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THE EFFECT OF DENTURE CLEANSERS ON TRANSVERSE STRENGTH AND COLOR STABILITY OF HEAT CURE POLYMERIZING ACRYLIC RESINS

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Abstract

Objective: The widespread use of denture cleaners has led to concerns regarding their effects on the transverse strength and color stability of heat-cured acrylic resin dentures. This study aimed to evaluate the impact of commercial and household denture cleaners on these two properties.
Methods: Eighty samples of heat-cured acrylic resin (2.5×10×64 mm) were randomly divided into four subgroups (N = 10) and immersed in distilled water (control), Professional® tablets, 1% sodium hypochlorite, and 1% vinegar solutions. The color components of the samples were measured using a spectrophotometer before and after immersion for 7 days, 14 hours, and 30 minutes (T1) and 12 days, 16 hours, and 10 minutes (T2). A three-point bending test was also performed.
Results: The maximum and minimum transverse strengths at T1 were observed in 1% sodium hypochlorite solution and distilled water, respectively, while the control group and 1% sodium hypochlorite had the highest and lowest strengths at T2. The control and 1% vinegar groups exhibited the lowest and highest color changes at T1 and T2, respectively, while the Professional® tablet and 1% sodium hypochlorite had the lowest and highest color changes.
Conclusion: The use of Professional® denture cleaners is recommended as it has the least detrimental effect on the transverse strength and color stability of heat-cured acrylic resin dentures. This finding can be useful for patients and clinicians in selecting appropriate denture-cleaning solutions.

Keywords: Denture cleaner, Heat-cured acrylic resin, Transverse strength, Color stability.

Introduction

The maintenance of clean dentures is crucial to prevent complications related to the proliferation of microorganisms and the subsequent formation of bacterial plaque. These biofilms can serve as significant etiological factors in the development of various problems, such as infections, impaired respiration, tissue irritation, and stomatitis. Therefore, it is essential to utilize denture cleaners in different forms, such as powders, tablets, pastes, creams, and foams, to maintain proper hygiene[13]. A complete edentulous denture requires high transverse strength, which combines compressive and tensile strength to withstand flexural stress caused by repeated chewing. Therefore, denture materials with high flexural strength are necessary. Cold-cure acrylic resin dentures have lower flexural strength than heat-cure acrylic resin dentures, and immersion in cleaners can significantly decrease their strength.[4]. Cold-cure acrylic resin dentures have lower flexural strength than heatcure acrylic resin dentures, and immersion in cleaners can significantly decrease their strength.[5].

Color stability is critical for dental materials, such as acrylic resins, and discoloration indicates material degradation. [6]. Daily denture cleaner use can cause discoloration in denture base resins, posing a significant concern for dentists and patients. Factors such as changes in material matrix, pigmentation, solubility, water adsorption, microleakage, surface roughness, and chemical erosion can cause color changes. Immersion time is positively correlated with color changes in acrylic resins.[7]

The current research aimed to assess the impact of various denture cleaners on the transverse strength and color stability of heat-cured acrylic resin dentures.

Materials and Methods
Eighty [3] rectangular HCAR (Acropars, Marlic Medical Instruments CO, Tehran) samples(figure 1), with dimensions of 2.5 × 10 × 64 mm (ISO 1567:1988), were allocated into two groups of 40. Each group was randomly subdivided into four subgroups (N = 10).

Figure 1. Heat cure resin samples

Figure 2. Professional denture cleaner tablets

The control group, Subgroup A, was immersed in distilled water, while Subgroups B, C, and D were immersed in denture cleaning solutions: Professional® tablet solution(figure 2), 1% sodium hypochlorite solution (deionized water and sodium hypochlorite, active chlorine 5%), and 1% vinegar,

respectively.(Figure 3) Before immersion, all acrylic samples underwent a color test using a spectrophotometer(figure 4), and color components were recorded for each sample. The samples underwent two immersion periods: one for 7 days, 14 hours, and 30 minutes (equivalent to five minutes of immersion per day for six years), and another for 12 days, 16 hours, and 10 minutes (equivalent to five minutes of immersion per day for ten years)[1]. The immersion was conducted at room temperature with the manufacturer's instructions, with the solution in each group being replaced every 24 hours. Following each immersion, the samples were rinsed with water for 10 seconds and airdried. The transverse strength of the samples was determined after each immersion(figure 5) using a universal testing machine and a 3-point bending test, applying a force of 1 mm/min until failure, and calculating the strength using the provided equation:
$S = 3PL/2bd^2$
[S: Transverse Strength, P: the force applied in Newtons, L: size between two supports (50 mm), b: width of specimens (10 mm), d: height of specimens (2.5 mm)]

Figure 3. Specimens immersed in different solutions

Figure 4. Color matching of samples with VITA Easyshade

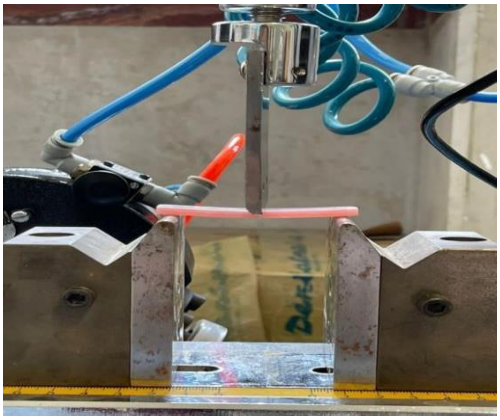

Figure 5. Testing the flexural strength of samples with universal testing machine

Following each immersion, washing, and drying cycle, the samples were analyzed using a spectrophotometer in accordance to international de l'Eclairage (CIE Lab) standards. The resulting color differences were determined using the provided equation.:

$$\Delta E = \sqrt{(\Delta a)^2 + (\Delta b)^2 + (\Delta L)^2}$$

The data were analyzed utilizing a one-way analysis of variance (ANOVA) test, adopting a significance level of 0.05. The outcomes regarding the impact of the denture cleaning solutions on both the color stability and transverse strength of the samples were subsequently reported.

Results

The study aimed to evaluate the flexural strength and discoloration of samples immersed in four different solutions. (Tables 1 and 2) The highest flexural strength was found in samples immersed in sodium hypochlorite solution, while the lowest was found in the control group immersed in distilled water, with a statistically significant difference ($p = 0.0001$). Samples immersed in sodium hypochlorite solution exhibited a statistically significant difference in flexural strength compared to other solutions ($p \leq 0.05$).

Based on the results of the changes in color components after immersion, it can be inferred that denture cleaners can cause pale and yellow color changes, particularly with a significant increase in components L and b, and to some extent, component a. (Table 2)

Table 3 illustrates that the distilled water group had the lowest ΔE, while the vinegar immersion solution group had the highest ΔE after seven days, 14 hours, and 30 minutes. The difference between the control group and the vinegar and sodium hypochlorite groups was statistically significant ($p \geq 0.05$), with a significant difference observed between the ΔE of vinegar and the other three groups. Both the vinegar immersion solution and sodium hypochlorite groups exhibited a significant difference compared to the control group ($p \geq 0.05$). In laboratory studies, ΔE was converted to NBS units, which is a ratio of ΔE (ΔE x 0.92). Based on this conversion, the color change is classified as follows, from low to high: Trace (0.00-0.5), Slight (0.5-1.5), Noticeable (1.5-3.0), Appreciable (3.0-6.0), Much (6.0-12.0), and Very much (12.0 >).[8]

Based on the NBS system and the findings presented in Tables 3 and 4, the results indicate that distilled water and Professional® denture cleaners caused the least discoloration (ΔE) compared to sodium hypochlorite and vinegar. Therefore, distilled water and Professional® denture cleaners are considered to be better immersion and cleaning solutions.

Discussion

Hydrolysis is a chemical reaction that involves the breaking of chemical bonds in a substance by water. During hydrolysis, water molecules decompose into hydrogen and hydroxyl ions, which then participate in the reaction. This reaction breaks down polymers, proteins, fats, and nucleotides. The rate of hydrolysis can be increased using acids, bases, or enzymes.[9] Acrylic resin, being a polymer, can be decomposed through several methods, one of which is hydrolysis. [10] The porosity of the matrix structure of the polymer allows it to absorb water, thereby enhancing its flexural strength upon contact with water.[11] The high polarity of the resin molecules results in the extended absorption of water by acrylic resins. The rate of water absorption is directly proportional to the components of high-polarity resins, which form hydrogen bonds with water molecules.[12]

Samples immersed in sodium hypochlorite had the highest flexural strength (3.16 ± 0.73 MPa) after a 7-day, 14-hour, and 30-minute immersion period, while those in distilled water had the lowest (2.32 ± 0.41 MPa). However, after a 12-day, 16-hour, and 10-minute immersion period, the samples in distilled water exhibited the highest flexural strength, while those in sodium hypochlorite had the lowest. Acidic hydrolysis occurs faster than alkaline hydrolysis, making the flexural strength initially higher in sodium hypochlorite's alkaline environment. However, over time, hydrolysis accelerates in the alkaline medium, leading to increased surface roughness and decreased flexural strength compared to vinegar, which justifies its higher shelf life.[10] The porosity of the matrix structure of polymers leads to water absorption upon contact with water, which in turn increases their flexural strength [11]. The long-term water absorption of acrylic resins is due to the polarity of their molecules, as high-polarity resins form hydrogen bonds with water molecules, thereby determining the rate of water absorption [12]. After a 7-day, 14-hour, and 30-minute immersion period, samples immersed in sodium hypochlorite solution exhibited the highest flexural strength (3.16 ± 0.73 MPa), while those immersed in distilled water solution exhibited the lowest (2.32 ± 0.41 MPa). However, after 12-day, 16-hour, and 10-minute immersion, the samples in distilled water exhibited the highest flexural strength, while those in sodium hypochlorite exhibited the lowest. Acidic hydrolysis is faster than alkaline hydrolysis, so sodium hypochlorite initially has higher flexural strength than vinegar. However, hydrolysis accelerates in the alkaline medium, increasing surface roughness and decreasing flexural strength over time. A study found that 1% sodium hypochlorite immersion significantly decreased flexural strength and increased surface roughness of HCAR after three months.[13] This finding is consistent with Sharma's study, where the samples' flexural strength decreased over time after immersion in sodium hypochlorite solution. Sharma's study found no significant difference in the flexural strength and surface roughness of samples cleaned with phytidant 100% and vinegar over three months. In general, the flexural strength of samples immersed in vinegar and sodium hypochlorite decreased with increasing immersion time. In contrast, the samples immersed in distilled water and Professional® tablets exhibited an increase in flexural strength with increasing immersion time. Distilled water is a neutral buffer solution that resists pH changes, and the samples immersed in this solution become brittle gradually with increased water absorption, resulting in higher flexural strength during the second immersion. The chemical composition of Professional® tablets comprises a solid acid-base combination containing sodium bicarbonate and potassium monopresulfate and a weak acid-base combination containing citric acid and sodium carbonate, resulting in a neutral pH buffer environment. This behavior is similar to that of distilled water, which exhibits high resistance to pH changes. Therefore, the advantage of Professional® tablets over distilled water in cleaning dentures is likely due to the presence of antimicrobial compounds.[13-14]

In another study, the flexural strength of heat-cured and self-curing acrylic resins was evaluated following immersion in three different denture cleaners, including two alkaline peroxide-based cleaners and sodium hypochlorite. The present study's findings are consistent with a previous study, which reported a significant decrease in the flexural strength of heat-cured acrylic resin after exposure to denture cleaners. The use of sodium hypochlorite resulted in decreased flexural strength in both types of polymethyl methacrylate resin, while the use of alkaline peroxide did not affect the flexural strength. Therefore, sodium hypochlorite is not a suitable detergent for other dentures due to its detrimental effect on the flexural strength of heat-cured acrylic resin.[5]

In a study, the impact of vinegar, salt, and chlorhexidine cleaning solutions on the flexural strength of acrylic base denture resin was investigated. The samples were immersed in solutions for one week, one month, and three months. The results demonstrated that the flexural strength of resin samples immersed in vinegar decreased. This finding is consistent with the current study's results, indicating that vinegar, as a weak acid, smoothens the surface layer of the materials, reduces interchain forces, and ultimately decreases the flexural strength of the resin.[15]

Color stability of cosmetic restorations has been extensively studied in vitro. The stability can be assessed visually or with instrumental techniques, such as chlorometers and spectrophotometers. The latter is more accurate, and the CIE lab system is used to determine color changes. Base denture resins can change color over time due to internal and external factors. [16]. Internal factors are associated with changes in the properties of materials due to prolonged exposure to temperature and humidity in the oral cavity. It includes the absorption or adsorption of foreign substances [17]. Discoloration can result from dehydration, water absorption, leakage of material components, surface roughness or wear, chemical change or destruction over time, oxidation, and others. However, studies have shown that external factors have a more significant impact on the color change of base dentures than internal factors.[18-20]

A previous study compared the effect of 3.8% sodium perborate cleaner and sodium hypochlorite denture cleaner on color change and found that sodium perborate caused a more significant color change due to its efficient chemical reaction with oxygen molecules, resulting in the dissolution of the resin's plasticizer and hydrolysis. In the current study, the distilled water group exhibited the lowest color change (ΔE) at T1, while the vinegar immersion solution group showed the highest ΔE compared to the pre-immersion period. Additionally, after 12 days, 16 hours, and 10 minutes, the ΔE of the samples immersed in sodium hypochlorite solution was higher than in other cases, and the Professional® denture cleaning solution caused the least color change due to its low dye absorption. Distilled water and Professional® tablets caused the least color change among the studied denture cleaners and are therefore better cleaning options than other materials.[21]

In another study, the impact of two denture cleaners, Fittydent and Dentipur, on the stability of HCAR was evaluated. The results showed a significant difference in color change among the groups, which was not observed after 60 days of immersion.[22]

In a different study, the impact of three denture cleaning solutions, including 5.25% sodium hypochlorite (Vitex), 2.5% white vinegar (Verda), and Corega denture cleaning tablets, on discoloration was evaluated. Acrylic resin denture bases were examined, and a higher color changeability was observed for sodium hypochlorite 5.25% compared to the other studied cleaners and water. Additionally, the effect of vinegar on the color change of rough surfaces was more significant than on smooth surfaces.[23] These findings are consistent with the present study, which also showed significant color changes after immersion in sodium hypochlorite and vinegar. In another study, the impact of denture cleaners on the surface roughness of HCAR dentures was evaluated. The results revealed that the surface roughness of the samples immersed in sodium hypochlorite was significantly higher than those immersed in vinegar solution.[24] The current study's findings align with the previous study, as both show that staining occurs due to an increase in surface roughness of samples immersed in sodium hypochlorite solution. Another significant finding of this study was an increase in ΔE during T2 compared to T1 in samples immersed in distilled water, sodium hypochlorite, and vinegar solutions. However, for the Professional® denture cleaning solution group, ΔE decreased at T2 compared to T1. Immersion time in commercial solutions appears to be a crucial factor in reducing discoloration.[6]

Conclusion

In conclusion, this study provides valuable insights into the impact of different denture cleaning solutions on the flexural strength and color stability of acrylic resin denture bases. The results demonstrate that the use of Professional® denture cleaner can be advantageous in maintaining the quality and longevity of denture bases, as it has the least detrimental effect on both flexural strength and color stability. This finding is particularly relevant for denture wearers who need to clean their dentures regularly to prevent bacterial and fungal growth, as well as discoloration and deterioration of the denture material. Moreover, the study highlights the importance of considering immersion time in commercial cleaning solutions, as longer immersion times can lead to greater discoloration and reduction in flexural strength. Therefore, denture wearers are advised to follow the recommended cleaning instructions for their denture cleaners and consult with their dentists regarding the best cleaning options for their specific denture type. Additionally, further research is needed to investigate the long-term effects of denture cleaning solutions on the properties of denture materials and their impact on oral health.

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Table 1: Investigation and comparison of Flexural Strength in the studied groups at different times

Time / Cleaner	7 days, 14 hours, and 30 minutes T1	12 days, 16 hours, and 10 minutes T2	P-Value
Control	^{A}2.32±0.41	^{A}2.68±0.27	0.03
Professional Tablet	^{A}2.34±0.16	^{A}2.48±0.44	0.35
1% Vinegar	^{A}2.56±0.31	^{A}2.51±0.44	0.77
1% Sodium Hypochlorite	^{B}3.16±0.73	^{A}2.40±0.29	0.007
P-value	0.0001	0.39	

* ANOVA
**Different uppercase letters show a statistically significant difference in each column (P-value ≥0.05) (between detergent groups by time)

Table 2: Comparison of the mean rate of color change in (ΔE) the study groups at different times

	Group	L	a	b	Immersion time
Before immersion	Control	83	-0.1	3.3	T_1
	1% Sodium Hypochlorite	91.5	0.6	5.6	
	Vinegar 1%	83.7	-0.9	4.2	
	Professional Tablet	84.9	0.2	4.4	
After immersion	Control	84.1	1.8	3.6	T1
	1% Sodium Hypochlorite	93.4	3.5	7.2	
	Vinegar 1%	92.5	2.1	5.5	
	Professional Tablet	85.4	۲/۱	۴/۵	
Before immersion	Control	83.4	0.5	3.2	T2
	1% Sodium Hypochlorite	83.7	0.7	3.4	
	1% Vinegar	84.3	0.5	3.4	
	Professional Tablet	84.7	0.2	3.7	
After immersion	Control	85.4	0.2	4.2	T2
	1% Sodium Hypochlorite	93.1	3.3	7.9	
	1%Vinegar	94.4	1.5	4.6	
	Professional Tablet	84.7	1	2.2	

Table 3: Investigation and comparison of color change (ΔE) in the study groups at different times

Time / Cleaner	7 days, 14 hours, and 30 minutes T1	12 days, 16 hours, and 10 minutes T2	P-Value
Control	^{A} 2.69±0.95	^{A}3.15±1.53	0.425
Professional Tablet	^{AB} 3.29±1.04	^{A}2.82±0.54	0.47
1% **Vinegar**	^{c}9.99 ±2.1	^{B}10.65±1.7	0.45
1% **Sodium Hypochlorite**	^{B}5.57±3.54	^{C}13.34±3.06	0.0001*
P-value	0.0001	0.0001	

* ANOVA

**Different uppercase letters show a statistically significant difference in each column (P-value ≥0.05) (between detergent groups by time)

Table 4: NBS values (Δ/Ex 0.92) for measuring material color after exposure to different solutions

Time / Cleaner	7 days, 14 hours, and 30 minutes T1	12 days, 16 hours, and 10 minutes T2
Control	2.47	2.89
Professional Tablet	3.02	2.59
1% Vinegar	9.19	9.79
1% Sodium Hypochlorite	5.12	12.27