

Effect of Staining Solutions and Repolishing on Composite Resin Color Change

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Abstract

Background and Aim: Success of composite restorations mainly depends on their color stability when in service. The present study aimed at assessing the effect of staining solutions and repolishing on composite resin color change.

Materials and Methods: In this experimental study, 200 specimens were fabricated with A2 and B2 shades of Spectrum (TPH, Dentsply) and Point 4 (Kerr, USA) composite resins (100 specimens each). Specimens were divided into 5 groups of 10 samples each and immersed in coffee, tea, coke, orange juice and distilled water for 30 days. Specimens were photographed with a digital camera (Fine Pix S9600). Color analysis was done with CS Photoshop software (CIE lab color space) at baseline, after color change and after repolishing. Obtained results were analyzed using Three-way ANOVA and LSD test. Level of significance was set at $p < 0.05$.

Results: All specimens showed a significant color change in all solutions except for water ($\Delta E > 3.3$). The greatest color change occurred in B2 Spectrum composite resin in coffee while the smallest color change was observed in A2 Point 4 specimens in water. Except for water and coke, the difference in color change between the two composite resins in all solutions was statistically significant. Color changes of B2 shade were significantly higher than those of A2. Significant improvements were observed in color of specimens after their repolishing. However, color change of specimens in coffee and tea did not improve to the clinically acceptable level by repolishing.

Conclusion: Color change of composite restorations depends on the type and shade of composite resin as well as patient's nutritional habits.

Key Words: Imaging, Composite resin, Color change, Polishing

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Introduction

Success of composite resin restorative materials greatly depends on their color stability over time. Color stability of composite restorations at service is an important criterion for appropriate selection of composite resin [1].

Discoloration of tooth-colored restorations may be due to the intrinsic or extrinsic factors. Intrinsic

color changes are defined as change in color of the resin material itself such as change in resin matrix or at the matrix/filler interface and chemical discolorations associated with alteration or oxidation of amine catalyst, polymeric matrix structure or non-reacted methacrylate groups. Extrinsic factors include staining due to the superficial or deep absorption of staining substances as the result of ex-

posure to external sources. Degree of color change due to external sources varies from patient to patient based on the oral hygiene status, nutritional habits, cigarette smoking and consumed beverages [2].

Reduction of surface roughness of a restoration is essential to prevent external staining since the composition of composite resin and characteristics of its constituents have a direct impact on the smoothness of composite surface. The polishing techniques can also influence the surface texture and stainability of the restoration [3]. In the recent years, various types of composite resins in different shades have been introduced to the market that are selected based on their tooth color coordination.

Several color systems are used for describing color parameters among which, the CIE and Munsell color systems have the highest application in studies.

In recent CIE systems, three parameters of X, Z and Y (chromaticity coordinates) are used through which the Hue and Chroma of the respective color can be determined. This system characterizes color by specifying the point on the chromaticity diagram. In CIE $L^*a^*b^*$ color system, three parameters of L, a and b are used for color characterization where L is lightness, a is the position of object in red-green parameter and b is the position of object in yellow-blue parameter. In this system, color change is assessed by ΔE . The advantage of ΔE is that the color change is compared three-dimensionally [4]. Color change at $\Delta E > 3.3$ is clinically perceptible [5].

Devices used for the measurement of color include colorimeter, spectrophotometer, spectroradiometer and digital camera. During the recent years, use of digital camera and subsequent data analysis by a computer has become increasingly popular. Advantages of this method include color assessment at all areas of a specimen in an image rather than color assessment in just one point, its low cost and its efficacy for use in universities [6]. Studies on the comparison of color change between different color shades of Vita Shade Guide are scarce. Therefore, the present study evaluated the effect of staining solutions and repolishing on color change of composite resins.

Materials and Methods

In this interventional laboratory study two types of microhybrid composite resins were used. Table 1 shows the characteristics of understudy composite resins. A2 and B2 shades were selected for this study due to their popularity in daily practice of esthetic dentistry. One hundred specimens were fabricated from each material using a plastic mold measuring 8 mm in diameter and 2 mm in height. Two celluloid strips were placed beneath and over the specimens. The mold containing composite resin was placed in between two glass slabs. Specimens were light-cured for 40 seconds from the top using LED light curing unit (Kerr, Demetron II) with an intensity of 710-840 mW/cm². The superior and lateral surfaces of samples were polished using course, medium, fine and superfine Sof-Lex (3M, USA) Finishing and Polishing Discs and a low speed hand piece with moderate pressure. Each disc was used for 30 seconds at dry condition. Samples were rinsed with water after each phase of polishing and dried with paper towel. Specimens were then photographed with fine pix S9600 digital camera under standard conditions at three time points of before staining, after staining and after repolishing.

Fifty samples of each group were randomly divided into 5 subgroups for the 5 understudy solutions (n=10). Specimens were attached to a string and completely immersed in solutions in a vertical position. To prepare coffee solution, 3.6 g of coffee powder was dissolved in 300 ml of boiling water and after 10 minutes of boiling, samples were immersed in it and the solution containing specimens was stored in an incubator (55 L, Pico, Iran) at 37° C. Two Golestan teabags (2x2 g) were placed in 300 ml of boiling water for 3 minutes. Samples were then soaked into the tea solution and stored in an incubator at 37° C.

One hundred percent natural orange juice and coca cola were obtained from the market (Table 2). Specimens were immersed in solutions for 30 days (37° C) (Coffee manufacturers have specified that the mean time duration for drinking a cup of coffee is 15 minutes and the mean consumption rate of coffee by coffee drinkers is 2-3 cups a day. Thus, the 30-day storage time is approximately equal to 30 months of coffee consumption). Solutions were refreshed daily. Specimens were rinsed with water

after each time of removal from the solution and gently cleaned with a soft toothbrush to eliminate

Table 1. Characteristics of understudy composite resins and polishing discs

Brand Name	Composition	Shade	Batch	Manufacture
Point 4	Bis- GMA,TEGDMA,UDMA, Photo initiator, Bariumaluminium boro silicate (mean particle size < 0/4 µm)	A ₂ , B ₂	2895145	Kerr,USA
Spectrum TPH	Bis- GMA, TEGDMA,Bis-EMA Photo initiator, Bariumaluminium Boro silicate(mean particle size < 1µm)	A ₂ , B ₂	554143	Dentsply Germany
Sof-Lex	Aluminum oxide, Grit: coarse (40 µm), medium (29 µm), Fine (14 µm), Extra Fine (5 µm)		19580	3M ESPE Brasil

Table 2. Understudy media (solutions)

Solutions	Composition	Brand name	PH
Tea	Caffeine, tannins, theophylline, vitamin, glucose	Golestan	5/3
Coffee	Caffeine, potassium, magnesium, zinc copper, calcium	Nestle	5/1
Orange juice	Ascorbic acid, potassium, citric acid, folic acid	100% natural	3/8
Coke	Water, sugar, caramel, orthophosphoric acid, caffeine	Coca cola	2/4
Water	-	Deionized distilled water	6

any debris attached to their surface due to their immersion in solutions. At the end of 30-day period, samples were photographed for the second time and then the surface of specimens was once again polished under similar conditions mentioned in the first phase of polishing. Color assessment was done before and after color change and after repolishing using digital photography and color of specimens was reported according to the CIE L*a*b* system. Photography of samples was done with a Fine Pix S9600 digital camera under conditions described by Bengel [7]. Specimens were placed on a black background in the same location with 25 cm distance from the lens. An 18% Gray card was placed at the corner of picture for reference. In professional photography, 18% Gray card is used to provide a standard reference object for exposure determination and reflects 18% of the light. Gray card is a neutral target with equal red,

blue and green values. Specimens were photographed in a dark room. Two 6500 Kelvin lamps were at the two sides of specimens with 45° angle relative to the horizon lighting the samples. Camera settings were adjusted in A position, with 1:1 magnification, no flash and 100 ISO. Images were transferred to a computer and evaluated in Adobe Photoshop CS that has a standard program for image editing used for visualization and color measurement of images. Steps taken to obtain comparable images are as follows: The images to be analyzed were first opened through the Open<File menu.

To adjust the coloring, the image>adjust>level menu was opened. The eye dropper tool was used to pick up the gray value; the cursor was moved over the Gray card and left clicked. By doing so, the overall image color was adjusted. The RGB color mode was changed to LAB via Im-

age>Mode>Lab color menu which was required for obtaining $L^*a^*b^*$.

The respective area was selected for analysis with Magnetic Lasso tool. For elimination of light reflection that has a profound effect on the results, magic wand tool was used. To convert the $L^*a^*b^*$ values in Adobe Photoshop to CIE $L^*a^*b^*$, the following formula was used [7].

$$L^* = L \times \frac{100}{255}$$

$$a^* = \frac{(a - 128) \times 240}{255}$$

$$b^* = \frac{(b - 128) \times 240}{255}$$

ΔE was then calculated using the equation below [7]:

$$\Delta E = \sqrt{(l_2 - l_1)^2 + (a_2 - a_1)^2 + (b_2 - b_1)^2}$$

Threeway ANOVA was used to determine the effect of type of material, type of solution and the color shade on the overall color change (ΔE) and color parameters. LSD test was used for complementary comparison between various solutions based on the type of composite resin and color shade. $P < 0.05$ was considered statistically significant.

Results

Descriptive results of color changes are demonstrated in Table 3. The highest and lowest ΔE values belonged to B2 Spectrum composite in coffee solution ($\Delta E = 15.26$) and A2 Point 4 composite resin in water ($\Delta E = 0.96$), respectively (Table 3).

Three-way ANOVA showed that the effect of material, solution and color shade on ΔE after color change was statistically significant ($p = 0.001$). Two-way and three-way interactions between independent variables in this study were not statistically significant ($p < 0.05$).

ΔE of B2 Spectrum composite was significantly different in various solutions ($p = 0.00$) as it was significantly higher in coffee solution than in tea, coke, orange juice and water (Table 3). ΔE was not significantly different between coke and orange juice ($p = 0.065$).

ΔE of A2 Spectrum composite resin was significantly different in various solutions ($p = 0.00$) as it was significantly higher in coffee than in tea, coke, orange juice and water (Table 3). The difference in

this regard between orange juice and water was not significant ($p = 0.125$).

ΔE values of A2 and B2 shades of Point 4 composite resin were significantly different in various solutions ($p < 0.001$) as ΔE was significantly greater in coffee than in tea, coke, orange juice and water (Table 3).

In all solutions except for water and coke, color change of Spectrum was higher than that of Point 4 ($p < 0.01$). In all solutions except for water, color change of B2 shades of both composite resins was higher than that of A2 shade ($p < 0.001$) (Table 3). After repolishing, Three-way ANOVA revealed that type of composite resin or its shade did not have a significant effect on color parameters ($p = 0.089$). Although different solutions had a statistically significant effect on both types of composite resins ($p < 0.001$), the interactions between composite resin and its color shade ($p = 0.891$) and solution and composite resin ($p = 0.857$) were not statistically meaningful. A marked improvement in color was observed in understudy specimens after repolishing but the color in specimens immersed in tea and coffee did not improve to a clinically acceptable level after repolishing compared to the baseline value (Table 4). In Spectrum composite resin (B2 shade), the highest ΔE was observed in coffee and the lowest in orange juice. The difference in ΔE between solutions was statistically significant ($p = 0.01$). In A2 Spectrum composite resin and A2 and B2 Point 4 composite resin the highest ΔE occurred in coffee and the lowest in orange juice. The difference in ΔE between coke and water was not statistically significant.

Discussion

Color stability is a fundamental factor for long term esthetic results of tooth-colored restorations [1]. In the present study digital photography and Photoshop software were used to assess the color change of composite resins in 5 different solutions. This is considered a suitable technique due to the simplicity of photography and standardizing all conditions that may affect the final result [8]. This method also eliminates the hardship and high costs of working with spectrophotometer [6]. Akhavan [9], Ghasemi [10], Bengel [11] and Lee [12] adapted this technique in their studies. Specimens were polished using Sof-Lex Finishing and Polish-

ing Discs which are routinely used for this purpose [13]. A polished surface is a filler-rich surface with a high Knoop hardness score and is less susceptible to chemical solubility [14].

Table 3. The mean and SD values of ΔE for A2 and B2 shades of the two understudy composite resins in different solutions in comparison to the baseline value

Solutions	Number	A2 Spectrum		B2 Spectrum		A2 Point 4		B2 Point 4	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD
Coffee	10	13/90	1/08	15/26	1/35	13/29	1/12	14/32	0/60
Tea	10	8/54	97/0	11/45	1/24	7/65	0/12	9/86	1/12
Coke	10	3/64	1/12	5/81	0/59	3/62	1/00	5/70	0/73
Orange juice	10	1/88	0/87	4/08	0/54	1/42	0/20	3/24	1/06
Water	10	1/33	0/69	1/59	0/52	0/97	0/40	1/22	0/66

Table 4. The mean and SD values of ΔE for A2 and B2 shades of the two understudy composite resins in different solutions after repolishing compared to baseline values

Solutions	Number	A2 Spectrum		B2 Spectrum		A2 Point 4		B2 Point 4	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD
Coffee	10	4/54	0/94	5/24	1/78	4/30	1/28	4/63	0/77
Tea	10	3/55	1/10	3/70	0/79	3/60	1/05	3/91	0/97
Coke	10	1/47	0/80	2/37	0/35	1/38	0/78	1/56	0/58
Orange juice	10	1/01	0/41	1/91	0/75	1/30	0/60	1/37	0/75

In this study, the difference in color change between Spectrum and Point 4 composite resins was statistically significant in all solutions except for coke and water and Point 4 showed lower ΔE values. Spectrum is a photo-activated composite containing Bis-GMA and Bis-EMA resin matrix and filler particles smaller than one micron with 78 weight percent filler content. Point 4 is a high-strength microhybrid composite containing Bis-GMA and UDMA with a filler size of 0.4 micron and 77 weight percent non-organic filler content. It has been demonstrated that UDMA (present in Point 4) is more resistant to stains in comparison to Bis-GMA [3, 15]. Also, it absorbs less water under similar conditions [1]. Furthermore, it has been stated that composite resins with larger filler particles are more susceptible to color change due to water aging compared to composite resins with smaller filler particles. This finding is attributed to the hydrolytic reactions at the interface of filler/matrix [16, 17]. Additionally, composite resins with larger filler particles are more susceptible to staining [18, 19]. Another possible explanation for the poorer color stability of Spectrum compared to

Point 4 may be its larger filler particles. Understudy composite resins had a marked color change in coffee, tea and coke which is in accord with the findings of previous studies in this respect [20, 23]. In orange juice, both types of composite resins showed a significant color change in B shade. The extrinsic factors responsible for color change include absorption and adsorption of staining substances subsequent to exposure to external sources [21]. In our study, understudy composite resins demonstrated a greater color change in coffee and tea compared to coke and orange juice. Color change in coffee can be due to both absorption and adsorption of staining materials. Coffee stains are yellow with low polarity and a delayed release that penetrate into the organic phase of substances. This is probably due to the compatibility of polymeric substances with yellow stains of coffee [3, 21]. This finding has been confirmed in several studies [3, 21-23]. One study has demonstrated that tea causes a greater color change than coffee. However, the type of tea used in the mentioned study was green tea [24]. Tea has yellow stains with high polarity that precipitate on the surface through ad-

sorption [3, 21]. Also, studies have revealed that black tea and tannin-containing compounds lead to chemical reactions due to the presence of denaturing factors that cause stable discoloration [25]. After placement in coke, color of composite specimens changed and the difference in color change between the two types of composite resins was not statistically significant. Coke is a yellow-brown carbonated beverage. In addition to its decolorizing effect, coke has an erosive impact on composite resins [26]. A study has shown that a slight difference in filler/resin ratio has no effect on color change of restorations in low pH and alcoholic solutions [26]. Additionally, according to another study filler volume has a linear correlation with erosion resistance [26, 27]. Similar filler volume in Spectrum and Point 4 composite resins may be responsible for no significant difference in color change between the two. Studies have failed to find a difference in color change of microhybrid composites with the same filler volume in coke [26]. Orange juice has yellow stains and affects the substances both through its staining and erosive properties [28]. The pH of coke is approximately 2.4 due to the presence of orthophosphoric and carbonic acids. The pH of orange juice is 3.8 due to the presence of citric acid. Neamat et al, in their study demonstrated that low-pH staining solutions cause chemical erosion of compomer and lead to the release of ions from its matrix. They also reported that color change was higher in coke compared to orange juice which is in agreement with the present study results [29]. Gatelan et al, in their study concluded that red wine due to its tartaric acid content, orange juice due to its citric acid content and coke due to its carbonic and phosphoric acid content can result in discoloration and staining of composite resin. They added that absorption of alcoholic molecules of these solutions into the composite resin matrix leads to smoothness of the surface and higher stainability of the composite [30]. In both understudy composite resins, the color change between A and B shades in all solutions was statistically significant except for water ($P=0.00$) as B shade showed greater change in color compared to A shade in the tested media. B shade in the Vita Shade Guide is a yellow-red and A shade is a red-brown color. The lightness of B shade is higher than that of A shade [4]. Several

studies have demonstrated that lighter colors (with a higher L) show the effect of color change more significantly in contrast with the background [16]. Manabe in 2009 indicated that color change of B1 shade of composite resin was greater than that of A1 in coffee and tea [17]. Furthermore, Vichi in 2004 revealed that B shade composite resin had a greater color change after aging in 60° water [16]. Improvement in changed color after polishing was obvious in all specimens in various solutions. However, this improvement in specimens in coffee and tea solutions still had a statistically significant difference with the baseline values ($P=0.001$). Nature of coffee and tea stains is both extrinsic and intrinsic and even by repolishing, specimens immersed in these solutions could not return to their baseline color value but markedly improved which is in agreement with the results of previous studies [23]. Surface color change due to the penetration of staining materials into the organic phase leads to internal discoloration; thus, repolishing cannot reverse the color change back to the baseline color [23]. An SEM analysis showed that coffee and tea can cause organic matrix phase destruction and consequently, some filler particles are lost in some surface areas of composite restorations [31]. Our obtained results confirmed the study hypothesis that various solutions can affect color stability of composites and this effect is variable depending on the type of composite and shade. In clinical setting, some reactions can cause color change just like in-vitro conditions. However, these changes and staining of tooth-colored restorations are less frequent under in-vivo conditions due to the washing effect of saliva and patient's oral hygiene performance [1].

Conclusion

Within the limitations of this study, we may conclude that:

- 1.Except for water, all solutions caused a significant change in color of composite resin specimens during the study period and the greatest color change was due to coffee.
- 2.In all solutions except for water and coke, color change of Spectrum composite resin was greater than that of Point 4.

3. In all solutions except for water, color change of B2 shade in both composite resins was greater than that of A2.

4. After repolishing, although a significant improvement was observed in all understudy specimens, this improvement could not reach a clinically acceptable level compared to baseline in specimens immersed in coffee and tea.

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