doi:10.30934/kusbed.635438 **e-ISSN:** 2149-8571

Kocaeli Üniversitesi Sağlık Bilimleri Dergisi

ÖzgünAraştırma / Original Article

http://dergipark.gov.tr/kusbed

INFLUENCE OF DIFFERENT BEVERAGES ON COLOR STABILITY AND WHITENESS OF ADHESIVE RESIN CEMENTS

FARKLI İÇECEKLERİN ADHEZİV REZİN SİMANLARIN RENK STABİLİTESİ VE BEYAZLIK DEĞERİ ÜZERİNE ETKİSİ

Kubra Degirmenci[1*], Mustafa Hayati Atala[2]

[1]Bolu Abant Izzet BaysalUniversity, Faculty of Dentistry, Prothetic Dental Treatment Department, Bolu, Turkey, [2]Istanbul Medeniyet University, Faculty of Dentistry, Prothetic Dental Treatment Department, Istanbul, Turkey.

ORCID iD: Kubra Degirmenci: 0000-0001-6429-4923; Mustafa Hayati Atala: 0000-0003-1194-0703

*** Corresponding Author/Sorumlu Yazar:** Kubra Degirmenci, **e-mail/e-posta:** dtkubradegirmenci@outlook.com

Received/Geliş Tarihi: 21.10.2019 **Accepted/Kabul Tarihi:** 16.09.2020 **Published/Yayım Tarihi:**02.10.2020

Abstract

Objective: Knowledge about the chemical properties of new introduced resin adhesive cements how can affect esthetic maintenance of indirect restorations are limited. The aim of this study was to evaluate the color stability of three different adhesive resin cements exposed to different beverages.
Methods: Total eigthy four specimens (n=7) of each adhesive resin cement (TheraCem, BisCem and Duolink) were prepared. All specimens were aged by distilled water (control group), coffee, green tea and white tea for 24 days. CIELAB coordinates were acquired by means with spectrophotometer (Vita Easyshade, Vita Zahnfabrik, Bad Sackingen,). Color differences (ΔE) and whiteness index for dentistry (WI_D) were calculated. The values were analyzed by two-way ANOVA and Tukey honestly significant difference test was used to compare group (α=0.05).
Results: TheraCem showed highest ΔE values and Duolink lowest ΔE values after immersion in distilled water, coffee, green tea and white tea. All tested specimens indicated clinically unacceptable color changes (ΔE) after 24 days immersion in coffee, green tea and white tea.
Conclusion: Ingredients and chemical interactions of adhesive resin cements can alter water permeability of material and so color stability significantly affected. After 24 days, all beverages caused clinically noticeable color changes for all adhesive resin cement groups.

Keywords: *Color stability, resin cements, self-adhesive cements, spectrophotometer*

Öz

Amaç: Yeni tanıtılan rezin adeziv simanların kimyasal yapılarının indirekt restorasyonların estetik devamlılığını nasıl etkileyebileceği ile ilgili bilgi sınırlıdır. Bu çalışmanın amacı, farklı içeceklerin üç farklı adheziv rezin simanın renk stabilitesine olan etkisini değerlendirmektir.
Yöntem: Üç farklı adheziv rezin simandan (TheraCem, BisCem and Duolink) toplam 84 örnek hazırlandı (n=7). Tüm örnekler, distile su (kontrol grubu), kahve, yeşil çay ve beyaz çay içeceklerinde 24 gün boyunca yaşlandırıldı. Spektrofotometre (Vita Easyshade, Vita Zahnfabrik, Bad Sackingen,) ile CIELAB koordinat değerleri ölçüldü. Renk farklılıkları (ΔE) ve diş hekimliğinde kullanılan beyazlık indeksi (WI_D) değerleri hesaplandı. Veriler iki yönlü varyans analizi (ANOVA) ile değerlendirildi ve Tukey testi ile gruplar arası karşılaştırmalar yapıldı *(*α=0,05*)*.
Bulgular: Distile su, kahve, yeşil çay ve beyaz çayda bekletildikten sonra TheraCem en yüksek ΔE değerlerini, Duolink en düşük ΔE değerlerini gösterdi. Test edilen tüm örnekler, 24 gün kahve, yeşil çay ve beyaz çayda bekletildikten sonra klinik olarak kabul edilemeyen seviyede ΔE değerlerini gösterdi.
Sonuç: Adheziv rezin simanların içeriği ve kimyasal etkileşimler materyalin su geçirgenliğini ve renk stabilitesini önemli oranda etkileyebilir. 24 gün sonra, tüm içecekler adhezive rezin siman gruplarında klinik olarak fark edilebilir renk değişikliklerine neden olmuştur.

Anahtar Sözcükler: *Renk stabilitesi, rezin simanlar, adeziv rezin, spektrofotometre*

Introduction

Esthetic restorative materials such as ceramics and resins which are used in all-ceramic crowns, laminate veneers, inlays and onlays are popular for succesfully imitating the optical properties of natural teeth tissue.[1] The color stability of these restorations are important for esthetic demands and affected by various factors such as the translucency of ceramic material, color of underlying tooth structure and the type of adhesive resin cements being used to lute restorations.[2] So, the color stability of chosen adhesive resin cement can promote the esthetic longevity of the restorations.

Recently, adhesive resin cements have been preferred for luting indirect restorations thanks to their good mechanical properties e.g. shear bond strength, flexural and compressive strength.[3] So, cements can support retention and structural stability of the restorations. Adhesive resin cements can be classified according to steps applied: total etch, one-step etch, self-adhesive and dual cured adhesive resin cements.[4] Another categorization can be done in line with polymerization nature: chemical-cured, light-cured and dual-cured.[3] Dual-cured resin cements are mostly selected for indirect restorations because they can continue to harden further down restorations to where the curing light cannot reach.[5] Apart from these categories, self-adhesive cements have been presented below. These cements are new sort of resin cements which can be applied without the need of a pretreatment such as an etch procedure.[6] The advantage of self-adhesive resin cement type is to simplfy the clinical application for clinicans. But, because of insufficient scientific evidence about the color stability of these cements including active monomers, it should be thought how the esthetic integrity of indirect restoration can be affected by cementation with self-adhesive system.

Restorative materials should resist to staining in oral enviroment and show optimal color stability. Color stability of adhesive resin cements should be considered when esthetical integrity of restorations is researched. The color change of luting cements may be related to various extrinsic and intrinsic factors. The chemical and particule properties of the luting cements are intrinsic factors.[7] Intrinsic factors such as amine accelerators, peroxide and tertiary aromatic amines can cause color change in resin cements. Also, other factors related to oral conditions like colorant agents caused by food, beverages and smoking are extrinsic factors. These factors can change the color of adhesive resin cements by means of reaction to hydrophilic functional groups which the cements contain.[8,9] The reason for this is that these functional groups are prone to water sorption. So, the type of adhesive resin cement can show different color stability in different beverages.

The color change of resin based composite materials after immerison in various beverages such as coffee[8,10], black tea[11,12] and cola[13] has been evaluated in previous studies. These beverages are mostly consumed around the world and have great potential for stains. According to the researches, higher color changes have been observed in coffee and tea than in cola.[13,14] The ingredients of these beverages are probably effective in color changes. Tea and coffee have water soluble secondary metobolites such as flavonoids, phenols, saponins and theanins.[12] These ingredients can cause high color change of restorative materials in oral environment.

Nowadays, consuming healthy beverages which can accelerate basal metabolism and promote the cellular youth is an attractive habit. So, different tea types (camellia sinensis) have been becoming mostly consumed drinks like coffee around the world. Tea is known as a healthy and antioxidant beverage reducing risk of cancer, obesity and cardiovascular diseases.[15] Tea can be classified as white, green and black tea according to the fermentation procedures, and each types can contain different healthy metabolites.[16] Green and white tea contain more bioactive compounds than black tea, mostly polyphenols and theanine.[17] Also, it has been stated that theanine may be an affective factor for the changes in the color of resin based materials.[12]

In the light of these information, the aim of this study is to search and compare the color integrity of two dual cured self-adhesive resin cements and a dual cured resin cement after immersion in coffee, white tea and green tea. The hypothesis tested has been that there would be no difference between the effects of different beverages on the color changes of different adhesive resin cements.

Methods

In the study, three different adhesive resin cements were assessed (Table 1).

Table 1. Adhesive resin cements searched

Product	Shade	Polymerization Type	Lot No.	Manufacturer
Duolink	Translucent	Dual Cured	1700006465	BİSCO
BisCem	Translucent	Dual Cured	1700007372	BİSCO
TheraCem	Universal	Dual Cured	1700001627	BİSCO

These are two dual-cured self-adhesive resin cements (TheraCem Bisco; Schaumburg, IL, USA and BisCem Bisco; SchaumburgIL, USA) and one dual-cured adhesive resin cement (Duolink, Bisco; Schaumburg, IL, USA). The shade of two cements was translucent and the other was universal. The compositions of the cements are different each other (Table 2).

Table 2. Compositions of adhesive resin cements

Code	Base Resin	Catalyst
Duolink	Urethane Dimethacrylate, BisGMA, Tetrahydrofurfuryl Methacrylate, Trimethylolpropane Trimethacrylate.	Bisphenol A Diglycidylmethacrylate, Dibenzoyl Peroxide, technically pure.
BisCem	BisGMA, Proprietary.	Bis[2-(Methacryloyloxy)ethyl] Phosphate, 2-Hydroxyethyl Methacrylate, Bis(Glyceryl 1,3 Dimethacrylate) Phosphate,Dibenzoyl Peroxide, technically pure.
TheraCem	Portland Cement, Ytterbium w/ Barium Glass, Proprietary, Ytterbium Fluoride, BisGMA, Proprietary.	10-Methacryloyloxydecyl Dihydrogen Phosphate, 2-Hydroxyethyl Methacrylate, Tert-butyl Perbenzoate.

In total, eigthy four specimens (n=7) have been prepared from the cements with 10 mm in diameter and about 2 mm thickness using the special plastic mold (Figure 1). The cements were put inside the plastic mold and the mold was coated with a polyester resin strip and after that a glass slab was closed. The polymerization was achieved with a light

emitting diode light-curing unit (Elipar S10, 3M ESPE, Seefeld, Germany) with a light intensity of 1.200 mW/cm^2 for firstly 20 sn. The glass slab was removed and direct light polymerizing was finished for 40 seconds (Total 60 sn for each specimen). The surfaces of specimens were polished using SiC grinding sheets (#600, 1.000 and 1.500 respectively) with the polishing machine (Minitech 233, Presi, Grenoble, France) in order to obtain 2.00 mm-thickness approximately.

Figure 1. The special plastic mold used for the specimens preparation

A digital micrometer (Mitutoyo, Tokyo, Japan) was used to ensure standardization of the dimensions of all specimens having an accuracy of ± 0.01 mm. The specimens were cleaned in distilled water for 10 minutes and dried with compressed air. Each specimen was stored in distilled water at 37˚C for 24 hour in a dark glass flask after the first color measurements were performed. Four types of solutions studied were prepared: distilled water as a control group, coffee (Nescafe Classic, Nestle, Turkey), green tea (Lipton,Turkey) and white tea (Dogadan, Turkey) as testing groups (Table 3).

Table 3. Identifying of beverages used for coloring procedures in the study

Beverage	Description
Water	Distilled Water (Control Group)
Coffee	Nescafe, Classic, Nestle, Turkey
Green Tea	Lipton, Turkey
White Tea	Dogadan, Turkey

The coffee solution was prepared by mixing 2 gr of coffee powder (Nescafe Classic, Nestle, Turkey) in 200 mL of distilled water at 80ºC for 1 minute. The green and white tea solutions were prepared by keeping the tea bags in 200mL of distilled water at 80ºC for 3 minutes. The specimens were immersed in solutions in an incubator (37±2ºC, 1 Hz frequency). During the study, the specimens were kept in the solutions every day for 12 hours. The solutions were renewed every day.

Before the performance of color measurements, the specimens were washed in distilled water and dried with a filter paper for 30 sn. The mean CIE L*a*b* values of specimens were acquired by using a spectrophotometer (Vita Easyshade, Vita Zahnfabrik, Bad Sackingen, Germany) three times for each specimen, and the mean value was calculated. Measurements were obtained for four different intervals: before being immersed in solutions (t_0), 6 days(t_1), 12 days (t_2) and 24 days (t_3) after aging in the beverages. The following formulas were used to get ΔE and WI_D (Whiteness Index for Dentistry) values for the specimens;

$$\Delta E=[(L1-L2^*)+(a1-a2^*)^2+(b1-b2^*)^2]^{1/2}$$
$$WI_D=0.511L^*-2.32a^*-1.100b^*$$

Statistical analysis was performed in a global significance level of 95%. The variable was tested for normal distribution using Shapiro-wilk test ($p\geq0.05$). Two-way variance analysis (ANOVA) was used for evaluating significances for the color parameters ΔL, Δa, Δb, ΔE and WI_D considering adhesive cement type and immersion beverage as the main factors, and then Tukey's honest significant difference test was used for comparisons of the groups. Also, Regression analysis was used in assessing the correlation between ΔE_3 and WI_D values ($p<0.05$).

Results

In the study, it has been defined that the two main factors, beverage and adhesive resin cement and their interaction were significant according to two-way ANOVA. The mean and standard deviations of ΔL3, Δa3 and Δb3 values calculated (Table 4).

Table 4. Mean and standard deviations of ΔL3,Δa3, Δb3 and WI values and intergroup comparison according to post hoc tests

		Water	White Tea	Green Tea	Coffee
ΔL3	Duolink	-1.98±0.13^{aX}	-2.10±0.12^{bX}	-2.65±0.23^{cX}	-4.00±0.16^{dX}
	BisCem	-2.10±0.15^{aY}	-2.37±0.11^{bY}	-2.75±0.97^{cY}	-5.12±0.21^{dY}
	TheraCem	-2.45±0.16^{aZ}	-2.97±0.18^{bZ}	-3.27±0.21^{cZ}	-5.82±0.12^{dZ}
Δa3	Duolink	1.67±0.13^{aX}	1.80±0.16^{bX}	2.34±0.20^{cX}	4.94±0.09^{dX}
	BisCem	1.78±0.12^{aX}	1.94±0.19^{bX}	2.54±0.20^{cX}	5.45±0.35^{dX}
	TheraCem	2.78±0.16^{aY}	3.21±0.21^{bY}	3.48±0.12^{cY}	5.72±0.17^{dY}
Δb3	Duolink	2.11±0.16^{aX}	3.27±0.17^{bX}	3.35±0.26^{cX}	4.98±0.10^{dX}
	BisCem	2.61±0.15^{aY}	3.40±0.20^{bY}	3.50±0.20^{cY}	5.50±0.27^{dY}
	TheraCem	3.08±0.13^{aZ}	3.55±0.12^{bZ}	3.90±0.18^{cZ}	6.65±0.15^{dZ}
WI_{D3}	Duolink	8.31±0.78 ^{aX}	6.44±0.47 ^{bX}	3.88±0.76 ^{cX}	-3.81±0.39 ^{dX}
	BisCem	7.55±0.54 ^{aY}	6.04±0.51 ^{bY}	3.12±0.61 ^{cY}	-6.27±0.52 ^{dY}
	TheraCem	6.70±0.69 ^{aZ}	5.88±0.48 ^{bZ}	2.64±0.51 ^{cZ}	-9.22±0.41 ^{dZ}

*In each column, a,b,c,d define the horizontal significant differences and X,Y,Z define the vertical significant differences.

All beverages caused L value closely more negative values represent that the specimens have become darker. Analysis of the ΔL3 for luminosity at 24th day has shown significant differences between the specimens in the control and tested beverages conditions ($p<0.05$) (Table 4). Observed ΔL3 values of TheraCem in all beverage groups have been significantly and differently higher adhesive resin cements ($p<0.05$) (Table 4). The minimum change in luminosity values has been determined in Duolink group and the maximum change has been determined in TheraCem group ($p<0.05$) (Table 4). At 24th day, further changes in the values of the all specimens have been defined with the most positive values towards to red axis. Considering Δa3 values for adhesive cement groups, there have been observed more changes in the differences defined in TheraCem group than the changes detected in BisCem and Duolink groups ($p<0.05$) (Table 4). There is no significant differences between Δa3 values of Duolink and BisCem groups ($p>0.05$) (Table 4). The change in the color parameter b for

all the specimens after the immersion of beverages at 24th day, has been observed that it has been shifting to more positive values indicating the closer yellow axis. The most noticeable change in b values has been detected in coffee group for TheraCem (p<0.05) (Table 4). Also, a significant difference between Δb3 values of Duolink and BisCem groups has been defined (p<0.05) (Table 4). After the immersion procedure, the values of mean WI_D have been significantly different among adhesive resin cements, and it can be ranked as follows Duolink, BisCem and TheraCem (p<0.05). WI_D values have indicated some changes to darker axis for TheraCem, BisCem and Duolink in respectively (Table 4).

Considering the beverage types, WI_D values are lower for coffee, green tea, white tea and distilled water in respectively indicating darker to whiter specimens for all groups. The mean and standard deviations of ΔE1, ΔE2 and ΔE3 values were calculated (Table 5).

Table 5. Mean and standard deviations of ΔE1, ΔE2 and ΔE3 values and intergroup comparison according to post hoc tests

		Water	White Tea	Green Tea	Coffee
ΔE1	Duolink	1.24 ± 0.09^{aX}	1.42 ± 0.11^{bX}	1.92 ± 0.14^{cX}	3.28 ± 0.16^{dX}
	BisCem	1.34 ± 0.12^{aY}	1.55 ± 0.15^{bY}	1.98 ± 0.19^{cY}	3.95 ± 0.78^{dY}
	TheraCem	1.77 ± 0.17^{aZ}	2.20 ± 0.14^{bZ}	2.78 ± 0.12^{cZ}	4.72 ± 0.17^{dZ}
ΔE2	Duolink	2.27 ± 0.14^{aX}	2.97 ± 0.12^{bX}	3.47 ± 0.07^{cX}	6.01 ± 0.12^{dX}
	BisCem	2.58 ± 0.10^{aY}	3.54 ± 0.16^{bY}	3.81 ± 0.16^{cY}	6.68 ± 0.30^{dY}
	TheraCem	3.32 ± 0.09^{aZ}	3.97 ± 0.17^{bZ}	4.31 ± 0.26^{cZ}	7.07 ± 0.12^{dZ}
ΔE3	Duolink	3.25 ± 0.17^{aX}	4.20 ± 0.23^{bX}	5.02 ± 0.18^{cX}	8.08 ± 0.12^{dX}
	BisCem	3.57 ± 0.11^{aY}	4.64 ± 0.13^{bY}	5.44 ± 0.16^{cY}	9.32 ± 0.11^{dY}
	TheraCem	4.82 ± 0.07^{aZ}	5.62 ± 0.17^{bZ}	6.17 ± 0.14^{cZ}	10.54 ± 0.16^{dZ}

*In each column, a,b,c,d define the horizontal significant differences and X,Y,Z define the vertical significant differences.

ΔE1, ΔE2 and ΔE3 values of TheraCem has been significantly higher than the values of Duolink and BisCem (p<0.05) (Table 5). Considering control group, it can be easily concluded that there are significant differences between ΔE1, ΔE2 and ΔE3 values of all adhesive resin cements (p<0.05) (Table 5). It has been revealed thanks to the regression analysis that the correlation between ΔE3 and WI_D has been strong and reverse indicating 95% rate (r=0.943; p=0.00 p<0.05).

After storing for 24 days, noticeable color change values have been observed for all beverage groups. Coffee has been the significantly most effective beverage on the L, a and b parameters of the specimens (p<0.05) (Table 4). There is no significant difference between the effects of beverages on Δa3 values of Duolink and BisCem groups (p<0.05) (Table 4). However, the effects of beverages on the ΔL3 and Δb3 values of Duolink, BisCem and TheraCem groups are significantly different from each other (p<0.05) (Table 4). Observed ΔE1, ΔE2 and ΔE3 values in coffee has shown significant differences among adhesive resin cements (p<0.05) (Table 5). All changes in coffee have been observed above clinically acceptable ΔE values except ΔE1 value of Duolink (ΔE>3.3). Clinically unacceptable ΔE changes for tea types have been detected for 12nd day and 24th day of the evaluation (ΔE>3.3) (Table 5). For all adhesive resin cement groups, it has been observed that green tea has caused more changes than white tea has for all intervals (p<0.05). Evaluating all beverages, the most noticeable change has been found in TheraCem group, and the least noticeable change has been defined in Duolink group.

Discussion

In adhesive dentistry, self-etch adhesive resin cements have been presented to shorten luting procedures of indirect restorations to tooth substrates. Bond strength of these adhesive cements to enamel, dentin, root dentin and restorative materials have been evaluated in several studies.[18-21] According to the previous studies, bond strength of self-etch adhesive resin cements can be comparable to adhesive resin cements applied with etch and rinse pretreatment technique. However, there is a few study related to color stability of adhesive resin cement types.[1,8,22,23] Considering this research, there is a few study which focuse on how adhesive resin cements affect the esthetic integrity of indirect restorations.[1,5,7,8,22] Because of the similarity to compomers, adhesive resin cements are susceptible to discoloration on exposure to extrinsic factors such as food, coffee and tea in oral conditions.[24] Staining agents caused by these factors can reach to adhesive cements owing to microleakage between indirect restorations and tooth interface.[25] So, the present study has been designed to search for the questions regarding color changes of different type of adhesive resin cements in mostly preferred beverages around the world.

Recent years, healthy type of teas have been commonly introduced to promote general systemic health and accelerate rate of basal metabolism. Especially, green and white tea are suggested by dieticians to support lose weight in a healthy way. However, these type of teas may have some adverse effects such as discoloration which can affect esthetic appearance of restorations. As known widely, many investigations related to the color constancy of resin based composite materials have evaluated the effect of various beverages such as red wine[9], cola[26], coffee, black tea[13], green tea and also herbal tea.[27] Phenols, saponins, tannins and caffeine alkaloid can be predominantly responsible for the effect of color changes caused by coffee and tea.[12] The amount of these metabolites can affect the coloring potential of coffee and tea, so coffe can be considered to be one of the most staining beverages.[11] Results of the current study have indicated that staining effects of coffee on all adhesive resin cements is higher than tea. These results are in accordance with previous studies.[8,28,29] It can be explained that caffeine is the one of the metabolite with a high potential to stain.[12] Similarly, in the study, green tea has more caffein than white tea[17] and has caused more discoloration. So, the first null hypotheses tested has shown that the coffee and tea types would have no significant effect of color change on adhesive resin cements, and the relevant hypotheses has been rejected.

The adsorption of staining agents caused by beverages and the compositions of adhesive resin cements are another important factors for discoloration.[29] It has been observed that the color alterations of the adhesive resin cements after the immersion procedure are different from each other. Therefore, the second null hypotheses which indicates that no significantly different color change would be found among the samples of adhesive resin cements has been rejected. According to the results in the current study, TheraCem has shown lower color stability after the immersion procedure, and also has shown so higher water sorption than Duolink. It has been thought that this finding

is probably associated with ingredients of TheraCem. TheraCem is a self-adhesive resin cement, so including monomer acidic groups[6] can be related to high hidrophilicity and water sorption.[30] Also, high acidity can be associated with the amount of carbon carbon double bond (C=C) conversion.[31] The lower degree of remaining C=C bonds affect color change of polymers, in the previous study, it has been stated that the combination of acidic hydrophilic and hydrophobic monomer groups into a single step decrease the conversion of C=C bonds, and so permeability of the adhesive material increases.[32] The results of this study are in accordance with the findings of the analysis and study. The adhesion process of self-adhesive cements occur between monomer acidic groups of self-adhesive cements and hydroxyapatite of tooth tissue.[33] In the study, there is no hydroxyapatite, so self-adhesive cements remained more asidic and hydrophilic than probably their clinical usage. On the other hand, in the study, discoloration of two self-adhesive resin cements have been found different from each other. This finding is probably related to releasing fluoride ions of TheraCem. Since 2002, self-adhesive resin cements have developed and added some features like release of fluoride ions to protect recurrent carries.[6] According to manufacturer, TheraCem is a self-adhesive cement which releases fluoride ions, unlikely BisCem is not. The study is in accordance with the previous study which has stated that cements release better fluoride and it has shown less color stability.[34] Additionally, the shade of resin material can affect the level of color change.[35,36] It may be a reason for different color stability that the shade of TheraCem is natural, the other adhesive resin cements are translucent. These findings are in accordance with a previous study which has assessed the composite resin cements with different shades.[1] In the study, Duolink has shown better color stability than self-etch adhesive resin cements at 24th day. It can be related to matrix properties of resin cement. Matrix of resin materials can change water solubility of material and it is important to maintain color stability.[28] It has been stated that resin materials including urethane dimethacrylate indicate more color stability than including Bis-GMA as matrix.[12,37] The water absorbed by the resin matrix can form micro-cracks, and penetration of staining agents can occur.[14] Glass filler particles can absorb water on surface and can affect the color stability of resin material.[12] In accordance with this knowledge, the study has stated that the highest color change has been defined in the TheraCem group and the least color change has been found in the Duolink group.

The ability to perceive color differences may be affected because of the ambient light, assessment of individiuals and the properties of the material. So, spectrophotometer and digital instrument are widely used to define color changes of the material.[38] Spectrophotometer describes color characteristics of a material based on three parameters: Lightness-darkness (L), red-green (a), yellow-blue (b). These color coordinates developed by CIELAB and these parameters are widely used in dentistry to calculate color differences (ΔE).[39] Calculated ΔE values are used to figure out the distance between two colors. Previous studies have stated that different color acceptability thresholds for different restorative materials at $\Delta E \geq 2$[40], $\Delta E \geq 3.3$[41] and $\Delta E \geq 3.7$.[42] In the study, the most available studies for resin based materials, $\Delta E \geq 3.3$ are considered as threshold for clinical acceptability of color change.[43] In the study, both ΔE and WI_D have been used to analyze staining effect of beverages. Because, ΔE can be used to just define differences between specimens after exposurement to staining environment. Advantegously, WI_D values can define darker and whiter values. The superior point of this index is to provide visual perception of whiteness.[44] Higher WI_D values indicates whiter specimens, and lower WI_D values indicate darker samples. The darkest WI_D values for TheraCem and Whitest WI_D values for Duolink have been defined in the study. So, self adhesive cements can be darker under indirect restoration and can change the appareance of restoration over time.

Background and baseline measurement times can be effective during the performance of color measurements, so the thickness of specimens in the study was 2.0 mm to reduce the background effect. But for clinical conditions, adhesive resin cements should be thinner.[8] Color change measurements immediately after specimen preparation[34,42] or after water storage for 1 day can affect the results.[45,46] In a previous study, it has been stated that color changes of resin cements have been mostly detected in the first 24 hours of polymerization.[1] So, in the study, baseline measurements have been done immediately when specimen has been ready. The color stability of adhesive resin cements cannot be exactly defined under the in vitro experimental conditions. Because, overlaying restorations and dentin layers decrease the colorant effect of extrinsic factors to adhesive resin cements, and less exposure of staining agents would occur. Actually, the immersion of the specimens into the solutions has shown the results of long-term effect of beverages on the color stability of the adhesive resin cements in the study. Based on the previous studies, immersion for 6 days imitates three months, immersion for 12 days imitates six months and immersion for 24 days imitates one year of drinking effect.[1,26,29] Another clinical factor which is different from in vitro conditions is that marginal surfaces of indirect restorations can be changed by some factors such as chewing forces, tooth brushing, and so stains caused by beverages can be deposited on the altered rough surfaces. This in vitro study may not exactly reflect clinical conditions, but it can be a reference for further clinical studies in order to understand color stability of adhesive resin cements and how it could affect the esthetic prognosis of restorations. Within the limitations of the current study, some conclusions can be drawn. All resin adhesive cements searched clinically showed unacceptable alterations in color after 24 days in beverage storages. So, one year of drinking coffee and tea can cause darker changes of adhesive resin cements and reflection under luted of indirect restoration can disrupt esthetic success. Hydophilic groups ingredient and fluride ion releasing can contribute the color instability of adhesive resin cements. So, clinicians should consider chemical features of cement type used to lute indirect restoration which can affect esthetic appearance and require renew the restoration.

Conflict of Interest

No conflicts of interests to disclose.

Compliance of Ethical Statement

The study is in vitro study.

Financial Disclosure/Funding

The author(s) received no specific funding for this work.

Author Contributions

KD: Literature search, resources, materials; KD, MHA: Critical revision, data collection, acqusation of resources, materials, Data analysis and interpretation, Manuscript drafting/writing/editing, Project development.

References

1. Mina NR, Baba NZ, Al-Harbi FA, et al. The influence of simulated aging on the color stability of composite resin cements. *J Prosthet Dent.* 2019;121:306-310. doi: 10.1016/ j.prosdent.2018.03.014.
2. Barbon FJ, Moraes RR, Calza JV, Perroni AP, Spazzin AO, Boscato N. Inorganic filler content of resin based-luting agents and the color of ceramic veneers. *Braz Oral Res.* 2018;32:1-11. doi: 10.1590/1807-3107bor-2018.vol32.0049.
3. Haddad MF, Rocha EP, Assunção WG. Cementation of prosthetic restorations: from conventional cementation to dental bonding concept. *J Craniofac Surg*. 2011;22:952–958. doi: 10.1097/SCS.0b013e31820fe205.
4. Hill EE, Lott J. A clinically focused discussion of luting materials. *Aust Dent J.* 2011;56:67-76. doi: 10.1111/j.1834-7819.2010.01297.x.
5. Marghalani HY. Sorption and solubility characteristics of self adhesive resin cements. *Dent Mater.* 2012;28:187-198. doi: 10.1016/j.dental.2012.04.037.
6. Radovic I,Monticelli F, Goracci C,et al. Self-adhesive resin cements: A literature review. *J Adhes Dent*. 2008;10:251-258.
7. Yiu CK, King NM, Carrilho MR, et al. Effect of resin hydrophilicity and temperature on water sorption of dental adhesive resins. *Biomaterials.* 2006;27:1695-1703.doi:10.1016/ j.biomaterials.2005.09.037.
8. Shiozawa M, Takahashi H, Asakawa Y, Iwasaki N. Color stability of adhesive resin cements after immersion in coffee. *Clin Oral Investig*. 2015;19:309-317. doi:10.1007/s00784-014-1272-8.
9. Sedrez-Porto JA, Münchow EA, Cenci MS, Pereira-Cenci T. Translucency and color stability of resin composite and dental adhesives as modeling liquids-A one-year evaluation. *Braz Oral Res.* 2017;31:1-8. doi: 10.1590/1807-3107BOR-2017. 31.0054.
10. Bayindir F, Kürklü D, Yanikoğlu ND. The effect of staining solutions on the color stability of provisional prosthodontic materials. *J Dent.* 2012;40:41-46. doi:10.1016/j.jdent. 2012.07.014.
11. Arocha MA, Mayoral JR, Lefever D, et al. Color stability of siloranes versus methacrylate-based composites after immersion in staining solutions. *Clin Oral Investig*. 2013;17: 1481-1487. doi: 10.1007/s00784-012-0837-7.
12. Subramanya JK, Muttagi S. In vitro color change of three dental veneering resins in tea, coffee and tamarind extracts. *J Dent.* 2011;8:138-145.
13. Malekipour MR, Sharafi A, Kazemi S, et al. Comparison of color stability of a composite resin in different color media. *Dent Res J*. 2012;9:441-446.
14. Bagheri R, Burrow MF, Tyas M. Influence of food-simulating solutions and surface finish on susceptibility to staining of aesthetic restorative materials. *J Dent.* 2005;33(5):389-398.
15. Xing L, Zhang H, Qi R, et al. Recent Advances in the understanding of the health benefits and molecular mechanisms associated with green tea polyphenols. *J Agric Food Chem.*2019;67:1029-1043.doi: 10.1021/acs.jafc.8b06146.
16. Cheng TO. All teas are not created equal: the Chinese green tea and cardiovascular health. *Int J Cardiol*. 2006;108:301-308. doi:10.1016/j.ijcard.2005.05.038.
17. Boros K, Jedlinszki N, Csupor D. Theanine and Caffeine Content of Infusions Prepared from Commercial Tea Samples. *Pharmacogn Mag.* 2016;12:75-79. doi: 10.4103/0973-1296. 176061.
18. Goracci C, Cury AH, Cantoro A, et al. Microtensile bond strength and interfacial properties of self-etching and self-adhesive resin cements used to lute composite onlays under different seating forces. *J Adhes Dent.* 2006;8:327-335.
19. Yoshida Y, Nagakane K, Fukuda R, et al. Comparative study on adhesive performance of functional monomers. *J Dent Res.* 2004;83:454-458.
20. Bitter K, Priehn K, Martus P, et al. In vitro evaluation of push-out bond strengths of various luting agents to tooth-colored posts. *J Prosthet Dent.*2006;95:302-310. doi: 10.1016/j.prosdent.2006.02.012.
21. Wolfart M, Wolfart S, Kern M. Retention forces and seating discrepancies of implant-retained castings after cementation. *Int J Oral Maxillofac Implants*. 2006;21:519-525.
22. Archegas LR,Freire A,Vieira S, et al. Color stability and opacity of resin cements and flowable composites for ceramic veneer luting after accelerated ageing. *J Dent.* 2011;39:804-810. doi: 10.1016/j.jdent.2011.08.013.
23. Kilinc E, Antonson SA, Hardigan PC, et al. Resin cement color stability and its influence on the final shade of all-creamics. *J Dent.* 2011;39:30-36. doi: 10.1016/j.jdent.2011.01.005.
24. Ferracane JL,Stansbury JW, Burke FJ. Self-adhesive resin cements-chemistry, properties and clinical considerations. *J Oral Rehabil.* 2011;38:295-314. doi: 10.1111/j.1365-2842.2010.02148.x.
25. Uludag B, Yucedag E, Sahin V. Microleakage of inlay ceramic systems luted with self-adhesive resin cements. *J Adhes Dent.* 2014;16(6):523-529. doi: 10.3290/j.jad.a32811.
26. Guler AU, Yilmaz F, Kulunk T, et al. Effects of different drinks on stainability of resin composite provisional restorative materials. *J Prosthet Dent.* 2005;94:118-124. doi: 10.1016/j.prosdent.2005.05.004.
27. Dinç Ata G, Gokay O, Müjdeci A, et al. Effect of various teas on color stability of resin composites. *Am J Dent.* 2017;30:323-328.
28. Ertaş E, Güler AU, Yücel AC, et al. Color stability of resin composites after immersion in different drinks. *Dent Mater J.* 2006;25:371-376. doi: 10.4012/dmj.25.371.
29. Alberton Da Silva V,Alberton Da Silva S,Pecho OE, et al. Influence of composite type and light irradiance on color stability after immersion in different beverages. *J Esthet Restor Dent.* 2018;30:390-396. doi: 10.1111/jerd.12383.
30. Ito S, Hashimoto M, Wadgaonkar B, et al. Effects of resin hydrophilicity on water sorption and changes in modulus of elasticity. *Biomaterials.* 2005;26:6449-6459. doi: 10.1016/j.biomaterials.2005.04.052
31. King NM, Hiraishi N, Yiu CK, et al. Effect of resin hydrophilicity on water-vapour permeability of dental adhesive films. *Eur J Oral Sci.* 2005;113:436-442. doi: 10.1111/j.1600-0722.2005.00231.x
32. De Munck J, Van Meerbeek B, Yoshida Y, et al. Four-year water degradation of total-etch adhesives bonded to dentin. *J Dent Res.* 2003;8:136-140. doi: 10.1016/j.jdent.2008.04.011
33. Gaintantzopoulou M, Kakaboura A, Loukidis M, et al. A study on color stability of self-etching and etch-and-rinse adhesives. *J Dent.* 2009;37:390-396. doi: 10.1016/ j.jdent. 2009. 01.010.
34. Prabhakar A,Pattanshetti K, Sugandhan S. A comparative study of color stability and fluoride release from glass ionomer cements combined with chlorhexidine. *Int J Clin Pediatr Dent.* 2013;6:26-29. doi: 10.5005/jp-journals-10005-1181
35. Festuccia MS, Garcia Lda F, Cruvinel DR, et al. Color stability, surface roughness, and microhardness of composites submitted to mouthrinsing action. *J Appl Oral Sci.* 2012;20:200-205. doi: 10.1590/S1678-77572012000200013
36. Smith DS, Vandewalle KS, Whisler G. Color stability of composite resin cements. Gen Dent. 2011;59:390-394
37. Mundim FM, Garcia Lda F, Pires-de-Souza F deC. Effect of staining solutions and repolishing on color stability of direct

composites. *J Appl Oral Sci*. 2010;18:249-254. doi: 10.1590/S1678-77572010000300009
38. Barutcigil Ç, Yıldız M. Intrinsic and extrinsic discoloration of dimethacrylate and silorane based composites. *J Dent.* 2012;40:57-63. doi: 10.1016/j.jdent.2011.12.017
39. Baglar S, Keskin E,Orun T, et al. Discoloration Effects of Traditional Turkish Beverages on different composite restoratives. *J Contemp Dent Pract*. 2017;18:83-93. doi: 10.5005/jp-journals-10024-1996
40. O'Brien WJ, Groh CL, Boenke KM. A new small-color difference equation for dental shades. *J Dent Res.* 1990;69:1762-1764. doi: 10.1177/00220345900690111001
41. Vichi A, Ferrari M, Davidson CL. Color and opacity variations in three different resin based composite products after water aging. *Dent Mater*. 2004;20:530-534. doi: 10.1016/j.dental.2002.11.001
42. Kim BJ, Lee YK. Influence of the shade designation on the color difference between the same shade designated resin composites by the brand. *Dent Mater*. 2009;25:1148-1154. doi: 10.1016/j.dental.2009.04.001
43. Sabatini C, Campillo M, Aref J. Color stability of ten resin-based restorative materials. *J Esthet Restor Dent*. 2012;24:185-199. doi: 10.1111/j.1708-8240.2011.00442.x
44. Perez MM, Ghinea R, Rivas MJ, et al. Development of a customized whiteness index for dentistry based on CIELAB color space. *Dent Mater.* 2016;32(3):461-467. doi: 10.1016/j.dental.2015.12.008
45. Lepri CP, Palma-Dibb RG. Surface roughness and color change of a composite:influence of beverages and brushing. *Dent Mater J*. 2012;31:689-696. doi: 10.4012/dmj.2012-063
46. Topcu FT, Sahinkesen G, Yamanel K, et al. Influence of different drinks on the color stability of dental resin composites. *Eur J Dent.* 2009;3:50-56.