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Bioceramic-Based Biomaterial Products for Orthopedic Implants

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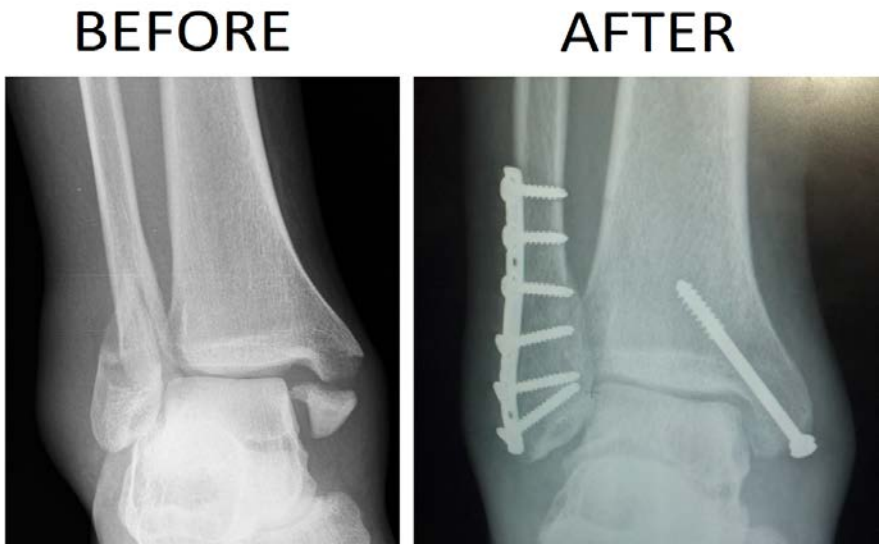
Problem Statement



- Titanium and stainless steel
  - –Not biodegradable
  - –High elastic modulus causes stress shielding
  - –Can damage bone during screw removal

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Objective

To develop a suitable, biocompatible composite material with properties similar to those of bone to be used in the 3D printing of orthopedic implants.

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Materials

- PLA
  - –Thermoplastic polyester, low cost, biocompatible, biodegradable, long degradation time
- HA
  - –Bioceramic, makes up 50% by volume of human bone, osteoconductive

In combination, PLA and HA form a biodegradable composite material that is inexpensive and promotes bone growth.

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Methodology

HA powder

+

PLA pellets

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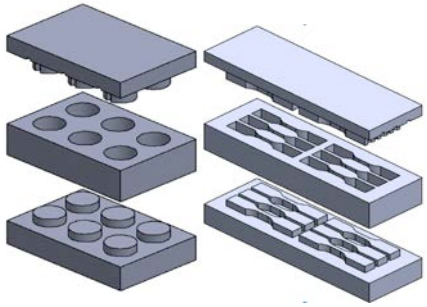
Torque rheometer



SolidWorks designs

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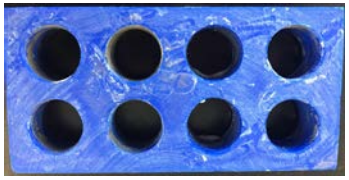

3D-printed compression mold

3D-printed tensile mold

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Compression specimen

Tensile specimen

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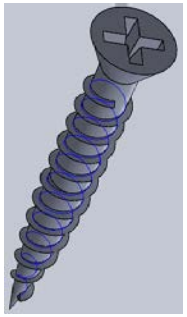

Screw design and molding

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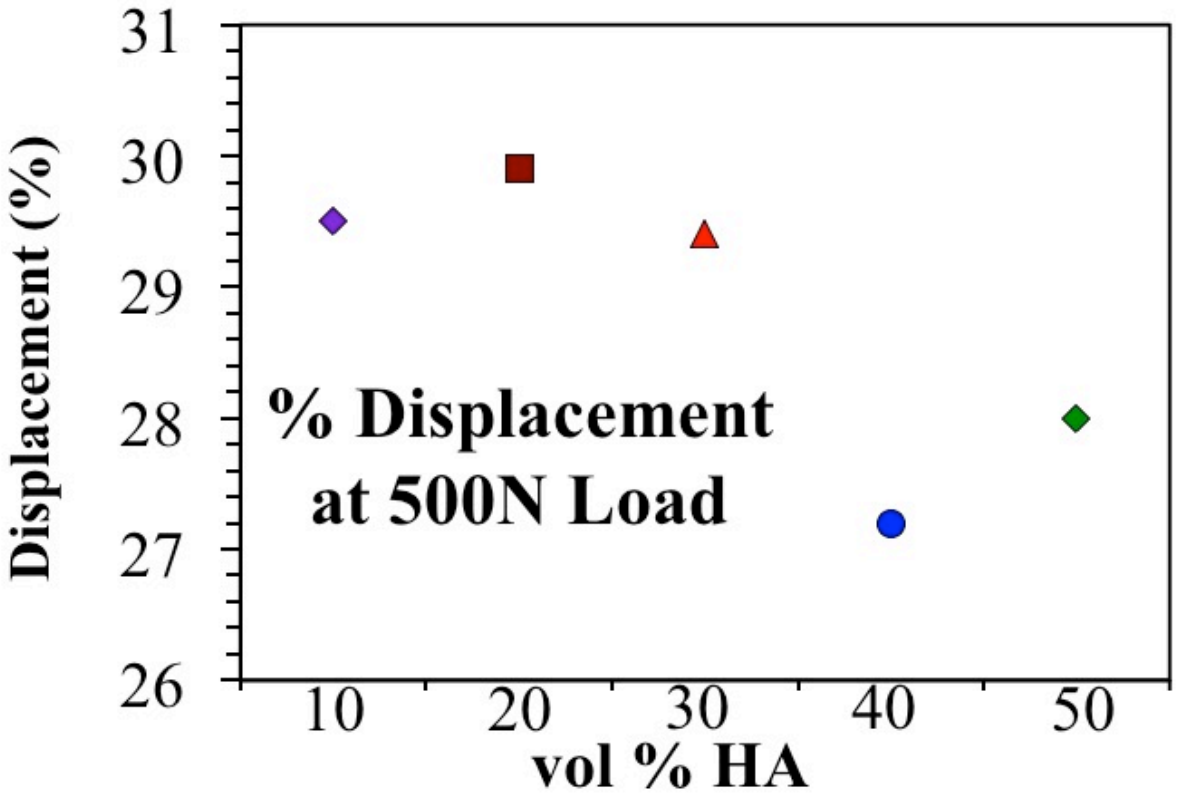
Stiffness wrt. Vol %



Samples with 40-50 vol % HA experience least deformation under 500 N compressive load.

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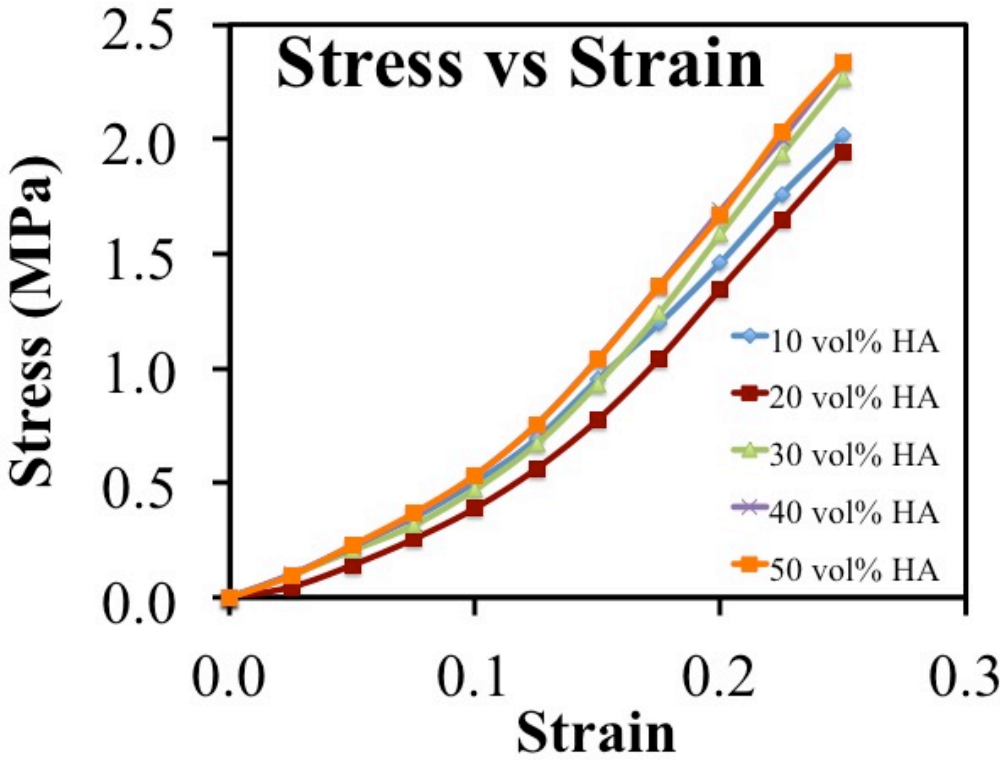
Stress vs Strain



Sample with 50 vol % HA show greatest ratio of stress to strain. At 25% strain, 50% volume HA sample has compressive strength of 2.34 MPa.

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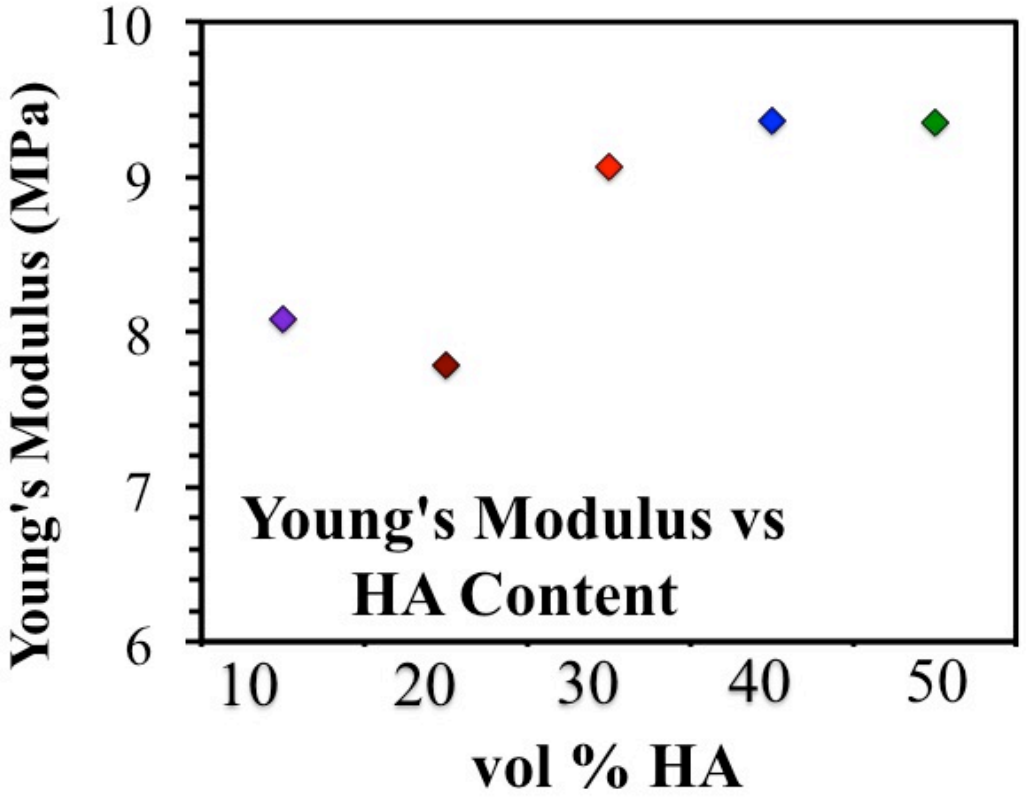
Young's Modulus



Samples with 30-50% volume HA have greatest elasticity.
Elasticity of 50% volume HA sample is 8.2% of that of bone.

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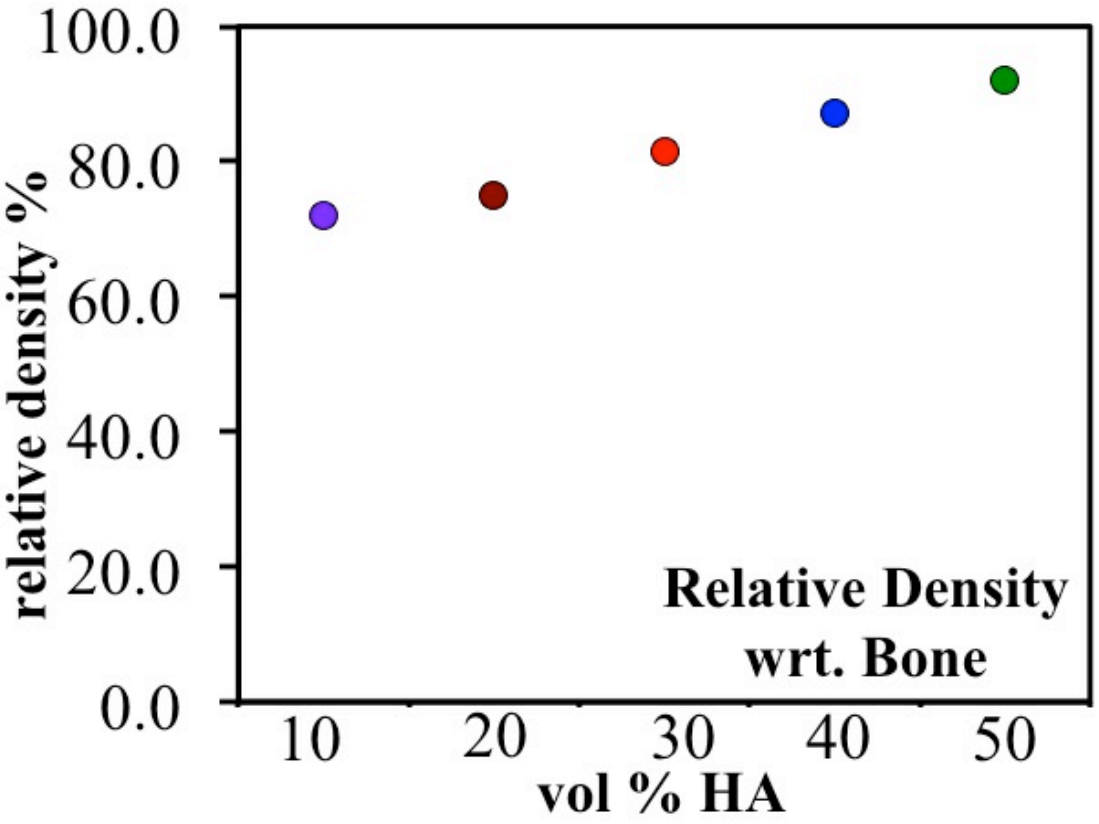
Relative Density wrt. Bone



Samples with 50 volume % HA have a relative density of ~92% wrt. human cadaver bone.

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Comparison wrt. Bone

	Titanium	50% vol HA/PLA Composite
Relative Density (%)	250	92
Relative Young's Modulus at 25% strain (%)	550	8.2
Relative Compressive Strength at 25% strain (%)	851	8.2

Density of 50 volume % HA sample is closer to that of bone than Ti.
Lower Young's modulus than that of Ti eliminates stress shielding.
Lower compressive strength eliminates damage to surrounding bone.

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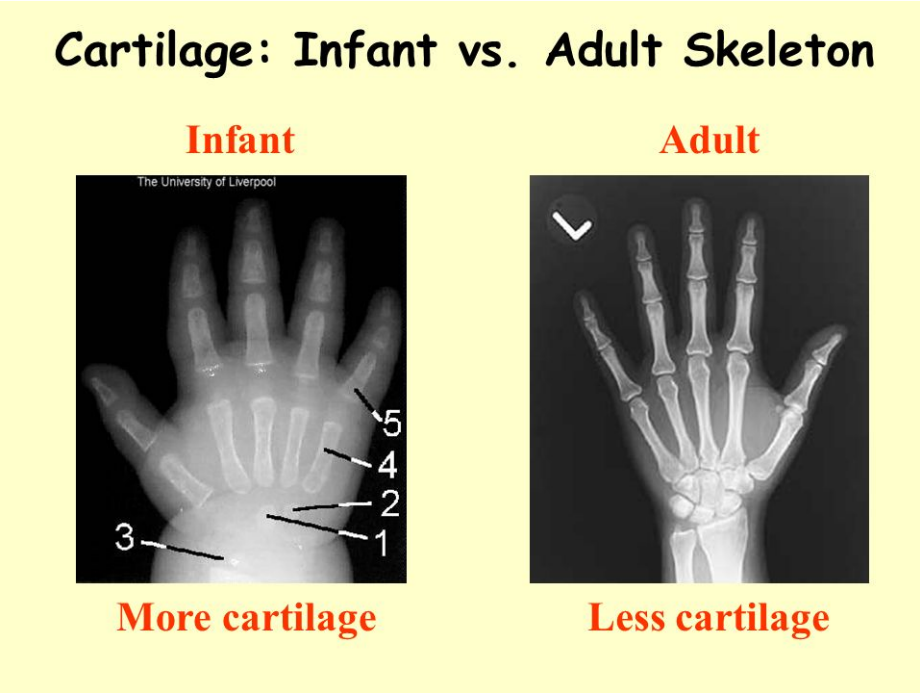
Significance

- 50 volume % HA samples most similar to bone
- Use as small-defect filler in low-load applications
- Human infant, feline, and canine fixations



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Future Work

- Biopolyester material filler, such as polyhydroxyalkanoate (PHA), combined with PLA/HA composite for modification of material flexibility
- Formulation of a composite with higher HA content to improve mechanical strength and elasticity
- Design and fabrication of 3D printed orthopedic screw