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ORIGINAL ARTICLE

Effect of in-office bleaching agents on the color changes of stained ceromers and direct composite resins

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Abstract

Purpose. To evaluate the effect of two in-office bleaching agents on the color changes of two ceromers (Ceramage and Adoro SR) and one direct composite resin (Gradia Direct Anterior) after staining by tea and coffee. ***Materials and methods.*** Twenty-four disk-shaped specimens were fabricated for each resin material and randomly divided into three groups ($n = 8$). The specimens were immersed in tea, coffee or deionized water, respectively, for 7 days. Each group was then equally divided into two sub-groups ($n = 4$), which were subjected to two in-office bleaching agents (BEYOND and Opalescence Boost), respectively. The color of the specimens was measured by a spectrophotometer at baseline, after staining and after bleaching. The color differences (ΔE values) between baseline and after treatments were calculated. ***Results.*** Statistical analysis indicated that the staining solution had significant influence on the color change of resin composites tested ($p < 0.001$). The discolorations of resin composites were perceptible after immersing in tea or coffee solutions ($\Delta E > 2.0$). There was no statistically significant difference between BEYOND and Opalescence Boost in stains removal from discolored resins ($p = 0.550$). The color changes in ΔE value between baseline and after bleaching were less than 2.0 for all resin composite groups. ***Conclusions.*** Tea solution produces severe discoloration of three resin composites tested. The two in-office bleaching agents can effectively remove the stains from two ceromers and one direct composite resin tested in this study.

Key Words: *ceromer, color, color difference, composite resin, in-office bleaching*

Introduction

Ceramic optimized polymers (Ceromer) were introduced as supplements to ceramic materials more than a decade ago [1]. Compared with traditional direct composite resins, indirect composite resins such as ceromers were reported to own superior mechanical properties and wear resistance [2,3]. Such enhanced properties may be attributed to a high degree of conversion obtained from the utilization of different polymerization procedures [4]. Accordingly, ceromers can be used to fabricate inlays/onlays, veneering, metal-free single-unit crowns and implant-supported restorations [4].

The color stability is crucial for the success of ceromers restorations as a dental resin composite material. The presence of pores within the polymerized material affected the discoloration resistance of the restorations made by these materials [5]. In general, the discoloration of dental composites is attributed to intrinsic and extrinsic factors. Intrinsic factors include the internal color change of resin composites under various physicochemical conditions such as ultraviolet exposure, thermal changes and humidity [6]. The extrinsic factors induced the surface or sub-surface color alteration through a superficial degradation or a slight penetration and adsorption of staining agents within the superficial layer of composite resins [7]. As resin-based composite materials, ceromers and direct composite resins are based on the same resin formulations [8]. Therefore, it is quite possible that ceromer

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restorations reflect the discoloration problem in clinical practice.

There are several approaches to remove the stains from composite resin restorations, e.g. toothpaste brushing, polishing and bleaching [7,9,10]. Bleaching, as an alternative strategy for stain removal, appears to be more efficient and conservative than toothbrushing and polishing [7]. The active agent of bleaching, hydrogen peroxide (HP), can interact with chromophore molecules and oxidize the macromolecules and pigment stains [11]. The bleaching treatment was reported to not only efficiently remove the stains on restorative materials [7], but also be easily managed by dentists [12].

Although there have been a number of studies on the discoloration of direct resin composites [6,13,14], little information was known on the color stability of ceromers [5]. Moreover, seldom *in vitro* evidence has shown whether in-office bleaching agents could induce oxidation to remove the ceromer staining. Thus, this study was conducted to analyze the color changes of ceromers after immersion in tea or coffee and evaluate the effect of two in-office bleaching agents on the removal of ceromers staining. The null hypotheses tested were that (1) ceromers have good color stability after storage in staining solutions and (2) the bleaching agents could remove the stains from ceromer materials.

Materials and methods

Two ceromers or indirect composite resins (Ceramage, Adoro SR) and one direct composite resin (Gradia Direct Anterior) were included for testing in this study.

Specimen fabrication

Twenty-four disk-shaped specimens for each of resin material, 10 mm diameter and 1.0 mm thick, were fabricated in polytetrafluoroethylene molds. The mold with the Gradia Direct Anterior composite resins (GC Corp, Tokyo, Japan) was held between two glass slides. Specimens were polymerized by a curing light (Mini LED, Satelec, Merignac, France) with an intensity of 1100 mW/cm^2, for 10 s on both top and bottom surfaces, respectively. The mold with Ceramage body materials (Shofu Inc, Kyoto, Japan) was light-polymerized in Solidilite (Shofu Inc.) for 3 min. The Adoro SR body materials (Ivoclar Vivadent, Schaan, Liechtenstein) were light cured in TargisPower Quick (Ivoclar Vivadent) for 20 s. This was followed by light polymerization for 25 min at 104°C in TargisPower (Ivoclar Vivadent).

To obtain identical surfaces, the top surfaces of specimens were polished successively with 600-, 800- and 1000-grit wet silicon carbide abrasive paper and the thickness of specimens were adjusted to 1.0 ± 0.02 mm. All prepared specimens were stored in deionized water at 37°C for 24 h.

Staining process

Twenty-four specimens from each resin material were randomly divided into three groups ($n = 8$). Eight specimens in each group were immersed in staining solutions (tea or coffee) or deionized water (control group) at 37°C for 7 days. Tea solution was prepared by immersing two tea bags (2 × 2 g) (Black tea, Lipton Yellow Label Tea, Unilever, Hefei, China) into 300 ml of boiling deionized water for 10 min. Twenty-six grams of coffee powders (Nescafe Classic, Nestle, Shanghai, China) were poured into 300 ml of boiling deionized water for 10 min with stirring. The control group specimens were stored in 37°C deionized water [15]. Specimens in each group were immersed in 50 ml solutions which were freshly prepared daily. After a 7-day staining period, the specimens were rinsed with deionized water and the loose surface stain deposits were removed gently using cotton pellets prior to storage in 37°C deionized water.

Bleaching process

The eight specimens in each solution were randomly divided into two sub-groups. The specimens in sub-groups ($n = 4$) were treated by in-office bleaching agents (BEYOND or Opalescence Boost). The bleaching gels were painted onto the top of the specimens according to the manufacturers' instructions. BEYOND group specimens were bleached by BEYOND™ II Advanced Formula Whitening Gel (35% hydrogen peroxide, Beyond Technology Corp., Stafford, TX, USA) and irradiated by Beyond lamp (Beyond whitening accelerator, Beyond Technology Corp.). Opalescence Boost group specimens were bleached by Opalescence Boost™ (38% hydrogen peroxide, Ultradent Products Inc., South Jordan, UT, USA) with chemical activation. The bleaching session contained three cycles with 10 min each. After the last cycle, the specimens were rinsed with deionized water for 1 min to remove the bleaching gels and stored in deionized water at 37°C for 24 h.

Color measurement

Specimens were rinsed with deionized water for 1 min and blotted dry with absorbent paper before each color measurement. The color co-ordinates of specimens was measured by a spectrophotometer (PR-650 Spectra Scan, Photo Research Inc., Los Angeles, USA) over a white background. The spectrophotometer was used to measure the reflectance spectra from 380–780 nm at a wavelength of 2 nm interval and subsequently converted to CIE $L^*a^*b^*$ values for a 2°

observer and illuminant D65 at an optical configuration of 0° observation and 45° illumination to the object [16]. The measurement aperture size was 1.5 mm. Before each session of the measurement, the spectrophotometer was calibrated with a white reflectance standard tile supplied by the manufacturer. Mean CIE L*a*b* values of each specimen were determined after separate measurements for three times. Color measurements were taken at baseline, after staining and after bleaching.

The color differences were calculated for each specimen: (1) between baseline and after staining (ΔE_1) and (2) between baseline and after bleaching (ΔE_2). The ΔE values were obtained using the formula [16]: $\Delta E = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2}$, where ΔL^*, Δa^*, Δb^* were the differences in color parameters for two time intervals. Chroma was calculated as $C^*_{ab} = (a^{*2} + b^{*2})^{1/2}$.

In this study, a ΔE value of greater than 2.0 was considered as the perceptible color difference [17].

Statistical analysis

The color differences (ΔE values) were analyzed by ANOVA (SPSS 16.0; SPSS, Chicago, IL, USA) ($p < 0.05$). A two-way ANOVA for ΔE_1 values was used to determine the effect of different solutions on the staining susceptibility of resin composites tested. For the ΔE_2 values, a three-way ANOVA was used to determine the efficiency of bleaching agents in discoloration removal on the resin composites. Tukey's multiple comparison test was performed to analyze the within-group effects at the significance level of $p < 0.05$.

Results

The color parameters of all composite materials at each interval time are given in Table I. Mean (SD) for color changes (ΔE) are listed in Table II. The two-way ANOVA for ΔE_1 values showed that the staining solutions significantly influenced the color changes of resin composites ($p < 0.001$), where tea showed the highest ΔE values among all resin composite groups. There was no statistically significant difference in the staining susceptibility for three resin composite groups ($p = 0.111$).

Tea and coffee produced perceptible color changes ($\Delta E > 2.0$) for ceromers and Gradia Direct Anterior specimens (Table II). After staining, a large reduction was detected in L* values and a moderate increment

Table I. The L*a*b* values of the three composite materials at each time interval.

		Tea			Coffee			DW		
		L*	a*	b*	L*	a*	b*	L*	a*	b*
Ceramage	Baseline	81.76 (0.49)	2.90 (0.09)	29.25 (0.65)	81.84 (0.25)	2.99 (0.13)	29.12 (0.41)	81.85 (0.27)	2.93 (0.20)	29.07 (0.33)
	After staining	75.63 (1.19)	5.19 (0.45)	29.63 (0.80)	79.87 (0.40)	3.18 (0.09)	28.87 (0.60)	80.73 (0.36)	2.97 (0.10)	28.36 (0.79)
	After bleaching (OP)	80.25 (0.12)	3.40 (0.12)	28.08 (0.22)	80.76 (0.53)	3.23 (0.08)	28.37 (0.25)	81.01 (0.11)	3.25 (0.11)	28.53 (0.12)
	After bleaching (BE)	81.99 (0.20)	3.20 (0.12)	27.96 (0.72)	81.67 (0.29)	3.48 (0.08)	27.39 (0.23)	81.70 (0.19)	3.55 (0.14)	27.37 (0.31)
Adoro SR	Baseline	83.54 (0.33)	1.00 (0.16)	29.27 (0.25)	83.54 (0.28)	1.01 (0.15)	29.42 (0.29)	83.44 (0.20)	0.87 (0.19)	29.23 (0.09)
	After staining	77.63 (0.73)	4.23 (0.58)	29.29 (0.54)	81.33 (0.26)	1.24 (0.18)	29.27 (1.03)	82.61 (0.25)	0.87 (0.14)	28.11 (0.23)
	After bleaching (OP)	82.52 (0.11)	1.24 (0.09)	28.32 (0.52)	82.27 (0.59)	0.89 (0.22)	29.36 (0.39)	83.07 (0.20)	0.83 (0.03)	28.59 (0.19)
	After bleaching (BE)	83.97 (0.29)	0.58 (0.19)	28.23 (0.30)	83.66 (0.28)	0.75 (0.18)	28.86 (0.13)	84.07 (0.14)	0.92 (0.27)	28.62 (0.19)
Gradia Direct Anterior	Baseline	81.82 (0.43)	2.18 (0.08)	26.95 (0.42)	81.72 (0.46)	2.14 (0.09)	26.96 (0.24)	81.82 (0.45)	2.19 (0.14)	27.05 (0.34)
	After staining	74.95 (0.70)	6.13 (0.59)	28.25 (0.50)	79.81 (0.25)	2.70 (0.19)	26.84 (0.20)	80.80 (0.50)	2.45 (0.10)	26.58 (0.30)
	After bleaching (OP)	80.13 (0.27)	2.80 (0.17)	26.97 (0.27)	80.61 (0.33)	2.50 (0.06)	27.20 (0.06)	81.12 (0.23)	2.54 (0.23)	26.63 (0.11)
	After bleaching (BE)	82.77 (0.24)	2.32 (0.06)	25.65 (0.35)	82.06 (0.13)	2.37 (0.03)	25.55 (0.09)	81.98 (0.19)	2.44 (0.04)	25.58 (0.23)

DW, Deionized water; OP, Opalescence Boost™; BE, BEYOND™ II Advanced Formula Whitening Gel.

Table II. Mean (SD) for color changes (ΔE) of all sub-groups of the three composite materials.

		Staining solutions		
Materials	Stage	Tea	Coffee	DW
Ceramage	After staining	6.59 (0.94)	2.06 (0.42)	1.48 (0.53)
	After bleaching (OP)	1.89 (0.25)	1.23 (0.47)	1.15 (0.33)
	After bleaching (BE)	1.11 (0.55)	1.89 (0.61)	1.93 (0.37)
Adoro SR	After staining	6.77 (1.01)	2.51 (0.39)	1.41 (0.14)
	After bleaching (OP)	1.61 (0.45)	1.43 (0.37)	0.74 (0.32)
	After bleaching (BE)	1.21 (0.35)	0.67 (0.15)	0.91 (0.31)
Gradia Direct Anterior	After staining	8.08 (0.70)	2.02 (0.49)	1.19 (0.57)
	After bleaching (OP)	1.87 (0.14)	1.30 (0.36)	1.04 (0.37)
	After bleaching (BE)	1.84 (0.57)	1.66 (0.40)	1.54 (0.24)

DW, Deionized water; OP, Opalescence Boost™; BE, BEYOND™ II Advanced Formula Whitening Gel.

was found in C^*_{ab} values for specimens immersing in tea or coffee (Figures 1,2,3 and Table I).

There was no statistically significant difference between the two bleaching agents in the stains removal from discolored specimens (p = 0.550). Although there were significant differences in the staining solutions and resin composite materials, the color differences between baseline and after bleaching were not perceptible (ΔE<2.0) for all resin composite groups (Table II). After bleaching, the L^* values and C^*_{ab} values for stained specimens nearly returned to the level of baseline values (Figures 1,2,3).

Discussion

The results of the present study show that both direct and indirect composite resin groups had perceptible color changes (ΔE>2.0) after immersing in tea or coffee solutions. Therefore, the first null hypothesis that ceromers have good color stability after storage in staining solutions was rejected.

Extrinsic stains might play a more important role in the clinically observed discolorations of ceromer restorations than intrinsic stain [15]. The discoloration of ceromer restorations may stem from the fact that resin-based restorative materials contain inherently more pores than ceramics [8]. These pores and the resin matrix in resin-based materials might absorb water during the storage of staining. Meanwhile, the colorants of tea or coffee might be adsorbed into the surface of ceromer materials and result in discolorations due to water absorption [13]. Specimens of ceromer produced notably extrinsic discoloration after staining in this study. The results were consistent with studies done by Kentrou et al. [5] and Stober et al. [15], in which clinically unacceptable color changes of indirect composite resins were found after immersing in wine, coffee and tea for 4 weeks (ΔE>3.3). Kolbeck et al. [18] also observed perceptible color changes for veneering resins after storage in wine for 10 days (the ΔE values from 3.8–9.8). The results of these previous investigations showed that

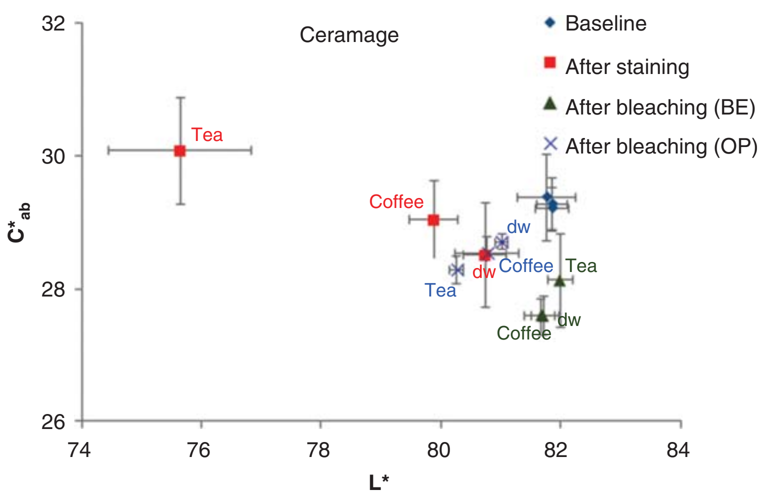

Figure 1. Distribution of the L^* and C^*_{ab} values of Ceramage at each time interval.

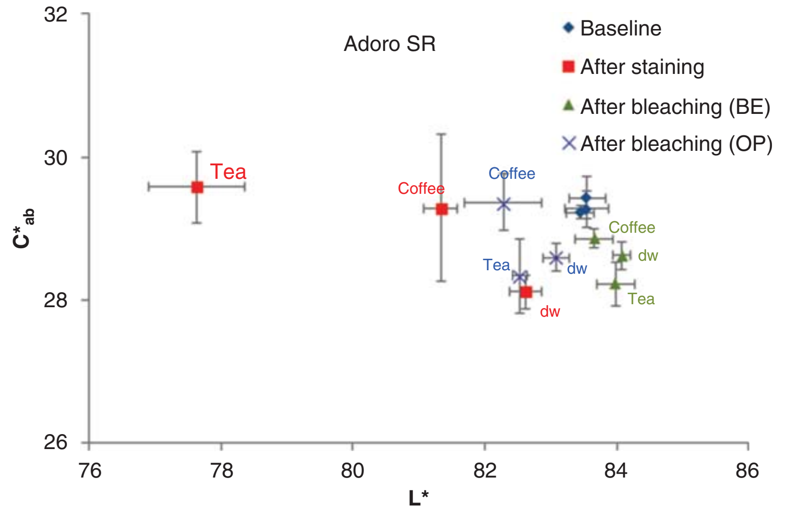

Figure 2. Distribution of the L* and C^*_{ab} values of Adoro SR at each time interval.

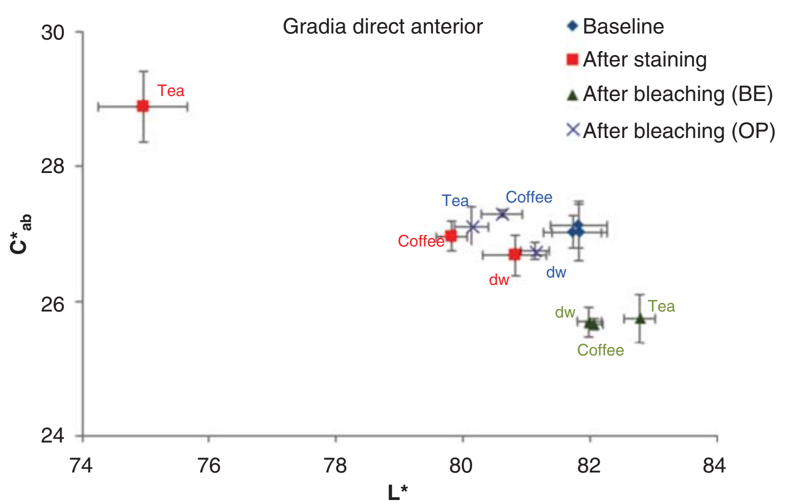

Figure 3. Distribution of the L* and C^*_{ab} values of Gradia Direct Anterior at each time interval.

the extrinsic factors can cause severe discolorations of ceromer materials due to the colorant from beverages or foods.

The second null hypothesis that the bleaching agents could remove the stains from ceromer materials was accepted, because the color of stained specimens was able to turn back to the baseline color. The color differences between baseline and after bleaching were not perceptible ($\Delta E<2.0$). The color change of the stained specimens also indicated that the staining only appeared on the superficial layer of composite resin materials after bleaching. The active agent of in-office bleaching (HP) oxidized the pigments on the surface of stained specimens, which accounted for the color changes of resin composites after bleaching [19]. This finding corroborated the results of several previous *in vitro* studies in which the high concentrated bleaching agents (30% hydrogen peroxide or 30% carbamide peroxide) were effective in removing the stains of direct composite resins [7,9,20].

In the current study, two different bleaching systems were applied for in-office bleaching treatments, including light activation and chemical activation. Theoretically, the advantage of light-activated bleaching agent is its ability to heat the hydrogen peroxide, thereby increasing the release of hydroxyl-radicals from hydrogen peroxide [21]. However, controversy still remains as to whether the light-activated bleaching techniques result in superior tooth brightening as compared to chemically activated bleaching therapies [11,21]. According to the results of the present study, there was no significant difference in removing the extrinsic stains for ceromer materials by using light-activated and chemically activated bleaching systems ($p = 0.550$). This finding is consistent with a previous study [20], which indicated that the different type of bleaching system showed no statistically significant effect on the color difference between baseline and after bleaching for stained specimens in direct composite resin tested.

The two in-office bleaching systems used in the present study did not affect the color of unstained specimens in control groups. After bleaching, the color changes were not perceptible for specimens in deionized waters groups (ΔE<2.0). Several previous studies have reported different effects of in-office bleaching on direct composite resin. Hubbezoglu et al. [22] and Hafez et al. [20] revealed that in-office bleaching agents (35% or 38% hydrogen peroxide) did not notably change the color of direct composite resins (ΔE<2.0), which is in agreement with the results of this study. However, in contrast, Monaghan et al. [23] found that 30% hydrogen peroxide produced significant color changes in composite resins (ΔE>3.0). Kara et al. [24] recently reported that appreciable color change (ΔE = 3.99) was observed in the ceromer specimens (Estenia) bleached with the 10% hydrogen peroxide, and noticeable color change (ΔE = 1.89) was observed in ceromer specimens treated with 10% carbamide peroxide. These results were different from the results of the current study. This might be due to the fact that the effect of bleaching on color changes of resin composites is related to the composition of material, bleaching agent and regimen treatment employed [25].

The bleaching procedure might affect the staining susceptibility of resin composites, although it can successfully remove extrinsic staining. The oxidation of bleaching agents could alter the surface property of resin composite materials [25]. The relative degradation and roughness of the surface of resin composites has a direct influence on their staining susceptibility [26]. Recently, there have been controversial results concerning the staining susceptibility of bleached resin composite materials. Celik et al. [27] reported that 20% carbamide peroxide had no effect on the staining susceptibility of resin composites when immersed in tea or coffee solutions. In contrast, Yu et al. [28] evaluated the effect of 15% carbamide peroxide bleaching gel on restorative materials staining susceptibility and found that bleaching treatment significantly increased the susceptibility to staining of resin composites. The apparent discrepancies may be explained, in part, by the different effects of bleaching agents on surface quality of resin composites in these studies. Therefore, further studies are expected to be undertaken to clarify the effect of bleaching agents on the surface property and the staining susceptibility of ceromer materials.

Conclusions

Within the limitation of this *in vitro* study, the following conclusions could be drawn:

(1) The discolorations of two ceromers that are indirect composite resins and one direct composite resin were all perceptible after immersing in tea or coffee solutions.
(2) In-office bleaching agents can effectively remove the stains of the three composite materials tested. The in-office bleaching agents did not change the color of the three unstained composite materials tested.
(3) There was no significant difference between the light-activated and chemically activated in-office bleaching systems in removing the extrinsic stains for the two ceromers and one direct composite resin material tested.

Declaration of interest: The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

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