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Effect of In-Office Bleaching Agents on Three Different Esthetic Restorative Materials: An In Vitro Study

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ABSTRACT

Objective: The purpose of this study was to evaluate the effect of two hydrogen peroxide concentrations, commonly used in In-Office bleaching, on the surface roughness and color change of different esthetic restorative materials.

Materials and Methods: Sixty disc samples (10 mm in diameter and 2 mm in thickness) of the different restorative materials used were constructed following the manufacturers' instructions. Samples were classified into three main groups (n=20) according to the type of restorative material: Group1: Microhybrid composite Filtek P90 Silorane, Group 2: IPS e-max Press and Group 3: Vitadur Alpha porcelain. Each of the three groups was divided into two subgroups (n=10) (a and b) according to the type of bleaching agent used (Opalesence Xtra Boost 35% hydrogen peroxide (HP) and Zoom 2 25% HP respectively). Samples of subgroups were further divided into two equal divisions (n=5) according to the type of test performed (Roughness testing and Color assessment). Each sample was assessed for surface roughness and color change before bleaching so that each sample served as its own control. Surface roughness was examined using Environmental scanning electronic microscope (ESEM). Color measurements were made with spectrophotometer using CIELAB color scale. One sample from each subgroup was examined to confirm their crystalline phase before and after bleaching using X-Ray Diffraction. Results were statistically analyzed.

Results: Significant differences in Ra values were observed between the unbleached and bleached samples, as well as between subgroups treated with Opalesence Xtra Boost and those treated with Zoom 2. The two bleaching agents had statistically significant effect on the color of restorative materials ($P<0.05$). Moreover, the color change was found to be significantly higher for the restorative materials treated with Opalesence Xtra Boost compared to Zoom 2, regarding their mean ΔE values.

Conclusion: Highly concentrated in-office bleaching systems adversely affected the surface roughness and color of Filtek P90 Silorane, IPS e-max Press and Vitadur Alpha porcelain.

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INTRODUCTION

Several factors may alter the appearance of smiles, including alterations in the form, texture, position, and color of the teeth. Discolored teeth can be treated with various restorative techniques, such as direct composite veneers, indirect porcelain veneers, and ceramic crowns or even with bleaching. Dental bleaching has become popular and often requested by patients wanting to improve their teeth shade (1). Bleaching techniques may be classified by whether they involve vital or non-vital teeth or whether the procedure is performed in-office or has an at-home component. Bleaching agents usually contain some forms of peroxide in gel or liquid form to be in contact with teeth for several minutes to several hours, depending on the formulation of material used (2-4). Currently, the bleaching agents are based primarily on hydrogen peroxide (HP) or its compounds such as carbamide peroxide (CP). Hydrogen peroxide is an oxidizing agent and can produce free radicals, these free radicals break up large macromolecular stains into smaller stain molecules (5).

Very often in the daily clinical practice, tooth- colored restorations exist in the teeth that are planned to be bleached (4).

The effects of such strong oxidizing agents on the physico-mechanical properties of restorative materials have, however, not been widely studied. Bleaching agents may cause structural changes on restorative materials that may compromise their physical properties and lead to premature failure (6-12).

The main reasons for the surface changes of restorations after bleaching seems to be related either to the type of the restorative material itself and to the PH, concentration of the bleaching agents, exposure time and components of the bleaching products, causing controversial results among the previous studies in this field(14-16).

Drastic color changes to existing restorations may compromise esthetics; therefore, it is important to understand the effect of bleaching agents on the color of restorative materials. The interaction between the bleaching agent and restorative material is of clinical significance because the color change may be noticed by the patient (10, 14, 15, 17).

The present study was conducted to evaluate the effect of two hydrogen peroxide concentrations, commonly used in in-office bleaching, on the surface roughness and color change of different esthetic restorative materials.

MATERIALS AND METHODS

Three different restorative materials; Filtek P90 Silorane, IPS e-max Press and Vitadur Alpha porcelain and two bleaching agents; Opalesence Xtra Boost and Zoom 2 were used in the present study (Table 1).

Table 1: Restorative materials used

Material	Composition	Manufacturer
Vitadur Alpha porcelain	SiO_2 62.0-68.0%, Al_2O_3 14.0-16.0%, CaO 1.0-4.0%, K_2O 7.0-8.0%, Na_2O 4.0-5.0%, $TiO_2 \approx 0.01\%$, $P_2O_3 \approx 0.01\%$, $Fe_2O_3 \leq 0.01\%$, MnO, MgO and ZrO_2 Traces	VITA Zanhfabrik Bad Sackingen, Germany
IPS-emax Press	SiO_2 > 57 % wt., Li_2O, K_2O, MgO, ZnO_2, Al_2O_3, P_2O_5	Ivoclar, Vivadent Germany
Filtek 90 Silorane	Matrix: 3, 4-Epoxycyclohexylethylcyclo-olymethylsiloxane, bis-3, 4-epoxycyclohexylethyl-phenylmethylsilane. Resin: Quartz, Yttrium fluoride, 0.04-1.7 um	3M ESPE, St, Pual, MN, USA
Opalesence Xtra Boost	38% hydrogen peroxide chemically activated bleaching gel.	Ultradent Products, South Jordon, Utah, USA
Zoom 2	25% hydrogen peroxide light assisted tooth whitening gel	Discus Dental, Culver City, USA

Sample Preparation

Microhybrid composite Filtek P90 Silorane, was packed into the Teflon mold, with the upper and lower surfaces covered with acetate matrix strips. The specimens were light-cured for 40 seconds with a wide-tipped prismatic light-polymerizing unit (3M Dental Products Division, St. Paul, Minn.) at 420 mW/cm2. Following light-curing, the samples were removed from the molds and placed at 37oC distilled water for 24 hours to assure complete polymerization.

For IPS e-max Press, the samples were fabricated by heat press technique. Subsequently, the samples were polished (Phoenix 4000, Buehler GmbH, Düsseldorf, Germany) under running water using 600 and 1,200-grit silicon carbide paper (3M ESPE, St. Paul, MN, USA) and were submitted to self- glazing according to the manufacturer's instructions. All of the samples were then ultrasonically cleaned in distilled water for 10 min and dried in a stream of oil-free compressed air and kept at room temperature before testing.

For Vitadur Alpha porcelain, the discs were fabricated using a split stainless steel mold for standardization. The porcelain powder was mixed with modeling liquid. The slurry was packed and condensed into the mold placed on a glass slab to ensure a smooth surface. The compacted non- sintered samples were transferred to the furnace on a thermal cotton pad and fired according to the manufacturer's recommendations in the Vita Vacuumed oven (Vita Zahnfabrik) at 960ºC. To compensate for the shrinkage firing of ceramic, defective specimens were adjusted by porcelain slurry addition and corrective firings (the weight of the samples must be standard ± 0.001 g).The fired discs were air cooled to room temperature. The ceramic samples were finished with a medium-grit diamond bur (Brasseler size 016 #848-11; Brasseler USA, Savannah, GA) on both sides to remove any irregularities and to create a flat surface. The discs were auto-glazed according to manufacturer's recommendations by firing at 940˚C for 1 minute.

Sample grouping

Sixty disc samples (10 mm in diameter and 2 mm in thickness) were classified into three main groups (n=20) according to type of restorative material:

Group 1: Microhybrid composite Filtek P90 Silorane.

Group 2: IPS e-max Press.

Group 3: Vitadur Alpha porcelain.

The samples of each group were subdivided into two equal subgroups (n=10) according to the type of bleaching agent used:

Subgroup (a): Bleached using chemically activated whitening gel (Opalesence Xtra Boost)

Subgroup (b): Bleached using light assisted whitening gel (Zoom 2).

Samples of the subgroups were further divided into two equal divisions (n=5) according to the type of test performed:

Division (1): Roughness testing. Division (2): Color assessment.

Each sample was assessed for surface roughness and color change before bleaching so that each sample served as its own control.

Roughness testing

Roughness was measured before and after bleaching application using ESEM (Environmental scanning electronic microscope (FEI, Multinational gathered at Netherlands). Software used XT document (x-ray tungsten filament document for microanalysis measurements Quanta 200 and 1000 X magnification). The (ESEM) captures an image for the analyzed sample with magnification up to 1000000 X. After capturing the image an order is given to the roughness software (XT document) to convert the captured image into three dimensions image that represent the roughness in the form of peaks. These peaks at the roughness image are present upon three coordinates which are [X (length), Y (width), Z (height)]. All the heights of the present peaks represented by Z-axis were measured in micrometers. Mean surface roughness values (Ra) were calculated for each sample. (Ra) describes the arithmetic mean of all values of the roughness profile over the evaluated length.

Color assessment

The color of the bleached samples was measured by spectrophotometer (Pocket Spee-ColorQA Pro, PocketSpee Techonologies Inc., Denver, Colo, USA). During baseline measurements, three measurements were performed for each sample, and the mean of the readings was calculated. The mean of each sample was calculated by use of the CIE Lab uniform color scale. The magnitude of the total color difference ΔE was calculated from the equation:

ΔE = (ΔL2+Δa2+Δb2)1/2

Where L* (lightness), a* (red-green), b* (blue- yellow).

To determine the color difference, it is necessary to compute and record the difference in all three color space

values, L*, a*, b*.These differences are then interpreted as:

ΔL=L2-L1 Where +ve values denote “lighter” and

–ve values “darker”

Δa=a2-a1 Where +ve values denote “less green” and -ve values denote “less red”

Δb=b2-b1 Where +ve values denote “less blue” and –ve values denote “less yellow”

Therefore, this formula provides numeric data that represent the differences in color perceived between two objects.

One sample from each subgroup was examined to confirm their crystalline phase before and after bleaching using Philips PW3710 analytical X-Ray Diffraction system with a Cu anode.

RESULTS

Statistical Analysis

Data analysis was performed using One- way analysis of variance ANOVA to evaluate the significance between groups. For analysis of color change One-way ANOVA was followed by Student’s t test between each two subgroups. P values ≤ 0.05 are statistically significant in all tests.

Roughness testing

Mean (Ra) values of each restorative material before and after treatment, with the respective standard deviations, are shown in Table (2) and Figure (1). Significant differences in Ra values were observed between the unbleached (control) and bleached samples, as well as between subgroups treated with Opalesence Xtra Boost and those treated with Zoom 2. Figure (2, 3 and 4) shows the surface roughness of each restorative material treated with Opalesence Xtra Boost and Zoom 2.

Color assessment

The mean ΔE values for the different groups were summarized in Table (3) and graphically represented in Figure (5). Regarding the restorative materials treated with Opalesence Xtra Boost bleaching agent, the IPS e-max Press showed the highest ΔE value (6.39) followed by microhybrid composite resin (4.60), meanwhile Vitadur Alpha porcelain recorded the lowest ΔE value (2.43). However, IPS e-max Press treated with Zoom 2 showed the lowest ΔE value (0.82) followed by VitadurAlpha porcelain (1.56), whereas microhybrid composite resin demonstrated the highest ΔE value (2.83). One-way ANOVA analysis showed that the two bleaching agents had statistically significant effect on the color of restorative materials (P = 0.000). Moreover, the color change was found to be significantly higher for the restorative materials treated with Opalesence Xtra Boost compared to Zoom 2, regarding their mean ΔE values. To clarify the effect of the two bleaching agents on the same restorative material, Student’s t test revealed that the color of each restorative material changed statistically when bleached with Opalesence Xtra Boost and Zoom 2 (p<0.05).

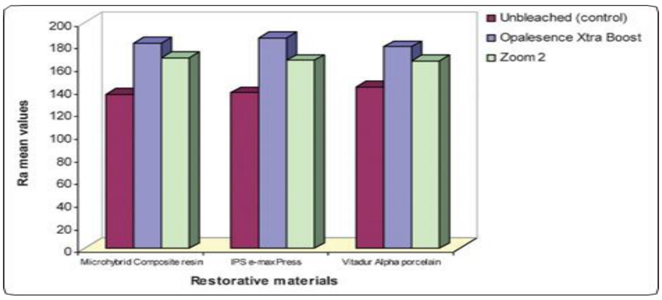

Fig. 1: Bar chart showing surface roughness (Ra) of different restorative materials with bleaching agents

Table 2: Statistical analysis (mean, standard deviation) for the surface roughness (Ra) of different restorative materials and bleaching agents.

Bleaching agent / Restorative material	Microhybrid composite resin		IPS e-max Press		Vitadur Alpha porcelain		P-value
	Mean	SD	Mean	SD	Mean	SD	
Unbleached (control)	135.67	3.39	137.33	3.27	142.17	1.47	0.003
Opalesence Xtra Boost	181.00	3.58	185.50	4.64	177.83	2.64	0.009
Zoom 2	168.17	2.23	166.00	1.90	165.67	1.63	0.083
P-value*	0.000		0.000		0.000		

*: Significant at P ≤ 0.05

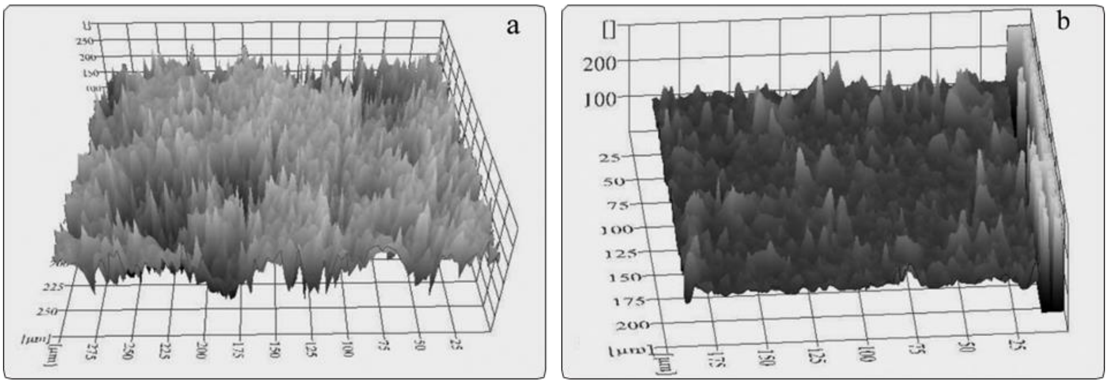

Fig. 2: ESEM photograph of microhybrid composite resin samples treated with a) Opalesence Xtra Boost, b) Zoom 2.

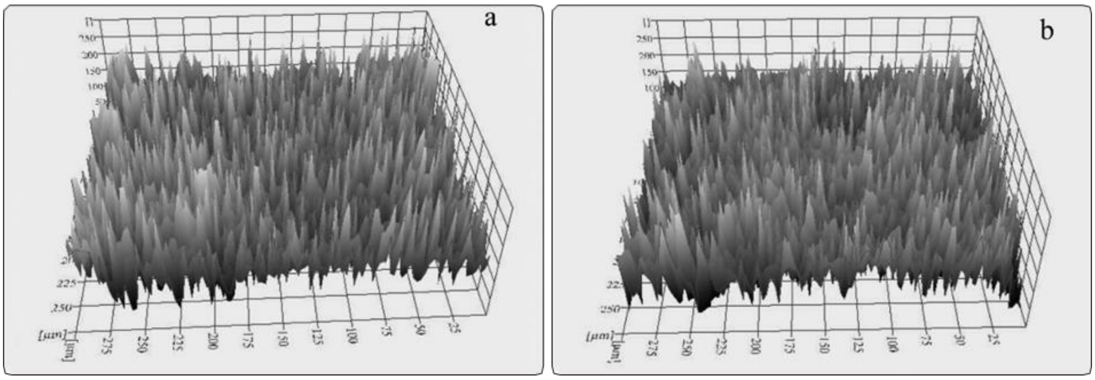

Fig. 3: ESEM photograph of IPS e-max Press samples treated with a) Opalesence Xtra Boost, b) Zoom 2

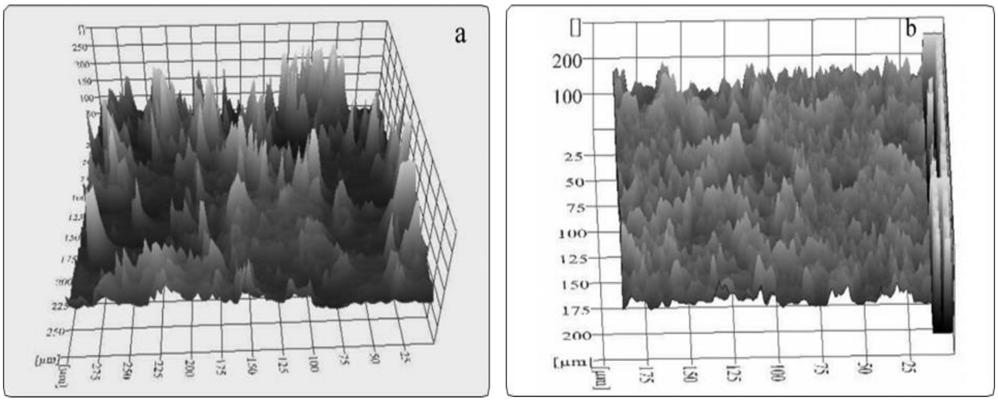

Fig 4: ESEM photograph of Vitadur Alpha porcelain samples treated with a) Opalesence Xtra Boost, b) Zoom2

Table 3: Statistical analysis (mean, standard deviation) for ΔE values of different restorative materials and bleaching agents.

Bleaching agent / Restorative material	Microhybrid composite resin		IPS e-max Press		Vitadur Alpha porcelain		P-value*
	Mean	SD	Mean	SD	Mean	SD	
Opalesence Xtra Boost	4.60	0.14	6.39	0.18	2.43	0.06	0.000
Zoom 2	2.83	0.08	0.82	0.12	1.56	0.10	0.000
P-value *	0.000		0.000		0.000		

*: Significant at P ≤ 0.05

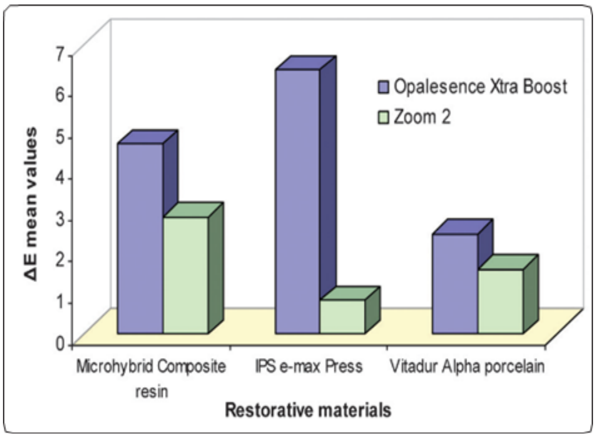

Fig 5: Bar chart showing ΔE values of different restorative materials with bleaching agents.

XRD Results

Figures (6 a, b and c) showed the XRD patterns of the unbleached microhybrid composite resin sample treated with Opalesence Xtra Boost and Zoom 2 re- spectively. XRD detected the presence of crystalline phases (SiO2, yttrium fluoride and yttrium hydride phases) in the unbleached sample matrix as shown in (Figure 6 a). The two phases SiO2 and yttrium fluoride were observed in the treated samples with the same ratio. However, the intensity of SiO2 and yttrium fluoride phases formed in sample treated by Zoom 2 were smaller than the intensity of those phases in sample treated by Opalesence Xtra Boost as shown in (Figures 6 b and c).

Figures (7 a, b and c) showed the XRD patterns of the unbleached IPS e-max Press sample, sample treated with Opalesence Xtra Boost and Zoom 2 respectively. XRD detected the presence of crystalline phase (Lithium silicate Li2Si2O5 phase) in the unbleached sample matrix as shown in the (Figure 7a). In sample treated with Opalesence Xtra Boost, it was observed that the Lithium silicate Li2Si2O5 and SiO2 phases were formed as shown in (Figure 7 b). The XRD pattern of the Zoom 2 treated sample detected the presence of Lithium silicate phase with smaller intensity than that formed in the unbleached sample as shown in (Figure 7 c).

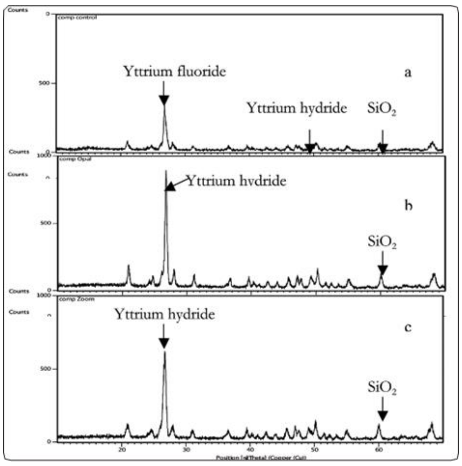

Fig 6: a): XRD patterns of the unbleached microhybrid com- posite resin sample, b) microhybrid composite resin sample treated with Opalesence Xtra Boost, c) micro- hybrid composite resin sample treated with Zoom 2.

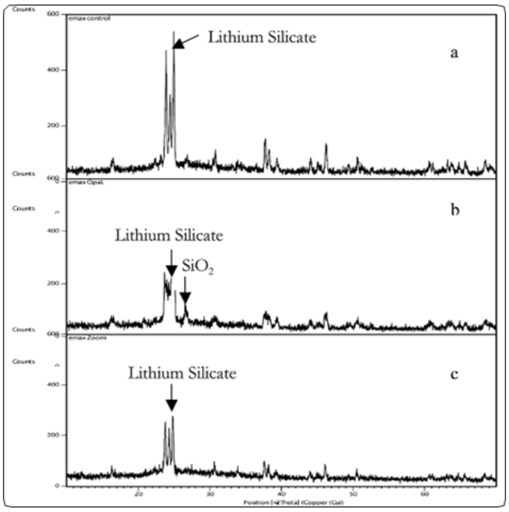

Fig 7: a) XRD patterns of the unbleached IPS e-max Press sample, b) IPS e-max Press sample treated with Opa-lesence Xtra Boost, c) IPS e-max Press sample treated with Zoom 2.

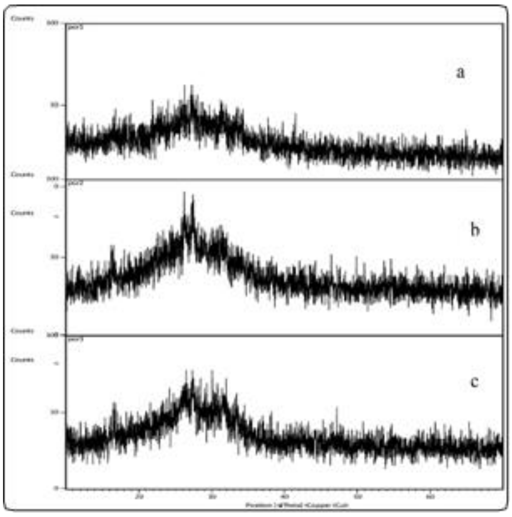

Fig 8 a): XRD patterns of the unbleached Vitadur Alpha porcelain sample, b) Vitadur Alpha porcelain sample treated with Opalesence Xtra Boost, c) Vitadur Alpha porcelain sample treated with Zoom 2.

Figures (8 a, b and c) showed the XRD patterns of the unbleached Vitadur Alpha porcelain sample, sample treated with Opalesence Xtra Boost and Zoom 2 respectively. XRD indicated that all unbleached and bleached samples were mainly in the amorphous state, in addition to the presence of nano-crystalline phase in sample matrix of treated samples, as shown in the Figure (8 a, b and c).

DISCUSSION

Tooth whitening is a popular technique used in esthetic dentistry, being widely accepted as an effective clinical procedure (19). Although considered relatively safe regarding systemic effects, recently, some controversy has arisen related to its effects on restorative materials (19). The effect of whitening agents on restorative materials should be analyzed for their potential deleterious consequences on physical and mechanical properties, these changes may have important clinical implications, since the prognosis and the longevity of a dental restoration may depend upon them (6-11). Over the past few years, in-office tooth bleaching systems employing the use of strong oxidizing agents have been introduced. From the advantages of this bleaching system; the treatment is totally under the dentist's control, the soft tissues are generally protected from the process and it has the potential for bleaching quickly in situations in which it is effective (20). Although there are several reports on the effect of home bleaching systems on restorative materials, little is known about the effects of the in-office bleaching technique on these materials. Clinically relevant bleaching regimens that followed manufacturers' recommendations were adopted for the current research. The bleaching products selected for the present study contained 38% hydrogen peroxide (Opalescence Xtra Boost) which represented the product with the highest hydrogen peroxide concentration available on the market and Zoom 2 which was a 25% hydrogen peroxide light assisted tooth whitening gel, intended only for in-office use by a dental professional. However, the literature evidence from in-vitro and clinical studies for the actual effects of light on tooth bleaching versus non- light bleaching agents is limited (21). In the present study, the two bleaching agents were applied to the surface of the samples for 45 min, representing the clinical conditions of the in-office bleaching procedure (21). This contrasted with several other bleaching studies in which materials were exposed continuously to bleaching products for several days to simulate cumulative effects over a period of time (4).

Silorane is a new monomer system obtained from the reaction of oxirane and siloxane molecules. This resin claimed to have combined the two key advantages of the individual components: low polymerization shrinkage due to the ring-opening oxirane monomer and increased hydrophobicity due to the presence of the siloxane species (21). Siloranes were stable and insoluble in simulated biological fluids or dilute hydrochloric acid (HCl). This reported advantageous characteristic serve to enhance the potential of silorane monomers being used successfully in dental composite materials (22).

Ceramics are expected to be chemically stable in the mouth, as dental prostheses must withstand degradation in the presence of a wide range of solutions with variable pH levels (23). Otherwise, ceramics could release potentially toxic substances and radioactive components and exhibit increased wear, abrasion of opposing dental structures, and increased plaque adhesion after exposure to such intra-oral challenges (23). Therefore, the present study was conducted on 2 types of dental ceramics; IPS e-max Press are pressable ingots consisting of lithium disilicate glass-ceramic material suitable for the fabrication of frameworks or fully anatomical restorations due to its high esthetic and high strength, however, there is no data exist in the literature on the effects of bleaching systems on IPS e-max Press. Vitadur Alpha is used as a veneering ceramic for alumina and zirconia cores in all-ceramic fixed partial dentures (FPDs) due to its excellent physical and mechanical properties (24).

The use of tooth-colored restorations, especially in the anterior segment of the dentition, was common place and the aesthetic results obtained by such materials were dependent on their being highly polished. Surface roughness decreases luster resulting in dull, non-aesthetic restorations, Ra is therefore an important variable to consider when examining the effects of bleaching materials, particularly as users of such products are prone to be highly conscious of the aesthetics of their dentition (13). Contact and non-contact methods are currently used for surface roughness measurement (25). One of the disadvantages of contact method using profilometer is that the stylus tip may damage or alter the tested surfaces (26). Therefore, non-contact method using Environmental scanning electronic microscope was used in the present study.

Ra values in the present study demonstrated that none of the tested ceramics were found to be chemically inert; both bleaching agents significantly alter the surface roughness of both ceramics (IPS e-max Press and Vitadur Alpha porcelain). This increased roughness may have been caused by the contact and possible diffusion of free radicals of hydrogen ions H+ or hydronium ions H O+ produced by bleaching agents (27), that may selectively leach alkali ions and cause dissolution in ceramic glass networks (23). Regarding the types of studied ceramics, IPS e-max Press revealed the greatest Ra values after bleaching with Opalesence Xtra Boost. This result seemed to show that dissolution in the ceramic glass matrix created irregularities within the lithium disilicate crystals. The results of the current study were in agreement with those of Butler et al. (28) who reported increased roughness of three porcelain formulations as a result of the application of 10% carbamide peroxide. Moraes et al. (29), Kamala and Annapurni (30), Torabi et al. (31) and Qasim et al. (32) reached the same conclusion after using 35% and 16% carbamide peroxide, respectively. Zaki and Fahmy (33) distinguished between autoglazed and overglazed ceramic restorations. They found that an in-office bleaching procedure with 35% carbamide peroxide followed by an at-home bleaching technique with 15% carbamide peroxide significantly increased the surface roughness of polished overglazed ceramic restorations, but did not affect autoglazed ceramic restorations. Additionally, Alayad (34), concluded that, surface roughness of bulk fill resin composite was altered by bleaching agents.

However, Duschner et al. (35) reported no changes in surface morphology of porcelain exposed to bleaching. This could have been due to the lower concentration of the bleaching agents used in their study, in addition, the chemical stability of ceramics against bleaching agents was observed after treatment with 15% carbamide peroxide for 56 h (9), 16% carbamide peroxide for 126 h(28), 10% or 15% carbamide peroxide and 38% hydrogen peroxide for 30 minutes or 45 minutes, respectively. The reason for the contrasting results on dental material properties by other researchers is unclear; it may be speculated that this is due to differences in study design or the vast array of bleaching products and their differences in formulation (35). Clinically, this implies that if we expose these ceramics to bleaching, we significantly increase their roughness, causing increase in plaque accumulation and wear to antagonist materials or teeth (27). In addition, an increase in surface roughness of ceramics may decrease strength and affect the clinical success and failure of ceramic restorations (36).

Color change is tested due to the alterations in color of the restorative materials because of the oxidation of surface pigments and amine compounds, which have also been indicated as responsible for color instability of restorative materials over time (39). In color assessment, the choice of an appropriate method is important because of the path length of incident light in the tested material (40). It is well known that instrumental evaluation presents more objective data versus the subjectivity of visual color determination (41,42), therefore, eliminating the subjective interpretation of visual color comparison. Colorimetry is a branch of the science of color based on the digital expression of the color perceived from the object. In assessing chromatic differences, generally 2 color systems are used: Munsell Color System and Standard Comission Internationale de L'Eclairage (CIE Lab) Color System. The American Dental Association recommends the use of CIE Lab color differential system (43). According to this system, all colors in nature are obtained through blending of 3 basic colors, red, blue and green, in various proportions. For standardized and reproducible evaluation of color changes of restorative materials, colorimeters are used analyzing L*a*b* values according to the CIELab-system. It has been claimed that under clinical conditions in the mouth, ΔE color differences have been reported to be relevant and perceptible only when higher than 3.3(44) or 3.6(45). Moreover, several authors have shown that color differences greater than 1 ΔE unit were considered to be visible to the naked eye by 50% of human observers, and ΔE values equal to or greater than 3.3 were considered as clinically unacceptable(45). On this ground, Spectrophotometers was used in the present study.

In the present study, application of Opalesence Xtra Boost (38% hydrogen peroxide chemically activated bleaching gel) gave color changes with $\Delta E > 3.3$ for microhybrid composite resin (4.60) and Zoom 2 (2.83). The interaction between this bleaching agent and restorative material could be of clinical significance, as the color change could be noticeable to the patient. The higher efficacy of 38% hydrogen peroxide gel could be due to an excess of active ingredient that readily diffused. Hydrogen peroxide is an aggressive oxidant capable of degrading the polymer matrix of resin-rich composite materials (4, 44). It breaks down into water and oxygen, as well as free radicals which result in oxidation of the pigments or amine compounds within the structure (4). In addition to its reactivity, hydrogen peroxide demonstrates an extensive ability for diffusion (46). Oxidation of the pigments may occur as a result of direct interaction with hydrogen peroxide on the resin surface (40). Peroxides might induce oxidative cleavage of polymer chains. Therefore, any unreacted double bonds are expected to be the most vulnerable parts of the polymers. Furthermore, free radicals induced by peroxides may impact the resin filler interface and cause filler-matrix debonding. Microscopic cracks are formed, resulting in surface roughness and leading to diffusion of agent and hence color change (46). This finding was in accordance with Monaghan et al. (47) who found that highly concentrated in- office bleaching systems affected the color of composite resin however low concentrations of home bleaching systems did not. Furthermore, the interaction between in-office solutions and both, teeth and restorations still raises concern, once higher peroxide concentrations could worsen possible harmful effects. Another study (48,49) found that the color change was especially noticeable when a high peroxide concentration (35% HP) was used on composite resin. The authors attributed these results to the volume of resin matrices and filler type.

This finding was also supported by the XRD results which revealed that composite resin treated with Opalesence Xtra Boost made the color more opaque and this optical characteristic might be due to the presence of crystalline phases in the sample matrix which was greater in samples treated with Opalesence Xtra Boost than in Zoom 2 treated sample. Moreover, this was shown clearly from the results of the surface roughness that revealed the mean (Ra) value of composite resin samples treated with Opalesence Xtra Boost were higher than those treated with Zoom 2.

Similarly, IPS e-max Press treated with Opalesence Xtra Boost gave color changes with $\Delta E > 3.3$ (6.39). On the other hand, the use of Zoom 2 did not lead to noticeable color change of the IPS e-max Press because the amount of color change of the bleached samples were lower than 1 ΔE unit (0.82). Differences in the bleaching effect of the agents on the same material might be attributed to their different hydrogen peroxide contents (48). This finding was supported by the results of the XRD which revealed that Opalesence Xtra Boost treatment made the IPS e-max Press sample more opaque. This optical characteristic might be due to the presence of SiO_2 crystalline phase in addition to Lithium silicate $Li_2Si_2O_5$ phase in sample matrix as shown in (figure 7 b). On the other hand, the color of Zoom 2 treated IPS e-max Press sample was close to unbleached sample. This might be due to the decrease of Lithium silicate phase and the disappearance of the SiO_2 phase in the sample matrix.

Furthermore, Vitadur Alpha porcelain demonstrated color change when exposed to Opalesence Xtra Boost and Zoom 2 bleaching agents. This was in agreement with the findings of Mehesen (50) who demonstrated that the colour of composite could be considerably altered by bleaching, and the colour stability could be endangered. Additionally, Zaki and Fahmy (33) bleaching technique with 15% carmabide peroxide changed the whiteness of polished overglazed ceramic restorations, but did not affect autoglazed ceramic restorations. Kim et al. (51) stated that surface topography influenced the color of porcelain, especially the CIE $L*$ value. In addition, rough surface texture will reflect an irregular and diffuse pattern of light, which will modify the color of the restoration (35.52). This color change might be due to some chemical changes that may have occurred by unstable free radicals that are generated from these compounds through either an oxidation or reduction reaction (53). Furthermore, it would seem that the reduction in the SiO_2 content after ceramic bleaching reported by Türker and Biskin could have caused this color change.

Overall, this study showed that bleaching could affect the surface roughness and color of dental ceramics; therefore, practitioners would be wise to advise patients to avoid bleaching composite and ceramic restorations, especially those of anterior teeth. However, this finding is in contradiction with the study done by Kaya and Bektaş (54) who found that, the office bleach containing 35% hydrogen peroxide produced statistically insignificant change in the roughness of nanohybrid and microhybrid composite resins.

It is important to acknowledge some limitations of this study. Firstly, only a limited number of materials and manufacturers were tested. This can lead to an extrapolation of results only occurring due to specific interactions between materials. Secondly, the size of the specimens did not correlate to the size of restorations intra-orally; therefore, following manufacturers' recommendations may not have produced the same results as would be produced clinically. Finally, the quantity of bleaching product used in the current study can be considered to be in excess of the in vivo situation, since there was no elution of the gel from the surface of the dental material. This is in contrast to the in vivo situation where it is known that peroxide levels within bleaching products are depleted during use. Thus, the experimental design in the current study was an exaggeration of what is anticipated under normal use.

CONCLUSION

Within the limitation of this study, it could be concluded that the high concentration of hydrogen peroxide in a proprietary bleaching gel had a noticeable surface roughness as well as color change effect on Filtek P90 Silorane, IPS e-max Press and Vitadur Alpha porcelain. Therefore, patients should be informed that their existing restorations might not match their natural teeth after bleaching.

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