Effect of denture cleansers on physical and mechanical properties of denture base acrylic resin

Namfon Boonsoe¹, Ratthida Kanson², Tularat Sookto³

¹Department of Dental, Chaiwan Hospital, Chaiwan, Udon Thani, Thailand, ²Department of Dental, Roi-Et Hospital, Mueang Roi Et, Thailand, ³Department of Prosthodontic, Faculty of Dentistry, Khon Kaen University Muang, Khon Kaen, Thailand

Abstract

Background: Maintenance of good denture hygiene is important and the immersion in various chemical disinfectants has been suggested. Dentures may undergo repeated cycles of immersion in denture cleansing solutions. Therefore, the effect that these cleansing solutions have on the physical and mechanical properties of denture base polymers should be considered.

Aim: This study aims to investigate the effects of three denture cleansers on the color, surface roughness, and flexural strength of heat-polymerized acrylic resin.

Materials and Methods: The specimens were prepared in two shapes, a rectangle with size 64 mm × 10 mm × 3.5 mm and a disk with diameter 50 mm × 0.5 mm. 84 samples were prepared for each shape and divided into four groups (n = 21) – tap water, Bony Plus®️, 0.5% lemongrass oil concentrate solution, and 5% vinegar solution. For each group, the soaking cycle consisted of 8 h immersion in the denture cleaner mixed with tap water, followed by washing under running tap water and then soaking for 16 h in distilled water at 37°C in an incubator. The physical properties were evaluated at 2 and 3 months.

Results: Samples immersed in 0.5% lemongrass oil exhibited the highest color change (P < 0.05), increased surface roughness, and decreased flexural strength when compared to the control group and 5% vinegar. Samples immersed in Bony Plus®️ and 0.5% lemongrass oil did not show significant differences in color change, surface roughness, and flexural strength after immersion for 2 and 3 months.

Conclusion: All three types of the denture cleansers caused more color changes, increased surface roughness, and lowered flexural strength than the control group. However, Bony Plus®️ and 0.5% lemongrass could be recommended as adjunctive denture cleansers.

Keywords: Chemical denture cleansers, color stability, flexural strength, heat-polymerized acrylic resin, surface roughness

Introduction

Denture-induced stomatitis is an inflammatory lesion of the palatal mucosa that affects approximately 50% of denture wearers.¹ Although it has a multifactorial etiology, it is mostly associated with poor denture hygiene, denture-induced trauma, fungal infection, overnight denture wearing, and dietary or systemic factors.²⁻⁵ The presence of denture plaque is a etiologic factor for denture stomatitis. A complex mixture of microbial has been observed in denture plaque⁶ and can act as a reservoir for diffused infections such as gastrointestinal infections.⁷⁻⁸ Therefore, adequate cleansing and maintenance of the dentures are essential for the removal of pathogenic biofilm. Several chemical denture cleansers have been used to remove Candida albicans from dentures, however, among the commercial denture cleansing products.⁹ Alkaline peroxide-based cleansers are considered to be effective due to their bactericidal and fungicidal effects which enable the dissolution of plaque matrix. However, they can lead to reduction in color stability and the hardness of the denture base resin on long periods of immersion.⁹ Commercial denture cleansers are not routinely used by patients due to insufficient information provided to them, restricted market access, and added expenses. Normally prefer using products which are easily available at home which are inexpensive. A commonly available household product is vinegar, which is a liquid consisting in about 5–20% acetic acid,
water, and other trickle chemicals. Low concentrations of acetic acid have been shown to remove C. albicans from denture base, deter growth them of all strains, and prevent forming biofilms, and all isolates in mature biofilms will be destroyed for after 3 h of exposure.\(^{[10-14]}\) The overnight immersion of complete dentures in 100% vinegar had an effect on reduction of the counts (cfu/mL) of Candida spp. in saliva and the presence of denture-induced stomatitis.\(^{[10]}\) This solution is inexpensive, easily available in the market and has low toxicity; however, the low pH of these solutions may irritate the mucosal tissues and lead to corrosion of metallic components.\(^{[14]}\)

Even though chemical immersion solutions have been recommended as complementary to mechanical methods of hygiene maintenance,\(^{[15]}\) these treatments are not always successful in completely removing C. albicans biofilm. Frequent application of anti fungal agents in denture wearers with persistent Candida infection so called Candida-associated denture stomatitis (CADS)\(^{[16]}\) can cause a drug resistance of C. albicans which contributes to treatment failure.\(^{[17,18]}\) Current challenges in the treatment of CADS using alternative products have revealed that herbal extracts have potential antimicrobial effects. Lemongrass has been reported that they have efficiency for against Candida species, which is effective and easily available. It could be considered an alternative method in reduction C. albicans biofilms on denture surfaces.\(^{[19-23]}\) If this herb is used for a possible supplementary treatment for CADS, the investigation toxicity of lemongrass and its possible effects on the mechanical or physical properties of acrylic surfaces are importance.\(^{[24-26]}\)

The purpose of this study was to investigate whether immersion in commercial denture cleanser, vinegar, and lemongrass oil would have an effect on the color stability, surface roughness, and flexural strength of heat-polymerized denture base acrylic resin.

**Materials and Methods**

**Specimen preparation**

Circular (50 mm × 0.5 mm) (ADA Specification No.12) and rectangular (64 mm × 10 mm × 3.3 mm) (ISO No. 20795-1) wax patterns were placed in lower half metal flasks, which were filled with Type III dental stone using conventional compression molding technique. For heat-polymerized acrylic resin (Meliodent®, Bayer Co., Germany), powder and liquid were mixed according to the manufacturer’s instructions; then, the acrylic resin was packed and pressed into the mold, following which it was cured in water at 74°C for 90 min followed by 100°C for 30 min. All flasks were cooled at room temperature before opened. A total of 84 disk-shaped and rectangular-shaped samples were fabricated. After complete polymerization, the specimens were removed from the molds. The excess resin was trimmed using a carbine bur and a handpiece at low speed and was polished with standard metallographic grinding papers no. P500, P1000, and P1200, respectively. The specimens were kept in distilled water at 37°C for 24 h to eliminate residual monomer.

**Immersion procedures**

A total of 80 disk-shaped heat-polymerized acrylic resin specimens were randomly divided into four groups (n = 21). The four test groups of each shape were soaked in alkaline peroxide effervescent denture cleansers, one of the two alternative solutions or tap water:

1. Bony Plus® (Bony fag, Principality of Liechtenstein, Switzerland). The effervescent cleansers were prepared according to the manufacturer’s directions, by adding one tablet, to 400 ml of tap water.
2. 5% vinegar solution diluted with tap water at a ratio of 1:6 was prepared from vinegar 57.2 ml was mixed with tap water 342.8 ml to get 400 ml of vinegar solution.
3. 0.5% lemongrass oil concentrate solution was prepared by mixing 2 ml in 398 ml tap water to make 0.5% (vol/vol).
4. Control group (tap water) 400 ml.

The 21 disk-shaped specimens and rectangular-shaped specimens of each group were immersed at the same time in the same container, with the vertical placement, ensuring that the solution covered all specimens. Each soaking cycle consisted of 8 h in water and three denture cleansers at room temperature (24–28°C) and then 16 h in distilled water at 37°C in an incubator, which was repeated for the period of 60 and 90 days. The denture cleansers were changed daily.

**Color analysis**

A color measurement of CIE L′*a′*b′ using the spectrophotometer (Ultrascan Colorquest® XE) was performed by one investigator after 60 and 90 days of immersion. The total color change (∆E) of each test specimen was calculated using this equation:

\[
\Delta E^{ab} = (\Delta L^2 + \Delta a^2 + \Delta b^2)^{1/2}
\]

Where, ∆L′, ∆a′, and ∆b′ are the differences between color baseline L′*a′*b′* and L′*a′*b′ after immersed in solutions for 60 and 90 days. Before the color measurement, the spectrophotometer was calibrated according to the manufacturer’s recommendation. To relate the color differences (∆E) to a clinical environment, the color data were quantified by the National Bureau of Standards (NBS) units through the formula NBS units= ∆E ×0.92.\(^{[27,28]}\)

**Figure 1:** Testing of flexural strength
Surface roughness test

The surface roughness (Ra, µm) was measured using a profilometer (TalyScan 150, Taylor Hobson Ltd., England), with a diamond stylus which was made to move across the surface, and was connected to a system that analyzed the information. The mean arithmetic roughness (Ra) was calculated from three lines as the mean roughness of the specimen. The tracing length was 3 mm and the cutoff value was 0.8 mm, at 0.5 mm/s.

Flexural strength test

Three-point flexural strength was determined using a universal testing machine as shown in Figure 1. The force was loaded on each specimen until fracture using a crosshead at 5 mm/min speed. Mean flexural strength in MPa was calculated by using the formula below, where \( P \) is the load in Newton, \( L \) is the distance [mm] between the supports, \( b \) and \( d \) are the width and thickness [mm] of the specimen respectively.

\[
S = \frac{3PL}{2bd^2}
\]

Statistical analysis

The results obtained were analyzed using the SPSS 12.0 program (SPSS Inc., Chicago, IL, USA). As the distribution was normal, the results of three assays were compared using two-way ANOVA followed by Bonferroni test to determine the significance level. Statistical analyses were performed at 95% level of confidence to determine the effect of the type of cleansing agent on surface roughness and color change in the acrylic resin base. Before analyses, data homogeneity of variance was tested using the Kolmogorov–Smirnov test.

Results

Color stability evaluation

Two-way ANOVA test showed a statistically significant difference among the types of denture cleansers \((P<0.0001)\). Bonferroni test indicated significantly higher ∆E for lemongrass than control group \((P<0.01)\) and vinegar \((P<0.01)\), but no significant differences were found between lemongrass and Bony Plus® after the 60 and 90 days stimulation [Table 1].

Surface roughness evaluation

For surface roughness, two-way ANOVA test showed statistically significant differences \((P<0.01)\). Further analysis with Bonferroni test showed significant differences between the control group and lemongrass, but there were no significant differences among the control group, Bony Plus®, and vinegar [Table 2].

Flexural strength evaluation

For flexural strength, two-way ANOVA test showed statistically significant differences \((P<0.01)\). Further analysis with Bonferroni test showed significant differences among the three test groups, whereas vinegar had the highest flexural strength followed by Bony Plus®. On the contrary, lemongrass had the lowest flexural strength [Table 3].

Discussion

This study investigated the effects of a commercial denture cleansing product (Bony Plus®), a household product (5% vinegar), and an alternative product (0.5% lemongrass) on physical and mechanical properties of heat-polymerized denture base acrylic resin, after daily repeated soaking for 8 h. For a total simulated usage of 60 and 90 days. The results showed that at the end of the study period, acrylic resins in all three test denture cleansing groups had color alteration, greater surface roughness, and lowered tensile strength.

Assessment of color can be made visually or by the use of instruments such as colorimeters and spectrophotometers. As the latter contains monochromators and photodiodes that can measure the reflectance curve of color every ≤10 nm, it is considered to be more accurate than colorimeters. To eliminate subjective error in color assessment, the present study used a spectrophotometer. The

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<td>5% vinegar</td>
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Different upper case letters represent statistically significant difference between groups. Different lower case letters represent statistically significant difference between immersion periods (ANOVA two-way followed by Tukey test, \(P<0.05\))

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<th>Table 2: Mean surface roughness (µm) and standard deviations for each denture cleanser at 60 and 90 days</th>
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MPa: Mean flexural strength, different upper case letters represent statistically significant difference between groups. Different lower case letters represent statistically significant difference between immersion periods (ANOVA two-way followed by Tukey test, \(P<0.05\))
results of this study showed that there were significant differences in the color change among the control group and all three test groups after 60 days of immersion, but there were no significant differences in the color change between control group and 5% vinegar and between Bony Plus® and 0.5% lemongrass after 90 days immersion. However, the color change for all groups increased with time and was classified as “appreciable” (3.52–5.13) in control and 5% vinegar, and “much” (6.99–8.04) in Bony Plus® and 0.5% lemongrass according to NBS.[30] The finding of this study was consistent with Paranhos et al. who also found the alkaline peroxide exhibited the highest color change after daily overnight (8 h) soaking with a total simulation time of 1.5 years. The authors indicated the importance of determining the adverse effects on denture base when such solutions were used for longer periods of immersion. The agents releasing oxygen with enzymes may suggest the hypothesis that the oxidation with strong alkaline solution can be deleterious to the denture polymer.[30] On the other hand, Sato et al. showed no color alterations after soaking in denture cleanser (Bony Plus®) for 15 min and 8 h with a simulated 30 days’ usage. The differences in the result could be due to the shorter study period and visual examination of color alterations.[31] In this present study, the color of the control group, tap water, was also affected but to a lesser extent than the three test groups. This could be due to leaching out of the coloring agents from the resin. In addition, opacity of the acrylic resin may also decrease following long periods of immersion due to monomer leaching out and water being absorbed.[32]

The analysis of mechanical properties showed the highest surface roughness and lowest flexural strength value for 0.5% lemongrass, followed by Bony Plus, 0.5% vinegar, and tap water. These findings were in agreement with Percacini et al., who had measured the color alteration, surface roughness, and flexural strength of heat-polymerized acrylic resin after immersion in Corega tablets and Bony Plus® over a period of 180 days.[32] The authors found that although the change in color was clinically insignificant, there was an increase in surface roughness and decrease in the flexural strength of the acrylic resin. Similar findings were observed in a report by Shah et al., in which denture cleansers had effects on the color and flexural strength.[33] These results contradict the study by Sato et al., which found no significant changes in the flexural strength of heat-cure acrylic resin with the use of chemical denture cleanser. The result of immersion in vinegar solution showed a minor change in color because it’s acidic nature without any peroxide content.[30] Similar finding was noted by Hong et al. who used ZTC-acid type of cleanser.[31]

Previous studies have suggested lemongrass oil to be effective against Candida spp.[22,23,34] Taweewchaisupapong et al. exhibited strong inhibitory effects of lemongrass oil against Candida dubliniensis in both planktonic and biofilm forms.[35] However, only a few studies have been conducted on the effects of lemongrass oil on the physical and mechanical property of acrylic resin. The result in this study showed that 5% lemongrass solution had the most whitening effect on acrylic resin and also led to increased surface roughness and decreased in flexural strength. This might be due to long and repeated exposures to α- and β-citral present in lemongrass (65–85%). Lemongrass also has a low pH (acidic) which can cause the decomposition and leakage of acrylic resin matrix. The resin matrix degradation occurs through hydrolysis, as the polymer molecules react and bind to H+ ions.[37]

This results in separation of the polymer chains, leading to increased porosity and lowered physical and mechanical properties. However, this study is not consistent with Madeira et al. who reported that the lemongrass extract at MIC (0.625 mg/ml) did not alter the color, roughness, and flexural strength after overnight immersion.[38] These difference in the result could be related to the methodology used to obtain the extract, lower concentration of lemongrass used, and the short immersion period of their study.[30]

**Conclusion**

The effects of 0.5% lemongrass on the physical and mechanical properties of denture base heat-polymerized acrylic resin were similar to a commercially available denture cleansing product, Bony Plus. All samples in the experiment groups at the end of 60 and 90 days period were whiter and with higher surface roughness and lower flexural strength than the control. As physical and mechanical damages can be attributed over long and repeated immersions, intermittent short immersions in 0.5% lemongrass can be considered due to its potent antifungal activities which might be useful in elderly edentulous patients with poor systemic health lacking adequate manual dexterity.

**Acknowledgement**

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Effect of denture cleansers on denture base acrylic resin

Boonsoe, et al.


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