# Effects of 3D Building Parameters and Dual Post-Curing on Mechanical Properties of 3D Printed Models Using Digital Light Processing

BUILD CSULB

CALIFORNIA STATE UNIVERSITY **LONG BEACH**

**Jonathan Piceno[1], Daniel Gonzalez[1] and Ehsan Barjasteh[2,3], Ph.D.**

[1]Department of Biomedical Engineering, [2]Department of Mechanical & Aerospace Engineering, and [3]Department of Chemical Engineering

## INTRODUCTION

- Additive manufacturing is the process in which a Computer-aided design model is created into a 3D object through a layer by layer format (1,2)
- Flexural strength, hardness, impact strength, and color stability are important to extend the use of temporary dental restorations (3)
- Denture bases may crack due to the fatigue caused by repeated flexing during mastication over many years (4)
- Therefore, a high flexural strength is required for dental resins to prevent failure under load.

## METHODS

**Resin Type**

- Acrylate based dental resin.

**3D Printing of Testing Models**

- Solidworks was used to create ASTM D760 Flexural Testing Models.(5)
- Flexural Models were printed using a digital light processing technique with a MoonRay Model S100 3D printer (λ = 405 nm & Intensity = 1.005 mW/cm$^2$).
- Two batches were printed for each orientation: Batch$_1$ = control group (N = 5) and Batch$_2$ = post-cured samples (N = 5).
- Samples were printed in 3 different thicknesses: 20, 50, & 100 µm.
- Samples were rinsed in Isopropyl Alcohol for 3 minutes to remove any unreacted resin.
- Six different orientations printed (**Figure 1**) :

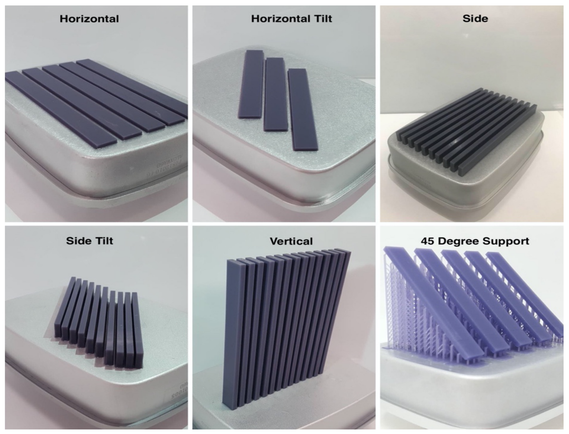


**Figure 1.**

## METHODS CONT.

**Testing of Flexural Models**

- **Three-Point Bend Test:** Allows for characterization of the flexural samples' max strength, elastic modulus, and max strain (Figure 2.) Samples were tested at a speed of 1mm/min.

$$\textbf{Support Span} = \frac{16 * Average\ Thickness}{2}$$

- **Dynamic Mechanical Analysis (Single Cantilever):** 3 samples were tested for each orientation. The protocol was initialized at 30°C and ramped up to 170°C by 5°C increments.
- **Dual Post-Curing:** Three batches of 50 µm samples (N=5) for each orientation were printed and post-cured at three different temperatures, 30°C, 40°C and 60°C for 3 different times 30 min, 60 min, and up to 90 min.

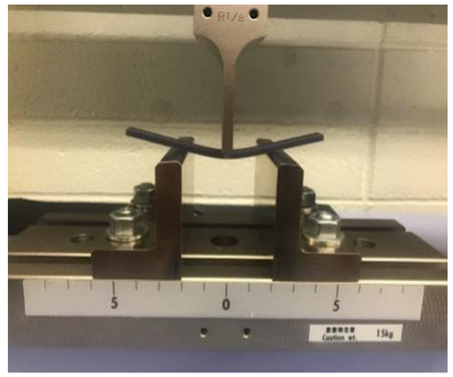

**Figure 2.**

## RESULTS

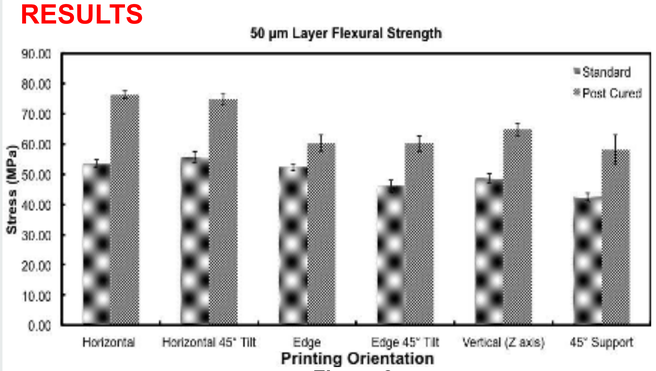


**Figure 3.**

- Horizontal orientation = strongest flexural strength & 45° support = lowest flexural strength (Figure 3.)
- After post-curing = increased flexural strength (Figure 3).

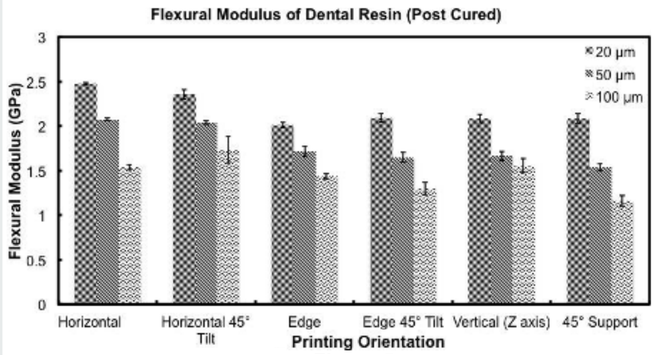


**Figure 5.**

- Similar trend for flexural modulus is seen for different layer thicknesses. (Figure 5.)
- Smaller layer thickness allows deeper light penetration light and results in higher degree of polymerization for this specific resin.

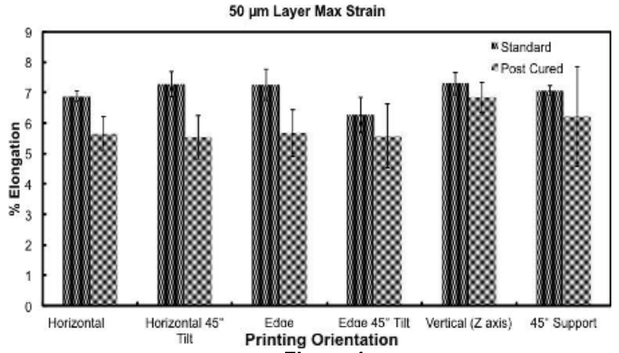


**Figure 4.**

- After post-curing = decrease in the max strain for all (Figure 4.)
- Inverse relationship: Flexural Strength vs Max Strain. (Figures 3. & 4.)

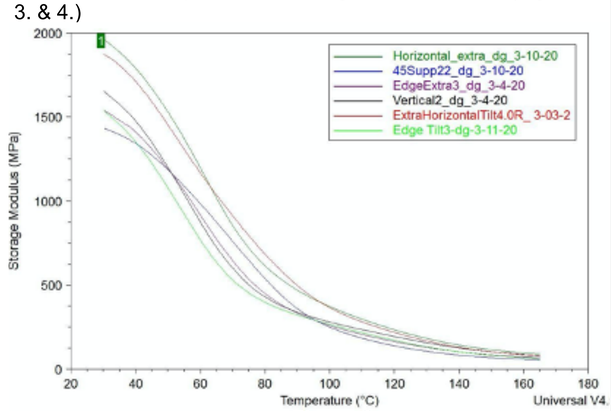


**Figure 6.**

- Highest storage modulus = Horizontal & lowest storage modulus 45° support (Figure 6.)
- DMA results confirm 3-point bend test results.

## RESULTS CONT.

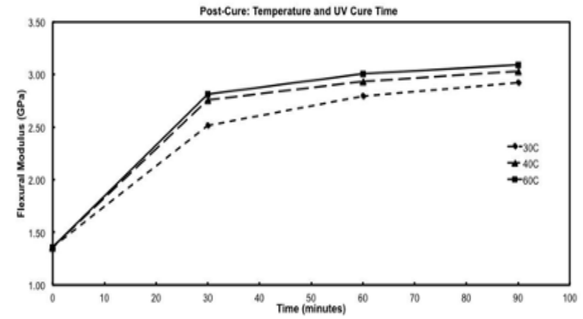


**Figure 7.**

- Increasing temperature as well as time of UV post-curing causes an increase in the Flexural Modulus (**Figure 7.**)
- Optimal modulus is reached when temperature is 40°C to 60°C from 60 to 90 minutes.
- Flexural modulus increases due to an increase in the kinetics of the unreacted monomer therefore resulting in a higher degree of conversion (6).

## CONCLUSION / FUTURE WORK

- Samples that had the force applied perpendicular to the direction that they were built in resulted in the highest flexural strength.
- Smaller layers and post-curing may be used to create strong dental models that are able to withstand the mechanical stress of surgery or overnight guards.
- Future work, the adhesion between layers should be studied and a different dental resin should be used to see if orientations results are the same.

## REFERENCES

1. Thareja, P. Mechanical Engineering Needs to Pursue Excellence. Journal of Advanced Research in Mechanical Engineering and Technology 2019, 06 (1&2),
2. Ventola, C. L. Medical Applications for 3D Printing: Current and Projected Uses https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4189697/
3. J. Jockusch and M. Özcan, "Additive manufacturing of dental polymers: An overview on processes, materials and applications," Dent. Mater. J., 2020, doi: 10.4012/dmj.2019-123.
4. B. C. Aguirre, J.-H. Chen, E. D. Kontogiorgos, D. F. Murchison, and W. W. Nagy, "Flexural strength of denture base acrylic resins processed by conventional and CAD-CAM methods," J. Prosthet. Dent., vol. 123, no. 4, pp. 641–646, Apr. 2020, doi: 10.1016/j.prosdent.2019.03.010
5. ASTM International. D790-17 Standard Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials. West Conshohocken, PA, 2014.
6. P. Kardar, M. Ebrahimi, and S. Bastani, "Influence of temperature and light intensity on the photocuring process and kinetics parameters of a pigmented UV curable system," J. Therm. Anal. Calorim., vol. 118, no. 1, pp. 541–549, Oct. 2014, doi: 10.1007/s10973-014-3984-z.

## ACKNOWLEDGEMENTS

This research was supported by the National Institute of General Medical Sciences of the National Institutes of Health under Award Numbers; UL1GM118979; TL4GM118980; RL5GM118978. The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health.