ORIGINAL RESEARCH ORİJİNAL ARAŞTIRMA

DOI: 10.5336/dentalsci.2024-105175

Effect of Beverages with Increased Consumption Since COVID-19 Pandemic on the Color of CAD/CAM Acrylic Resin and Bis-Acryl-Based Material: An *in vitro* Study

COVID-19 Pandemisinden Bu Yana Tüketimi Artan İçeceklerin, CAD/CAM Akrilik Rezin ve Bis-Akril Bazlı Materyallerin Rengi Üzerindeki Etkisi: Bir *in vitro* Çalışma

Kerem YILMAZ[a,b], Erdem ÖZDEMİR[c], Burak YILMAZ[d,e]

[a]Antalya Bilim University Faculty of Dentistry, Department of Prosthodontics, Antalya, Türkiye
[b]Bilimdent Oral and Dental Health Center, Antalya, Türkiye
[c]Private Dentist, Antalya, Türkiye
[d]The Ohio State University Dental Clinic, Columbus, USA
[e]University of Bern, School of Dental Medicine, Restorative, Preventive and Pediatric Dentistry, Bern, Switzerland

ABSTRACT Objective: To evaluate the effect of energizing, body resistance-increasing, immune-boosting beverages, multivitamin effervescent, black tea on the color of three bis-acrylic resin composite (BRC) and one computer aided design-computer aided manufacturing (CAD/CAM) polymethyl methacrylate (PMMA) material. **Material and Methods:** 168 rectangular specimens (2 mm thick) were prepared in (i) BRC1 (Oratemp), (ii) BRC2 (PrimmaArt), (iii) BRC3 (Hexa-Temp), (iv) PMMA (Eray PMMA Disc) (n=42). After baseline color measurements, the specimens were immersed in various beverages. On the 1st, 14th, 28th days, color measurements were repeated. Discolorations were calculated by CIEDE2000 and CIELAB formulas and analyzed by variance and Bonferroni tests (α=0.05). **Results:** The ΔE_{ab} and ΔE_{00} results of material, beverage and material-beverage pair at days 1, 14 and 28 were statistically significant (p<0.001). After 14 and 28 days, the highest discoloration was in BRC3-black tea (ΔE_{00}=4.4, ΔE_{ab}=6.9) and the lowest in PMMA-immune-boosting beverage with Sambucus Nigra (ΔE_{00}=0.7, ΔE_{ab}=1.5) (p<0.05). PMMA was more resistant to discoloration than BRCs. The magnitude of discoloration for BRCs was BRC2 (ΔE_{00}=2.3, ΔE_{ab}=4.0)>BRC3 (ΔE_{00}=2.0, ΔE_{ab}=3.8)>BRC1 (ΔE_{00}=1.5, ΔE_{ab}=2.6) (p<0.0001). **Conclusion:** Black tea and multivitamin may discolor the interim restorations more than energizing, body resistance-increasing, immune-boosting beverages. Regardless of the time point, CAD/CAM PMMA was more resistant to discoloration than tested bis-acrylic resin composites (p<0.005). Regardless of the time point, distilled water was more resistant to discoloration than tested other beverages (p<0.0001).

Keywords: Beverages; color; polymethyl methacrylate; acrylic resins; COVID-19

ÖZET Amaç: Bu çalışmanın amacı, enerji verici, vücut direncini artırıcı, bağışıklık sistemini güçlendirici içeceklerin, multivitamin efervesanın, siyah çayın üç bis-akrilik rezin kompozit (BRC) ve bir bilgisayar destekli tasarım/bilgisayar destekli üretim (CAD/CAM) polimetil metakrilat (PMMA) materyalinin rengine etkisini değerlendirmektir. **Gereç ve Yöntemler:** 168 dikdörtgen numuneler (2 mm kalınlığında) hazırlandı: (i) BRC1 (Oratemp), (ii) BRC2 (PrimmaArt), (iii) BRC3 (Hexa-Temp), (iv) PMMA (Eray PMMA Disk) (n=42). Başlangıç renk ölçümlerinden sonra, numuneler çeşitli içeceklere daldırıldı. 1., 14. ve 28. günlerde renk ölçümleri tekrarlandı. Renk değişimleri CIEDE2000 ve CIELAB formülleri ile hesaplandı ve ANOVA ve Bonferroni kullanılarak analiz gerçekleştirildi (α=0.05). **Bulgular:** Materyal, içecek ve materyal-içecek çiftinin 1, 14 ve 28. günlerdeki ΔEab ve ΔE00 sonuçları istatistiksel olarak anlamlıydı (p<0,001). 14 ve 28 gün sonra, en yüksek renk değişikliği BRC3-siyah çayda (ΔE_{00}=4,4, ΔE_{ab}=6,9) ve en düşük PMMA-Sambucus Nigra'lı bağışıklık kuvvetlendirici içecekte (ΔE_{00}=0,7, ΔE_{ab}=1,5) görüldü (p<0,05). PMMA, BRC'lere göre renk bozulmasına karşı daha dirençliydi. BRC'ler için renk değişiminin büyüklüğü BRC2 (ΔE_{00}=2,3, ΔE_{ab}=4,0)>BRC3 (ΔE_{00}=2,0, ΔE_{ab}=3,8)>BRC1 (ΔE_{00}=1,5, ΔE_{ab}=2,6) şeklindeydi (p<0,0001). **Sonuç:** Siyah çay ve multivitamin ara restorasyonların rengini, enerji veren, vücut direncini artıran, bağışıklık sistemini güçlendiren içeceklerden daha fazla etkiledi. Zaman noktasından bağımsız olarak CAD/CAM PMMA, test edilen bis-akrilik rezin kompozitlere göre renk değişimine karşı daha dirençliydi (p<0,005). Zaman noktasından bağımsız olarak, distile su renk değişimine karşı test edilen diğer içeceklerden daha dirençliydi (p<0,0001).

Anahtar Kelimeler: İçecekler; renk; polimetil metakrilat; akrilik rezinler; COVID-19

TO CITE THIS ARTICLE:
Yılmaz K, Özdemir E, Yılmaz B. Effect of beverages with increased consumption since COVID-19 pandemic on the color of CAD/CAM acrylic resin and bis-acryl-based material: An *in vitro* study. Turkiye Klinikleri J Dental Sci. 2025;31(1):89-99.

Correspondence: Kerem YILMAZ
Antalya Bilim University Faculty of Dentistry, Department of Prosthodontics, Antalya, Türkiye
E-mail: drkeremy@hotmail.com

Peer review under responsibility of Turkiye Klinikleri Journal of Dental Sciences.

Received: 19 Aug 2024 ***Received in revised form:*** 26 Nov 2024 ***Accepted:*** 11 Dec 2024 ***Available online:*** 24 Jan 2025

In esthetically critical areas, the color of interim restorations are required to remain stable throughout the treatment. Discoloration of interim crowns may occur as a result of the adhesion of staining pigments in beverages such as tea or coffee to the outer surface or adsorption to the substrate. While there are various studies examining the effect of beverages on the color of conventional interim crown materials,[1,2] there are limited number of studies on computer aided design/computer aided manufacturing (CAD/CAM) materials used for interim restorations.[1,2]

The social isolation during coronavirus disease-2019 (COVID-19) pandemic resulted in more time spent at home for most of the population worldwide, eating habits changed and the frequency of consumption of fruit juices, multivitamins and immune-boosting beverages containing vitamin C has increased. Despite their health supportive properties, these types of beverages are colored and may change the color of dental materials due to the acids and colorants they contain.[3] Beverages containing *Sambucus Nigra* (black elderberry), recommended as supportive therapy in the COVID-19 pandemic due to their antiviral effects, may discolor materials.[4] While there are limited studies on the effect of fruit juices containing vitamin Cand multivitamins on the color of dental materials, no previous study investigated the effect of energizing, body resistance-boosting, immune-boosting beverage with black elderberry, multivitamins on the color of bis-acryl and CAD/CAM materials used for interim restorations.[1,5-7]

Due to the re-emerging Mpox pandemic, social isolation is likely to continue and the use of immune-boosting beverages, energy beverages, body resistance-enhancing beverages and multivitamins is likely to increase further; therefore, investigating the effects of such beverages on the surface features of dental restorative materials is a critical requirement.[8]

The L^*,a^*,b^* parameters presented by the CIE and the CIELAB and CIEDE2000 formulas (ΔE_{ab} and ΔE_{00}, respectively) calculated by using these parameters are widely used in dentistry and dental research. ΔE_{ab} has been the most commonly used color difference formula to date, however, ΔE_{00}, correcting for inhomogeneity of the CIE L^*,a^*,b^* color space under reference conditions, is increasing popularity and is the recommendation of the CIE.[9]

The aim of this study was to evaluate the effect of immune-boosting beverage with black elderberry, multivitamin, energizing beverage, body resistance-increasing fruit juice and black tea on the color of three different bis-acrylic resin composite (BRC) and one CAD/CAM polymethyl methacrylate (PMMA) materials used for interim restorations over time. The null hypothesis was that the type of beverage and material would not affect the color change of restorative materials used for interim restorations over time.

MATERIAL AND METHODS

Three different types of BRC and one CAD/CAM PMMA material were tested (Table 1). Since present study was an *in vitro* study in which humans and animals, including material/data, were not used for experimental purposes, ethical approval was not required.

BRC1, BRC2, BRC3 specimens were prepared using a metal mold, squeezing into the molds with the help of a cartridge. The glass slide was placed on a polyester strip (TDV Polyester Matrix, TDV Dental, Santa Catarina, Brazil) to provide a uniform, non-porous surface. After waiting 5 min for polymerization of the specimens, the glass slide was removed. PMMA specimens were obtained by cutting the disks on a specimen cutting machine (Micracut 201, Metkon, Bursa, Türkiye). Cutting was carried out at low speed under water cooling. Polishing was performed with a polishing kit (Clearfil Twist Dia, Kuraray Noritake, Japan). The thickness (2 mm) of the specimens (10 mm by 12 mm) was verified with a micrometer (Absolute Caliper, Mitutoyo, Japan). The specimens were kept in distilled water for 24 hours in a 37°C incubator (UM 400, Memmert, Germany) and then the first color measurements [baseline (BAS)] were taken.

According to material type, four main groups, equal in number, were created. Each material group was divided into 6 subgroups according to the beverages they were kept in, which are displayed in Table 1. Specimen size calculation was performed using a statistical power analysis program (G*Power ver.

TABLE 1: Materials and beverages in the study.

	Name	Code	Content	Type	Manufacturer
Materials	Oratemp	BRC1	Ethoxylated bisphenol A dimethacrylate, triethylene glycol dimethacrylate, fillers, pigments	Manually with cartridge	Prevest DenPro, Jammu, India
	PrimmaArt	BRC2	Methacrylic monomers (UDMA, extended urethane dimethacrylate, TEDMA), triethylene-glycol-dimethacrylate, micro particles of aluminosilicate glass, pigments	Manually with cartridge	FGM Dental, Joinville, Brazil
	Hexa-Temp	BRC3	Methacrylate matrix (Bis-GMA, TEGDMA), inorganic filler (16 nm-3,22 μm), pigments	Manually with cartridge	Spident, Incheon, Korea
	Eray PMMA Disc	PMMA	PMMA, crosslinked methyl methacrylate, pigments	CAD/CAM system	Eraylar Akrilik, Ankara, Türkiye
Beverages	Galenik Distilled Water	DIS	Distilled water	Distilled water	Galenik Pharmacy, İzmir, Türkiye
	Lipton Earl Grey	TEA	Black tea, flavoring	Black tea	Unilever, Blackfriars-London, UK
	Sambucol Black Elderberry Plus Effervescent	SAM	Sambucus Nigra extract, ascorbic acid, zinc, citric acid	Immune-boosting beverage	Pharmacere Europe, West Sussex, UK
	Supraydn Effervescent	SUP	Vitamins A, C and other vitamins, calcium, iron and other minerals, citric acid, carotenes (colorant)	Multivitamin	Bayer AG, Leverkusen, Germany
	Red Bull	RED	Sucrose, citric acid, carbon dioxide, taurine, caffeine, vitamins, colorants (plain caramel, riboflavin)	Energizing beverage	Red Bull GmbH, Am Brunnen, Austria
	Cappy Support Fruit and Vegetable Beverage	CAP	Sugar, peach, carrot, apple, kiwi, orange, citric acid, vitamin C and B12, zinc	Body resistance-increasing beverage	The Coca Cola Company, Georgia, USA

BRC: Bis-acrylic resin composite; PMMA: Polymethyl methacrylate; CAD/CAM: Computer aided design-computer aided manufacturing.

3.1.9.7, Heinrich-Heine-Universität Düsseldorf, Germany) to determine a significant group effect. Adjusting for significance level (alpha) 0.05, power 0.80 and medium effect size (partial eta squared) 0.06, the minimum specimen size was calculated as 128. To make the study more powered, the number of specimens in each treatment group was determined as 7 and therefore the total number of specimen was determined as 168. In this case, the power of the study was determined as 0.89.[10]

A previous study reported that the average daily consumption time for 3.2 grams of tea was 15 minutes.[11] However, due to the social isolation caused by the COVID-19 pandemic, the amount of beverages consumed by individuals on a daily basis changed, making it difficult to make an accurate estimate of yearly consumption time.[12] Assuming that individuals consume beverages such as tea or coffee at an average of 3 cups per day, the materials were kept in the beverages for 28 days to simulate a period of over 2 years.[13]

The specimens were kept in storage containers. The volume of liquid collection of each compartment was 5 mL. After the specimens were removed from the measuring containers, the specimens were washed with water and wiped gently with tissue paper before beginning the measurements. After the measurements were completed, the cups were returned to their original places.

For TEA, 3.2 g tea sachets were placed in 200 mL distilled water. The beverage prepared with hot water was waited until it reached room temperature. For SAM, one effervescent tablet was immersed in 200 mL of water at room temperature. The effervescent tablet was allowed to dissolve. For SUP, the same method was used as for SAM. The solutions were changed 1 time each day during the test period. The containers were shaken every day for 2 hours to avoid precipitate formation.

Color measurements were performed before immersion in the beverages, on days 1, 14 and 28, and in custom-made color booth that prevents ambient light from causing errors. Figure 1 shows the images of the specimens after 28 days of immersion. Interior of booth was covered with a neutral grey background in accordance with previous studies.[14] Color measurements were performed on with a spectrophotometer (Vita Easyshade V, VITA Zahnfabrik, Germany) and the average of these measurements

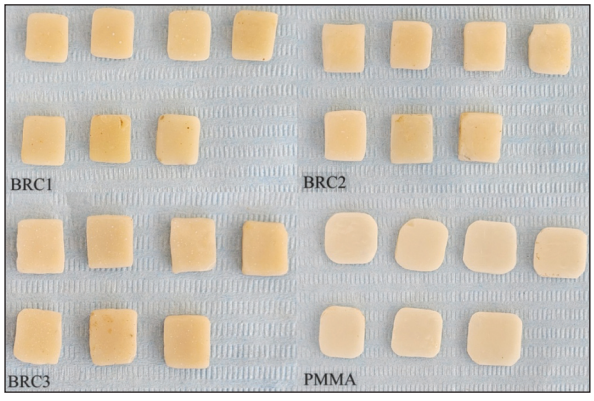

FIGURE 1: Images of some specimens after 28 days.

was recorded for statistical analysis. The Vita Easyshade V is a device that gives L^*, a^*, b^* color space coordinates.

Two different formula were used for color comparison. The first was the following CIELAB color difference formula, which is widely used for color difference evaluation:[15]

$$\Delta E_{ab} = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2}$$

The other formula used was the following CIEDE2000 color difference formula, which the CIE recommends for use today in color difference research:[16]

$$\Delta E_{00} = \left[\left(\frac{\Delta L'}{K_L S_L}\right)^2 + \left(\frac{\Delta C'}{K_C S_C}\right)^2 + \left(\frac{\Delta H'}{K_H S_H}\right)^2 + R_T \left(\frac{\Delta C'}{K_C S_C}\right)\left(\frac{\Delta H'}{K_H S_H}\right)\right]^{1/2}$$

The ISO has recommended the use of perceptibility and acceptability thresholds (PT and AT, respectively) for interpreting results on color. In this study, PT_{ab}/AT_{ab} values were determined as 1.1/3.3 and PT_{00}/AT_{00} as 0.8/1.8.[17-20]

Statistical analysis was performed with the SAS package (Software SAS 9.4, SAS Institute, USA). Two-way ANOVA was performed to assess the interaction of the two independent variables, material and beverage, and the main effects of each variable on colour changes. In addition, post-hoc tests with Bonferroni correction were used if a significant mean difference was found in any of these two independent variables. Statistical significance level was set as $p<0.05$. Cohen f test, one of the post-power tests, was added to the analyses to determine the effect size of the study.

RESULTS

Analysis of ΔE_{00} values with ANOVA test is given in Table 2. The effect of material, beverage and mate-

TABLE 2: 2-way ANOVA results for ΔE_{00} and ΔE_{ab}.

		Source	SS	MS	FValue	ProbF	Cohenf
ΔE_{00}	BAS-day 1	Material	20.505	6.835	9.779	0.000	0.098
		Beverage	31.745	6.349	9.084	0.000	1.152
		Material-beverage	55.600	3.707	5.303	0.000	0.267
	BAS-day 14	Material	26.868	8.956	11.499	0.000	0.109
		Beverage	66.252	13.250	17.013	0.000	0.268
		Material-beverage	41.712	2.781	3.570	0.000	0.169
	BAS-day 28	Material	36.845	12.282	20.350	0.000	0.176
		Beverage	35.262	7.052	11.686	0.000	0.169
		Material-beverage	49.899	3.327	5.512	0.000	0.239
ΔE_{ab}	BAS-day 1	Material	22.278	9.093	5.953	0.001	0.064
		Beverage	61.172	12.234	8.010	0.000	0.144
		Material-beverage	115.606	7.707	5.046	0.000	0.273
	BAS-day 14	Material	46.199	15.400	8.420	0.000	0.082
		Beverage	156.712	31.342	17.137	0.000	0.279
		Material-beverage	95.365	6.358	3.476	0.000	0.170
	BAS-day 28	Material	87.579	29.193	16.870	0.000	0.158
		Beverage	108.936	21.787	12.590	0.000	0.196
		Material-beverage	110.296	7.353	4.249	0.000	0.198

rial-beverage pair on discoloration between BAS-1st day, BAS-14th day, BAS-28th day was statistically significant (p<0.0001).

Bonferroni test results of ΔE_{00} for material-beverage pair are in Table 3. After 1 day, the highest discoloration was observed in BRC2 immersed in SAM (ΔE_{00}=4.6, p<0.0001) and the lowest in BRC3 immersed in CAP (ΔE_{00}=4.6, p=0.0034). After 14 days, the highest discoloration was observed in BRC3 immersed in TEA (ΔE_{00}=4.3, p=0.0101) and the lowest in PMMA immersed in DIS (ΔE_{00}=0.9, p=0.0260). After 28 days, the highest discoloration was observed in BRC3 immersed in TEA (ΔE_{00}=4.4, p=0.0101) and the lowest in PMMA immersed in SAM (ΔE_{00}=0.7, p<0.0001).

Bonferroni test results of ΔE_{00} for material and beverage are given in Table 4. After 1 day, TEA (ΔE_{00}=3.5) caused the highest discoloration and CAP (ΔE_{00}=2.2) caused the lowest (p<0.0001). After 14 days, TEA (ΔE_{00}=3.0) caused the highest discoloration and SAM (ΔE_{00}=1.1) caused the lowest (p<0.0001). After 28 days, TEA (ΔE_{00}=2.6) caused the highest discoloration and CAP (ΔE_{00}=1.3) caused the lowest (p<0.0001).

After 1 day, BRC1 (ΔE_{00}=3.1) caused the highest discoloration and PMMA (ΔE_{00}=2.3) caused the lowest (p=0.0007). After 14 days, BRC2 (ΔE_{00}=2.1) caused the highest discoloration and PMMA (ΔE_{00}=1.1) caused the lowest (p=0.0003). After 28 days, the highest discoloration was observed in BRC2

TABLE 3: Bonferroni test results for material-beverage of ΔE_{00}.

		DIS (n=28)	TEA (n=28)	SAM (n=28)	SUP (n=28)	RED (n=28)	CAP (n=28)	p[1]-value
BAS-day 1	BRC1	2.6 (0.98)^{C}	3.9 (1.19)^{A}	2.2 (0.15)^{b,C}	4.5 (0.81)^{a,A}	2.3 (0.31)^{b,C}	3.1 (0.78)^{a,B}	**<0.0001**
	BRC2	2.4 (0.33)^{C}	3.3 (0.63)^{B}	4.6 (0.85)^{a,A}	3.3 (1.06)^{b,B}	3.3 (0.87)^{a,B}	2.0 (0.30)^{b,C}	**<0.0001**
	BRC3	2.7 (0.89)^{B}	4.5 (2.46)^{A}	2.4 (0.31)^{b,B}	2.6 (0.61)^{c,B}	2.4 (0.33)^{b,B}	1.7 (0.89)^{b,C}	**0.0032**
	PMMA	2.3 (0.27)	2.5 (1.10)	2.3 (0.28)^{b}	2.1 (0.17)^{c}	2.2 (0.28)^{b}	2.1 (0.32)^{b}	0.6385
p-value		0.7048	0.1234	**<0.0001**	**<0.0001**	**0.0030**	**0.0034**	
BAS-day 14	BRC1	1.8 (0.43)^{a,B}	3.4 (1.37)^{b,A}	1.5 (0.56)^{a,B}	2.1 (0.65)^{b,B}	1.5 (0.87)^{b,B}	1.5 (0.71)^{B}	**0.0005**
	BRC2	1.3 (0.85)^{b,C}	2.7 (0.57)^{c,B}	1.7 (0.87)^{a,C}	3.3 (1.73)^{a,A}	2.3 (0.73)^{a,B}	1.4 (0.26)^{C}	**0.0021**
	BRC3	1.1 (0.42)^{b,C}	4.3 (2.73)^{a,A}	0.9 (0.31)^{b,C}	1.8 (0.94)^{b,B}	0.9 (0.32)^{c,C}	1.0 (0.37)^{C}	**<0.0001**
	PMMA	0.9 (0.22)^{b,B}	1.3 (0.27)^{d,A}	0.5 (0.11)^{b,B}	1.1 (0.19)^{c,B}	1.4 (0.14)^{b,A}	1.3 (0.42)^{A}	**<0.0001**
p-value		**0.0260**	**0.0101**	**0.0014**	**0.0056**	**0.0034**	0.2650	
BAS-day 28	BRC1	1.0 (0.25)^{B}	2.3 (0.67)^{b,A}	1.0 (0.64)^{b,B}	1.9 (0.93)^{b,A}	1.0 (0.30)^{b,B}	1.8 (0.85)^{A}	**0.0009**
	BRC2	1.4 (0.75)^{B}	2.7 (0.55)^{b,A}	3.1 (0.66)^{a,A}	2.6 (0.74)^{a,A}	2.3 (0.65)^{a,B}	1.6 (0.19)^{B}	**<0.0001**
	BRC3	1.4 (0.40)^{C}	4.4 (2.62)^{a,A}	1.1 (0.54)^{b,C}	2.4 (1.12)^{a,B}	1.0 (0.56)^{b,C}	1.7 (0.68)^{C}	**<0.0001**
	PMMA	1.2 (0.21)^{A}	0.9 (0.22)^{c,B}	0.7 (0.18)^{b,B}	1.3 (0.21)^{c,A}	1.3 (0.26)^{b,A}	1.1 (0.17)^{A}	**<0.0001**
p-value		0.4021	**0.0011**	**<0.0001**	**0.0275**	**<0.0001**	0.0859	

[1]Analysis of variance F-test p-value: Same superscript lowercase letters represent no significant difference in columns and same superscript capital letters indicate no significant difference in rows.

TABLE 4: Bonferroni test results of ΔE_{00} for material and beverage.

	DIS (n=28)	TEA (n=28)	SAM (n=28)	SUP (n=28)	RED (n=28)	CAP (n=28)	p[1]-value
BAS-day 1	2.5 (0.67)^{B}	3.5 (1.60)^{A}	2.9 (1.11)^{B}	3.1 (1.13)^{A}	2.6 (0.64)^{B}	2.2 (0.79)^{C}	**<0.0001**
BAS-day 14	1.3 (0.61)^{C}	3.0 (1.85)^{A}	1.1 (0.70)^{C}	2.1 (1.27)^{B}	1.5 (0.74)^{C}	1.3 (0.48)^{C}	**<0.0001**
BAS-day 28	1.3 (0.46)^{B}	2.6 (1.81)^{A}	1.5 (1.10)^{B}	2.1 (0.93)^{A}	1.4 (0.70)^{B}	1.6 (0.60)^{B}	**<0.0001**
			BRC1 (n=42)	**BRC2 (n=42)**	**BRC3 (n=42)**	**PMMA (n=42)**	
BAS-day 1			3.1 (1.12)^{A}	3.1 (1.06)^{A}	2.7 (1.39)^{B}	2.3 (0.50)^{B}	**0.0007**
BAS-day 14			2.0 (1.04)^{A}	2.1 (1.14)^{A}	1.7 (1.68)^{A}	1.1 (0.38)^{B}	**0.0003**
BAS-day 28			1.5 (0.81)^{B}	2.3 (0.83)^{A}	2.0 (1.66)^{A}	1.1 (0.30)^{B}	**<0.0001**

[1]Analysis of variance F-test p-value: Same superscript capital letters indicate no significant difference in rows.

(ΔE_{00}=2.3) and the lowest in PMMA (ΔE_{00}=1.1) (p<0.0001).

Analysis of ΔE_{ab} values with ANOVA test is given in Table 2. The effect of material and beverage and material-beverage pair on discoloration between BAS-1st day, BAS-14th day, BAS-28th day was statistically significant (p<0.005).

Bonferroni test results of ΔE_{ab} for material-beverage are in Table 5. After 1 day, the highest discoloration was observed in BRC3 immersed in SAM (ΔE_{ab}=6.8, p<0.0001) and the lowest in BRC3 immersed in CAP (ΔE_{ab}=2.5, p=0.0064). After 14 days, the highest discoloration was observed in BRC3 immersed in TEA (ΔE_{ab}=6.7, p=0.0175) and the lowest in PMMA immersed in SAM (ΔE_{ab}=1.0, p=0.0137). After 28 days, the highest discoloration was observed in BRC2 immersed in TEA (ΔE_{ab}=6.9, p=0.0021) and the lowest in PMMA immersed in SAM (ΔE_{ab}=1.5, p<0.0001).

Bonferroni test results of ΔE_{ab} for material and beverage are shown in Table 6. After 1 day, TEA (ΔE_{ab}=5.1) and CAP (ΔE_{ab}=3.3) caused the highest discoloration (p<0.0001). After 14 days, TEA (ΔE_{ab}=4.8) caused the highest discoloration and SAM (ΔE_{ab}=1.9) caused the lowest (p=0.0001). After 28 days, TEA (ΔE_{ab}=4.3) caused the highest discoloration and DIS (ΔE_{ab}=2.4) caused the lowest (p<0.0001).

TABLE 5: Bonferroni test results for material-beverage of ΔE_{ab}.

		DIS (n=28)	TEA (n=28)	SAM (n=28)	SUP (n=28)	RED (n=28)	CAP (n=28)	p[1]-value
BAS-day 1	BRC1	3.6 (1.36)^{B,C}	5.3 (1.61)^{A,B}	3.0 (0.20)^{b,C}	6.2 (1.13)^{a,A}	3.2 (0.47)^{b,C}	4.3 (1.16)^{a,B,C}	**<0.0001**
	BRC2	3.6 (0.47)^{C}	4.7 (0.92)^{C}	6.8 (1.17)^{a,A}	4.9 (1.67)^{a,b,B}	4.9 (1.33)^{a,B}	3.1 (0.41)^{a,b,C}	**<0.0001**
	BRC3	3.9 (1.32)^{A,B}	6.4 (3.79)^{A}	3.5 (0.41)^{b,B}	3.9 (0.60)^{b,A,B}	3.6 (0.49)^{b,A,B}	2.5 (1.24)^{b,B}	**0.0064**
	PMMA	3.6 (0.41)	3.9 (1.71)	3.7 (0.42)^{b}	3.4 (0.25)^{b}	3.5 (0.44)^{b}	3.3 (0.50)^{a,b}	0.7021
p-value		0.9244	0.2454	**<0.0001**	**0.0003**	**0.0020**	**0.0127**	
BAS-day 14	BRC1	3.0 (0.60)^{B}	5.9 (2.26)^{a,b,A}	2.3 (0.97)^{a,b,B}	3.9 (1.44)^{a,b,B}	2.6 (1.48)^{a,b,B}	2.9 (1.29)^{B}	**0.0004**
	BRC2	2.6 (1.51)^{B}	4.1 (0.93)^{a,b,A,B}	2.7 (1.27)^{a,B}	5.8 (1.90)^{a,A}	3.6 (0.98)^{a,B}	2.9 (0.51)^{B}	**0.0003**
	BRC3	2.1 (0.74)^{B}	6.7 (4.04)^{a,A}	1.8 (0.78)^{a,b,B}	3.3 (1.39)^{b,B}	2.0 (0.84)^{b,B}	2.0 (0.71)^{B}	**<0.0001**
	PMMA	2.0 (0.49)^{A}	2.6 (0.40)^{b,A}	1.0 (0.21)^{b,B}	2.3 (0.43)^{b,A}	2.8 (0.18)^{a,b,A}	2.8 (0.78)^{A}	**<0.0001**
p-value		0.2223	**0.0175**	**0.0137**	**0.0010**	**0.0452**	0.1521	
BAS-day 28	BRC1	1.7 (0.52)^{B}	4.2 (1.45)^{a,b,A}	1.6 (1.12)^{b,B}	3.5 (1.87)^{a,b,A,B}	1.6 (0.57)^{b,B}	3.0 (1.21)^{A,B}	**0.0003**
	BRC2	2.7 (1.59)^{B}	4.1 (0.81)^{a,b,A,B}	4.8 (1.01)^{a,A}	5.3 (1.39)^{a,A}	3.6 (0.80)^{a,A,B}	3.5 (0.46)^{A,B}	**0.0011**
	BRC3	2.8 (1.01)^{A}	6.9 (3.76)^{a,A}	2.2 (1.07)^{b}	5.2 (1.95)^{a,b,A,B}	1.8 (1.23)^{b}	3.7 (1.60)^{A,B}	**0.0002**
	PMMA	2.5 (0.54)^{A}	2.0 (0.52)^{b,A,B}	1.5 (0.39)^{b,B}	2.8 (0.47)^{b,A}	2.8 (0.60)^{a,b,A}	2.4 (0.40)^{A}	**0.0001**
p-value		0.1683	**0.0021**	**<0.0001**	**0.0121**	**0.0003**	0.1154	

[1]Analysis of variance F-test p-value: Same superscript lowercase letters represent no significant difference in columns and same superscript capital letters indicate no significant difference in rows.

TABLE 6: Bonferroni test results of ΔE_{ab} for material and beverage.

	DIS (n=28)	TEA (n=28)	SAM (n=28)	SUP (n=28)	RED (n=28)	CAP (n=28)	p[1]-value
BAS-Day 1	3.7 (0.95)^{B}	5.1 (2.33)^{A}	4.2 (1.67)^{A,B}	4.6 (1.48)^{A,B}	3.8 (0.99)^{B}	3.3 (1.07)^{B}	**<0.0001**
BAS-Day 14	2.4 (0.95)^{B}	4.8 (2.75)^{A}	1.9 (1.05)^{B}	3.8 (1.84)^{A}	2.7 (1.10)^{B}	2.6 (0.92)^{B}	**0.0001**
BAS-Day 28	2.4 (1.06)^{C}	4.3 (2.64)^{A}	2.5 (1.62)^{C}	4.2 (1.81)^{A,B}	2.5 (1.16)^{C}	3.1 (1.11)^{B,C}	**<0.0001**
			BRC1 (n=42)	**BRC2 (n=42)**	**BRC3 (n=42)**	**PMMA (n=42)**	
BAS-Day 1			4.3 (1.56)^{A,B}	4.7 (1.58)^{A}	4.0 (2.04)^{A,B}	3.6 (0.77)^{B}	**0.0121**
BAS-Day 14			3.4 (1.82)^{A}	3.6 (1.62)^{A}	3.0 (2.46)^{B}	2.3 (0.75)^{C}	**0.0027**
BAS-Day 28			2.6 (1.56)^{B}	4.0 (1.32)^{A}	3.8 (2.61)^{A}	2.3 (0.65)^{B}	**<0.0001**

[1]Analysis of variance F-test p-value: Same superscript capital letters indicate no significant difference in rows.

After 1 day, the highest discoloration was observed in BRC2 (ΔE_{ab}=4.7) and the lowest in PMMA (ΔE_{ab}=3.6) (p=0.0121). After 14 days, the highest discoloration was observed in BRC2 (ΔE_{ab}=3.6) and the lowest in PMMA (ΔE_{ab}=2.3) (p=0.0027). After 28 days, the highest discoloration was observed in BRC2 (ΔE_{ab}=4.0) and the lowest in PMMA (ΔE_{ab}=2.3) (p<0.0001).

DISCUSSION

The null hypothesis that beverages would not change the color of materials used for interim restorations depending on time was rejected. PT and AT values are crucial values used in research where discoloration is measured. There is no consensus as to which PT/AT value is valid. Dietschi et al., in their study reporting that the ΔE_{ab} PT/AT value for resin composites was 1.1/3.3, reported that the PT value was determined as the average of 0.7 to 1.7, and the AT value was determined as the average of 2.6 to 3.8.[17] Rizzante et al. reported ΔE_{ab} AT value of 3.3 for resin composites immersed in beverages.[18] In the studies of Miletic et al. for resin composites on extracted teeth, Marcedo et al. for bis-acrylic resin composites 0.8/1.8 was selected as the ΔE_{00} PT/AT value.[19,20] Taking into account abovementioned studies, 1.1/3.3 for PT_{ab}/AT_{ab} and 0.8/1.8 for PT_{00}/AT_{00} are accepted in this study.

In this study, the formulas ΔE_{ab} and ΔE_{00} were used to calculate the color difference data. In CIELAB, the color space is uniform and the individual parameters (L^*, a^*, b^*) are assumed to be of equal importance. However, it has been reported that the interpretation of PT and AT thresholds using L^*, a^*, b^* parameters required high sensitivity and therefore it was recommended to use the K_L, K_C, K_H parametric factors, which provide a better determination of human visual thresholds. Although ΔE_{00} is a more advanced formula recommended by the CIE, the majority of studies evaluating beverage-induced discoloration of resin composite materials use the ΔE_{ab} formula. Therefore, both values were presented in this study. According to this study, the results obtained with the two color difference formulae were consistent with each other, as in previous studies.[21,22]

According to the results obtained after 28 days, TEA-BRC1 (ΔE_{00}=2.3, ΔE_{ab}=4.2), TEA-BRC2 (ΔE_{00}=2.7, ΔE_{ab}=4.1), TEA-BRC3 (ΔE_{00}=4.4, ΔE_{ab}=6.9), SAM-BRC2 (ΔE_{00}=3.1, ΔE_{ab}=4.8), SUP-BRC1 (ΔE_{00}=1.9, ΔE_{ab}=3.5), SUP-BRC2 (ΔE_{00}=2.6, ΔE_{ab}=5.3), SUP-BRC3 (ΔE_{00}=2.4, ΔE_{ab}=5.2), RED-BRC2 (ΔE_{00}=2.3, ΔE_{ab}=3.6) combinations showed clinically unacceptable discoloration.

Polishability of surfaces is one of the factors affecting the color stability of resin-based dental materials. In the present study, discolorations in materials 28 days after exposure to beverages were BRC2 (ΔE_{00}=2.3, ΔE_{ab}=4.0)> BRC3 (ΔE_{00}=2.0, ΔE_{ab}=3.8)> BRC1 (ΔE_{00}=1.5, ΔE_{ab}=2.6)> PMMA (ΔE_{00}=1.1, ΔE_{ab}=2.3). Consistent with the results of the study of Yannikakis et al., in the present study, the methacrylate-containing materials used for interim restoration showed a more stable discoloration compared to the bis-acrylic-containing materials, probably due to its homogeneous structure.[23]

Another factor affecting the discoloration in materials used for interim restorations is the method of production. Unlike CAD/CAM materials used for interim restorations, complete polymerization may not occur in materials obtained manually in the laboratory or clinic due to oxygen contact. This study, which shows that the color stability of CAD/CAM PMMA materials used for interim restorations was better than bis-acrylic materials used for interim restorations, was comparable with previous studies on CAD/CAM materials used for interim restorations.[2,24] In their study, Song et al. obtained results similar to those in the present study, bis-acrylic-based and PMMA materials were tested, and the discoloration caused coffee at the end of the 4-week period was above the clinically perceptible level.[24] The authors reported that the major reason for the discoloration was water absorption.

A positive impact of high level polymerization of CAD/CAM PMMA materials used for interim restorations is the formation of a less porous structure that allows less water absorption. In a previous study of Rayyan et al., which yielded results consistent with this study, CAD/CAM PMMA specimens kept in coffee, tea, cola and wine exhibited higher

color stability compared to BRCs, could be due to lower porosity and water absorption.[25]

Since the polymers in BRCs are more polar than the polymers in acrylic resins, the risk of absorption of color-changing substances into the structure increases. Mickeviciute et al. obtained results similar to this study, and showed that the reason for BRC materials used for interim restorations are less color-stable compared to PMMA materials used for interim restorations is that BRCs have a different monomer-polymer composition that increases the adhesion of liquid molecules to the structure.[26]

The water absorption mechanism in resin-based materials is a diffusion-controlled process that occurs in the resin matrix. Decomposition products formed by water diffusion and colored peroxide formed by the oxidation of the polymer matrix cause yellowing in the color of the material.[27] In this study, the fact that BRC1 (ΔE_{00}=1.00, ΔE_{ab}=1.7) caused less discoloration compared to BRC2 (ΔE_{00}=1.4, ΔE_{ab}=2.7) and BRC3 (ΔE_{00}=1.4, ΔE_{ab}=2.8) can be explained by the fact that it has a different chemical content that prevents water diffusion. However, the information presented by the manufacturers or explained in the literature about the compositions and crosslinking magnitudes of the materials is not sufficient to reach a definitive conclusion.[28]

The discoloration of dental materials may differ according to the type of beverage. The low polarity yellow pigments of black tea adsorb to the material surface and cause color change. Additionally, the oxalic, malic and citric acids it contains make pigment retention easier by increasing surface roughness. In their study by Almohareb et al., using BRC and CAD/CAM PMMA, they tested tea, coffee and cola. In their study, which yielded similar results to this study, the least discoloration occurred with cola as a beverage and CAD/CAM PMMA as a material.[29] Insufficient polymerization, polymerization shrinkage and preparation errors have been shown as the reasons for more discoloration in BRCs compared to CAD/CAM PMMAs.

Beverages tested in this study, other than black tea, included energy and immune-boosting beverages with black elderberry. After 28 days, the discoloration due to TEA (ΔE_{00}=2.6, ΔE_{ab}=4.3) was significantly higher than with SAM (ΔE_{00}=1.5, ΔE_{ab}=2.5) or RED (ΔE_{00}=1.4, ΔE_{ab}=2.5). The pigments in black tea may adhere to the surface and lead to increased concentration (absorption), as well as increased density and accumulation (adsorption). In a study by Bayindir et al. with similar results to this study, it was reported that black tea caused higher discoloration than the energizing beverage and this was due to the fact that the yellow pigments were more compatible to attach to the polymer structure in the interim restoration materials compared to the pigments in the energizing beverage.[30]

Discoloration may occur due to aging in materials kept in water or saliva. In the present study, although the discoloration caused by distilled water on the materials after 28 days was below the clinically unacceptable level, the order was BRC2 (ΔE_{00}=1.4, ΔE_{ab}=2.7), BRC3 (ΔE_{00}=1.4, ΔE_{ab}=2.8)> PMMA (ΔE_{00}=1.2, ΔE_{ab}=2.5)> BRC1 (ΔE_{00}=1.0, ΔE_{ab}=1.7). This result is consistent with the results of the study of Rutkunas et al. who tested PEMA, PMMA, two different bis-acrylic and two different resin composites.[31] In their study, where a ΔE_{ab} change of 2.59 was detected in PMMA specimens kept in distilled water, it was found that the magnitude of discoloration varied depending on the brand of the material. In a study by Al-Akhali et al. on BRC and PMMA materials immersed in distilled water, clinically perceptible discoloration was found, similar to the present study, and water absorption and photo-oxidation were reported as the cause.[32]

The beverage, abbreviated CAP in this study, is claimed to increase body resistance thanks to the mixture of fruit (peach, carrot, kiwi, orange) juices and vitamins it contains. The results obtained regarding fruit juice are compatible with the study of Türker et al. In both studies, discoloration was found to be clinically acceptable.[33]

One of the factors causing discoloration in the tested specimens may be the acidic character of the beverages, which causes surface degradation. In the present study, SUP (ΔE_{00}=2.1, ΔE_{ab}=4.2) caused a discoloration close to TEA (ΔE_{00}=2.6, ΔE_{ab}=4.3). The discoloration on the material surface immersed in

SUP after 28 days is BRC2 (ΔE_{00}=2.6, ΔE_{ab}=5.6)> BRC3 (ΔE_{00}=2.4, ΔE_{ab}=5.2)> BRC1 (ΔE_{00}=1.9, ΔE_{ab}=3.5)> PMMA (ΔE_{00}=1.3, ΔE_{ab}=2.8). In previous studies on multivitamins, researchers reported that the material and beverage type and immersion time were effective factors in discoloration.[6,7,34]

In the present study, after 28 days SAM (ΔE_{00}=1.5, ΔE_{ab}=2.5), RED (ΔE_{00}=1.4, ΔE_{ab}=2.5) and DIS (ΔE_{00}=1.3, ΔE_{ab}=2.4) led to a similar degree of discoloration. After 28 days, the discoloration caused by SAM was BRC2 (ΔE_{00}=3.1, ΔE_{ab}=4.8)>BRC3 (ΔE_{00}=1.1, ΔE_{ab}=2.2)>BRC1 (ΔE_{00}=1.0, ΔE_{ab}=1.6)> PMMA (ΔE_{00}=0.7, ΔE_{ab}=1.5). The factors affecting the discoloration may be the pigment type of beverage, the material structure and the manufacturing technique. In a previous study of Berber et al., which yielded similar results to this study, sour cherry juice, which is a natural source of anthocyanins like black elderberry, was tested, and the polishing method and the type of filler in the material were shown to cause discoloration.[35]

A limitation of this study was that intraoral conditions were not completely simulated. Rectangular specimens with a flat surface were prepared for color measurement. In laboratory studies, the advantage for repeatability of creating a flat surface compared to the curved surfaces of natural teeth is offset by possible errors due to edge loss and environmental conditions. Since the Vita Easyshade V device was used in the latest studies to investigate the color change of resin composite materials, this device was used in present study.[19] A custom-made booth was prepared to minimize possible errors that may occur due to environmental conditions, and to ensure repeatability and standardization of measurements.[14]

Increased consumption of energy beverages due to social isolation caused by pandemics such as COVID-19 and Mpox, which have become a global health threat, and increased consumption of body resistance-increasing beverages, multivitamins and immune-boosting beverages to support treatment have led to the need to investigate the effect of such beverages on the surface properties of dental restorative materials. Future studies are needed on the effect of energizing beverages, multivitamins or natural anthocyanin beverages that also have immune-boosting properties on discoloration of various dental materials.

CONCLUSION

Results under limitations of this study:

1. After 28 days, the discoloration for all material-beverage pairs except for the PMMA-immune-boosting beverage pair (ΔE_{ab}=0.7) was higher than the clinical perceptibility threshold determined for the CIEDE2000 formula (PT_{00}=0.8). After 28 days, no pair was found to have a discoloration lower than the clinical perceptibility threshold determined for the CIELAB formula (PT_{ab}=1.3).

2. When the beverages were examined regardless of material, the discoloration after 28 days was higher than the clinical acceptability threshold for black tea (ΔE_{00}=2.6, ΔE_{ab}=4.3) and multivitamin (ΔE_{00}=2.1, ΔE_{ab}=4.2), but between the clinical perceptibility and acceptability thresholds for the other beverages.

3. When the materials were examined regardless of beverage, the discoloration after 28 days was higher than the clinical acceptability threshold for BRC2 (ΔE_{00}=2.3, ΔE_{ab}=4.0) and BRC3 (ΔE_{00}=2.0, ΔE_{ab}=3.8), but between the clinical perceptibility and acceptability thresholds for the other materials.

4. The highest and lowest discolorations were found as follows, respectively: BRC2-immune-boosting beverage (ΔE_{00}=4.6, ΔE_{ab}=6.8) and BRC3-body resistance-increasing beverage (ΔE_{00}=1.7, ΔE_{ab}=2.5) for BAS-Day 1, BRC3-black tea (ΔE_{00}=4.3, ΔE_{ab}=6.7) and PMMA-immune-boosting beverage (ΔE_{00}=0.5, ΔE_{ab}=1.0) for BAS-Day 14, BRC3-black tea (ΔE_{00}=4.4, ΔE_{ab}=6.9) and PMMA-immune-boosting beverage (ΔE_{00}=0.7, ΔE_{ab}=1.5) for BAS-Day 28.

Acknowledgements

I would like to thank Pharmacist Gülşah Akbülbül Yılmaz for her efforts.

Source of Finance

During this study, no financial or spiritual support was received neither from any pharmaceutical company that has a direct connection with the research subject, nor from a company that pro-

vides or produces medical instruments and materials which may negatively affect the evaluation process of this study.

Conflict of Interest

No conflicts of interest between the authors and / or family members of the scientific and medical committee members or members of the potential conflicts of interest, counseling, expertise, working conditions, share holding and similar situations in any firm.

Authorship Contributions

Idea/Concept: *Kerem Yılmaz;* ***Design:*** *Kerem Yılmaz;* ***Control/Supervision:*** *Kerem Yılmaz, Erdem Özdemir;* ***Data Collection and/or Processing:*** *Kerem Yılmaz;* ***Analysis and/or Interpretation:*** *Kerem Yılmaz;* ***Literature Review:*** *Erdem Özdemir;* ***Writing the Article:*** *Kerem Yılmaz, Erdem Özdemir, Burak Yılmaz;* ***Critical Review:*** *Burak Yılmaz;* ***References and Fundings:*** *Erdem Özdemir;* ***Materials:*** *Kerem Yılmaz.*

REFERENCES

1. Ergün G, Mutlu-Sagesen L, Ozkan Y, Demirel E. In vitro color stability of provisional crown and bridge restoration materials. Dent Mater J. 2005;24(3):342-50. [Crossref] [PubMed]
2. Guler AU, Kurt S, Kulunk T. Effects of various finishing procedures on the staining of provisional restorative materials. J Prosthet Dent. 2005;93(5):453-8. [Crossref] [PubMed]
3. Ali A, Sohaib M, Iqbal S, Hayat K, Khan AU, Rasool MF. Evaluation of COVID-19 disease awareness and its relation to mental health, dietary habits, and physical activity: a cross-sectional study from Pakistan. Am J Trop Med Hyg. 2021;104(5):1687-93. [Crossref] [PubMed] [PMC]
4. Martin BR, Richardson J. An exploratory review of potential adjunct therapies for the treatment of coronavirus infections. J Chiropr Med. 2021;20(4):199-217. [Crossref] [PubMed] [PMC]
5. Koczorowski R, Linkowska-Swidzińska K, Gedrange T, Swidziński T. Analysis of colour stability of selected provisional prosthetic materials: an in vitro study. Biomed Tech (Berl). 2009;54(4):205-10. [Crossref] [PubMed]
6. Yildirim S, Uslu YS. Effects of different pediatric drugs and toothbrushing on color change of restorative materials used in pediatric dentistry. Niger J Clin Pract. 2020;23(5):610-8. [Crossref] [PubMed]
7. Almutairi M, Moussa I, Alsaeri N, Alqahtani A, Alsulaiman S, Alhajri M. The effects of different pediatric drugs and brushing on the color stability of esthetic restorative materials used in pediatric dentistry: an in vitro study. Children (Basel). 2022;9(7):1026. [Crossref] [PubMed] [PMC]
8. Karagoz A, Tombuloglu H, Alsaeed M, Tombuloglu G, AlRubaish AA, Mahmoud A, et al. Monkeypox (mpox) virus: classification, origin, transmission, genome organization, antiviral drugs, and molecular diagnosis. J Infect Public Health. 2023;16(4):531-41. [Crossref] [PubMed] [PMC]
9. Melgosa M. CIE/ISO new standard: CIEDE2000. 2013. [Link]
10. AlSheikh R, Almajed Y, Al Eid F, Zainaldeen S, Ahmad Siddiqui I, Gaffar B. The effect of beverage temperature on the surface roughness, microhardness, and color stability of the monoshade composite resin: an in vitro study. Saudi Dent J. 2024;36(5):740-4. [Crossref] [PubMed] [PMC]
11. 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(2):371-6. [Crossref] [PubMed]
12. Bakaloudi DR, Evripidou K, Jayawardena R, Breda J, Dardavessis T, Poulia KA, et al. The impact of lockdowns on caffeine consumption: a systematic review of the evidence. Int J Environ Res Public Health. 2022;19(9):5255. [Crossref] [PubMed] [PMC]
13. Yamanel K. Farklı içeceklerin diş rengindeki restoratif materyallerin renk stabiliteleri üzerine etkisi [Effect of different drinks on color stability of tooth colored restorative materials]. SDU Journal of Health Sciences. 2018;9(2):26-31. [Crossref]
14. Luo XP, Zhang L. Effect of veneering techniques on color and translucency of Y-TZP. J Prosthodont. 2010;19(6):465-70. [Crossref] [PubMed]
15. Kurtulmus-Yilmaz S, Cengiz E, Ulusoy N, Ozak ST, Yuksel E. The effect of home-bleaching application on the color and translucency of five resin composites. J Dent. 2013;41 Suppl 5:e70-5. [Crossref] [PubMed]
16. Sampaio CS, Belfus J, Avila A, Cordero C, Freitte M, Ferrari V, et al. Effect of different fabrication steps on color and translucency of a CAD/CAM feldspathic ceramic. J Esthet Restor Dent. 2021;33(7):1038-44. [Crossref] [PubMed]
17. Dietschi D, Abdelaziz M, Krejci I, Di Bella E, Ardu S. A novel evaluation method for optical integration of class IV composite restorations. Aust Dent J. 2012;57(4):446-52. [Crossref] [PubMed]
18. Rizzante FAP, Bombonatti JSF, Vasconcelos L, Porto TS, Teich S, Mondelli RFL. Influence of resin-coating agents on the roughness and color of composite resins. J Prosthet Dent. 2019;122(3):332.e1-332.e5. [Crossref] [PubMed]
19. Miletic V, Marjanovic J, Veljovic DN, Stasic JN, Petrovic V. Color stability of bulk-fill and universal composite restorations with dissimilar dentin replacement materials. J Esthet Restor Dent. 2019;31(5):520-8. [Crossref] [PubMed]
20. Macedo MGFP, Volpato CAM, Henriques BAPC, Vaz PCS, Silva FS, Silva CFCL. Color stability of a bis-acryl composite resin subjected to polishing, thermocycling, intercalated baths, and immersion in different beverages. J Esthet Restor Dent. 2018;30(5):449-56. [Crossref] [PubMed]
21. Forville H, Favoreto MW, Wendlinger M, Dias RM, Ferreira Borges CP, Reis A, et al. Evaluation of at-home bleaching protocol with application on different surfaces: bleaching efficacy and hydrogen peroxide permeability. Restor Dent Endod. 2023;48(4):e33. [Crossref] [PubMed] [PMC]
22. Tinastepe N, Malkondu O, Iscan I, Kazazoglu E. Effect of home and over the contour bleaching on stainability of CAD/CAM esthetic restorative materials. J Esthet Restor Dent. 2021;33(2):303-13. Erratum in: J Esthet Restor Dent. 2022;34(3):577. [Crossref] [PubMed]
23. Yannikakis SA, Zissis AJ, Polyzois GL, Caroni C. Color stability of provisional resin restorative materials. J Prosthet Dent. 1998;80(5):533-9. [Crossref] [PubMed]
24. Song SY, Shin YH, Lee JY, Shin SW. Color stability of provisional restorative materials with different fabrication methods. J Adv Prosthodont. 2020;12(5):259-64. [Crossref] [PubMed] [PMC]
25. Rayyan MM, Aboushelib M, Sayed NM, Ibrahim A, Jimbo R. Comparison of interim restorations fabricated by CAD/CAM with those fabricated manually. J Prosthet Dent. 2015;114(3):414-9. [Crossref] [PubMed]
26. Mickeviciute E, Ivanauskiene E, Noreikiene V. In vitro color and roughness stability of different temporary restorative materials. Stomatologija. 2016;18(2):66-72. [PubMed]

27. Weyhrauch M, Igiel C, Pabst AM, Wentaschek S, Scheller H, Lehmann KM. Interdevice agreement of eight equivalent dental color measurement devices. Clin Oral Investig. 2015;19(9):2309-18. [Crossref] [PubMed]

28. Sham AS, Chu FC, Chai J, Chow TW. Color stability of provisional prosthodontic materials. J Prosthet Dent. 2004;91(5):447-52. [Crossref] [PubMed]

29. Almohareb T, Alkatheeri MS, Vohra F, Alrahlah A. Influence of experimental staining on the color stability of indirect computer-aided design/computer-aided manufacturing dental provisional materials. Eur J Dent. 2018;12(2):269-74. [Crossref] [PubMed] [PMC]

30. Bayindir F, Kürklü D, Yanikoğlu ND. The effect of staining solutions on the color stability of provisional prosthodontic materials. J Dent. 2012;40 Suppl 2:e41-6. [Crossref] [PubMed]

31. Rutkunas V, Sabaliauskas V. Effects of different repolishing techniques on colour change of provisional prosthetic materials. Stomatologija. 2009;11(4):102-12. [PubMed]

32. Al-Akhali AAM, Al-Hamzi M, Al-Shami IZ, Al-Kholani AI, Madfa AA. Effect of khat extract on color stability of digitally and manually fabricated provisional restorations: an in vitro comparative study. BMC Oral Health. 2023;23(1):700. [Crossref] [PubMed] [PMC]

33. Türker SB, Koçak A, Aktepe E. Effect of five staining solutions on the colour stability of two acrylics and three composite resins based provisional restorations. Eur J Prosthodont Restor Dent. 2006;14(3):121-5. [PubMed]

34. Faghihi T, Heidarzadeh Z, Jafari K, Farhoudi I, Hekmatfar S. An experimental study on the effect of four pediatric drug types on color stability in different tooth-colored restorative materials. Dent Res J (Isfahan). 2021;18:75. [Crossref] [PubMed] [PMC]

35. Berber A, Cakir FY, Baseren M, Gurgan S. Effect of different polishing systems and drinks on the color stability of resin composite. J Contemp Dent Pract. 2013;14(4):662-7. [Crossref] [PubMed]