# 3D-Printed PLA Radius Models Replicate Cadaveric Flexural Biomechanics


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**INTRODUCTION:** The radius is one of the most frequently fractured bones, especially in pediatric and geriatric populations. Current biomechanical testing of radius fractures typically relies on cadaveric specimens, which are costly, exhibit variability, and can be difficult to obtain in sufficient quantities. With advances in 3D printing technology, there is increasing potential to create low-cost, customizable, and anatomically accurate bone models that can be used for both biomechanical research and surgical planning. The primary objective of this study was to see if there was any significant difference in flexural biomechanical behavior between 3D-printed models of the radial diaphysis and historical values from cadaveric bone.

**METHODS:** A de-identified computed tomography (CT) scan of a healthy adult male was obtained and imported into 3DSlicer, a free, open-source software, to segment and generate an anatomically accurate 3D model of the radius. This model was then exported as an STL file and prepared for 3D printing. Midshaft radius models were printed on a Bambu P1S fused deposition modeling (FDM) printer using ELEGOO White PLA filament with a fixed gyroid infill of 20% and wall thicknesses ranging from one to seven walls. Samples underwent three-point bending tests on an Instron mechanical testing machine following ASTM D790 standards to collect force-displacement data (Figure 2). The models' moments of inertia were calculated using the cross section of the diaphyseal midpoint and were then used to generate stress-strain curves, from which flexural strength and modulus were calculated (Table 1). Ten replicates of the best-performing configuration were tested and compared to published cadaveric data using Welch's t-tests with significance $p < 0.05$.

**RESULTS:** The 6-wall, 20% infill models showed a mean flexural strength of 66.13 MPa (SD = 5.59 MPa) and a flexural modulus of 4.07 GPa (SD = 0.335 GPa). Welch's t-tests showed no significant difference from cadaveric data ($p = 0.063$ for strength, $p = 0.272$ for modulus).

**DISCUSSION:** Using 3D-printed PLA models of the human radial diaphysis, optimized for wall thickness and infill density, we approximated the flexural mechanical properties of male cadaveric bone, the sex with data most predominant in biomechanical literature. These results support the use of low-cost, customizable printed models as standardized substitutes for biomechanical testing, which can reduce the need for cadaveric specimens and improve access for research and training. Our research has the potential to improve patient care by better explaining radial shaft fractures and planning subsequent fixations; however, there are several limitations to consider. The printed models are isotropic only along the tested axis, with properties dependent on layer orientation, and this study examined only bending loads, while radius fractures in vivo can result from a combination of bending, torsion, and compression. Future work should evaluate additional loading conditions, investigate fatigue behavior, and explore other materials or composite designs to better reproduce the anisotropic properties of native bone.

**CLINICAL RELEVANCE:** Accessible, anatomically accurate, and mechanically comparable 3D-printed radius models can provide a reproducible alternative to cadaveric bone for preclinical testing, surgical planning, and education, potentially broadening research opportunities in settings where cadaveric material is limited or unavailable.


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**IMAGES AND TABLES:**

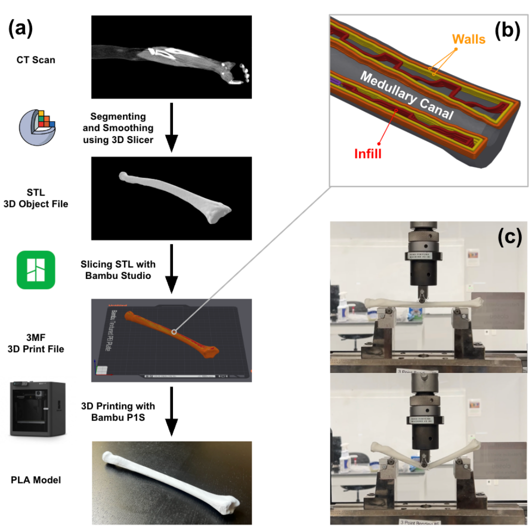


**Figure 1.**
**(a)** Model Preparation Workflow
**(b)** Sliced Radius Model with Infill (15%) and Wall Count (2)
**(c)** 3-Point Bending Setup

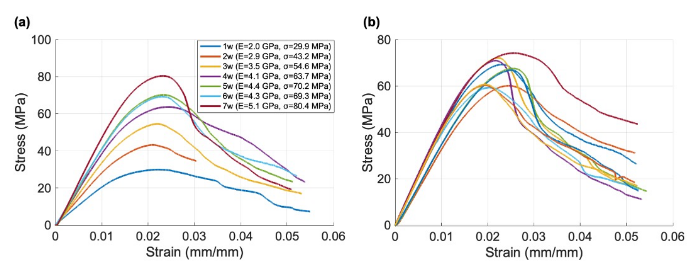


**Figure 2.** Stress-strain curves for **(a)** 1 to 7 walls and **(b)** 6 walls (n = 10) sample 3-point bending

| | Mean Flexural Strength (MPa) | Standard Deviation | Mean Flexural Modulus (GPa) | Standard Deviation |
|---|---|---|---|---|
| **Cadaver** | **80.31** | **14.55** | **3.66** | **0.780** |
| **5 wall** | **56.49** | **4.27** | **3.67** | **0.321** |
| **6 wall** | **66.13** | **5.59** | **4.07** | **0.335** |
| **7 wall** | **67.68** | **5.29** | **4.28** | **0.070** |

**Table 1.** Flexural Strength and Modulus of Cadaver and 5, 6, and 7 Wall 3D-Printed PLA Radius Prints