing greater repeatability at angles larger than 50º. The angle dependence is related with Snell's law. Similar results are shown in Fig. 1 e), where measurements with the bone sample (without soft tissue) are presented. Although, the influence of the soft tissue could slightly affect the signals trajectory when passing through it, as is observed in guided wave characterizations where additional modes can be induced[2)]. Present results suggest the possibility of implementing shear wave evaluation in *in vivo* bone measurements for a reliable bone diagnosis.

1. L. Bustamante et al., Jpn. J. Appl. Phys., accepted.
2. N. Bochud et al., Scientific reports, 7, 43628. (2017).

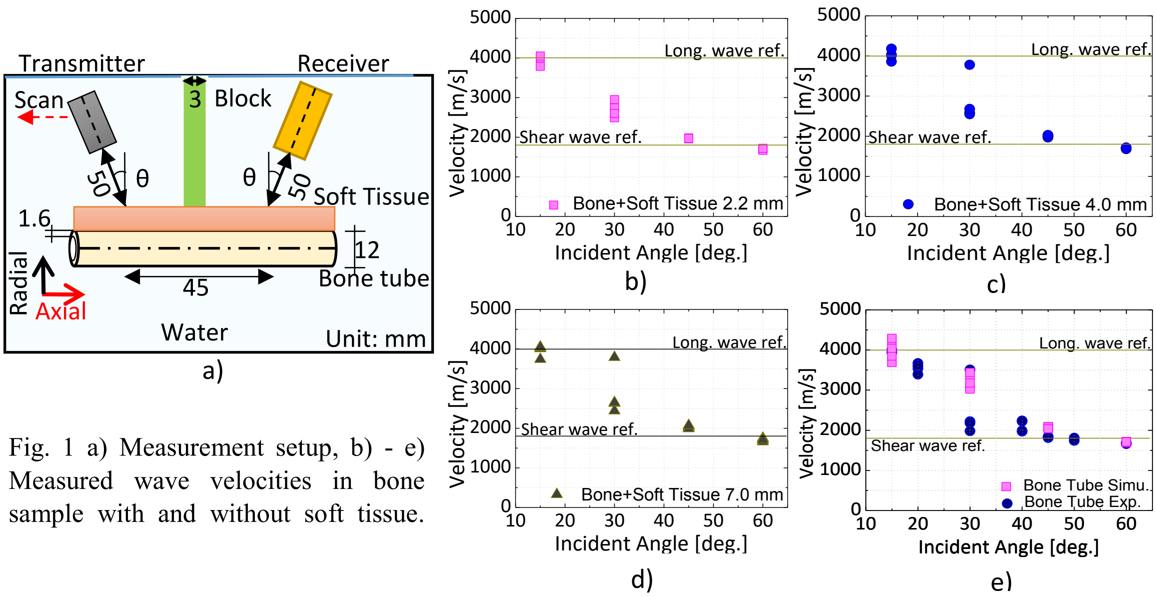

Fig. 1 a) Measurement setup, b) - e) Measured wave velocities in bone sample with and without soft tissue.