Color Stability and Surface Roughness of a Laboratory-Processed Composite Resin as a Function of Mouthrinse

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ABSTRACT

Statement of the Problem: Mouthrinses can cause discoloration on indirect resin composites.
Purpose of the Study: The purpose of the study was to investigate the effect of different mouthrinses on the color changes and surface roughness of a laboratory-processed composite.
Methods and Materials: Fifty discs were made using GC Gradia/GC indirect composites and divided into five groups which immersed in artificial saliva and four different types of mouthrinses. The samples were immersed daily for 14 days in 20 mL of the solutions for 2 minutes twice a day (with a 12-hour interval between exposures). Measurements were carried out at four different times: 1 hour after sample preparation (t_0), 1 day (t_1), 7 days (t_2), and 14 days (t_3) after the first immersion in the solutions. The color before and after immersion was measured according to Comission Internationale de L'Eclairage (CIE L*, a*, b*) System and ΔL^*, Δa^*, Δb^*, and ΔE^* values were calculated. The surface roughness Ra (μm) of the specimens was evaluated using a profilometer.
Results: There were significant differences between the groups at all time representing ΔE values ($p < 0.001$). At (t_1) time representing ΔRa value, there were significant differences between the groups ($p < 0.05$). At (t_2, t_3) time representing ΔRa values, there were significant differences between the groups ($p < 0.001$). Pharmol Zn immersed specimens showed ΔE values between 1.04 and 3.67.
Conclusions: The result of this study indicated that the mouthrinses affected the color stability of indirect composites.

CLINICAL SIGNIFICANCE

Based on the results of this study, patients with resin composite restorations should be warned by the dentists about the discoloration of the restorations and the time period of the mouthrinse that will be used.

INTRODUCTION

Discoloration of tooth-colored resin-based materials may caused by several intrinsic and extrinsic factors. Among intrinsic factors, the most important factors are type of resin matrix, percentage and particle size distribution of the incorporated fillers,[1] type of photo initiator,[2] and percentage of remaining double bonds.[3]

Extrinsic factors for discoloration of resin composites include staining by adsorption or absorption of colorants from exogenous sources such as coffee, tea, nicotine, beverages, and mouthrinses.[1,4,5]

Mouthrinses are mostly used as an important caries and gingivitis control method, and a breath freshener. Because of the anti-inflammatory, antiseptic, and

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analgesic properties, they are occasionally administered after tooth preparation in order to reduce local inflammation and tenderness, and to hasten mucosal healing.[6–8] Today, the number of people using mouthrinse solutions for anti-microbial control has increased not only because of professional recommendations, but also due to the capacity of such materials to provide cooling sensation and to reduce halitosis.[9] Mouthrinse solutions have various components such as detergents, emulsifiers, organic acids, dyes, and alcohol. Alcohol, which can be part of the composition of some mouthrinse solutions, has antiseptic properties and helps the breakage or dissolution of active principles (antimicrobial agents, especially essential oils), in addition to preserving the components of the formula, although its addition does not contribute directly to the control of biofilm and prevention of gingivitis. However, alcohol may have some unwanted effects, like lesions in oral tissues including burning or sore sensation and mucosal peeling or stomatitis—and softening of resin composites.[10–12] Also, frequent use of mouthrinses may have detrimental effects on oral and dental tissues.[7,13]

Recently introduced laboratory-processed resin composite systems attempt to resolve some of the problems inherent with dental ceramic. These new generation indirect resins have a higher density of inorganic ceramic filler than those of traditional direct and indirect composites.[14] These materials are advocated for a wide range of fixed prosthodontic applications such as inlays, onlays, veneering, metal-free single unit crowns, and short-span anterior bridges.[15] They use a postcuring process that results in superior flexural strength to feldspathic porcelain, minimal polymerization shrinkage, and wear rates comparable to tooth enamel.[16] Also, favorable esthetics, repairability, and fast simple laboratory procedures are the advantages of these veneering materials.[17]

There are very few studies on the effect of mouthrinses on resin composites, especially laboratory-processed composites. The objective of this study was to investigate color stability and surface roughness of an indirect composite exposed to different mouthrinses for

a continuous soaking period at four different times. This research tested the hypothesis that mouthrinse solutions promote changes in color and surface roughness of the indirect composite.

MATERIALS AND METHODS

Fifty specimens were made from the fine hybrid composite GC Gradia (GC Europe, Leuven, Belgium). A total of 40 test material cylinders 8 mm in diameter and 2 mm thickness were produced in A2 shades with the help of 8×2 mm split steel molds, and 10 specimens were used for the control group (distilled water). The stainless steel mold was clasped between two glass plates, and finger pressure was applied to extrude excess resin. The thin glass plate was then removed before polymerizing in the light-curing unit. Each specimen was polymerized with Labolight LV-III light-curing unit (GC Europe, Leuven, Belgium) for 5 minutes. All specimens were finished with SiC papers, grits 1,000 under running water. They were polished with universal polishing paste (Ivoclar Vivadent AG, Liechtenstein). The specimens were stored in 20 mL of distilled water at 37°C during the whole experiment. Alcohol containing mouthrinse Listerine (Leuven, Belgium), Curasept ADS 205 (Curaden Healthcare, Saronna VA, Italy); alcohol-free mouthrinse-Oral B (J&J Sıhhi Malzeme San. ve Tic. Ltd. Şti. İstanbul, Turkey); zinc chloride containing Pharmol Zn (Çözüm İlaç, Turkey) and artificial saliva were used in the study. The composite, mouthrinses, and artificial saliva investigated in this study and their composition are presented in Table 1. The samples were immersed daily for 14 days in 20 mL of the solutions for 2 minutes twice a day (with a 12-hour interval between exposures). Measurements were carried out at four different times: 1 hour after sample preparation (t_0), 1 day (t_1), 7 days (t_2), and 14 days (t_3) after the first immersion in the solutions. The measurements were made in the same environment by a single operator previously calibrated. Before beginning the study the pH of the mouthrinses to be tested was determined using a pH meter (Mettler Toledo, MP220 pH Meter, UK). The color measurements were determined with a digital spectrophotometer (Vita Easyshade, Vita Zahnfabrik,

TABLE I. Materials used in this study and their compositions

Materials	Composition	pH	Manufacturer
GC Gradia	Urethane Dimethacrylate, Ethyleneglycol dimethacrylate (75 wt % filler: ceramic, prepolymer, SiO2)		Leuven, Belgium
Listerine	(PR-009972) Aqua, propylene glycol, sorbitol, poloxamer 407, sodium lauryl sulfate, eucalyptol, benzoic acid, sodium benzoate, methyl salicylate, thymol, sodium saccharin, sodium fluoride, menthol, sucralose, aroma, CL 42053	4.6	Johnson and Johnson Sıhhi Malzeme San. Ve Tic. Ltd. Şti. İstanbul, Turkey
Oral-B anti-plaque alcohol-free mouthrinse	Aqua, glycerin, polysorbate 20, aroma, methylparaben, cetylpyridinium chloride, sodium fluoride, sodium saccharin, sodium benzoate, propylparaben Cl42051	6.45	Procter & Gamble UK, Weybridge, Surrey, UK
Pharmol Zn	Zinc chloride, acide borique, deionized water, glycerin, cosmotic color (Cl 19140, Cl 42090)	5.84	Çözüm İlaç, Turkey
Curasept ADS 205 Oral-Rinse	Aqua, xylitol, propylene glycol, peg-40, hydrogenated castor oil, ascorbic acid, clorhexidine digluconate, aroma, sodium fluoride, poloxamer 407, sodium benzoate, sodium metabisulfite, sodium citrate, Cl 42090	5.78	Curaden Healthcare, Saronna (VA), Italy
Artificial saliva	Carboxymethyl cellulose, sorbitol, sodium chloride, sodium fluoride, magnesium chloride, calcium chloride, sodium phosphate, nipacin, distilled water	6.09	

Bad Säckingen, Germany) using standard illuminant according to Comission Internationale d'Eclairage (CIE Lab) on the white baseline. The amount of color shift was recorded in CIELab system, which is a three-dimensional color space: white-black (ΔL*), red-green (Δa*), and blue-yellow (Δb*). At the end of the test period, the samples were removed, submerged in distilled water, and dried with tissue paper. The baseline and after treatment L*, a*, and b* values of the test samples were determined, three measurements were made for each specimen, and the mean CIE L*a*b* values were calculated and used to obtain ΔE values. The general color shift was calculated according to the following formula:

$$\Delta E = \left[(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2 \right]^{\frac{1}{2}}$$

After colorimetric measurements, surface roughness of the same specimens was evaluated using a profilometer (Mitutoyo Surf Test 402 Analyzer; Mitutoyo Corp, Kawasaki, Japan). To measure the roughness profile value in micrometer, the diamond stylus (5-µm tip radius) was moved across the surface under a constant load of 3.9 mN and a speed of 0.100 mm/s with a range of 600 µm during testing. The instrument was calibrated using a standard reference specimen. This procedure was repeated three times at a different location for each specimen to obtain the general surface characteristics of the specimens. The average values of these measurements were considered to be the Ra values.

In addition, the clinical relevance of the results has been interpreted through the literature findings for visual thresholds: 50:50% perceptibility threshold (ΔE* = 1.74) and 50:50% acceptability threshold (E* = 3.48) according to ISO/TR 28642.[18,19] Statistical analyses were performed with SPSS 18.0 software (SPSS Inc., Chicago, IL, USA). Descriptive statistics were expressed as mean ± standard deviation. Differences among the groups were analyzed by the Kruskal–Wallis test. Mann–Whitney *U*-test with Bonferoni correction test was used for post-hoc test after the Kruskal–Wallis test. Repeated measures were evaluated with the Friedman test. The Wilcoxon test with Bonferroni correction was used as a post-hoc test, if the Friedman test is statistically significant. *p* value of less than 0.05 was considered statistically significant for all tests.

RESULTS

The mean and standard deviations of ΔE and ΔRa values of the groups are presented in Table 2.

TABLE 2. Mean and standard deviations of ΔE values, ΔRa values, and regression analysis of indirect composite resin at different immersion solutions and time

	Artificial saliva			Listerin			Curasept			Oral-B			Pharmol Zn		
	ΔE	sig.*ΔRa	sig.*Reg	ΔE	sig.*ΔRa	sig.*	ΔE	sig.*ΔRa	sig.*	ΔE	sig.*ΔRa	sig.*	ΔE	sig.*ΔRa	sig.*
t_1	0.60±0.23 a,b	0.02±0.17 a,b	r=−0.33, p=0.347 a,b	0.61±0.34 a,b	0.04±0.02 a,b	r=−0.34, p=0.339 a	1.78±0.89 NA	0.03±0.05 a	r=−0.40, p=0.247 a	1.42±1.4 NA	0.01±0.02 a	r=0.19, p=0.596 a	1.04±0.54 a,b	0.01±0.01 a,b	r=0.23, p=0.524
t_2	0.96±0.40 a	0.03±0.03 a	r=−0.24, p=0.500 a	2.17±0.56 a	0.23±0.07 a,c	r=0.08, p=0.827	3.33±1.30 NA	0.04±0.03 b	r=0.006, p=0.987	2.39±1.34 NA	0.02±0.01 b	r=−0.4, p=0.184	3.67±2.67 a	0.02±0.01 a,c	r=0.02, p=0.952
t_3	1.36±0.73 b	0.03±0.01 b	r=0.11, p=0.763	2.10±0.71 b	0.30±0.06 b,c	r=0.50, p=0.145	3.19±1.10 NA	0.07±0.02 a,b	r=−0.24, p=0.514	2.47±1.95 NA	0.06±0.05 a,b	r=0.37, p=0.290	3.66±2.35 b	0.03±0.01 b,c	r=0.56, p=0.089
sig	p=0.007	p=0.008		p=0.001	p<0.001		p=0.067	p=0.002		p=0.067	p=0.004		p=0.001	p<0.001	

*Intergroup comparison (same column)—same letters mean statistically significant difference (p<0.05).

At (t_1) time representing ΔE value, there were significant differences between the groups ($p < 0.001$). When comparing between within the groups, there was no significant difference between artificial saliva and Listerin, Curasept and Oral-B, Oral-B and Pharmol Zn groups, respectively ($p > 0.05$). At (t_2) time representing ΔE value, there were significant differences between the groups ($p < 0.001$). The ΔE value of artificial saliva group was significantly different from other test groups regarding intergroup comparison ($p < 0.001$). At (t_3) time representing ΔE value, there were significant differences between the groups ($p < 0.001$). When comparing between and within the groups, there were significant differences between artificial saliva and Curasept, artificial saliva and Pharmol Zn, Listerin and Curasept, Listerin and Pharmol Zn groups, respectively ($p < 0.05$).

The mean Ra values for all groups (μm) are presented in Table 3. The immersion solutions affected surface roughness significantly at both time intervals ($p < 0.001$). At (t_1) time representing Ra$_1$ value, there were significant differences between the groups. At (t_2) and (t_3) time representing Ra$_2$ and Ra$_3$ values, there were no significant differences between Curasept and Oral-B groups.

At (t_1) time representing ΔRa value, there were significant differences between the groups ($p < 0.05$). When comparing between within the groups, there were significant differences between artificial saliva and Listerin, Listerin and Oral-B, Listerine and Pharmol Zn, Curasept and Pharmol Zn groups, respectively ($p < 0.05$). At (t_2) time representing ΔRa value, there were significant differences between the groups ($p < 0.001$). When comparing between within the groups, there were no significant differences between artificial saliva and Oral-B, artificial saliva and Pharmol Zn, Oral-B and Pharmol Zn groups, respectively ($p > 0.05$). At (t_3) time representing ΔRa value, there were significant differences between the groups ($p < 0.001$). When comparing between within the groups, there were no significant differences between artificial saliva and Pharmol Zn, Curasept and Oral-B groups, respectively ($p > 0.05$).

TABLE 3. Mean Ra values and standard error of indirect composite resin at different immersion solutions and time

	Artificial saliva		Listerin		Curasept		Oral-B		Pharmol Zn	
	Ra (μm)	sig.*	Ra (μm)	sig.*	Ra (μm)	sig.*	Ra (μm)	sig.*	Ra (μm)	sig.*
t_0	0.77±0.14	a,b,c	0.92±0.03	a,b,c,	0.77±0.02	a,b,c	0.82±0.01	a,b,c	0.75±0.01	a,b,c,
t_1	0.78±0.01	a,d,e	0.97±0.01	a,d,e	0.81±0.02	a,d	0.83±0.02	a,d	0.76±0.01	a,d,e
t_2	0.80±0.02	b,d	1.15±0.06	b,d,f	0.82±0.02	b,e	0.84±0.02	b,e	0.77±0.14	b,d,f
t_3	0.81±0.02	c,e	1.23±0.05	c,e,f	0.85±0.01	c,d,e	0.88±0.05	c,d,e	0.78±0.01	c,e,f
sig.	$p<0.001$		$p<0.001$		$p<0.001$		$p<0.001$		$p<0.001$	

*Intergroup comparison (same column)—same letters mean statistically significant difference ($p<0.05$).

Spearman's correlation analysis revealed that there was no significant correlation between values of color changes and roughness changes in any time and any immersion solution ($p > 0.005$).

DISCUSSION

This study was planned to determine the effects of four commercial mouthrinses on the color stability and surface roughness of an indirect composite.

Some studies focused on possible damages caused by mouthrinses and other solutions on surface characteristics of esthetic restorative materials in different exposure protocols.[20–23] Immersion of all samples in the mouthrinses for 12 uninterrupted hours was the treatment method in the previous studies.[22,24] The employment of a more clinically relevant exposure protocol, which could simulate the regular mouthrinse application by the patient, was chosen in this study.[20,25,26]

Color stability is a significant factor affecting longevity of dental prostheses. There are two generally accepted thresholds used in color studies, perceptibility, and acceptability. The threshold of perceptibility defines the level at which 50% of viewers can perceive a difference between two color specimens and 50% cannot. The second is the threshold of acceptability, which sets an upper limit for a color difference between specimens that is recognized by most people as an acceptable match. A recent study performed to determine the

perceptibility and acceptability thresholds for dental ceramics using CIE ΔE Lab (ΔELab) color difference formula and a novel TSK Fuzzy Approximation defined that the 50:50% perceptibility threshold was $\Delta E^* = 1.74$, whereas the acceptability threshold was $\Delta E^* = 3.48$.[18]

The color stability methodology used in the present study is according to previous studies that used spectrophotometry and the CIELab coordinate system.[27–29] It was chosen to evaluate color variation (ΔE) because it is appropriate for small color changes determination and have advantages such as repeatability, sensitivity, and objectivity.[22] Although CIEDE2000 (ΔE_{00}) color difference formula provided a better fit than CIELAB formula in the evaluation of color difference thresholds of dental restorations, color and color difference are quantified using the CIELAB color space and associated ΔE^*_{ab} mostly. Recent reports showed significant correlations between ΔE_{ab} and ΔE_{00} values after polymerization. The majority of reported correlations showed only that the values obtained from these formulas were proportional, but not that the two color differences formulas could be used interchangeably to evaluate the color differences of resin composite.[18] The use of CIELAB color space for comparison in evaluation is the inherent limitation of portable spectrophotometer which was used in this present study.

A smooth surface texture is important for the color of the restoration, since a smooth surface will reflect a greater amount of light than a rough surface.[30,31] Finishing and polishing procedures may also influence

surface smoothness, which is related to early discoloration. Rough surfaces mechanically retain surface stains better than smooth surfaces.[32] Therefore, a ground and polished surface was used and all the specimens' surfaces were standardized.

It was reported that composite filler leaching was much higher in artificial saliva than in distilled water.[33] Besides, for depositing a pellicle layer, artificial saliva was used in the present study. Saliva and the subsequent accumulation of pellicles act as a matrix for the deposition of stains, which may result in discoloration.[34]

It is important that the composite resin presents uniform filler particle distribution in the polymer network to minimize the formation of filler-rich and filler-depleted areas within the composites. This is especially important regarding the performance of composites in aqueous environments, such as mouthrinse solutions, since voids or nonbonding spaces at the filler/matrix interface may increase the water sorption of composites.[35] According to Kawaguchi and colleagues,[36] microhybrid composites present a lower coefficient of light transmission due to the various sizes of their particles, which contributed to the higher values of ΔE.

Not only the filler particles of the composites but also the resinous matrix composition affects the water sorption of composite resins. It has been reported that under normal curing conditions, Urethane Dimethacrylate-based composite resins presented lower water sorption and higher color stability than other dimethacrylates in their resin matrix.[37,38]

At the end of 14-day immersion period, the smallest changes in color, below the 50:50% perceptibility threshold, were recorded for immersion in artificial saliva solution, which corresponds to excellent color stability according to ISO/TR 28642.[19] Accordingly, color stability of specimens which were immersed in different solutions (Listerin, Curasept and Oral-B, respectively) ranged between 50:50% perceptibility and 50:50% acceptability threshold. Immersion solution-dependent changes in color of composite

resins used in the present study were at greater than 50:50% acceptability threshold level which was immersed in Pharmol Zn solution (ΔE = 3.67). According to the results of this study, Pharmol Zn immersed specimens showed ΔE values between 1.04 and 3.67. This high discoloration might be attributed to the zinc chloride ingredient of the mouthrinse.

According to Villalta and colleagues and Trauth and colleagues,[25,39] low pH and alcohol concentration of solutions affect the surface roughness of composite resins. Similarly, Listerine and Curasept that have alcohol ingredients and more acidic mouthrinses (pH 4.6; pH 5.78) than the others showed the most surface roughness changes in all time exposures respectively in this study. Also Pharmol Zn and Oral B, which are alcohol free, showed the least ΔRa values. According to Sarret and colleagues,[40] alcohol acts as a plasticizer of the polymeric matrix, making the material more ductile. This may increase the erosion of the surface and cause more surface roughness. On the other hand, Elembaby reported that alcohol-free mouthrinse yielded perceptile color changes on resin-based restorative materials.[41]

When time factor was considered, it was demonstrated that for all tested groups, a higher discoloration and surface roughness shown after 1 day, 7 days, and 14 weeks, respectively. It was reported that longer exposure with mouthrinses may result statistically significant differences in surface roughness.[25,42] In addition, the pH of the solutions can affect the roughness of the resin composite as softening by the acid media. The results of this study are in agreement with the ones of Turssi and colleagues, in which the most acidic mouthrinse Listerine with 4.6 pH value showed the most surface roughness change in all time periods.[43]

Under clinical conditions, the effect of the mouthrinses on resin composite may be different, being dependent on many factors that could not be replicated in vitro.[22] Not only saliva and salivary pellicle, but also foods, beverages and tooth brushing may affect the physical and aesthetic properties of the resin composite. Further clinical investigations are needed to determine whether the tested mouthrinses are ideal for the patients with resin composite restorations.

CONCLUSIONS

Within the limitations of this study, the following conclusions can be drawn:

The composite resins tested in the present study demonstrated acceptable color stability when stored in different types of mouthrinse solutions except for Pharmol Zn
Mouthrinses can be considered stainable solutions
The chemical formulation of individual mouthrinses can significantly control their ability to stain
Listerine and Curasept that have alcohol ingredients and more acidic mouthrinses showed the most surface roughness changes in all time exposures respectively
Pharmol Zn and Oral B, which are alcohol-free mouthrinses, showed the least surface roughness values

Based on the results of this study, patients with indirect resin composite restorations should be warned by the dentists about the discoloration of the restorations and the time period of the mouthrinse that will be used.

DISCLOSURE

The authors do not have any financial interest in the companies whose materials are included in this article.

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