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Evaluation of the Effect of Tea Tree Oil Denture Cleanser on the Properties of Dental Polymers

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ABSTRACT

This research aimed to assess the effect of immersing heat-cured acrylic resin in tea tree oil solution as a long-term disinfectant. The effect of immersing heat-cured acrylic resin in tea tree oil denture cleanser 180 times on its hardness, UV absorption, water sorption, and solubility was investigated in this study. Ninety heat-cured acrylic resin specimens were prepared and divided into three sets, each consisting of 30 specimens. The specimens were placed in different solutions: distilled water, a solution containing 0.75% tea tree oil, and a solution containing 1% tea tree oil. Each group comprised 10 specimens, and each specimen was submerged for 10 min in accordance with its group. This process was repeated 180 times. After 180 times of immersion, tea tree oil solutions showed non-significant differences ($P > 0.05$) in surface hardness and statistically significant changes in UV absorption, water sorption, and solubility ($P < 0.05$). The heat-cured acrylic resin immersed 180 times showed that 0.75% tea tree oil concentration improved solubility and water absorption but not surface hardness and UV absorption. Moreover, 1% tea tree oil concentration enhanced water sorption and solubility. It also decreased UV absorption, but it did not influence hardness. Thus, a 0.75% tea tree oil disinfectant solution is intended to be a long-term denture cleanser.

Keywords: Acrylic resin, Tea tree oil, Surface hardness, UV-absorption, Water sorption

1. INTRODUCTION

Regular maintenance of dentures is crucial for preserving the health of the oral mucosa and extending the lifespan of removable partial dentures. Insufficient oral health can arise from the colonization of dentures by bacteria and fungi, thereby giving rise to denture stomatitis and angular cheilitis. The acrylic resin should be smooth and polished to minimize or avoid plaque accumulation **(Fatalla et al., 2020).** The transfer of opportunistic microorganisms through the air can result in cross-infection and expose healthcare staff and patients to the risk of sickness; these microorganisms can vary in their level of pathogenicity **(Abass and**

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Ibrahim, 2012; Khalaf et al., 2023). Ensuring the complete cleaning of prosthetic devices and dental equipment is imperative to minimize cross-contamination **(Ellakwa and El-Sheikh, 2006).** Individuals who wear dentures often use denture cleansers as a means of cleaning. **(Salem and Al-Khafaji, 2006)** mentioned four types of denture cleansers that are employed to eliminate effectively the soft food particles and stubborn deposits of calculus and stains on the denture base and teeth. Among the several approaches employed, mechanical and chemical methods are the most prevalent **(Salem and Al-Khafaji, 2006).** Brushing teeth using a toothbrush, together with the use of toothpaste, soap, and other underwater cleansers, is a widely recognized method for the mechanical elimination of plaque **(Degirmenci et al., 2020)**. This particular technique is commonly employed by individuals seeking dental treatment; however, it is inadequate for effectively cleansing the recessed areas of dentures that can serve as an ideal environment for microbes **(Fatalla et al., 2020).** Chemical cleaning may be employed to avoid issues with dentures. People all over the world look for disinfectants that can be used to keep prosthetic surfaces clean **(Pavarina et al., 2003).** However, studies have shown that chemical cleaners may damage some of the prosthetic properties **(Powral et al., 2017).** Investigations have been made into whether natural denture cleaners are feasible. de Souza et al. explored the effectiveness of propolis as a natural material for denture cleansing **(de Souza et al., 2019)**. Biocompatibility and safety are the main benefits of using natural plant products as disinfectants. Both of these factors have few negative effects. In addition, their price makes them highly desirable **(Kanathila et al., 2011).**

Tea tree oil (TTO) was initially derived from the leaves of the native Australian plant *Melaleuca alternifolia* via steam distillation. In addition to their corresponding alcohols, monoterpene and sesquiterpene hydrocarbons comprise the majority of TTO components. Numerous studies have provided evidence of the antiseptic and antibacterial properties **(Carson et al., 2002)** and the anti-inflammatory and antifungal effects of TTO, particularly its effectiveness against *Candida* infections **(Mondello et al., 2003).** However, phytoconstituents are chemical compounds found in natural products that have a specific therapeutic effect in the treatment and prevention of diseases linked to biofilm **(Noumi et al., 2010).** TTO has a phytoconstituents component, which exhibited antifungal action against Candida albicans **(de Groot and Schmidt, 2016; Ramage et al., 2012).** Despite the beneficial disinfectant effect of TTO, previous studies about its effect as a denture cleanser for heat-cured acrylic resin dentures or investigations about the acrylic resin properties for short- or long-term periods have been lacking.

As a result, the goal of this work was to evaluate how the frequency of immersion (180 times) in TTO solution affected the physicomechanical properties (hardness, UV absorption, water sorption, and solubility) of the heat-cured acrylic resin.

2. MATERIAL AND METHOD

2.1 Specimen Preparation

Ninety specimens of heat-cured acrylic resin (SR Triplex Hot, Ivoclar Vivadent, Liechtenstein) were produced in accordance with the manufacturer's instructions. Subsequently, the resin was introduced into a primary mold **(Mahmood et al., 2017).** The plastic models were fabricated with a laser cutting machine according to the designated dimensions for each experimental trial. A master mold, which was cut to dimensions of 30 × 15 × 2.5 mm (length, width, and thickness, respectively) was utilized in the hardness test

(**Salem and Al-Khafaji, 2007).** A turning machine was employed to cut the aluminium foil precisely into circular discs with a diameter of 50 mm and a thickness of 0.5 mm. The UV absorption test and the water sorption and solubility test were conducted following the guidelines outlined in ADA No. 12 **(ADA No. 12, 1999; Abed, 2022).** The excess material was eliminated from each acrylic specimen by employing a prosthetic engine that was outfitted with stone and acrylic burs. These burs were consistently cooled with water to reduce the risk of overheating, which might result in the deformation of the specimens. The polishing procedure was performed using rouge to obtain a polished surface on the specimens. The rouge was placed into a dental lathe machine and rotated at a speed of 1500 revolutions per minute while maintaining a continuous flow of water for cooling purposes **(Jasim and Abass, 2021).**

2.2 Preparation of TTO Solution

The TTO solution was prepared by mixing pure TTO (Now Foods, Bloomingdale, IL 60108, USA) based on the specimen groups with 1% tween 80 as an emulsifying agent and distilled water (DW) by using a magnetic stirrer **(Noori et al., 2023)**.

2.3 Immersion Technique

Each specimen was immersed for 10 min in (0.75% and 1%) TTO solutions and DW to replicate the process of cleaning a patient's dentures. Then, the specimens were removed from each solution by using tweezers and rinsed with DW thoroughly for 1 min. Afterwards, they were handled and dried by wiping them with an absorbent paper for 30 s.
This process was repeated 30 times daily, followed by storing the specimens in DW for the next day. Then, the immersion process was repeated 180 times, and the testing was performed **(Peracini et al., 2010).**

2.4 Specimen Grouping

A total of 90 specimens were performed and distributed into three sets:
1. Hardness test,
2. UV-absorption test,
3. Water sorption and solubility tests.

Each set consists of thirty specimens distributed into three groups with ten specimens in each group:
Group 1: immersed in distilled water (DW),
Group 2: immersed in 0.75% TTO,
Group 3: immersed in 1% TTO

2.4.1 Surface Hardness Test

The indentation hardness of the specimens was measured using a shore D hardness tester **(Faiq and Attiyah, 2017)**. The applied force was 50 N, a value considered appropriate for the manipulation of acrylic resin **(Tawfeeq and Al-Khafaji, 2023).** The device was equipped with a cylindrical component of 1.6 mm in diameter, which was placed at one end. Additionally, it featured a pointed indenter with a diameter of 0.8 mm. The digital scale was linked to an indenter. Every individual specimen was exposed to five indentations. Afterwards, the average value was calculated **(Fatalla et al., 2020).**

2.4.2 UV Absorption Test

The equipment measured the ultraviolet light absorption by wavelength **(Kadhim et al., 2016; Majeed et al., 2019)**. The UV light spectrum was measured from 200 nm to 400 nm to determine the specimen's UV light absorption. Above the light source, disk-shaped specimens were exposed. Then, the spectrophotometer's computer screen recorded absorbed light values **(Abed and Al-Khafaji, 2023).**

2.4.3 Water Sorption and Solubility Test

Thirty specimens were placed in a desiccator with newly dried silica gel following ADA 1999. The discs were kept in an incubator set at 37 °C ± 2 °C. Once removed, the specimens were stored at room temperature for 60 ± 10 min in a second desiccator with freshly dried silica gel. A computerized balance with 0.000l g precision weighed them next **(Abass et al., 2020)**. The technique was repeated every day at a constant time until a "conditioned mass" (M1) of unchanging weight was reached, where each specimen's 24-hour weight loss did not exceed 0.2 mg (0.0002 g). In this study, the experimental groups were immersed 180 times in a cleaning solution for 10 min, whereas the control group was immersed in DW. After removing the discs from the liquids with tweezers, we dried them with a clean hand towel. Subsequently, a period of 15 s was allocated for the waving process, followed by a subsequent weighing that occurred one minute later. M2 was the mass of the discs after the removal from the liquids. The discs were reconditioned in a desiccator at 37 °C ± 2 °C, which was previously used for the sorption test, to calculate solubility. Reconditioned mass (M3) was calculated.
The following Eq. (1) was used to get the values for sorption for each disc, and the results should be rounded to the nearest 0.1 mg/cm^2.
Where:

$$WSP = (M2 - M1)/S \tag{1}$$

In accordance with Eq. (2), the solubility value for each specimen was determined with a precision of 0.01 mg/cm^2.

Where:

$$WSL = (M1 - M3)/S \tag{2}$$

WSP = sorption mg/cm^2
WSL = solubility (mg/cm^2)
S = surface areas of the disc (cm^2).

Statistical analysis using SPSS (IBM SPSS version 20) includes comparative statistics (mean, standard deviation, and standard error). Moreover, inferential analysis methods such as one-way analysis of variance (ANOVA) and, for significant tests, post hoc Tukey HSD were performed.

3. RESULTS AND DISCUSSION

3.1 Hardness Test

The hardness test is an easy and accurate way of realizing the mechanical properties of polymer-based goods. How well it can detect variations in the concentration of polymer monomers is genuinely remarkable **(Azevedo et al., 2005).** According to (**Consani et al., 2016)**, the PMMA denture should be sufficiently hard to resist wear and abrasion, since this has a big impact on its flexibility **(Shukur, 2021)**. **Table 1** displays the ANOVA test's mean, standard deviation, and P value for this investigation. The test results indicate that group 3 exhibits the least resistance to pressure, with groups 2 and 1 following closely behind. Moreover, the changes in the resistance that occur after the immersion of the heat-cured acrylic resin in TTO for a long time are not statistically significant ($P > 0.05$). Immersing acrylic resin in solutions does not significantly change its surface hardness, possibly because cross-linking agents are present. Denture bases do not also dissolve in organic fluids because of these cross-linking agents. Therefore, using TTO did not significantly weaken or lower the surface hardness of the heat-cured acrylic resin. Our finding is consistent with the investigation by Nimer and Jassim, who concluded that the assessed surface hardness parameters were not affected by submerging heat-cured specimens in a 1% ascorbic acid solution, regardless of whether the curing process was carried out via water bath or autoclave **(Nimer and Jassim, 2020).** Additionally, Heidrich et al. discovered that the hardness test results remained unchanged following a 12-month immersion in liquid containing 8% rosemary oil, 2% castor oil, and 12% propolis glycolic extract **(Heidrich et al., 2018).** Pereira et al. also found the same result when they soaked the heat-cured in different denture cleaners for 150 and 300 h **(Pereira et al., 2019).**

Table 1. Descriptive statistics and P-value of hardness test.

Groups	N	Mean	Std.	SE	F	P
Group 1	10	85.5860	0.12834	0.04058	1.758	0.191*
Group 2	10	85.51550	0.16043	0.05073		
Group 3	10	85.4800	0.08692	0.02749		

Note: *Level of significance $P < 0.05$

3.2 UV Absorption Test

In relation to the UV absorption test, **Table 2** shows the means and standard deviations of denture cleaners, with a significant difference ($P < 0.05$) across treatments using one-way ANOVA. The Tukey HSD multiple comparison test in **Table 3** shows that compared with group 1, group 3 has statistically significant differences; compared with groups 1 and 3, group 2 reveals nonsignificant differences. This outcome may be due to the propensity of polymeric materials to degrade in acidic environments **(Mutlu-Sagsen et al., 2001).** Moreover, the surface integrity of polymers was impacted by a low PH. This result is due to the loss of structural ions caused by acidic conditions, which significantly weaken the polymer surface **(Madhyastha and Kotian, 2013)**. Consequently, their effect increases as the concentration increases. This result is in agreement with **(Peracini et al., 2010)**, who studied the effect of immersing acrylic resin in Corega Tabs, Bony Plus, and DW for 180 days of simulation**.**

Table 2. Descriptive statistics and one-way ANOVA test of UV-absorption test.

Groups	N	Mean	Std.	SE	F	P
Group 1	10	2.422090	0.0769090	0.0243208	5.091	0.013*
Group 2	10	2.371750	0.1087772	0.0343984		
Group 3	10	2.292560	0.0858922	0.0271615		

Note: * Level of significance P < 0.05

Table 3. Post hoc test (Tukey HSD) of UV-absorption test.

Groups	Mean difference (I-J)	S.E	P
Group 1-2	0.0503400	0.0409267	0.446
Group 1-3	0.1295300	0.0409267	0.010*
Group 2-3	0.0791900	0.0409267	0.148

Note: * Level of significance P < 0.05

3.3 Water Sorption Test

Regarding the water sorption, **Table 4** shows that compared with the mean values in group 1, the mean values decreased with the increasing TTO concentration after 180 times of immersion. Moreover, the one-way ANOVA test shows significant differences (P < 0.05) across groups. **Table 5** shows that compared with group 1, groups 2 and 3 had a significant difference (P < 0.05), as revealed by the post hoc test. This finding indicates that the experimental groups were better at water absorption than the control group. This outcome may be related to the fact that acrylic polymers have an affinity for water molecules because of the presence of polar carbonyl groups **(Tsuboi et al., 2005**). Therefore, water molecules progressively penetrate the resin **(Tsuboi et al., 2005**) via the intermolecular gaps within the polymers, which are barely spaced apart **(Ristic and Carr, 1987).**

Table 4. Descriptive statistics and one-way ANOVA test of water sorption test.

Groups	N	Mean	Std.	S.E	F	P
Group 1	10	0.790	0.0994	0.0314	13.017	0.000*
Group 2	10	0.660	0.1075	0.0340		
Group 3	10	0.550	0.1080	0.0342		

Note: * Level of significance P < 0.05

Table 5. Post hoc test (Tukey HSD) of water sorption test.

Groups	Mean difference (I-J)	S.E	P
Group 1-2	0.1300	0.0470	0.026*
Group 1-3	0.2100	0.0470	0.000*
Group 2-3	0.1100	0.0470	0.067

Note: * Level of significance P < 0.05

3.4 Solubility Test

The results in **Table 6** show that the ratio of the experimental groups was lower than that of group 1. The P value was significant (P < 0.05), as shown also in **Table 6**. A post hoc (Tukey HSD) test in **Table 7** shows a statistically significant difference in groups 2 and 3 (P < 0.05), compared with group 1. The hypothesis proposes a potential association between the residual monomer and the observed drop in weight during the solubility test. This association may explain the result of this study. A residual monomer is often produced in the highest quantity from acrylate during the initial stages of water storage, as observed in general (**Miettinen et al., 1997**).

Table 6. Descriptive statistics and one way ANOVA test of solubility test.

Groups	N	Mean	Std.	SE	F	P
Group 1	10	0.077	0.00949	0.00300	17.840	0.000 *
Group 2	10	0.055	0.01080	0.00342		
Group 3	10	0.052	0.01033	0.00327		

Note: * Level of significance P < 0.05

Table 7. Post hoc test of solubility test.

Groups	Mean difference (I-J)	S.E	P
Group 1-2	0.02200	0.00457	0.000*
Group 1-3	0.02500	0.00457	0.000*
Group 2-3	0.00300	0.00457	0.790

Note: * Level of significance P < 0.05

Moreover, water molecules are smaller and simpler than the complex compounds found in denture-cleaning solutions, enabling them to enter and exit acrylic resin. Therefore, soaking the acrylic resin samples in chemical solutions may result in lower water sorption and solubility values than soaking them in DW (**Salem and Al-Khafaji, 2006).** Thus, TTO has an advantageous effect on the acrylic specimens by decreasing water absorption and solubility, which adversely affects the vertical dimension. Moreover, prosthesis exhibits a higher level of comfort than their initial fabrication.

4. CONCLUSIONS

This study was performed to examine the physicomechanical properties of heat-cured acrylic resin after being immersed in TTO 180 times. A 0.75% TTO disinfectant solution is the highly recommended long-term denture cleanser in this study because it does not change the UV absorption or surface hardness of the heat-cured acrylic resin. It also improves water sorption and solubility. The main points are concluded as follows:

1. The 0.75% TTO concentration did not affect surface hardness or UV absorption, it also showed enhancements in water sorption and solubility of acrylic resin (0.055 and 0.660 mg/cm^2), respectively, compared to DW.
2. The 1% TTO concentration did not affect hardness property, and it was associated with poor UV light absorption (2.292560 nm) compared to other groups. It also caused improvements in water absorption and solubility properties (0.550 and 0.052 mg/cm^2), respectively, which were considered better than the DW and 0.75% TTO groups.

Credit Authorship Contribution Statement

Zahraa S. Noori: Writing –original draft, Methodology, Validation, Software, Conceptualization. Aseel M. Al-Khafaji: Writing –review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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تقييم تأثير منظف طقم الأسنان بزيت شجرة الشاي على خصائص بوليمرات الأسنان

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الخلاصة

يهدف هذا البحث إلى تقييم تأثير غمر راتنج الأكريليك المعالج بالحرارة في محلول زيت شجرة الشاي كمطهر طويل الأمد. تم في هذه الدراسة دراسة تأثير غمر راتينج الأكريليك المعالج بالحرارة في منظف طقم الأسنان بزيت شجرة الشاي لمدة 180 مرة على صلابته، وامتصاصه للأشعة فوق البنفسجية، وامتصاص الماء، والذوبان. تم تحضير تسعين عينة من راتينج الأكريليك المعالج بالحرارة وتقسيمها إلى ثلاث مجموعات، تتكون كل منها من 30 عينة. تم وضع العينات في محاليل مختلفة: ماء مقطر، محلول يحتوي على 0.75% زيت شجرة الشاي، ومحلول يحتوي على 1% زيت شجرة الشاي. تتكون كل مجموعة من 10 عينات، وتم غمر كل عينة لمدة 10 دقائق وفقًا لمجموعتها. وتكررت هذه العملية 180 مرة. بعد 180 مرة من الغمر، أظهرت محاليل زيت شجرة الشاي اختلافات غير مهمة (P > 0.05) في صلابة السطح وتغيرات ذات دلالة إحصائية في امتصاص الأشعة فوق البنفسجية، وامتصاص الماء، والذوبان (P < 0.05). أظهر راتنج الأكريليك المعالج بالحرارة المغمور 180 مرة أن تركيز زيت شجرة الشاي بنسبة 0.75% يحسن قابلية الذوبان وامتصاص الماء ولكن ليس صلابة السطح وامتصاص الأشعة فوق البنفسجية. علاوة على ذلك، فإن تركيز زيت شجرة الشاي بنسبة 1% يعزز امتصاص الماء وقابلية الذوبان. كما أنه يقلل من امتصاص الأشعة فوق البنفسجية، لكنه لا يؤثر على الصلابة. وبالتالي، يوصى بشدة باستخدام محلول مطهر بزيت شجرة الشاي بنسبة 0.75% كمنظف طويل الأمد لأطقم الأسنان.

الكلمات المفتاحية: راتنج الأكريليك، زيت شجرة الشاي، صلابة السطح، امتصاص الأشعة فوق البنفسجية، امتصاص الماء.