

Color Stability of Resin Composites after Immersion in Different Drinks

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Received February 16, 2006/Accepted April 13, 2006

The purpose of this study was to evaluate the discoloration of two nanohybrids, two microhybrids, and a posterior composite resin restorative material upon exposure to different drinks – namely tea, cola, coffee, red wine, and water. The colors of all specimens before and after storage in the solutions were measured by a colorimeter based on CIE Lab system, and the color differences thereby calculated. Data were analyzed by two-way analysis of variance (ANOVA) and Tukey's HSD test. According to ANOVA, the restorative material, staining agent, and their interaction were found to play a statistically significant role ($P=0.0001$) in color change. Among the staining agents, water consistently showed the lowest ΔE^* value for all materials, whereas red wine showed the highest ΔE^* value. In other words, for all the materials tested, their color change in staining agents ranked in this increasing order: water < cola < tea < coffee < red wine. In terms of comparison among the five restorative materials, Filtek P60 and Z250 were observed to manifest less color change than the nanohybrids and Quadrant LC.

Key words : Color stability, Resin composite, Drink

INTRODUCTION

Composite resins have been widely used in both posterior and anterior restorations since their first introduction to the dental field. When compared to the porcelain veneers and ceramic crowns, resin composite restorations are still plagued with several significant drawbacks despite continual improvements^{1,2}. Besides polymerization shrinkage and secondary caries, plaque accumulation and color stability are some of their major problems too³.

Discoloration of composite resins can be induced internally or externally. In visible light-cured composite resin system, camphorquinone is generally used as the photoinitiator. However, if curing is inadequate, unconverted camphorquinone will cause a yellowish discoloration. Further, other components of the photoinitiator system – namely tertiary aromatic or aliphatic amines which act as so-called synergists or accelerators, they also tend to cause yellow or brown discoloration under the influence of light or heat⁴. These are internally induced discolorations which are permanent and which are related to polymer quality, filler type and amount, as well as the synergist added to the photoinitiator system^{5–7}. As dental practitioners cannot interfere in nor meddle with the content of composite resins, internal discoloration depends on the manufacturer's formulations, except due to improper light curing.

In the oral environment, be it superficial degradation or a slight penetration and adsorption of staining agents at the superficial layer of composite resins, it can cause discoloration of the surface or subsurface of resin restorations⁸. The resin's affinity

for extrinsic stains is modulated by its conversion rate and physico-chemical characteristics – with water sorption rate being of particular importance^{9,10}. Other important factors that affect stainability are surface roughness, surface integrity, and polishing technique. On this note, various finishing and polishing techniques have been examined with different types of resin composite to produce a smooth surface^{11–16}.

Previous studies concerning color stability have shown that drinks (such as coffee, tea, red wine, and cola) and mouthrinses have varying degrees of staining effect on auto- and light-cured composite resin restorative materials. The staining potential of these drinks and solutions vary according to their composition and properties^{8,10,17–19}.

Recently, nanofill composite materials have been developed. These materials use submicrometer particles (nanofillers) to further enhance the optical and physical properties of the resins. Nanofilled composites have been recommended to be suitable for both anterior and posterior restorations by manufacturers in their product advertisements, although their long-term clinical performance and color stability are yet to be known and proved^{20,21}. Further, studies that evaluate the discoloration properties of nanohybrid composites are severely lacking, such that limited dental literature is available to provide guidance on selection of nanohybrid resin composites for clinical usage.

The purpose of this study, therefore, was to evaluate the color stability of two commercially available nanohybrid resin composites, and thereby compare the results obtained against two universal

microhybrids and a posterior resin composite upon exposure to distilled water, coffee, tea, red wine, and cola.

MATERIALS AND METHODS

Staining agents and restorative materials

Five different solutions served as staining agents in this study: distilled water, coffee, tea, red wine, and cola. Restorative materials to be evaluated for their color stability were namely: one posterior resin composite (Filtek P60, 3M ESPE, Seefeld, Germany), two universal resin composites (Filtek Z250, 3M ESPE; Quadrant LC, Cavex, Haarlem, Netherlands), and two nanohybrid composite resins (Grandio, Voco, Cuxhaven, Germany; Filtek Supreme, 3M ESPE). Other details concerning the restorative materials used in this study (e.g., composition and lot number) are shown in Table 1.

Specimen preparation

Twenty-five cylindrical specimens were prepared for each resin composite material using a brass mold with a socket. Each specimen had a diameter of 15 mm and a height of 2 mm. Materials were dispensed, manipulated, and polymerized according to the manufacturers' instructions. Polymerization was carried out using Curing Light XL 3000 (3M, St Paul, MN, USA; light intensity of 400 mW/cm²) for 20 seconds with the light tip approximately 1 mm away from the specimen. For the purpose of surface standardization, all specimens were wet ground with 600-grit silicon carbide abrasive papers for 10 seconds on a 300-rpm grinding machine (Buehler Metaserv, Buehler, Germany). After which, specimens were stored in distilled water at 37°C for 24 hours.

Color change measurement

Twenty five specimens per restorative material were

divided into five groups (n=5). The colors of all specimen groups were measured before exposure (baseline) with a colorimeter (Minolta CR-300, Minolta Co., Osaka, Japan) using CIE (Commission Internationale d'Eclairage)²²⁾ L*a*b* relative to standard illuminant A against a white background. Since color difference evaluation was the focus of this study, the choice of illuminant was not important¹⁸⁾.

Before each measurement session, the colorimeter was calibrated according to the manufacturer's recommendations by using the supplied white calibration standard. L* refers to the lightness coordinate, and its value ranges from zero (black) to 100 (white). Measurements were repeated three times for each specimen, and the mean values of L*, a*, and b* were calculated. After baseline color measurements were made, each group was stored for 24 hours. Storage time of 24 hours was selected as the standard time. However, according to the manufacturer of the coffee, the average consumption time for one cup of coffee is 15 minutes, and among coffee drinkers the average consumption quantity is 3.2 cups per day. Therefore, a 24-hour storage time simulates about one month of coffee consumption.

Group W served as the control group where specimens were stored in 37°C distilled water. In Group C, specimens were stored in 37°C coffee (Nescafe Classic, Nestle, Switzerland); 3.6 g of coffee powder was dissolved in 300 ml of boiling distilled water as per the manufacturer's recommendation. After 10 minutes of stirring, the solution was filtered through a filter paper. In Group T, specimens were stored in 37°C tea (Yellow Label Tea, Lipton, Rize, Turkey). Tea solution was prepared by immersing two prefabricated tea bags (2 × 2 g) into 300 ml of boiling distilled water for 10 minutes. In Group RW, specimens were stored in 37°C red wine (Yakut, Kavaklıdere, Ankara, Turkey). In Group Co, specimens were stored in 37°C cola (Coca-Cola, The Coca-Cola Co., Is-

Table 1 Contents of composite materials used in this study

Product	Composite resin type	Composition	Lot number	Manufacturer
Filtek P60	Microhybrid	Bis-GMA, UDMA, Bis-EMA	4UL	3M ESPE AG, Seefeld, Germany
Filtek Z250	Microhybrid	Bis-GMA, UDMA, Bis-EMA	4AE	3M ESPE AG, Seefeld, Germany
Quadrant LC	Microhybrid	Bis-GMA, TEGDMA,	S010111C	Cavex, Haarlem, Netherlands
Filtek Supreme	Nanohybrid	Bis-GMA, UDMA, TEGDMA, Bis-EMA	5BW	3M ESPE AG, Seefeld, Germany
Grandio	Nanohybrid	Bis-GMA, TEGDMA, UDMA	490935	Voco, Cuxhaven, Germany

tambul, Turkey).

After 24 hours of immersion, the specimens were rinsed with distilled water for five minutes and blotted dry with tissue paper before color measurement. Colors of the specimens after storage in different solutions were measured using the colorimeter as described earlier. Color variation, ΔE^* , before and after storage in the 3-D $L^*a^*b^*$ color space was calculated as follows^{23,24}:

$$\Delta E^* = [(L_1^* - L_0^*)^2 + (a_1^* - a_0^*)^2 + (b_1^* - b_0^*)^2]^{1/2}$$

Statistical analysis

Two-way analysis of variance (ANOVA) was used to evaluate the effects of material type and staining agent on color change, including the possibility of interaction between the two factors using a statistical software (SPSS for Windows, Version 12.0.1, SPSS Inc., Chicago, IL, USA). Then, the means were compared by Tukey's HSD test ($\alpha=0.05$).

RESULTS

According to ANOVA, the restorative material, staining agent, and their interaction were found to play a statistically significant role ($P=0.0001$) in color change. The means and standard deviations of color difference of each resin composite in each staining solution are given in Table 2, as well as the differences among groups.

For all the resin composite restorative material groups, the lowest ΔE^* values were consistently observed in Group W, followed by Group Co. There were no significant differences in color difference between Group T and Group C, and these groups also demonstrated higher ΔE^* values than Group W and Group Co. The highest color difference for all the resin composite restorative materials tested was observed in Group RW.

In terms of comparison among the five different restorative materials, no significant differences were observed between the Filtek P60 and Filtek Z250 material groups. Moreover, these groups demonstrated significantly less color change than the nanohybrids

(Grandio and Filtek Supreme) and Quadrant LC (a universal resin composite) – whereby differences in color change were not significant among the latter three material groups.

DISCUSSION

Besides visual assessment, color determination in dentistry can be performed instrumentally using spectrophotometers and colorimeters²⁵. Instrumental colorimetry can potentially eliminate subjective errors in color assessment, and more importantly it is more precise than the naked eye in measuring slight differences in colored objects on flat surfaces^{26,27}. Colorimeters measure the amount of light reflected by selected colors (e.g., red, green, and blue), and color measurement is often reported using the CIELAB color system – a method developed by the Commission Internationale d'Eclairage for characterizing colors based on human perception²². In this system, the color difference value, ΔE^* , is expressed as a relative color change between repeated color measurements. In fact, CIELAB is a popular color system employed in many studies. In this system, ΔE^* value of 3.7 is considered clinically perceptible – and therefore unacceptable; as such, higher values of ΔE^* are not desirable²⁸. In the present study, color change values for all resin composite restorative materials in tea, coffee, and red wine were greater than or equal to 3.7. These values were considered visually perceptible as well as clinically unacceptable.

During color measurement, both the actual color of the surface and the lighting condition under which the surface is measured will affect the measured color¹⁸. In the present study, a standard illuminant A against a white background was used. As color difference evaluation was the focus of this study, the choice of illuminant was not important. When color is measured with an instrument that has a small window for both illumination and collection of light, a considerable fraction of the light entering the specimen is probably lost²⁹. To minimize the edge loss effect, the diameter of the specimens (15 mm) prepared in this study was greater than the aperture

Table 2 Means and standard deviations of color changes and differences between groups for composite resin restorative materials tested

Group	Mean ΔE (SD) *				
	Filtek P60	Filtek Z250	Quadrant LC	Grandio	Filtek Supreme
Group W	0.8 (0.2)	1.4 (0.3)	1.7 (0.4)	1.5 (0.4)	1.3 (0.1)
Group Co	2.5 (0.3)	2.4 (0.3)	2.8 (0.3)	2.7 (0.3)	2.3 (0.4)
Group T	3.9 (0.2)	3.4 (0.3)	4.0 (0.3)	4.3 (0.4)	4.2 (0.4)
Group C	4.3 (0.5)	4.0 (0.4)	4.5 (0.2)	4.7 (0.3)	4.6 (0.4)
Group RW	5.1 (0.3)	5.6 (0.3)	6.3 (0.3)	5.6 (0.2)	6.2 (0.3)

*: Vertical and horizontal lines connect groups that are not significantly different at $P>0.05$.

W: Water; Co: Cola; T: Tea; C: Coffee; RW: Red Wine.

size of the instrument (3 mm × 8 mm). Moreover, all measurements were done using the same measuring geometry.

The structure of a resin composite and the characteristics of particles have direct impact on surface smoothness and the susceptibility to extrinsic staining. Besides material composition, the finishing and polishing procedures may also influence the composite surface quality and are therefore linked to the early discoloration of resin composites⁸.

In the present study, difference in filler size between restoratives might have allowed the nanohybrid materials to attain a lower surface roughness value than the microhybrid counterparts. During finishing and polishing operations, filler particles might be plucked out leaving voids. It has been reported that in nanohybrids, smaller particles were shaved off and smaller voids were left on the surface as compared to the microhybrids¹⁶. According to the present study, this advantage of nanohybrids (Supreme and Grandio) did not seem to render them stain-resistant. Although surface roughness analysis of the test samples was not performed in this study, wet grinding with 600-grit SiC papers was done to standardize finishing and polishing procedures.

Results of the present study revealed that Filtek Z250 and P60 were more stain-resistant than Supreme. These three resin composites from the same manufacturer have nearly the same composition and practically the same filler loading by volume (Z 250 and P60: 60%; Supreme: 59.5%). However, agglomerated particles — so-called nanoclusters — present in Supreme seemed to be less color-resistant than the zirconia-silica micron-sized fillers present in Z250 and P60, which could be due to the former's relatively high water sorption character. In a previous study¹⁵, discoloration of Supreme and Venus (a microhybrid resin composite; Heraeus Kulzer, Germany) against black tea, coffee, and red wine — after various types of finishing and polishing operations — was evaluated. In agreement with our study, it was found that Supreme showed higher stainability than the microhybrid counterpart, especially when the surface was finished with superfine diamond bur.

The resin matrix used in the materials has also been shown to play an important role in staining susceptibility^{4,8,13,19}. Urethane dimethacrylate (UDMA) seems to be more stain-resistant than bis-GMA because of its low water absorption and solubility characteristics. It was reported that the water uptake in bis-GMA based resins increased from 3 to 6% while that in TEGDMA increased only from 0 to 1%¹⁹. The resin systems of Filtek Z250 and P60 consist of three major components: bis-GMA, UDMA, and bis-EMA. The majority of TEGDMA, a somewhat hydrophilic monomer, has been replaced with a blend of UDMA and bis-EMA. According to the

manufacturer, these resins impart a greater hydrophobicity to the resin composite. Against this background, the stain resistance capability of Z250 and P60 might be attributed to a low water sorption rate stemming from the use of hydrophobic resin system.

Filtek Supreme has almost the same matrix formulation as Filtek Z250 and P60, with the exception of containing small amounts of TEGDMA. Quadrant LC consists of both bis-GMA and TEGDMA in its matrix system, while Grandio consists of bis-GMA, TEGDMA, and UDMA. Unlike Z50 and P60, the other three resin composites tested in this study contain TEGDMA — which might be responsible for the high water absorption and discoloration rates.

The drinks tested in this study induced varying degrees of discoloration in the resin composites tested. Red wine caused the highest discoloration ($\Delta E=5.1-6.3$) in all composite materials, followed by coffee ($\Delta E=4.0-4.7$). In a previous study³, it was found that red wine caused the most severe discoloration when red wine, tea, coffee, mouthrinse, and UV irradiation were used as staining agents to evaluate the stainability of composite materials. Similarly, Guler *et al.*¹⁸ found that red wine produced the most severe discoloration in light-polymerized composite provisional restorative materials and microhybrid composites, followed by coffee, coffee with artificial creamer, and tea with sugar.

According to Um and Ruyter¹⁰, although cola had the lowest pH and that it might damage the surface integrity of resin composite materials, it did not produce as much discoloration as coffee and tea possibly due to its lack of yellow colorant. Both tea and coffee contained yellow colorants which had 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. Discoloration by tea due to adsorption of polar colorants onto the the surface of resin composite materials could be removed by toothbrushing, whereas discoloration by coffee was due to both absorption and adsorption of 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 due to compatibility of the polymer phase with the yellow colorants of coffee¹⁰. Further, the findings of Bagheri *et al.*¹⁹ also lent support to the present study in that coffee, tea, and red wine caused more discoloration than soy sauce and cola.

The results of the present study provided information on the color stability of resin composites (including the recently introduced nanohybrid composites) and the staining potential of some drinks commonly consumed in daily life. While the latter could have been well researched and documented in previous studies, this study showed that nanohybrids

did not exhibit superior stain resistance against these beverages.

CONCLUSIONS

The color stability of five composite restorative materials was evaluated after 24 hours of immersion in various staining solutions. Within the limitations of this study, the following conclusions were drawn:

1. Filtek P60 (posterior resin composite) and Filtek Z250 (universal resin composite) – which did not contain TEGDMA – were found to be more color-stable than the materials which contained TEGDMA: Filtek Supreme and Grandio (nanohybrid resin composites), as well as Quadrant LC (universal resin composite).

2. For all resin composite restorative materials tested, their color change values in tea, coffee, and red wine were greater than or equal to 3.7. In other words, their color change in these staining agents was visually perceptible as well as clinically unacceptable.

It is noteworthy that materials which contained TEGDMA showed higher discoloration values, meaning that TEGDMA was responsible for the discoloration due to its hydrophilic character. 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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