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Ji-Hyung Kim · Yong-Keun Lee · Bum-Soon Lim · Sang-Hoon Rhee · Hyeong-Cheol Yang

Effect of tooth-whitening strips and films on changes in color and surface roughness of resin composites

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Abstract Though the effectiveness of film and strip type tooth-whitening agents on the bleaching of tooth has been confirmed, there have been few studies on their influence on restorative materials. The purpose was to investigate the effect of tooth-whitening film and strip on the changes in color and surface roughness of dental resin composites. The composites used were Filtek Supreme (3M ESPE), Point 4 (Kerr), and Spectrum TPH (Dentsply). Specimens were prepared 10 mm in diameter and 1 mm in thickness. Film type (Night Effect, Crest; Simply White Night, Colgate) and strip type (Whitestrips Professional, Crest; Claren, LG) agents were used, and bleaching procedures were performed for 2 weeks according to the manufacturers' recommendations. Color was measured according to the CIELab color scale with a spectrophotometer. Color difference (ΔE_{ab}^*) and surface roughness (*Ra*) were measured. After bleaching, the ΔE_{ab}^{*} values were 0.90– 1.67, which was too small to be perceptible (<3.3). The increase in Ra values was significant in some composite-whitening agent combinations (P < 0.01), however the value was less than 0.30 μ m after bleaching. Therefore the change in surface roughness was clinically insignificant. We conclude that the influence of toothwhitening film and strip on the color and surface roughness of dental resin composites was negligible.

Keywords Color · Resin composite · Surface roughness · Tooth-whitening film · Tooth-whitening strip

Introduction

The use of tooth-whitening agents to improve the appearance of natural dentition has become a popular pro-

J.-H. Kim · Y.-K. Lee ()→ B.-S. Lim · S.-H. Rhee · H.-C. Yang Department of Dental Biomaterials Science,
College of Dentistry, Seoul National University,
28 Yeongeon-dong, Jongro-gu, Seoul, Korea
e-mail: ykleedm@snu.ac.kr
Tel.: +82-2-740-8693
Fax: +82-2-740-8694 cedure. Tooth-whitening agents effectively whiten the tooth [11]. Contemporary agents are based primarily on hydrogen peroxide or its compounds such as carbamide peroxide or sodium perborate, and these are often used in combination with an activating agent such as heat or light. Tooth whitening is believed to occur through oxidation of organic substances in tooth by oxide free radicals that are generated from the tooth-whitening agent [2]. The oxidation process changes the chemical structure of interacting organic substances of tooth, which results in color change [25].

The effectiveness of tooth-whitening strips and film on the color improvement of natural dentition has been reported in a clinical study [5]. There were significant changes in *CIE L*^{*} and *CIE b*^{*} values of tooth after bleaching with tooth-whitening strip [7]. An experiment on the effects of low concentrations of home bleaching agents on the characteristics of tooth surface did not show any significant changes in enamel, dentin, or the dentinoenamel junction [23]. However, in an examination of highly concentrated carbamide peroxide for office bleaching, some changes were found in the structure of enamel [16].

Resin composite is a very popular esthetic restorative material of which the color matching with the tooth has been of great concern for practitioners and patients. Highly concentrated office bleaching systems affected the color of resin composite, but low concentrations of home bleaching systems did not [14, 15]. In a study on the surface roughness (Ra) of restorative materials after bleaching, there was no significant change in porcelain, a slight change in resin composite, and significant change in glass ionomer [20]. On the other hand, there was no significant change in Ra values of resin composite after in-office bleaching [22].

In previous studies, there were varied degrees of change in color and surface roughness of resin composites after bleaching. There have been diverse works on the whitening effectiveness of recently introduced film and strip type tooth-whitening agents in natural dentition but few on esthetic restorative materials. Recently, a nanofilled resin composite with primary filler size of 5–20 nm was introduced [21]. Its surface properties may be different from those of hybrid composites.

The purpose of this study was to evaluate the effects of two types of home bleaching systems on the changes on color and surface roughness of microhybrid and nanofilled resin composites.

Materials and methods

Resin composites and whitening systems

Three brands of resin composites of A2 and B2 shades were studied (Table 1). The shade designations of A2 ad B2 are taken from the Vita lumin vacuum shade guide (VITA, Bad Säckingen, Germany). One nanofilled resin composite was coded as FS. The fillers were a combination of aggregated zirconia/silica cluster fillers with primary particle size of 5–20 nm and a nonagglomerated/nonaggregated 20 nm silica filler. The filler loading was 78.5 wt/%. PT contained approximately 75 wt/% (57 vol/%) inorganic filler with an average particle size of 0.4 μ m, and SP contained 77 wt/% of microfiller (average 1 μ m, maximum 5 μ m) and submicron filler (0.01–0.04 μ m).

Two types of tooth-whitening systems for home bleaching were applied (Table 2). There were some differences in application protocols for the two systems, but both made thin films on the substance surface. The strips acted just as donors of this film.

Preparation of composite specimens

Specimens 10 mm in diameter and 1 mm thick were made with a polytetrafluoroethylene mold. Resin composite was packed into the mold, with the upper and lower surfaces covered with acetate matrix strips. The specimens were light-cured for 40 s by dividing the specimens into three areas each with a Spectrum 800 light-curing unit (Dentsply/Caulk, Milford, Del., USA) with an intensity setting of 400 mW/cm², and the output of the curing light was checked with a radiometer (SDS/Kerr, Orange, Calif., USA).

The specimens were rubbed against a sheet of wet silicon carbide paper of 1500 grit for 50 strokes of 15 cm in length to remove the oxygen inhibition layer and resin-rich layer from the surface. All specimens were stored in distilled water at 37°C for 24 h and cleaned in distilled water in an ultrasonic cleaner for 60 min. Twenty-five specimens were made for each material and shade.

Whitening procedure

Film type whitening agent was simply applied on the blot-dried surface of composite specimen. According to the manufacturers' recommendations, the working time of this type is during sleep at night. Generally, most people sleep approximately 8 h; therefore, the working time of this type was estimated at 8 h [9]. Strip type whitening agent was prepared in 10-mm squares. According to the manufacturers' recommendations, its working time is 30 min twice a day. It is recommended that all the whitening systems need 2 weeks of this regimen for the maximum whitening effect.

All the specimens were stored in a 37°C, 100% relative humidity chamber during the whitening procedure. After removing the bleaching agent after each application (8 h or 30 min), the specimens were washed in distilled water for 30 s. These procedures were repeated once a day for the film type and twice a day for the strip type. The control specimens were kept in the chamber under the same conditions during the 2-week period but without any treatment.

Color measurement

Color was measured according to CIELab color scale relative to the standard illuminant D65 over a dentine shade disk of 20 mm in diameter and 8 mm in thickness (*CIE L**=66.81, *a**=2.99, and *b**=15.22) on a reflection spectrophotometer (CM-3500d) (Minolta, Tokyo, Japan) with SCE geometry. The dentin shade disk was made of Filtek Supreme A2 dentin shade resin composite (3M ESPE, St. Paul, Minn., USA). Refractive index liquid (*n*=1.50± 0.0002) (Cargille, Cedar Grove, New Jersey, USA) was placed between the resin specimen and the background so that an optical connection was achieved [4, 19]. Illuminating and viewing configuration was CIE diffuse/8° geometry. Measurements were repeated five times for each specimen.

Color differences (ΔE^*_{ab}) were calculated by the equation $\Delta E^*_{ab} = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2}$. Changes in color, three-color coordinates, and chroma using the equation $C^* = [(CIE \ a^*)^2 + (CIE \ b^*)^2]^{1/2}$ were compared after 1- and 2-week bleaching.

Surface roughness measurement

Surface roughness (Ra) was measured with a Surtronic 3P surface profilometer (Taylor-Hobson, Leicester, England). For each specimen, five measurements were made, with cutoff value of 0.8 mm

Table 1 Resin composites used in this study

Code	Brand name	Shade	Batch number	Manufacturer
FS	Filtek Supreme	A2E	3AK	3 M ESPE, St. Paul, Minn., USA
	L.	B2E	3AE	
PT	Point 4	A2	207473	SDS/Kerr, Orange, Calif., USA
		B2	305110	
SP	Spectrum TPH	A2	0202000916	Dentsply/Caulk, Milford, Delaware, USA
	*	B2	0202001299	

Table 2 Bleaching systems used in this study

Туре	Code	Brand name	Ingredient	Batch number	Manufacturer
Film	NE	Night Effects	19% sodium percarbonate	31195614J	Procter & Gamble, Cincinnati, Ohio, USA
type	SW	Simply White Night	18% carbamide peroxide	3097AM	Colgate, New York, New York, USA
Strip	WP	Whitestrips Professional	6.5% hydrogen peroxide	3155BT2	Procter & Gamble, Cincinnati, Ohio, USA
type	CL	Claren	3% hydrogen peroxide	A29A1	LG, Seoul, Korea

and measuring length of 3 mm. Prior to measuring, the profilometer was calibrated against a reference block ($Ra=6.07 \mu m$). The measurements were made before and after the bleaching procedures.

Statistical analysis

Differences in color change and Ra values caused by the whitening systems were analyzed by analysis of variance and Scheffe's multiple range test with SPSS version 11.0 software (SPSS, Chicago, Ill., USA) (*P*=0.01). Differences in Ra values before and after bleaching were compared with *t*-test (*P*=0.01).

Results

Changes in color (ΔE_{ab}^*) after 2-week application of the tooth-whitening systems are given in Table 3. Since the changes in three-color coordinates (*CIE L*^{*}, *a*^{*}, and *b*^{*}) and chroma were small, the data are not presented as a table. In FS composite, there was no remarkable difference in the changes of color and color coordinates in composites. ΔE_{ab}^* values after 1-week application were 0.64–1.27, and those after 2 weeks were 1.28–1.67. In PT, ΔE_{ab}^* values after 1-week application were 0.29–1.09, and those after 2-weeks were 0.90–1.55. In SP, ΔE_{ab}^* values after 1-week application were some significant differences in the changes of color and color coordinates from the tooth-whitening systems, these values were very small ($\Delta E_{ab}^* < 1.67$).

Ra values before and after 2-week application are shown in Fig. 1 for FS composites, in Fig. 2 for PT, and in Fig. 3 for SP. The values before treatment were 0.12– 0.27 μ m for FS composite, 0.17–0.23 μ m for PT, and 0.15–0.24 μ m for SP. In FS B2, the *Ra* values increased significantly when SW and WP were applied (*P*<0.01). In PT A2, *Ra* values increased significantly after application of SW, and in PT B2, the *Ra* value increased significantly after application of WP (*P*<0.01). In other cases, there were no significant changes in *Ra* values after application

Table 3 Mean changes of color (ΔE_{ab}^*) after 2-weeks application. Standard deviations are in parentheses. *AVG* average value of five groups, *DG* different groups by bleaching method, *NS* no significantly different groups, *Ctr* control, < significantly different group marker (Scheffe's multiple range test, *P*<0.01)

SH	TX	FS	PT	SP
A2	NE (Gr 1) SW (Gr 2) WP (Gr 3) CL (Gr 4) Ctr (Gr 5) AVG	$\begin{array}{c} 1.28 \ (0.15) \\ 1.38 \ (0.23) \\ 1.33 \ (0.08) \\ 1.67 \ (0.23) \\ 1.28 \ (0.08) \\ 1.39 \ (0.22) \\ 5 \ 1.2 \ (4.5) \\ \end{array}$	$\begin{array}{c} 1.28 \ (0.14) \\ 0.99 \ (0.06) \\ 0.90 \ (0.08) \\ 1.08 \ (0.07) \\ 1.48 \ (0.18) \\ 1.15 \ (0.24) \\ 2.25 \end{array}$	$\begin{array}{c} 1.12 \ (0.11) \\ 1.04 \ (0.19) \\ 1.22 \ (0.05) \\ 1.30 \ (0.07) \\ 1.47 \ (0.22) \\ 1.23 \ (0.20) \\ 2.15 \end{array}$
B2	NE (Gr 1) SW (Gr 2) WP (Gr 3) CL (Gr 4) Ctr (Gr 5) AVG DG	1.58 (0.14) 1.60 (0.11) 1.62 (0.11) 1.49 (0.16) 1.45 (0.17) 1.55 (0.15) NS	3.2<3	2<5 1.42 (0.12) 1.41 (0.18) 1.34 (0.15) 1.37 (0.14) 1.40 (0.09) 1.39 (0.14) NS



Fig. 1 *Ra* values of FS composites (mean and SD). **P*<0.01. *Ctl* control group



Fig. 2 *Ra* values of PT composites (mean and SD). **P*<0.01. *Ctl* control group

of bleaching agents (*P*>0.01). All the *Ra* values after polishing were less than 0.30 μ m.

Discussion

Whitening of tooth is expected when a tooth-whitening agent is applied on teeth. Which kind of effect is expected after application to restorative materials? Since the composition and accordingly the characteristics of tooth and esthetic restorative materials are obviously different, it is very hard to get the same outcome from two different substances. Therefore, the best result would be no difference from the surface properties of restorative materials.

After the application of tooth-whitening agents, whitening of tooth results from oxidation of organic substances



Fig. 3 Ra values of ST composites (mean and SD). Ctl control group

by free radicals [2]. In case of dental resin composites, whitening agents may have an influence on resin matrix, filler, or both. However, fillers are basically glass or ceramic, and therefore the influence of hydrogen peroxide on fillers would be very small. Instead, the resin matrix may be chemically degraded by the concentrated or repeated application of hydrogen peroxide. If this agent were to degrade the coupling system of resin composite, the staining accumulation would change. In strip and film type whitening agents, since the application protocols were changed from those of previous whitening agents, the influence on resin composites were expected to differ from that of previous agents.

In the present study, the revised version of a strip type bleaching agent (WP) was applied, with a higher concentration of hydrogen peroxide (6.5%) than its predecessor (5.3%). Clinically, WP provided 96% more tooth whitening efficacy than a carbamide peroxide tray system and 52% more tooth whitening efficacy than the 5.3% hydrogen peroxide strip [18]. Another brand of 6.5% hydrogen peroxide strip was reported to be effective and safe [12]. However, there was no perceptible change in color of resin composites ($\Delta E_{ab}^*=0.90-1.67$) after 2-week application.

This clinical trial was conducted to evaluate color improvement following bleaching for 2 weeks with a strip type tooth-whitening agent containing 5.3% hydrogen peroxide. As a result, the whitening strip group experienced a significant reduction in yellowness of $-2.0 \ CIE \ b^*$ units vs baseline and $-1.95 \ CIE \ b^*$ units vs controls [8]. In the present study, the average change in $CIE \ L^*$ value of all composites after application of WP for 2 weeks was 0.53, that of the *CIE a*^{*} value was 0.93, and that of the *CIE b*^{*} value was 0.44. Therefore, the influence of WP on the changes in color coordinates of resin composites was small compared with those of teeth.

Comparison of the whitening effectiveness on teeth of two vital bleaching systems of strip and gel was conducted. Between two groups, strip type showed a statistically significant or directionally favorable whitening response [10]. However, in the present study, the changes in CIE L^* of all combinations of composites and whitening systems after 2-week application were from -0.26 to 1.00, in CIE a^* from 0.79 to 1.27, and in CIE b^* from -0.13 to 1.08. The range of color change varied according to the composite and whitening system; however, the ranges of color change after 2-week application were 1.28–1.67 in FS, 0.90–1.55 in PT, and 1.04–1.42 in SP, regardless of shade and whitening system. Therefore, though the changes in color were measured with a spectrophotometer, these values are not perceptible in clinical conditions ($\Delta E_{ab}^* < 3.3$) [1]. Color change (ΔE_{ab}^*) of resin composite after in-office bleaching with 30% hydrogen peroxide was >3 in some composites [15]. However, the home bleaching systems used in the present study showed no perceptible color change in resin composites.

The clinical efficacy of film type tooth-whitening agents was evaluated; these agents showed significant reductions in tooth yellowness and significant increases in tooth brightness. NE gave Δb^* (change in *CIE* b^* value before and after bleaching) of -1.53 and ΔL^* of 1.28, and SW gave Δb^* of -0.46 and ΔL^* of 0.78. It was concluded that NE provided whitening superior to that of SW [3]. In the present study, the mean value of Δb^* after 2-week application was 0.72 and that of ΔL^* was 0.10 for NE. For SW, that of Δb^{π} was 0.67 and that of ΔL^{π} was 0.10. Therefore, it could be concluded that there was no significant difference in color change in resin composites between the two agents. Clinical study demonstrated a highly significant, more than six times better whitening benefit from WP than from SW; the mean value for WP in Δb^* was 2.57 and in ΔL^* was 2.13 [6]. In the present study, the mean value for WP of Δb^* in resin composites was 0.44, and that of ΔL^* was 0.53. For SW, that of Δb^* was 0.67 and that of ΔL^* was 0.10.

The effects of office bleaching agents on the surface finish of resin composite have been evaluated. No significant changes in surface roughness after bleaching were observed [22]. In office bleaching, the concentration of hydrogen peroxide is 35% and the duration of application is short (three times 30 min, with 1-week intervals). Although the home bleaching agents used in the present study have low concentrations of hydrogen peroxide (3.0-6.5%), their durations of application are longer than with office bleaching systems. Therefore, the question of their potential effects on the surface change of resin composite was raised. In the present study, some cases revealed significantly increased Ra values (FS B2-SW, $\Delta Ra=0.14 \ \mu m$; FS B2-WP, $\Delta Ra=0.17 \ \mu m$; PT A2-SW, $\Delta Ra=0.07 \ \mu m$; PT B2-WP, $\Delta Ra=0.09 \ \mu m$). There was no clear difference in changes of Ra values by the type of resin composite, whether microfilled and microhybrid.

The *Ra* values after polishing of esthetic restorative materials varied, depending on the clinical polishing system, and ranged from 0.22 μ m to 1.35 μ m [24]. Those of resin composite after polishing were 0.10–0.15 μ m, 0.24–0.34 μ m, and 0.06–0.10 μ m, respectively, according to the

polishing system [13]. These values of packable resin composites after polishing with commercial polishing systems were determined. Before polishing (Mylar strip), *Ra* was in the range of 0.04–0.22 μ m, and that after polishing was 0.20–1.70 μ m [17]. Therefore, *Ra* values after application of tooth-whitening systems of the present study (0.13–0.30 μ m) were within the clinically acceptable range. From them, it could be concluded that the change in surface roughness was clinically insignificant.

In the present study, specimens were polished with 1500-grit silicon carbide paper. This procedure made the surface roughness of specimens similar to that in clinical, highly polished conditions. Although the primary particle sizes of FS composites were small, they were aggregated or agglomerated. Therefore, it might be assumed that the size of aggregated particles was similar to that of hybrid resin composites from the fact that the *Ra* values of PT and SP were similar to that of FS.

In film type whitening agents, the amount differs according to the application method. In the present study, although the film thickness (amount of whitening gel) might have varied with film and composite, uniformly thin films were formed on the surface of composites. Direct measurement of film thickness was impossible. Bleaching procedures simulated clinical application methods as closely as possible. Therefore, the methodology of the present study might have clinical relevance, though the influence of saliva was not simulated.

Conclusions

The available results indicate that color change after bleaching with strip and film type tooth-whitening agents was not clinically perceptible ($\Delta E^*_{ab}=0.90-1.67$). The *Ra* value after bleaching was less than 0.3 µm, which was within the value after clinical polishing procedures. Therefore, changes in color and surface roughness of resin composites were clinically insignificant. Also, there was no difference in the change of color and surface roughness according to the type of resin composite, whether nanofilled or microhybrid.

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