Original Article

Color Recovery Effect of Different Bleaching Systems on a Discolored Composite Resin

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ABSTRACT

Background and Purpose: Discoloration of resin-based composites is a commonly encountered problem, and bleaching agents may be used for the therapy of the existing discoloration. The purpose of this study was to investigate *in vitro* color recovery effect of different bleaching systems on the heavily discolored composite resin. **Materials and Methods:** Fifty disk-shaped dental composite specimens were prepared using A2 shade nanohybrid universal composite resin (3M ESPE Filtek Z550, St. Paul, MN, USA). Composite samples were immersed in coffee and turnip juice for 1 week in each. One laser activated bleaching (LB) (Biolase Laserwhite*20) and three conventional bleaching systems (Ultradent Opalescence Boost 40% (OB), Ultradent Opalescence PF 15% home bleaching (HB), Crest 3D White [Whitening Mouthwash]) were tested in this study. Distilled water was used as control group. The color of the samples were measured using a spectrophotometer (VITA Easy shade Compact, VITA Zahnfabrik, Bad Säckingen, Germany). Color changes ($\Delta E00$) were calculated using the CIEDE2000 formula. Statistical analyses were conducted using paired samples test, one-way analysis of variance, and Tukey's multiple comparison tests ($\alpha = 0.05$). **Results:** The staining beverages caused perceptible discoloration ($\Delta E00 > 2.25$). The color recovery effect of all bleaching systems was statistically determined to be more effective than the control group ($P < 0.05$). Although OB group was found as the most effective bleaching system, there was no statistically significant difference among HB, OB, and LB groups ($P > 0.05$). **Conclusion:** Within the limitation of this *in vitro* study, the highest recovery effect was determined in office bleaching system among all bleaching systems. However, home and laser bleaching systems were determined as effective as office bleaching system.

KEYWORDS: *Composite resin, discoloration, home bleaching, laser activated bleaching, office bleaching, whitening mouthwash*

INTRODUCTION

Resin-based composite materials, the most commonly used esthetic restorative materials in dentistry, have resulted in great improvements in adhesive dentistry. Due to the increase in the number of available color shades, color matching for composite resin restorations has become much more straightforward. In addition, due to the development of nanofilled types of composite resins, better surface finishes and a smooth texture are successfully providing a more natural appearance.[1,2] Although composite resins are quiet successful, over time, external stains and internal discoloration may occur in composite restorations. It is possible to replace the entire restoration. However, it is very expensive. The other cost-effective alternatives are finishing-polishing method and bleaching of the restoration. The interaction between the bleaching agent and restorative material is of clinical significance and it should be evaluated by researchers.[3]

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The effect of bleaching on dental restorative materials has been reviewed recently.[4] Currently, the bleaching agents are based primarily on hydrogen peroxide or other peroxide derivatives such as carbamide peroxide.[5] Due to their organic matrix, composite resin materials, especially, tend toward chemical alteration compared to ceramic restorations.[6] Concentration or repeated application of peroxide may degrade the resin matrix of composites.[7] Hydrogen peroxide exhibits high oxidation and reduction capability and may generate free radicals.[8] In addition to its reactivity, hydrogen peroxide has shown high diffusion property.[9-11] Possibly, peroxides induce oxidative cleavage of polymer chains. By this way, unreacted double bonds are expected to be the most vulnerable parts of the polymers.[6] Moreover, free radicals induced by peroxides may impact the resin-filler-interface and cause a filler-matrix debonding, as discussed elsewhere. This may cause microscopic cracks resulting in an increase in surface roughness as monitored in the scanning electron microscopic pictures.[6,8] As a result, the clinical longevity of the composite restoration may be effected by chemical softening from bleaching.[12]

Bleaching can be achieved with a variety of methods or systems, which are generally categorized as in-office (professionally administered), at-home (professionally dispensed) or over-the-counter (self-administered).[13] Whitening mouthwashes (WMs) have recently appeared in the market and manufacturers have claimed that they are able to prevent discoloration and fight plaque build-up. In general, these mouthwashes contain a low concentration of hydrogen peroxide (1.5%) and sodium hexametaphosphate, which protect the teeth surface from new stains.[14]

The results of instrumental color matching are monitored using symbols of the color notation systems; items represented by these symbols are supposed to be supported with visual findings.[15] Several color notation systems, Commission International de l'Eclairage (CIE), the most frequently used one being the CIELAB or CIE76 system have been recommended.[16] The color coordinates of the CIELAB system are L* (lightness, achromatic coordinate, ranging from black to white), a*ab (-a* green, +a* red), and b*ab (-b* blue, +b* yellow). The CIE 2000 or CIEDE2000 is the most recent and officially recommended as the new CIE color difference equation.[17]

The aim of this study was to compare the color recovery effect of different bleaching systems on discolored composite resin *in vitro*.

The null hypotheses were: (1) bleaching systems would not achieve effective color recovery on discolored composite, (2) there would be no significant differences among tested bleaching systems.

Materials and Methods

For this experimental *in vitro* study, fifty dental composite specimens were prepared. In each specimen's preparation, A2 shade nanohybrid universal composite resin was used (Filtek Z550 nano hybrid universal restorative, 3M ESPE, St. Paul, MN, USA). Composite material was placed in a polytetrafluoroethylene mold with an inner diameter of 8 mm and a height of 1.5 mm and confined between two opposing transparent polyethylene terephthalate strips (Mylar, Henry Schein, Melville, NY, USA) on a glass plate. Photopolymerization of the samples was performed for 20 s with a LED curing light (Elipar Free Light S10, 3M ESPE, St. Paul, MN, USA). The irradiation of the curing light was regularly monitored with the light intensity meter dock of the curing unit. The composite discs were finished and polished using aluminum oxide discs (Sof-Lex; 3M ESPE, St. Paul, MN, USA) in descending sequence of granulation. At the end of this process, the samples were immersed in distilled water at 37°C for 24 h.

The initial (baseline) CIE L*a*b*color values of the composite samples were measured with a spectrophotometer (VITA Easyshade Compact, VITA Zahnfabrik, Bad Säckingen, Germany). The composite samples were subjected to two cycles of staining with coffee (Nescafe 3 in1, Bursa, Turkey– 3 g of coffee powder was dissolved in 150 ml of boiling water as per the manufacturer's recommendation) and turnip juice (Doğanay şalgam suyu; Istanbul, Turkey). All the samples were immersed in coffee for 1 week and subsequently in turnip juice for an additional week. All the staining solutions were renewed daily.

To evaluate the color recovery effect of the different bleaching methods, discolored composite samples were divided into five subgroups (n = 10). Four whitening agents were tested in this study; Biolase Laserwhite *20 (laser activated bleaching [LB]) (Irvine, CA, USA), Ultradent Opalescence Boost (OB) 40% (office bleaching) (South Jordan, Utah USA), Ultradent Opalescence PF 15% (home bleaching [HB]) (South Jordan, Utah USA), Crest 3D White (WM) (Procter and Gamble, Cincinnati, OH, USA). Distilled water was used for the control group. Laser White 20 (45% hydrogen peroxide) was used in conjunction with a diode laser (Biolase Technology Inc., Irvine, CA, USA) with a spectral wavelength of 940 nm and an output of 7 W. The whitening headpiece of the laser device was placed in proximity to the gel and activated for 30 s. The whitening gel was allowed to remain on the samples for a minimum of 5 min after the second laser cycle.

All bleaching systems were applied by the procedure given in the manufacturer's directions. All steps were carefully obeyed. The specimens were stored in distilled water before the bleaching procedures. Details of the bleaching systems used in this study are showed in Table 1.

CIE L*a*b* values of each sample were the measured at baseline, after staining and after bleaching. Color changes were calculated with the CIEDE2000 formula. The clinical acceptability threshold was set at 2.25 ΔE00 units as mentioned by Ghinea *et al.*[18]

Statistical analysis was performed using statistical software, SPSS version 18.0 (SPSS Inc., Chicago, IL, USA). After verifying the normality, color differences between staining and bleaching periods for each bleaching system were analyzed with paired samples test. Differences among ΔE00 (after bleaching) of bleaching systems were analyzed using one-way analysis of variance (ANOVA) and Tukey's multiple comparison test ($\alpha = 0.05$).

Results

The mean CIELAB color parameters after staining and bleaching are shown in Figures 1-3. After immersion in the staining solutions, L* values decreased from baseline recordings, whereas a* and b* values increased. This led to a yellow shade of the specimens that is visible to the naked eye. The distribution of L*, a*, and b* obtained in this study indicated that all bleaching systems increased L* and b* values while decreasing a* values following treatment.

Mean color differences and standard deviations after staining and bleaching are presented in Figure 4. Immersion in staining beverages caused perceptible discoloration on the composite resin samples (ΔE00 > 2.25). Paired samples test showed that color differences between staining and bleaching periods for each bleaching system were statistically significant ($P < 0.01$).

One-way ANOVA test showed that there was a statistically significant difference among groups ($P < 0.001$). In addition, Tukey's multiple comparison tests showed that the most effective bleaching system was OB group. However, there was no statistically significant difference among HB, OB, and LB groups ($P > 0.05$) [Figure 5].

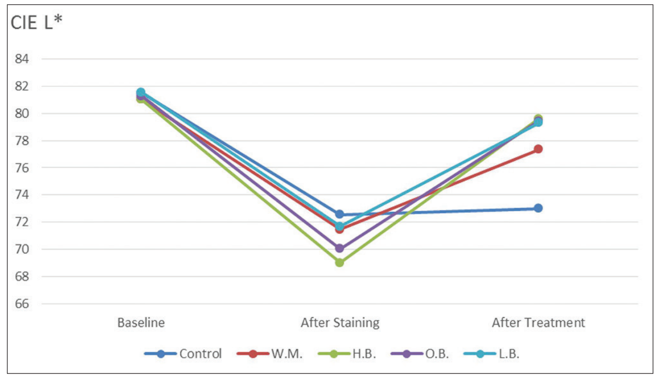

Figure 1: Mean Commission International de l'Eclairage L* values after staining and bleaching procedures. (WM = Whitening mouthwash, HB = Home bleaching, OB = Office bleaching, LB = Laser activated bleaching)

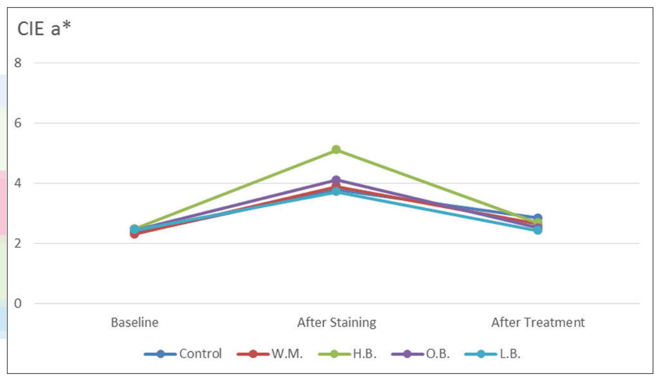

Figure 2: Mean Commission International de l'Eclairage a* values after staining and bleaching proceures. (WM = Whitening mouthwash, HB = Home bleaching, OB = Office bleaching, LB = Laser activated bleaching)

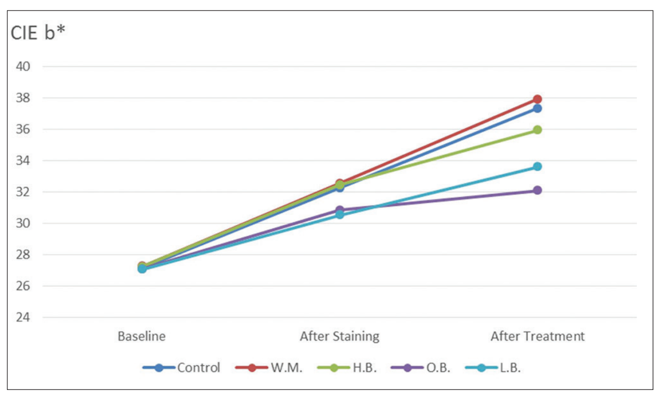

Figure 3: Mean Commission International de l'Eclairage b* values after staining and bleaching procedures. (WM = Whitening mouthwash, HB = Home bleaching, OB = Office bleaching, LB = Laser activated bleaching)

Table 1: Details of mouthwash product and bleaching gels used in this study

Materials	Manufacturer	Concentration	Number of applications	Duration of each application	Light activation source
Biolase Laserwhite*20	Biolase Technology Inc., Irvine, CA, USA	45% hydrogen peroxide	2	6 min	Diode laser (940 nm)
Opalescence Boost	Ultradent Products, Inc., South Jordan, Utah USA	40% hydrogen peroxide	2	20 min	-
Opalescence PF	Ultradent Products, Inc., South Jordan, Utah USA	15% carbamide peroxide	1×14	8 h/day	-
Crest 3D white multi-care whitening mouthwash	Procter and Gamble, Cincinnati, OH, USA	1.5% hydrogen peroxide	1×30	2 min/day	-

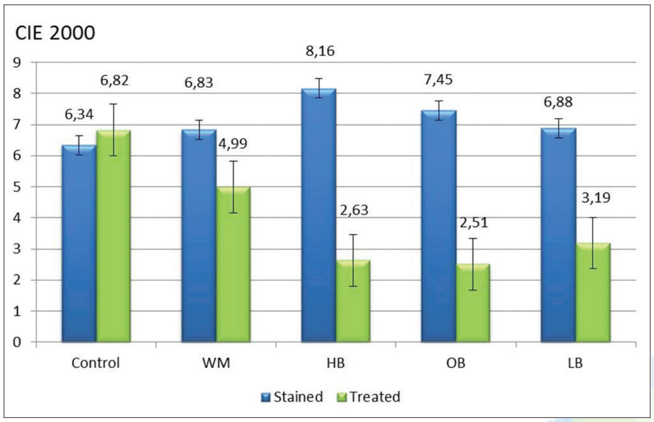

Figure 4: Mean color changes at after staining and bleaching procedures according to ΔE00 color calculations. Error bars represents standard deviations. (WM = Whitening mouthwash, HB = Home bleaching, OB = Office bleaching, LB = Laser activated bleaching)

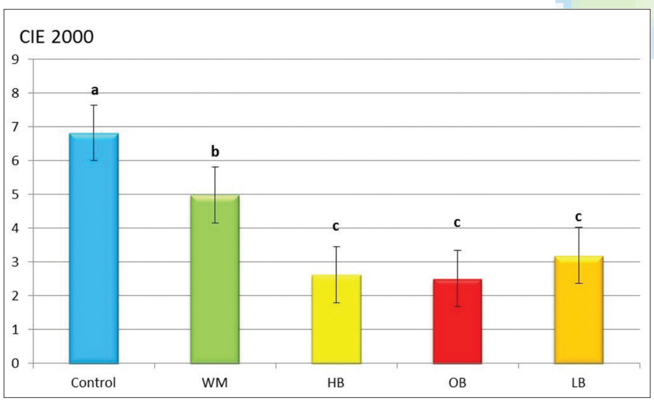

Figure 5: The results of Tukey's multiple comparison tests points according to ΔE00 (after bleaching) color calculations. Error bars represents standard deviations. (WM = Whitening mouthwash, HB = Home bleaching, OB = Office bleaching, LB = Laser activated bleaching)

Discussion

Since the bleaching of teeth is extremely popular, the effect of bleaching on the aesthetic appearance of dental materials should be taken into account. Therefore, this complicates the process of establishing and maintaining a good color match between dental restoration and the adjacent tooth structure.[19] Discoloration of composite resin is still a major reason for the esthetic failure of materials, which can be a reason for the replacement of restorations in esthetic areas. This process has disadvantages for both the patient and dentist in terms of time and financial cost.[20]

Filler type may affect the staining susceptibility of a material. Inorganic fillers may de-bond from the resin matrix and leave a void, which causes an increase in the roughness of the surface, forming a surface susceptible to exterior staining. It has been reported that in nanohybrids, smaller voids remain on the surface. As a result of this, smaller particles were de-bonded from the resin compared with other materials.[21,22] However, actual staining in the oral cavity requires a longer period and also the intermittent nature of stain exposure, saliva and other fluids diluting the staining media, and polishing of the restorations by brushing. The degree of color change, which results from both intrinsic and extrinsic factors, are effected by factors such as the degree of polymerization, water sorption, diet, oral hygiene, and the surface smoothness of restorations.[23] The color changes of composites are also effected by the differences in resin shades, curing conditions, resin thickness, background colors for color measuring, storage methods of specimens during observation, color measuring methods, type of color measuring instruments, and observation methods.[24-26] In this study, to get rid of the possible discoloration due to the salivary components, restorative materials were kept in 37°C distilled water, and A2 shade was chosen for all restoratives to minimize the effect of shade. As a result, immersion in coffee and turnip juice caused perceptible discoloration on the composite resin samples (ΔE00 > 2.25).

In this study, color changes were calculated with the CIEDE2000 formula. Recent studies claimed that CIEDE2000 color difference formula provides a better fit in the evaluation of color differences.[27] This formula incorporates specific corrections for nonuniformity of CIELAB color space, specifically for the interaction between chroma and hue differences in the blue region, and a modification of a* coordinate of CIELAB, which mainly effects colors with low chroma.[27] These formulas can be used interchangeably when evaluating the color differences of dental materials. Authors determined a contemporary acceptable color difference threshold using both CIELAB and CIEDE2000 color difference formulas (3.46 for ΔEab*and 2.25 for ΔE00). These values are reported in the literature as the threshold at which 50% of observers find that the color difference is perceived as disturbing.[28] In this study was found that the staining beverages caused perceptible discoloration (ΔE00 > 2.25).

This study assessed the color recovery effect of different teeth bleaching systems on a discolored composite resin. The paired samples test showed that color differences between staining and bleaching periods for each whitening systems were statistically significant ($P < 0.01$). In addition, Tukey's multiple comparison tests showed that the most effective bleaching system was OB group. Thus, the null hypotheses, that bleaching systems would not achieve effective color recovery on stained composite, and there would be no significant differences among tested bleaching systems, were rejected.

It has been reported that peroxide concentration and application duration are two key factors that determine the overall whitening efficacy of products containing peroxide.[29] A solution of 10% carbamide peroxide breaks down into urea, ammonia, and carbon dioxide, and is equivalent to 3.5% hydrogen peroxide. Some techniques involve high-concentration hydrogen peroxide formulations as active ingredients (35%–50%).[30] A study by Canay and Cehreli[3] showed that 10% hydrogen peroxide provided better color changes of composite resins compared with 10% carbamide peroxide, and the color change of all the composite resins bleached with hydrogen peroxide solution was clinically detectable with the naked eye. Fay *et al.*[31] found that 10% carbamide peroxide successfully removed cranberry and tea stains from composite resin samples. Türkün and Türkün[32] compared the effect of polishing and bleaching in the removal of coffee and tea stains from three resin-based composites and showed that both methods were effective with in-office bleaching showing slightly better results than polishing.

Some manufacturers suggest that auxiliary lights can be used in in-office bleaching treatment, as they claim the lights to be capable of catalyzing hydrogen peroxide decomposition and therefore accelerated the action of the bleach.[33] Although such laser bleaching techniques do lighten teeth more quickly, short-term postoperative sensitivity may result. In general, bleaching is accompanied by some increased tooth or gingival sensitivity. Researchers and clinicians may be reluctant to adopt bleaching therapies due to the tooth sensitivity issue, which has been reported as a side effect when hydrogen peroxide is used. It has been suggested that the higher the concentration of a bleaching agent, the higher the risk of tooth sensitivity.[34] However, it has been reported that irradiation with laser light can produce some beneficial effects on sensitivity.[35,36] The laser is accepted to be the most valuable energy source for in-office bleaching with the short and simple application in the office.[34,35] Many patients are positive about the shorter application time, and not being responsible if they have in-office treatment, and hence they opt for in-office treatments if available, to expedite the whitening effect. For this situation, bleaching with laser irradiation is more significant.

Differences in bleaching effect of the agents on the same material might be attributed to their different hydrogen peroxide contents. The higher efficacy of 35% hydrogen peroxide gel could be due to an excess of active ingredient that readily diffused. It is noteworthy that carbamide peroxide is a vehicle for the delivery of low concentrations of hydrogen peroxide.[37]

In this study, highest recovery effect was determined in office bleaching system among all bleaching systems. However, home and laser bleaching systems were determined as effective as office bleaching system. In the current study, the HB agent was left in contact with the restorative materials for 8 h/day for 14 days. This may explain why the HB agent was effective than the other bleaching systems.

The WM used in this study has a low concentration of hydrogen peroxide and sodium hexametaphosphate, which may prevent new stains on the tooth surface. These agents work either by bleaching or by the removal and prevention of stains. A previous study showed that various peroxide-based WMs did not have a bleaching effect on stained teeth.[38] However, Torres *et al.*[39] reported that WMs showed similar results to the 10% carbamide peroxide in color changes. In the present study, Crest 3D White multi-care mouthwashes used for 30 days according to the manufacturer's recommendations showed significantly higher values than the control group. The efficacy of WMs may be reduced since they are in contact with the teeth for a shorter period compared with the bleaching gel used at home. The results of this study showed that the amount of time the stained teeth were immersed in the mouthwash was a significant factor in tooth whitening.

Numerous studies have shown that although bleaching is effective in whitening certain types of discolored teeth, there has been no consensus on the effect of peroxide bleaches on resin composite restorative materials. Such wide variations in the data suggest that some tooth colored restorative materials may be more susceptible to alteration and some bleaching agents are more likely to cause those differences. The discrepancies between these studies may be explained by the different experimental methodologies, bleaching agents applied, and restorative materials used.[40,41] In the present study, bleaching products were applied with clinically relevant bleaching regimes in accordance with the manufacturer's instructions.

In vitro studies are limited in their attempt to simulate the clinical conditions. It was shown that peroxide concentration in bleaching products is depleted during use, depending on the *in vivo* situation.[40] In this study, as with most other studies, during the bleaching treatments the bleaching agents were neither diluted nor buffered with any water-based content, such as saliva or distilled water.[41,42] In this study, specimens were stored in distilled water. Therefore, one of the limitations of this *in vitro* study was the lack of saliva. In the clinical application of bleaching products, even with tray-based systems, the concentration of active bleaching ingredients has been showed to be reduced due to the effect of saliva.[43] In the present study, the HB agent was left in contact with the restorative materials for 8 h/day for 14 days without the dilution effect of saliva. However, in the oral cavity, it may require a longer period to reach the desired color changes. The use of one type of composite material of a single shade is another limitation for this study. The composition of composite resin and shade may affect the discoloration and whitening processes.

Conclusion

Within the limitation of this *in vitro* study, the highest recovery effect was determined in office bleaching system among all bleaching systems. However, home and laser bleaching systems were determined as effective as office bleaching system.

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Conflicts of interest

There are no conflicts of interest.

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