Dependence of dispersive properties of cancellous bone on bone mineral and collagen content

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Background

- Ultrasonic estimation of fracture risk prediction in osteoporotic patients is based on measurements of slope-of-attenuation and speed-of-sound in cancellous bone.
- Fracture risk prediction can be affected by frequency-dependent attenuation and phase velocity.
- We have previously investigated the relationship between frequency-dependent attenuation and phase velocity via the Kramers-Kronig relations.*

*Waters *et al.*, Proc. 2004 IEEE International Ultrasonics Symp. (in press).

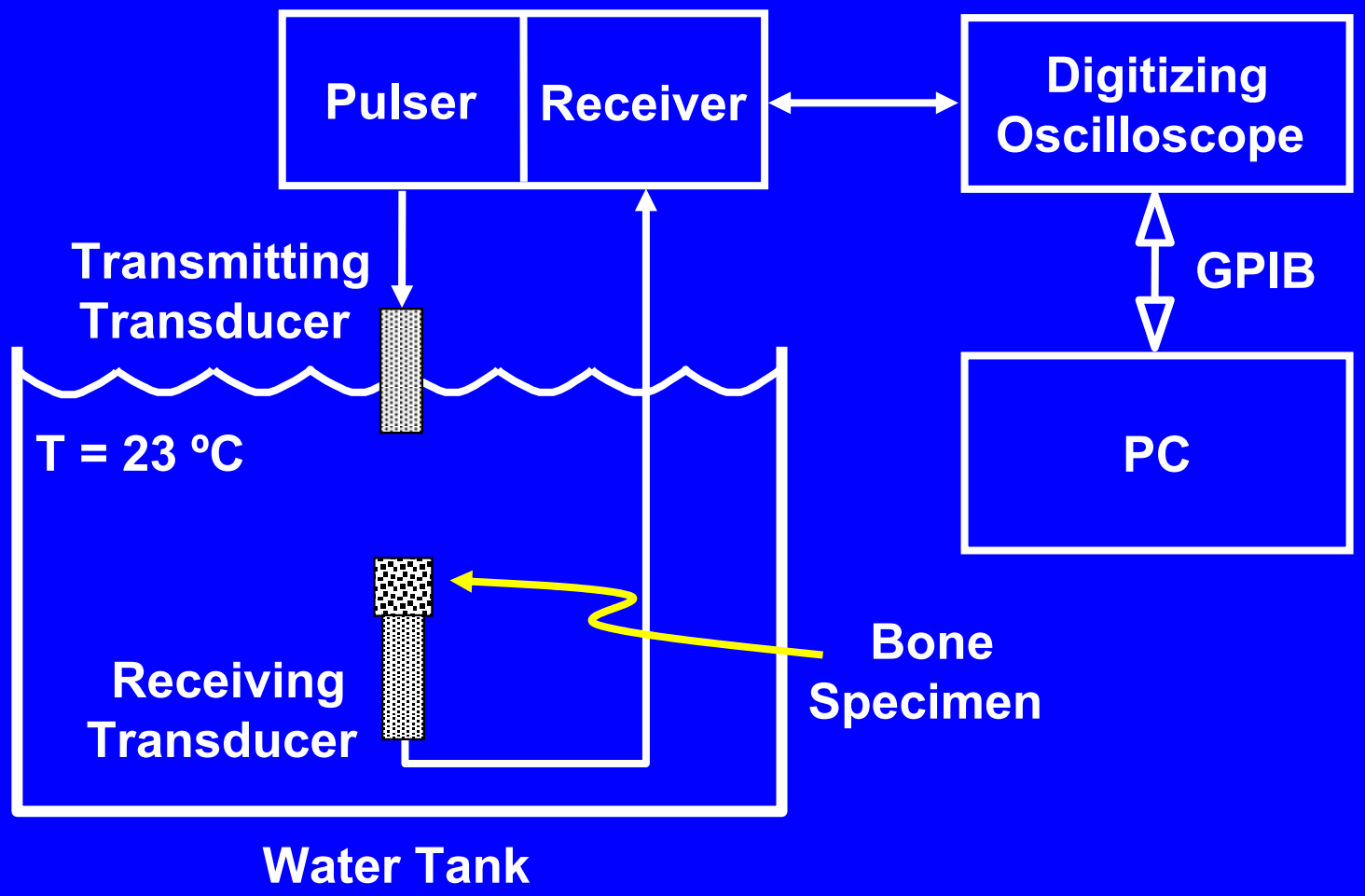
Objective

- Investigate the effect of bone mineral and collagen content on the frequency dependence of phase velocity (*i.e.*, dispersion) in cancellous bone
- Investigate whether dispersion can serve as an estimate of bone mineral density (BMD)
- Investigate whether the change in dispersion is useful for monitoring changes in bone mineral and/or collagen content

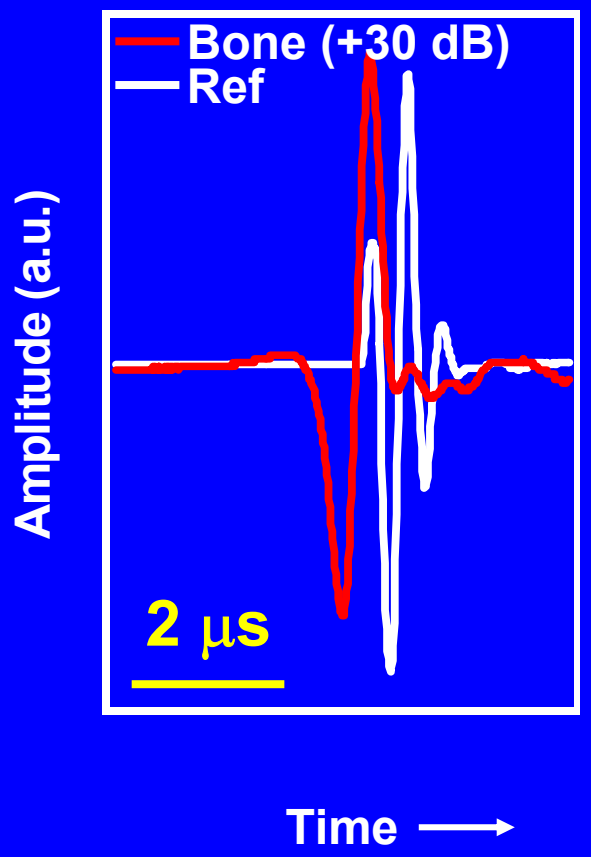
Specimen Preparation

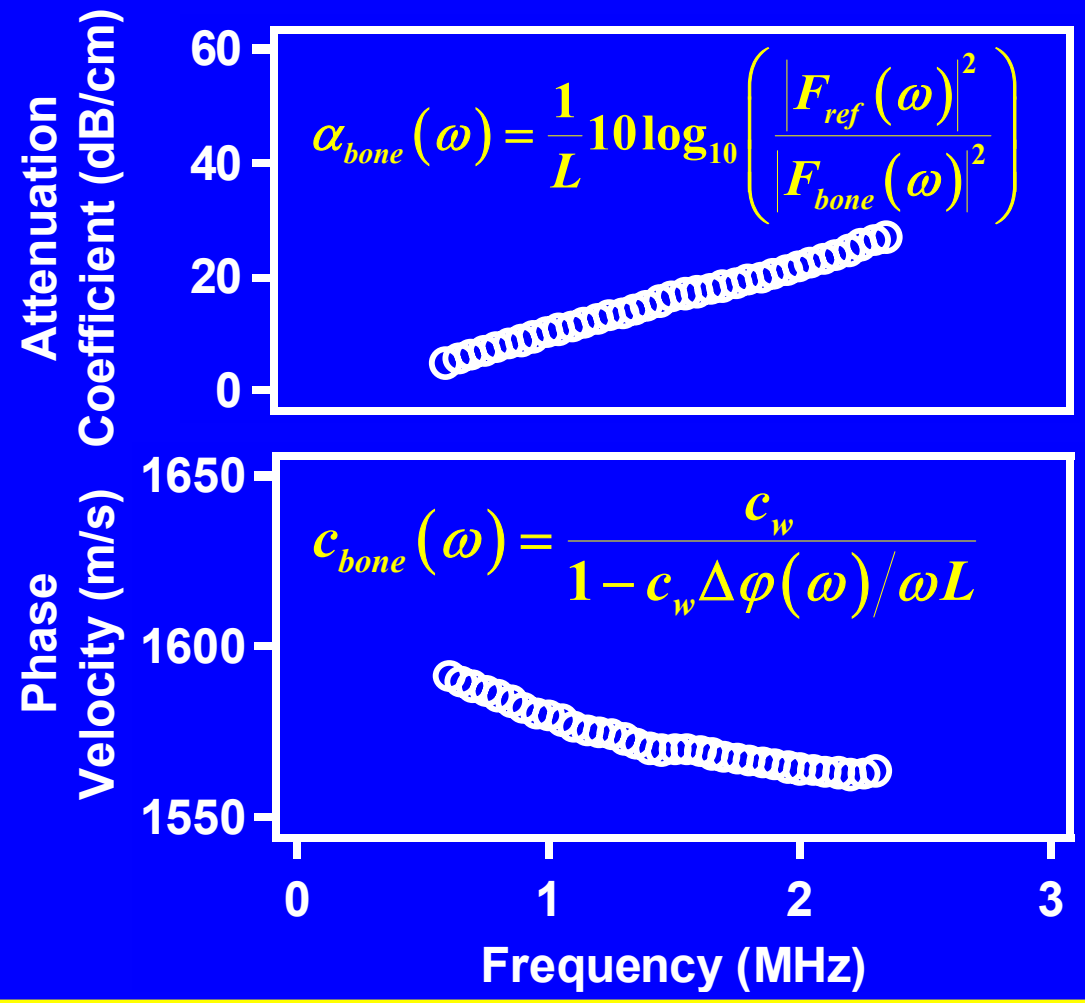
- Human cancellous bone specimens (n = 14) were excised from tibia and marrow was then removed
- Specimens were cut into cubes, each side approximately 1.5 cm long
- Each specimen was chemically treated (72 hours)
  - Demineralized with EDTA (n_M = 10)
  - Decollagenized with collagenase (n_C = 4)
- Measurements were performed along 3 axes before (Pre) and after (Post) treatment
  - Transverse: Anterior-Posterior (AP) and Medial-Lateral (ML) directions
  - Longitudinal: Superior-Inferior (SI) direction (demineralization treatment only)

Experimental Setup

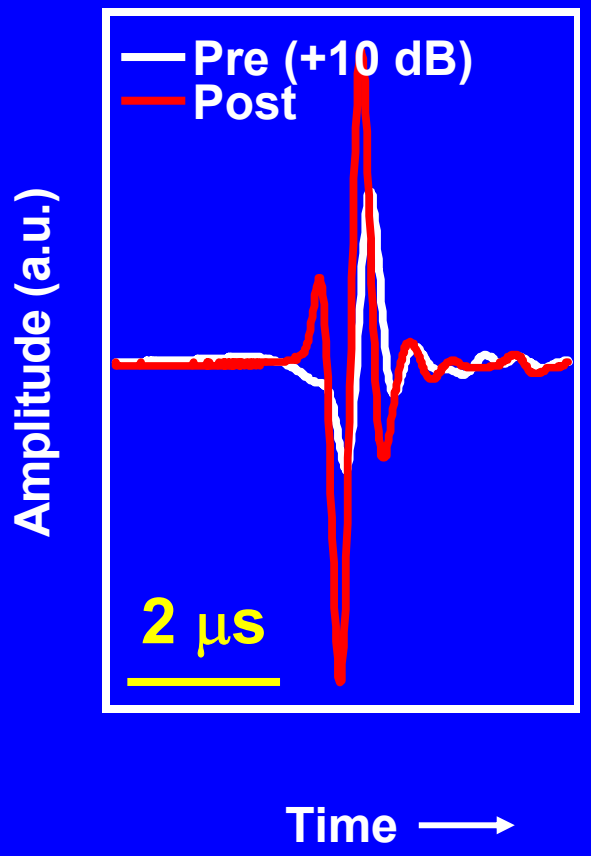


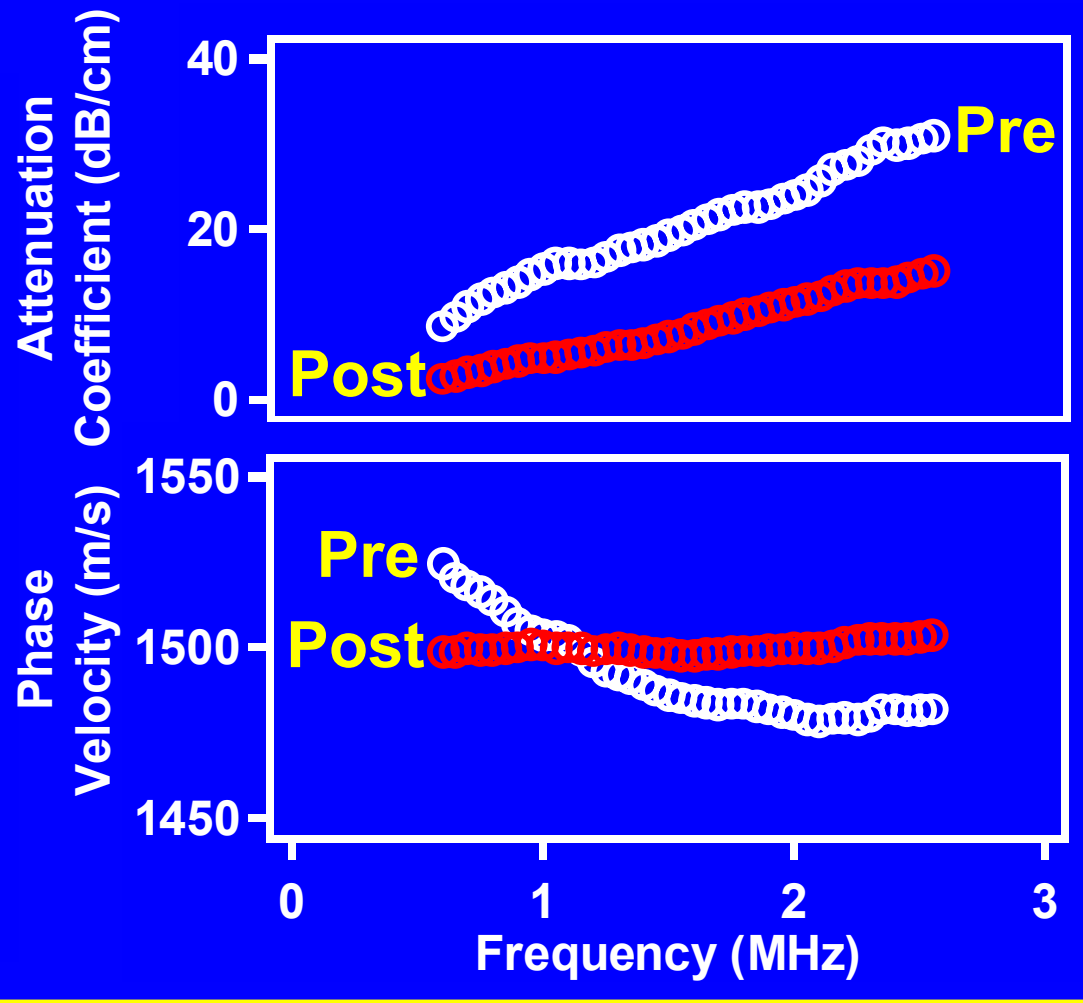
Spectral Analysis



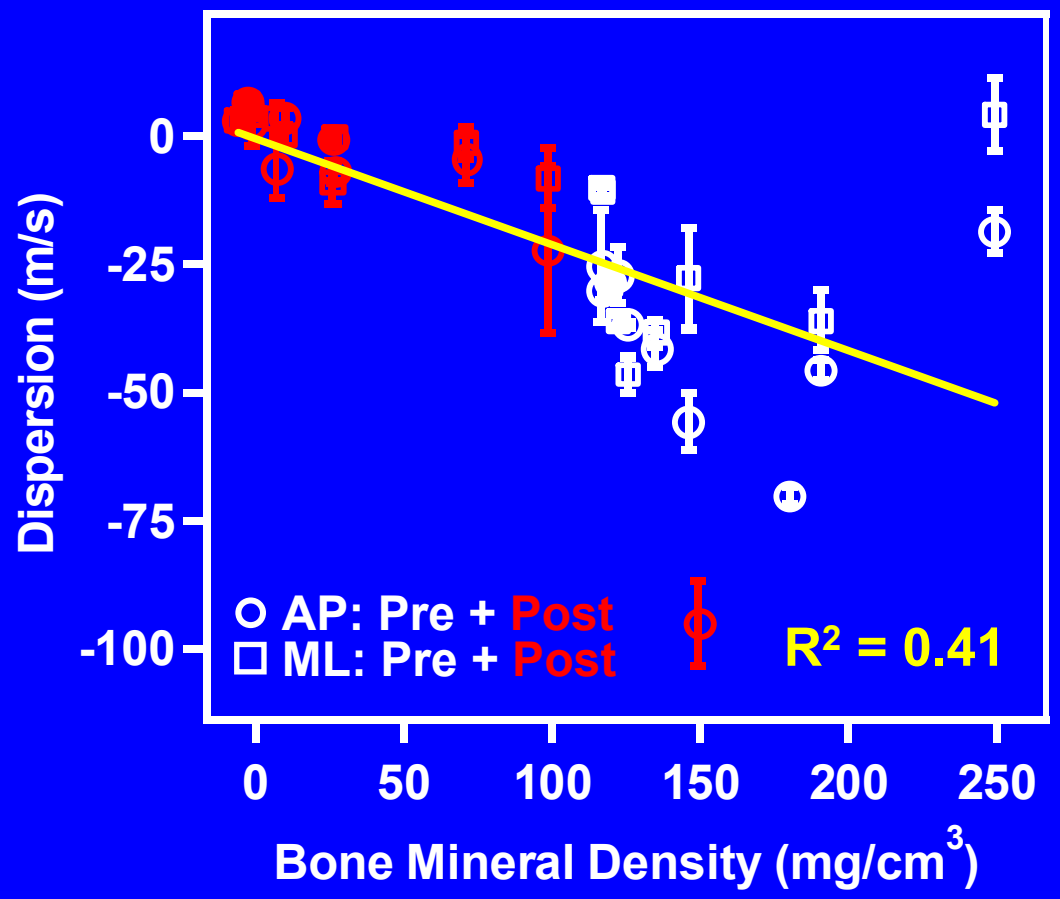


Demineralization: Transverse

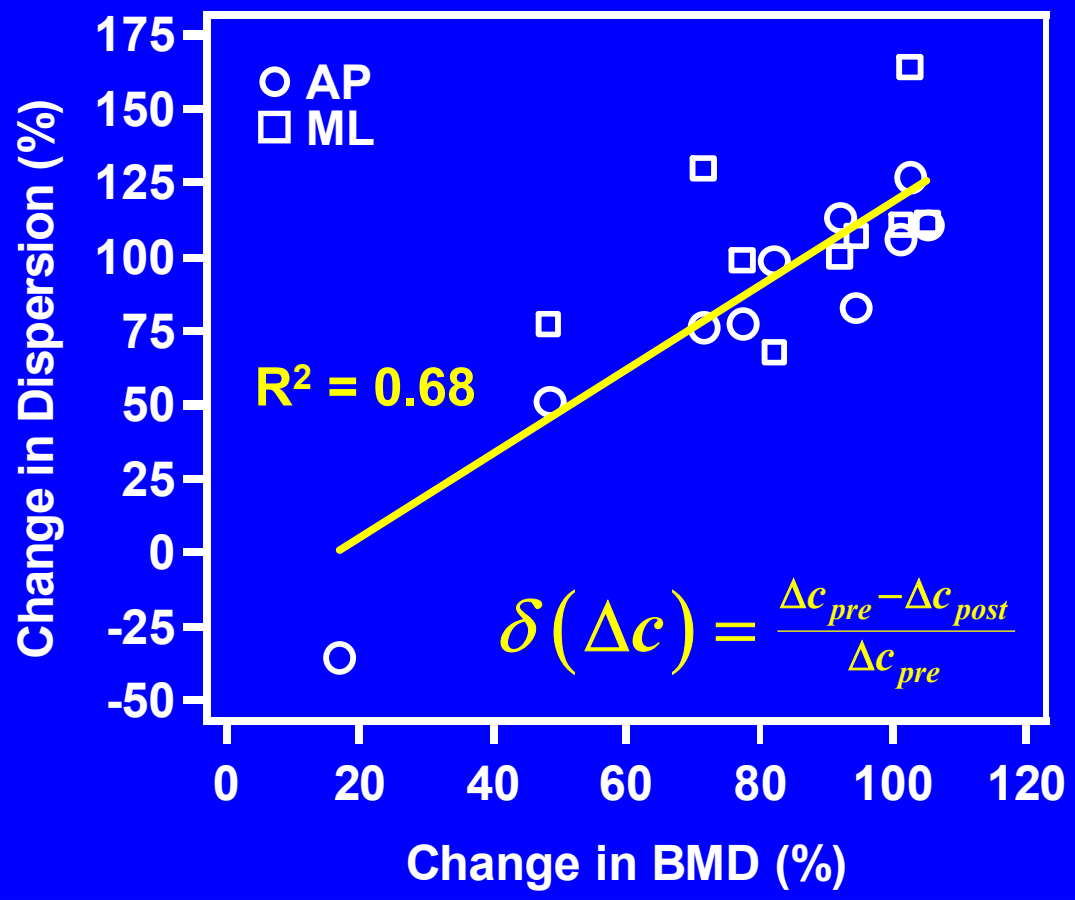




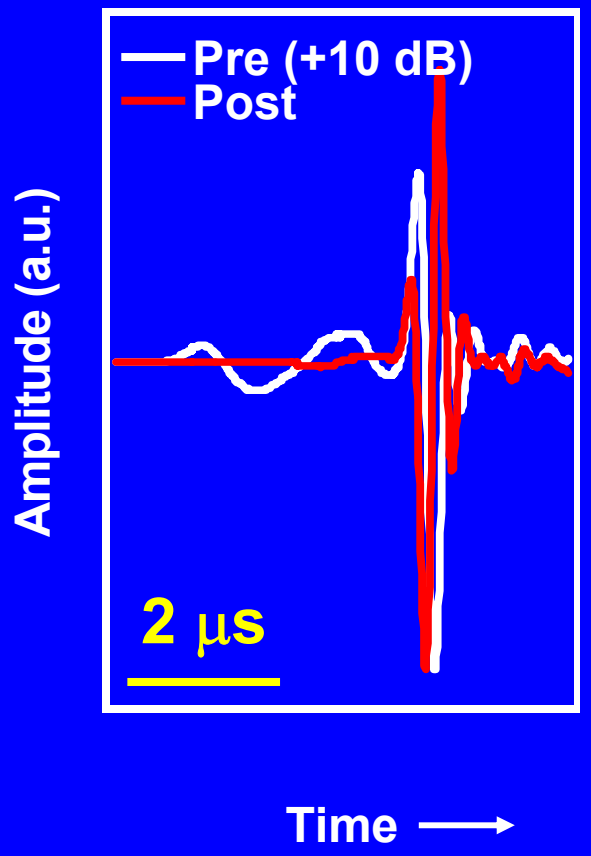
Dispersion: Transverse

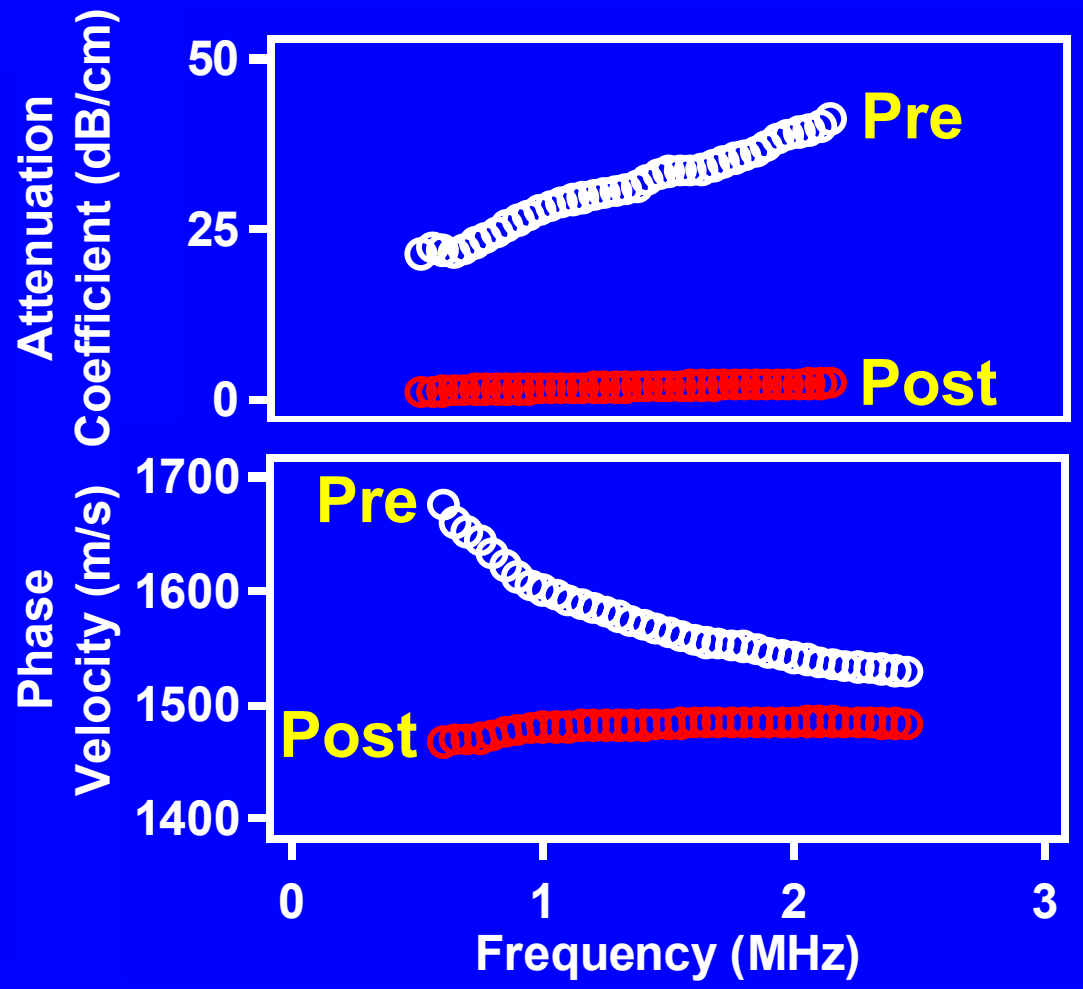


Change in Dispersion: Transverse

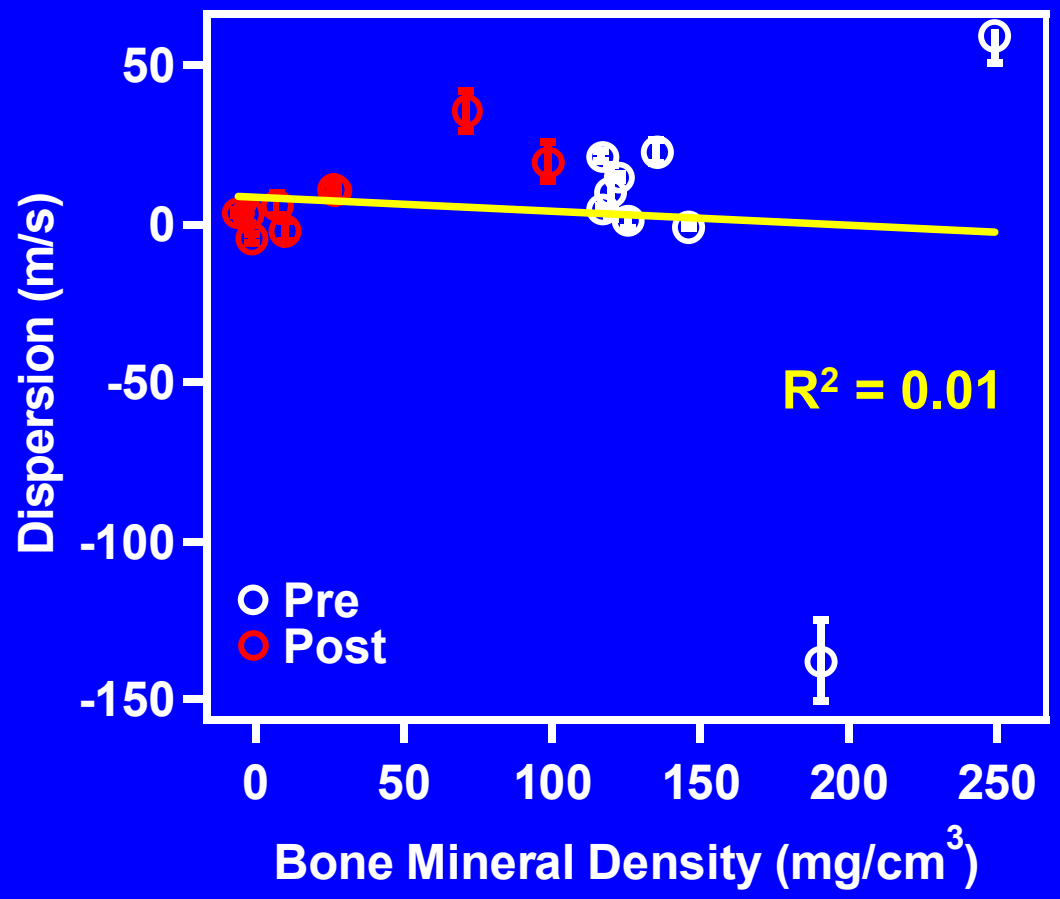


Demineralization: Longitudinal

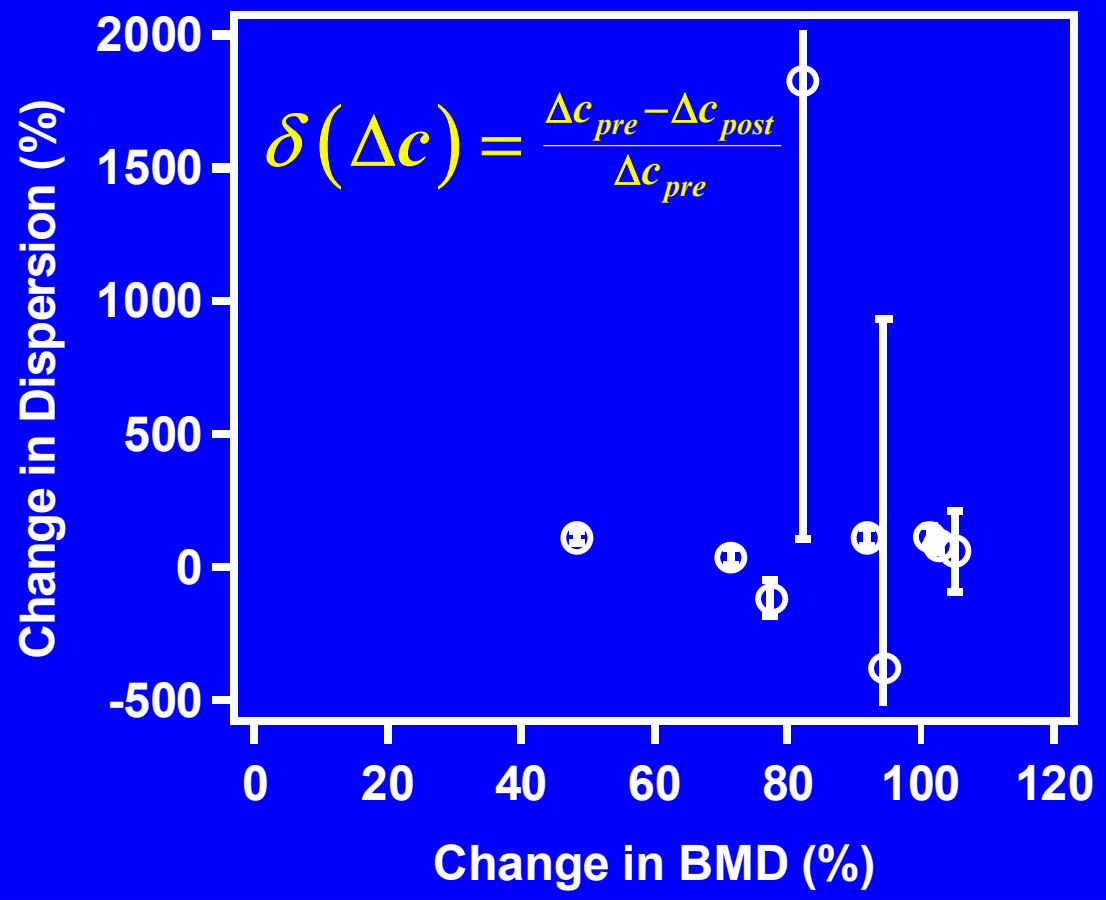




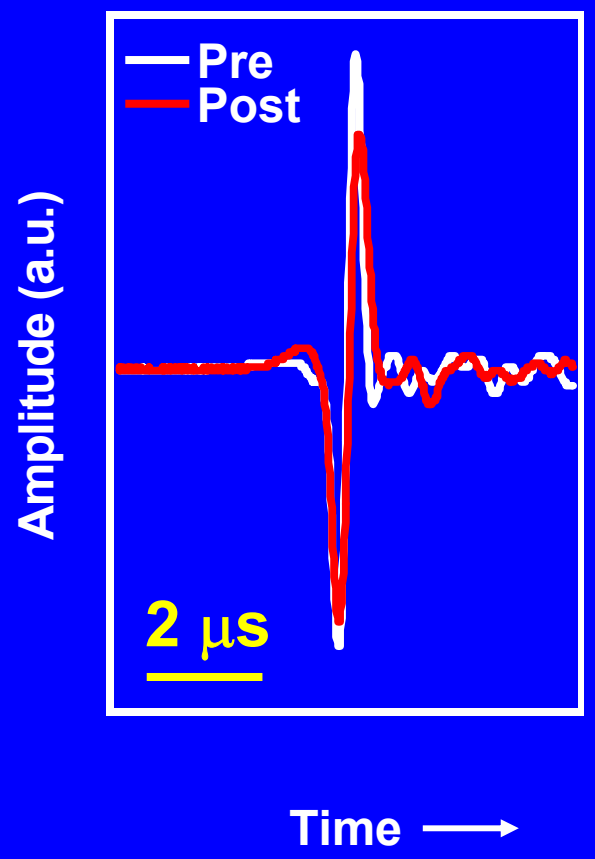
Dispersion: Longitudinal

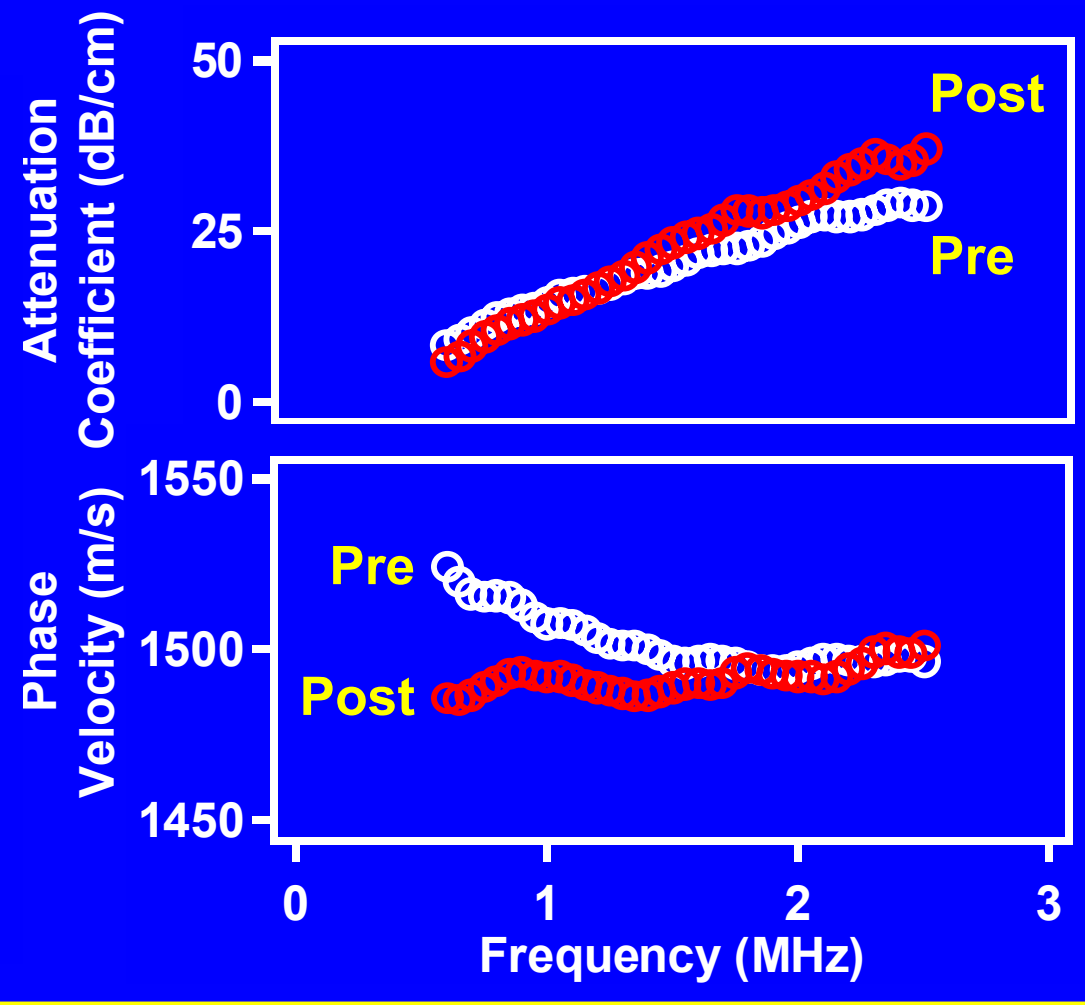


Change in Dispersion: Longitudinal

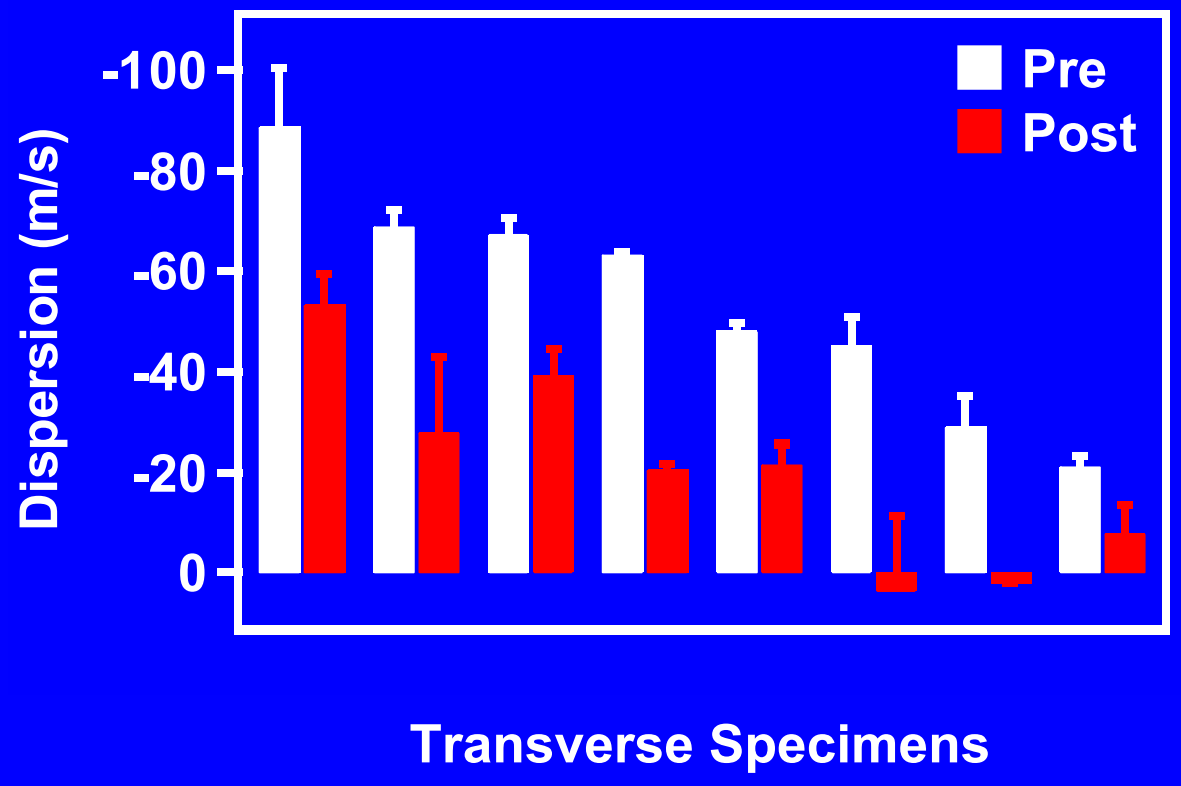


Decollagenization: Transverse





Dispersion: Transverse



Observations

- Dispersion is sensitive to bone mineral content
  - Magnitude of dispersion decreases with decreasing BMD in the transverse direction
  - Best correlation is in AP direction
- Dispersion is sensitive to collagen content
  - Magnitude of dispersion decreases with decreasing collagen in the transverse direction
  - Collagen appears to play a smaller role in dispersion properties than bone mineral

Perspectives

- Continue to investigate the relationship between changes in dispersion and changes in bone mineral density
- Quantify the change in collagen content due to collagenase and its effect on the propagation properties
- Develop computational tools to facilitate understanding of the propagation and scattering properties of cancellous bone

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