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RESEARCH ARTICLE

Color Change of Esthetic Restorative Materials for Different Staining and Whitening Dentifrices

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Background: As the importance of the esthetic function of teeth increases, the use of esthetic restoration materials and whitening treatment are increasing. The purpose of this study was to investigate the color change of esthetic restoration materials upon using staining and whitening toothpaste.

Methods: Light curing (LC) packable composite resin, LC flowable resin, LC glass ionomer (GI), and self-curing GI specimens were colored in coffee or curry for three hours a day for seven days. After that, regular toothpaste, whitening toothpaste containing hydrogen peroxide, and whitening toothpaste containing activated charcoal were applied for three minutes three times a day for two weeks. Luminosity (L), chromaticity a (a), and chromaticity b (b) were measured using a spectrophotometer once a week.

Results: In the coffee-colored group, the change in $L^2*a^2*b^2$ (E^2) with time was significant ($p=0.004$), there was no difference for different toothpaste types ($p=0.646$), and there was significant difference ($p<0.001$) for different esthetic restorative materials. The change of E^2 in the curry-colored group was significant only for different esthetic restorative materials ($p<0.001$). In the coffee-colored group, the L, a, and b values of the light-curing GI showed greater change than other materials after staining and one week after whitening, turning dark, red, and yellow. In the curry-colored group, L did not differ for different materials and times, and a and b showed the greatest difference in light-curing GI after staining and one and two weeks after whitening.

Conclusion: The use of whitening toothpaste for two weeks was not different from the use of general toothpaste in the removal of staining or whitening. Since light-curing GI is the most vulnerable to coloration, it is recommended that coloring by food chromogen should be explained in advance, before using light-curing GI for teeth restoration.

Key Words: Composite resins, Dentifrices, Glass ionomer cement, Staining, Tooth bleaching agent

Introduction

With the recent improvement in economic standards, patients now demand not only functional restoration methods in dental treatment, but also esthetic restoration methods[1]. As interest in bright tooth color grows, so does the need for teeth bleaching performed by dentists, and various home bleaching products are being developed.

Nevertheless, food and beverages that people eat or drink contain various sources of chromatogen, which affect the color of esthetic restorative materials. In everyday life, coffee, green tea, black tea, coke, and red wine cause discoloration of prostheses[1], with coffee staining the most[2-5], which has been claimed to be rich in chromatogen[6]. Recently, as the preference for coffee has increased in South Korea[1], coffee is more likely to cause changes in the color of esthetic restorative materials used for patients in South Korea. Among the foods, Indian food is known to stain the most[6], with curry staining more than red pepper paste or kimchi[7].

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The degree of stain differs depending on the type of esthetic restorative material such as resin, compomer, glass ionomer (GI), and resin-modified GI (RMGI). Light curing GI is more susceptible to staining than chemical curing GI[8], and RMGI is more susceptible to staining than conventional GI[9]. There is also a difference in staining depending on the composition of the resin or the weight of the filler[10], and air curing results in lower color stability compared to pressure and heat curing[11]. A rough surface is easier to stain[6], and the changes on the surface of esthetic restorative materials are expected to affect the degree of staining[12-16].

While many studies have attempted to observe changes in esthetic materials by whitening agents used in home bleaching or in-office bleaching[4,7,17-19], there are few studies on the color changes of aesthetic materials in whitening toothpaste[20,21]. Since whitening toothpaste is generally used with brushing, it is difficult to distinguish between the effect of the toothpaste and the effect of removing the color with physical force. This study aims to examine and compare the stain removal effect of whitening toothpaste on esthetic restorative materials in the absence of physical force such as brushing, and to investigate differences between esthetic restorative materials.

Materials and Methods

1. Fabrication of specimens

The used esthetic restorative materials included light curing packable composite resin (Hanfil; Handae Chemical, Jincheon, Korea), light curing flowable resin (Hanfil Flow; Handae Chemical), light curing glass ionomer cement (uniGlass Fil LC; INOD, Elmshorn, Germany), and self-curing glass ionomer cement (uniGlass Fil; INOD). Specimens were fabricated in the form of 10 mm in width, 24 mm in length, and 1 mm in height. For light curing, a light curing machine (Ecolight; Dmetec, Bucheon, Korea) was used as close as possible in the vertical direction for 20 seconds according to the user guidelines. For self-curing, specimens were left alone for 30 seconds to allow self-curing according to the user guidelines. A total of 72 specimens were manufactured with eight specimens for each material, and the color of the material was kept consistent at A2.

2. Staining

As sources of chromatogen, coffee (Kanu Columbia blend mild roast Americano; Maxim, Seoul, Korea) and curry (Ottogi beef curry; Ottogi, Anyang, Korea) were selected by referring to the previous studies on staining and considering the frequency of consumption in South Korea. Coffee and curry were diluted in distilled water according to the manufacturer's instructions. In order to keep the specimens under conditions consistent with the oral conditions, they were immersed in the source of chromatogen for a total of three hours per day, with each hour equivalent to the time of breakfast, lunch, and dinner, and soaked in distilled water at other times for seven days.

3. Whitening

A commercially available whitening toothpaste containing hydrogen peroxide (White Scandal Whitening toothpaste; Kumho-dp, Seoul, Korea) and a whitening toothpaste containing activated carbon (2080 Pure Black Clean Charcoal; Aekyung, Seoul, Korea) were used, as well as a toothpaste not containing whitening-related materials (2080 Signature Total Blue; Aekyung) as a control. Since it was recommended to brush the teeth for three minutes, three times a day in South Korea, the specimens were treated accordingly. In order to examine the changes in color caused by the whitening toothpaste, unlike in previous studies[20,21], only toothpaste was applied to the specimens without exerting physical force such as brushing. The specimens were treated with toothpaste for two weeks.

4. Color measurement

A spectrophotometer (Shimadzu UV-2450; Shimadzu, Kyoto, Japan) was used to measure luminosity (L) indicating lightness, chromaticity a (a) indicating redness or greenness, and chromaticity b (b) indicating yellowness or blueness of each specimen were measured at baseline, one week after staining, one week after whitening, and two weeks after whitening. The color of each specimen was measured repeatedly three times, and the average value was used as the representative value. After that, a

calculation was performed using the equation, $E^2 = L^2*a^2*b^2$, where E denoted the algebraic distance between two points in the color space.

5. Statistical analysis

Repeated measure ANOVA was used to measure the change over time in E^2, the difference in color source, the difference between toothpastes, the difference in materials, and the interaction between them. As a result, the difference between toothpaste was not significant (p=0.962), and there was no interaction between toothpaste and material (p=0.542), and between toothpaste and source of chromatogen (p=0.505). Therefore, in order to further analyze the difference between the esthetic restorative materials in detail considering the source of chromatogen, L, a, and b were analyzed using repeated measure ANOVA and ANOVA. IBM SPSS 20.0 (IBM Corp., Armonk, NY, USA) was used, and the significance level was 0.05.

Results

1. Changes according to the type of toothpaste, type of esthetic restorative material, and time

Table 1 shows the changes in E^2 for the coffee-stained group. As a result of assessing the changes according to the type of toothpaste, type of esthetic restorative material, and time in the coffee-stained group, the change over time was significant (p=0.004), with no difference according to the type of toothpaste (p=0.646), and with a significant difference according to the type of esthetic restorative material ($p < 0.001$). There was no interaction between time and toothpaste for E^2 in the coffee-stained group, but there was an interaction between time and material (p=0.044). Table 2 shows the changes in E^2 for the curry-stained group. As the results of evaluation changes according to the type of toothpaste, type of esthetic restorative material, and time in the curry-stained group, none of the change over time, difference according to the type of toothpaste, and interaction between the variables was significant, but there was a significant difference according to the type of esthetic restorative material ($p < 0.001$).

Table 1. E^2 Change for Different Types of Dentifrices and Esthetic Restorative Materials over Time in Coffee Staining

Material	Dentifrices	Before staining	1 week after staining	1 week after whitening	2 week after whitening
Self-curing GI	Normal (n=3)	7,345.89±377.12	6,685.13±692.77	7,608.45±697.60	6,334.08±990.87
	Hydorgen peroxide (n=3)	6,542.76±417.99	6,194.15±395.61	6,784.29±340.03	5,978.69±1,049.30
	Activated carbon (n=3)	7,126.50±181.17	6,700.87±696.92	7,129.49±483.11	6,357.06±1,216.00
Light-curing GI	Normal (n=3)	5,486.77±206.60	3,990.83±114.40	4,483.41±119.07	4,547.70±95.33
	Hydorgen peroxide (n=3)	5,054.16±504.76	4,184.16±50.52	4,773.27±56.82	5,269.37±642.86
	Activated carbon (n=3)	5,654.57±315.95	4,055.69±373.09	4,755.58±241.16	3,979.92±1,521.02
Flowable resin	Normal (n=3)	4,453.39±340.06	4,315.84±217.99	4,315.65±65.12	4,501.76±501.12
	Hydorgen peroxide (n=3)	4,522.56±339.79	4,320.98±282.44	4,550.31±332.42	4,411.05±154.73
	Activated carbon (n=3)	4,434.97±105.08	4,260.58±190.91	4,270.91±127.03	4,890.18±1,168.63
Packable resin	Normal (n=3)	4,965.70±147.83	4,661.34±85.23	4,888.64±256.39	4,295.79±1,005.59
	Hydorgen peroxide (n=3)	4,811.51±129.77	4,486.39±26.87	4,748.81±58.09	4,638.07±147.95
	Activated carbon (n=3)	4,883.91±184.20	4,718.11±81.87	4,903.33±109.26	4,825.25±57.50

Values are presented as mean±standard deviation.
GI: glass ionomer.
p-value: repeated-measure ANOVA.
Between-subjects effects: dentifrices, p=0.646; esthetic restorative materials, $p < 0.001$; dentifrices*esthetic restorative materials, p=0.478.
Within-subjects effects: time, p=0.004; time*dentifrices, p=0.657; time*esthetic restorative materials, p=0.044; time*dentifrices*esthetic restorative materials, p=0.594.

Table 2. E^2 Change for Different Types of Dentifrices and Esthetic Restorative Materials over Time in Curry Staining

Material	Dentifrices	Before staining	1 week after staining	1 week after whitening	2 week after whitening
Self-curing GI	Normal (n=3)	7,329.75±157.72	7,269.02±955.06	7,267.97±646.55	6,719.03±1,500.59
	Hydorgen peroxide (n=3)	7,244.89±32.82	7,374.73±1,066.38	7,109.10±548.10	7,609.60±1,022.57
	Activated carbon (n=3)	7,370.25±328.05	7,206.34±802.71	7,588.62±639.52	6,855.83±2,102.13
Light-curing GI	Normal (n=3)	5,771.95±528.04	6,243.17±697.45	6,005.53±545.28	5,377.62±614.14
	Hydorgen peroxide (n=3)	5,610.42±59.46	5,929.07±65.49	5,750.57±50.19	5,502.65±343.07
	Activated carbon (n=3)	5,013.69±427.41	5,553.64±656.73	5,614.25±502.65	4,958.04±1,179.72
Flowable resin	Normal (n=3)	4,380.23±177.73	4,403.02±64.42	4,340.34±66.30	4,356.72±38.69
	Hydorgen peroxide (n=3)	4,437.20±110.53	4,484.52±132.12	4,493.20±108.50	4,761.40±538.28
	Activated carbon (n=3)	4,415.84±112.95	4,418.54±142.17	4,433.34±11.15	5,093.18±1,254.44
Packable resin	Normal (n=3)	4,729.40±78.07	4,789.15±196.60	4,615.29±43.43	4,240.25±703.19
	Hydorgen peroxide (n=3)	4,849.16±76.43	5,073.11±151.20	5,131.63±203.53	4,696.47±288.37
	Activated carbon (n=3)	4,953.64±27.49	5,097.41±79.18	4,907.49±217.40	4,914.43±227.27

Values are presented as mean±standard deviation.
GI: glass ionomer.
p-value: repeated-measure ANOVA.
Between-subjects effects: dentifrices, p=0.733; esthetic restorative materials, p＜0.001; dentifrices*esthetic restorative materials, p=0.684.
Within-subjects effects: time, p=0.235; time*dentifrices, p=0.541; time*esthetic restorative materials, p=0.292; time*dentifrices*esthetic restorative materials, p=0.988.

Table 3. Luminosity (L), Chromaticity a (a), and Chromaticity b (b) Changes for Different Esthetic Restorative Materials over Time in Coffee Staining

Color measurement	Difference	Self-curing GI	Light-curing GI	Flowable resin	Packable resin	p-value
L	Before-1 week after staining	3.10±2.58^{a}	13.14±5.21^{b}	1.63±0.80^{a}	2.09±0.89^{a}	＜0.001
	Before-1 week after whitening	−0.96±3.22^{a}	6.32±4.35^{b}	0.67±1.45^{a}	−0.07±1.65^{a}	＜0.001
	Before-2 weeks after whitening	4.32±7.97	6.63±11.51	−0.95±4.29	1.80±5.05	0.209
	p-value	0.560	0.032	0.166	0.208	
a	Before-1 week after staining	0.15±0.24^{a}	−4.51±0.87^{b}	−0.86±0.56^{c}	−1.30±0.20^{c}	＜0.001
	Before-1 week after whitening	−0.04±0.18^{a}	−2.17±0.51^{b}	−0.79±0.35^{c}	−1.22±0.24^{c}	＜0.001
	Before-2 weeks after whitening	−0.27±0.68^{a}	−1.35±1.15^{b}	−0.68±0.37^{ab}	−1.57±0.49^{b}	0.002
	p-value	0.115	＜0.001	0.292	0.113	
b	Before-1 week after staining	−1.61±1.93^{a}	−14.78±1.67^{b}	−2.72±1.63^{a}	−0.95±1.23^{a}	＜0.001
	Before-1 week after whitening	−0.48±2.59^{a}	−7.87±1.74^{b}	0.03±1.37^{ac}	2.27±1.18^{c}	＜0.001
	Before-2 weeks after whitening	0.04±2.61^{a}	−4.37±1.73^{b}	0.77±0.97^{a}	3.63±1.33^{c}	＜0.001
	p-value	0.235	＜0.001	＜0.001	＜0.001	

Values are presented as mean±standard deviation.
GI: glass ionomer.
p-value: repeated measure ANOVA.
^{a,b,c}Tukey *post-hoc* analysis.

2. Difference between esthetic restorative materials in staining and whitening

Since there was almost no difference in whitening according to the type of toothpaste, the differences in L, a, and b were assessed for each esthetic restorative material. In the coffee-stained group, the L and a values were significant in light curing GI, and the b value was significant in light curing GI, flowable resin, and packable resin (Table 3). The change in all of the L, a, and b was the most prominent in light curing GI one week after staining and one week after whitening, compared to other materials, and the color turned darker, redder, and

Table 4. Luminosity (L), Chromaticity a (a), and Chromaticity b (b) Changes for Different Esthetic Restorative Materials over Time in Curry Staining

	Difference	Self-curing GI	Light-curing GI	Flowable resin	Packable resin	p-value
L	Before-1 week after staining	0.57±4.11	1.06±2.40	1.09±0.72	0.92±0.67	0.966
	Before-1 week after whitening	−0.09±2.85	−1.32±1.51	−0.10±0.94	−0.36±1.72	0.471
	Before-2 weeks after whitening	−0.09±0.67	0.90±0.40	−0.22±0.26	−0.67±0.43	0.330
	p-value	0.724	0.180	0.106	0.213	
a	Before-1 week after staining	0.39±0.46^{a}	4.41±1.06^{b}	2.38±0.34^{c}	2.28±0.45^{c}	<0.001
	Before-1 week after whitening	−0.20±0.09^{a}	1.89±0.67^{b}	0.02±0.38^{a}	−0.12±0.44^{a}	<0.001
	Before-2 weeks after whitening	−0.09±0.67^{a}	0.90±0.40^{b}	−0.22±0.26^{a}	−0.67±0.43^{a}	<0.001
	p-value	0.013	<0.001	<0.001	<0.001	
b	Before-1 week after staining	−2.33±1.79^{a}	−18.40±4.76^{b}	−7.55±2.03^{c}	−8.17±1.44^{c}	<0.001
	Before-1 week after whitening	0.96±0.98^{a}	−6.75±2.87^{b}	−0.06±1.43^{a}	0.54±1.51^{a}	<0.001
	Before-2 weeks after whitening	1.74±1.04^{ac}	−3.53±1.35^{b}	0.42±1.24^{a}	2.71±1.71^{c}	<0.001
	p-value	<0.001	<0.001	<0.001	0.001	

Values are presented as mean±standard deviation.
GI: glass ionomer.
p-value: repeated measure ANOVA.
^{a,b,c}Tukey *post-hoc* analysis.

yellower (Table 3). In the curry-stained group, no change was observed in the L value over time or according to the type of material, but the a and b values showed a difference over time and according to the type of material (Table 4). As for the a value, and a and b values show the most prominent difference in light curing GI one week after staining, one week after whitening, and two weeks after whitening. The color turned redder and yellower compared to the baseline.

Discussion

This study attempted to investigate the changes in color caused by staining and whitening with different esthetic restorative materials and toothpastes. As a result, the color of light curing GI changed more by staining or whitening, compared to that of resin or chemical curing GI. The findings of previous studies on the color difference due to staining or whitening (bleaching) of esthetic restorative materials suggesting that GI showed a more severe color change than resin were in line with the results of this study. Kim et al.[1] reported that the color change of RMGI and GI was greater than that of resin after bleaching with carbamide peroxide, and that the resin showed no significant difference in the coffee-stained group while RMGI and GI showed a significant difference in color. Lee and Kim[8] argued that light curing GI was more susceptible to staining than chemical curing GI, which was in line with the results of this study demonstrating a more prominent change in light curing GI. In particular, whitened GI was reported to have more cracks or pits on the surface than resin, showing an increase in stain susceptibility after bleaching[12-17]. However, there was also a study reporting that the color returned to the color before whitening two weeks after stopping bleaching[12]. The resin was also susceptible to staining[7] and whitened resin became more susceptible to staining[15], but the change in color was not significant enough to necessitate resin replacement after bleaching[22]. In many of the cited studies, a staining experiment was performed after bleaching an esthetic restorative material, but this study performed staining prior to observing whether the stain was removed by the application of whitening toothpaste.

Recently, the whitening toothpastes containing about 3% hydrogen peroxide have been sold to meet the demand for brightening the color of teeth. Even though the concentration of hydrogen peroxide contained in whitening toothpaste is low, some users have reported adverse effects such as tooth hypersensitivity, gingival irritation, and decalcification. Activated carbon can adsorb contaminants, and it has been used as a folk remedy to clean teeth. Recently, companies are selling whitening toothpaste

containing activated carbon. However, as there has been no research on whether toothpaste containing activated carbon is effective for whitening reported, this study included the whitening toothpaste in the experiment. In the results of this study, there was no difference according to the type of toothpaste (regular toothpaste, whitening toothpaste containing hydrogen peroxide, and toothpaste containing activated carbon) during the two-week whitening experiment period, with no increase or decrease in the value of E^2. The results of other studies also reported no consistent increase or decrease during the whitening or staining period[7,21,23]. Nevertheless, previous studies in which teeth were brushed with whitening toothpaste reported that the color of teeth became lighter, showing different results from those of this study[20,21]. Since the lightness was reported to increase with the use of more abrasive toothpaste[21], and tooth brushing with general toothpaste was also found to be effective in removing stains from esthetic restorative materials[23], the difference could have been caused by the absence of brushing in this study. Furthermore, a study using whitening toothpaste reported its effectiveness after four weeks[20], and a longer-term study seemed necessary to assess the difference between whitening toothpaste and general toothpaste as this study only used whitening toothpaste for two weeks.

Notes

Conflict of interest

No potential conflict of interest relevant to this article was reported.

Author contributions

Conceptualization: HyeonSoo Jang, YeLim Seo, YoungJu Kim, GaYoung Lee, YouLim Kim, and Soo-Jeong Hwang. Data acquisition: EunJung Choi, HyeonSoo Jang, YeLim Seo, YoungJu Kim, GaYoung Lee, and YouLim Kim. Statistical Analysis: Soo-Jeong Hwang. Supervision: EunJung Choi and Soo-Jeong Hwang. Writing–original draft: EunJung Choi, HyeonSoo Jang, YeLim Seo, YoungJu Kim, GaYoung Lee, YouLim Kim, and Soo-Jeong Hwang. Writing–review & editing: Soo-Jeong Hwang.

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