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Research Article

Effects of Different Chemical Disinfectants on Physical Properties of Denture Base Acrylic Resin Material

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Abstract

Statement of the problem: There is still a lack of data regarding the effects of exposure to different chemical disinfectants on the color stability, light translucency, and surface roughness of dentures is limited.

Objective: This study aims to investigate the impact of six different chemical disinfectants on the color change, translucency, and surface roughness properties of heat-polymerized denture base acrylic resin.

Material & Methods: Totally 70 rectangular blocks (10×10×2 mm) were polymerized from the heat-polymerized acrylic denture base resin material. The surfaces of the specimens polished with 600- and 1200-grit waterproof abrasive paper. Each specimen were immersed in six denture cleansers. The total immersion time of a specimen in selected chemical disinfectant was 36 hours. Color changes, translucency and, surface roughness were measured after immersion process. The results were statistically analyzed with 1-way ANOVA and the Tukey honestly significant difference (HSD) test (α=.05).

Results: According to the results of the 1-way ANOVA test, significant differences were observed in the ΔE_{00}, TP_{00} and Ra properties among the acrylic resin groups following immersion in chemical disinfectants ($P<0.05$). ΔE_{00} value of the CG group was significantly higher than that of the NS, SH, G, and E groups ($P<0.05$). The TP_{00} values of the NS and G groups were demonstrated significant differences compared with C group ($P<0.05$). The Ra values of the SH, SP, G, CG and, E groups were significantly increased after immersion process, in comparison with C and NS groups ($P<0.05$).

Conclusions: Color stability, translucency and surface roughness of the denture base heat polymerized acrylic resin is influenced by chemical disinfectants.

Keywords: Chemical Disinfectants, Color Stability, Translucency, Surface Roughness,

Introduction

Removable dentures are still a satisfactory treatment option for edentulous patients.[1] The fabrication stages of these prostheses involve working with a variety of materials and substantial equipment that can not be disinfected or sterilized easily. Therefore dentures can potentially become contaminated at any stage during their fabrication process in clinics and laboratories.[2-6] The impressions, dental stone casts, polishing wheels and other dental materials etc. are being potential areas for cross-contamination between dental professionals and patients. The viruses and bacteria that firstly carried by impressions may lead to cause denture-related ear infections, airway infections, or cross-contamination.[5-10]

As the prevalence of life-threatening infections continues to rise, there is a growing interest in effectively managing the spread of such infections. Thus, the thorough disinfection of dentures has become a crucial practice to prevent cross-contamination and protect the health of patients.[6,10-12] Established disinfection methods known to be effective fall into two primary categories: chemical and physical methods.[13] Chemical disinfectants are favored for their cost-effectiveness and user-friendliness. However, resin-based materials have a notable disadvantage in that they tend to absorb water, potentially compromising their physical and mechanical properties.[1,14,15] This water absorption issue can be exacerbated if the resin material comes into contact with a liquid containing colorants, possibly leading to discoloration.[10,16] Furthermore the effects of various chemical disinfectants on dimensional stability, hardness, wettability, and flexural strength of the resin-based materials has also been reported.[14,17]

The aesthetics of the removable dentures play a crucial role in meeting patients' expectations. The color matches between underlying tissue and denture base is an important requirement for aesthetics. Therefore color stability of denture base acrylic resin is an essential factor for long-term patients' satisfactions from their dentures. Additionally translucency of the removable dentures plays a major role in the aesthetics due to the "chameleon" effect, which allows the adjacent and underlying structures to reflect and show trough. To protect the aesthetics of dentures in long-term clinical use it is important to protect color stability and translucency.[1,18]

Change in color is indicative of the aging or damage of these materials and can be quantitatively assessed through colorimetry or spectrophotometer. This method relies on digitally expressing the perceived color of an object. Among the color systems used to assess,[2,13,14,15] The international de l'Eclairage (CIE Lab*) color system is commonly employed.[14,16] The American Dental Association (ADA) recommends the use of the CIELAB system, which defines all natural colors as combinations of three primary colors: red, blue, and green in specific proportions. This technique is widely adopted by dental researchers to investigate the color attributes of dental materials.[16,19] However, recent research has shown that the CIEDE2000 color difference formula is more effective than the CIELAB formula in evaluating visual tolerances. This encourages the use of the CIEDE2000 system in dentistry.[20]

Denture cleansers are commonly employed to inhibit the colonization of Candida albicans and related Candida species, as well as to prevent the formation of denture plaque. These commercial denture cleansers can be categorized into various groups, including neutral peroxides with enzymes, enzymes alone, acids, hypochlorites, peroxides, natural remedies, and mouth rinses designed for denture care. The daily use of denture cleansers has the potential to impact the physical and mechanical properties of denture base materials.[17,21]

While the color stability of denture base acrylic resins and hard direct reline acrylic resins when exposed to food colorants has been extensively studied, limited information is available regarding the impact of denture cleansers on color stability, translucency and surface roughness of denture base acrylic resins.[2,16,18,19,22] Therefore the current study aimed to determine the effect of 6 different denture cleansers on the color stability, translucency and, surface roughness of heat-polymerized denture base acrylic resin. The null hypothesis is that there would be significant differences in color stability, translucency and, surface roughness properties of the denture base acrylic resin after immersion in the chemical disinfectants.

Materials & Methods

Totally 70 rectangular blocks (10×10×2 mm) were manufactured from the heat-polymerized acrylic denture base resin (Kemdent, UK) by using custom made silicon molds according to the manufacturer's instructions. Following the polymerization stage, the specimens were embedded in distilled water for 24 hours at 37°C. The surfaces of the specimens polished with 600- and 1200-grit waterproof abrasive paper (Atlas English Abrasives Co., UK) by the same operator to reach a standard smoothness. Then specimens rinsed with tap water and air dried. Specimens were randomly divided into seven experimental study groups (n=10) according to

the selected chemical disinfectants that widely used in medical practice, as listed in Table 1 and with tap water as a control group. Each specimen was preserved in high-density polyethylene containers labeled with the name of the group and numbered from 1 to 10. The specimens were kept in the same container throughout the study.

Table 1. Test liquids used

Liquids		**Dilution**	**Manufacturer**
Tap water	(C)	-	
Neutral soap	(NS)	-	Sonett Ekoorganik, Istanbul, Turkey
Sodium hypochlorite	(SH)	2%	Aklar Kimya, Ankara, Turkey
Glutaraldehyde	(G)	2%	Aklar Kimya, Ankara, Turkey
Sodium perborate	(SP)	4%	Aklar Kimya, Ankara, Turkey
Enzyme	(E)	2%	GlaksoSmithKline KK, Tokyo, Japan
Chlorhexidine gluconate	(CG)	4%	Drogsan, Ankara, Turkey

The specimens were immersed in each denture cleansers for 15 minutes at room temperature (23°C±2°C). Then the specimens washed with tap water and distilled water and immersed in distilled water for 10 minutes at 37°C. This immersion cycle procedure was repeated 144 times and the total immersion time of a specimen in selected chemical disinfectant was 36 hours. After the immersion cycle had completed the specimens dried with absorbent paper and spectrophotometric measurements were performed with a SP 60 spectrophotometer (X-Rite Inc., USA).

Before starting the spectrophotometric measurements the spectrophotometer was calibrated according to the manufacturer instructions. To calculate color difference (ΔE_{00}), the CIE color parameters of the control group specimens were measured, and average L*, a*, and b* values were obtained. These average values were taken as the reference (L*=49.9, a*=19.39, and b*=4.2) and used to calculate the ΔE_{00} values of the immersed specimens. The color measurements for the E_{00} calculations were made over the gray background. Measurements were taken from the center of the specimens, and average values were recorded based on three measurements. The color changes of the specimens were measured with using the following formula;

$$\Delta E_{00} = \left[\left(\frac{\Delta L'}{K_L S_L}\right)^2 + \left(\frac{\Delta C'}{K_C S_C}\right)^2 + \left(\frac{\Delta H'}{K_H S_H}\right)^2 + R_T\left(\frac{\Delta C'}{K_C S_C}\right)\left(\frac{\Delta H'}{K_H S_H}\right)\right]^{1/2}$$

The lightness, chroma and hue differences represent with the factors ΔL', ΔC', ΔH'. KL, KC and KH are the factors of weighted. SL, SC and SH are demonstrated the averaging factors of the lightness, chroma and hue. The overall correction factor which based on the differences in chroma and hue is RT. The weighted parametric factors KL, KC and KH were set to 1.[10]

The perceptibility (PT) and acceptability thresholds (AT) were accepted as the threshold values for ΔE_{00} values of 0.78 and 1.81, respectively, as proposed by Paravina et al.[20] All measurements were performed under the D65 type illuminant with a 10° observation angle. The measurement geometry of the spectrophotometer was 45/0.

The translucency of the specimens groups was estimated by calculating the translucency parameter (TP_{00}) using the equation formula given below that based on the CIEDE2000 color difference model.

$$TP_{00} = \left[\left(\frac{\Delta L'}{K_L S_L}\right)^2 + \left(\frac{\Delta C'}{K_C S_C}\right)^2 + \left(\frac{\Delta H'}{K_H S_H}\right)^2 + R_T\left(\frac{\Delta C'}{K_C S_C}\right)\left(\frac{\Delta H'}{K_H S_H}\right)\right]^{1/2}$$

ΔL', ΔC' and ΔH' are show the differences in terms of lightness, chroma and hue of the specimens over a black and white background.

Following the color difference and translucency measurements of the specimen groups the surface roughness (SR) (Ra) measurements were performed with a contact profilometer (TR100 Surface Roughness Tester; Checkline Europe BV). Three readings were performed for each specimen and the average SR calculated. The over evaluation lengths were 4 mm and the cut-off value was 0.25 mm for per group (measuring range Ra: 0.05 to 15.0 μm).

Statistical analysis was performed by using a software program SPSS 26 (IBM, Chicago, IL). The results of the ΔE, TP_{00} and Ra were statistically analyzed with 1-way ANOVA and the Tukey honestly significant difference (HSD) test ($P<0.05$).

Results

The results of 1-way ANOVA test for estimating the effect of different chemical disinfectants application on ΔE_{00}, TP_{00} and Ra properties of the specimen groups are shown in Table 2. According to the results of the 1-way ANOVA test, significant differences were observed in the ΔE_{00}, TP_{00} and Ra properties among the acrylic resin groups following immersion in chemical disinfectants ($P<0.05$).

Table 2. One-way ANOVA results of ΔE_{00}, TP_{00} and, Ra values.

ANOVA					
Experimental Treatments	**Sum of squares**	***df***	**Mean square**	**F**	**Sig.**
ΔE00					
Between Groups	6.141	5	1.228	7.819	<0.001
Within Groups	8.482	54	.157		
Total	14.622	59			
TP00					
Between Groups	8.909	6	1.485	3.820	<0.003
Within Groups	24.485	63	.389		
Total	33.394	69			
Ra					
Between Groups	.633	6	.106	67.345	<0.001
Within Groups	.099	63	.002		
Total	.732	69			

The mean, standard deviation, minimum and, maximum ΔE_{00}, TP_{00} and Ra values of all specimen groups are shown in Table 3. Color changes were observed in all groups after immersion in chemical disinfectants compared to the C group. Based on the Tukey HSD test results (Table 3), the ΔE_{00} value of the CG group was significantly higher than that of the NS, SH, G, and E groups ($P<0.05$). However, no significant difference was observed between the CG and SP groups ($P=0.093$).

Table 3. The descriptive statistics of ΔE00, TP_{00} and Ra.

Descriptives					
Liquids	**N**	**Mean**	**Std deviation**	**Minimum**	**Maximum**
ΔE_{00}					
NS	10	$.39^{A}$	.23	.17	.96
SH	10	$.56^{A}$	.29	.17	1.05
G	10	$.67^{A}$	.18	.34	0.94

SP	10	.86^{AB}	.49	.36	1.61
E	10	.46^{A}	.22	.11	.84
CG	10	1.35^{B}	.70	.60	2.36
TP_{00}					
C	10	9.76^{A}	.37	9.23	10.30
NS	10	10.91^{B}	.88	8.62	11.77
SH	10	10.16^{AB}	.47	9.55	10.89
G	10	10.72^{B}	.29	10.29	11.14
SP	10	10.31^{AB}	.49	9.14	10.74
E	10	10.32^{AB}	.60	9.22	10.96
CG	10	10.60^{AB}	.95	8.28	11.55
Ra					
C	10	.279^{A}	.090	0.04	.36
NS	10	.320^{A}	.002	.31	.33
SH	10	.504^{B}	.003	.49	.53
G	10	.494^{B}	.005	.49	.50
SP	10	.496^{B}	.005	.49	.51
E	10	.511^{B}	.002	.50	.52
CG	10	.532^{B}	.049	.51	.67

Different superscript letters represent significant differences between groups according to the Tukey HSD test ($P<0.05$).

The TP_{00} values of the NS and G groups were demonstrated significant differences compared with C group ($P<0.05$). While the TP_{00} values of all experimental groups increased, no statistically significant differences were observed between the SH, SP, E, and CG groups compared to the C group ($P>0.05$).

The Ra values of the SH, SP, G, CG and, E groups were significantly increased after immersion process, in comparison with C and NS groups ($P<0.05$). The NS group exhibited a Ra value similar to that of the C group ($P=0.266$).

Discussion

The null hypothesis that there would be significant differences in color stability, translucency and, surface roughness properties of the denture base acrylic resin after immersion in the chemical disinfectants was accepted.

The color stability of the prostheses may be the most important factor for the patients' satisfaction.[1,14] The color of the ceramic dental restorations is mostly stable in long-term clinical use whereas the resin-based restorations can not provide this due to the water sorption.[1,14] The acrylic resin based dentures are exposed to oral fluids and also disinfectants during their usage.[10,14] Therefore the current study searched the effect of the frequently used disinfectant liquids effects on physical properties of heat-polymerized acrylic resin. The current study demonstrated that after immersion in chemical disinfectants color changes of all specimen groups increased compared to the C group. However ΔE_{00} value of the CG group was significantly higher ($P<0.05$) than that of the other disinfectants groups except SP group ($P=0.093$).

The previous studies reported that denture cleansers cause bleaching due to the coloring material leaching out, loss of soluble components, staining effect of external colorants and water absorption in acrylic resin materials.[6,14,23,24] These factors may explain the increasing ΔE_{00} values of the experimental groups in this study. Polychronacis et al[10] reported that the firstly G (2.6%) and secondly the CG (0.12%) disinfectants were showed the most discoloration effect on denture teeth. When compared this result with the present study the percentage concentration of the disinfectants were different, the CG=4% and G=2%. Although the direct comparison of the results is not possible, due to the differences in experimental materials and experiment procedures, thus the significantly higher discoloration effect of the CG ($\Delta E_{00}=1.35$) in the present study compared with Polychronacis et al[10] study, may be explained with the higher concentration of the CG. Additionally another reason for significantly increasing the ΔE_{00} value of the CG group is proven staining effect of the CG solution. Although the significant color change differences were seen in the present study, the average was between the acceptability threshold ΔE_{00} values ($P>0.78$, $P \leq 1.81$) reported in literature.

Pişkin et al[6] and Hong et al[14] reported that the ΔE_{00} of the specimen groups increased by increasing immersion time in disinfectant solutions. They reported that the probable changes in surface properties of the specimens could be a factor in color changes. The present study also searched the effects of the chemical disinfectants on SR of the specimens groups after immersion process. The Ra values of the SH (0.504), SP (0.496), G (0.494), CG (0.532) and, E (0.511)

groups were significantly increased after immersion process, in comparison with C (0.279) and NS (0.320) groups. The NS group exhibited a Ra value similar to that of the C group. Gad et a[l1] reported that after immersion the acrylic resins in distilled water the water sorption and solubility of the specimens groups increased. These situations cause the changes in mechanical properties of the acrylic resins. Therefore the increasing SR values of the present study may be the result of the changes in mechanical properties of the specimens groups.

Translucency is one of most important optical property for aesthetic of the dentures.[1,18] The clinicians should take into account this parameter in addition with the color stability of the dentures. Translucency is regulated by the interaction of light that undergoes transmission, reflection, absorption and scattering in a material.[1] The refractive index mismatch is known to change during polymerization as monomers convert into poylmers, but also after aging due to the hydrolytic changes.[18] The researcher mostly studied the TP of the denture teeth and composite resins rather than acrylic resin. Polychronacis et al[10] were searched the TP of the denture teeth after immersion in chemical disinfectants. They reported that no significant differences were seen in TP among disinfectants groups after immersion periods. Divnik-Resnik et al[18] studied the effects of bioflovonaid-containing mouth rinsing on the optical properties of the tooth colored restorative materials. They reported that the differences in TP_{00} values of the experimental groups were in the acceptable match ($0.6 < TP_{00} \leq 2.6$).

As the studies are limited on the effect of chemical disinfection on TP_{00} of the heat polymerized acrylic resin materials it is difficult to compare the result of the current study. Gad et al[1] searched the water sorption, solubility and, translucency of the 3D printed acrylic resins. The control group of the their study was a heat polymerized acrylic resin. They measured the TP_{00} before and after the thermal cycling that was replicated 6 mouths use in oral cavity and the control group' TP_{00} value was decreased after thermal cycling (before=11.09, after=8.38). In the present study the TP_{00} values of the experimental groups were not measured before exposed to the chemical disinfectants. However the results discussed with the control group, the distilled water. All experimental groups demonstrated an increasing rate compared to C group (9.76). However the results of the NS (10.91) and G (10.72) groups were significantly increased ($P<0.05$). As reported in the previous studies the chemical disinfectant could have a bleaching and whitening effect on resin materials.[6,14,23,24] This effect may increase the translucency of the specimens in the present study.

The results of the current study indicated that the color stability, translucency and SR properties of the heat-polymerized acrylic resin were affected by disinfectant solutions. The tap

water was the control group in the current study. As reported in the previous literature[1,5,6,15] the distilled water also effects the mechanical and physical properties of the resin based materials therefore not measuring the ΔE_{00}, TP_{00} and SR properties of the experimental groups before the immersion in the distilled water and disinfectants solutions could be a limitation of the current study. Furthermore the oral fluids which taken with foods may cause stains and changes in mechanical properties. Additionally as recently the resin-based materials have been manufacturing with 3D printers there is also need further investigations to learn the chemical disinfectants effects on 3D printed acrylic resin.

Conclusions

The results of the current study reached the following conclusions. All disinfectant solutions increased the ΔE_{00} values of the heat-polymerized acrylic resin, mostly the CG. The translucency of the heat-polymerized acrylic resin increased especially in the NS and G groups. All chemical disinfectants affect the surface roughness of the heat-polymerized acrylic resin in an increasing way.

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