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Influence of SLA Printing Parameters on the Mechanical Performance and Printing Efficiency of Dental Photopolymer Resin

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ABSTRACT

Stereolithography (SLA) is widely used in dental additive manufacturing due to its high dimensional accuracy, good surface finish, and ability to fabricate customized complex geometries. However, the performance of SLA-printed dental components is strongly influenced by printing parameters, particularly layer thickness and build orientation. This study investigated the effects of layer thickness and build orientation on the printing efficiency, dimensional accuracy, and tensile properties of dental photopolymer resin fabricated using SLA technology. Tensile specimens were printed using three-layer thicknesses of 25, 50, and 100 μm and three build orientations: perpendicular, vertical, and horizontal. Printing time, resin consumption, dimensional error, ultimate tensile strength (UTS), and Young's modulus were evaluated. The results showed that decreasing the layer thickness increased printing time due to the higher number of printed layers and repeated curing/separation cycles, while resin consumption was mainly affected by build orientation and support structure. Dimensional accuracy was orientation-dependent, with vertical specimens showing higher width error and horizontal specimens showing higher thickness error. For tensile properties, the highest strength and stiffness were obtained from the specimen printed with 50 μm layer thickness in the vertical orientation, which showed the highest UTS of 60.42 N/mm² and Young's modulus of 818.04 N/mm². This improvement was attributed to more effective tensile force transfer along the loading direction. Overall, the 100 μm layer thickness is suitable for reducing printing time, while the 50 μm vertical condition is recommended for improving the strength and stiffness of SLA-printed dental photopolymer resin.

Keywords: SLA, dental photopolymer resin, tensile properties, layer thickness, build orientation, additive manufacturing

1. INTRODUCTION

Additive manufacturing technologies have gained significant attention in dental applications due to their capability to fabricate customized components with high precision and complex geometries. Among these technologies, stereolithography (SLA) is widely used because of its excellent surface finish, fine resolution, and ability to produce highly detailed dental structures such as surgical guides, orthodontic appliances, and temporary restorations [1].

SLA technology operates through the layer-by-layer photopolymerization of liquid resin using ultraviolet (UV) light. The mechanical performance of SLA-printed components is strongly influenced by process parameters, particularly layer thickness and build orientation. Layer thickness affects interlayer bonding and printing resolution, while build orientation influences stress transfer behavior and anisotropic mechanical properties during tensile loading [2]. Previous studies reported that stereolithography-fabricated polymers exhibit directional dependence in tensile properties due to layer stacking orientation and curing strategy [3]. However, limited studies have focused specifically on the influence of SLA printing parameters on dental photopolymer resin.

Therefore, this study aims to investigate the influence of layer thickness and build orientation on the mechanical performance of dental photopolymer resin fabricated using SLA technology.

2. MATERIALS AND METHODS

2.1 Photopolymer Resin

The material used in this study was a commercial dental photopolymer resin obtained from Formlabs. The resin is primarily composed of acrylate monomers, acrylate oligomers, and photoinitiators, which are suitable for stereolithography (SLA) additive manufacturing processes. The photopolymer resin was used as the printing material for fabrication of all tensile test specimens. The mechanical properties of the photopolymer resin provided by the manufacturer are summarized in Table 1.

Table 1. Mechanical properties of Photopolymer resin dental model [4]

Properties	Values
Tensile strength	61 N/mm^2
Elongation at break	5 %
Elastic modulus	2,500 N/mm^2
Flexural strength	95.8 N/mm^2
Flexural modulus	2,300 N/mm^2

2.2 SLA and processing parameters

The tensile test specimens were designed according to ASTM D638 standard using computer-aided design (CAD) software and exported in STL format for printing preparation. The specimens were fabricated using a commercial stereolithography (SLA) 3D printer (Formlabs 3) as shown in Fig1.

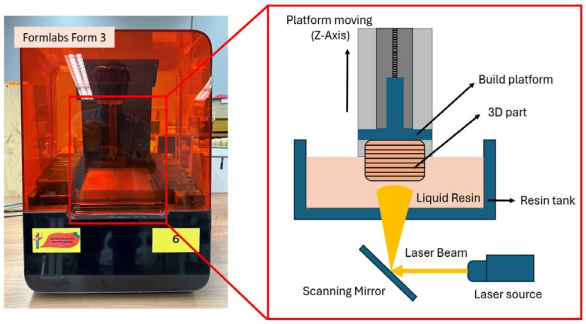


Figure 1. Formlabs Form 3 3D printer and the stereolithography process

The influence of SLA printing parameters on the mechanical performance of dental photopolymer resin was investigated using two primary process parameters layer thickness and build orientation. Three levels of layer thickness were selected, consisting of 25 µm, 50 µm, and 100 µm. In addition, three different build orientations were investigated, including perpendicular, vertical, and horizontal orientations. A total of nine experimental conditions were designed, with three replicates for each condition, as summarized in Table 2.

Table 2. SLA processing parameters used in this study

Sample	Layer Thickness	Build Orientation
S1	100 µm	Perpendicular
S2		Vertical
S3		Horizontal
S4	50 µm	Perpendicular
S5		Vertical
S6		Horizontal
S7	25 µm	Perpendicular
S8		Vertical
S9		Horizontal

After fabrication, all printed specimens were cleaned using isopropyl alcohol (IPA) to remove uncured resin from the surface and subsequently post-cured under ultraviolet (UV) light according to the manufacturer's recommendations to ensure complete polymerization prior to tensile testing.

2.3 Printing Efficiency Measurement

Dimensional accuracy was evaluated by measuring the width and thickness of the printed specimens using a digital Vernier caliper. The measured values were compared with the designed CAD dimensions, and the percentage error was calculated. Printing time and resin consumption were obtained directly from the slicing software based on the selected layer thickness, build orientation.

2.4 Mechanical Properties Testing

To evaluate the mechanical behavior of the SLA-printed dental photopolymer resin, tensile tests were performed using a QC-506M1 universal testing machine at room temperature. The specimens were prepared in accordance with the ASTM D638-14 standard (Type IV geometry), and the crosshead speed was set to 5 mm/min. The tensile strength, and Young's modulus were recorded for all samples to evaluate the influence of SLA printing parameters on the mechanical performance of the fabricated specimens. Experimental setup for tensile testing is shown in Fig2.

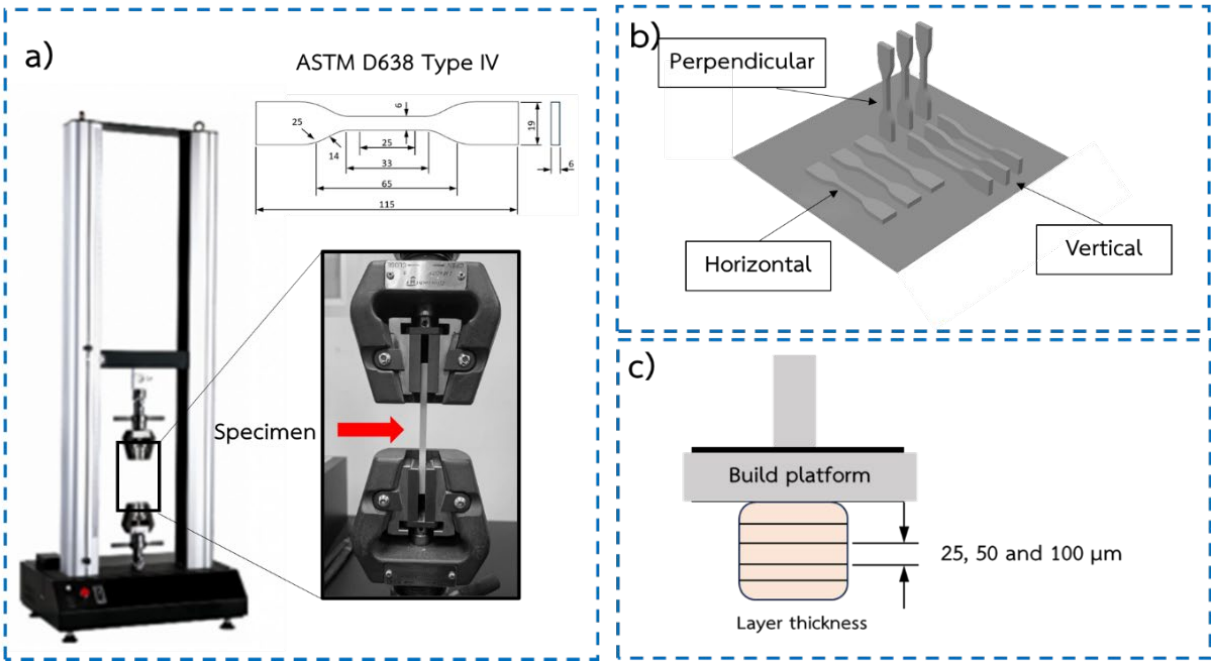


Figure 2. a) Experimental setup for tensile testing and schematic illustration of b) build orientations and c) Layer Thickness SLA-printed parameter

3. RESULTS AND DISCUSSION

3.1 Printing Time and Resin Consumption

The printing efficiency results showed that layer thickness strongly affected printing time. The 25 µm layer thickness required the longest printing time because it increased the number of printed layers and repeated curing/separation cycles, as shown in Fig. 3. In contrast, the 100 µm layer thickness provided the shortest printing time due to the lower number of layers. Resin consumption was mainly influenced by build orientation. Specimens printed in orientations requiring more support consumed more resin, even though the specimen geometry was identical. Therefore, reducing layer thickness increased printing

time, while build orientation mainly controlled resin consumption.

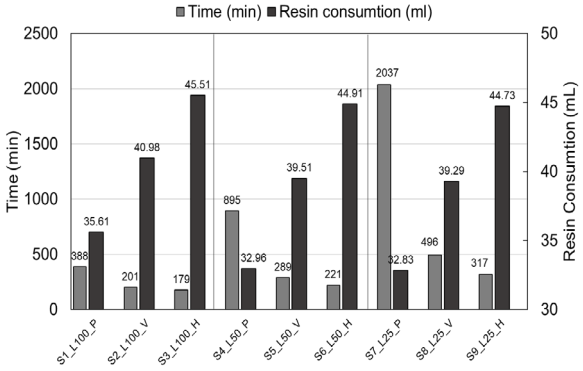


Figure 3. Printing time and resin consumption of SLA-printed dental resin specimens with different parameters

3.2 Dimensional Accuracy

Dimensional error influenced by adhesion force during the layer separation process. According to Stefan adhesion [5], a larger contact area between the cured layer and the window can generate a higher separation force. This repeated pulling force during printing slightly deforms the specimen in the direction associated with the build orientation or larger projected area [6]. This explanation agrees with the present results, where the Vertical orientation showed higher width error, while the Horizontal orientation showed higher thickness error, as illustrated in Fig. 4. Therefore, the dimensional deviation of SLA-printed dental resin specimens was orientation-dependent [6], and the dimension affected by layer separation force tended to show error.

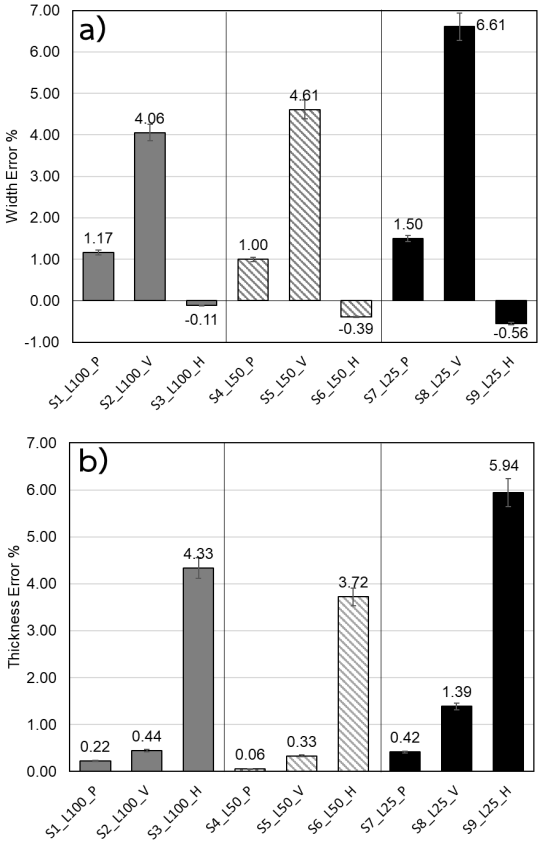


Figure 4. Dimensional accuracy of SLA-printed dental resin specimens fabricated with different parameters (a) width error % and (b) thickness error%

3.3 Effect of SLA Parameter on Ultimate Tensile Strength (UTS) and Youngs modulus

The highest UTS was obtained from S5 (60.42 N/mm²). A similar trend was observed for Young's modulus, where S5 also showed the highest value of 818.04 N/mm², as illustrated in Fig. 5. This suggests that the 50 µm layer thickness with Vertical orientation provided the best combination of strength and stiffness. This improvement can

be attributed to the ability of the Vertical orientation to absorb and transfer tensile force more effectively along the loading direction, thereby increasing resistance to deformation and crack propagation [7].

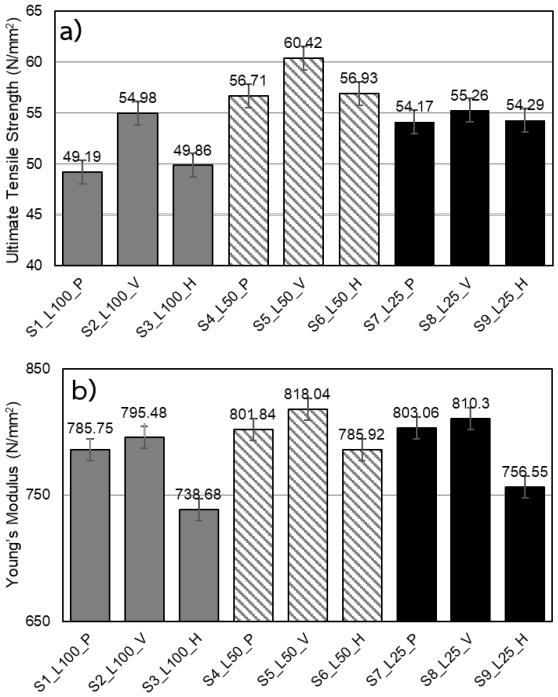


Figure 5. Tensile properties of SLA-printed dental resin specimens fabricated with difference parameters (a) ultimate tensile strength and (b) Young's modulus

4. CONCLUSIONS

This study investigated the influence of layer thickness and build orientation on the printing efficiency, dimensional accuracy, and tensile properties of SLA-printed dental photopolymer resin. The key findings are:

Decreasing the layer thickness increased the printing time. Therefore, the 25 µm condition required the longest printing time, while the 100 µm condition provided the shortest printing time. Resin consumption was mainly influenced by build orientation due to the different support structure requirements.

Dimensional accuracy was dependent on orientation. The Vertical orientation resulted in higher width error, whereas the Horizontal orientation resulted in higher thickness error.

For tensile properties, the best performance was obtained from S5, printed with 50 µm layer thickness and Vertical orientation, which showed the highest UTS of 60.42 N/mm² and Young's modulus of 818.04 N/mm². This was due to better force transfer along the loading direction, which improved strength and stiffness.

5. ACKNOWLEDGMENTS

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6. REFERENCES

1] Revilla-León M, Özcan M. Additive manufacturing technologies used for processing polymers: Current status

and potential application in prosthetic dentistry. J Prosthodont 2019; 28:146-158.

[2] Ngo TD, Kashani A, Imbalzano G, Nguyen KTQ, Hui D. Additive manufacturing (3D printing): A review of materials, methods, applications and challenges. Compos Part B 2018; 143:172-196.

[3] Chantarapanich N, Puttawibul P, Sitthiseripratip K, Sucharitpwatskul S, Chantaweroad S. Study of the mechanical properties of photo-cured epoxy resin fabricated by stereolithography process. Songklanakarin J Sci Technol 2013; 35:91-98.

[4] Formlabs Inc. Dental Model: material data sheet. FLDMBE02 [Internet]. Somerville (MA): Formlabs Inc.; 2017 Feb 10 [cited 2026 May 19]. Available from: https://formlabs.com

[5] NewPro3D. Effects of print window material on separation force of 3D printed objects in DLP SLA printing processes [Internet]. NewPro3D – Forcast Research & Development Corp.; 2018 May 17 [cited 2026 May 19]. Available from: https://wiki.ubc.ca/images/f/f5/Pull_Force_Testing_-_Lab_Report_v4.pdf

[6] de Castro EF, Nima G, Rueggeberg FA, Giannini M. Effect of build orientation in accuracy, flexural modulus, flexural strength, and microhardness of 3D-Printed resins for provisional restorations. J Mech Behav Biomed Mater. 2022; 136:105479.

[7] Pandzic A. Influence of layer height, build orientation and post curing on tensile mechanical properties of SLA 3D printed material. Ann DAAAM Proc Int DAAAM Symp 2021;32(1):200-208.