Original Article

DOI: 10.14235/bas.galenos.2022.86719
Bezmialem Science 2023;11(2):213-20

Effect of Translucency on Color Stability of Resin-based Composites

Yarı Saydamlığın Rezin Bazlı Kompozitlerin Renk Stabilitesi Üzerindeki Etkisi

Nevin ÇOBANOĞLU[1], Fatma SAĞ GÜNGÖR[1], Omar Faezabdulateef ABDULATEEF[2], Mehmet Semih VELİOĞLU[3], Elif Can ŞİMŞEK BALABAN[1]

[1]Selçuk University Faculty of Dentistry, Department of Restorative Dentistry, Konya, Turkey
[2]Ministry of Health, Al-anbar General Health Directorate, Fallujah Specialist Dental Center, Iraq
[3]Beyhekim Oral and Dental Health Center, Konya, Turkey

ABSTRACT

Objective: This study evaluated the effect of translucency on the color stability of resin-based composites (RBCs).

Methods: Different translucent/opaque shades of RBCs were used: Filtek Ultimate (FU); A2 Enamel, A2 Dentin, A2 Body, IPS Empres Direct (IED); A2 Enamel, A2 Dentin, GC Essentia (GC); LE, MD, Estelite Σ Quick (EQ); OA2, A2, CeramX duoSphertec and One (CX); E2, D2, A2. Disc-shaped specimens were stained in coffe and then brushed. The color changes (ΔE) were calculated between baseline and treatment. One-way ANOVA and Tukey's post-hoc test were used for statistical analysis (α=0.05).

Results: After staining, the difference between the ΔE values of RBCs was not statistically significant, except GC LE. After both staining and brushing, the ΔE values of the enamel shades were the highest, and the order of ΔE values was body > dentin for ESQ and CX, dentin > body for FU.

Conclusion: The ΔE values of the enamel shades were the highest after both staining and brushing.

Keywords: Composite resin, color stability, translucency, whitening toothpaste, toothbrush

ÖZ

Amaç: Bu çalışmada, yarı saydamlığın rezin bazlı kompozitlerin (RBC) renk stabilitesi üzerindeki etkisi değerlendirildi.

Yöntemler: RBC'lerin farklı yarı saydam/opak tonları kullanıldı: Filtek Ultimate (FU); A2 Mine, A2 Dentin, A2 Body, IPS Empres Direct (IED); A2 Mine, A2 Dentin, GC Essentia (GC); LE, MD, Estelite Σ Hızlı (EQ); OA2, A2, CeramX duoSphertec ve One (CX); E2, D2, A2. Disk şeklindeki numuneler kahve ile renklendirildi ve daha sonra fırçalandı. Renk değişiklikleri (AE), başlangıç ve tedavi sonrası olarak hesaplandı. İstatistiksel analiz için one-way ANOVA ve Tukey post-hoc testleri kullanıldı(α=0,05).

Bulgular: Renklenmeden sonra, RBC'lerin ΔE değerleri arasındaki fark, GC LE dışında istatistiksel olarak anlamlı bulunmadı. Hem renklendirme hem de fırçalama sonrasında en yüksek ΔE değerleri mine renklerinde görüldü ve ΔE değerlerinin sırası ESQ ve CX için body > dentin, FU için ise dentin > body şeklinde bulundu.

Sonuç: En yüksek ΔE değerleri hem renklenme hem de fırçalama sonrasında mine renklerinde görüldü.

Anahtar Sözcükler: Kompozit rezin, renk stabilitesi, yarı saydamlık, beyazlatıcı diş macunu, diş fırçası

Introduction

The general aesthetic understanding prefers natural looking aesthetics as much as possible (1). To achieve ultimate aesthetics, restorations should mimic not only the color of the natural tooth but also the translucency. Its translucency provides a "lifelike" vitality and a natural appearance to the completed restoration (2). For this reason, composite resin manufacturers produce resins with

Address for Correspondence: Elif Can ŞİMŞEK BALABAN, Selçuk University Faculty of Dentistry, Department of Restorative Dentistry, Konya, Turkey
E-mail: simsekelifcan@gmail.com **ORCID ID:** orcid.org/0000-0003-0105-2390

Received: 01.06.2022
Accepted: 09.12.2022

Cite this article as: Çobanoğlu N, Sağ Güngör F, Abdulateef OF, Velioğlu MS, Şimşek Balaban EC. Effect of Translucency on Color Stability of Resin-based Composites. Bezmialem Science 2023;11(2):213-20

different colors and different translucency/opaque shade options. In some cases, it is sufficient to use only a universal composite resin to create a natural looking restoration. However, in some cases, more opaque composite resins are required to mask the composite resin-tooth interface, hide the dark background of the oral cavity, cover tooth tissue that appears darker than normal, and recreate the high value needed in the center of the tooth (3). Although these opaque composite resins (dentin) sometimes remain on the buccal surfaces of restorations, they are often coated with translucent (enamel) because of the terminology "dentin" and "enamel" used for different pastes of resin-based composites. In addition, translucent resins are used to enrich the optical properties of the incisal area of the tooth.

In addition to accurately imitating the optical properties of natural teeth with restorative materials, the color stability of these restorations is also very important for clinical success (4). Some intrinsic and extrinsic factors affect color stability in resin-based composites. Chemical changes within the material, such as oxidation of unreacted monomers and photoinitiator components that are not consumed during photopolymerization (5), hydrolysis of silane between filler particles and polymer matrix (6), are the causes of intrinsic discoloration. Diffusion of ions and pigments that can accumulate on the composite resin causes extrinsic discoloration (7). Diet and oral hygiene habits significantly affect the color stability of composite resins (8,9). The translucency property of composite resins depends on many factors affecting the chemical composition of the composites, such as filler content, particle composition, monomer properties, and minor pigment additions (10,11). These factors can also affect their coloration stability. On the other hand, it is speculated that the highly translucent character may compromise the optical stability, since pigments and oxidized unreacted species may become more apparent in the bulk of the restoration (12). There are many studies in the literature investigating the color stability of composites. However, there are very few studies evaluating the effects of translucency in composites on color stability (3,12).

The aim of this study was to determine the color stability of five different trademark resin-based composite systems in the different available translucent/opaque shades. The hypotheses of this study were that:

1. There is no difference between the color stability of resin based composites subjected to coffee solution.

2. There is no effect of translucency within each brand on color stability.

3. There is no difference between the color stability of the resin based composites subjected to tooth-brushing simulation.

Methods

In this study, five commercially-available resin based composites indicated for aesthetic restorations were selected in different translucent/opaque shades: Filtek Ultimate (FU); A2 Enamel, A2 Dentin, A2 Body, IPS Empres Direct (IED); A2 Enamel, A2 Dentin, GC Essentia (GC); LE (Enamel), MD (Dentin), Estelite Σ Quick (EQ); OA2 (Dentin), A2 (Body), Ceram X duo Sphertec (CX); E2 (Enamel), D2 (Dentin), Ceram X One (CX); A2 (Body). The compositions and manufacturers of the resin based composites used are included in Table 1.

Fourteen disc-shaped specimens were made for each composite resin using a cylindrical polytetrafluoroethylene (teflon) mold of 8-mm inner diameter and 2-mm thickness. After composite insertion, top surface was covered with a Mylar strip and made flat by pressing down with a glass slab. The specimens were light activated for 30 s from the top surface using a large spectrum (385-515 nm) light emitting diode curing unit (Blue lex LD-105, Monitex Industrial Co, Taiwan) with irradiance of 1,200 mW/cm^2. The samples were stored in dry/dark condition for 24 h. Then, they were polished with OneGloss (Shofu) polishing rubbers containing aluminum oxide particles that provided finishing and polishing by changing the application pressure only in one step.

Then the samples were randomly divided into two groups as staining and non-staining (n=7). The samples in the non-staining group were kept in water for 3 weeks. The samples in the staining group, after 1 week water storage, immersed in coffee solution (Nescafe Gold Nestl´e, Suisse S.A. Switzerland, Batch-01740202A) for 45 minutes a day and in water at other times for 2 weeks (13,14). Coffee solution was preferred as it was one of the most consumed beverages worldwide as a coloring solution. The coffee manufacturer states that the average time for consumption of one cup of a drink is 15 min, and, among coffee drinkers, the average consumption of coffee is 3.2 cups per day. Thus approximately 14 days of coloration was simulated. The coffee solution was obtained by adding a spoonful of soluble coffee to 250 mL of boiled water, followed by stirring and cooling to room temperature. The solution was then inserted in 96- well eppendorf plates with the specimens and daily prepared.

The samples in the staining group, after staining with coffee solution for 2 weeks , were brushed with an electrical toothbrush (Oral-B Professional, Braun, Frankfurt, Germany) fixed on a holder and with a whitening toothpaste (Colgate Optic White, Colgate-Palmolive, Poland) with a paste-to-water ratio of 1:1 for 45 second. The content of the toothpaste used in the study is shown in Table 1. The average brushing time was assumed to be 120 seconds twice a day, which equated to approximately 3 seconds of brushing a tooth surface per day. According to this calculation, brushing for 45 seconds could be equal to approximately 2 weeks of brushing as in our staining period.

The color of specimens was measured with a VITA Easyshade V (VITA Zahnfabrik, Bad Säckingen,Germany) spectrophotometer, calibrated before starting and after the measurement of every 10 samples. The diameter of the measuring tip was 6 mm. Composite discs were placed on a flat White surface. The spectrophotometer tip was always placed perpendicularly to the disc surface (7). Measurements were made from the center of the samples each time, with the measuring tip of the device right in the middle. Color measurement of the all samples was made at baseline (after 24 h of specimen's curing and dry/dark storage). Then, it was made after 3 weeks of immersion in water in the non-staining group, and it was made at the end of the coloring period with coffee and after brushing it was repeated in the staining group. Before the color was measured, the specimens were washed in water for 1 min and dried with tissue paper. The color measurement of each specimen was repeated three times by a single operator, and the mean of the three readings was taken. The variation in color was established based on the coordinates: L (lightness, 0-100), a (-a* = green, +a* = red) and b (-b* = blue, +b* = yellow) of the CIEL*a*b* scale. The color changes of the samples were evaluated with the ΔE * parameter calculated using L, a and b values. The ΔE * value is the color change that an observer can detect after the application and in time intervals. This value alone is more significant than L, a, b values.

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

$\Delta L^* = L2-L1$

$\Delta a^* = a2-a1$

$\Delta b^* = b2-b1$

ΔE were calculated between baseline and after the treatments.

Statistical Analysis

The SPSS 15.0 package program (SPSS Inc., Chicago, IL, USA) was used for statistical analysis of the data. First of all, whether the data showed normal distribution and the homogeneity of the variances were checked. Since the data showed normal distribution and the variances were homogeneous, the one-way analysis of variance (One-Way ANOVA), a parametric test method, was used for the statistical evaluation of the color change (ΔE) data of the samples. Tukey HSD test was used to compare the differences between groups.

Results

The standard deviations and mean of ΔE values are shown in Table 2 and Figure 1.

Table 1. Composition of the commercially available resin-based composites and toothpaste used in this study

Material	Components	Filler content % (w/w)	Manufacturer
Essentia	Matrix: UDMA, Bis-MEPP, Bis-EMA, Bis-GMA, TEGDMA Filler: prepolymerised fillers, barium glass, fumed silica	81	GC Corporation, Tokyo, Japan
IPS empress direct	Matrix: UDMA, Bis-GMA, TEGDMA Filler: Barium glass, ytterbium trifluoride, and mixed oxides (0.5 μm)	81.2	Ivoclar Vivadent; Schaan, Liechtenstein
Tokuyama Estelite Σ Quick	Matrix: Bis-GMA, Bis-MPEPP, TEGDMA, UDMA Filler: Supra-nano Spherical filler (200nm spherical SiO2-ZrO2), Composite Filler (include 200nm spherical SiO2-ZrO2).	82	Tokuyama Dental corporation, Taitou-ku Tokyo, Japan
Ceram.X one Universal	Matrix: methacrylate modified ploysiloxane, dimethacylate resin, ethyl4 (dymethylamino)benzoate Filler: Barium-aluminium borosilicate glass (1.1-1.5 μm), Methacrylate functionalized silicon dioxide nano filler (10 nm)	76	Dentsply De Trey, Konstanz, Germany
Ceram X Duo Sphertec	Matrix:Methacrylate modified polysiloxane, dimethacrylate resin, ethyl4(dimethylamino)benzoate, Fillers: barium aluminium-borosilicate glass, methacrylate functionalized silicon dioxide nano filler,	76	Dentsply De Trey, Konstanz, Germany
Filtek Utimate	Matrix: Bis-GMA, UDMA, TEGDMA, bis-EMA and PEGDMA resins Filler: Silica, zirconia and aggregated zirconia/silica cluster fillers, 0.6 – 10 μm in size	78.5	3M ESPE, Seefeld, Germany
Colgate Optic White	Sodium monofluorophosphate (1300 ppm flüoride), propylene glycol, calcium pyrophosphate, glycerin, PEG/PPG-116/66 copolymer, PEG-12,PVP, silica, flavor, sodium lauryl sulfate, tetrasodium pyrophosphate, hydrogen peroxide, disodium pyrophosphate, sodium saccharin, sucralose, BHT		Colgate, Palmolive, Poland

UDMA: Urethane dimethacrylate, Bis-MEPP: Bisphenol a ethoxylate dımethacrylate, BIS-EMA: Ethoxylated bisphenol A glycol dimethacrylate, Bis-GMA: Bisphenol A diglycidyl methacrylate, TEGDMA: Triethylene glycol dimethacrylate, PEGDMA: Polyethylene glycol dimethacrylate

After storage in water, there was a color change between the baseline and post- immersion period for all composite resins. CX A2 resins showed the least color change and FU Dentin showed the most color change. Although the difference between these two resins was statistically significant, the differences between the other resins were not statistically significant.

Coffee staining caused statistically significantly more coloration for all resin-based composites compared to samples stored in water. GC Enamel stained more than all resins. The difference between the ΔE values of other composite resins except GC Enamel was not statistically significant.

After brushing, except CX dentin, the ΔE values for all composite resins were lower than the ΔE values after staining, but higher than the ΔE values of water storage group. ΔE values of GC enamel and IED enamel were statistically significantly higher than other resins.

When composite resins of the same brand were compared within themselves, the color change values of the enamel shades were the highest after both staining and brushing, for all commercial brands, except CX enamel after staining. The amount of color change of dentin and body shades differed according to the brands. Although the difference between them was not

Table 2. Resuts for color difference (ΔE) considering three periods: ΔE 1 (baseline and water storage) ΔE 2 (Baseline and coffee solution storage) and ΔE 3 (baseline and brushing). Values are given as means ± standard deviations (n=7). Different letters show statistically significant differences ($p<0.05$), uppercase letters indicate columns; lowercase letters point to lines

Estelite Σ quick	ΔE 1	ΔE 2	ΔE 3
A2 (body)	1.84±0.79 Aabc	8.73±3.66 Ba	4.96±2.03 Cab
OA2 (dentin)	1.26±0.27 Aabc	7.53±1.39 Ba	3.55±1.29 Ca
Filtek ultimate			
A2 (body)	1.06±0.42 Aabc	8.13±3.39 Ba	2.82±1.30 Ca
A2 (dentin)	2.21±0.86 Ab	8.65±2.24 Ba	4.29±1.01 Ca
A2 (enamel)	2.03±1.19 Aabc	10.30±2.27 Ba	5.19±2.24 Cab
IPS empres direct			
A2D (dentin)	1.40±0.41 Aabc	8.53±2.02 Ba	4.51±1.88 Cab
A2E (enamel)	1.64±0.90 Aabc	9.82±2.71 Ba	7.51±2.49 Bbc
Ceram X			
D2 (dentin)	1.54± 0.83 Aabc	9.95±2.85 Ba	3.30±1.58 Aa
E2 (enamel)	1.22±0.56 Aabc	9.15±2.10 Ba	5.56±1.76 Cab
A2 (body)	0.85±0.45 Ac	11.13±3.32 Ba	5.12±1.23 Cab
GC essentia			
MD (dentin)	1.89±0.70 Aabc	10.75±2.36 Ba	4.75±1.34 Cab
LE (enamel)	1.78±0.56 Aabc	19.07±1.78 Bb	9.86±2.09 Cc

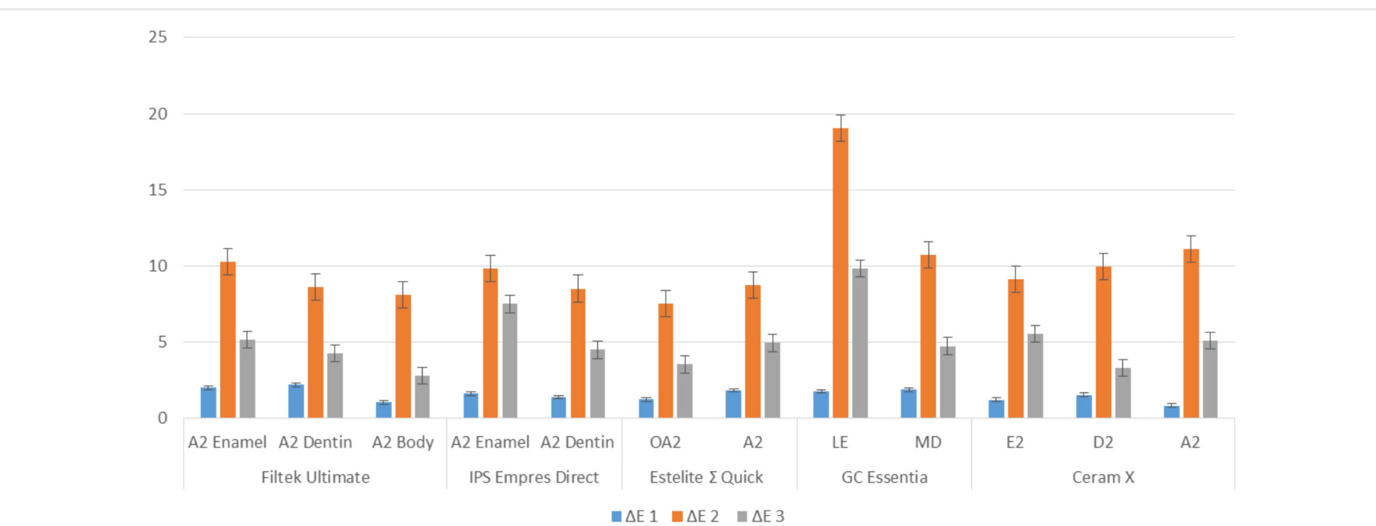

Figure 1. Results for color difference (&8710;E) considering three periods: &916;E 1 (baseline and water storage) &916;E 2 (Baseline and coffee solution storage) and &916;E 3 (baseline and brushing). Values are given as means ± standard deviations

statistically significant, the order of ΔE values in both staining and brushing groups was body > dentin for ESQ and CX and it is dentin > body for FU.

Discussion

In the present study, the color stability of composite resins and the effect of translucency on the color stability were evaluated. For this purpose, resin-based composite systems of different brands and their different translucent/opaque shades were used.

In order to evaluate the color stability of composite resins, some samples were stored in water. Because the color change in composite resins with immersion in water was reported in previous studies (15-17). Similarly to these studies, there was a color change between the baseline and post- water immersion period in the present study.

There is no colorant in the water, but a color change occurs as a result of the absorption of water into the resin matrix (18). The refractive indexes of the polymer and water are different from each other, altering the light transmission after water accesses the polymer structure and leading to changes in color perception (19). On the other hand, it has been previously reported that in resin based composites, color change may occur as a result of oxidation of unreacted monomers held in the polymer network and photoinitiators that are not consumed during exposure to light (5). The release of these components causes color change when placed in an aqueous environment (5,20,21).

In the present study, after storage in water, CX A2 resins showed the least color change and FU Dentin showed the most color change. Although the difference between these two resins was statistically significant, the differences with the other resins were not statistically significant. Sideridou et al. (22) reported that the hydrophilicity of resin was in the following order: TEGDMA > Bis-GMA > UDMA and Bis-EMA. The reason CX A2 shows the least color change may be related to a low water absorption rate due to the absence of TEGDMA. In fact, both Ceram X sphertec one and duo do not contain TEGDMA. However, even small chemical differences such as pigment additions that can affect the translucency of dental resin-based composites can affect the stability of coloration (10,11).

Chen attributed the discoloration of nano-composites to their clusters that had a much larger surface area per unit mass, which might cause staining when their interface was not perfectly silanized and integrated into the resin (23). Ertaş et al. (24) found that FU nanofill composite demonstrated more color changes than composites of the same manufacturer with nearly the same composition and practically the same filler loading by volume. They stated that this might be due to the relatively high water absorption character of the agglomerated particles and nanoclusters present in Filtek Ultimate.

Water storage alone does not cause more than one point of color change (25). However, chemical changes in the material may lead to a decrease in the resistance to staining (26). Excessive water absorption causes the deformation of the resin structure and the formation of microcracks by hydrolysis of silane. Subsequently, the dyeing agents can seep into the microcracks between the filler-resin matrix and the interfacial spaces and cause discoloration (27). Changes in the formulation of composite resins, such as organic matrix components, amounts and sizes of inorganic filler particles, affect water absorption and therefore color stability.

The changes in formulations of resin-based composites, including organic matrix components, amounts and sizes of inorganic filler particles, affect their water absorption and hence color stability.

On the other hand the most important factor causing extrinsic discoloration of composite resins is surface roughness, which causes biofilm accumulation. Good finishing and polishing operations reduce surface roughness. There are important studies in the literature suggesting that aluminum oxide discs can be used to obtain smoother surfaces because they abrade filler particles and resin matrices at the same rate (28,29). Barbosa et al. (30) stated that they might be acceptable as a clinical standard for polishing composites. In this study, OneGloss (Shofu) polishing rubbers containing aluminum oxide particles were used but the surface roughness of the samples was not measured.

Coffee has been shown to cause significant color change in composite resins in some previous studies (3,12). As coffee is a dark solution, it has a large amount of pigment that can accumulate in the structure of the restorative, absorbing more light and causing more opacity by increasing light diffusion (31). Similarly, in the present study, coffee caused statistically significantly more coloration for all resin-based composites compared to samples stored in water. GC Enamel stained more than all resins. Therefore, the first hypothesis of our study was rejected. In other words, a difference was found between the color stability of the composite resins subjected to the staining process. The difference between the ΔE values of other composite resins except GC Enamel was not statistically significant.

The samples in some studies were not kept in continuing contact with the staining solution, to reflect the clinical situation more closely (32,33). Similarly, in this study, samples were kept in coffee solution for forty five minutes a day, and in distilled water for the rest of the day. Then, the samples subjected to coffee staining for 14 days were brushed for 45 seconds with an electrical toothbrush and whitening toothpaste. Whitening toothpastes remove extrinsic stains on the tooth surface by means of some abrasive and whitening substances. Generally, commercial whitening toothpastes use pyrophosphate as the whitening agent, but Colgate Optic White toothpaste also contains hydrogen peroxide. It also contains silica as an abrasive (34).

In this study, the translucency of the resins was not measured, but generally the resins ranged from less translucent to more translucent in the order of opaque, dentin, body, enamel (12). In the present study, GC Enamel was statistically significantly more stained with coffee than GC Dentine. Thus, the second hypothesis of our study was also rejected. In other words, translucency affected the color stability of resin based composites.

The third hypothesis of our study was also rejected. Because, after brushing, ΔE values of GC Enamel and IED Enamel were statistically significantly higher than other resins.

When composite resins of the same brand were compared within themselves, the color change values of the enamel shades were the highest after both staining and brushing, for all commercial brands, except CX enamel after staining. These results are consistent with the results of the study of Salgado et al. (3) in which they found that high translucent materials had the lowest color stability for all commercial composite brands they used in their study.

These results may be related to the protocol of the study. In the present study, all surfaces of the samples were exposed to coffee solution and color measurements were made on a white background. Since the enamel shades were more translucent, it might cause the stains on the back of the samples to be determined more than opaque resins. This speculation may be more likely for the period after brushing in which the stains on the upper surface of the specimens have been removed. In this study, also the ΔE values of IED Enamel were not statistically different from other resins after staining, but were higher after brushing. In compatible with this explanation, in a study evaluating the translucency of resins, lower lightness, lower croma, higher hue presented by more translucent shades were associated with the increased black background effect as a result of the increased translucency (3).

Additionally, another study showed that less chromatic composite resin shades tended to have less color stability than shades that were more chromatic (35). It was stated that pigments and unreacted and subsequently oxidized contents might compromise optical stability due to the possibility that they became more pronounced in resins with high translucency (12).

On the other hand, the translucency of composites is determined by macroscopic phenomena such as monomer properties, content and composition of filler particles, as well as relatively small pigment additions and potentially all other chemical components (10). These chemical differences that affect the translucency can also affect the color stability of the resins.

The amount of color change of dentin and body shades differed according to the brands. When composite resins of the same brand were compared within themselves, although the difference between them was not statistically significant, the order of ΔE values in both staining and brushing groups was body > dentin for ESQ and CX and it is dentin > body for FU.

Except CX Dentin, the ΔE values after brushing for all composite resins were lower than the ΔE values after staining, but higher than the ΔE values of water storage group. In other words, brushing with whitening toothpaste removed some of the coffee discoloration, but failed to achieve the color change values in samples not subjected to coffee solutions. Although this result was also valid for opaque resins such as dentin, which might prevent the discoloration of the back surface of the sample from being seen, the reason for these results might be that the lower surfaces of the samples were not brushed. Another reason for these results may be that as Jonier states, although it is possible to remove the external stain by brushing, internal stains may remain (36).

Surface roughness of a sample affects instrumental color coordinates. Under diffuse reflection conditions measured by spectrophotometer, resin composites with a rough surface appear lighter and less chromatic than those with a smooth surface (37). In our study, even 14 days of brushing simulation may have increased the surface roughness and had an effect on color change. Studies in the literature have generally examined the effect of long-term tooth brushing simulations on the surface roughness of composite resins (38-40). In a study, different color and surface roughness values were observed in composite resins that were subjected to tooth brushing in situ with a whitening toothpaste for a relatively short time (90 days) as in our study (41). In the same study, it was reported that whitening toothpastes were not associated with color change on the composite. However, the abrasiveness of whitening toothpastes affects the surface roughness of different restorative materials.

It is also important to state that in vitro studies have limitations. In this in vitro study, different translucent/opaque shades were evaluated separately, but it should be aware that the use of different pastes by layering will change the current outcomes. In addition, there are many variables that can affect the overall appearance and color stability of the restorations, such as the operator's knowledge and skills regarding the restorative procedure, and the patient himself/herself eating and staining beverages' consumption habits and oral hygiene habits.

Study Limitations

The limitation of this study was that color measurements made on a white background were more likely to cause stains on the back of the samples to be detected more than opaque resins, due to the more transparent enamel tones.

Conclusion

Storage in water had minor effects on color stability, while subjected to coffee had a more important effect. There was no significant difference in color stability between resin-based composite brands. The translucent shades of the same brand, enamel shades, showed the greatest color changes, but the amount of color change of dentin and body shades differed according to the brands. The color change values of the samples subjected to the coffee solution decreased significantly after brushing with the whitening toothpaste, but these values were still greater than the color change values of the samples not subjected to the coffee solution.

Ethics

Ethics Committee Approval: *In vitro* study.

Informed Consent: *In vitro* study.

Peer-review: Externally peer reviewed.

Authorship Contributions

Concept: N.Ç., F.S.G., O.F.A., M.S.V., E.C.Ş.B., Design: N.Ç., F.S.G., O.F.A., M.S.V., E.C.Ş.B., Data Collection or Processing: N.Ç., F.S.G., O.F.A., M.S.V., E.C.Ş.B., Analysis or Interpretation: N.Ç., F.S.G., O.F.A., M.S.V., E.C.Ş.B., Literature Search: N.Ç., F.S.G., O.F.A., M.S.V., E.C.Ş.B., Writing: N.Ç., F.S.G., O.F.A., M.S.V., E.C.Ş.B.

Conflict of Interest: No conflict of interest was declared by the authors.

Financial Disclosure: The authors declared that this study received no financial support.

References

1. Yu B, Ahn JS, Lee YK. Measurement of translucency of tooth enamel and dentin. Acta Odontol Scand 2009;67:57-64.
2. Lee YK, Powers JM. Calculation of colour resulting from composite/compomer layering techniques. J Oral Rehabil 2004;31:1102-8.
3. Salgado VE, Rego GF, Schneider LF, Moraes RR, Cavalcante LM. Does translucency influence cure efficiency and color stability of resin-based composites? Dent Mater 2018;34:957-66.
4. Arimoto A, Nakajima M, Hosaka K, Nishimura K, Ikeda M, Foxton RM, et al. Translucency, opalescence and light transmission characteristics of light-cured resin composites. Dent Mater 2010;26:1090-7.
5. Albuquerque PP, Moreira AD, Moraes RR, Cavalcante LM, Schneider LF. Color stability, conversion, water sorption and solubility of dental composites formulated with different photoinitiator systems. J Dent 2013;41(Suppl 3):67-72.
6. Vichi A, Ferrari M, Davidson CL. Color and opacity variations in three different resin-based composite products after water aging. Dent Mater 2004;20:530-4.
7. Dietschi D, Campanile G, Holz J, Meyer JM. Comparison of the color stability of ten new-generation composites: an in vitro study. Dent Mater 1994;10:353-62.
8. Omata Y, Uno S, Nakaoki Y, Tanaka T, Sano H, Yoshida S, et al. Staining of hybrid composites with coffee, oolong tea, or red wine. Dent Mater J 2006;25:125-31.
9. Yesilyurt C, Yoldas O, Altintas SH, Kusgoz A. Effects of food-simulating liquids on the mechanical properties of a silorane-based dental composite. Dent Mater J 2009;28:362-7.
10. Kim JH, Lee YK, Powers JM. Influence of a series of organic and chemical substances on the translucency of resin composites. J Biomed Mater Res B Appl Biomater 2006;77:21-7.
11. Johnston WM, Ma T, Kienle BH. Translucency parameter of colorants for maxillofacial prostheses. Int J Prosthodont 1995;8:79-86.
12. Piccoli YB, Lima VP, Basso GR, Salgado VE, Lima GS, Moraes RR. Optical stability of high-translucency resin-based composites. Oper Dent 2019;44:536-44.
13. Mundim FM, Garcia Lda F, Pires-de-Souza Fde C. Effect of staining solutions and repolishing on color stability of direct composites. J Appl Oral Sci 2010;18:249-54.
14. Tuncer D, Karaman E, Firat E. Does the temperature of beverages affect the surface roughness, hardness, and color stability of a composite resin? Eur J Dent 2013;7:165-71.
15. Gianordoli-Neto R, Padovani GC, Mondelli J, de Lima Navarro MF, Mendonça JS, Santiago SL. Two-year clinical evaluation of resin composite in posterior teeth: A randomized controlled study. J Conserv Dent 2016;19:306-10.
16. Buchalla W, Attin T, Hilgers RD, Hellwig E. The effect of water storage and light exposure on the color and translucency of a hybrid and a microfilled composite. J Prosthet Dent 2002;87: 264-70.
17. Çelık EU, Aladağ A, Türkün LŞ, Yilmaz G. Color changes of dental resin composites before and after polymerization and storage in water. J Esthet Restor Dent. J Esthet Restor Dent 2011;23:179-88.
18. Venz S, Dickens B. NIR-spectroscopic investigation of water sorption characteristics of dental resins and composites. J Biomed Mater Res 1991;25:1231-48.
19. Ikeda T, Sidhu SK, Omata Y, Fujita M, Sano H. Colour and translucency of opaque-shades and body-shades of resin composites. Colour and translucency of opaque-shades and body-shades of resin composites. Eur J Oral Sci 2005;113:170-3.
20. Albuquerque PP, Bertolo ML, Cavalcante LM, Pfeifer C, Schneider LF. Degree of conversion, depth of cure, and color stability of experimental dental composite formulated with camphorquinone and phenanthrenequinone photoinitiators. J Esthet Restor Dent 2015;27(Suppl 1):49-57.
21. Ferracane J, Berge H, Condon JR. In vitro aging of dental composites in water--effect of degree of conversion, filler volume, and filler/matrix coupling. J Biomed Mater Res 1998;42:465-72.
22. Sideridou I, Tserki V, Papanastasiou G. Effect of chemical structure on degree of conversion in light-cured dimethacrylate-based dental resins. Biomaterials 2002;23:1819-29.
23. Chen MH. Update on dental nanocomposites. J Dent Res 2010;89:549-60.
24. Ertaş E, Güler AU, Yücel AC, Köprülü H, Güler E. Color stability of resin composites after immersion in different drinks. Dent Mater J 2006;25:371-6.
25. Burrow MF, Makinson OF. Color change in light-cured resins exposed to daylight. Quintessence Int 1991;22:447-52.
26. Yap A, Low JS, Ong LF. Effect of food-simulating liquids on surface characteristics of composite and polyacid-modified composite restoratives. Oper Dent 2000;25:170-6.
27. Mair L. Staining of in vivo subsurface degradation in dental composites with silver nitrate. J Dent Res 1991;70:215-20.
28. Herrgott AM, Ziemiecki TL, Dennison JB. An evaluation of different composite resin systems finished with various abrasives. J Am Dent Assoc 1989;119:729-32.
29. van Dijken JW, Ruyter IE. Surface characteristics of posterior composites after polishing and toothbrushing. Acta Odontol Scand 1987;45:337-46.
30. de Souza FB, Guimarães RP, Silva CH. A clinical evaluation of packable and microhybrid resin composite restorations: one-year report. Quintessence Int 2005;36:41-8.

31. Tan BL, Yap AU, Ma HN, Chew J, Tan WJ. Effect of beverages on color and translucency of new tooth-colored restoratives. Oper Dent 2015;40:56-65.
32. Bezgin T, Özer L, Tulga Öz F, Özkan P. Effect of toothbrushing on color changes of esthetic restorative materials. J Esthet Restor Dent 2015;27(Suppl 1):65-73.
33. Nasim I, Neelakantan P, Sujeer R, Subbarao CV. Color stability of microfilled, microhybrid and nanocomposite resins--an in vitro study. J Dent 2010;38(Suppl 2):137-42.
34. Simões ACCD, Dionizio A, Câmara JVF, Sabino-Arias IT, Levy FM, Ventura TMO, et al. Do commercial whitening dentifrices increase enamel erosive tooth wear? J Appl Oral Sci 2020;28:e20190163.
35. Mutlu-Sagesen L, Ergün G, Ozkan Y, Semiz M. Color stability of a dental composite after immersion in various media. Dent Mater J 2005;24:382-90.
36. Joiner A. Whitening toothpastes: a review of the literature. J Dent 2010;38(Suppl 2):17-24.
37. Powers JM, Dennison JB, Lepeak PJ. Parameters that affect the color of direct restorative resins. J Dent Res 1978;57:876-80.
38. Halis G, Köroğlu A, Şahin O, Dede DÖ, Yilmaz B. Effect of simulated tootbrushing on surface roughness of sealant agent coupled nanohybrid composite resins. J Esthet Restor Dent 2022;34:907-14.
39. Kamonkhantikul K, Arksornnukit M, Takahashi H, Kanehira M, Finger WJ. Polishing and toothbrushing alters the surface roughness and gloss of composite resins. Dent Mater J 2014;33:599-606.
40. Cilli R, de Mattos MC, Honorio HM, Rios D, de Araujo PA, Prakki A. The role of surface sealants in the roughness of composites after a simulated toothbrushing test. J Dent 2009;37:970-7.
41. de Moraes Rego Roselino L, Tonani Torrieri R, Sbardelotto C, Alves Amorim A, Noronha Ferraz de Arruda C, Tirapelli C, et al. Color stability and surface roughness of composite resins submitted to brushing with bleaching toothpastes: An in situ study. J Esthet Restor Dent 2019;31:486-92.