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Comparison of color stability of a composite resin in different color media

Mohammad Reza Malekipour[1], Ala Sharafi[1], Shantia Kazemi[2], Saber Khazaei[2], Farzaneh Shirani[3]

[1]Department of Operative Dentistry, Faculty of Dentistry, Azad University, Khorasgan (Isfahan Branch), [2]Dental Students' Research Center, [3]Dental Material Research Center and Department of Operative Dentistry, School of Dentistry, Isfahan University of Medical Sciences, Isfahan, Iran

ABSTRACT

Background: Color change of composite restorations in different color media during the time is a common problem in esthetic dentistry, causing the need to replace the restoration, and spending a great deal of cost and time to patients. The aim of this study is to investigate the effects of different common drinks consumed by patients on one of the widely used composites in dentistry.

Materials and Methods: Sixty-five disk-shaped specimens were prepared with a light-cured composite (Z100-shade A2) and divided into five groups of 13 specimens. Samples of each group were immersed in staining solutions (tea, coffee, lemonade, and cola) and distilled water (as control). Color values (L*, a*, b*) were measured relative to the standard illuminant D65 over a white background, using the CIE L*a*b* system. Color change values were calculated before and after 1, 7, and 14 days of immersion. Repeated measures and one-way analysis of variance (ANOVA) and paired t tests were applied for statistical analysis.

Results: Tea and coffee produced the most discoloration, whereas, water exhibited the least color change after immersion for 14 days in Z100 ($P < 0.05$). After one day of immersion, coffee caused the lowest discoloration in the test composite, compared to tea, cola, distilled water, and lemonade ($P < 0.05$).

Conclusion: Staining solutions and immersion time are significant factors that affect color stability of composite resins.

Key Words: Composite resin, discoloration, storage media, time

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Address for correspondence: Dr. Farzaneh Shirani, Dental Materials Research Center and Department of Operative Dentistry, School of Dentistry, Isfahan University of Medical Sciences, Hezar jerib St, Isfahan, Iran.
E-mail: fshirani48@yahoo.com

INTRODUCTION

Nowadays patients seek better color-matching restorations and composite resins to satisfy this need.[1] Hence, the proper color match to the adjacent tooth is important not only in the first period of service, but also over a longer period of time.[2] Therefore, the success of composite restorations is due to their color stability over time and one of the important criteria for the composite selection is its color stability during its service.[2-4]

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Discoloration of composite resins can be caused by internal or external factors. Internally induced discolorations are permanent and are related to polymer quality, filler type, and amount, as well as the synergist added to the photoinitiator system. In light-cured composite resins, if curing is inadequate, unconverted camphorquinone will cause a yellowish discoloration. Furthermore, other components of the photoinitiator system namely tertiary aromatic or aliphatic amines tend to cause yellow or brown discoloration under the influence of light or heat. The resin's affinity for extrinsic stains is modulated by its conversion rate and physicochemical characteristics, with the water sorption rate being of particular importance. In the oral cavity, because of superficial degradation or a slight penetration and adsorption of staining agents at the superficial layer of the composite resins, discoloration of the surface or subsurface of the resin restorations can result. Moreover, externally induced discoloration can be related to surface roughness, surface integrity, and the polishing technique.[5]

Color perception is a psychological issue and is affected by the observer's skill and may be reported differently on different occasions. To overcome such errors, color evaluating devices were employed and the data were recorded in the CIE L*a*b* system.[2] The CIE system uses three-dimensional colorimetric measurements: L* values correspond to the brightness of the color, a* values to the red–green content, and b* values to the yellow–blue content. The color changes (ΔE) are calculated from the L*, a*, and b* values for each specimen, according to the following formula, which determines the three-dimensional color space: $\Delta Elab^* = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2}$, while luminosity values (DL*) were reached using $\Delta L^* = L^*(t_x) – L^*(t_0)$, where ($t_x$) represents immersion time and (t_0) the baseline.[6] A perceptible color change that is $\Delta E^* > 1.0$ will be referred to as acceptable up to the value $\Delta E^* = 3.7$, in subjective visual determinations made *in vitro* under optimal lighting conditions.[7]

Many investigations have been done on color stability of composites in different beverages. Most of these investigations include the influence of tea and coffee on the color stability of different dental restorative materials, such as, glass ionomer cements, resin veneers, indirect composites, provisional resin materials, and compomers. Some of these experiments show that changes in color and shade are greatest in tea,[8] whereas, some indicated coffee had the most effect in color change in the samples.[9] Hence, the present study is aimed at investigating the effects of different common drinks consumed by patients on one of the common composites in dentistry (Z_{100} dental restorative composite), which has been investigated without relying on human color perception. The hypothesis of this research study is that different color media have no effect on the color stability of composite resins at different times.

MATERIALS AND METHODS

Sixty-five disk-shaped material specimens (10 mm in diameter × 2 mm in thickness) were prepared using a glass mold (ring), with the desired dimensions. The mold was placed on a glass plate and the material was condensed into the mold from the top. The composite material was delivered directly from the syringe into the ring on top of the glass plate. The material was pressed using plastic instruments and a mylar matrix cellulose strip was then placed onto the ring and pressed on the top surface of the material. The tip of a light-curing unit (Coltolux 4, Coltene / Whaledent, Inc., Mahwah, NJ, USA) was positioned at a distance of 2 mm from the material surface and each material was activated by light according to the manufacturers' instruction (Z100 3M ESPE, A2 shade / USA). Following this the composites were cured for 40 seconds using a light curing unit (coltolux 2.5-Coltene Waledent Inc./USA). To ensure adequate curing, the specimens were cured for another 20 seconds after the glass blocks were removed.[10]

The upper side of the composites was marked for color testing. In the next step the specimen surfaces were polished using grit-1000 silicon carbide paper disks (soflex-3M ESPE-Ultra thin / USA). It was expected that polishing helped with creating conditions that were closer to the clinical circumstances. Sixty-five composite specimens were randomly divided into five groups of 13 specimens, and labeled. Before placing the samples in different drinks, restoration colors were determined using a spectrophotometer. The first group was stored in distilled water to serve as control. The other groups of specimens were immersed in cola (group 2), Behnoosh Lemonade (group 3), Ahmad Tea (group 4), and Farmand Turkey Coffee (group 5). The samples were soaked in different drinks for periods of one day, seven days, and fourteen days. Prior to testing the color change with a spectrophotometer and after removing the samples from the beverages, the specimens were sanitized from contaminants with an ultrasonic cleaner (SONICA Mod 2200 mh-Soltec 230 / 240 v / ITALY), washed in distilled water for five minutes, and dried with absorbent paper towels.

The specimens' colors were measured by using a Reflective spectrophotometer (Spectroflash 600-Data Color International/ USA). The aperture size was set to 6 mm and the specimens were exactly aligned with the device. A white background was selected and measurements were made according to the CIE L*a*b* color space relative to the CIE standard illuminant D65. The color changes of the specimens were evaluated using the following formula:[11]

$$\Delta E = \left[(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2 \right]^{\frac{1}{2}}$$

Data were analyzed using the SPSS 12 Software. Repeated measures ANOVA were applied for each group separately and if it was significant, the Paired *t*-test was also applied. The analysis of variance test was used for the end color changes between different groups at different time durations. *P*-value less than 0.05 was considered as a significant level.

RESULTS

Table 1 shows that the amount of ΔE in all groups was greater than 3.3, which indicates that the storage of specimens in different color media and at different time periods causes a clinically diagnosable color change in comparison to the baseline. The highest color change was caused by tea, at different time periods, and the minimum color change was caused by water, after seven and fourteen days, and coffee after one day of submersion.

The difference between the color changes of different groups, at different time periods, was statistically significant and the paired *t* test showed that this difference in ΔE was significant between all time periods in distilled water and coffee. Also ΔE was significant between the first and seventh and the first and fourteenth day of submersion in coca-cola. One-way analysis of variance shows that color changes in each of the specified time durations among the five groups of beverages are statistically significant ($P < 0.05$). Least significant difference (LSD) Post Hoc test between groups showed that discoloration in solutions and different time periods did not follow the same pattern. On the other hand, after one day of immersion, the discoloration in coffee solution was significantly lower and after fourteen days discoloration was significantly higher in comparison to other groups. However, tea had the most discoloration for the whole time period [Figure 1].

DISCUSSION

One of the features that should be investigated and experimented over time is the color stability of the composites. This study was carried out to see whether or not the consumption of beverages at special periods, after placement of restoration, may cause changes in the composite color.

The specific objective of this study was to investigate the cumulative effect of the colorant solutions on the dental composites. For this purpose the composite resins were used for one, seven, and fourteen days of immersion treatments, because the composites remained in the oral cavity for a long time, with various staining substances, at different times and periods.

Color perception is a psychological issue and is affected by the observer's skill and may be reported differently on different occasions. To overcome such errors color evaluating devices were employed and the data were recorded in the CIE L*a*b* system.[2] In the present study the color change was compared using three values of ΔE, namely, the overall color change after a period of submersion,[12] similar to the research of Bagheri *et al*.[13,14]

The composite disks were finished using the Soft-Lex system, which has a high filler surface with higher knoop hardness, and is less susceptible to chemical degradation.[15]

It has been revealed that different beverages are the contributing factors to composite color stability. Also,

Table 1: The comparison between average color changes ΔE in each group for different time durations

Groups	Number	ΔE_1 Mean ± Standard deviation	ΔE_2 Mean ± Standard deviation	ΔE_3 Mean ± Standard deviation	Test result
1	13	6.17 ± 0.59	5.55 ± 0.39	5.39 ± 0.35	0.001
2	13	6.39 ± 0.86	6.19 ± 0.78	6.16 ± 0.04	0.02
3	13	5.97 ± 1.09	5.97 ± 1.04	5.92 ± 1.24	0.7
4	13	6.72 ± 0.74	6.98 ± 0.4	6.88 ± 0.5	0.3
5	13	4.78 ± 1.5	5.94 ± 1.22	6.78 ± 1.4	0.001

ΔE_1: is the average color change of specimens after one day of submersion, ΔE_2: is the average color change of specimens after seven days of submersion, ΔE_3: is the average color change of specimens after fourteen days of submersion the soaking time is of great importance, as it affects the composite color stability as well.[2,14] In this study, all the solutions, even distilled water, has caused discoloration in the composite resin, with ΔE higher than 3.7. The rise in the ΔE value of the control sample (distilled water), after being soaked for one day has probably been caused by the increased water absorption by the composite and departure of soluble materials from the structure.[2]

If the resin matrix is capable of absorbing water, it is also capable of absorbing any other fluid, which ultimately leads to discoloration. Water sorption is mostly due to direct absorption in the resin matrix. Glass filler particles cannot absorb water, yet they can contribute to water adsorption at the surface of the material. The level of water sorption is a function of the resin content of the material and the strength of the resin-filler interface. Extreme water sorption causes the expansion and plasticizing of the resin, which leads to reduced longevity of the composite resin and hydrolysis of saline, which in turn creates microcracks. As a result, the microcracks or the interfacial gaps at the interface, between the filler and matrix, allow stain penetration and discoloration.[9] Moreover Z_{100} is a light activated composite, which contains BIS-GMA (Bisphenol A diglycidyl ether dimethacrylate) and TEGDMA (tri ethylene glycol dimethacrylate) as the resin matrix and 66% (volume) silica / zirconia. The filler average particle size is 0.6 µm. Different studies have shown that the presence of TEG DMA in materials cause a high amount of hydrophilic capacity and more sensation of Bis-GMA to tonality and water absorption in comparison to Ultra DMA (UDMA). UDMA is more resistant to stain than Bis-GMA. Also, lower water sorption happens in the same situation.[13] Moreover, it has been noted that a composite with large filler particles are more prone to water aging discoloration than a composite with small filler particles, which is in line with the hydrolytic degradation matrix filler interfaces. Thus, a composite with large filler particles has more color permeability than a composite with small filler particles. Accordingly, we can conclude that the Z_{100} composite, in the presence of small-to-large filler particles, with a BIS-GMA and TEG- DMA resin base, is more prone to color discoloration and water sorption. Clinically, visible discoloration has been seen in all groups, even in the distilled water.[16-18]

As we know composite Z_{100} is a microhybrid composite with small and large filler particles, so after the finishing and polishing procedure, many voids are left on the composite surface, which affect its quality and also increase the external discoloration.

Adversely, according to Paravina *et al*.'s study, the apparent color difference is related to rough surfaces, which are a result of the polishing techniques of composites.[19] Polishing the composite up to Grit-1000 greatly helps to better stimulate the clinical circumstance. The results signify that the highest water sorption, and therefore, stain ability occurs during the first day in the samples that are soaked in tea. Similarly, the most water sorption and color change in the seven-day test occurs in the tea-soaked samples. After 14 days of being soaked, tea and coffee samples demonstrate essentially the same color change. The color change in tea and coffee are significantly higher compared to other drinks, which is compatible with the findings in the Bagheri *et al*. study, due to more color changes of specimens in coffee and tea solutions.[13]

In this study all solutions especially coffee, tea, and cola showed visible discoloration in composite. This is in line with the findings obtained in other investigations.[20-23] Coffee had the least and the most discoloration on the first and fourteenth day, respectively. This may be due to the delayed effect of coffee on the resin composite discoloration. Adsorption and absorption can be the cause of coffee discoloration. Coffee includes yellow color causing materials that have low polarity, which are released with delay and penetrate to the organic part of the materials, which may be due to the matching of the polymeric materials with the yellow color causing materials in the coffee. Time has been a dominating factor in a further color change in the coffee-soaked samples, as shown by different values of ΔE found over time. This finding is in confirmation with the findings of Gupta *et al*.[2]

In the present study the color change in coffee and tea drinks were essentially the same after 14 days of immersion. Tea showed the most discoloration at all times, which was similar to another study that did not study the role of coffee.[24] On account of denaturized materials in Black tea and a compound with tannins, these materials caused chemical interactions that led to stable discolorations.[25] Both tea and coffee contained yellow colorants with different polarities. Higher polarity components (like those in tea) were eluted first, while lower polarity components (like those in coffee) were eluted at a later time.

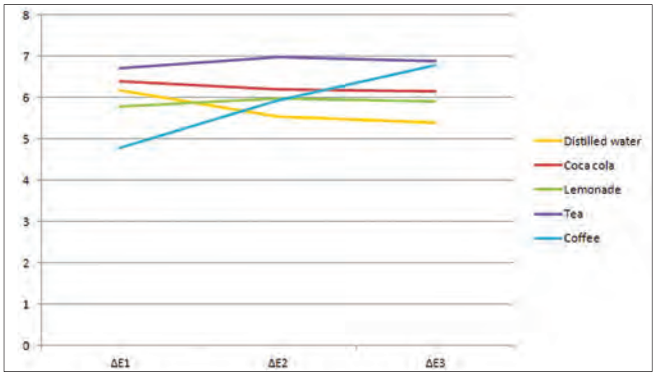

Figure 1: Illustrates comparison between color changes of five groups for different time durations

Discoloration by tea due to adsorption of polar colorants onto the surface of the resin composite materials could be removed by brushing the teeth, whereas, discoloration by coffee was due to both absorption and adsorption of the polar colorants onto the surface of materials. This adsorption and penetration of colorants into the organic phase of the materials were explained by the authors as probably being due to the compatibility of the polymer phase with the yellow colorants of coffee.

Furthermore, results of this study showed that the color change in group 2 (Coca) dropped with time. Ruyter demonstrated that cola had the lowest pH and that it might damage the surface integrity of the resin composite materials. It did not produce as much discoloration as coffee or tea, possibly due to its lack of yellow colorant.[26] Furthermore, the findings of Bagheri *et al*. also lent support to the present study, in that, coffee, tea, and red wine caused more discoloration than soy sauce and cola.[13]

The results of the present study provided information on the color stability of the Z_{100} resin composite and the staining potential of some drinks commonly consumed in daily life. Although the latter could have been well-researched and documented in previous studies, this study showed that colored solution in different time periods caused the composite's discoloration differently.

CONCLUSIONS

The color stability of Z_{100} composite restorative materials was evaluated after one, seven, and fourteen days of immersion, in various staining solutions. Within the limitations of this study, the following conclusions were drawn:

1. Filtek Z_{100} (the universal resin composite) was found to be susceptible to color change
2. For the Z_{100} resin composite restorative material tested, color change values in different color media were greater than or equal to 3.7. In other words, the color change in these staining agents was visually perceptible, as well as, clinically unacceptable. In clinical practice, patients should be aware of the staining effects of the drinks tested in this study, while practitioners should take into consideration the staining susceptibility of the resin composites.

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