Original Article

In Vitro Stain Removal Capability of Household Vinegar as a Denture Cleaning Solution

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Abstract

Household vinegar consists of acetic acid, which is a chelating agent. Therefore, it has the potential to remove coffee stains on acrylic resin surfaces. As a result, the purpose of this study was to evaluate the capability of vinegar on removing coffee stains on acrylic resin surfaces. One hundred and twenty heat-polymerized acrylic resin specimens with the dimensions of 20 x 50 x 2 mm were stained using coffee solutions, then specimens were subjected to 4 stain removal methods (N = 30 each): immersion in distilled water for 8 hours (Group 1), immersion in 5 % vinegar for 8 hours (Group 2), ultrasonication in distilled water for 15 minutes (Group 3), and ultrasonication in vinegar for 15 minutes (Group 4). Stain removal ability was evaluated by determining two color difference values: ΔE_1 (comparing between stained specimens before and after stain removal procedures) and ΔE_2 (comparing between the baseline specimens and after stain removal procedures). Data were analyzed using One-way analysis of variances (ANOVA) and post-hoc Tukey's HSD test at a confidence level of 95 %. There was no statistically significant difference in ΔE_1 values between Groups 1, 2 and 4 ($p < 0.05$). Group 3 showed a significant lower ΔE_1 values than other groups. For ΔE_2, the results indicated that ΔE_2 value in Group 1 is significantly lower than other groups. In conclusion, immersion of acrylic denture base in vinegar or distilled water for 8 hours and ultrasonication in vinegar for 15 minutes showed the same result on stain removal ability. However, all coffee stains on acrylic resin surfaces were not removed completely by all methods.

Key words: Denture cleanser; Vinegar; Acrylic resin; Stain

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Introduction

Maintaining cleanliness of dentures is essential to maintain good oral health in elderly patients. Poor hygiene of dentures may result in the accumulation of stains, plaque and calculus on the denture surfaces, which can lead to the colonization of pathologic microorganisms causing denture stomatitis.[1] Staining of dentures can be caused by beverages such as tea or coffee, especially in the case of drinking those beverages over long period of times. Poor denture esthetics caused by staining may affect the patient's confidence, sociability and quality of life. Patients may request the dentist to remove stains and clean the denture to improve the esthetics so that it would not be a burden for the patient.[2] It could be useful for elderly patients to use non-toxic household chemicals as denture cleansers.

Household vinegar is used as a popular cleaning agent. It has been used to clean the countertops, glass surfaces, coffee makers, and other smooth surfaces.[3] Vinegar has also been suggested to be used as a denture cleanser because of its antimicrobial potential.[4,5] Using vinegar as a denture cleanser showed reduction of *Candida albicans* from the acrylic resin surfaces.[6] However, there is a lack of study on the coffee stain removal ability of vinegar on acrylic resin denture bases.

Drinking coffee causes staining on the surface of acrylic resin denture bases which is difficult to remove by using mechanical method. It has been hypothesized that oxidative polymerization and calcium bridging of polyphenols in coffee causes stain formation and its stabilization on material surfaces.[7,8] An effective method to remove such stable stains is to use chelating agents that can inhibit or destroy the polymerization reaction and calcium bridging of polyphenols. Acetic acid existing in vinegar appears to be a chelating agent.[9] Therefore, vinegar has the potential to be able to clean the stained acrylic resin surfaces. The purpose of this study was to evaluate the coffee stain removal ability of household vinegar from acrylic resin surfaces. In addition, the effect of using vinegar together with an ultrasonic cleaner to remove coffee stained on acrylic resin surfaces was investigated as well.

Materials and methods

One hundred and twenty rectangular shaped heat-polymerized acrylic resin specimens (Meliodent, Heraeus Kulzer, Hanau, Germany) with the dimensions of 20 x 40 x 2 mm were prepared as specified by the manufacturer, at ratio of 2.2 (powder) to 1 ml (liquid). Acrylic resin was heat polymerized at 73 ± 1°C for 90 minutes followed by water at 94 °C for 30 minutes. After samples were allowed to cool, the excess and flashes were removed. Specimens were manually finished using a circular motion with sequences of 600, 800, 1,000 and 1,200-grit sandpaper and wet polished with slurry pumice on a rag wheel, followed by calcium carbonate.

Stains were created by immersing specimens in a coffee solution prepared with 1 tablespoon of coffee powder (Nestcafe', Nestle, Bangkok, Thailand) mixed with 100 ml of boiling water. Specimens were exposed to the coffee solution at 37° ± 1°C for 30 days. The coffee solutions were renewed every 3 days. After 30 days of immersion, acrylic resin specimens were

run through with water for 30 seconds and kept in a dry condition for 24 hours prior to the stain removal experiments.

Stained specimens were subjected to 4 different stain removal methods (N = 30 each): immersion in distilled water for 8 hours (Group 1), immersion in 5 % household vinegar (Heinz, Win Chance Foods, Samutprakarn, Thailand) for 8 hours (Group 2), ultrasonication in distilled water for 15 minutes (Group 3), and ultrasonication in 5 % household vinegar for 15 minutes (Group 4). All experiments were conducted in closed containers at room temperature. Stain removal ability of each experimental group was evaluated by determining two color difference values (ΔE_1 and ΔE_2). The ΔE_1 was calculated by comparing color difference on stained specimens between before and after being subjected to stain removal procedures. The ΔE_2 calculation was performed by comparing color changes between the baseline specimens (before being stained) and stain removal specimens. All color measurements were performed using spectrophotometer (Hunter Lab Model ColorQuest XE, Hunter Associates Laboratory, Reston, VA, USA). The spectrophotometer was calibrated according to the manufacturer's instruction prior to the experiment. Two color difference values (ΔE_1 and ΔE_2) were calculated using the CIE L*a*b* system and quantified by the National Bureau of Standards (NBS) with NBS units (NBS unit = $\Delta E \times 0.92$)[10,11] Categorization of color differences according to NBS[10,12] was shown in Table 1.

The results of color difference were analyzed by using One-way analysis of variances (ANOVA) and Tukey's HSD test to determine whether there were significant differences among the color difference values in all experimental groups. All data were analyzed at a confidence level of 95 % using statistical software (SPSS 17.0, SPSS for Windows; SPSS Inc, Chicago, IL, USA).

Results

Means, standard deviations (SD) and NBS units of the ΔE_1 and ΔE_2 were presented in Table 2.

The results of One-way ANOVA for ΔE1 showed a statistically significant difference among the experimental groups ($p < 0.05$) (Table 3). Further analysis with Tukey's HSD test indicated a significantly lower ΔE_1 value for Group 3 (Table 2). However, there is no statistically significant difference in color changes between Groups 1, 2 and 4. For ΔE_2, the results of One-way ANOVA (Table 3) showed a statistically significant difference among the experimental groups ($p < 0.05$). Tukey's HSD test indicated a significantly lower ΔE_1 value for Group 1. However, there is no statistically significant difference in color changes between Groups 2, 3 and 4 (Table 2).

Discussion

The purpose of this study was to evaluate stain removal capability of 4 different cleaning protocols using household vinegar as a cleaning solution. The results showed a statistically significant difference in the color changes of the stained acrylic resins when comparing before and after cleaning among all experimental groups. Therefore, according to the results of this study, the research hypothesis was rejected.

Vinegar appears to be a mild acid which has a distinctive sour taste and a pungent smell, but it also seems to have an antimicrobial effect.[13,14] However, the volume of acetic acid used in household vinegar is comparatively small (approximately 5 % by volume). Vinegar has been reported to be an alternative solution for cleaning dentures. Overnight immersion of acrylic resin denture based in 5 % vinegar showed significant reduction of *Candida albicans* on the acrylic resin surfaces, *in vitro*[6] A previous study reported that immersion of 4 % household vinegar for 8 hours showed comparable antifungal properties to other commercial products.[15] Another study was performed to evaluate antifungal properties of 100 % white vinegar compared to other chemicals. The result showed that immersion of contaminated specimens 10 minutes in 100 % white vinegar showed the most effective results and author suggested that this agent is cost-effective and easy to access and thus may be appropriate for household use.[16] Besides the antifungal properties, household vinegar has a potential on stain removal capability.[7-9] However, lack of study on stain removal capability is presented.

Table 1 *Categorization of color differences according to National Bureau of Standards*

Critical marks of color difference	NBS Units
Trace	0.0 – 0.5
Slight	0.5 – 1.5
Noticeable	1.5 – 3.0
Appreciable	3.0 – 6.0
Much	6.0 – 12.0
Very much	> 12.0

Table 2 *Mean values ± standard deviation of color change and NBS units of all experimental groups*

Group	ΔE1		ΔE2	
	Mean ± SD	NBS Units	Mean ± SD	NBS Units
1	1.96 ± 0.44^{a}	1.80	3.94 ± 0.39^{A}	3.61
2	1.99 ± 0.44^{a}	1.83	4.65 ± 0.60^{B}	4.28
3	1.12 ± 0.41^{b}	1.03	4.71 ± 0.70^{B}	4.33
4	1.76 ± 0.65^{a}	1.61	4.48 ± 0.69^{B}	4.12

Mean values with same superscripts do not significantly differ from each other for the color change value at given stain removal conditions ($p < 0.05$)

Table 3 *One-way ANOVA for the color change ΔE_1 and ΔE_2 of specimens*

		Sum of Squares	df	Mean Square	F value	*p*
Between Groups	ΔE_1	14.780	3	4.930	20.11	0.000*
	ΔE_2	11.080	3	3.690	10.11	0.000*
Within Groups	ΔE_1	28.420	116	0.250		
	ΔE_2	42.390	116	0.370		
Total	ΔE_1	43.195	119			
	ΔE_2	53.750	119			

* p is significant at $p < 0.05$.

This *in vitro* study evaluated the stain removal ability of the stained acrylic resins after being immersed in vinegar and distilled water. Moreover, the use of vinegar together with a mechanical cleaning method was evaluated. The creation of coffee stains was according to protocols mentioned in a previous study.[17] Before being stained, all specimens were controlled to have trace color difference, that is, the ΔE values between specimens were less than 1, which is the minimum ΔE value that humans can perceive in color difference.[18] After being stained, the color differences among the specimens were standardized to have an ΔE value less than 1 meaning that all specimens had the same stain intensity before the cleaning experiment. This study performed immersion in vinegar for 8 hours which was mimicking the overnight soaking of dentures. Also various studies showed the effective antifungal properties of vinegar after 8-hour immersion.[15,16] Long-term exposure of acrylic resins to acids could affect their mechanical properties. A previous study was performed to evaluate the flexural strength of acrylic resin after immersion in an experimental cleanser containing oxalic acid. The results showed significant reduction in flexural strength of acrylic resin after 48-hour immersion.[19] To date, there is lack of data regarding the effect of vinegar containing acetic acid on flexural strength of acrylic resin. In this study, the authors performed a pilot experiment to evaluate flexural strength of acrylic resin after 8-hour immersion in vinegar and the results showed no significant reduction in flexural strength. However, further experiment regardingthe effect of long-term immersion in vinegar on the physical and mechanical properties of acrylic resin should be performed.

Based on the results of this study, all cleaning protocols showed capability of coffee stain removal from the acrylic resin surfaces. The ΔE_1 values were greater than 1 in all experimental groups, meaning that the reduction of stains could be detected by human eyes. This study used NBS units to quantify the color changes. NBS units in Groups 1, 2 and 4 showed that color

changes were noticeable, but Group 3 was categorized as only having slight change. Overnight immersion of stained acrylic resin specimens in either distilled water or vinegar showed the same cleaning capability. Using an ultrasonic cleaner with vinegar exhibited better result on stain removal ability compared to using an ultrasonic cleaner with distilled water. According to the ΔE_2 results the color of specimens after being exposed to all cleaning protocols appeared to be clinically different ($\Delta E_2 > 3.7$)[10] from the baseline color, before being stained. There was a significant lower ΔE_2 value of Group 1 than other groups meaning that the color of specimens after immersion in distilled water for 8 hours was closer to the baseline than other groups. This seems to be controversial to the stain removal ability considering the ΔE_1 values in which Group 1 showed no significant stain removal ability compared to others. This could be an error during specimen preparation. Each specimen was prepared in separated mold and processed separately resulting in difficulty to achieve exactly the same baseline color of specimens. Even though the baseline color was controlled not to be clinically different among specimens ($\Delta E < 1$), there were some color differences among baseline specimens which ranged from 0 to 1. However, the differences of ΔE_2 value of Group 1 compared to others were less than 1 which was not clinically significant. Therefore, it can be assumed that although vinegar showed a stain removal potential, immersion of specimens in vinegar for 8 hours and using ultrasonic cleaner together with vinegar for 15 minutes was not sufficient to completely eliminate the coffee stains on the acrylic resin surfaces.

Additional investigations regarding using vinegar as a stain removal solution for denture base materials are required by varying other influential factors such as cleaning duration and vinegar concentration. Furthermore, additional studies on the effect of vinegar on the physical and mechanical properties of an acrylic resin denture base are required.

Conclusion

This *in vitro* study investigated the effect of vinegar on stain removal capability from acrylic resin surfaces with stain removal protocols. Within the limitations of this study, the results showed that all cleaning protocols used in this study showed stain removal potential as the $\Delta E1$ values were greater than 1. Coffee stains could not be removed completely by all protocols. However, there was no statistically significant difference in stain removal ability among the immersion specimens in distilled water for 8 hours, immersion specimens in 5 % vinegar for 8 hours, and ultrasonicated specimens in vinegar for 15 minutes ($p < 0.05$). Using an ultrasonic cleaner together with distilled water showed the least stain removal ability.

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