Original Article

Evaluation of the Impact of Rosemary Oil on Specific Properties of 3D-Printed Acrylic Resin Material

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ABSTRACT

Objective: To assess the impact of rosemary oil concentrations (1%, 2%, 3%) on the surface roughness and hardness of 3 dimensional-printed acrylic resin

Study Design: Descriptive study

Place and Duration of Study: This study was conducted at the College of Dentistry, Mustansiriyah University, Iraq, from 1st February 2026 to 31st March 2026.

Methodology: 32 bar-shaped samples with dimensions of (65x10x2.5 mm) length, width, and thickness, which were separated into four main groups (Control group, Group 1%, Group 2%, and Group 3%) based on the concentration of rosemary oil addition.

Results: The surface roughness test had the highest mean value 1.911 after adding 1% rosemary oil, and the lowest mean value 0.883 after adding 2% rosemary oil. The results also showed that the maximum mean value of the surface hardness test was 79.525 after adding 1% rosemary oil, while the lowest mean value was 76.475 after adding 2% rosemary oil.

Conclusion: The addition of rosemary oil at selected concentrations improved the surface characteristics of 3 dimensional-printed acrylic resins by increasing hardness and reducing roughness.

Key Words: Three dimensional-printed acrylic resin, Rosemary oil, Surface roughness. Surface hardness.

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INTRODUCTION

Three-dimensional (3D) printing technology allows the production of complex dental structures with a high level of precision that is difficult to achieve using conventional manufacturing techniques. In addition, it improves efficiency, reduces production time, and provides greater flexibility in the design and fabrication process, making it increasingly popular in prosthodontics[1].

Despite the advantages of 3D printing, acrylic resins used in dental applications still exhibit several limitations. These materials may show reduced surface hardness, which can affect their resistance to wear during clinical use. Moreover, increased surface roughness may promote microbial adhesion and biofilm formation, which can negatively influence oral hygiene and the longevity of dental prostheses[2].

Three-dimensional printed resin exhibited inferior properties such as strength, hardness, increased candida adhesion and roughness of surface in comparison to the heat polymerized resin[3,4]. Surface roughness is an important factor in dental materials, as rough surfaces can facilitate the accumulation of microorganisms and increase the risk of oral infections[5].

Hardness testing is recognized as a simple and effective method of assessing the mechanical properties of polymer-based products. The increased mechanical

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properties, particularly hardness, can be used to improve wear resistance[6].

Recently, natural bioactive agents such as plant-derived essential oils have gained attention in dentistry due to their antimicrobial, antioxidant, and biocompatible properties. These natural substances are considered safer alternatives to synthetic additives and may help improve the biological performance of dental materials[7].

Oral microbial infections can be effectively treated with herbal medicines with little to no adverse effects. As a result, there is a global trend in the direction of studying them in an effort to discover herbal-based, biologically safe drugs with strong antifungal properties[8].

Among these herbal remedies are plant oils. Numerous studies have lately examined the effects of different oils on Candida albicans, and the results indicate that plant oils are a desirable treatment with strong antifungal properties for denture-induced stomatitis[9].

The use of naturally occurring products has recently gained popularity. Essential oils are concentrated hydrophobic liquids with a range of pharmacological properties that are extracted from plants. Because essential oils have antimicrobial qualities, several nations employ them in herbal medicine[10].

Rosemary (Rosmarinus officinalis L.), a prominent medicinal and aromatic herb of the Lamiaceae family, has long been cultivated. Rosemary is believed to have been utilized as a culinary, cosmetic, and medicinal element in ancient Egypt, Mesopotamia, China, and India[11]. This is a plant that is frequently employed in modern medicine. Among the many therapeutic benefits of rosemary are antibacterial and antioxidant qualities[12]. Despite the increasing use of 3D-printed acrylic resins in dentistry, information regarding the influence of natural additives on their surface properties remains limited. Therefore, this study was conducted to investigate the effect of adding rosemary oil at different concentrations (1%, 2%, and 3%) to 3D-printed acrylic resin. Specifically, the study evaluated changes in surface hardness and surface roughness following the incorporation of rosemary oil.

METHODOLOGY

This descriptive study was conducted at College of Dentistry, Mustansiriyah University, Iraq from 1st February 2026 to 31st March 2026 letter No.ERC/S-26-13 dated January 13, 2026. Thirty-two specimens were divided into four major groups: add of oil. (1) Control group: This group comprised of 8 specimens of 3D-printed acrylic with no add of oil. (2) Group (1%): This group comprised of 8 specimens of 3D-printed acrylic treated with 1 ml of rosemary oil. (3) Group (2%): This group comprised of 8 specimens of 3D-printed acrylic treated with 2 ml of rosemary oil. (4) Group (3%): This group comprised of 8 specimens of 3D-printed acrylic treated with 3 ml of rosemary oil. All specimens were prepared for testing, including (surface roughness test and hardness test).

Fabrication of 3D specimen blocks: The designing procedure was done using software Materialise magics (version 24.0; Materialise, Leuven, Belgium), in which the 3D design was created virtually. The design of specimens for surface roughness, hardness had specific dimensions according to specification for that test and materials. The design of surface roughness test and hardness was the same which was bar shaped specimen according to ADA specifications No.12, 1999 with dimensions of (65x10x2.5 mm) length, width, and thickness. The samples were designed by using (HALOT BOX) software before printing, to test the mechanical and physical property tests according to ADA specifications No.12, 1999 with a rectangular bar 2.5× 10× 65 mm3 (±0.2 mm) for roughness and hardness test. The sample plans were saved as STL file then imported into the 3D printing software (Creality/Halote R6).

The file is exported to 3D printer software (HALOT BOX) as shown in figures 1-3 and printed with 90-degree angle. After printing was finished, the samples were taken off the platform and the support structures were cut off. The samples were then cleaned with 99% ethanol in an ultrasonic cleaner to remove the excess monomer (Fig. 4). The samples were washed by two steps; first prewashing 2 minutes and second post washing 2 minutes according to recommendation in ultrasonic and then left in air 30 minutes to dry before post curing.

Each group made from 3D printing resin after printing process was placed in the UV curing chamber for 10 minutes according manufacturer instruction of the resin. After completing post-curing stage, polishing burs and dental disks were used to polish and finish the samples. Polishing was performed on a single surface of every specimen, specifically the surface designated for hardness measurement. The opposite surface was reserved for surface roughness testing and was not polished.

Surface roughness test was performed using surface roughness profilometer tester (TR200) with 0.001 micrometer accuracy at the University of Technology, Materials Engineering Department (Fig. 5). This tester contained a diamond sensitive needle (stylus) used 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 micrometers (μm).

The Shore hardness durometer is widely used to determine the indentation hardness of polymers such as plastics and rubber. The measurement is based on the depth of penetration of a standardized indenter under a defined spring force, which is converted into a hardness value ranging from 0 to 100. For harder materials, the Shore D scale is applied, where a sharper indenter and higher force are used compared to Shore A. The hardness value is inversely related to the penetration depth; thus, harder materials exhibit lower indentation. Standardized testing procedures, including indenter geometry, applied force, and duration of force application, are defined to ensure accuracy and repeatability of results.

A statistical package was used to analyze the data by SPSS-20. Two means were compared using the LSD test and the one-way ANOVA test. A significance level $p<0.05$ was considered significant.

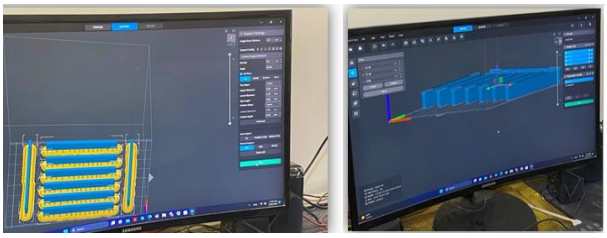


Figure No. 1: 3D printer software



Figure No. 2: (Creality/Halote R6) 3D printing



Figure No. 3: Final printed specimens at the printer plate



Figure No. 4: Ultrasonic cleaner



Figure No. 5: Surface roughness profilometer tester (TR200) with 0.001µm accuracy

RESULTS

The surface roughness test's descriptive statistics is shown in Table 1. The highest mean value of the test was 1.911 following the addition of 1% rosemary oil, while the lowest mean value was (0.883) following the addition of 2% rosemary oil. When one-way ANOVA test was applied, a highly significant ($p> 0.05$) difference in groups value (Table 2). The addition of rosemary oil, the surface hardness test included, the findings showed that the greatest mean value of the surface hardness test was (79.525) after addition of 1% rosemary oil while the lowest mean value of the surface hardness test was (76.475) after addition of 2% rosemary oil (Table 3). One-way ANOVA test was used and indicated a highly significant ($p>0.05$) difference between the group values (Table 4).

Table No. 1: Descriptive statistics for surface roughness

Groups	Mean	Std. Deviation	Std error	Minimum	Maximum
100 % (control)	0.936213	0.0043182	0.0015267	0.9290	0.9430
99%	1.910625	0.0437039	0.0154517	1.8387	1.9393
98%	0.882838	0.0083125	0.0029389	0.8710	0.8930
97%	1.590125	0.2178433	0.0770193	1.3067	1.9110
Overall	1.329950	0.4552447	0.0804767	0.8710	1.9393

Table No. 2: One-way ANOVA and multiple comparisons between groups by LSD to compare surface roughness

ANOVA					
	Sum of Squares	**Df**	**Mean Square**	**F**	**P-value**
Between Groups	6.079	3	2.026	163.885	0.000
Within Groups	0.346	28	0.012		
Total	6.425	31			
LSD					
(I) Groups	**(J) Groups**		**Mean Difference (I-J)**		**P value**
100 % (control)	99%		-0.9744125		0.000
	98%		0.0533750		0.345
	97%		-0.6539125		0.000
99%	98%		1.0277875		0.000
	97%		0.3205000		0.000
98%	97%		-0.7072875		0.000

Table No. 3: Descriptive statistics for surface hardness

Groups	**Mean**	**Std. Deviation**	**Std error**	**Minimum**	**Maximum**
100 % (control)	78.150	0.5210	0.1842	77.0	78.8
99%	79.525	0.3196	0.1130	79.0	80.0
98%	76.475	0.7479	0.2644	75.4	77.6
97%	77.350	0.8734	0.3088	76.4	78.8
Overall	77.875	1.2969	0.2293	75.4	80.0

Table No. 4: One-way ANOVA and multiple comparisons between groups by LSD to compare surface hardness

ANOVA					
	Sum of Squares	**Df**	**Mean Square**	**F**	**P-value**
Between Groups	40.270	3	13.423	31.664	0.000
Within Groups	11.870	28	0.424		
Total	52.140	31			
LSD					
(I) Groups	**(J) Groups**		**Mean Difference (I-J)**		**P value**
100 % (control)	99%		-1.3750		0.000
	98%		1.6750		0.000
	97%		0.8000		0.020
99%	98%		3.0500		0.000
	97%		2.1750		0.000
98%	97%		-0.8750		0.012

DISCUSSION

The application of three-dimensional printing technology for acrylic materials has increased markedly in recent years. Advances in printing accuracy and material performance have enhanced its reliability, encouraging its use in an expanding range of dental procedures[13]. The primary goal of 3D printing technology is to manufacture functional materials in a rapid manner. During the printing process, the material is formed in successive layers, with the build platform moving to allow each new layer to be cured before the next one is added[14,15]. Several factors must be carefully controlled during the 3D printing process, as they can influence the properties of the printed material. These factors include the depth of polymerization, layer thickness, printing volume, printing direction, and light-induced shrinkage from the curing source[16]. Some disadvantages like poor mechanical properties of resin required strengthening acrylic resin materials properties[17] by adding various reinforcing materials such as fibers, nanoparticles[18,19].

Rosemary oil is a natural essential oil extracted from the plant Rosmarinus officinalis. It contains several active compounds, including cineole, camphor, and α-pinene, which contribute to its biological properties. In dentistry, rosemary oil has demonstrated effectiveness against oral microorganisms, particularly Candida albicans, which is commonly associated with denture stomatitis. Studies have shown that rosemary oil exhibits strong antifungal activity and can reduce microbial growth[20]. The addition of rosemary oil can improve certain mechanical properties, such as hardness, without significantly affecting surface

roughness. Moreover, its antimicrobial activity may reduce microbial adhesion on denture surfaces, thereby improving their clinical performance[21].

Steve et al[22] examined the mechanical characteristics of 3D printed denture base resin containing microcapsules loaded with plant essential oils and found that while the incorporation of plant oils had little effect on flexural modulus and Vickers hardness, it had a negative impact on flexural strength and surface roughness. Sulaiman et al[23] also examined the effects of adding grapefruit seed skin particles to 3D-printed acrylic at various concentrations on the degree of conversion, surface hardness, flexural strength, and tensile strength. They came to the conclusion that the addition of grapefruit seed skin particles to 3D-printed acrylic is advised due to its notable improvements in the mechanical properties of 3D printed denture base resin. Aziz et al[24] tested cleansers on 3D printer resin and concluded that when they used as a denture cleaner, thyme essential oil preserves surface roughness better than Polident denture cleanser, although it has less of an impact on the hardness and transverse strength of the 3D Printed denture foundation. Finally, an experimental study by Rashid[25] assessed the effects of various ratios of Vitis vinifera oil with concentrations of 1%, 2%, and 3% on the 3D-printed resin material's surface roughness, hardness, and color change. The study found that the hardness, roughness, and color change value of 3D printer acrylic resin were unaffected by the addition of 1% Vitis vinifera oil (an antifungal oil) when compared to the control group. Roughness is necessary test in prevention microorganism to attached to denture base, the results of this study revealed that the roughness decreased in addition of rosemary oil with 2% concentration while the surface hardness increased in addition of rosemary oil with 1% concentration in that significantly improved the mechanical properties of 3D printed acrylic resin. This can be explained by better dispersion of rosemary oil with 3D printed acrylic resin matrix that blended with enough homogeneity between the two materials at the previously mentioned specific concentrations and enhanced properties by lowering roughness value and increasing hardness readings.

Due to its composition and the fact that 3D-printed resin has less double bond conversion than traditional polymethylmethacrylate denture material, pure resin without any additions, referred to as the control group, has a lower surface hardness than the rosemary 1% concentration group[26]. The degree of conversion and stability are increased when oil is added to 3D-printed resin. The strength of the resin-oil bond may also account for this increase. The experimental groups' surface hardness was also considerably raised by the enhanced degree of conversion[23].

CONCLUSION

Addition of rosemary oil with concentration of 2% decreased surface roughness of 3D printed acrylic resin (recorded the lowest mean value) and addition of rosemary oil with concentration of 1% increased surface hardness of 3D printed acrylic resin (recorded the highest mean value). Addition of rosemary oil in specific concentrations improved surface hardness and reduced surface roughness of 3D printed acrylic resin.

Author's Contribution:

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Drafting or Revising Critically:	Shaymaa Majid Abdulhameed, Issam Ahmed Mohammed, Samir Samier
Final Approval of version:	All the above authors
Agreement to accountable for all aspects of work:	All the above authors

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