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The Color Effect of Bleaching Agent on Different Composite Restoration Materials after Aging

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Abstract:

Background: In this study, composite samples of four different types were exposed to carbamide peroxide 16% and hydrogen peroxide 40%, and the results were compared with a control group. The aim of this study was to investigate color changes in a variety of composite materials after bleaching treatments and to compare them with one another.

Materials and Methods: A total of 36 composite discs from each composite (Z100, Z250, Z350, P90) were prepared with dimensions of 3 mm × 8 mm. The aging process and staining of samples were done for 4 weeks, then specimens were placed on 5000 cycle in thermocycling device. The samples were numbered, and primary color of each specimen was recorded. Samples of each composite material were divided into two subgroups, 12 specimens each and each subgroup were exposed to different bleaching treatments: (1) Untreated control group and (2) carbamide peroxide 16% (home bleaching) and hydrogen peroxide 40%. After 14 days of treatment, secondary colors and color changes were recorded accordingly. The data were analyzed by analysis of variance and Tukey, and a $P = 0.05$ was calculated.

Results: The mean ΔE reported after treatment of home bleaching in composite Z100 (17.4), Z250 (21.1), Z350 (17.0), P90 (16.9) and after office bleaching treatment in composite Z100 (16.0), Z250 (21.1), Z350 (16.6), P90 (17.5) with difference from the untreated samples of Z100 (2.5), Z250 (2.8), Z350 (2.3), P90 (2.4). All composites were significantly brighter after bleaching treatments than the control group (ΔE >3.3). In our study, there was no significant difference between the effectiveness of different bleaching methods.

Conclusions: Hydrogen peroxide and carbamide peroxide bleaching agents are effective in whitening of the discolored composite. These two treatments are not significantly different in terms of their effects. Among different composites, Z250 showed the greatest color change among all others.

Key Words: Aging, bleaching, carbamide peroxide, composite, hydrogen peroxide

Introduction

Paying attention to cosmetic features of teeth has increased dramatically. According to a paper published in 2011, 21% and 28% of people in America are unhappy with the color of their teeth and concerned about the appearance of their smile.[1] Various ways to improve the beauty of smile are provided one of the most common of which is to use bleaching agents for color correction and teeth brightness.[2] Due to advantages such as the availability of materials, low cost, high safety, and low post-treatment side effects, bleaching is very welcomed and is widely used in cosmetic dental treatment.[3] There are two main categories of in-office and at-home bleaching treatments. In at-home method, the materials are prescribed by a dentist and used by patient at home inside a tray mainly containing hydrogen peroxide (up to 10%) and carbamide peroxide (up to 16% or more concentration).[4] While in in-office bleaching treatment, materials containing high concentrations of hydrogen peroxide (30-35%) or carbamide peroxide (35%) are used only for professional use in an office environment.[4] The basis of all bleaching methods is similar and includes the use of peroxide compounds or their derivatives such as carbamide peroxide. These oxidizing substances produce free radicals during decomposition.[5] Teeth stain removal is often done by truncating color molecules by oxidation together with breaking conjugated bonds by OOH and H radicals so that molecules with lower molecular weight reflect less light.[6] Many people have restored teeth in the mouth. It is reported that about 40% of people have at least one restored tooth in their mouth.[7] Moreover, composites which are tooth-colored materials have been welcomed by the public and are widely used in dental restoration.[5] Therefore, it is necessary to evaluate the treatment effect of bleaching on composite properties to determine the best treatment for the selected patients. Oral environment is one of the harshest environments for an industrial material. The presence of bacteria and their products, excessive chewing forces, liquid and warm environment, and ever-changing pH of mouth are the causes of such complexity.[8] Composite restorations in the mouth change during their clinical life.[9] After polymerization of the composite in the oral cavity, water molecules, and some ions penetrate into the polymeric matrix and the monomers that have not reacted, the ions released from fillers or activator solution exit from composites.[9] Withdrawing these materials, results in shrinkage and weight loss while water absorption increases the material weight. All these processes can make changes in the material properties such as changing the hardness of the material.[9] Therefore, the composites with clinical performance may further experience different variations in the face of bleaching materials. This study examined color changes. Human color perception results from light. Differences in color parameters including value (L), Hue, and Chroma (a, b) are diagnosed by eye. To determine the color of materials, these three mentioned parameters are specified as number in the setting of color detection devices.[10] Applying a spectrophotometer, as the most reliable test to determine the color, is accepted in dentistry. Red-green intensity is represented as "a," intensity of blue-yellow is represented as "b," and value of sample is represented as "L."[8]

Taking advantage of a spectrophotometer in office due to the size and the type of the prepared sample is not possible, and the smaller handheld devices such as Easy Shade (Vita/Germany) devices are used. This device also uses the spectrophotometric method. It has a 5 mm-diameter probe that is placed on the tooth surface and specifies the variables L-a-b.[11] During bleaching treatment, as teeth are exposed to gel, dental restorations will also be faced with this material.[9] It is reported that 100% of observers have detected $\Delta E = 3.3$[12] and accordingly, the studies that have investigated composites color improvement are classified into two categories:

The first category includes the studies that have proposed office bleaching as a treatment for discolored composites.[9,12-17] Moreover, the second category is associated with studies that do not consider these changes and have proposed methods such as exchanging or polishing the restorations.[16-19] This study aimed to investigate the effect of bleaching on the color of 4 aged composites and zero assumptions including:

1. Bleaching with hydrogen peroxide (40%) and carbamide peroxide (16%) in aged composites do not lead to any change in color
2. Changing the color of different types of aged composites is not different after bleaching.

Materials and Methods

Specimen fabrication sample

Four composites examined in this study had been manufactured by 3M company (3M ESPEUSA) and are as follows: Z250 (microhybrid), Filtek Z350 (nanofilled), Filtek P90 (cavities), and Filtek Z100 (hybrid). The characteristics of this composite are shown in Table 1. From each composite sample, 36 discs of 8 mm *d*iameter and 3 mm thick were prepared. All composites shade was chosen as A3. To prepare, disks were placed on a Mylar Tape (Maquira Dental Product - Brazil) and the plastic mold with dimensions of 3 mm × 8 mm was put on it. The composite was placed inside the mold, and its surface was covered with a Mylar tape.[2] Before curing, a glass slab was placed on the surface of the composite to remove its additions and reduce porosities in it and then the initial curing was done. Then, the slab was removed and sample curing was carried out for 40 s of each level with light cured light-emitting diode (Demi/Kerr/USA). Meanwhile, the intensity of light curing unit was measured with radiometer Demetron (Kerr/Taiwan) for several times with the power of 800 MW/cm^2. Samples were filed using silicon carbide polishing discs (Tor - Russia) and the low-speed handpiece with medium, fine and superfine disks in one direction.[2] Then, they were washed with water for 2 min to clean the surface debris and were held in distilled water at 25°C at room temperature for 24 h to complete the polymerization process.[2]

Table 1: The composite materials used in this study.

Materials	Composition	Manufacturer
Filtek Z250 Microhybrid	Matrix: Bis-GMA, UDMA, and Bis-EMA	3M ESPE
	Filler: Zirconia/silica (0.01-3.5 lm)	
	Filler by volume: 60%	
Filtek Z350 Nanofilled	Matrix: Bis-GMA, UDMA, TEGDMA, and Bis-EMA	3M ESPE
	Filler: Combination of aggregated zirconia/silica cluster filler (0.6-1.4 μm) and non-aggregated 20-nm silica filler	
	Filler volume: 63%	
Filtek P90 Sailoran	Matrix: New ring-opening silorane	3M ESPE
	Filler: Epoxy functional silane-treated SiO_2 and ytterbium fluoride (0.1-2 μm)	
	Filler volume: 55%	
Filtek Z100 Hybrid	Matrix: Bis-GMA and TEGDMA	3M ESPE
	Filler: Single filler 100% zirconia/silica (0.01-3.5 lm)	
	Filler volume: 66%	

Bis-GMA: Bisphenol A glycidyl methacrylate, UDMA: Urethane dimethacrylate, TEDGMA: Triethyleneglycoldimethacrylate, Bis-EMA: Ethoxylated bisphenol A glycol dimethacrylate

Samples aging

The samples were placed at room temperature every day for 3 h in staining solution containing tea (Ahmad/England) and coffee (Nestle/Brazil), and the solution was replaced on a daily basis.[9] After this time, the samples to 5000 cycles were held at a temperature of 5-55°C for 30 s per temperature[20] in the thermo-cycling device (Desertion - Iran) to simulate the thermal aging process.[21] Examples of each group were numbered, and the color of each composite sample group was recorded after 24 h storage in distilled water by Easy Shade (Vita/Germany).[9] Then, the specimens of each composite group were divided into three subgroups with 12 samples with a convenient method.[2]

- Group A (control group): The samples of this group were stored in artificial saliva for 14 days, and bleaching treatment was not carried out for them[2]

- Group B (office bleaching): The samples were subject to bleaching treatment in three 30-min periods with hydrogen peroxide 40% gel (White Smile Power Whitening YF, White Smile/Germany). The time interval between the two treatments was considered a week[2]
- Group C (home bleaching): The samples were subject to carbamide peroxide 16% gel (White Smile Power Whitening YF, White Smile/Germany), for 4 h a day for 14 days.[2]

In this period, test samples were held at room temperature and were washed with "water spray" to remove bleaching agents from the surface. The samples were held at artificial saliva at treatment intervals.[22]

Color evaluation

About 24 h before the test, all samples were stored in distilled water to remove substances that affect the color of samples. The samples were then dried and their color was evaluated and recorded with Easy Shade (Vita/Germany),[16] and the color change was calculated according to the formula $\Delta E = [(\Delta a)^2 + (\Delta b)^2 + (\Delta L)^2]^{½}$ to be examined statistically.[9]

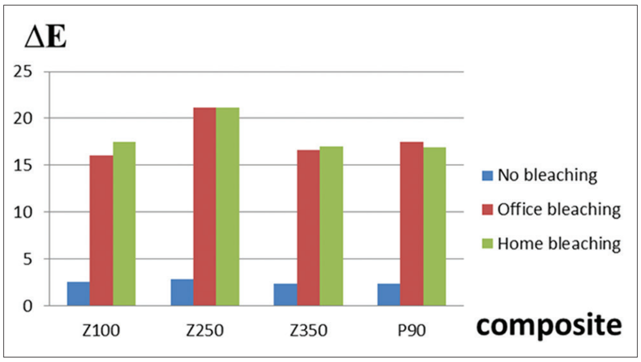
Data analysis method

After collecting information, they were coded and entered into the computer. Statistical Package for the Social Sciences (SPSS) 18 software and two-way analysis of variance (ANOVA), and *post-hoc* Tukey test were used to analyze the data. In addition, a significance level of 0.05 was considered.

Findings

The results related to color change (ΔE) at various composites are represented in Table 2 and illustrated in Graph 1. Data were analyzed with ANOVA statistical test using SPSS software. ANOVA showed that the behavior of different types of composites was different if exposed to home bleaching. Therefore, the samples were compared with the Tukey test. The results of this analysis have been identified in Table 3.

A composite variable was investigated, and the results of color change for each composite were obtained. The obtained data were analyzed by Tukey honest significant difference (HSD) test to investigate the significant difference of the groups. The results of this analysis are shown in Table 3.



Graph 1: Mean color changes in the groups studied.

It was noticed that color changes in the composite Z250 are significantly more than other groups. However, the color changes in other composite groups were not significantly different. Graph 2 displays color changes of each composite regardless of the type of bleaching treatment.

In the following, bleaching treatment variable was studied, and the average ΔE for each group of bleaching treatments was investigated regardless of the type of composite. Tukey HSD test was used to evaluate the results of ΔE. The results of this test are shown in Table 4.

Table 2: Mean color changes in the groups studied.

Composite	Bleaching method	MeanΔE	Standard deviation
Z100	No bleaching	2.58	0.76
	Office bleaching	16.04	2.68
	Home bleaching	17.46	1.46
Z250	No bleaching	2.83	0.99
	Office bleaching	21.13	3.43
	Home bleaching	21.12	2.23
Z350	No bleaching	2.34	1.49
	Office bleaching	16.61	2.26
	Home bleaching	17.00	2.55
P90	No bleaching	2.41	1.95
	Office bleaching	17.53	2.36
	Home bleaching	16.94	2.94

Table 3: Tukey HSD analysis of ΔE on composite types (α=0.05).

Composite 1	Mean EΔ	Composite 2	Mean	*P* value
Z100	12.032	Z250	−3.00	0.000
		Z350	0.04	1.000
		P90	−0.26	0.958
Z250	15.034	Z100	3.00	0.000
		Z350	3.04	0.000
		P90	2.73	0.000
Z350	0.98711	Z100	−0.04	1.000
		Z250	−3.04	0.000
		P90	−0.3	0.935
P90	12.296	Z100	0.26	0.958
		Z250	−2.73	0.000
		Z350	0.30	0.935

Table 4: Tukey HSD analysis of color changes in a variety of bleaching (α=0.05).

Bleaching method 1	Mean EΔ	Bleaching method 2	Mean	*P* value
No bleaching	2.543	Office bleaching	−15.28	0.000
		Home bleaching	−15.59	0.000
Office bleaching	17.832	No bleach	15.28	0.000
		Home bleaching	−0.30	0.782
Home bleaching	18.137	No bleach	15.59	0.000
		Office bleaching	0.30	0.782

The results showed that the post-treatment color changes of office bleaching and home bleaching treatments are significantly more than the control group without treatment, whereas no significant difference was found between the two treatments. Graph 3 displayed these changes.

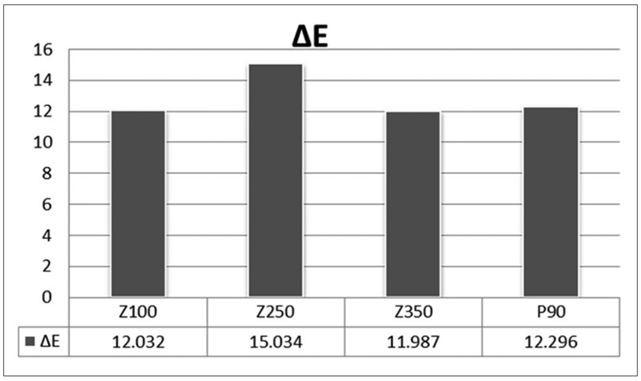
Comparing bleaching treatments with the control group was evaluated in each composite separately, and its results can be observed in Table 5.

The results showed that bleaching aged composites with carbamide peroxide 16% and hydrogen peroxide 40% impact on their color because the composites under treatment were more subject to color change than the samples of the control group which was significant ($P < 0.05$), and finally, home and office treatments were evaluated individually in each composite and analyzed with the significance level of 0.05 (Table 6).

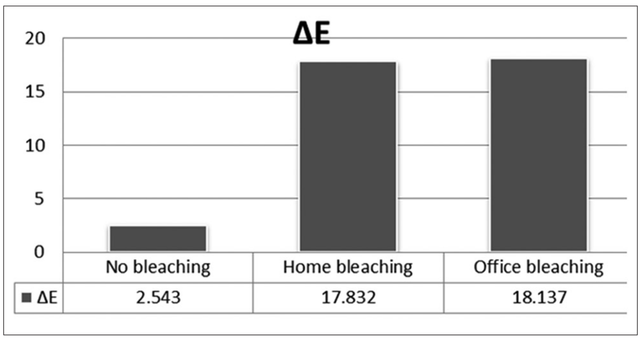
The results showed that the difference between the composite groups was not significant in none of the composite groups ($P > 0.05$).

Discussion

Composites color stability is an important factor in long-term durability of cosmetic restoration. The created discoloration in restoration can be due to intramolecular composite destruction or external stain that penetrates into the composite in sorption process.[23] In this study, the composite ability to return to a lighter color after bleaching was investigated. The results of this study also reject the second null hypothesis



Graph 2: Color changes based on composite type.



Graph 3: The color changes according to bleaching treatment

stating that office bleaching and home bleaching will not change the color of aged stained composites because both types of bleaching treatments significantly improve the color of stained composites in all groups. Although HP40% and CP16% had no significant difference in ΔE, the ΔE in these groups was significantly higher than that of the control group. Bleaching effect was significant in all composites in terms of the composite. Changing the color of Z250 was significantly higher than in other groups, but no significant difference was observed among other composites. In all composite groups in the control group, a color change <3.3 was observed in the control group after 14 days of storage in artificial saliva. This change may be due to detachment of the surface chromogenic molecules that are weakly bonded to the surface. This bond has been broken during storage, and these molecules are released into the environment which makes the composite color lighter although this difference is not significant. The effect of carbamide peroxide (16%) has been investigated by Al-Nahedh and Awliya,[13] Villalta *et al.*,[9] Kamangar *et al.*,[14] and Farah and Elwi.[15] They have confirmed the results of this study that the stained composites create ΔE more than 3.3. Cathelan has mentioned that color change with ΔE = 3.3 can be recognized by 100% of observers and is clinically acceptable.[24] Mendes *et al.*,[18] Al Qahtani and Binsufayyan,[19] de Andrade *et al.*,[16] and Canay and Cehreli's[17] research results are incompatible with the results of our research, and they have mentioned that a home bleaching treatment is ineffective in composites color change. In Mendes *et al.*'s study, Z350 composite was investigated, and it was reported that the color changes were not clinically acceptable after bleaching with hydrogen peroxide (10%). The reason for this difference can be mentioned as clinically significant level considered as 3.7 in Mendes *et al.*'s study. The reason for this choice was a study conducted by Johnson, in 1989, and according to United States Public Health Service criteria, the significant ΔE is taken as 3.7.[25] On the other hand, the method of applying bleaching gel was also different. About the home bleaching treatment, it should be mentioned that

Table 5: Comparison of bleaching treatments on aged composites (α=0.05).

Composites	Mean of home bleaching and control group	*P* value	Mean of office bleaching and control group	*P* value
Z100	14.87	0.000	13.45	0.000
Z250	18.29	0.000	18.3	0.000
Z350	14.66	0.000	14.27	0.000
P90	14.53	0.000	15.12	0.000

Table 6: Comparison of home based and office based bleaching on aged composites (α=0.05).

Composite	Mean of home bleaching and office bleaching	*P* value
Z100	1.42	0.194
Z250	0.009	1.000
Z350	0.397	1.000
P90	0.589	1.000

bleaching period was coordinated and equal to 14 days, but the duration of exposure to bleaching agent in Mendes *et al.*'s study was only 30 min/day while our study, according to the manufacturer's instructions, had considered this time as at least 4 h.[3] In de Andrade *et al.*'s study, although the Easy Shade device had been used as in our study, the number of color change shades was investigated for significance. In Canay and Al Qathani's studies, the stage of aging and staining had not been done, and only bleaching effect had been investigated on different composites. The bleaching gel brand can also be effective and different gels had been used in the studies some of which included hydrogen peroxide with lower concentration for home bleach applications[26] while we have used White smile combinations and the composition of home bleaching gel was carbamide peroxide 16%. The concentration of peroxide was also different in studies ranging from 10% to 22%. In investigating the effect of hydrogen peroxide 4015, the researches carried out by de Andrade *et al.*,[16] Garoushi *et al.*,[12] Villalta *et al.*,[9] Kamangar *et al.*,[14] Al-Nahedh and Awliya,[13] and Canay and Cehreli[17] are in line with that of our study indicating that composites after staining after exposure to hydrogen peroxide bleaching agent with high concentrations create acceptable clinical changes with ΔE more than 3.3. Mendes *et al.*'s research results[18] are different with our results. This study has shown that hydrogen peroxide bleaching is ineffective in changing the color of composites. Mendes *et al.* reported in his study about Z350 composite that color changes after bleaching with hydrogen peroxide 35% was not clinically acceptable. This difference may be due to the clinical significance level as mentioned previously. In Mendes *et al.*' study, this criterion was intended as 3.7.[17] On the other hand, the method of applying bleaching gel was also different so that the office bleaching gel was used only two periods and each period was used in only 15 min while bleaching gel was used in our study for three periods each time for 3 cycles of 15 min.[4] The concentration of peroxide bleaching gel brand and accelerate procedures varied reactions in studies. In comparing the two methods of at-home and in-office treatments, the results showed that there was no significant difference between the two methods of bleaching treatments in any of composite groups, and both treatments will lead to the improved color of composites with stain. The results of this study are consistent with that of Mendes *et al.*'s study,[18] in which both types of bleaching treatments have the same effects on changing the color of composites. This difference could be due to the exposure to oxidizing substances of teeth which was acted according to factory instruction in this study. However, in Canay's study, composite materials were placed in the bleaching solution equally. Because carbamide peroxide is transformed to urea, ammonia, carbon dioxide, and hydrogen peroxide (almost 30%), the cumulative concentration of hydrogen peroxide is higher in in-office bleaching solution. In contrast, Al-Nahedh and Awliya[13] reported that home bleaching teeth were more effective in improving the teeth color, which is different with the results of this study. Al-Nahedh and Awliya has mentioned the reason for this change as the longer time of exposure to bleaching gel in the in-home treatment. However, this study attempted to equalize the exposure time with the materials with different concentrations. In addition, in Al-Nahedh and Awliya's study, the bleaching method with different concentrations of oxidative and composite materials was used. Although bleaching effect was significant in all composites, Z250 color change was more than other groups, and this difference was significant. However, other materials were not significantly different. This difference may be due to higher absorbed stain or more effective bleaching on the composite Z250. Although various studies have reported that attracting the stain in nanohybrid composites like Z350 is more than other composites. However, microhybrid composites also absorb a large stain.[27,28] There are different forms for Z350 composite with different filler percentage and translucency and the dentine type with high filler percentage Z350 composite has been used in this study. It may be noted that, more stain absorption on Z250, is resulting from less percentage of filler in this material compared to the dentin type (Table 1). The only composite of this study, which has less filler than Z250, is Silorane P90 composite which has a different type of matrix.[4] The sorption of a composite is depending on the volume fraction of its matrix and the higher amount of resin leads to increase of water absorption and staining.[29] On the other hand, the area of bleaching effect contains a greater proportion of matrix that will accelerate the influence of free radicals and intensify the whitening reaction. The binding of chromogenic molecules to composite molecules was also impressive such that the weaker connections will be removed with greater ease. The strength of these binds will be determined by the composite monomers. Although Bis-glycidyl methacrylate is common in all types of methacrylate composites, the combination of other monomers is different in various composites. Asmussion and Khokhar stated that urethane dimethacrylate (UDMA) monomer was more resistant to stain absorption than other composite monomers. Besides, Pearson and Longman announced that this monomer reduces the amount of water absorption capacity of composite.[26,27] Khalachandra and Turner reported in a study that the presence of 0-1% of triethyleneglycol-dimethacrylate (TEG DMA) monomer, increases the composite water absorption by as much as 3-6%. According to the compounds mentioned in the factory catalog, Z250 composite contains UDMA but lacks TEG DMA. The possibility is that chromogenic molecules binding may be due to the less influence of surface water and is more easily removed by bleaching agents.[28] Al Nahda stated in their study that the stains in Z250 composite establish weaker binds to the surface than other composites[17] and have a less penetration depth. Accordingly, more amount of chromogen is affected by the bleaching agent, and more color change is observed. The staining materials used in this study are frequently used in everyday life and have the potential for staining in tooth-colored restorative materials.[9,13,18] Considering that the objective of this study is to investigate the ability to remove stain in composites, these materials were applied to the samples at the same time that this technique has already been introduced by Iazzetti *et al*.[30] To simulate the conditions with the oral cavity, staining was discontinuously carried out on a daily basis for 4 weeks. After each daily staining, diluting the environment and cleansing were carried out by artificial saliva to perform a more exact simulation.[18] To remove staining, there are other methods such as micro- and macro-abrasion that its effectiveness is confirmed.[13] The limitations of this study include the lack of investigating and comparing other methods of improving the color of composites after staining. On the other hand, although the results of this study reported more bright dental restorations, it is possible that changing the color of the composite and the restored teeth are not the same and cause cosmetic problems. We, therefore, need to conduct clinical studies to investigate the ultimate beauty of restoration. Moreover, the absence of mechanical forces that simulate occlusion as well as lack of restoration of exposure to ultraviolet light that causes intrinsic color changes limits the generalizability of the aging results. In addition, bleaching agents can be found in different compositions, pH, and concentrations that may have an impact on their reactions. An extensive review of these substances in exposure to dental composite restorations will provide a wider range of vision.

Conclusion

Bleaching of aged composites lead to more clarification of composite and removing stains compared to control group and the most color change is associated with Z250 composite. However, there was no significant difference among color change of other groups.

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