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Bone Material Properties in Osteogenesis Imperfecta: A Matter of Quantity Over Quality

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Osteogenesis Imperfecta (OI) is a collagen-related genetic disorder resulting in a high susceptibility to bone fracture. The mechanisms behind bone fragility in OI are not yet well understood. In addition to a characteristic low bone mass, i.e., structural deficiency, studies in mice suggest that the material properties of bone tissue may also be compromised in OI [1, 2]. However, little is known about bone material properties in humans with this disorder. The objectives of this study were investigate relationships between bone material properties, bone volume fraction, volumetric tissue mineral density (vTMD), and donor age in children with OI.

Ten small diaphyseal specimens from long bones of eight children with mild to severe OI (ages 3-16) were obtained during routine osteotomy procedures. Longitudinal beams were machined from these specimens, and elastic modulus and yield strength were measured in bending. Bone volume fraction (1 – intracortical vascular porosity), representing the quantity of bone material per unit volume, and vTMD, representing the density of the bone material, were determined by synchrotron micro-computed tomography.

Average elastic modulus and flexural strength were 4.8 GPa (SD 2.0 GPa) and 91 (39 MPa), respectively. Bone volume fraction was 0.80 (0.12), and vTMD 1.58 g/cm³ (0.12 g/cm³). Each property was associated significantly with volume fraction, but not with vTMD or donor age (Table 1, Figure 1).

Reduced modulus and flexural strength were observed compared to typical values for children and adolescents [3]. Volume fraction and vTMD were also lower than in normal pediatric bone [4]. Unlike in normal bone tissue [3], bone properties in children and adolescents with OI did not appear related to age. Results of this preliminary study indicate that bone material properties at the mesoscale in OI may be associated more with bone quantity (volume fraction) than with the quality (density) of the bone material itself. These results offer valuable insight toward a better understanding of bone fragility in OI.

References

1. Misof et al. 2005, Bone 36:150-8.
2. Jepsen et al. 1997, J Biomech 30:1141-7.
3. Currey and Butler 1975, JBJS Am 57:810-4.
4. Jameson et al. 2013, Proc SPIE Vol. 8672.

Table 1. Pearson's correlation coefficients between bone material properties, bone volume fraction (V_f), volumetric tissue mineral density (vTMD), and donor age in children and adolescents with OI. (*P<0.05)

Material property	Factor	Slope	P value	R
Elastic modulus (GPa)	Vf (-)	15.1	0.002*	0.86
	vTMD (g/cm ³)	7.41	0.186	0.46
	Age (years)	-0.113	0.503	-0.24
Flexural strength (MPa)	Vf (-)	260	0.010*	0.76
	vTMD (g/cm ³)	27.8	0.809	0.09
	Age (years)	-0.971	0.771	-0.11

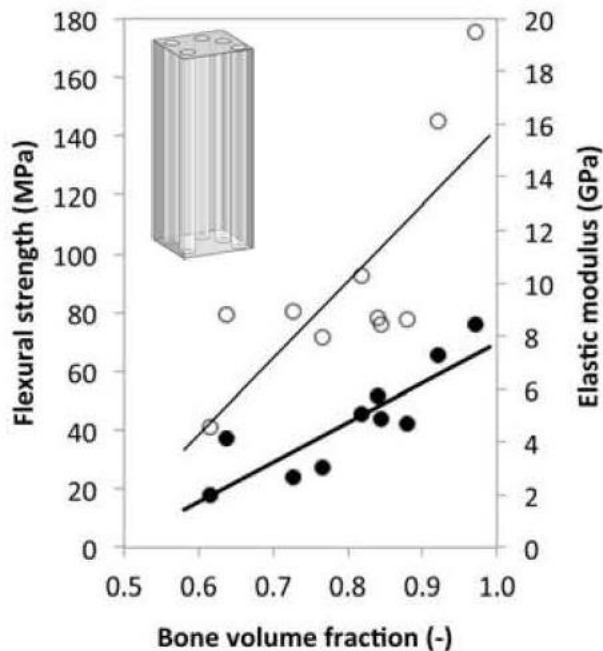


Figure 1. Relationships between diaphyseal bone material properties and volume fraction in pediatric OI bone: elastic modulus (black circles), strength (white circles).