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The Effect of Bleaching Agents on the Color Stability of Ceromer and Porcelain Restorative Materials *In Vitro*

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Clinical Relevance

Clinicians should be aware that bleaching might induce color changes of some restorative materials.

SUMMARY

Purpose: The aim of this *in vitro* study was to determine the color changes of five different restorative materials after exposing these materials to two different home bleaching agents.

Methods: This study applied bleaching agents to an ultralow-fusing porcelain, a low-fusing porcelain, two types of heat-pressed glass ceramics, and a ceromer. A total of 24 disc-shaped specimens were fabricated (with a diameter of 10 mm and a thickness of 2 mm) from each material (n=12). The initial color measurements were taken with a spectrophotometer. The first set of specimens were bleached with 10% hydrogen peroxide (HP) for one hour daily for 10 days. The other set of specimens were bleached with 10% carbamide peroxide (CP) bleaching gel for eight hours daily for 14 days. Data were analyzed with the one-way analysis of variance and Kruskal-Wallis statistical test. The difference in the prebleaching and postbleaching color of each material was considered to be statistically significant at $p < 0.05$.

Results: The study found a statistically significant difference among the color changes of the test groups after exposing them to both bleaching agents ($p<0.05$). Appreciable color change was observed in the Estenia ($\Delta E=3.99$) specimens that were bleached with the HP, and noticeable color changes were observed in the Estenia ($\Delta E=1.89$) and IPS Empress 2 ($\Delta E=1.66$) groups when they were treated with the CP.

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Conclusions: **Restorations (especially polymer-containing restorative materials) should be protected before any bleaching procedure due to the high risk of color change.**

INTRODUCTION

The number of people seeking optimum dental esthetics is growing worldwide, and one of the most common esthetic problems patients hope to rectify is discolored teeth.[1] Teeth can be treated with various restorative techniques, such as direct composite veneers, indirect porcelain veneers, ceramic crowns, or even bleaching.[2] New esthetic restorative materials are being introduced almost daily, yet porcelain remains the esthetic material of choice for most clinicians. Their preference for porcelain restorations, in their many forms, arises from their excellent biocompatibility, the strength and surface texture of the material, and their overall esthetic properties.[3]

Tooth bleaching has become popular in dentistry because it has been shown to be an effective and noninvasive treatment. The procedure may be performed at a dental office, or the patient may perform the treatment at home by using a custom-made tooth tray with the agent in gel form and applying the tray to the teeth.[4,5] Currently available home bleaching agents often contain up to 10% hydrogen peroxide (HP) or 22% carbamide peroxide (CP) as their active ingredients, but products containing 10% CP appear to be most popular.[6,7] Treatment times for home bleaching vary extensively and depend on how much time per day the patient spends using the suggested technique.[8] One of the most popular forms is the whitening strip, which is a trayless system with a flexible polyethylene strip that holds peroxide in close contact with the tooth surface. This trayless system has been reported to result in meaningful whitening within a two-week period with short contact times and a lower total peroxide dose than other vital bleaching regimens.[9]

New home bleaching agents also continue to enter the market, and they vary with respect to peroxide concentration, delivery method, contact time, product formulation, and other factors, all of which have the potential to impact the patient's overall clinical tolerability and individual oral response.[9,10] However, patients need to be informed of bleaching's potential effects on the structure and color of enamel and restorative materials. These new products, combined with greater consumer cosmetic awareness and desire, lead to a need for controlled, randomized, nonbiased comparisons of available home bleaching products. Such research provides one source for a comparative assessment of the safety and effectiveness of the various vital bleaching systems. Color research is particularly amenable to comparative testing because objective measurement methods for color are readily available.[9] Numerous studies have shown that bleaching is effective at whitening certain types of discolored teeth, but its effect on restorative materials is not clearly understood.[11-16]

Therefore, the purpose of this study was to determine the quantitative color changes in five different restorative materials as a result of simulated home bleaching with 10% CP and 10% HP *in vitro*. The research hypothesis was that both bleaching systems would have meaningful effects on the color change of restorative materials.

MATERIALS AND METHODS

This study tested two bleaching products on five restorative materials. The materials, product names, and manufacturers are listed in Table 1.

Two types of heat-pressed glass ceramic (Empress 2 and Empress e-Max, Ivoclar, Schaan, Liechtenstein) specimens (10 mm in diameter and 2 mm in thickness) were waxed (BEGO, Bremen, Germany), sprued, and then pressed after investment. All procedures were performed with IPS Empress 2 and Empress e-Max materials (Ivoclar), following the manufacturer's recommendations. Two feldspathic porcelains (VITA VM 9 [Vita Zahnfabrik Bad Säckingen, Germany], Finesse [Ceramco Inc, Burlington, NJ, USA]) were selected for the fabrication of feldspathic ceramic discs. A mold was made using vinyl polysiloxane putty (Virtual, Ivoclar) to facilitate the fabrication of the porcelain discs (10 mm in diameter, 2 mm thick). The porcelain was mixed with sculpting liquid and condensed into the mold. Tissue (Selpak, Eczacibasi Holding, Istanbul, Turkey) was used to absorb the excess moisture. After drying, the discs were carefully removed from the mold, placed on a sagger tray, and fired according to the manufacturers' recommendations (760°C for Finesse and 950°C for VITA VM 9) in a porcelain oven (Vita Vacumat 40 T, Vita Zahnfabrik). A total of 96 discs (24 for each porcelain tested) were made. The color A3 or the color corresponding to A3 was selected for each material. The specimens were then trimmed with a thin, cylindrical diamond bur (D-Z Labor, Drendel and Zweiling GmbH & Co, Berlin, Germany) and were further air particle abraded with 50-μm aluminum-oxide powders. All the ceramic specimen surfaces were then polished

Table 1: *Materials Tested*

Materials	Product Name	Manufacturer	Batch Numbers
Lithium-disilicate–based all-ceramic	IPS Empress 2	Ivoclar Vivadent AG, Schaan, Liechtenstein	H13049
Lithium-disilicate–based all-ceramic	IPS Empress e-Max	Ivoclar Vivadent AG, Schaan, Liechtenstein	H27646
Ultralow-fusing porcelain (760°C)	Finesse	Ceramco Inc, Burlington, NJ, USA	PC413115
Low-fusing porcelain (950° C)	VITA VM 9	Vita Zahnfabrik, Ballyweg 6D–79713 Bad Säckingen, Germany	20790
Ceromer	Estenia	Kuraray Co, Osaka, Japan	053BA
Hydrogen peroxide	Opalescence Trèswhite (10%)	Ultradent, South Jordan, Utah, USA	B41T1
Carbamide peroxide	Opalescence (10%)	Ultradent, South Jordan, Utah, USA	B385J

with a special polishing kit (Optrafine, Ivoclar) that had a slow-speed handpiece (NSK, Tokyo, Japan) running at 15,000 rpm.

Holes 10 mm in diameter were drilled in a 2-mm-thick polytetrafluoroethylene plate to form the ceromer specimens. These restorative materials were placed into the mold separately and sandwiched between two glass plates. In accordance with the manufacturer's directions, a curing light (800 mW/cm^2) was applied to the top of the filled molds for 180 seconds by use of a light-polymerizing unit (Bluephase, Ivoclar Vivadent AG). The distance between light source and specimen was standardized by the use of a 1-mm glass slide. For final polymerization, the specimens were put into a special oven (Estenia CS-110, Kuraray Co, Osaka, Japan) and then polymerized at 114°C for 15 seconds. A total of 24 ceromer specimens were made. The specimens were polished with medium, fine, and superfine polishing kits (Astrapol, Ivoclar Vivadent AG) on a slow-speed handpiece (10,000 rpm) in accordance with the manufacturer's directions.

After the finishing procedures, specimens were subjected to ultrasonic treatment (Biosonic UC 50, Coltene Whaledent, Cuyahoga Falls, OH, USA) in distilled water to remove any surface residues. They were then dried. All specimens were stored in distilled water in screw-top vials (Isolab, Laborgeräte GmbH, Wertheim, Germany) at room temperature for 24 hours before any test procedure.

The specimens in each group were then randomly divided into two subgroups (n=12). The bleaching procedure was performed over a period of 10 days for the HP group and 14 days for the CP group. The specimens in the CP group were immersed in the bleaching gels for an average of eight hours per day, and the specimens in the HP group were immersed for one hour per day, in accordance with the manufacturer's directions. Throughout the experiment, specimens were stored in a dark environment at room temperature (24°C ± 2°C). At the end of each bleaching procedure, the treated specimens were rinsed with running tap water for one minute to remove the bleaching agents and placed in fresh distilled water until the next daily application.

Color Measurement

Before and after treatment, the color of every specimen was measured with a spectrophotometer (VITA Easyshade, VITA Zahnfabrik). This instrument measures the spectral reflectance of a color and converts it into a tristimulus value, which is the internationally accepted numerical form. The spectrophotometer's CIE L*a*b* output is based on D65 illuminant and a 2° standard observer. Three measurements were made, and the average reading was calculated for each specimen. The instrument was recalibrated after measurement of each group (n=12). The CIE L*a*b* measurements make it possible to evaluate the amount of perceptible color change in each specimen. The CIE L*a*b* color space is a uniform three-dimensional color order system. Equal changes in any of the three coordinates can be perceived as visually similar. Total color differences were calculated with the following

Table 2: *National Bureau of Standards (NBS) System of Expressing Color Differences*

NBS Units	Critical Remarks of Color Differences
0.0–0.5	Excessively mere change
0.5–1.5	Mere: Mere change
1.5–3	Noticeable: Perceivable change
3–6	Appreciable: prominent change
6–12	Much: Excessively marked change
12 or more	Very much: Change to other color

equation:[17,18]

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

The critical remarks of the color change (ΔE) were quantified by the National Bureau of Standards (NBS), which rates the way that a color change is evaluated by the human eye (Table 2). The formula used for this conversion is NBS units = $\Delta E \times 0.92$.

Statistical Analysis

The results of scores were entered into a spreadsheet (Excel, Microsoft, Redmond, WA, USA) for calculation of descriptive statistics. One-way analysis of variance (ANOVA) tests were used to analyze the data if the normality and equal variance assumptions were met (α=0.05). Statistical software (SPSS 15.0 for Windows, SPSS Inc, Chicago, IL, USA) was used to perform the analysis. If the data did not meet the assumptions for ANOVA, a nonparametric analysis (Kruskal-Wallis test) was used to analyze these data. To compare the effects of bleaching agents on color change in each material, an independent samples *t*-test was performed. The statistically meaningful level was accepted as $p < 0.05$.

Table 3: *Kruskal-Wallis Test of Color Change for Carbamide Peroxide Groups*

χ^2	*df*	Significance
39.672	4	0.000

Table 4: *One-way ANOVA of Color Change for Hydrogen Peroxide Groups*

	SD	Sum of Square	Mean of Square	*F*	*p*
Between groups	4.170	4	1.042	16.750	0.000
Within groups	3.423	55	0.062		
Total	7.592	59			

Abbreviations: ANOVA, analysis of variance; SD, standard deviation.

RESULTS

Statistically significant color changes were found in both bleaching agent groups ($p<0.05$) (Tables 3 and 4). Appreciable color change was observed in the Estenia (ΔE=3.99) specimens bleached with the HP, and noticeable color change was observed in the Estenia (ΔE=1.89) and IPS Empress 2 (ΔE=1.66) groups treated with the CP.

The comparative evaluation of bleaching agents on the color change of materials revealed that the differences between the bleaching agents were significant for the e-Max, Finesse, and Estenia groups ($p<0.05$) (Table 5). Means and standard errors of the resulting measured ΔE values are represented graphically in Figure 1.

DISCUSSION

Colorimeters and spectrophotometers are used for color analysis in dental research. Literature has shown that there are no significant differences between colorimeter and spectrophotometer measurements.[19,20,21] The most important differences between colorimeter and spectrophotometer mea-

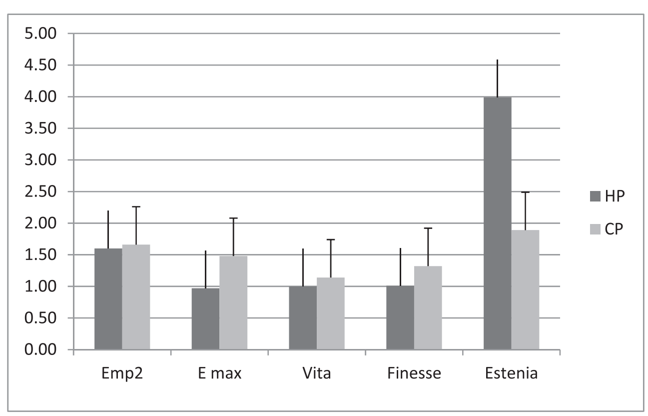

Figure 1. *Mean values and standard deviations of the groups.*

Table 5: *Result of Independent-samples t-test*

	HP	CP			
ΔE	**Mean**	**Mean**	**SD**	***t*-test**	***p*-value**
Empress 2	1.60	1.66	0.10	−0.593	0.560
e-Max	0.97	1.48	0.11	−4.459	<0.001*
Vita	1.00	1.14	0.12	−1.061	0.306
Finesse	1.01	1.32	0.11	−2.731	0.012*
Estenia	3.99	1.89	0.17	11.697	<0.001*

Abbreviations: CP, carbamide peroxide; HP, hydrogen peroxide; SD, standard deviation.
** The differences among bleaching agents are significant (p<0.05).*

surements are their wavelength range and the diversity of the light sources they use. In the clinic, the numerical values of minimal color changes and differences are not possible to distinguish visually. Results vary over time from person to person and for the same people as well. Statistically available and objectively evaluated results of color can be obtained from color-measuring devices like the spectrophotometer.[22] For these reasons, in the present study, the spectrophotometer was used to detect fine color changes.

Color measurement studies always make more than one measurement for each specimen. Based upon measuring the various regions of each specimen, average values were obtained in one study through five color measurements per specimen,[16] and other studies have made three measurements per specimen.[7,23] The present study copies these latter studies and took three measurements of each sample (looking at three different regions on each sample), and then averaged these three values for each sample.

Multiple measurements are important because the same sample can have varying thicknesses, which will affect the darkness or lightness of one region's color. One study found that thickness and light transmission affect the color of a sample.[24] In response to this finding, previous color studies[25,26,28] standardized all samples to be 2 mm in thickness. Other previous studies prepared the color samples to be 10 mm in diameter[28,29] and 6 mm in diameter,[22] which is suitable for the optical screen of the color measurement device.

This *in vitro* study measured the quantitative color changes of five different restorative materials as a result of simulated home bleaching with 10% CP and 10% HP. The results of this study support the hypothesis that the different bleaching systems produce different results on restorative materials because there were significant differences in color change within groups.

After examining color changes in the materials after implementing 10% HP or 10% CP on two types of heat-pressed glass ceramics, an ultralow-fusing porcelain, a low-fusing porcelain, and a ceromer, the average color change (ΔE) values that were found in the restorative materials were as follows: after application of HP, e-Max = 0.97, Vita = 1.00, Finesse = 1.01, Empress 2 = 1.60, and Estenia = 3.99. After the application of CP, Vita = 1.14, Finesse = 1.32, e-Max = 1.48, Empress 2 = 1.66, and Estenia = 1.89. For NBS unit color evaluations, the results between the values of 0.5 to 1.5 are "slight," results between the values of 1.5 to 3 are "noticeable," and results between 3 to 6 are "appreciable" color changes.[7] The porcelains (e-Max, Vita, and Finesse) exhibited slight changes in color after HP implementation. The HP-treated Empress 2 porcelain showed a noticeable color change, and the HP-treated Estenia samples exhibited appreciable color changes. The e-Max, Vita, and Finesse treated with CP underwent slight changes, and Empress 2 and Estenia showed noticeable changes after CP treatment.

Regarding the differences in performance between the bleaching agents, the e-Max, Finesse, and Estenia restorative materials were found to have statistically significant differences because they responded differently to CP than they did to HP.

In the present study, the two bleaching agents caused more color changes in the Estenia samples than they did in the other samples. The reason for this is that ceromers contain microhybrid inorganic silanized fillings buried in an organic matrix that was polymerized with light.[32] Estenia is also a hybrid ceramic with a large amount of particulate filling produced for indirect use in both anterior and posterior restorations. It contains a high level of filling in its matrix (92% lanthanum oxide filling and glass filling with very fine particles). Also, it is known that the mechanical properties of the materials with a polymer structure, such as composite materials, are reduced due to their ability to absorb water.[33] It is thought that the materials with a polymer structure have less color stability in the face of several chemical agents than do porcelains.

Another finding from the present study is that IPS Empress 2 and IPS e-Max materials are both porcelain materials shaped under pressure and heat treatment that nevertheless display changes in color to differing extents in the face of bleaching agents. The reason for this is thought to result from the fact that the two materials have different crystal structures (crystal sizes and rates).

Several previous studies have reported that there are not any clinical and statistical differences in the color of glazed porcelain restoration materials treated with bleaching agents.[8] In a clinical study, Haywood and Parker[34] reported that the "nightguard vital bleaching" method, which contains 10% CP, had no effect on glazed porcelain and that the discoloration that occurs in porcelain restorations not reinforced with metal is connected to the change in the color underneath the tooth's surface. Another study has reported that the bleaching process applied to the vital teeth had no effects on color change or other physical properties of porcelain restoration materials.[35] The reasons the results of previous studies are different from those of the present study are presumably that the restorative materials were different and that the porcelain sample surfaces were not glazed in the present study.

In a study by Kao and others,[36] the effects of the bleaching agents containing 10% CP on dental structure and on feldspathic porcelain (Finesse) restorative material were examined. Although the discoloration was less noticeable on the porcelain than it was on the dental structures, the ΔE value was determined to be 1.2. This result agrees with the current study.

In a study conducted by Zaki and Fahmy,[16] it was reported that the bleaching agent containing 15% CP had numerically little whitening effect on autoglazed feldspathic porcelain (Duraceram) because it did not bring about any statistically significant change in color. However, it has been observed that discoloration occurs on the surfaces of feldspathic porcelain treated with overglaze and polishing as a result of the application of a bleaching agent. Similarly, in a study by Rosentritt and others,[37] the bleaching agent was reported to bring about a change in color on some restorative materials (composite, compomer, and ormocer). These results also support the results of the current study.

Canay and Cehreli[7] have also observed that as a result of the application of a 10% CP bleaching agent, the change in color was greater in polyacid-modified composites than in composites with hybrid and macro filling. They have reported that the change in color is associated with the matrix content, the amount of filler, and the composite type.

There are some limitations of the current study design that must be noted. As in many *in vitro* studies, the oral environment cannot be fully simulated. It would be useful to support the results of this study with other clinical studies or with the studies that could imitate the oral environment better in order to find out whether the effects of the bleaching agents change with exposure to saliva. Furthermore, the current study also examined only a low concentration of the products found in self-applied bleaching systems. Further research is required to examine the effects of high concentrations of HP and CP, such as those found in professionally applied power bleaching systems. The spectrophotometer was used to detect fine color changes, and the color differences were calculated with the old formula named CIE 76 in the present study. However, in further studies other analysis methods (colorimeters or even digital cameras and imaging systems) and other, newer formulas like CIE Delta E 2000 could be used.

CONCLUSION

In conclusion, statistically significant differences among the color changes of all test groups were found after exposing them to bleaching agents. Appreciable change was observed in the Estenia specimens that were treated with the HP, and noticeable change observed in the Estenia and IPS Empress 2 specimens that were treated with the CP. Therefore, restorations (especially those with polymer content) should be protected before any bleaching, for fear of color change. Patients should be advised that color of existing restorations may not match the bleached restorations after bleaching, and replacement may be required.

Conflict of Interest

The authors of this manuscript certify that they have no proprietary, financial, or other personal interest of any nature or kind in any product, service, and/or company that is presented in this article.

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