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The effects of whitening mouthrinses on the color stability of CAD/CAM resin matrix ceramics

Murat Eskitaşçıoğlu[1]*

1 Van Yuzuncu Yil University Faculty of Dentistry, Department of Prosthodontics, Van, TR

*** Corresponding Author:** Murat Eskitaşçıoğlu **E-mail:** drdtmurat@yahoo.com.tr

ABSTRACT

Objective: This study aimed to evaluate the color change of CAD/CAM resin matrix ceramic, which was exposed to three different whitening mouth rinses and artificial saliva for 12 and 180 hours.

Material and Methods: A total of 60 samples were produced from prefabricated CAD/CAM resin matrix ceramic blocks for experimental study. The samples were randomly divided into four subgroups according to the whitening mouthrinses: Listerine Advanced White, Colgate Optic White, Oral B 3D White Luxe, and artificial saliva. Spectrophotometric measurements were made from each sample at 3 different times, before (initial) exposure to mouthrinses, 12 hours and 180 hours after exposure ($\Delta E001$, $\Delta E002$ and $\Delta E003$). While using the generalized linear models method for the comparison of $\Delta E00$, ΔL, Δa, and Δb color changes according to the mouthrinse and exposure time; multiple comparisons were made with the Tukey HSD Test. The significance level was taken as $p<0.050$.

Results: The results of the two-way analysis of variance showed that the used mouthrinse and the exposure time had a statistically significant effect on the $\Delta E00$ values representing the color change ($p<0.001$), while the interaction between the mouthrinse and the time of use did not play an important role ($p=0.165$).

Conclusion: After exposure time of 180 hours, all whitening mouthrinses induce color change of resin matrix ceramics above clinically noticeable level.

Keywords: Color, CAD/CAM, Hydrogen Peroxide

INTRODUCTION

Today, rising living standards have induced significant changes in individuals' lifestyles and habits, and as a result, human lifespan has been extended (1). Scientists have played an important role in the management of the process by shifting the focus of their work to the technological support of this increasing time (2). All this movement has increased the acceleration of development of computer aided design / computer aided manufacturing (CAD/CAM) technologies in the field of dentistry; in this way, it is aimed to meet both the aesthetic and functional expectations of the patients in the long-term (3). Thus, today, CAD/CAM equipment has shrunk in size, decreased in cost, increased in diversity, and made it possible to produce tooth-colored restorations with excellent aesthetics with alternative materials to traditional dental ceramics (4).

In the search for alternatives, dental materials science first applied to the method of strengthening traditional ceramics with particles such as leucite, lithium disilicate and zirconia (5). However, as stated by Jeong et al., there is still a need for a skilled ceramicist and a laboratory environment in the production of these restorations, and the necessity of heat treatments such as firing in the production of the restoration did not provide a significant reduction in production time (6). Thus, the search continued; force-absorbing resin matrix ceramics with excellent polishability without the need for heat treatment and exhibiting both high resistance and high optical properties to clinical routine at the same time were introduced (7, 8). Although the collaboration of this development with simple milling and polishing techniques allows the production of aesthetic restorations in a short time, the researchers have drawn the note that the effects of monomers such as urethane dimethacrylate (UDMA) and N,N-dimethylacrylamide (DMA), which are also included in the composite resin composition, on the color of resin matrix ceramics should be questioned (9).

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There is consensus in the dental literature that solutions affect the color of composite resins (10). While many studies have examined in detail the effects of acidic beverages, such as cola, orange juice, and wine, on the color of composite resins (11, 12), some researchers have drawn attention to the effects of mouth rinse, which is an indispensable element in the prevention of oral diseases and in the control of oral health, due to its blue and green color (13). Gasparri et al. took these studies one step further and examined the question of how mouthrinses with a whitening effect affect the dental restoration color, while it has an effect on the natural tooth (14).

Whitening mouthrinses were introduced to the market a few years ago with active ingredients such as hydrogen or carbamide peroxide to prevent discoloration, fight plaque accumulation, and prevent discoloration accumulation, and, most importantly, create a fast whitening effect (15). The lower cost compared to the professional whitening procedure and the ease of transportation has enabled these mouthrinses to gain rapid popularity among patients, and paved the way for their accessible forms to vary in terms of concentration, amount, and active ingredient (16). However, scientific publications have not been able to follow this pace, and conflicting results have been reported on the effects of whitening mouthrinses (17, 18). To the present author's knowledge, studies have evaluated the effects of whitening mouthrinses on restorations only in terms of microhardness, microleakage and surface roughness, and the main active ingredient of mouthrinses included in this assessment was limited to hydrogen peroxide. However, as it is known, whitening mouthrinses can contain many active ingredients other than hydrogen peroxide (19). In addition, as Lee et al. also noted, clarification of the effects on the color of the restoration is critical for the long-term use of these solutions (3). In addition, it should not be ignored that different effects can be observed on each restorative material.

Based on this deficiency in the literature, in the current study, it was aimed to evaluate the color change of CAD/CAM resin matrix ceramic exposed to three different whitening mouthrinses for 12 and 180 hours and to compare it with the determined artificial saliva group, as the control. The first null hypothesis of the study is that no significant color change will occur depending on the exposed solution. The second null hypothesis is that the color change values calculated depending on the exposure times will not show a significant difference.

MATERIAL AND METHODS

Preparation of Specimens and Exposure to Mouthrinses

In the current study, a CAD/CAM resin matrix ceramic and three different whitening mouthrinses were used as the restorative material, and artificial saliva was used as the control group. The details of the restorative materials and solutions like manufacturer, composition etc. are summarized in **Table 1**.

A2 color prefabricated CAD/CAM resin matrix ceramic blocks were used in the production of the samples. A total of 60 plates in the form of 12X14X1.2 mm were produced from the relevant blocks by cutting under water cooling with the help of a diamond precision cutting disc. (n=15). The surface of each sample to be measured was abraded by a single operator for 1 minute under finger pressure with 600-800-1000-1200 grid silicon carbide sandpapers, respectively. Care was taken to keep each sample in an ultrasonic cleaner containing isopropyl alcohol for 10 minutes in order to prevent contamination on the sample surface. In accordance with the manufacturer's instructions, a transparent colored varnish specific to the material was applied to the sample surface, which was dried with a clean towel, with the help of an applicator and left for 10 seconds.

Table 1. Details of the restorative materials and solutions that used in study

Material/Solution	Brand Name	Manufacturer	Composition
CAD/CAM Resin Matrix Ceramic	**Cerasmart**	GC Europe, Leuven, Belgium	Bis-MEPP, UDMA, DMA) and 71% silica and barium glass nanoparticles
Whitening Mouthrinse	**Listerine Advanced White**	Johnson&Johnson, Skillman, NJ, USA	Water, Alcohol, Hydrogen Peroxide, Tetrapotassium Pyrophosphate, Pentasodium Triphosphate, Citric Acid, Poloxamer 407, Sweeteners, Sodium Saccharin, Sucralose.
Whitening Mouthrinse	**Colgate Optic White**	GABA International AG, Therwil, Switzerland	Water, Glycerin, Sorbitol, Pyropylene Glycol, PVM/MA Copolymer, Tetrapotassium Pyrophosphate, Polysorbate 20, Sodium Fluoride, Sodium Saccharin, CI 42051.
Whitening Mouthrinse	**Oral B 3D White Luxe**	Procter&Gamble, GmbH, GrossGerau, Germany	Water, Glycerin, Alcohol, Aroma, Methylparaben, Poloxamer 407, Sodium Fluoride, Cetipyridinium Chloride, Sodium Saccharin Pyropylparaben, CI42051, CI47005
Artifical Saliva	-	-	Sodium chloride (0.4 g/L), potassium chloride (0.4 g/L), calcium chloride-H2O (0.795 g/L), sodium dihydrogen phosphate-H2O (0.69 g/L), sodium sulfur-9H2O (0.005 g/L), and 1000 mL distilled water

The polymerization of the varnish was achieved with an LED light device (3M ESPE Elipar S10, 3M ESPE, St. Paul, USA) with a light intensity of 1200 mW/cm2 throughout. The thickness of the samples after surface treatment was measured from three different points with a digital caliper with 0.01 mm precision and care were taken to ensure that the surfaces were uniform. Those with a final thickness of 1.2±0.2 mm were included in the study. The samples were then randomly divided into four subgroups according to the whitening mouthrinses: Listerine Advanced White, Colgate Optic White, Oral B 3D White Luxe, and artificial saliva as a control. Before the exposure procedure, the mouthrinses were left at room temperature for a minimum of 6 hours, pH values were measured with a digital pH meter, and pH values were adjusted using pH4 and pH7 buffer solutions (Sigma-Aldrich Chemical Company, Merck KGaA, Darmstadt, Germany) when necessary. The same procedure was repeated 4 times for each solution in order to calculate the average pH value. Since a previous study reported that continuous exposure of dental materials to a mouthrinse for 12 hours had clinically the same effect as mouthrinse usage for 1 year (2 times a day, for 1 minute)(20); in the present study, samples were subjected to a 12- and 180-hour mouthrinse exposure procedure. In this way, it was aimed to simulate the effect of whitening mouthrinse use on the color of CAD/CAM resin matrix ceramics for 1 and 15 years.

Spectrophotometric Analysis

Color measurements of the samples were made under standard D65 lamp illumination on a neutral gray background using The International Commission on Illumination (CIE) L*, a*, b* color system. A spectrophotometer with previously reported with high reproducibility (Spectroshade Micro, MHT Optic Research, Verona, Italy) was used for measurements (21). SpectroShade Downloader Version 1.1.1.0 (MHT Optic Research, Verona, Italy) software was used for data processing. Before each measurement, the spectrophotometer was calibrated according to the manufacturer's instructions using white and green calibration units. In order to standardize the data, the measurements were repeated 3 times, and the average was taken and entered into the Microsoft Excel® program.

In the evaluation of the color change due to exposure to mouthrinse, ΔE00, which represents the distance of two colors to the 3-dimensional space, was used. The following formulation was used for the calculation of ΔE00:

ΔE00 = [(ΔL/KLSL)2+ (ΔC/KCSC)2+(ΔH′/KHSH)2 + RT (ΔC′/KCSC)2+ (ΔH′/KHSH)2] 1/2

As previously defined by Paravina et al. when ΔE00>1.77, discoloration is clinically unacceptable, and when ΔE00=0.81, the color difference was considered to be at a visually detectable level (22).

Measurements were made from each sample at 3 different times, before (initial) exposure to mouthrinses, 12 hours and 180 hours after exposure. While the color change occurring at the inital and after 12 hours of exposure was accepted as ΔE001, the color change occurring between 12 and 180 hours of exposure was calculated as ΔE002 and the color change occurring after the initial and 180 hours exposure was calculated as ΔE003. In addition, ΔL, Δa and Δb calculations were made at the same time intervals in order to interpret the spatial position change of the color change.

Statistical analysis

Data were analyzed with Minitab V14. Conformity to the normal distribution was examined using the Shapiro-Wilk Test. While using the generalized linear models method for the comparison of ΔE00, ΔL, Δa and Δb color changes according to the mouthrinse and exposure time; multiple comparisons were made with the Tukey HSD Test. Analysis results were presented as mean±standard deviation. Significance level was taken as p<0.050.

RESULTS

The results of the two-way analysis of variance showed that the used mouthrinse and the exposure time had a statistically significant effect on the ΔE00 values representing the color change (p<0.001), while the interaction between the mouthrinse and the time of use did not play an important role (p=0.165). However, Listerine Advanced White was found to induce the highest color change (3±1.33) regardless of exposure time. As predicted, the lowest ΔE00 value was calculated in the artificial saliva group (0.86±0.42). Tukey HSD test showed that statistically similar ΔE00 values were detected in Colgate Optic White and Oral B 3D White Luxe groups (Table 2). In addition, it is remarkable that ΔE001 values in all mouthrinse groups are lower than ΔE002 and ΔE003 values, and it can be interpreted that whitening mouthrinses induce the main color change after at least 1 year or more than 1 year of use. ΔE003 values calculated in all whitening mouthrinses except the control group are above the threshold value determined as 1.77; this shows that as a result of long-term use of the related mouthrinses, a clinically unacceptable color change is produced in the CAD/CAM resin matrix ceramic.

According to the current findings, the interaction between the used mouthrinse, the exposure time, and the duration of use affect the ΔL values statistically significantly (p<0.001). Based on that, the lowest ΔL value was detected in the artificial saliva group with -0.42 and in the ΔL1 time period, while the highest change was found in the Listerine Advanced White group with 3.61 in the ΔL3 time period (Table 3). When the mouthrinses were evaluated independently of the duration of use, the highest ΔL value belonged to the Listerine Advanced White group with 2.41 and was followed by the Oral B 3D White Luxe (2.23) and Colgate Optic White (2.03) groups, respectively. While available data reveal that whitening mouthrinses have a statistically similar effect on ΔL (p>0.05); pointed out that the artificial saliva group showed a quite different effect from the mouthrinse groups. In addition, while ΔL data showed a positive increase in all time periods in the whitening mouthrinse groups; ΔL values in the artificial saliva group have a negative course. This means that the color of the samples in the artificial saliva group darkened; and the whitening mouthrinse groups caused a whitening effect on the color of the samples.

Statistical results revealed that Δa values showed a significant change like ΔL depending on the interaction between used mouthrinse and exposure time, duration of use and mouthrinses ($p<0.001$). According to the Tukey HSD test findings, the effects of artificial saliva and Listerine Advanced White groups on Δa values were statistically similar, and the highest Δa value was found in the Oral B 3D White Luxe group with 0.96 in the Δa1 time period (Table 4). In addition, regardless of the duration of use, while the color of CAD/CAM resin matrix ceramic shifts to red in the artificial saliva and Listerine Advanced White groups; the fact that the sample color shifts to green in the Oral B 3D White Luxe and Colgate Optic White groups is a very significant finding.

It was determined that the Δb values of CAD/CAM resin matrix ceramics differed statistically depending on the mouthrinse to which they were exposed ($p<0.001$). Accordingly, while the mean value of Δb obtained in the artificial saliva group was 0.27, the value obtained in the Listerine Advanced White group was -0.31, -0.19 in the Colgate Optic White group and -0.31 in the Oral B 3D White Luxe group (Table 5). These findings also mean that the samples exposed to clinical artificial saliva change to yellow color, while all other whitening mouthrinses show a blue color change. In addition, a statistically significant effect was found on the Δb values of the samples ($p=0.018$). The main reason for this effect is that the value calculated in the time period Δb1 is different from the other time periods.

Table 2. Descriptive statistics of ΔE00 color change values by mouthrinse and time

Mouthrinses	Duration Time of Use			Total
	$\Delta E_{00}1$	$\Delta E_{00}2$	ΔE_{003}	
Artifical Saliva	0.84 ± 0.45	0.52 ± 0.15	1.22 ± 0.27	0.86 ± 0.42^{c}
Listerine Advanced White	2.51 ± 1.4	3.24 ± 1.58	3.23 ± 0.93	3 ± 1.33^{a}
Colgate Optic White	1.24 ± 0.81	1.68 ± 0.66	2.59 ± 0.94	1.84 ± 0.97^{b}
Oral B 3D White Luxe	1.67 ± 0.86	2.73 ± 0.82	2.68 ± 0.85	2.36 ± 0.95^{b}
Total	1.56 ± 1.1^{b}	2.04 ± 1.4^{a}	2.43 ± 1.07^{a}	2.01 ± 1.24

Mean ± standard deviation; a-c: There is no difference between the averages of main effects with the same letter.

Table 3. Descriptive statistics of ΔL color change values with mouthrinse and time

Mouthrinses	Duration Time of Use			Total
	ΔL1	ΔL2	ΔL3	
Artifical Saliva	-0.42 ± 0.28^{F}	0.02 ± 0.17^{EF}	-0.4 ± 0.4^{F}	-0.27 ± 0.36^{b}
Listerine Advanced White	0.81 ± 0.77^{DEF}	2.8 ± 1.35^{ABC}	3.61 ± 1.02^{A}	2.41 ± 1.58^{a}
Colgate Optic White	1.37 ± 1.1^{CDE}	1.68 ± 1.15^{BCD}	3.05 ± 1.32^{AB}	2.03 ± 1.37^{a}
Oral B 3D White Luxe	0.62 ± 1.03^{DEF}	2.72 ± 0.91^{ABC}	3.34 ± 1.11^{A}	2.23 ± 1.54^{a}
Total	0.6 ± 1.05^{c}	1.8 ± 1.49^{b}	2.4 ± 1.92^{a}	1.6 ± 1.69

Mean ± standard deviation; a-c: There is no difference between the averages of main effects with the same letter. A-F: There is no difference between interactions with the same letter.

Table 4. Descriptive statistics of Δa color change values with mouthrinse and time

Mouthrinses	Duration Time of Use			Total
	Δa1	Δa2	Δa3	
Artifical Saliva	0.52 ± 0.32^{ABCD}	0.27 ± 0.23^{ABCD}	0.79 ± 0.17^{AB}	0.52 ± 0.32^{a}
Listerine Advanced White	1.22 ± 1.52^{A}	-0.45 ± 1.91^{CDE}	0.77 ± 0.82^{ABC}	0.51 ± 1.6^{a}
Colgate Optic White	-0.05 ± 0.33^{BCDE}	-0.45 ± 0.39^{CDE}	-0.51 ± 0.28^{DE}	-0.34 ± 0.38^{b}
Oral B 3D White Luxe	0.96 ± 0.61^{AB}	-1.02 ± 0.75^{E}	-0.07 ± 0.27^{BCDE}	-0.04 ± 0.99^{b}
Total	0.66 ± 0.95^{a}	-0.42 ± 1.11^{b}	0.25 ± 0.72^{a}	0.16 ± 1.03

Mean ± standard deviation; a-c: There is no difference between the averages of main effects with the same letter. A-E: There is no difference between interactions with the same letter.

Table 5. Descriptive statistics of Δb color change values with mouthrinse and time

Mouthrinses	Duration Time of Use			Total
	Δb1	Δb2	Δb3	
Artifical Saliva	0.16 ± 0.08	0.24 ± 0.13	0.4 ± 0.16	0.27 ± 0.16^{a}
Listerine Advanced White	-0.51 ± 0.48	0.04 ± 0.63	-0.47 ± 0.55	-0.31 ± 0.59^{b}
Colgate Optic White	-0.25 ± 0.3	-0.04 ± 0.57	-0.29 ± 0.55	-0.19 ± 0.49^{b}
Oral B 3D White Luxe	-0.3 ± 0.42	-0.17 ± 0.4	-0.46 ± 0.32	-0.31 ± 0.39^{b}
Total	-0.23 ± 0.42^{b}	0.02 ± 0.48^{a}	-0.21 ± 0.55^{b}	-0.14 ± 0.49

Mean ± standard deviation; a-b: There is no difference between the averages of main effects with the same letter

DISCUSSION

Recent in vitro studies detail the harmful effects of peroxide-containing whitening mouthrinses on enamel, dentin and restoration microhardness, and reported that they may also have effects on restoration color (13, 23). As a result of the current research originating from this focus, it was found that ΔE00, ΔL, Δa and Δb values showed a significant change depending on the used mouthrinse and the duration of use ($p<0.001$). Therefore, both the first and second null hypotheses of the study were rejected.

The present study was designed to evaluate the effects of three different mouthrinses containing hydrogen peroxide and alternative bleaching agents on the color of CAD/CAM resin matrix ceramic. And since the whitening efficacy becomes noticeable after using twice a day for a minimum of 2 weeks, as promised in the majority of whitening mouthrinses (15), the exposure time to the mouthrinse is clinically determined as 12 and 180 hours, corresponding to 1 and 15 years. In addition as reported by Zhang, the recommended minimal thickness for a molar crown restoration is 1 mm (24). In the light of this information, the thickness of the CAD/CAM resin matrix ceramic samples used in the research was adjusted to be 1.2 mm. Swain reported that in his in vitro research, a serious change was detected in both optical and surface properties of dental restorative materials exposed to solutions with lower pH values (25). Therefore, the pH of the solutions tested in the methodology of the present experiment was measured at regular intervals; when deemed necessary, the values were regulated with the help of buffer solutions, and changes that may arise from pH changes and differences were tried to be eliminated.

The change in the color of teeth or restorative materials can be evaluated through many different methods: color scale, colorimeter, digital cameras, spectrophotometers, etc. (15). However, current scientific studies have revealed the shortcomings of scale and digital photographs, which offer easier use, and cause these methods to be defined as inaccurate and subjective (26). The advantages of spectrophotometers, such as the ability to convert data into quantitative data, and the ability to interpret measurements by analyzing the basic components of color in many different color systems, have made it an instrument that researchers often prefer (27). However, Sasany et al. pointed out that the biggest limitation in the use of spectrophotometer is the size of the measurement window; reported that if the measurement window of the instrument to be preferred is smaller than the sample size, the edge loss effect can be observed and the measurement consistency will be negatively affected (28). Considering all these data, in order to guarantee the quality in the color measurement methodology in the current study, a spectrophotometer with a measurement window larger than the sample size was preferred.

The most important finding of the current study is that both short-term and long-term use of whitening mouthrinse triggers a significant ΔE00 value change compared to the control group, artificial saliva. This means that whitening mouthrinses have a whitening effect not only on the tooth surface, but also on CAD/CAM resin matrix ceramics. This finding may be due to the fillers structure with the resin matrix embedded in the porcelain mesh of the resin matrix ceramics. As is known, resin matrices are inherently prone to water absorption (29) and this means the development of an internal discoloration just as with composite restorations (30). Reporting that feldspathic porcelain exhibited significantly higher color stability in the results of an in vitro study examining CAD/CAM resin matrix ceramic and CAD/CAM feldspathic porcelain in terms of susceptibility to color change supports the existing data (31). Among the whitening mouthrinses evaluated, Listerine Advanced White exhibited a higher and clinically detectable ΔE00 value at all time periods. This may be due to the fact that the active ingredient in Listerine Advanced White is hydrogen peroxide. Canay et al. stated that they detected a clinically distinguishable color change in composite resins exposed to 10% hydrogen peroxide (32). On the other hand, in Derafashi et al. study that evaluating the effects of different mouthrinses on the color stability of CAD/CAM materials, they associated the significant color change detected in the Listerine group with the softening of the resin matrix by the alcohol in its content (26). On the other hand, Leal et al. stated that the main reason for the effect was due to both the alcohol content above 30% and the hydrogen peroxide content, since alcohol had a higher sorption and solubility effect on the materials and this increased the penetration of hydrogen peroxide (33). Pelino et al. also noted that the calculated color change in composite resins after 3 months of use was 1.28, in which they included Listerine Advanced White as a whitening mouthrinse (13). And all these studies support the present result. However, Anagnostou et al. applied whitening strips containing carbamide peroxide and hydrogen peroxide from two different concentrations to composite resins and reported that they calculated a color change below the clinically noticeable level in all groups (34). This result may be due to the fact that the application method was strip rather than the product content in the related study and the way it came into contact with the composites was quite different from a mouthrinse.

The current study results show that the duration of use has a significant effect on the calculated ΔE00 value for all solutions; it was found that the observed color change increased as the usage time increased. Therefore, the highest calculated value belongs to the time period ΔE003. Alpkılıç et al. reported that the calculated color change increased with time in all solutions, including the artificial saliva group, which was preferred as the control group, in their study where they examined the color stability of CAD/CAM materials exposed to different mouthrinses (5). In an in vitro study investigating the effects of different mouthrinses on human enamel and the color of different restorative materials, it was noted that increasing the exposure time increased the calculated ΔE value (13). In fact, if physicians will support the use of long-term mouthrinse in patients who will undergo restoration of lamina veneers and crowns, material selection is important; because there are also authors who stated that long-term use in CAD/CAM materials with resin matrix content increases discoloration (28). Harorli et al. also investigated the effects of different whitening mouthrinses on the color of composite resins and determined the exposure time of the samples as 1 and 24 hours. Although there is no clinically noticeable color change in the findings, it is possible to see that the increase in the exposure time results in an increase in the ΔE value (35). All researchers associated this observed condition with the cumulative effect of mouthrinse increasing with time. According to the research of Ntovas et al., the effectiveness of mouthrinse decreases after 3 weeks of use, and there is not always a positive correlation between the increase in time and color change (15). This difference in data may be due to the use of a maximum application time of 180 hours in the current study.

Every in vitro study inherently has limitations in reflecting in vivo. In the present study, the lack of pellicle layer and the deprivation of the washing effect of saliva are an important example of this situation. However, surface morphological changes that will contribute significantly to the elaboration of the results are excluded from the evaluation. In addition, the mouthrinses used were not selected according to the active ingredients or their concentrations, but by considering the commercial sales frequency. And all of these are important limitations of this research.

CONCLUSION

Based on the findings of this in vitro study, the following conclusions were drawn:

1. There is a significant change in the ΔE00, ΔL, Δa and Δb values of CAD/CAM resin matrix ceramics depending on the preferred whitening mouthrinse and usage time.

2. After exposure time of 180 hours, all whitening mouthrinses induce color change of resin matrix ceramics above clinically noticeable level.

3. Listerine Advanced White is a whitening mouthrinse that triggers the highest ΔE00 values in all time periods.

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