

In-Office Bleaching Induced Color Change and Microhardness of Tooth-Colored Restorative Materials

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Abstract

Objective: Tooth discoloration is becoming a major concern as greater emphasis is being placed on esthetics. With the growing awareness of esthetics the use of tooth bleaching agents are now amplified. There may be a number of tooth colored restorations on the teeth to be bleached. The aim of this study is to identify the effects of these bleaching agents on the color and mechanical properties of the existing composite restorations.

Material and Methods: The effect of two different concentrations of in office bleaching agents (35% and 38% Hydrogen peroxide) on the color and microhardness of a composite and a compomer were tested. Total 120 discs were fabricated 10mm diameter and 2 mm thickness. Sixty specimens were prepared from each restorative material group. The specimens in each group were randomly divided into two subgroups with thirty specimens each. Each subgroup was treated with one of the bleaching agents and was tested for color by using reflectance spectrophotometer with CIELAB and for microhardness by Vickers Microhardness tester.

Results: The results reveal that there is a significant statistical difference in the color change and microhardness values between the baseline and after bleaching observations among the groups.

Conclusions: The effects of in-office tooth whiteners on color change and microhardness were material dependent.

Keywords: *In-Office Bleaching; Color Change; Microhardness; Restorative Materials*

Introduction

Tooth discoloration is becoming a major concern as greater emphasis is being placed on esthetics [1]. With the growing awareness of esthetics the use of bleaching agents are now amplified [1]. Bleaching agents were first used to whiten teeth in the late 1870's [2]. It is a relatively non-invasive technique employed to lighten teeth which may be stained extrinsically or intrinsically. Bleaching techniques may be classified as those involving lightening of vital or non-vital teeth or whether the procedure is performed in-office or at-home [3,4].

There may be a number of tooth colored restorations on the teeth to be bleached. Any tooth colored restorative material must simulate the natural tooth in color, translucency and texture, and must be color stable for long periods of time [5]. Discoloration of restorations can be caused by extrinsic or intrinsic causes. Extrinsic causes include plaque accumulation and surface stains, surface or subsurface color alteration, reaction and slight penetration of staining agents within the superficial layer of resin composites implying to its superficial degradation [6]. Intrinsic stains can be caused by physicochemical reactions in the deeper portions of the restorations [7].

Bleaching agents utilize some form of peroxide commonly hydrogen peroxide and carbamide peroxide in either gel or liquid form to be applied on the teeth for several minutes to hours, depending on the formulation used [8-11]. The effect of bleaching is directly related to the time of exposure and the concentration of the active bleaching agent used [4]. The longer the exposure time and the greater the concentration of the active ingredient, higher will be the oxidation process and color change. High concentrations of hydrogen peroxide like 30% to 35% have been reported to cause surface roughening of teeth and etching like patterns [12].

Bleaching agents are widely used these days and they may affect the color of existing composite restorations. The effect of bleaching agents on the color of the restorative materials is material dependent [13]. Other related side effects are porosity, reduction in hardness and increase in roughness on the surface of the existing composite restorations [4,14].

Studies investigating the effect of bleaching treatments on the microhardness of tooth colored restoration have shown controversial results. Either decrease or increase in the microhardness of restorations induced by bleaching treatments has been reported. However other studies demonstrated no significant alteration in the surface microhardness of resin based composites [15-17].

There are a number of studies on the effects of home bleaching agents on various types of composites [16] less is known about the effects of in-office bleaching systems on fluoridated glass filler polyacid modified composite resins or compomer. This study therefore determines and compares the effect of in-office bleaching agents on the color and microhardness of hybrid composite and compomer.

Methods and Materials

Composites

To assess the effect of different concentrations of in office bleaching agents on the color changes and microhardness of tooth colored restorative materials, two types of resin based filling materials were selected to investigate if composition affects the results. These tooth colored restorative materials include a hybrid composite (Spectrum TPH, Dentsply-DeTrey, Konstanz, Germany) and a polyacid modified composite (Dyract eXtra, Dentsply-DeTrey, GmbH, Konstanz, Germany), both of A2 shade (Table 1).

Material	Manufacturer	Shade	Type	Organic Matrix	Filler Size	Filler Volume
Spectrum TPH	Densply DeTrey Germany	A 2	Hybrid Composite	Bis-GMA-adduct Bis-EMA TEGDMA	Barium alumino boro silicate glass-< 1.5 μm, Silicon dioxide-0.04 μm	57%
Dyract eXtra	Densply DeTrey Germany	A 2	Compomer	Bisphenol-A-dimethacrylate Urethane resin TEGDMA TMPTMA	Strontium fluoride glass-0.8 μm	50%

Table 1: Restorative materials used.

Bleaching agents

Two bleaching agents were used namely Pola Office (35% hydrogen peroxide) marketed by (SDI Dental limited, Bayswater, Victoria, Australia) and White Smile (38% hydrogen peroxide) marketed by (GmbH, Weinheimer Straße, Germany). Pola office claimed that it will not lighten any restorative material. Both the bleaching agents were recommended for in-office use by dentists for vital and non-vital teeth.

Preparation of the specimen

For color and microhardness measurement sixty disc shaped specimens from each of the restorative resin were made (120 in total). Each disc has a 10 mm diameter and 2 mm thickness prepared in polytetrafluoroethylene mold. The specimens were prepared by placing the mold on a transparent polyester film strip and a glass microscope slide. The material was condensed into the mould and was over-filled. Another polyester film strip was placed in contact with the material by taking care that no void is left and then covered with another glass microscope slide. Slight pressure was applied to extrude the excess material. The material was then polymerized by using a blue light emitting diode (LED) light curing unit (Mectron, medical technology, starlight pro, Italy) from both the sides. This source emitted light at 440 - 480nm and had an intensity of > 1.000 mW/cm² calibrated by a built in radiometer before the curing process. The materials were polymerized according to the manufacturer instructions (Spectrum TPH-20 sec and Dyract eXtra-10sec). The tip of the light source

was kept in contact with the glass slide during polymerization and a distance of 1 mm was maintained between the light source and the specimen by the use of this glass slide. After light curing all the specimens were stored in dark containers containing distilled water for 24 hours at room temperature to ensure complete polymerization. The top surface of the specimens was then polished by using a sequence of three (medium, fine and superfine) Sof-Lex (3M ESPE, USA) disks and a slow speed hand piece.

Bleaching procedure

Sixty specimens were prepared from each restorative material group. The specimens in each group were randomly divided into two subgroups with thirty specimens each. Each subgroup was treated with one of the bleaching agents. The specimens were taken out of distilled water and were washed with running water for one minute before the bleaching procedure.

The first subgroup from each group was treated with Pola office (35% hydrogen peroxide). The bleaching agent was applied on the polished surface of the discs with the help of cotton applicator. The gel was left for eight minutes and was exposed to LED curing light (Mectron, medical technology, starlight pro, Italy) for 20 seconds during this stage. After 8mins the bleaching gel was removed with the help of suction tip. The whole procedure was repeated three times on the same top surface of discs and the entire procedure is completed in a time period of less than one hour.

The second subgroup from each group was treated with White Smile (38% hydrogen peroxide). The bleaching gel was applied directly on the surface of the disc with the help of dispensing syringe and was left for 12 minutes. During this stage the gel was activated by curing led lamp (Mectron, medical technology, starlight pro, Italy) for 10 seconds. After 12 minutes the bleaching gel was removed with the help of suction tip. The whole procedure was repeated three times on the same top surface of discs and the entire procedure is completed in a time period of around one hour.

After the last application the specimens from both the subgroups were rinsed under running water for one minute to remove the bleaching agent, blotted dry and again stored in distilled water at room temperature until color testing.

Before treating the specimens with bleaching agent baseline color measurement was taken for all the specimens using reflectance spectrophotometer (Data Color by Technicolor solution, USA) with CIELAB (Comission Internationale de Eclairage L*, a*, b*) system. Prior to baseline color measurement the specimens were rinsed under tap water for one minute and blotted dry. For baseline color measurement each specimen were positioned so that their surfaces were in contact with the aperture head of the calorimeter. Before each measurement the spectrophotometer was calibrated according to the manufacturer recommendations with the supplied white calibration standard. Each specimen was measured three times and the average baseline values of L*, a* and b* were calculated automatically by the spectrophotometer. L* represents the degree of grey and corresponds to the value of brightness, means that high L* values are obtained from bright or white specimens. The value a* represents the red-green axis and the value b* represents blue-yellow axis. This measurement was taken as a baseline measurement for the corresponding material to evaluate the color change after treating with the bleaching agents.

After bleaching the same procedure was repeated for all the specimens of each material to determine the chromatical values. The mean values of ΔL^* , Δa^* and Δb^* after three measurements were automatically calculated and recorded by the spectrophotometer. The magnitude of total color difference represented by ΔE^* was calculated from mean ΔL^* , Δa^* and Δb^* values for each specimen by using the following equation:

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

Where ΔL^* , Δa^* and Δb^* are changes in L*, a* and b* values after bleaching respectively. ΔE^* values > 1 were considered to be visible to the naked eye, and $\Delta E^* \geq 3.3$ were considered as clinically unacceptable.

Microhardness measurement

After polishing the specimens of both the materials and their baseline color measurement, these specimens are subjected to baseline microhardness measurement by a digital microvickers hardness tester (Wolpert Group, USA). The specimens were blotted dry and placed beneath the indenter of microvickers tester and subjected to a load of 50 grams for a dwell time of 30 seconds. The dimensions of each indentation were measured using the graduated eyepiece of the microscope in the testing machine. On the top surface of each specimen, three indentations were made at random and a mean value was calculated as the Vickers Microhardness Number (VMN) for that specimen.

Microhardness measurements were taken two times, once 24 hours after polymerization as baseline and once after bleaching on the same specimens.

Statistical analysis

The data for microhardness was analyzed using Repeated Measure Design Analysis of Variance (ANOVA) with restorative materials and bleaching products as main effects. The data for color measurement was analysed using One-Way ANOVA to analyze significance of results within groups. Tukey’s post hoc tests were performed on both the analysis for pair-wise comparison of values amongst different groups. Mean and standard deviation was calculated using SPSS statistical software program (version 16.0). The study parameters were considered significant at 95% confidence interval.

Results

Effect of bleaching on color

Table 2 shows mean ΔE* values and standard deviation of all the groups. A complete evaluation of color change based on ΔE* values was carried out by one-way ANOVA. The results reveal that there is a significant statistical difference in the color change among the groups (p = < 0.0001).

Materials n = 60	35% Bleaching Agent (Pola Office) n = 30	38% Bleaching Agent (White Smile) n = 30	P Value
Hybrid Composite (Spectrum TPH)	0.80 (± 0.32)	0.87 (± 0.38)	0.860
Compomer (Dyract Extra)	1.31 (± 0.43)	1.28 (± 0.40)	0.990
P Value	< 0.000	< 0.001	< 0.0001
n = number			

Table 2: Mean and Standard Deviation (± sd) ΔE* values for all experimental groups.

To find out the effect of different bleaching agents on the same restorative material Tukey’s test was applied. It revealed that the color of each restorative material did not change statistically when bleached with 35% (Pola Office) and 38% hydrogen peroxide (White Smile) (p > 0.05), when comparing the mean ΔE* values of the specimens.

However when compared among the resin restorative materials, bleaching with 35% and 38% hydrogen peroxide led to statistically significant differences (p < 0.05). Hybrid composite treated with pola office showed statistically significant color change when compared with compomer specimens bleached with Pola Office and white smile (p < 0.05). Similarly there is a statistically significant difference in the color change of hybrid composite treated with white smile compared with compomer specimens treated with white smile and pola office (P < 0.05). The compomer specimens showed more color change then hybrid composite bleached with pola office and white smile when comparing the mean ΔE* values of the specimens.

Effect of bleaching on microhardness

Table 3 shows mean and standard deviation for VHN of the materials before and after treatment. The result of Repeated Measure Design ANOVA reveals that there is significant interaction between materials and treatments. The results show that there is a statistically significant difference between the baseline and after bleaching observations (p < 0.0000). Tukey’s test reveals that the effect of in-office bleaching agents on hardness is material dependent. No significant difference in hardness was observed between treatment groups of hybrid composite (p > 0.05). For compomer specimens treated with Pola Office were significantly harder than those treated with White Smile when comparing the mean VH values of the specimens.

Bleaching with 35% and 38% hydrogen peroxide led to statistically significant differences in each pair observation among hybrid composite and compomer (p < 0.05). It was also found that hybrid composite is significantly harder than polyacid modified composite for all treatment groups.

Material n = 60	35% Bleaching Agent (Pola Office) n = 30		38% Bleaching Agent (White Smile) n = 30		P value
	Baseline	After bleaching	Baseline	After bleaching	
Hybrid Composite (Spectrum TPH)	47.83 (± 0.99)	48.42 (± 2.01)	47.74 (± 1.05)	47.99 (± 1.60)	0.838
Compomer (Dyract Extra)	38.70 (± 1.41)	41.26 (± 2.66)	38.38 (± 1.40)	39.60 (± 1.80)	0.011
P value	0.000		0.000		
n= number					

Table 3: Mean and Standard Deviation (± sd) HV of the materials baseline and after treatment.

Discussion

Tooth bleaching has become an extremely popular method of whitening teeth. Since restorations may be present on teeth, the effect of this procedure on the esthetic properties of restorative tooth colored filling materials needs to be identified. Changes in the chemical and morphological structure of the composite by the acidic component of the bleaching agents must be taken into consideration. This is of prime importance when trying to establish and maintain good color match between the tooth colored restoration and the adjacent tooth structure. Drastic color changes may compromise esthetics and involve replacement of the existing restoration therefore it is important to understand the effect of bleaching agents on the color of restorative materials.

Current bleaching techniques are based primarily on oxidation by hydrogen peroxide or one of its precursors. The overall whitening efficacy is determined by the peroxide concentration and duration of its application. The contemporary bleaching gels for home or in-office bleaching technique are based on 6 - 20% and 25 - 40% peroxide concentration respectively [16,18].

Whitening of tooth results from oxidation of organic matrix by free radicals [19]. In case of tooth colored filling materials the bleaching agents may affect the resin matrix, filler particles or both. Fillers are less affected as they are usually glass or ceramic particles. Instead, chemical degradation of resin matrix may occur due to high concentration and repeated application of hydrogen peroxide. A number of studies have evaluated the effect of bleaching on dental hard tissues [20,21]. Studies showing the effect of bleaching agents on dental restorative materials presents controversial findings on physical, chemical and morphological properties. Some authors have reported changes in microstructure and hardness of the composites after bleaching [16,22,23] but others have reported only slight or no effect [22,23]. Bleaching with 35% carbamide peroxide and 35% hydrogen peroxide have also shown to increase surface hardness [22]. Therefore to determine the changes in color and microhardness of resin composites two concentration of hydrogen peroxide 35% and 38% are tested.

Spectrophotometers and calorimeters have been used to measure color changes since they eliminate the subjective interpretation of visual color comparison [24]. The CIELAB system was selected for measuring the chromatical values because it determines small color differences appropriately. Various studies have reported that color differences >1 ΔE* unit were considered to be visible to naked eye by 50% of human observers, whereas ΔE* values ≥ 3.3 were considered clinically unacceptable [24,25]. In the present study none of the bleaching treatments resulted in ΔE* values equal to or greater than 3.3. However compomer (Dyract extra) treated with 35% and 38% hydrogen peroxide gave ΔE* values greater than 1. The interaction between this restorative material and the bleaching agents is of clinical significance as the color change may become perceptible to the patient. However the specimens of hybrid composite (Spectrum TPH) bleached by 35% and 38% hydrogen peroxide did not lead to noticeable color change because the amount of color change was less than 1 ΔE* unit.

The results of this study indicated that, hybrid composite showed slightly lower affection by the bleaching agent when compared to compomer. Differences in color change between different composite materials might be a result of different monomer structure, volume of resin matrix, filler content and different degrees of conversion of resin matrix. Hybrid composites contain Bis-GMA adduct and TEGDMA. Bis-GMA adduct is a very tough resin that gives excellent wear properties whereas compomer contains Bisphenol-A-dimethacrylate and TEGDMA, which may be less resistant to the bleaching action [24].

The filler content of compomer is less as compared to hybrid composite as can be seen from table 1 indicating that more resin matrix was available to be degraded by high concentration of hydrogen peroxide leading to more color change in compomer filling material [24,26]. This suggested that the volume of resin matrix and filler type had a great influence on the color parameters of resin based filling materials than the structure of organic matrix [8]. Other studies have also shown more color change in polyacid modified composites or compomer as compared to other composites [13,27]. The results of this study indicate that the color change is material dependent.

Hardness is defined as resistance of a material to indentation or penetration. For dental materials any reduction in material's strength, proportional limit or resistance to abrasion by the chemical softening resulting from bleaching has deleterious effect on the long term survival of the restoration. As hardness is related to all these properties any reduction in hardness can affect the restorative material [22].

The effectiveness of bleaching products is known but their effect on tooth colored restorative materials is a controversy [28]. Hydrogen peroxide is a powerful oxidative agent and generate free radicals capable of degrading the polymer matrix of resin-rich composite materials [8,24]. In addition to its reactivity hydrogen peroxide also demonstrates its ability for diffusion. Peroxide might induce oxidative cleavage of the polymer chains. Therefore any unreacted double bonds are the most vulnerable parts of polymers causing filler-matrix debonding, resulting in softening and reduction in microhardness of the restoration [22]. This may increase the surface roughness by causing surface cracks [3,22]. The differences in composites hardness obtained after same bleaching treatment may be attributed to the different polymers in their organic matrix and the type and particle size of filler content [24]. The effect of bleaching on the hardness and surface texture was material and time dependent [3,15].

The hardness of composite resin exposed to bleaching agents has been reported to increase [28], decrease [15] or be unchanged [15,18,22]. such wide variations suggest that some of the filling materials may be more prone to alterations and some of the bleaching agents are more likely to cause those alterations. In this study the effect of bleaching products on hardness were found to be material dependent. No significant difference in hardness was observed between treatment groups of hybrid composite. In case of compomer significant difference was observed between the treatment groups. Compomer specimens treated with pola office showed greater increase in hardness as compared to compomer specimens treated with white smile. Both the bleaching agents are highly concentrated the greater increase in hardness of compomer treated with pola office might be due to less contact time of the bleaching agent with the restorative material as compared to white smile, however the exact mechanism is still not clear and need further investigation.

In this study significant difference is observed between the baseline and after bleach values for all the materials. Therefore bleaching products should not be used arbitrarily when tooth colored resin restorations are present [22]. For all treatment groups the hybrid composite is significantly harder than the polyacid modified composite [22].

Conclusion

Within the limitations of this study following conclusions are drawn:

1. None of the bleaching agents tested made any significant clinical effects - with $\Delta E^* \geq 3.3$ - on the color of resin composites tested.
2. Compomer bleached with 35% and 38% hydrogen peroxide yielded $\Delta E^* > 1$, a noticeable color change to the naked eye.
3. The effects of in-office tooth whiteners on color change and hardness were material dependent.
4. For hybrid composite (Spectrum TPH), no significant difference in hardness was observed between the treatment groups.
5. For polyacid modified composite significant difference in hardness was observed between the treatment groups.
6. Significant difference in hardness was observed between the baseline and after bleach values for all materials.
7. For all treatment groups the hybrid composite is significantly harder than the polyacid modified composite.

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