Int J Clin Exp Med 2015;8(6):8968-8976
www.ijcem.com /ISSN:1940-5901/IJCEM0008445

Original Article

Effects of cold light bleaching on the color stability of composite resins

Liqun Cao[1*], Lijuan Huang[2*], Meisheng Wu[1], Hua Wei[1], Shouliang Zhao[1,2]

[1]*Department of Conservative Dentistry, Laboratory of Oral Biomedical Science and Translation Medicine, School of Stomatology, Tongji University, Shanghai 200072, P.R. China;* [2]*Department of Stomatology, Huashan Hospital, Shanghai Medical College, Fudan University, Shanghai 200040, P.R. China.* [*]*Equal contributors.*

Received March 25, 2015; Accepted June 4, 2015; Epub June 15, 2015; Published June 30, 2015

Abstract: To evaluate the effects of cold light bleaching on the color stability of four restorations using a thermocycling stain challenge. 160 specimens (10 mm in diameter and 2 mm thick) were fabricated from 4 composite resins (Gradia Direct-A, Z350XT, Premisa, and Précis) and divided into 4 subgroups. Color was assessed according to the CIEL*a*b* color scale at baseline, after the first cycle of bleaching, after thermocycling stain challenges, and after the second cycle of bleaching. Mean values were compared using three-way analysis of variance, and multiple comparisons of the mean values were performed using the Tukey-Kramer test. All groups showed significant color changes after stain challenge, the color change was more significant in Gradia Direct and Z350XT than in Premisa and Précis. After the second cycle of bleaching, color mostly recovered to its original values. The color stability of Gradia Direct and Z350XT was inferior to that of Premisa and Précis. The discoloration of composite resin materials can be partly removed after cold light bleaching.

Keywords: Composite resin, color stability, cold light bleaching, color assessment

Introduction

Resin-based tooth-colored materials have been widely used since their introduction because of their excellent esthetic properties and simplified bonding procedures. Despite recent improvements in their formulation, the color stability of composite resins after long-term oral environment exposure remains a concern in dental restorative procedures. Unacceptable color matching is one of the most common reasons for the replacement of restorations [1, 2]. Color stability has therefore been considered as one of the most important factors when selecting composite resins for aesthetic restorations [3].

The discoloration of composite resin materials can occur due to intrinsic and extrinsic causes. Intrinsic discoloration is determined by the quality of the resin matrix, the photo-initiator and the inorganic filler [4, 5]. The intrinsic color of aesthetic materials may change when materials are aged under various physical-chemical conditions such as thermal change and humidity [6]. Additionally, extrinsic discoloration is mainly caused by colorants contained in beverages and foods through adsorption and absorption. The staining of resin-based materials by colored solutions such as coffee, tea, red wine, fruit juices, and cola drinks [7-10] have been reported.

Discoloration of restorations can be assessed by visual and instrumental mechanisms. Instrumental techniques eliminate the subjective interpretation of visual color comparison; thus, even slight color changes in dental materials can be detected using spectrophotometers and colorimeters [7, 11, 12]. Studies have shown that color differences of aesthetic restorations showing $\Delta E^*>1$ are visually perceptible, deeming $\Delta E^*>3.3$ to be the critical value for the visual perception of the restoration [4, 11, 13]. In principle, no color difference ($\Delta E^*=0$) indicates a material with complete color stability or that unstained by colorations [12].

Tooth bleaching, sometimes described as "tooth whitening", has become an effective and

Table 1. Resin composites and bleaching system used in this study

Material	Type	Shade	Composition	Manufacturer
Gradia Direct-A	Microhybrid	A3	Matrix: UDMA, dimethacrylate comonomers	GC Corp, Tokyo, Japan
			Filler: Prepolymerized filler, silica (0.85 μm)	
			Filler (wt%): 73%	
Z350XT	Nanofilled	A3E	Matrix: Bis-GMA, Bis-EMA, UDMA, TEGDMA	3M ESPE, MN, USA
			Filler: Zirconia, silica (20 nm, 0.4-10 μm)	
			Filler (wt%): 78. 5%	
Premisa	Nanohybrid	A3E	Matrix: Bis-GMA, TEGDMA	Kerr Corp, CA, USA
			Filler: Silica nanoparticles, Barium glass, Prepolymerizedfiller (20 nm, 0.4 μm, 30-50 μm)	
			Filler (wt%): 84%	
Précis	Nanohybrid	A3E	Matrix: Bis-GMA, TEGDMA	Kerr Corp, CA, USA
			Filler: Silica nanoparticles, Barium glass, Prepolymerizedfiller (50 nm, 0.4 μm)	
			Filler (wt%): 78%	
Beyond	In-office bleaching gel		35% hydrogen peroxide, H_2O, thickening agent, gel, pH 4. 03	Beyond Technology, CA, USA

noninvasive way for treating discolored teeth in dentistry [14]. There are three fundamental bleaching approaches, namely, in-office bleaching, at-home bleaching and over the counter bleaching products [15]. In-office bleaching systems employ the use of strong oxidizing agents. The advantages are that 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 [16]. The cold-light bleaching technique is a light-activated, in-office bleaching technique using blue LED light (wavelength between 480 nm and 520 nm), and it is widely applied in dentistry. The cold-light lamp is equipped with a filter to exclude the harmful infrared (wavelength λ>750 nm) and ultraviolet (λ>380 nm) light. The exclusion of infrared light reduces its thermal pulp damage and the ultraviolet is excluded to reduce the risk of possible side effects of ultraviolet radiation on living cells. This technique has been proven to be effective in bleaching discolored teeth [17].

The aim of this study was to assess the effects of cold light bleaching on the color stability of four aesthetic restorations using a thermocycling stain challenge.

Materials and methods

Composite selection and disc preparation

Four composite resins marketed for aesthetic restorations were selected as experimental materials: Gradia Direct-A, Z350XT, Premisa, and Précis. The compositions of the resin matrices and fillers of these composites are listed in **Table 1**. Composite resin was injected into Teflon molds (10 mm in diameter and 2 mm thick) and placed on a glass plate with a Mylar strip. The molds containing slightly overfilled composites were covered by a second Mylar strip and a glass plate. Pressure was applied to the covering glass plate to expel excess materials and create a smooth surface. Specimens were polymerized by a LED light curing unit (Smartlite ps led, Dentsply, USA) with a light intensity of 950 mW/cm^2 using 40 s of exposure to the top and bottom surfaces, respectively. The discs were removed from the molds and stored in deionized water for 24 h to ensure complete polymerization. The top surfaces of all specimens were then polished with wet SiC paper, using consecutive grit numbers 800, 2000, and 6000. A total of 160 discs, 40 of each of the composite materials, were randomly divided into four subgroups with ten samples in each.

Subgroup A: The samples were bleached + polished + stain challenges + rebleached.

Subgroup B: The samples were bleached + unpolished + stain challenges + rebleached.

Subgroup C: The samples were not bleached + stain challenges + bleached.

Subgroup D: The samples were stored in deionized water.

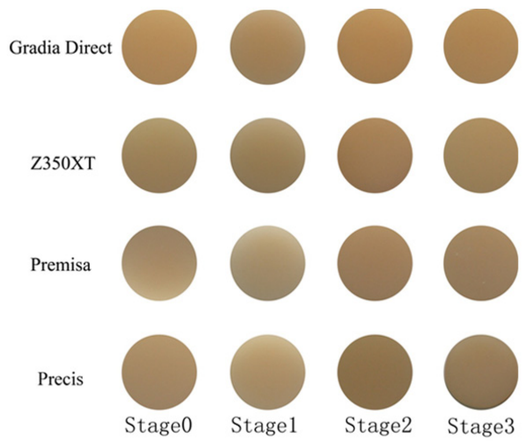

Figure 1. The typical images of composite resin discs of subgroup A.

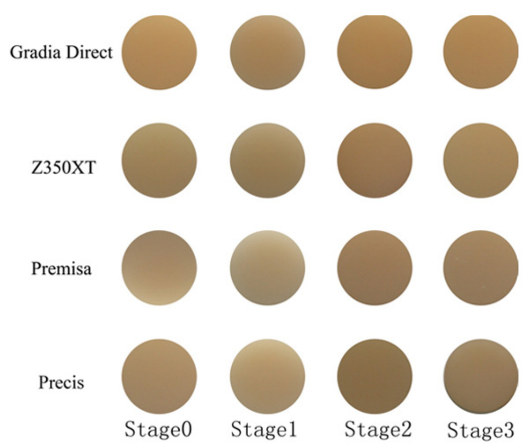

Figure 2. The typical images of composite resin discs of subgroup B.

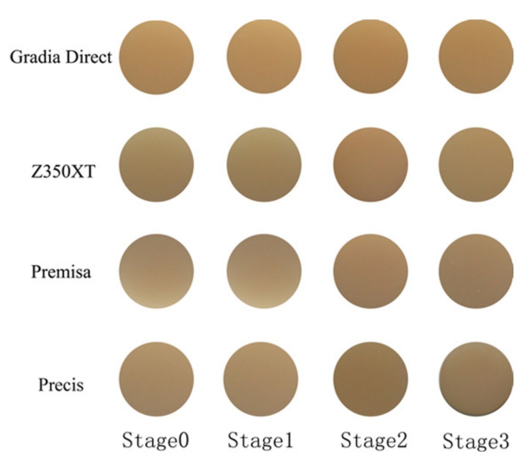

Figure 3. The typical images of composite resin discs of subgroup C.

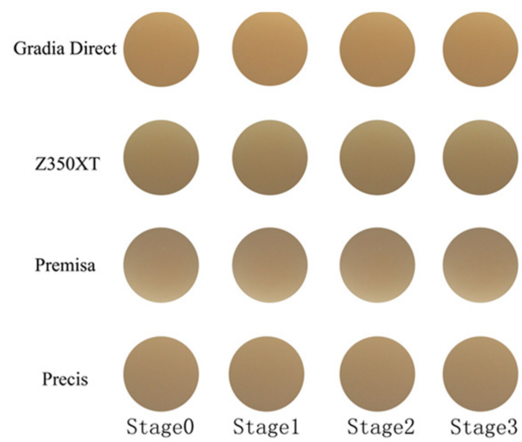

Figure 4. The typical images of composite resin discs of subgroup D.

Bleaching process

The bleaching agents used in this study are listed in **Table 1**. All specimens were taken out of the storage environment and dried with compressed air for 15s. Then, the bleaching agent was applied on the specimens according to the standard bleaching procedure extraorally as follows: (1) turned the head of the matched light (Beyond Technology, CA, USA) upon the specimen surfaces; (2) painted the specimen surfaces with corresponding whitening gels to form a 2-mm thick layer; (3) started the timer and turned on the light at the same time, with the first bleaching episode lasting for 15 min at room temperature; (4) removed the bleaching agents carefully with soft cotton pellets and then repeated the (1), (2), (3) steps four times; (5) removed the bleaching gel carefully with soft cotton pellets under running distilled water; (6) dried the surfaces of the specimens.

Dietary colorant selection and preparation

The dietary colorants used in this study were common beverages with natural and artificial colors that may cause staining of composite resin surfaces. Two different beverages were used in this experiment: black tea (Lipton, Unilever, Co., Ltd, Shanghai, China) and a grape, orange and apple fruit punch (Huiyuan, Co., Ltd, Beijing, China). For the preparation of tea solution, 10 g of tea was added to 1000 ml of water and boiled for 4 min. The tea solution was cooled to 55°C, and equal parts of the fruit beverages were chilled to 5°C before use.

Table 2. Mean values of color coordinates of Gradia Direct-A at different experimental stages

	ΔL1*	Δa1*	Δb1*	ΔL2*	Δa2*	Δb2*	ΔL3*	Δa3*	Δb3*
Subgroup A	0.04 (0.19)	0.20 (0.09)	-0.68 (0.55)	-2. 74 (0.29)	0.25 (0.14)	0.84 (0.29)	-1. 13 (0.29)	0.04 (0.15)	-0.17 (0.61)
Subgroup B	-0.09 (0.15)	0.14 (0.11)	-0.69 (0.34)	-3. 12 (0.49)	0.27 (0.12)	1. 03 (0.365)	-0.81 (0.16)	0.01 (0.08)	0.05 (0.30)
Subgroup C	-0.21 (0.15)	0.10 (0.06)	-0.10 (0.36)	-2. 44 (0.50)	0.23 (0.11)	0.90 (0.23)	-0.79 (0.64)	-0.03 (0.23)	-0.11 (0.29)
Subgroup D	-0.21 (0.31)	0.05 (0.07)	0.06 (0.31)	-0.02 (0.28)	0.19 (0.11)	0.11 (0.25)	0.07 (0.23)	0.10 (0.14)	-0.27 (0.29)

Table 3. Mean values of color coordinates of Z350XT at different experimental stages

	ΔL1*	Δa1*	Δb1*	ΔL2*	Δa2*	Δb2*	ΔL3*	Δa3*	Δb3*
Subgroup A	-0.07 (0.11)	0.50 (0.06)	-1. 28 (0.35)	-3. 19 (0.71)	0.72 (0.19)	2. 49 (0.87)	-1. 38 (0.29)	0.82 (0.20)	-0.31 (0.43)
Subgroup B	-0.03 (0.16)	0.53 (0.06)	-0.98 (0.16)	-3. 74 (0.58)	0.93 (0.24)	3. 21 (1. 14)	-1. 91 (0.50)	1. 10 (0.20)	-0.10 (0.35)
Subgroup C	0.04 (0.14)	0.07 (0.08)	0.15 (0.25)	-2. 28 (0.58)	0.44 (0.25)	1. 96 (1. 21)	-1. 09 (0.48)	0.85 (0.24)	0.18 (0.43)
Subgroup D	0.01 (0.16)	0.06 (0.52)	0.04 (0.22)	0.42 (0.16)	0.22 (0.07)	-0.06 (0.19)	0.49 (0.22)	0.24 (0.09)	-0.32 (0.22)

Table 4. Mean values of color coordinates of Premisa at different experimental stages

	ΔL1*	Δa1*	Δb1*	ΔL2*	Δa2*	Δb2*	ΔL3*	Δa3*	Δb3*
Subgroup A	0.56 (0.13)	0.17 (0.06)	-1. 55 (0.22)	-0.55 (0.14)	0.45 (0.08)	0.11 (0.39)	-0.02 (0.19)	0.15 (0.13)	-1. 22 (0.44)
Subgroup B	0.46 (0.24)	017 (0.09)	-1. 18 (0.36)	-0.98 (0.37)	0.56 (0.05)	0.72 (0.44)	-0.02 (0.28)	0.17 (0.11)	-0.60 (0.63)
Subgroup C	0.13 (0.19)	0.11 (0.74)	0.12 (0.28)	-0.85 (0.20)	0.42 (0.13)	1. 60 (0.46)	-0.15 (0.32)	0.24 (0.52)	-0.10 (0.98)
Subgroup D	0.05 (0.07)	0.10 (0.08)	0.04 (0.18)	0.08 (0.06)	0.18 (0.06)	-0.28 (0.15)	0.08 (0.10)	0.16 (0.07)	-0.65 (0.11)

Table 5. Mean values of color coordinates ofPrécis at different experimental stages

	ΔL1*	Δa1*	Δb1*	ΔL2*	Δa2*	Δb2*	ΔL3*	Δa3*	Δb3*
Subgroup A	0.45 (0.08)	0.18 (0.09)	-2. 02 (0.35)	-1. 09 (0.57)	0.31 (0.12)	-1. 22 (0.63)	-0.33 (0.37)	0.14 (0.07)	-1. 93 (0.51)
Subgroup B	0.49 (0.23)	014 (0.08)	-2. 68 (0.37)	-1. 00 (0.34)	0.32 (0.09)	-1. 28 (0.87)	-0.33 (0.31)	0.12 (0.09)	-2. 29 (0.43)
Subgroup C	-0.15 (0.11)	0.04 (0.52)	0.12 (0.31)	-1. 41 (0.36)	0.22 (0.09)	0.37 (0.40)	-0.30 (0.31)	0.11 (0.05)	-0.24 (0.38)
Subgroup D	-0.24 (0.09)	0.01 (0.08)	-0.11 (0.21)	-0.25 (0.20)	0.11 (0.07)	-0.30 (0.29)	-0.07 (0.12)	0.12 (0.11)	-0.63 (0.35)

Thermocycling stain challenges

The hot tea solution and fruit juice were added to a proprietary the rmocycling apparatus with computer controlled mechanical arms transporting the composite discs between the hot tea (55°C) and cold beverage (5°C) tanks with a dwell time of 30 s and a transportation time of 15 s. A total of 75 s were needed to complete one cycle. The tea and juice solutions were continuously stirred at 150 rpm in the hot tank and circulated with an immersion circulator at 5L/min in the cold tank to reflect the dynamic nature of beverage ingestions and to prevent any colorant precipitation [18]. The discs were thermocycled for 1000 cycles for approximately 21 h and then removed, gently washed for 30 s, and placed in deionized water before color assessment.

Color measurements

The color of composite discs was assessed in the CIE L*a*b*color system using a clinical spectrophotometer (VITA Easyshade Compact, VITA Zahnfabrik, Bad Säckingen, Germany). The VITA Easyshade compact is a hand-held spectrophotometer that consists of a cordless handpiece with a 5 mm-diameter probe tip and 1 mm-diameter fiber optic bundles. During the measurement process, the specimen was illuminated by the periphery of the tip, directing the light from white LEDs into the specimen surface.

CIEL*a*b* color system defines the color space by L*, a*, and b* coordinates. L* represents the lightness, or black/white character of the colors. The coordinates a* and b* describe the chromatic characteristics of the colors. a* coordinate represents the red-green axis, and the b* coordinate represents the yellow-blue axis.

Color measurements were performed in a custom-made viewing booth with D65 illumination. The instrument was calibrated according to the manufacturer's instructions. The spectrophotometer's "tooth single" measurement mode was selected and the probe was placed in the center of the specimen. Three consecutive measurements were made for each specimen and the mean L*, a*, and b* values were calculated.

Repeated bleaching

To assess the dynamic nature of the colorant's effects over time, the same composite discs were subjected to a second round of bleaching. The color of the discs was assessed again in the CIEL*a*b* color space.

Statistical analysis

The mean and standard deviation estimated from the specimens for each subgroup were statistically analyzed. The mean values of the different groups were compared using three-way analysis of variance, and multiple comparisons of the mean values were performed using the Tukey-Kramer test. In the present study, $P<0.05$ was considered to be the level of significance.

Results

Images of composite resins

In order to illustrate the cold light bleaching on the color stability of the restorations, one specimen of each group was photographedat different stages. **Figures 1-4** show the typical images of composite resin discs of different groups. The color change was observed in these typical images.

Color changes within each composite resin

Tables 2-5 show the color changes (ΔL*, Δa* and Δb*) among the four composite resins at different stages of the experiment as compared to the baseline.

After the initial cycle of bleaching, all four composite resins showed a statistically significant change in Δa* and Δb* ($P<0.05$). Positive Δa* indicates a shift towards the red color, whereas negative Δa* indicates a shift towards the green color. Positive Δb* indicates a shift towards the yellow color, whereas negative Δb* denotes a shift towards the bluecolor. Gradia Direct-A, Premisa and Précis also showed a statistically significant change in ΔL* ($P<0.05$), and no significant change in the ΔL* of Z350XT was found ($P>0.05$). Positive ΔL* indicates that the specimens became lighter, whereas negative ΔL* indicates that the specimens became darker.

After the thermocycling stain challenges, all four composite resins showed a statistically significant change in ΔL* and Δb* ($P<0.05$). Z350XT, Premisa and Précis also showed a statistically significant change in Δa* ($P<0.05$), and no significant change in Δa* of Gradia Direct-A was found ($P>0.05$), indicating that this composite resin was more resistant to green staining than the other three composite resins.

After the second cycle of bleaching, the CIEL*a*b* values did not fully regress to the baseline. Statistically significant differences remained in the ΔL* of all four composite resins ($P<0.05$), where no difference from the baseline in Δa* and Δb* values was found ($P>0.05$).

Color differences among the composite resins

Table 6 shows the color differences (ΔE*) among the four composite resins at different stages of the experiment as compared to the baseline. After the cycle of thermocycling stain challenges, all four composite resins showed a statistically significant color change (increase in ΔE2* values). After the second cycle of bleaching, ΔE3* values of all four composite resins regressed towards their first values (ΔE1*). Moreover, the overall color (ΔE*) was significantly different among group A, group B, and group C at each experimental stage, and the color stability of group B is inferior to that of other groups. Gradia Direct and Z350XT showed greater color changes than the other two composite resins after the stain challenges and after bleaching ($P<0.05$).

Discussion

Currently, dentistry is experiencing a trend of increasing demand from patients for superior esthetic restorations. Over the past decade, there has been a marked change in the tooth-colored restorative materials. Such materials have become an important part of modern dentistry. Meanwhile, in daily clinical practice, tooth-colored restorations exist in the teeth that may be planned to be bleached. Therefore,

Table 6. Changes in overall color (ΔE*) from baseline at different experimental stages

	Gradia Direct-A			Z350XT			Premisa			Précis		
	ΔE1	ΔE2	ΔE3	ΔE1	ΔE2	ΔE3	ΔE1	ΔE2	ΔE3	ΔE1	ΔE2	ΔE3
Subgroup A	0.81 (0.43)	2. 89 (0.30)	1. 27 (0.38)	1. 39 (0.31)	4. 15 (0.99)	1. 70 (0.28)	1. 67 (0.20)	0.81 (0.13)	1. 26 (0.39)	2. 08 (0.35)	1. 75 (0.69)	1. 99 (0.55)
Subgroup B	0.74 (0.32)	3. 32 (0.46)	0.87 (0.16)	1. 13 (0.16)	5. 10 (0.86)	2. 24 (0.48)	1. 31 (0.34)	1. 41 (0.36)	0.78 (0.48)	2. 74 (0.34)	1. 77 (0.66)	2. 34 (0.44)
Subgroup C	0.43 (0.15)	2. 63 (0.47)	1. 06 (0.14)	0.31 (0.13)	3. 11 (1. 17)	1. 47 (0.49)	0.35 (0.17)	1. 91 (0.29)	0.81 (0.67)	0.35 (0.15)	1. 35 (0.32)	0.59 (0.19)
Subgroup D	0.46 (0.16)	0.41 (0.15)	0.45 (0.18)	0.26 (0.10)	0.53 (0.13)	0.67 (0.22)	0.21 (0.10)	0.36 (0.12)	0.69 (0.10)	0.34 (0.11)	0.49 (0.23)	0.67 (0.33)

it is important for dentists to understand the effects of bleaching agents on the color stability of the restorative materials.

Color changes can be evaluated using a visual method and color measurement devices. The color evaluation by visual comparison may not be a reliable method due to inconsistencies inherent in color perception and specification amongst observers [19]. Most of the color measurement devices utilized in dentistry use the ΔE* from the Commission International de l'Eclairage CIE (L*a*b*) color system to determine the color differences or changes. In this scheme, color is measured in three coordinate dimensions of L*, which represents lightness (from white to black; similar to value), a*, which corresponds to the green-red axis (negative value indicates green; positive value indicates red), and b*, which corresponds to the blue-yellow axis (negative value indicates blue; positive value indicates yellow) [20]. The total color change is described by $\Delta E^*=[(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2}$ [21]. Several studies have shown that color differences greater than one unit (ΔE*>1) can be perceptible visually by 50% of human observers [22], and the general population can distinguish color differences of value (ΔE*>3. 3) and are considered clinically significant [23]. In this study, the color change (ΔE*) was from 0.21 to 5. 10, and it was higher than 3. 3 in subgroup B of Z350XT.

The mechanism of the color changes of restorative materials induced by bleaching is still not clear. It is believed that free prehydroxyl (HO^{2-}) radicals formed by H_2O_2 breakdown may induce oxidative cleavage of polymer chains [24]. In addition, the free radicals are eventually combined to form molecular oxygen and water, a chemical process that may accelerate the hydrolytic degradation of composites [25] and impact color alterations. In the literature, it has been suggested that color change after exposure to bleaching agents might be dependent on the matrix structure, volume and the type of filler particles of the resin composite [22, 26]. However, a resin composite with higher resin content is expected to be more prone to degradation and therefore may undergo color changes [27]. The greatest color change of Gradia Direct-A and Z350XT specimens, when compared to the other composites tested in this study, may be attributed to these structural differences.

The degree of color change can be influenced by a number of factors, such as incomplete polymerization, water sorption, chemical reactivity, diet, oral hygiene and surface smoothness of the restoration [28, 29]. The physicochemical properties of the monomer used in the resin matrix may have a direct impact on the resistance to staining [30]. As purported by the manufacturers, Gradia Direct-A is primarily composed of UDMA resin; Z350XT contains Bis-GMA, Bis-EMA and TEGDMA; Premisa and Précis have almost the same matrix formulation of Bis-GMA and TEGDMA. Water uptake in Bis-GMA-based resins increases proportionally with TEGDMA concentration [31, 32] and reduces with the partial substitution of TEGDMA to UDMA [31]. UDMA seems to be less susceptible to staining than Bis-GMA [30, 32]. However, the results of this study are controversial. Gradia Direct-A and Z350XT seem to be more susceptible to staining than the other resins.

The filler volume, particle size and composition used in the filler may also influence the resistance to staining. Gradia Direct-A containing greater filler size could be more susceptible to discoloration. As a nanofilled composite resin, Z350XT seems to be more susceptible to staining, possibly due to the porosity of the aggregated filler particles. Moreover, Dietschi [33] showed that the staining may be related to water sorption. The water acts as a carrier for staining agents in the water sorption process 4); therefore, stain adsorption tends to follow the evolution of water sorption, occurring during the thermocycling stain challenges.

It is interesting to note that the color of stained specimens mostly returned to its original color after the second cycle of bleaching for all the groups tested even after a large discoloration due to staining. The results of this study showed how effective the bleaching agents were in removing the exterior staining for dental resin composites. Although the bleaching agent can successfully remove the exterior staining from composite resin, it also can increase the surface roughness of the composite resin, therefore, the restoration may stain more easily after bleaching. Therefore, in this study, after the first cycle of bleaching, the specimens of subgroup A were polished again, because the polished composite resins have been found to be more stable under bleaching than the unpolished analogues [34].

When composite resins were immersed in water, the color differences were imperceptible and clinically acceptable. This observation confirms that water sorption by itself did not alter the color of composites to a considerable extent [35].

Conclusions

Under the conditions of the present study, it can be concluded that color stability was significantly different among the selected composite resins, with Gradia Direct and Z350XT showing more severe discoloration than Premisa and Précis. Furthermore, the discoloration of composite resin materials can be partially removed after cold light bleaching.

Disclosure of conflict of interest

None.

Address correspondence to: Shouliang Zhao, Department of Stomatology, Huashan Hospital, Shanghai Medical College, Fudan University, Shanghai 200040, P.R. China; Department of Conservative Dentistry, Laboratory of Oral Biomedical Science and Translation Medicine, School of Stomatology, Tongji University, Shanghai 200072, P.R. China. E-mail: slzhao@fudan.edu.cn

References

[1] Mjör IA, Moorhead JE, Dahl JE. Reasons for replacement of restorations in permanent teeth in general dental practice. Int Dent J 2000; 50: 361-366.
[2] Braga SR, Vasconcelos BT, Macedo MR, Martins VR, Sobral MA. Reasons for placement and replacement of direct restorative materials in Brazil. Quintessence Int 2007; 38: e189-194.
[3] Demirci M, Yildiz E, Uysal O. Comparative clinical evaluation of different treatment approaches using a microfilled resin composite and a compomer in Class III cavities: two-year results. Oper Dent 2008; 33: 7-14.
[4] Schulze KA, Marshall SJ, Gansky SA, Marshall GW. Color stability and hardness in dental composites after accelerated aging. Dent Mater 2003; 19: 612-619.
[5] Çelik EU, Aladağ A, Türkün LŞ, Yilmaz G. Color changes of dental resin composites before and after polymerization and storage in water. J EsthetRestor Dent 2011; 23: 179 -188.
[6] Iazzetti G, Burgess JO, Gardiner D, Guler E, Kurt S. Color stability of fluoride-containing restorative materials. Oper Dent 2000; 25: 520-525.
[7] Guler AU, Yilmaz F, Kulunk T, Guler E, Kurt S. Effects of different drinks on stain ability of resin composite provisional restorative materials. J Prosthet Dent 2005; 94: 118-124.
[8] Catelan A, Briso AL, Sundfeld RH, Goiato MC, dos Santos PH. Color stability of sealed composite resin restorative materials after ultraviolet artificial aging and immersion in staining solutions. J Prosthet Dent 2011; 105: 236-241.
[9] Ardu S, Braut V, Gutemberg D, Krejci I, Dietschi D, Feilzer AJ. A long-term laboratory test on staining susceptibility of esthetic composite resin materials. Quintessence Int 2010; 41: 695-702.
[10] Mohan M, Shey Z, Vaidyanathan J, Vaidyanathan TK, Munisamy S, Janal M. Color changes of restorative materials exposed in vitro to cola beverage. PediatrDent 2008; 30: 309-316.
[11] Um CM, Ruyter IE. Staining of resin-based veneering materials with coffee and tea. Quintessence Int 1991; 22: 377-386.
[12] Bagheri R, Burrow MF, Tyas M. Influence of food-simulating solutions and surface finish on susceptibility to staining of aesthetic restorative materials. J Dent 2005; 33: 389-398.
[13] Stober T, Gilde H, Lenz P. Color stability of highly filled composite resin materials for facings. Dent Mater 2001; 17: 87-94.
[14] Dahl JE, Pallesen U. Tooth bleaching-a critical review of the biological aspects. Crit Rev Oral Biol Med 2003; 14: 292-304.
[15] Heymann HO. Tooth whitening: facts and fallacies. Br Dent J 2005; 198: 514.
[16] Auschill TM, Hellwig E, Schmidale S, Sculean A, Arweiler NB. Efficacy, side-effects and patients' acceptance of different bleaching techniques (OTC, in-office, at-home). Oper Dent 2005; 30: 156-163.
[17] Wang W, Zhu Y, Li J, Liao S, Ai H. Efficacy of cold light bleaching using different bleaching times and their effects on human enamel. Dent Mater J 2013; 32: 761-766.
[18] Ren YF, Feng L, Serban D, Malmstrom HS. Effect of common beverage colorants on color stability of dental composite resins: The utility of a thermocycling stain challenge model in vitro. J Dent 2012; 40 Suppl 1: e48-56.
[19] Brook AH, Smith RN, Lath DJ. The clinical measurement of tooth colour and stain. Int Dent J 2007; 57: 324-330.
[20] Chu SJ, Devigus A, Mieleszko A. Fundamentals of color. Shade matching and communication in esthetic dentistry. Quintessence Pub. Co., Inc; 2004. pp. 85-88.

[21] Commission Internationale de L'Eclairage. 1979. Recommendations on uniform color spaces, color difference equations, psychometric color terms. CIE. Pub1979; 15Suppl 2: 9-12.

[22] Canay S, Cehreli MC. The effect of current bleaching agents on the color of light - polymerized composites in vitro. J. Prosthet Dent 2003; 89: 474-478.

[23] Ruyter IE, Nilner K, Moller B. Color stability of dental composite resin materials for crown and bridge veneers. Dent Mater 1987; 3: 246-251.

[24] Fasanaro TS. Bleaching teeth: history, chemicals, and methods used for common tooth discolorations. J Esthet Dent 1992; 4: 71-78.

[25] Söderholm KJ, Zigan M, Ragan M, Fischlschweiger W, Bergman M. Hydrolytic degradation of dental composites. J Dent Res 1984; 63: 1248-1254.

[26] Hubbezoglu I, Akaoğlu B, Dogan A, Keskin S, Bolayir G, Ozcçelik S. Dogan OM. Effect of bleaching on color change and refractive index of dental composite resins. Dent Mater J 2008; 27: 105-116.

[27] Kurtulmus-Yilmaz S, Cengiz E, Ulusoy N, Ozak ST, Yuksel E. The effect of home-bleaching application on the color and translucency of five resin composites. J Dent 2013; 41Suppl 5: e70-75.

[28] Patel SB, Gordan VV, Barrett AA, Shen C. The effect of surface finishing and storage solutions on the color stability of resin-based composites. J Am Dent Assoc 2004; 135: 587-394.

[29] Türkün LS, Türkün M. Effect of bleaching and repolishing procedures on coffee and tea stain removal from three anterior composite veneering materials. J EsthetRestor Dent 2004; 16: 290-301.

[30] Khokhar ZA, Razzoog ME, Yaman P. Color stability of restorative resins. Quintessence Int 1991; 22: 733-737.

[31] Sarafianou A, Iosifidou S, Papadopoulos T, Eliades G. Color stability and degree of cure of direct composite restoratives after accelerated aging. Oper Dent 2007; 32: 406-411.

[32] Ertaş E, Güler AU, Yücel AC, Köprülü H, Güler E. Color stability of resin composites after immersion in different drinks. Dent Mater J 2006; 25: 371-376.

[33] Dietschi D, Campanile G, Holz J, Meyer JM. Comparison of the color stability of ten new-generation composites: an in vitro study. Dent Mater 1994; 10: 353-362.

[34] Polydorou O, Hellwig E, Auschill TM. The effect of different bleaching agents on the surface texture of restorative materials. Oper Dent 2006; 31: 473-480.

[35] Villalta P, Lu H, Okte Z, Garcia-Godoy F, Powers JM. Effects of staining and bleaching on color change of dental composite resins. J Prosthet Dent 2006; 95: 137-142.