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Some Properties of 3D Printed Acrylic Resin Material Modified by Antifungal Vitis Vinifera Oil

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Abstract

Objective: The aim of the study was to study the consequences of different ratio of Vitis vinifera oil on the surface hardness, surface roughness and color change of 3D printed resin material**.**

Material and Methods: 80 samples have been intended according to ADA specification 40 samples for hardness and roughness test and 40 samples for color change test, these two groups subdivided into four groups based on Vitis vinifera oil concentration 1%, 2%, 3% and control group without adding oil (0%). For each group, 10 specimens were prepared from 3D printer acrylic resin denture base, hardness was tested by shore D tester, Roughness test was done by TR 200 portable tester and color change test by spectrophotometer.

Results: The control group recorded the maximum mean value for hardness and 3% Vitis vinifera recorded the lowest value, while for roughness and color test the minimum value recorded by control and 3% Vitis vinifera oil showed the maximum value for them, for all test the differences between control and 1% were not significant, but there were significant differences with 2% and 3%.

Conclusion: The addition of 1% Vitis vinifera oil (antifungal oil) showed no adverse effect in hardness, roughness and color change value of 3D printer acrylic resin in comparison to control group.

Keywords: Vitis vinifera oil, 3D printer acrylic resin, properties.

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Introduction

The non-metallic materials using in manufacturing of dentures have a long tradition in dentistry [1,2]**.** Recent advancements in 3D printing had utilizing resin as a key component for creating objects through a layering process were the speed, flexibility, competitive and tangible design were some of its advantages [3,4]. 3D-printed resin exhibited inferior properties such as strength, hardness, increased candida adhesion and roughness of surface in in comparison to the heat-polymerized resin [5-7]. However, studies and a notable challenge demonstrated to advance their properties and susceptibility to fungal growth, compromising their integrity by incorporating different additives that will improve properties of 3D-printed materials. Delves into the innovative integration of antifungal oil into 3D printer resin, focusing on the consequential evaluation of resin properties. Discern the effects of this incorporation, providing valuable insights for applications that demand 3D-printed materials with heightened on the advancement of its properties. The 3D FLEXO Denture Base V2 3D Printer Resin is a specialized

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material designed for use in 3D printing applications, particularly in the production of denture bases. According to the manufactural of this material this resin is specifically formulated to provide the necessary properties and characteristics required for the fabrication of high-quality dentures using 3D printing technology.

Vitis vinifera seed extract encompass proanthocyanins, which have been assessed for different health conditions [8,9], have many medicinal uses and indications used to treat a range of health problems and to protect against bacterial infections [10-12]. Also, it minimizes degradation of collagen and thus could have the potential in holding up the periodontitis progression [13] and had most beneficial antifungal activity that prevent adhesion of *C. Albians* to the denture base material [14,15]. No study concerning the addition of Vitis vinifera oil to 3D printer acrylic has been done. Taqa et al. [16] demonstrated the effect of incorporation of grape oil into cold acrylic material and showed that incorporation of (2.5%) oil into cold cured acrylic showed significant decrease in transverse strength in comparison with a control group. It also showed significant difference in lightness in different concentrations (1.5%, 2%, 2.5%).

The 10% w/w of the same oil when incorporated to soft liner mainly improved the antifungal effect and tensile bond strength of the soft lining material that attached to the base of the denture material not compromising the surface roughness of the liner material [14]. Hardness was one mechanical property which had the ability to resist to abrasion forces (scratching, and/or penetration), without deformation [17]. A rough surface exhibited most retention of microorganisms which compromised the longevity of this material [18]. Color and transparency were aesthetic properties of 3D printed resin that can influence the visual appeal and functionality of the printed prosthesis [19].

This study specifically aims to evaluate the surface hardness, surface roughness and color change of 3D printed resin after incorporating with different concentration of antifungal oil (Vitis vinifera) focusing on determining the optimal oil percentage without compromising these properties, hypothesizing an improvement in properties. Despite potential benefits, there was a gap in research regarding this impact on properties of 3D resin.

Material and Methods

Preparation of test specimens

The design of specimens for surface hardness, surface roughness and color change were done according to specification for that test and materials. The design of surface hardness and surface roughness were the same which was rectangular shaped according to (ADA No.12, 1999)[20] the dimensions was (65x10x2.5 mm) length, width and thickness subsequently as seen in Figure 1A, while for color change the sample as disc, with dimensions of (50 ± 1mm in diameter and 0.5 ± 0.05 mm in thickness) according to ADA specification No.12, 1999 [20] (Figure 1B).

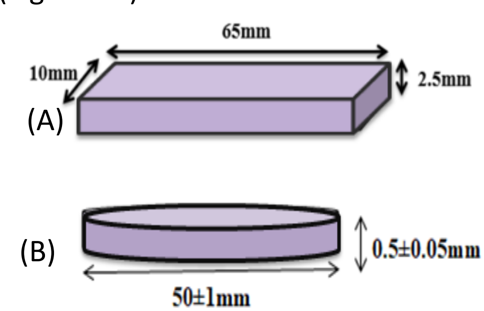

Figure 1. Specimen design. A surface hardness, surface roughness; B color change.

Specimens grouping

80 samples were prepared for this study constructed from (3D Flexo Denture Base V_2 resin, Germany) 40 samples for hardness and

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roughness test and 40 samples for color change test, these two groups subdivided into four groups depended on Vitis vinifera oil concentration 1%, 2% , 3% and control group without adding oil (0%) for each group, 10 specimens were prepared (Table 1).

Table 1. Percentage of Vitis vinifera oil mixed with 3D printed resin.

Vitis vinifera Oil % group	3D printed Resin	Vitis vinifera oil (ml)
Control (0%)	100 ml	0 ml
Vitis vinifera oil (1%)	99 ml	1 ml
Vitis vinifera oil (2%)	98 ml	2 ml
Vitis vinifera oil (3%)	97 ml	3ml

Software Design

The specimens were designed by using the CHITUBOX software before printing. The sample data were saved as STL file (Standard Tessellation Language) to measure the mechanical and physical property tests according to ADA specification [20], with a rectangular 2.5× 10× 65 mm^3 (±0.2 mm) for surface hardness and surface roughness while as disc its dimensions 50 ± 1mm in diameter and 0.5 ± 0.05 mm in thickness for color change, then STL file imported into the 3D printing software (Phrozen 3D printer, Taiwan) according to device instructions.

Printer processing

The file was exported to 3D printer software (Phrozen 3D printer, Taiwan) (Figure 2) and printed. After completed the printing (Figure 3 A,B,C), when the samples were removed from the platform stage then the support structure was cut from the samples and the samples was washed by ethanol 99% (Italy) in an ultrasonic device cleaner (Bella gusto, China) (Figure 4), for 2 minutes, to remove the excess monomer based on the instruction of manufactural then left in air for thirty minutes for drying prior of post curing.

Figure 2. Printing procedure while cover of printer closed.

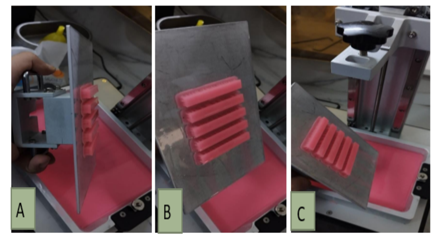

Figure 3(A, B, C) Final printed specimens at the printer plate.

Figure 4. Ultrasonic cleaner device.

Post-curing procedure

After printing process each 3D printing resin group subjected to post- curing that they were placed in the UV curing chamber for 10 minutes according manufacturer instruction of resin. After completed post-curing stage, polishing disk dental burs are used to polish all specimens. all specimens prior to testing were put in an incubator temperature was 37^{o}C for 48 hours as claimed by ISO 20795-1 [21].

Shore D hardness test

The Shore D hardness tester was used (China), according to ISO7619 (ASTMD 2240). The device was vertically placed over the specimen, which was

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encouragement on horizontal, rigid base. The distance from the indenter of hardness tester and the specimen surface was around 5to 12mm. The contact period from the specimen surface to the indenter was six seconds. For each specimen, approximately five hardness measurements were obtained from the scale reading value, then the mean of these values was computed [22,23].

Surface roughness test

Rectangular shaped specimen printed the dimensions was 65x10x2.5 mm length, width and thickness subsequently by printer. Surface roughness test was performed using surface roughness profilometer tester (TR200) with 0.001 micrometer accuracy at the University of Technology, Materials Engineering Department. This tester contained a diamond sensitive needle (stylus) using to track the irregularities on the surface. Three separated locations on the specimen's surface were just touched by the stylus to have three readings for each sample, so according to profilometer instructions; the sample was located on a stable, rigid surface and the stylus should be allowed to contact the first point, then it was moved for 11 mm across the sample, the readings appeared on the digital scale in a spontaneous manner. Later, a roughness values were determined by calculating the mean values of these reading in µm [24,25].

Color change test

An objective method used for evaluation the color change via measuring the amount of absorbed light percentage was performed by using UV –visible spectrophotometer [26]. Specimens were placed on the outlet light of the device and subjected to light, absorbing light percentage was obtained at device screen. The instrument then auto zeroed with nothing in the sample across the working range to establish a baseline. Spectrophotometer Shimadzu used in the study measures the wavelength that range from 190 – 1100 nm; by measures intensity of light through a sample (I) and comparing with the intensity of light before passes through the sample (Io). The absorbance (A) was expressed in a percentage (%) [27,28].

Results

Surface Hardness Test

The descriptive statistic as showed in Table 2, showed that the hardness of 3D printer resin decreased significantly with the addition of Vitis vinifera oil. the control group (without oil) recorded the maximum hardness value the average hardness was 33.1875. The average hardness decreased even further in groups D (3% oil), to 31 (minimum hardness value).

Table 3 showed post hoc analysis for action of Vitis vinifera 1%, 2% and 3% concentration on hardness test of resin materials, the differences were significant between all groups excluding between: (control with1% oil) and (2% oil with 3% oil) the differences was not significant $p > 0.05$.

Surface roughness test

Table 4 showed the descriptive analysis of all groups. Control group showed the minimum mean value for roughness test while the group 3% recorded the maximum mean value for roughness test. ANOVA test showed the differences was significant among groups (p-value ≤ 0.0001).

Table 5 showed post hoc analysis for the action of Vitis vinifera 1%, 2% and 3% concentration on roughness of resin materials, the differences were significant between all groups excluding between control with 1% oil and 2% oil with 3% oil ($p > 0.05$).

Color change test

Table 6 showed the descriptive analysis of all groups control group recorded the minimum mean value for color change while 3% oil recorded the maximum mean value for color change.

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Table 2. Descriptive and ANOVA analysis for the action of visit vinifera with different concentration on surface hardness test.

Groups	N	Mean	Std. Deviation	Std. Error	Minimum	Maximum	P-value ANOVA test
Control	10	33.1875	1.28000	.45255	31.00	34.50	0. 001
1%	10	33.0625	1.76144	.62276	30.00	35.50	
2%	10	31.1250	.95431	.33740	29.00	32.00	
3%	10	31.0000	.80178	.28347	29.00	32.00	

Table 3. Post hoc analysis for the action of visit vinifera with different concentration on hardness test.

(I) groups	(J) groups	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Control	1%	.12500	.62623	.843	-1.1598	1.4098
	2%	2.18750*	.61623	.002	.9027	3.4723
	3%	2.06250*	.62523	.003	.8877	3.4463
1%	2%	2.06250*	.62733	.003	.7777	3.3473
	3%	1.93750*	.61724	.005	.6527	3.2223
2%	3%	-.12600	.63423	.844	-1.4098	1.1598

*. The mean difference was significant at the 0.05 level.

Table 4. Descriptive and ANOVA analysis for the action of Vitis vinifera oil with different concentration on roughness test.

Groups	N	Mean	Std. Deviation	Std. Error	Minimum	Maximum	ANOVA P-value
Control	10	.1931	.06501	.02298	.13	.29	≤0.0001
1%	10	.3190	.13363	.04724	.13	.48	
2%	10	.4863	.11480	.04059	.34	.63	
3%	10	.5355	.18441	.06520	.28	.80	

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Table 5 showed post hoc analysis for the action of Vitis vinifera 1%, 2% and 3% concentration on roughness of resin material.

(I) groups	(J) groups	Mean Difference (I-J)	Std. Error	Sig.	Lower Bound	Upper Bound
Control	1%	-.12588	.05580	.066	-.2607	.0089
	2%	-.34238*	.06580	.000	-.4772	-.2076
	3%	-.29313*	.05470	.000	-.4279	-.1583
1%	2%	-.21650*	.06660	.003	-.3513	-.0817
	3%	-.16725*	.05670	.017	-.3020	-.0325
2%	3%	.04925	.06670	.460	-.0855	.1840

*. The mean difference is significant at the 0.05 level.

Table 6. Descriptive and ANOVA analysis for the action of visit vinifera with different concentration on color changes test.

Groups	No.	Mean	Standard Deviation	Standard Error	Minimum	Maximum	P-value
Control	10	1.434	.28943	0.10233	1.04	1.434	ANOVA ≤0.0001
1%	10	1.4450	.11502	0.04066	1.34	1.68	
2%	10	1.5325	.29198	0.10323	1.08	1.86	
3%	10	1.6588	.03441	0.01217	1.62	1.70	

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Table 7. Post hoc analysis for the action of grape oil with 1%,2%,3% concentration on color changes.

(I) groups	(J) groups	Mean Differences (I-J)	S.E	p-value	95% Confidence Interval	
					Lower Bound	Upper Bound
Control	1%	2.40875*	.10607	.000	2.1894	2.6281
	2%	2.32125*	.10707	.000	2.1019	2.5406
	3%	2.19500*	.10617	.000	1.9757	2.4143
1%	2%	-.08750	.10717	.421	-.3068	.1318
	3%	-.21375	.10708	.056	-.4331	.0056
2%	3%	-.12625	.10618	.248	-.3456	.0931

*. The mean difference is significant at the 0.05 level.

ANOVA test analysis showed the differences were significant among all groups ($p \leq 0.0001$). Table 7 showed post hoc analysis for the action of Vitis vinifera 1%, 2% and 3% concentration on color change of resin materials, the differences were significant between all groups except between: (1% oil with 2% oil) and (2% with 3% oil) the differences was not significant $p > 0.05$.

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Discussion

3-Dimensional printing acrylic improved rapidly, by enhancing reliability, accuracy and carried to apply in the dentistry [29]. The aim of 3D was to produce rapid and functional materials. The 3D printed material was built up layer above layer while build plate was lifted to permit the next layer for curing [30].

Many factors should be kept in control during the processing of 3D printing, the properties were affected via the depth of polymerization, thick layer, volume, direction and shrinkage of the light from the source [31,32]. 3D FLEXO Denture Base V2 resin was used in this study was a medical-grade resin designed specifically for printing dental prosthetic bases. It features unique properties that make it suitable for these applications. However, some disadvantages like poor mechanical properties of resin required strengthening acrylic resin materials properties [33] by adding various reinforcing materials such as fibers, nanoparticles [34-36].
Recently extracts were used to improve the properties of acrylic material, in addition to its antibacterial and antifungal effects [37,38]. Oils plant's extract had wide range for applications in dentistry so using to treat denture stomatitis because effect related to their composition. In this study Vitis vinifera oil used to be incorporated into 3D acrylic resin due to documented and noticeable antimicrobial and antifungal effect in many previous studies [10-12,14,15]. This oil had antibacterial against many organisms including *S. aureus*, *E. coli*, *K. pneumoniae* and *P. aeruginosa* [39]. It derived from the seeds of grapes and has gained attention in various fields due to its unique properties. It is rich in antioxidants, vitamins and acids. This extract had more naturally occurring polyphenolic components that composed of free flavanols monomeric for example the (proanthocyanins) which have anti-inflammatory effect [11]. This study attempted to modify the properties of 3D printed acrylic material by addition of Vitis vinifera oil, which had many applications in wide range felids in pharmaceuticals dentistry.

The measurement of resin hardness played a crucial role in this study, allowing for the assessment of the impact of this oil proportions on 3D printer resin, many factors influencing the hardness of 3D printer resin. Previous studies have indicated that the addition of certain additives could either increase or decrease the hardness of resin, depending on their chemical composition and interaction with the resin matrix. However, none of these studies specifically investigated the effects of Vitis vinifera oil incorporation on resin hardness. Therefore, the present research aims to fill this gap in this study by evaluating the hardness of 3D printer resin after incorporation with this oil. The standardized testing method using a Shore D durometer provided accurate and reliable measurements [40], the addition of this oil to 3D printer resin affects the hardness of the resin. The higher the ratio of Vitis vinifera oil in the resin, the control group recorded the lower the hardness of the resin in the group 1% the hardness was greater than groups 2% and 3%, and the hardness decreased statistically between them, but the statistically differences were no significant between group 1% and control group also in groups 2% and 3%, the hardness was not significant. The presence of this oil may introduce additional chemical bonds or alter the existing ones, leading to changes in the resin's mechanical properties, including hardness. There are several possible explanations for this

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decrease in hardness, Vitis vinifera oil could act as a wetting agent, which might reduce the bonding between the molecules in the resin. Another explanation is that the oil could be a polymerization inhibitor, which could reduce the formation of chemical bonds between the molecules of resin [41] and lead to form less hard resin.

Findings suggest that incorporating Vitis vinifera oil could be a useful tool in the development of 3D printer resins with specific properties. For example, it could help to make 3D printer resins less hard, which might be beneficial in applications that require fracture resistance such as soft lining materials.

The effects of this oil when incorporation into 3D printer resin on the hardness were a significant aspect to consider in resin formulation. This importance had provided an overview of the topic, discussed the mechanisms of oil incorporation, outlined the experimental design and testing procedure, and highlighted the significance of the findings.

Roughness test one of the important method useful to determine the mechanical properties of acrylic resin materials. Roughness is necessary test in prevention microorganism to attached to denture resin base [42]. The results of this study showed that surface roughness increase when concentration of Vitis vinifera oil increased. Although the differences was no significant between control and 1% oil but there were significant differences between control and (2%,3%) oil the unnoticeable increasing of roughness with the oil groups might reveal that the oil coated particles of polymer and this particle coating would decrease the conversion of monomer into polymer that result in high amount of residual monomer, and this residual monomer affect adversely the mechanical properties especially the roughness property [43].

Vitis vinifera oil also could act as a lubricant, which might reduce the friction between the molecules [14]. Another possible reason for increasing roughness might related to flexibility in specimens with high concentration of the oil percentage [14,41]. These results agreed with previous work [14] that showed increasing roughness with 5% Vitis vinifera oil groups incorporated to soft liner acrylic material.
Color Stability was the most important clinical properties because the quality of appearance of prosthesis is very important, feature needed by patients therefore should satisfied their expectation [44]. Color and transparency are aesthetic properties of 3D printer resin that can influence the visual appeal and functionality of the printed objects. Resins are available in a wide range of colors, allowing for the creation of visually appealing objects Both extrinsic and intrinsic factors was responsible for causing color change in acrylic resin material, the intrinsic factor include the discoloration of resin itself and changes in matrix that occur during aging process of material, while extrinsic include stain accumulation [45]. The addition of the oil to acrylic resin increased color test value however, the differences were no significant between: control and 1% oil and this slight increasing not induced change to the point causing degrading the organic matrix and cause staining the increasing in value of color change in the oil groups in comparison to control group might be due to reacted monomer, that coated with the oil they and could protect against light [46]. It is possible that the increasing in color test in group 2% and 3% oil could be because of the oil on the resin structure that could be because of the oil during the thermal

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processing because this oil when was added to the resin it interacts with the polymer matrix, affecting its crosslinking density and overall structure [41]. This result agreed with previous work [16] that showed significant differences in color change of grape oil (1.5%, 2%, 2.5) from standard group when incorporated to cold cured acrylic.

Conclusion

The incorporation of Vitis vinifera oil into 3D printer acrylic showed that the impact of 1% Vitis vinifera oil had no effect on hardness, roughness and color change values.

Conflicts of interest

The authors declare no competing interest.

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