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Effect of Post- processing Time and Temperature on the Flexural Strength for DLP 3D-Printing Materials

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Abstract

The use of three-dimensional (3D) printing in dentistry is appealing, parts made from acrylic-based 3D-printed resin must go through the same light and thermal treatment post-curing procedures to improve their mechanical qualities. This study aims to evaluate the effect of post-curing process by using many degrees from different temperatures and multiple times on the bending strength of 3D printer resin.

Twenty-eight samples were fabricated in the current study; the restoration was accomplished through the creation of an STL file using the AutoCAD program and then sent to the program of printer.

ASIGA DentaBASE resin at a wavelength of 385-405 nm was used for 3D printing to create samples placed at a right angle to the platform. Post-curing temperatures both 40ºC and 60ºC for times that vary (15 min and 30 min), then evaluated flexural properties, the results showed that the post-curing temperature have significant effect on bending strength. The flexural was **130.97±7.2** MPa (mean ± standard deviation) in the group treated at 60 ºC for 30 min, more than the values in other groups. The results of this study validate that the post-curing temperature was influenced by the bending property of 3D printed resin, while post-time had no effect except for initial post-curing (15 min).

Introduction:

Three-dimensional printers are now easier to work with , more affordable, lighter, and more reasonably sized than they were short while ago (1). They can contribute to producing multiple structures or complex during the same time (2) Popularity used 3D printers in the dentistry restoration and other dental applications are based on the digital light processing (DLP) or stereolithography (SLA) method. In each method, the object forms in layer by layer from a photopolymer. In DLP, a digital projector light, in SLA, employ a laser light track is utilized to actively polymerize the resin, whereas through all layers to building the 3D structures (3) The main structures of photopolymer material are monomers, oligomers, and photopolymerization initiators (4). Dental restorations are affected in the human oral by stresses, such as parafunctional habits and chewing energy. One crucial characteristic of dental materials that reveals their mechanical behavior is flexure strength. Therefore, it is crucial to research the flexure strength of resin printed resins (5). There are three categories of elements that might have an impact on a resin- printed flexural strength: preprinting, printing, and post-printing variables. Reinforcing compounds are added to the 3D-printed resin as preprinting factors. Printing characteristics including layer thickness, printing direction, using a third party, and where printed items are placed on the printing part platform are examples of printing factors. The post-processing parameters the times and use temperature used in the curing unit are post-printing variance (6). The idea of the post-curing treatment is to raise the quality of the printing of the prosthesis. When the 3D printer starts building the component, it produces approximately eighty percent of the entire polymerization. Post-curing is required to complete the twenty percent that remains with a standard UV source curing unit and object can reach their optimum strength (7). To accomplish complete and homogeneous polymerization of the unreacted monomers, the photo-resin polymerized resin undergoes a second heat treatment step in a box equipped with an ultraviolet light source. The three-point (bending test) was originally developed to represent the flexural pressure on a denture experienced during eating (8). Bending highlights, the material's durability before yielding, characterized by its flexibility strength. The base of dentures is prone to fracture when loaded dynamically or statically. Consequently, the highest flexural strength score are clinically significant to enhancing the base fracture resistance (9, 10). Based on flexure force is important to determine the ability of a material to resist fracture during mastication and fabricating dentures (11). This study was carried out to investigate the influence of post-curing duration and temperature on material characteristics that were manufactured by 3D printers and printing methods.

Material and Methods

Specimens' grouping

In present study, a total of (28) specimens were made from Denta BASE ASIGA resin (Sydney, Australia) and the work subject or divided into four groups each group consist of 7 Specimen depending on post-curing temperature and time. The of (AUTOCAD) software allowed the specimens to be designed and printed to achievement the mechanical test, with strip 3×10×60 mm for properties (12). The samples plans were saved in a limited program named an STL file and then converted or transmitted to the 3D printing system (13, 14).

Printing steps

In the first step, object file is transmitted to the printer composer (SIGA max printer, Australian) and printed the samples with a ninety-degree angle to the platform this observed in Fig.(1.A) (15). After completed the work in side printing. Open the cover and the sample was lift from the platform by special equipment then the sample was washed with Isopropanol 99.9 to get rid of the uncured monomer and improve biological properties (13). The sample was washed in two steps, each step 2 min with new solution according to the recommendation in ultrasonic then was left in open air for 30 minutes to dry this can be seen in Fig.(1.B) before post-curing (16, 17).

Post-curing

To obtain good mechanical and physical properties has been done by post-curing of each group in the form cure equipment form lab USA, compatible with 405 nm Ultraviolet by projector energy 39 W, with applied at temperature degree (40°C or 60°C) and time (15 and 30) min immersion in vat filled with pure glycerin (18).

Flexural strength test

The processing of product objects according to the ISO 20795-1 standard, 28 bar specimens each group (n = 7) were kept at 37 ºC for 48 h before testing. A universal testing device (model czl203-JIANQIAO) with a crosshead speed of 5 mm/min was used to load them as shown as in Fig (2). All specimens were set up on two parallel supports that had a span length of 50 mm between them. The highest force applied prior to fracture was measured in newtons, and the specimen was subsequently uniaxially stressed until it broken. the flexural in mega Pascal's as follows (19)

FS = 3FL/ (2bd2)

F is the force used to fracture the sample that occurred, (L) the distance among the start supports, (d) is height(thick) of the sample (b) the width of a specimen.

Statically analysis

The results were evaluated using a statistical analysis method involving descriptive statistics (mean value, standard deviation, maximum and lowest values of the transverse test, as well as a bar chart for mean values and comparison test type (Tukey) tests in statistical analysis and Excel 2013 for visual representation, as well as IBM SPSS statistical program version 25.

Results

Table (1) summarizes a bending strength result at tests in the current study, additionally Figure (3) displays a descriptive statical graph with bars denoting the standard deviations, mean distribution, standard error, maximum, and minimum in the testing group that produced the values for the flexural strength test contact to (28) samples. Table (1) recorded the flexural strength values for all samples and displayed the statical descriptive flexural strength test results for four testing groups. Group 60°C-30min had the higher average value (130.97) MPa, followed by groups 60°C-15min, 40°C-30min, and 40ºC-15min (130.6, 118.4, and 115.53 MPa, respectively), depending on the Table (1). Table (2) summarizes the outcomes of one-way ANOVA testing to determine if there was a statistically significant difference among and within groups. According to the table data, the difference in bending strength values between each (four) groups below the test appeared to be statistically significant.

The Tukey comparison test was employed to determine the mean outcomes of diverse groups., as appeared in Table (3), with group temperature and time (40ºC15min, 60ºC15min, 40C30min and 60ºC30min) a significant difference in comparison between 40ºC15 to (60ºC15min and 60ºC30min) groups but not significant to 40C30min, also significant difference when compared between 40ºC30min to (60ºC15min and 60ºC30min), and last not significant between 60ºC15min and 60ºC30min in the Tukey test.

Discussion

Flexural strength shows the degree of a material's resistance to fracture when subjected to static loads (20). The qualities of the product are often enhanced by post-processing after 3D printing. It may also be thought of an extension of the curing or reaction that began during printing, though (21). Gradually increasing the 3D printed specimens' flexural strength until 60ºC at 30 minutes group of post-curing temperature, as shown in Table (1), higher temperatures would hasten polymerization through stimulating free radical diffusion and so raising the likelihood of their reacting throughout the specimen (22) The results of the present study of post-curing temperature supported or agreed with Nam et al. they observed improved diffusion of residual monomers (23) while the result of the effect post-curing time on the flexural strength disagrees with Byarsaikhan,et al. while Byarsaikhan et al. study results represent a statically significant increase gradually (24) Also, agree with (25) those who studied the effect of post-curing time on mechanical properties for different materials at different time, Kim et al. reached that the post-curing duration have not significant effect (25) .

Conclusion

This study examined how the time of the post-curing time and temperature affected the mechanical (flexural strength) characteristics of photo sensitive resin utilized for 3D printing. The following conclusions made given the constraints of this study:

(1) The flexural properties are significantly enhanced by raising the post-curing temperature.
(2) The time post-curing not affected significantly on flexural strength.

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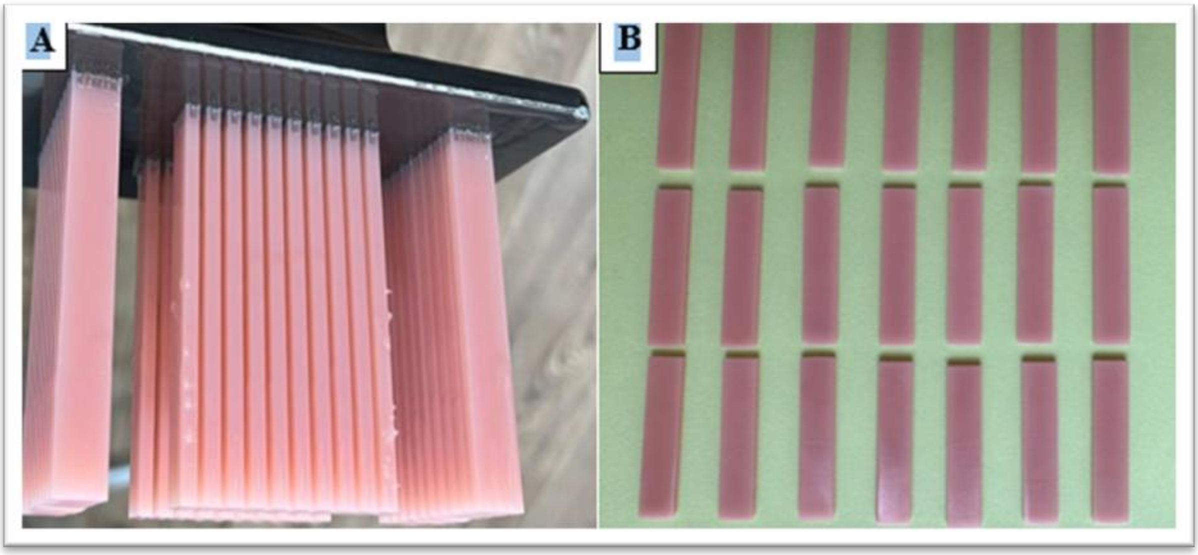

Fig.1 (A) Samples after printing , B - Samples left to dry before post curing

Fig.2. Flexural strength samples using universal apparatus for testing

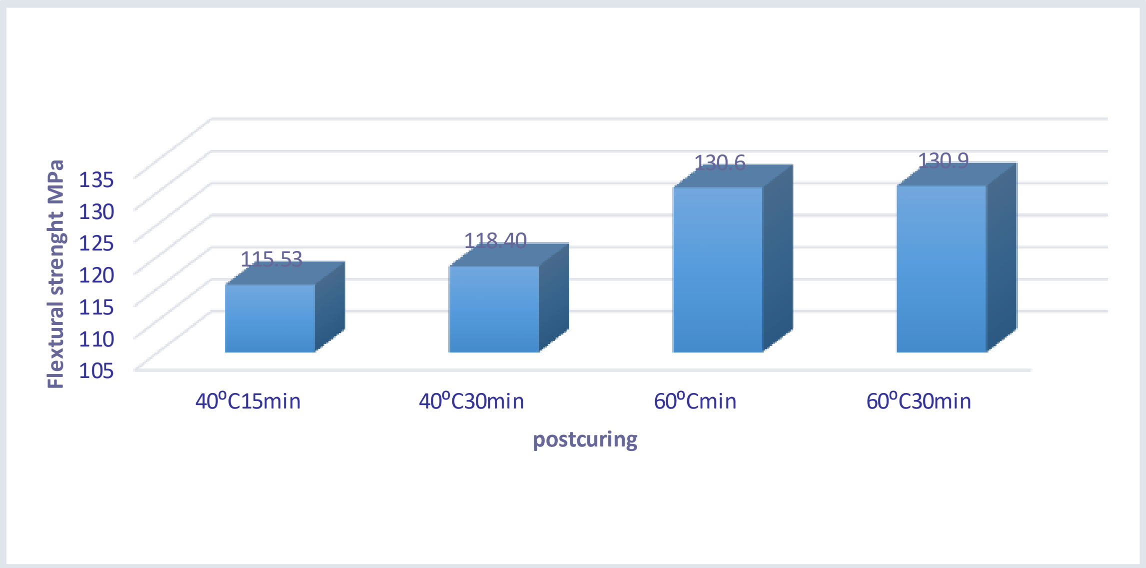

Fig 3. The bar chart depicts the mean distribution of flexural tests among the examined groups

Table 1. Descriptive statistics of flexural strength

Groups	**N.**	**Mean.**	**Std. Deviation.**	**Std. Error**	**Min**	**Max**
40C15 min	**7**	**115.5357**	**5.77152**	**2.18143**	**106.61**	**122.25**
40C30min	**7**	**118.4086**	**5.12145**	**1.93573**	**109.15**	**124.10**
60C15min	**7**	**130.6886**	**7.53281**	**2.84713**	**120.08**	**140.08**
60C30min	**7**	**130.9757**	**7.23942**	**2.73625**	**122.81**	**140.46**
Total	**28**	**123.9021**	**9.40060**	**1.77655**	**106.61**	**140.46**

Table 2. One-way ANOVA test evaluating the flexural strength

	Sum Squares	df	Mean Square.	F	Sig.
Between Groups.	1373.872	3	457.957	10.859	.000
Within Groups	1012.153	24	42.173		
Total	2386.025	27			

Table 3. Tukey test

Group		Mean Difference	Sig.	95% Confidence Interval	
				Lower Bound	Upper Bound
40C15 min	40C30min	-2.87286	.841	-12.4486	6.7029
	60C15min	-15.15286*	.001	-24.7286	-5.5771
	60C30min	-15.44000*	.001	-25.0158	-5.8642
40C30MIN	60C15min	-12.28000*	.009	-21.8558	-2.7042
	60C30min	-12.56714*	.007	-22.1429	-2.9914
60C15min	60C30min	-.28714	1.000	-9.8629	9.2886

Abbreviation

3d- printer	Three-dimensional printer
STL	Stander tessellation language
min	minute
Sig	significant
W	watt
Cº	Celsius
Fig.	Figure
MPa	Mega Pascal
Std.	Stander deviation
ANOVA	Analysis of variance
DF	Degree of freedom
UV	ultraviolet
SPSS	statistical package for the social science

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