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Tea Tree Oil Addition on Surface Roughness and Strength of High-Impact Acrylic Resin Material

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Abstract

Objective: Polymethylmethacrylate (PMMA) is porous and rough in nature; this allows food to stick to it and microbes to proliferate, maybe resulting in oral disease. Selecting the right denture cleanser is not enough to prevent all fungi from adhering to the denture or decrease roughness. The essential tea tree oil (TTO) possesses antifungal, antioxidant, and antibacterial characteristics. TTO will be used to study its effect on the surface roughness and impact strength of high-impact acrylic denture material after incorporation with TTO at concentrations of 0%, 6%, and 9% by volume. **Materials and Methods**: 60 specimens were made and categorized into two groups. Each group consisted of 30 samples and was divided into three different concentrations of TTO (0%, 6%, and 9% by volume). After 48 h incubation in distilled water, all samples were assessed by two tests, the surface roughness test and the impact strength test. Atomic force microscopy (AFM) was used to prove the effect of TTO on the surface morphology at the nanoscale of high-impact acrylic. **Results**: Tea tree oil had a statistically significant effect on surface roughness, which led to a decrease in surface roughness of high-impact acrylic. Also, TTO has a significant effect on the impact strength of high-impact acrylic at a 9% concentration, which causes a decrease in impact strength ($P>0.05$), but 6% TTO has a non-significant effect on high-impact acrylic ($P<0.05$). That means 6% TTO is the better concentration to use to improve the property of acrylic. **Conclusion**: The high-impact acrylic resin incorporated with the tea tree oil is effective. It appeared that 6% vol TTO will decrease the surface roughness and not significantly affect the impact strength of high-impact acrylic.

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Introduction

Polymethyl methacrylate (PMMA) was the most widely utilized material for denture resin due to its aesthetically pleasing appearance, minimal water absorption, low toxicity, and excellent color stability [1]. PMMA is porous and rough in nature; this allows food accumulation, discoloration of acrylic, compromised oral hygiene, reduced long-term success of prosthetic appliances, and the growth of microorganisms, which increases the risk of developing denture stomatitis, which is mostly caused by Candida albicans and can result in candidiasis. Therefore, it is essential to clean dentures after meals [2,3]. Also, the polymethyl methacrylate remained weak and unable of withstand the forces applied during chewing, and broken dentures are the most frequent complaint from denture users that dentists hear. These can be brought on by inadvertent prosthesis prognosis-induced overload oral stresses or due to the denture base prosthesis becoming excessively rigid with time because of chronic failure induced by recurrent bite forces [4]. Research indicates that 67% of dentures suffer from degeneration after a few years of makeup [5]. To prevent fractures, high-impact PMMA was developed [6]. Particles of butadiene-styrene rubber are mixed with the powdered denture foundation components. The rubber is grafted with a methacrylate group to provide a covalent connection between the particles and the polymer network. PMMA with a high impact was developed to resist fractures. The addition of a rubber phase as a butadiene-styrene copolymer has led to elevated costs and diminished transverse strength [7,8]. Some oils that are extracted from medicinal plants are utilized in biomaterials as a natural substitute that improves the properties of acrylic and has strong antifungal and antibacterial qualities. According to recent studies, plant oils with strong antifungal properties hold promise as

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a treatment for stomatitis brought on by dentures [9,10]. In addition to their economic worth, the primary benefits of utilizing natural plant extracts include safety, biocompatibility, and the absence of unwanted effects [2]. Research is being done on the therapeutic use of essential oils. Tea tree oil (TTO) is utilized in PMMA because it has antibacterial, antifungal, and antioxidant properties [11,12]. The leaves of Melaleuca alternifolia, a plant from the area in Australia that produced tea tree oil (TTO), may be steam-distilled to obtain the oil. TTO was composed of several compounds, primarily hydrocarbons of monoterpene and sesquiterpene and their alcohols. TTO possessed antiseptic and antibacterial properties, according to multiple studies [13]. The current study aimed to investigate the surface roughness and impact strength of high-impact acrylic's characteristics following its incorporation with TTO.

Materials and Methods

Specimen grouping

In this study, 60 specimens of the high-impact PMMA (Veracril® / Opti-cryl high impact, Newstetic, Colombia) were made**;** the concentration of TTO that is incorporated with high-impact heat-cure acrylic resin is 6 wt.% and 9 wt.% by volume, and the specimens will be created. A total of specimens of high-impact acrylic were carried out and categorized into two sets. Each set includes 30 specimens spread among three different groups. (Group one: control; group two: 6% TTO; and group three: 9% TTO), including 10 specimens per group. Two tests are used in this study, including the impact strength test and the surface roughness test. Before the testing procedures, every specimen was incubated at 37°C for 48 hours after being stored in distilled water [14].

The first control group was preserved in distilled water with 0% TTO.

The second group was the incorporation of high-impact acrylic with a 6% TTO.

The third group was the incorporation of high-impact acrylic with a 9% TTO.

A total of 60 specimens were used in the study.

The measurement and mixing of high-impact PMMA components

The preparation was performed for each percentage (0%, 6%, and 9%) of TTO by volume (ml) to be able to withdraw with a micropipette, while the powder of high-impact acrylic was calculated by using a digital balance of 0.000 grams. TTO was added to the monomer of high-impact acrylic. The proportion of polymer to monomer (powder-to-liquid ratio of (2:1) by weight) P|L [15].

General test specimen preparation

For surface roughness

A carving machine was used to create a round stainless-steel mold and a cover for it. According to ISO 20795-1, 2013, the specimen's thickness was 0.5 mm ± 0.1 mm, and its diameter was 50 mm ± 1 mm [16]. In both halves of the flask, the steel mold and lid were immersed in stone, as indicated in Figure 1. Following the investment of the stainless-steel mold and cover, the two components that made up the flask were then separated. The testing was conducted using a profilometer instrument, and the specimen was positioned on a level surface as shown in Figure 2. Three measurements were obtained for each specimen: one at the center and two equally from the center towards the boundaries on both sides. The average Ra values were computed in micrometers (μm).

Figure 1. The steel mold and lid were immersed in stone inside flask.

Figure 2. A profilometer instrument to measure the surface the roughness of specimen.

For the test of impact strength

The designs were made using dimensions of 80 mm in length, 10 mm in width, and 4 mm in thickness in accordance with ISO 179 [17].

According to the manufacturer's recommendations (water/powder ratio of 25 mL/100 g), the type 4 dental stone (Zhermack®, Italy) was prepared and put into the flask's lower section after it had been painted with separating media (IZO-SOL, Zhermack, Italy). The mold and plastic design were then inserted into the stone and left to harden. Following the stone setting, the whole surface was painted with a separating substance, including the stone and plastic pattern. Following that, the flask's top half was placed over its bottom half, filled with the new stone mixture, covered, and left to solidify. Therefore, the two halves of the flask were taken apart, and the designs were taken out, as shown in Figure 3. The specimens were then constructed, finished, and polished as shown in Figure 4.

Figure 3. Flask and plastic mold for impact strength test.

Figure 4. Finishing and polishing of impact strength specimen.

The Charpy impact testing apparatus was utilized to perform the impact strength assessment, as shown in Figure 5. The Charpy impact strength of unnotched specimens was obtained using the following formula:

Impact strength = $E/B.D \times 103$ [18].

E is the energy absorbed for fracture measured in joules.

B represents the samples' width in millimeters.

D represents the thickness of the samples in millimeters.

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The specimen was positioned vertically and impacted by a freely swinging pendulum of 5 joules, with the scale reading indicating the impact energy in joules.

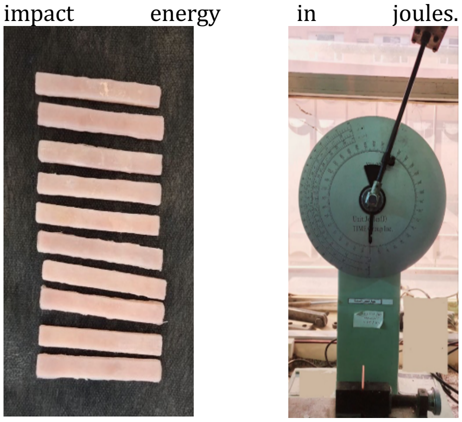

Figure 5. Specimen of impact test and Charpy impact testing machine.

Atomic force microscope (AFM)

Atomic Force Microscopy (AFM) is a nanoscale imaging technology that offers three-dimensional surface characterization with sub-nanometer resolution. It is extensively utilized in polymer research to assess morphological alterations, surface roughness, and nanomechanical characteristics following the modification or incorporation of plasticizers, fillers, or essential oils [19]. AFM employs a sharp probe affixed to a flexible cantilever to examine a surface. Intermolecular interactions between the tip and the surface induce deflections in the cantilever, which are documented to generate high-resolution maps (Figure 6).

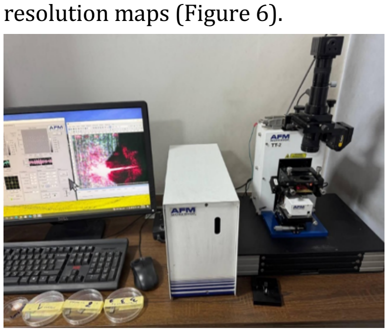

Figure 6. Atomic force microscope device.

Statistical analysis

Individual surface roughness and impact strength were calculated and compiled to determine the average and standard deviation for every category; IBM SPSS version 20 was employed. Tukey HSD and one-way ANOVA were used to compare the outcomes between the groups. $P < 0.05$ was set as the significant level.

Results

The group control demonstrated the greatest mean value (0.1431) upon examination of the pigmented specimens from each specific group. The experimental groups came after that, with group 9% showing the minimal average value (0.0851). All the specimens utilized in the experiment showed a statistically significant decrease in surface roughness, according to the findings shown in Table 1.

Tables 2 to 6 summarize results for all comparisons.

Atomic force microscope (AFM)

The AFM results show the mean surface roughness (sa) of the control group is 0.03308 µm (Figure 7), while the surface roughness after the addition of TTO at 6% is 0.024834 µm (Figure 8) and at 9% is 0.022768 µm (Figure 9). The incorporation of TTO into the high-impact acrylic results in a reduction in the surface roughness, as confirmed by the AFM images. A roughness and irregular topography were observed in the control sample; however, the addition of 6% v/v and 9% v/v TTO resulted in a reduction in the surface irregularities. revealed that there was a change in the surface morphology.

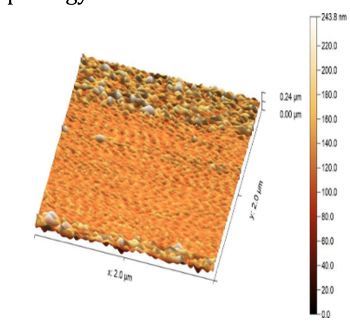

Figure 7. The results of the AFM surface topography analysis for the high-impact acrylic resin.

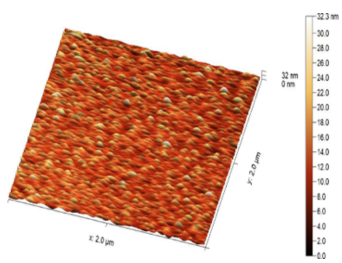

Figure 8. AFM surface topography results for high-impact acrylic resin with 6% v/v TTO.

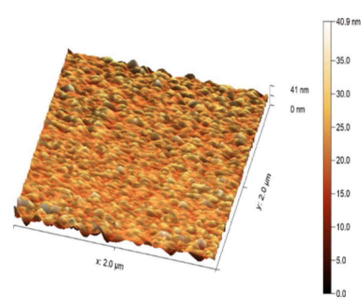

Figure 9. AFM surface topography results for high-impact acrylic resin with 9% v/v TTO.

Discussion

The oral cavity experiences many alterations when utilizing an artificial prosthesis, potentially resulting in microbial colonization. Individuals who wear dentures are at an elevated risk of getting denture stomatitis, largely characterized by the presence of Candida albicans, which may result in the onset of candidiasis. This results from the roughness of the denture due to the nature of acrylic, leading to the adherence of microbes [2,20].

Natural tea tree oil significantly decreased surface roughness when administered to acrylic resin, so the incorporation of TTO (6%, 9%) by volume into the high-impact acrylic in the experiment groups in comparison to the control groups. TO has strong antioxidant and antimicrobial properties, in which the terpinen-4-ol has significant effects on the growth and function of Candida cells (Noumi Emira), which may change the permeability and membrane characteristics of fungal cells [21].

The impact strength values for the incorporation of 6% TTO have no significant difference from the control ($P > 0.05$), whereas the incorporation of 9% TTO has a significant effect ($P < 0.05$) and decreases impact strength; therefore, 6% TTO is the better concentration to have been used because it has no effect on impact strength.

These results may be attributed to the concentration of supplementary oil, which functions as an elastomer for high-impact PMMA acrylic resin [22,23]. The incorporation of oil elastomer enhanced the material's energy absorption and reduced the likelihood of resin cracking, hence increasing the prosthetic device's resistance to mechanical failure [24].

Conclusion

This study was performed to examine the surface roughness and impact strength of high-impact acrylic after incorporation with 6% and 9% TTO. The 6% and 9% of the oil group that incorporated with high-impact acrylic lead to a decrease in surface roughness of high-impact acrylic and a non-significant effect on impact strength with 6% TTO, but with 9% TTO it causes a decrease in the impact strength; therefore, the recommended concentration of tea tree oil is 6% TTO.

Conflict of Interest

None.

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Table 1. Descriptive statistics for test of surface roughness.

Sample	N	Mean	Standard Deviation	Standard Error	Minimum	Maximum
Control	10	0.1431	0.004841	0.001531	0.136	0.149
6% tea tree oil	10	0.1033	0.003713	0.001174	0.097	0.108
9% tea tree oil	10	0.0851	0.002807	0.000888	0.081	0.089
Total	30	0.1105	0.024916	0.004549	0.081	0.149

Table 2. ANOVA analysis of surface roughness test.

Sample	Sum of Squares	Degrees of freedom	Mean Square	F	p-value
Between Groups	0.018	2	0.009	585.286	0.000
Within Groups	0.0	27	0.0		
Total	0.018	29			

Table 3. Comparative analysis of surface roughness among groups utilizing Tukey HSD.

(I)	(J)	(I-J) Mean Difference	Standard Error	p-value
Control	6% TTO	0.398	0.001734	0.000
	9% TTO	0.058	0.001734	0.000
6% TTO	9% TTO	-0.0182	0.001734	0.000

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Table 4. Descriptive statistics for the impact strength.

Sample	N	Mean	Standard Deviation	Standard Error	Minimum	Maximum
Control	10	13.925	0.23717	0.075	13.5	14.25
6% tea tree oil	10	13.8	0.2582	0.08165	13.5	14.25
9% tea tree oil	10	13.375	0.3385	0.10704	13	13.75

Table 5. ANOVA test for impact strength test.

Sample	Sum of Squares	Degrees of freedom	Mean Square	F	p-value
Between Groups	1.663	2	0.831	10.5	0.000
Within Groups	2.138	27	0.079		
Total	3.8	29			

Table 6. Multiple comparisons of impact strength between groups using Tukey HSD.

A multiple comparison test in Table 6 showed a statistically significant difference between control and 9% TTO, and 6% and 9% TTO ($P < 0.05$), while between control and 6% TTO there was a non-significant difference ($P > 0.05$), which explains why the 6% had no effect on the impact strength of high-impact acrylic.

(I)Group	(J)group	Mean Difference(I-J)	Standard Error	P-value
Control	6% TTO	0.125	0.12583	0.587
	9% TTO	0.55	0.12583	0.000
6% TTO	9% TTO	-0.425	0.12583	0.006