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A Comparison of the Bleaching Effectiveness of Chlorine Dioxide and Hydrogen Peroxide on Dental Composite

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This study was carried out to verify if composites could be bleached using chlorine dioxide as compared with hydrogen peroxide. 3M ESPE Filtek Z350 Universal Restorative discs were prepared (n=40), with dimensions 5 mm diameter x 2 mm thickness. The discs were divided into 4 groups of 10 discs each. Color assessment was performed by CIEDE2000. The discs were stained with coffee, tea, wine and distilled water (control) solutions for 14 days, 5 hours daily. Color assessment was repeated on stained discs and followed by bleaching of 5 discs from each group using chlorine dioxide and hydrogen peroxide in-office systems. Finally, a last color assessment was performed and compared statistically. DE2000 after bleaching was very close to baseline for both the bleaching agents, although chlorine dioxide showed better results than hydrogen peroxide. After staining, there was a clinically significant discoloration ($\Delta E2000 \geq 3.43$) for the tea, coffee and wine groups, and discoloration ($\Delta E2000$) was seen more in the wine group as compared to tea and coffee. Overall, the control group (distilled water) had the least color change in the three intervals. After bleaching, the color in all specimens returned close to the baseline. The color differences between bleaching and baseline were less than 3.43 for all groups. The obtained results show that chlorine dioxide is slightly superior to hydrogen peroxide in the bleaching of composites, while maintaining the shade of the composite close to the baseline.

Key Words: dentistry, composite, bleaching, chlorine dioxide, hydrogen peroxide, CIEDE2000.

Introduction

Composite resin restorations have been widely used since their introduction due to their excellent esthetic properties. However, a major disadvantage is their discoloration after prolonged exposure to the oral environment, leading to their replacement due to unacceptable color matching (1).

Composite resin restorations have a tendency to stain over long-term exposure to several beverages and food materials (2). The typical commonly consumed beverages, which can cause staining, are coffee (3), tea (2), wine (3) and carbonated drinks (4). Replacement of the restoration following discoloration can be avoided by bleaching[3], which is more convenient for the dentist as well as more economical for the patient in terms of both time and money.

Bleaching can be performed using a variety of bleaching agents and hydrogen peroxide is considered the best, but has shown to have deleterious effects on the properties of composite. Therefore, a comparative study was carried out to assess the effectiveness of bleaching agents through color changes obtained with chlorine dioxide, which is a very popular industrial bleaching agent (5), and hydrogen peroxide, which is the most widely used dental bleaching agent (6).

This study aimed to explore chlorine dioxide as a possible alternative to hydrogen peroxide.

Material and Methods

Composite Selection and Disc Preparation

The chosen composite was 3M ESPE Filtek Z350 Universal Restorative, which is a widely used visible light-activated direct restorative nanocomposite designed for anterior and posterior restorations (3M ESPE, St. Paul, MN, USA). The composite resin was injected into stainless steel molds (5 mm diameter x 2 mm thickness) and covered by a glass plate with a Mylar strip. Finger pressure was applied to the covering glass plate to expel excess materials and create a smooth surface. The composite resins were then polymerized in a LED-curing unit (with a 430-480 nm wavelength range) for 40 s to allow thorough polymerization from both sides.

The discs were removed from the molds and stored in de-ionized water for a day in an incubator maintained at 37 °C to allow thorough leaching of any non-polymerized resins, establishing equilibrium in water uptake. The polished discs were then stored in de-ionized water for 24 h before use. A total of 40 discs, 10 in each group, were prepared.

Baseline Color Assessment

The color of the polished composite discs was assessed according to the Commission Internationale de l'Eclairege (CIE) Delta E 2000 (CIEDE2000) color space using an Eye1 spectrophotometer (X-rite, Grand Rapids, MI, USA). The CIEDE2000 formula was developed by members of the CIE Technical Committee, providing an improved procedure for the computation of industrial color differences (7).

Δ E 0 0 = [(Δ L / k L S L) 2 + (Δ C / k C S C) 2 + (Δ H / kHSH)2+RT(ΔC*ΔH/SC*SH)]1/2

Where ΔE00 is the change in color; RT is a hue rotation term; ΔL, ΔC, and ΔH are the compensation differences for neutral colors (primed values; L,C,H); SL is the compensation for lightness; SC is the compensation for chroma; SH is the compensation for hue; and kL, kC, and kH are constants and usually unity.

The diameter of the discs exactly coincided with the diameter of the reflectance handle aperture of the spectrophotometer. A mold was prepared and an outline of the position of the reflectance arm was traced over it, in order to place discs in an identical manner every time, thus avoiding the error due to positioning.

Each sample with the side that was exposed for color assessment, was kept a note of and at every interval, the same side of the same sample was assessed against the previous readings.

Staining Beverage Preparation, the Staining Process and Color Assessment

The dietary colorants used in this study were common beverages, which may cause staining of composite resin surfaces with their natural colors. Three different beverages were used in this experiment: coffee (Nescafé Sunrise Coffee-Chicory mix, Nestlé, Gurgaon, India), tea (Brooke Bond Taj Mahal; Hindustan Unilever Limited, Mumbai, India), and red wine (Raya red wine, Nandi Hills; Grover Vineyards Limited, Bangalore, India).

Coffee was prepared by boiling 1.3 g of coffee from a sachet in 100 mL of water for two minutes. Tea was prepared by immersing a 2 g tea bag in 100 mL of boiling water. The wine was directly poured into the test tubes. The samples were kept in incubators for 5 h, after which they were washed with distilled water, immersed in distilled water, and kept in the incubators at 37 °C. This was carried out for 14 days with fresh solutions of beverages each day. A control group with distilled water was also kept for consideration. Finally, the samples were washed and kept in distilled water for a day and color assessment was performed prior to bleaching, as mentioned above.

Bleaching and Post-Bleaching Color Assessment

Samples were bleached following the initial color assessment. The hydrogen peroxide-based system was Opalescence Boost 40% concentration (Ultradent Products, Inc. South Jordan, UT, USA) while the chlorine dioxide-based system was DioxiWhite Pro Teeth Whitening System with DioxiCare 500–750 ppm/0.050-0.075% concentration; (Frontier Pharma, Long Island, NY, USA). Bleaching was performed as per the manufacturer's instructions. Opalescence Boost 40% is a red gel supplied in two separate syringes, which were mixed and applied with a mixing tip for three cycles of 15 min each. The DioxiWhite in-office bleaching agent gel was mixed in a closed container to keep the concentration of chlorine dioxide constant. Application was repeated seven times for 5 min each time, after which bleaching gel was changed. Polymerizing light was used for chlorine dioxide. Each sample was individually bleached. After this, all the samples were assessed for color changes on the same side as previously described.

Statistical Analysis

A limit of DE2000 of 3.43 was interpreted as a clinically acceptable difference in this study, which is equivalent to the conventional clinically significant value of 3.3 ΔE*ab (8-10) and was calculated by the help of an automatic calculating computer program available at http://www.boscarol.com/DeltaE.html. Data was entered in an MS Excel sheet and analyzed using the Statistical Package for Social Sciences (SPSS version 16). The independent-sample t-test was used to analyze the significance of results between

Table 1. Comparison of two bleaching agents for different staining beverage. Mean values and SDs of ΔE2000s for intervals of staining and baseline, bleaching and baseline, and bleaching and staining

	Tea			Coffee			Wine			Control		
	Agent 1	Agent 2	p value	Agent 1	Agent 2	p value	Agent 1	Agent 2	p value	Agent 1	Agent 2	value
STBL	7.06 (3.28)	8.92 (3.59)	0.41	9.26 (4.44)	6.90 (1.91)	0.30	14.04 (2.85)	11.76 (3.43)	0.28	0.90 (.98)	0.88 (1.55)	0.98
BBL	0.98 (2.40)	0.92 (2.57)	0.97	2.54 (4.29)	0.68 (1.46)	0.09	3.22 (1.40)	0.80 (1.20)	0.01	0.20 (1.01)	0.40 (1.83)	0.54
BST	6.08 (2.99)	8.00 (3.58)	0.38	4.72 (0.94)	6.22 (2.18)	0.19	10.72 (2.07)	10.96 (2.70)	0.87	0.70 (1.38)	1.28 (0.28)	0.38

(STBL: Staining and baseline; BBL: Baseline and bleaching; BST: Bleaching and staining; Agent 1: Hydrogen peroxide; Agent 2: Chlorine dioxide P value<0.05 is considered as statistically significant) hydrogen peroxide and chlorine dioxide. One-way ANOVA test was used to analyze the effect of the bleaching agents among the different stains. A p value of <0.05 was used as a cut-off level for statistical significance.

Results

Mean values and significant differences (SDs) of ΔE2000 for intervals of staining and baseline, bleaching and baseline, and bleaching and staining are listed in Table 1. After staining, there was a clinically significant discoloration (ΔE2000≥3.43) for the tea, coffee and wine groups, and discoloration (ΔE2000) was seen more in the wine group as compared to tea and coffee. Overall, the control group (distilled water) had the least color change in the three intervals. After bleaching, the color in all specimens returned close to the baseline. The color differences between bleaching and baseline were less than 3.43 for all groups. Statistical analysis results showed that the color change between bleaching and baseline was better for chlorine dioxide as compared to hydrogen peroxide for the tea, coffee and wine groups. The color change observed between bleaching and baseline was significantly better with chlorine dioxide on the wine group (Table 2).

The statistical analysis showed that the color change between bleaching and baseline was better for chlorine dioxide compared to hydrogen peroxide for each stain. Among the stains, wine caused the most discoloration, followed by tea and coffee. Tea stains were bleached well by both agents; coffee and wine were better bleached by chlorine dioxide.

Discussion

To date, the use of chlorine dioxide in dentistry has been restricted to disinfection of waterlines (11), soft denture liners and acrylic dentures (12). Further, some studies have shown its usage as a mouth rinse (13-15) to reduce oral malodor. However, to our knowledge, there are no studies stating its usage as a bleaching agent. Restorative composites have been previously subjected to bleaching with hydrogen peroxide, which is the most widely used bleaching agent; nevertheless, its efficacy in bleaching such composites is now being questioned (6). The use of hydrogen peroxide increases the sensitivity of teeth (16) and decreases the enamel-composite bond strength (17). Some researchers have proved that bleaching may adversely affect the surface texture of composites and that surface roughness significantly changes with bleaching, although the extent of these effects varied according to composite shade and bleaching agent (18). It has also been shown that nanocomposites are more prone to staining but are more effectively bleached than microhybrid composites (3). Further, bleaching does not increase the staining susceptibility of nano or microhybrid composites (19,20). In a previous study, the researchers concluded that the effect of bleaching on the surface texture was material-dependent and time-dependent and that bleaching with 38% hydrogen peroxide and 15% carbamide peroxide did not cause major surface texture changes on the polished surfaces of the restorative materials (21). There is also evidence that bleaching of nanocomposites yields color changes to nearly baseline with minimal surface roughness as observed by scanning electron microscopy (22). Due to the deleterious effects of hydrogen peroxide on the surface of composites, it is contra-indicated to be used on them. Future studies should focus on testing chlorine dioxide's effects on the surface of composite, and if it holds good, chlorine dioxide can be a possible alternative to hydrogen peroxide.

Most previous studies follow CIELAB for the color assessment of dental materials as indicated by the CIE in 1976. In this study, we used CIEDE2000, which has consistently performed better than other color difference formulae to predict visual results more accurately than with observer uncertainty (23). The composite resin shades were also tested and it was found that the new CIEDE2000 color space is better than CIELAB (24).

Table 2. Mean values (SDs) of color change

Treatment	Agent 1					Agent 2				
	Tea	Coffee	Wine	Control	p value	Tea	Coffee	Wine	Control	P value
STBL	7.06 (3.28)	9.26 (4.44)	14.04 (2.85)	0.90 (0.98)	<.001	8.92 (3.59)	6.90 (1.91)	11.76 (3.43)	0.88 (1.58)	<.001
BBL	0.98 (2.40)	2.54 (4.29)	3.22 (1.40)	0.20 (1.01)	.043	0.920 (2.57)	0.68 (1.46)	0.80 (1.20)	0.40 (1.83)	0.97
BST	6.08 (2.99)	4.72 (0.94)	10.72 (2.07)	0.70 (1.38)	<.001	8.00 (3.58)	6.22 (2.18)	10.96 (2.70)	1.28 (0.28)	<.001

STBL: Staining and baseline; BBL: Baseline and bleaching; BST: Bleaching and staining; Agent 1: Hydrogen peroxide; Agent 2: Chlorine dioxide. P value<0.05 is considered as statistically significant

The present results show that chlorine dioxide is superior to hydrogen peroxide in terms of color of the bleached samples compared to their baseline color before staining. As is true for all *in vitro* studies, the constraint of reproducing accurate clinical conditions also applies to the present study.

Resumo

Este estudo foi realizado para verificar se resinas compostas podem ser clareadas com uso do dióxido de cloro, em comparação com peróxido de hidrogênio. Foram preparados discos com resina restauradora Filtek Z350 3M ESPE (n=40), com dimensões 5 mm de diâmetro × 2 mm de espessura. Os discos foram divididos em 4 grupos de 10 discos cada. A avaliação da cor foi realizada por meio do CIEDE2000. Os discos foram manchados com soluções de café, chá, vinho e água destilada (controle) por 5 h diárias durante 14 dias. A avaliação da cor foi repetida nos discos manchados e seguida por clareamento de 5 discos de cada grupo, utilizando dióxido de cloro ou peróxido de hidrogênio pela técnica de consultório. Finalmente, uma última avaliação da cor foi realizada e as técnicas comparadas estatisticamente. DE2000 após o clareamento foi muito próxima ao baseline, para ambos os agentes clareadores, embora o dióxido de cloro tenha mostrado melhores resultados do que o peróxido de hidrogênio. Após o manchamento, houve uma descoloração clinicamente significativa ($\Delta E2000 \geq 3,43$) para os grupos de chá, café e vinho, sendo que o clareamento ($\Delta E2000$) foi melhor obtido com o grupo do vinho, em comparação com chá e café. No geral, o grupo controle (água destilada) teve a menor mudança de cor nos três intervalos. Após o clareamento, a cor em todos os espécimes voltou próxima ao baseline. As diferenças de cor entre o clareamento e o baseline foram inferiores a 3,43 para todos os grupos. Os resultados indicam que o dióxido de cloro é ligeiramente superior ao peróxido de hidrogênio no clareamento de resinas compostas, mantendo a cor próxima à escala do baseline.

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