Axial and circumferential guided waves in cortical bone: progress in measurement and simulation

J.-G. Minonzio[a], Q. Grimal[a], E. Bossy[b], D. Cassereau[a,c], C. Prada[b] et P. Laugier[a]
[a]Laboratoire d'Imagerie Paramétrique, UPMC Univ Paris 06, CNRS UMR 7623, 15 rue de l'Ecole de Médecine, 75006 Paris, France
[b]Institut Langevin, ESPCI, UMR CNRS 7587, 1 rue Jussieu, 75231 Paris Cedex 05, France
[c]ESPCI ParisTech, 10 rue Vauquelin, 75005 Paris, France
jean-gabriel.minonzio@upmc.fr

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Cortical bone porosity has been evidenced as being a major 'footprint' of bone loss and fragility. Several studies report that cortical bone behaves like a waveguide. Guided mode wavenumbers together with appropriate waveguide modelling have therefore the potential for providing estimations of effective stiffness coefficients (which are largely determined by cortical porosity) and also cortical thickness. However, data interpretation is challenging due to the nature of the waveguide and the surrounding tissues. Recently, important progresses have been made towards measurement and identification of guide modes wavenumbers in cortical bone. Several anatomical sites are studied, including the central skeleton (femur neck) that should be primarily targeted and peripheral skeletal sites (long bones such as the tibia and the radius) because of their better accessibility to measurements. In a first step, specific experimental set-up, consisting of transmit/receive multi-element arrays, have been proposed to measured guided waves propagating either axially in long bones or circumferentially in the femur neck. Signal processing techniques have been developed and adapted to measure the frequency-dependent wavenumbers of guided modes in both above mentioned experimental configurations, taking into account the limited array aperture, signal attenuation, the cortical thickness variation along propagation path and the misalignment between the probe and the surface of inspected specimens (e.g., caused by surrounding soft tissues). In parallel, numerical simulations have been performed using bone models reconstructed from scanner-ray microcomputed tomography data (30 μm voxel) in order to help the interpretation of the guided wave propagation. Tests on bone phantoms (made of transverse isotropic absorbing material), on in vitro specimen and preliminary in vivo results will be presented.