# Photoacoustic and Ultrasound Dual–mode Bone Assessment – A Clinical Feasibility Study

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## Background

The clinically employed ultrasound (US) bone assessment methods measure bone mineral density as well as bone mechanical properties. These methods, however, have limited sensitivity to the chemical and molecular information in the bone. The emerging photoacoustic (PA) techniques have the capability to probe the highly sensitive optical contrast in deep biological tissues. The PA signal generated in the bone contains not only microstructural information but also chemical and molecular information, both highly relevant to bone health. This study aims at developing a new approach based on the combination of PA and US methods for comprehensive and accurate evaluation of bone conditions.

## Methods

First, we investigated the PA signal generation and propagation in calcaneus bone by conducting simulations based on a mathematical model and experiments on *ex vivo* human calcaneus bones. Then, through both simulations and *in vivo* experiments, we studied the feasibility of segmenting the PA signal from human calcaneus bone guided by US measurement. Furthermore, we explored the multi-wavelength PA measurement for characterizing the chemical components in human trabecular bone. In addition, by studying the power spectrum of the PA signal generated in trabecular bone *in vivo*, we explored the feasibility of PA spectral analysis (PASA) technique in characterizing bone microstructures.

## Results/Discussion

The initial results have demonstrated that PA measurement can locate and evaluate the trabecular part of human calcaneus bone *in vivo*, non-invasively. The PA measurements can probe the optical absorption spectra of not only non-organic mineral, i.e. hydroxyapatite, but also organic components including hemoglobin and lipid. Hence, the chemical and molecular properties which are directly associated with bone pathological conditions can be assessed in a non-invasive manner. In addition, the change in bone microarchitecture can be reflected by the frequency component of PA signal. The quantified spectral parameters from PASA on human subjects are correlated with the results from the gold-standard DEXA. The simultaneous US measurement not only provides bone mechanical information for verifying PA results but also offers the space reference which is helpful in segmenting the PA signal from the trabecular bone.

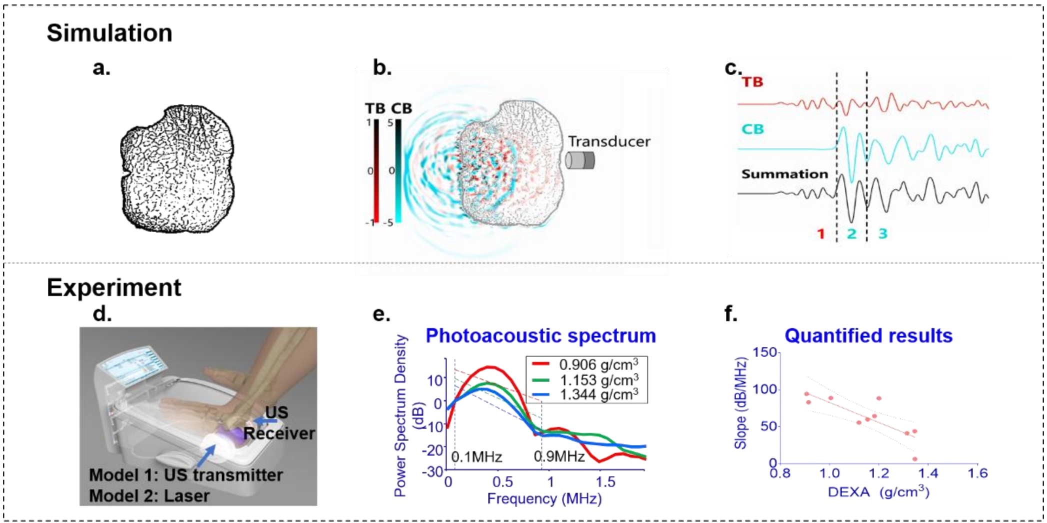


**Fig. 1. Simulation and experimental results of PA measurements from human calcaneus bones.** a) The micro-CT image of a human calcaneus bone used in modeling. b) The propagation of the PA signals from the cortical part (CB) and the trabecular part (TB) of the calcaneus bone. c) The received PA signal in the time domain. d) The diagram of the PA and US dual-mode measurement system developed and used in our experiments. e) The power spectrum density of the PA signals acquired *in vivo* from human calcaneus bones with different bone densities. f) The quantified PA spectral parameter *slope* in correlation with the measurements from the gold-standard DEXA.