ORIGINAL RESEARCH

Comparison and Effect of Common Beverages on Color Stability of Different Esthetic Restorative Materials: An *In Vitro* Study

Abdulkhaleq Mohammed Qaraghuli[1], Antonio Signore[2], Stefano Benedicenti[3], Mohamed Tarek El Halawani[4], Luca Solimei[5]

Abstract

Aim: The aim of this *in vitro* study is to assess the color stability of different esthetic veneer restorative materials (feldspathic ceramic, hybrid ceramic, zirconia-reinforced lithium silicate glass ceramic, and composite resin) after being exposed to commonly consumed beverages that have staining potential.

Materials and methods: Sixty specimens were prepared into rectangular blocks with fixed dimensions of 10 × 12 × 2.5 mm. Machinable feldspathic ceramic (FC), zirconia-reinforced lithium silicate glass ceramic (LS), and a hybrid ceramic (HC) were milled using CAD/CAM ($n = 15$), and specimens of microparticle composite resin (MPC) were manually prepared by with the same dimensions ($n = 15$). All specimens were randomly divided into three subgroups (= 5) according to immersing solutions used (coffee, black tea, and red wine). All specimens were immersed for a period of 72 hours. A colorimetric evaluation was done for each specimen before and after immersion using a spectrophotometer and the difference in color was calculated according to the CIE-Lab system.

To analyze the data, two-way ANOVA and one-way ANOVA tests of significance were used to compare between the different study groups, followed by pairwise comparisons using *post hoc* test (Tukey).

Results: Different restorative materials showed statistical significance regarding color change after staining ($p < 0.001$); however, no statistical significance in color change ($p > 0.05$) was found between the different beverages used.

Conclusion: All tested ceramic materials had better color stability compared with composite resin. All the staining beverages used in the current study might cause a significant color change in the tested restorative materials.

Clinical significance: The color stability of esthetic restorative materials affects their clinical performance in the oral cavity, where the restorative materials are usually exposed to staining beverages that are frequently consumed by patients. Therefore, it is important to understand the staining effect of the different beverages on esthetic restorative materials.

Keywords: Ceramics, Color, Composite, Esthetic materials, Zirconia.

The Journal of Contemporary Dental Practice (2022): 10.5005/jp-journals-10024-3419

Introduction

The introduction of new and improved restorative materials and fabrication techniques changed the esthetic restorative treatment patterns and resulted in a higher demand for esthetic dentistry. The color stability of an esthetic restoration is a crucial factor to its longevity and long-term success in the oral cavity. Color stability throughout the functional lifetime of a restoration is as important as the mechanical characteristics of the material. Color changes over time may limit the quality and longevity of laminate veneers and other esthetic restorations.[1]

Several factors are associated with the staining of restorative materials in the oral environment. Prolonged exposure to staining solutions discolors ceramic materials, composite resins, resin matrix ceramics (hybrid ceramic, nanoceramics), and CAD-/CAM-processed composite resins affecting their optical and esthetic properties.[2–4]

Knowledge of the optical properties of dental restorative materials is important in achieving esthetic restorations. The longevity and esthetic appearance of tooth-colored restorations depend on the color stainability of the material.[5]

Color change of dental esthetic restorations may be caused by intrinsic and/or extrinsic factors. The more common extrinsic factors are mainly due to staining by absorption of colorants from exogenous sources, such as beverages, coffee, tea, red wine, smoking nicotine, and mouth rinses, as well as on the

[1]Department of Surgical Sciences and Integrated Diagnostics, University of Genoa, Largo R Benzi, Genoa, Italy; Department of Dentistry, Al-Farabi University College, Baghdad, Iraq

[2]Department of Therapeutic Stomatology, Institute of Dentistry, IM Sechenov First Moscow State Medical University, Moscow, Russia

[3,5]Department of Surgical Sciences and Integrated Diagnostics, University of Genoa, Largo R Benzi, Genoa, Italy

[4]Conservative Dentistry Department, Faculty of Dentistry, Alexandria University, Alexandria, Egypt; Prosthodontics Department, Faculty of Dentistry, Alamein International University, Al Alamein City, Matrouh, Egypt

Corresponding Author: Abdulkhaleq Mohammed Qaraghuli, Department of Surgical Sciences and Integrated Diagnostics, University of Genoa, Largo R Benzi, Genoa, Italy; Department of Dentistry, Al-Farabi University College, Baghdad, Iraq, Phone: +9647704333814 e-mail: dr.abdulkhaleq91@gmail.com; dr.abdulkhaleq@alfarabiuc.edu.iq

How to cite this article: Qaraghuli AM, Signore A, Benedicenti S, *et al*. Comparison and Effect of Common Beverages on Color Stability of Different Esthetic Restorative Materials: An *In Vitro* Study. J Contemp Dent Pract 2022;23(11):1085–1090.

Source of support: Nil

Conflict of interest: None

---

exposure time to such substances. In composite materials, the most important intrinsic factors affecting color stability are the percentage and particle size of fillers, type of resin matrix, type of photo-initiator, and percentage of double bonds remaining in the material.[6,7]

Differently, intrinsic factors in ceramic restorations depend on their composition and the presence or absence of a glaze layer. Glazing of ceramic restorations is considered of utmost importance to the color stability as it affects their stain resistance. Nevertheless, even minor occlusal adjustments of ceramic restorations after cementation result in the removal of the surface glaze, which increases the surface roughness of the ceramic. A rough surface on the restoration increases its susceptibility to extrinsic staining and may affect the shade of the restoration due to a reduction in the amount of reflected light.[6]

The Commission Internationale de l'Eclairage L*a*b* (CIELab) system measures chromaticity and defines the color of an object in a uniform three-dimensional space. Color difference, ΔE values, may be calculated as through differences in the color parameters (L*, a*, b*).[8] If $\Delta E = 0$, this indicates that the material being tested is believed to be color stable, while values of ΔE between 0 and 2 indicate a color difference that is negligible. However, some studies point out that even ΔE values >0.4 may be perceivable by a trained human observer.[5,9–11] Although ΔE values between 3 and 5 are considered by some authors to be clinically acceptable, they are significant due to being perceptible by trained and untrained observers alike. Lastly, ΔE values of more than 5 are not considered acceptable, and indicate that the restoration should be replaced.[12,13]

Spectrophotometers are used to evaluate the color of both teeth and restorations by measuring the wave-length that is reflected or transmitted from one object at a time. They are considered more accurate than colorimeters as they are not affected by any subjective interferences of the color, whereas colorimeters provide an overall measurement of the light absorbed.[14]

This study aimed at measuring the color change in different esthetic restoration materials, before and after being subjected to different types of staining beverages. The first null hypothesis tested was that there is no difference in color change between different restorative materials. The second null hypothesis tested was that there is no difference in staining potential among staining solutions used in the study.

MATERIALS AND METHODS

The current original *in vitro* study was conducted during a 3-month time period, at the Department of Surgical Sciences and Integrated Diagnostics, University of Genoa, Genoa, Italy.

Grouping of the Specimens

Sixty specimens were prepared into rectangular slices of fixed dimensions (10 × 12 × 2.5 mm) and divided into four groups ($n = 15$) according to the material used: a machinable feldspathic ceramic (VITABLOCS® Triluxe forte; Vita Zahnfabrik GmbH, Bad Sackigen, Germany), a zirconia-reinforced lithium silicate glass ceramic (VITA SUPRINITY®; Vita Zahnfabrik GmbH, Bad Sackigen, Germany), a hybrid ceramic (VITA ENAMIC®; Vita Zahnfabrik GmbH, Bad Sackigen, Germany), and a microparticle composite resin (VITAVM® LC; Vita Zahnfabrik GmbH, Bad Sackigen, Germany).

Each group was then subdivided randomly into three equal subgroups ($n = 5$) according to immersion solution used (Subgroup C: coffee, Subgroup T: black tea, and Subgroup W: red wine). The grouping of the specimens is shown in Table 1.

Table 1: Grouping of the specimens

	Restorative materials			
Staining solutions	*Group FC ($n = 15$)*	*Group HC ($n = 15$)*	*Group LS ($n = 15$)*	*Group MPC ($n = 15$)*
Subgroup C	5	5	5	5
Subgroup T	5	5	5	5
Subgroup W	5	5	5	5
Total	60 specimens			

C, coffee; FC, Feldspathic ceramic (VITA BLOCS® TRILUXE FORTE); HC, hybrid ceramic (VITA ENAMIC®); LS, zirconia-reinforced lithium silicate glass ceramic (VITA SUPRINITY®); MPC, microparticle composite (VITA VM®LC); T, black tea; W, red wine

Specimen Preparation

All specimens from the Feldspathic ceramic group (FC), the zirconia-reinforced lithium silicate group (LS), and the hybrid ceramic group (HC) were first designed using computer-aided designing software (CAD Rhinoceros; Robert McNeel & Associates, NY, USA) into rectangular slices of 10 × 12 mm with a thickness of 2.5 mm. The specimens were then milled using a milling machine (Cara DS mill 2.5; Kulzer, Hanau, Germany) from machinable blocks of shade 2M2.

After milling, each group underwent treatment and finishing according to the manufacturer's material recommendations. For the FS group, the specimens were treated using a self-glaze cycle in a ceramic oven (Mod.vita 6000MP; Vita Zahnfabrik GmbH, Bad Sackigen, Germany) with a maximum temperature of 950°C, and a holding time at maximum temperature for 1 minute. In the LS group, crystallization firing was performed (with a max temperature of 840°C, and a holding time at maximum temperature for 8 minutes in vacuum, then cooking with thermal cycle of 800°C maximum temperature, and a holding time of 1 minute without vacuum) in a ceramic oven (Mod.Vita 6000MP; Vita Zahnfabrik GmbH, Bad Sackigen, Germany). As for the HC group, mechanical polishing was achieved using handpiece with special rubbers and brushes (Vita enamic polishing set; Vita Zahnfabrik GmbH, Bad Sackigen, Germany).

For the final group, microparticle composite resin (MPC) of shade A2 (VITAVM® LC; Vita Zahnfabrik GmbH, Bad Sackigen, Germany) was manually prepared by the operator using a polyvinyl siloxane silicone mold with the same parameters and thickness of CAD/CAM-prepared ceramic specimens (10 × 12 mm with a thickness of 2.5 mm). First, an impression was taken for a master specimen to act as a negative replica for the composite material. The composite resin was placed into the silicone mold and compressed with composite plastic instrument. The excess composite was removed before light curing followed by placement of mylar film on the top of the specimen with a glass slab placed over it in order to create uniform and smoothed surface of the final composite layer. The composite specimens were polymerized for 40 seconds on each side to ensure complete polymerization using light curing unit 1000 mW/cm^2 (Coltolux® LED; Coltene Ch, Altstatten, Switzerland).

After that, composite resin specimens were contoured and finished using abrasive discs of different grits: coarse 80 µm, fine 20 µm, and extrafine 10 µm (OptidDisc™; Kerr Dental, Brea, CA, USA) for 15 seconds with each disc type. Polishing was done using fine and extrafine grit aluminum oxide paste (Prisma-Gloss; Dentsply Sirona, Charlotte, NC, USA) to produce a natural-looking luster on composite surface using concave-shaped polishing brush (Optishine™; Kerr Dental, Brea, CA, USA). The finishing and polishing procedure was done under magnification loupes with light (EyeMag Pro s 4.5 × 300 mm; Carl Zeiss Meditec AG, Jena, Germany) also used to check any imperfections in the specimens.

Immersion Solution Preparation

Coffee for subgroup C was prepared using Illy classic coffee (Illycaffe S.p.A., Trieste, Italy) by adding three tablespoons of coffee to a coffee kettle (Bialetti S.p.A., Brescia, Italy) per 600 mL of boiling distilled water according to the manufacturer's suggested concentration brewed for 3–4 minutes, and then left to cool. In subgroup T, black tea with cardamom flavoring (Ahmad Tea London Ltd., Winchester Road, United Kingdom) was prepared by adding two tablespoons to 1 liter of boiled water in a tea kettle and brewed on quiet fire for 4–5 minutes according to the manufacturer's recommendations. For subgroup W, red wine (I Somelieri Freisa, Piomonte, Monferrato Italy) was used for immersion of specimens.

The prepared solutions were poured into 60 glass cups, and each specimen was immersed into the solution in a separate cup for 72 hours at room temperature to simulate 3 months of consumption.[15] After the immersion period was over, all specimens were rinsed with distilled water for 2 minutes and blotted dry with absorbent tissue paper before the final color measurements.

Colorimetric Measurement

Before color measurement, the spectrophotometer calibration was done according to manufacturer instructions and recalibrated before color data collection of each group. The operator was blinded as to which group/solution the specimens that were being tested belonged to. The color of all specimens was measured at time (0 hour) as a baseline color and after (72 hours) with a spectrophotometer (Easyshade V, VITA Zahnfabrik GmbH, Bad Sackigen, Germany). The color of each specimen was recorded using the Commission Internationale de l'Eclairge L*a*b (CIE Lab) values.

The color measurements were done using an acrylic mold that has a hole on the central part of its surface. Each specimen was placed on the acrylic mold and the scanning tip of the spectrophotometer was pointed through this hole in order to measure the color of the central part for each specimen. All the color measurements and the experiment procedures were done by the same operator. The difference in color (ΔE) before and after immersion was calculated through differences in the color parameters using the following equation:

$$\Delta E^{*} = \left[(L1^{*} - L0^{*})^{2} + (a1^{*} - a0^{*})^{2} + (b1^{*} - b0^{*})^{2} \right]^{1/2}$$

L1: the value of *L* after immersion

L0: the value of *L* before immersion

a1: the value of *a* after immersion

a0: the value of *a* before immersion

b1: the value of *b* after immersion

b0: the value of *b* before immersion.

Table 2: General linear model (two-way ANOVA) showing the effect of each factor on ΔE and the interaction between

	F	p
Beverages	2.280	0.113
Materials	23.636*	<0.001*
Beverages*Materials	1.036	0.414

*Statistically significant at $p \leq 0.05$

Table 3: Comparison between the ΔE found in the materials used in the study regardless of the beverage used.

	Group FC *(n = 15)*	*Group HC* *(n = 15)*	*Group LS* *(n = 15)*	*Group MPC* *(n = 15)*
ΔE	0.67 ± 0.39	2.37 ± 1.49	0.95 ± 0.30	6.04 ± 3.72
Sig. bet. grps	$p_1 = 0.096$, $p_2 = 0.980$, $p_3 < 0.001^*$, $p_4 = 0.208$, $p_5 < 0.001^*$, $p_6 < 0.001^*$			

p_1: p value for comparing between group FC and group HC; p_2: p value for comparing between group FC and group LS; p_3: p value for comparing between group FC and group MPC; p_4: p value for comparing between group HC and group LS; p_5: p value for comparing between group HC and group MPC; p_6: p value for comparing between group LS and group MPC; *Statistically significant at $p \leq 0.05$

Statistical Analysis of the Data

Data were fed to the computer and analyzed using IBM SPSS software package version 20.0 (IBM Corp, Armonk, NY, USA). The statistician was blinded during the statistical analysis by using a different numbering system for the groups. The Kolmogorov–Smirnov test was used to verify the normality of distribution. Quantitative data were described using range (minimum and maximum), mean, standard deviation, and median. Significance of the obtained results was judged at the 5% level. Data were analyzed using two-way ANOVA analysis of variance and *F*-test (ANOVA), then pairwise comparisons were done using *post hoc* test (Tukey).

RESULTS

According to two-way ANOVA, the restorative materials (FC, HC, LS, and MPC) showed a statistically significant role in color change ($F = 23.636$, $p < 0.001$), while there was no statistical significance found among the different beverages (coffee, black tea, and red wine) in color change ($F = 2.280$, $p = 0.113$) (Table 2).

In comparison between all restorative material groups according to ΔE values, there was no significant difference between the three groups (Group FC, Group HC, and Group LS) ($p > 0.05$). However, there was a significant difference between group MPC and all other groups ($p < 0.001$) with composite having the highest mean ΔE value ($\Delta E = 6.04 \pm 3.72$) (Table 3).

In specimens immersed in the coffee solution, the highest ΔE value was observed in group MPC ($\Delta E = 5.62 \pm 1.60$), followed by group LS ($\Delta E = 0.98 \pm 0.43$) and group HC ($\Delta E = 0.88 \pm 0.44$), then followed by the lowest ΔE value for group FC ($\Delta E = 0.62 \pm 0.26$). Using ANOVA, there was a significant difference between group MPC and groups FC, HC, and LS ($p < 0.05$). There was no significant difference between group FC, group HC, and group LS ($p > 0.05$) as shown below in Tables 4 and 5.

For the tea solution, the highest ΔE value was observed also in group MPC followed by group HC, then group LS, and the lowest

Table 4: Comparison between the ΔE found in the materials used in the study according to the type of beverage used

	Group FC *(n = 5)*	*Group HC* *(n = 5)*	*Group LS* *(n = 5)*	*Group MPC* *(n = 5)*	*F*	*p*
Coffee						
Min. – Max.	0.30 – 0.90	0.40 – 1.40	0.30 – 1.40	3.60 – 7.70		
Mean ± SD.	0.62 ± 0.26	0.88 ± 0.44	0.98 ± 0.43	5.62 ± 1.60	38.345^{*}	$<0.001^{*}$
Median (IQR)	0.70 (0.4 – 0.8)	0.70 (0.6 – 1.3)	1.0 (0.9 – 1.3)	5.10 (5.0 – 6.7)		
Sig. bet. grps	$p_1 = 0.964, p_2 = 0.912, p_3 < 0.001^{*}, p_4 = 0.998, p_5 < 0.001^{*}, p_6 < 0.001^{*}$					
Tea						
Min. – Max.	0.20 – 1.40	0.70 – 4.20	0.50 – 1.10	3.0 – 8.80		
Mean ± SD.	0.64 ± 0.48	2.68 ± 1.50	0.82 ± 0.26	4.78 ± 2.34	9.288^{*}	0.001^{*}
Median (IQR)	0.50 (0.3 – 0.8)	2.6 (1.8 – 4.1)	0.90 (0.6 – 1.0)	4.1 (3.3 – 4.7)		
Sig. bet. grps	$p_1 = 0.146, p_2 = 0.997, p_3 = 0.001^{*}, p_4 = 0.204, p_5 = 0.130, p_6 = 0.002^{*}$					
Red wine						
Min. – Max.	0.10 – 1.30	2.20 – 4.30	0.90 – 1.20	3.10 – 17.10		
Mean ± SD	0.74 ± 0.46	3.56 ± 0.81	1.04 ± 0.15	7.72 ± 5.88	5.879^{*}	0.007^{*}
Median (IQR)	0.80 (0.5 – 1.0)	3.9 (3.5 – 3.9)	1.0 (0.9 – 1.2)	4.4 (4.1 – 9.9)		
Sig. bet. grps	$p_1 = 0.461, p_2 = 0.998, p_3 = 0.009^{*}, p_4 = 0.553, p_5 = 0.163, p_6 = 0.013^{*}$					

F: *F* for ANOVA test, pairwise comparison between each 2 groups was done using *post hoc* test (Tukey). *p*: *p* value for comparing between the studied groups. p_1: *p* value for comparing between group FC and group HC; p_2: *p* value for comparing between group FC and group LS; p_3: *p* value for comparing between group FC and group MPC; p_4: *p* value for comparing between group HC and group LS; p_5: *p* value for comparing between group HC and group MPC; p_6: *p* value for comparing between group LS and group MPC; * Statistically significant at $p \leq 0.05$

Table 5: Comparison between the Δ*E* found using the different beverages used in the study according to the type of material

	Coffee *(n = 5)*	*Tea* *(n = 5)*	*Red wine* *(n = 5)*	*F*	*p*
Group FC					
Min. – Max.	0.30 – 0.90	0.20 – 1.40	0.10 – 1.30		
Mean ± SD	0.62 ± 0.26	0.64 ± 0.48	0.74 ± 0.46	0.121	0.887
Median	0.70 (0.4 – 0.8)	0.50 (0.3 – 0.8)	0.80 (0.5 – 1.0)		
Group HC					
Min. – Max.	0.40 – 1.40	0.70 – 4.20	2.20 – 4.30		
Mean ± SD	0.88 ± 0.44	2.68 ± 1.50	3.56 ± 0.81	8.995^{*}	0.004^{*}
Median	0.70 (0.6 – 1.3)	2.6 (1.8 – 4.1)	3.9 (3.5 – 3.9)		
Sig. bet. grps	$p_1 = 0.040^{*}, p_2 = 0.003^{*}, p_3 = 0.388$				
Group LS					
Min. – Max.	0.30 – 1.40	0.50 – 1.10	0.90 – 1.20		
Mean ± SD	0.98 ± 0.43	0.82 ± 0.26	1.04 ± 0.15	0.700	0.516
Median	1.0 (0.9 – 1.3)	0.90 (0.6 – 1.0)	1.0 (0.9 – 1.2)		
Group MPC					
Min. – Max.	3.60 – 7.70	3.0 – 8.80	3.10 – 17.10		
Mean ± SD	5.62 ± 1.60	4.78 ± 2.34	7.72 ± 5.88	0.807	0.469
Median	5.10 (5.0 – 6.7)	4.1 (3.3 – 4.7)	4.4 (4.1 – 9.9)		

F: *F* for ANOVA test, pairwise comparison between each 2 groups was done using *post hoc* test (Tukey); *p*: *p* value for comparing between the studied groups; p_1: *p* value for comparing between coffee and tea; p_2: *p* value for comparing between coffee and red wine; p_3: *p* value for comparing between tea and red wine; *Statistically significant at $p \leq 0.05$

Δ*E* value was in group FC. In terms of comparing group FC, group HC and group LS differences in color change were not significant between all of them ($p > 0.05$). There was only a significant difference in color change ($p < 0.05$) when comparing between group FC and group MPC (Tables 4 and 5).

Still, in the red wine solution statistically, there is no significant color change among groups FC, HC, and LS ($p > 0.05$); however, there was a significant difference in color change between group FC and group MPC ($p < 0.05$) and between group LS and group MPC ($p < 0.05$) (Table 4). Regarding the three staining agents (coffee, black tea, and red wine) used in this study, all of them cause color change in restorative materials with the highest Δ*E* noted in red wine $\Delta E = 3.27 \pm 3.96$ followed by tea $\Delta E = 2.23 \pm 2.16$ and then coffee $\Delta E = 2.03 \pm 2.28$, regardless of the type of restorative material. But statistically there is no significant difference between them ($p > 0.05$).

Discussion

Color stability of restorative materials is an essential and crucial factor in longevity, durability, and esthetic appearance of dental restorations. Unpredictable color stability and susceptibility to staining are major problems of esthetic restorations. Knowledge of the optical properties of dental restorative materials is important in achieving esthetic restorations. Besides visual assessment, color determination in dentistry can be performed instrumentally using spectrophotometers and colorimeters.[16] Instrumental color measurement can potentially eliminate subjective errors in color assessment, and more importantly, it is more precise than the naked eye in measuring very little differences in colored objects on flat surfaces.[15]

Generally, there are two accepted thresholds used in color studies: perceptibility and acceptability. The threshold of perceptibility defines the level at which 50% of viewers can perceive a difference between the color of two specimens and 50% cannot perceive the difference. While, the threshold of acceptability sets an upper limit for color difference between different specimens that is recognized by most people as an acceptable approach. Several studies were performed to determine the perceptibility and acceptability thresholds for dental restorative materials using the CIELab system. According to the CIELab, the color parameters (L, a, and b) of materials may be calculated from the reflectance spectrum using a standard illuminant, observer, and recommended geometry.

Δ*E* value of >3.3 or 3.7 has been considered unacceptable in various investigations as it represents a color difference that is clinically distinguishable in the intraoral environment.[5,17–22] Nevertheless, Douglas et al.[5] using a regression model predicted that a color difference of Δ*E* 2.6 would be perceptible to 50% of dentists when viewed in a patient's mouth. A novel method, the TSK Fuzzy Approximation defined that the 50:50% perceptibility threshold was $\Delta E = 1.74$, whereas the acceptability threshold was $\Delta E = 3.48$.[6,23]

The purpose of this *in vitro* study was to evaluate the color stability of different dental veneer restorative materials (FC, HC, LS, and MPC) after exposure to different staining solutions (coffee, black tea, and red wine) and to analyze which staining solution has a more significant effect among others.

The specimens in this study were immersed in the staining beverage (coffee, black tea, and red wine) for 72 hours to simulate patient consumption of such drinks for 3 months. According to Ertan Ertas et al.,[15] the manufacturers of the coffee suggested the average consumption time for one cup of coffee is 15 minutes, and among coffee drinkers the average consumption quantity is 3.2 cups per day. Therefore, a 72-hour storage time in immersion solutions simulates about 3 months of coffee consumption.

The first null hypothesis of the current study has been rejected due to the significant difference in color stability among the different restorative materials used in the study. However, the second null hypothesis was accepted due to the lack of statistical significance difference between the beverages tested. Even though there was no statistical significance between the different beverages, it was noted that red wine had higher Δ*E* values than coffee and black tea in all restorative material groups.

Even though there was no statistical significance between the study groups, group FC showed the best color stability among the other study groups, with the lowest Δ*E* values (0.67 ± 0.39) followed by LS with Δ*E* values of 0.95 ± 0.30. Both of these ceramics had color change differences that were considered clinically acceptable and well below the perceptibility threshold of $\Delta E < 1.74$ and the acceptability threshold of $\Delta E < 3.7$. Gawriołek et al. reported that ceramic restorative materials exhibit better color stability than composite resins and the results of this study are in agreement.[4]

Group HC showed color change differences (2.37 ± 1.49) less than MPC (6.04 ± 3.72), and it is considered clinically acceptable, however, the color change was perceivable as it is $\Delta E > 1.74$ more than the perceivability threshold. These results are in agreement with Acar et al.,[14] who concluded in their *in vitro* study that the color change of the hybrid ceramic was perceivable but clinically acceptable after thermocycling in a coffee solution.

Hybrid ceramic materials consist of hydrophobic urethane dimethacrylate (UDMA) and hydrophilic triethylene glycol dimethacrylate (TEGDMA), which exhibits higher water absorption and therefore permits any hydrophilic colorant to penetrate into the resin matrix.[24,25] As a result, the hybrid ceramic materials may be susceptible to discoloration by food dyes or beverages such as coffee, tea, and red wine, which are commonly consumed by the general population.

Composite resin specimens (MPC) showed higher color change when compared with all other groups in all staining solutions with $\Delta E = 7.72$, $\Delta E = 5.62$, and $\Delta E = 4.78$ for red wine, coffee, and tea respectively, which are all not clinically acceptable. Guler et al.[26] found similar results indicating that red wine produced the most severe discoloration in light-polymerized composite provisional restorative materials and microhybrid composite followed by coffee, coffee with artificial creamer, and tea.

Nonetheless, in another study, Claudio et al.[27] concluded that the immersion of specimens in red wine, over a 28-day period, did not influence the color stability of tested composite resin materials, except the nanofilled composite Filtek Supreme XTE (3M ESPE, St. Paul, MN, USA), and that coffee produced more color change in all composite resins tested.

The particle characteristics and microstructure of a resin composite have a direct impact on its surface polishability and susceptibility to extrinsic staining. Besides material composition, the finishing and polishing procedures may also influence the composite surface quality;[28] therefore, care was taken in this study during the finishing and polishing of such restorations.

The low sample of the current study is a limitation, as a higher sample is needed for generalization of the results. Another limitation of the study concerns the method of application of the staining agent. Even though the length of application time of the staining beverage can be approximately related to patient's habits in drinking those staining agents, however, in the oral cavity the staining agent does not stay continuously in contact with the restorative material and might be interrupted by brushing. *In vitro* studies with larger sample sizes and long-term clinical trials are needed to better understand the full effect on patients.

Conclusion

Within the limitations of this *in vitro* study, it can be concluded that the type of restorative material chosen for construction of dental veneer restorations may affect the color stability of the final restoration. Feldspathic ceramics have better color stability (lower discoloration) among all dental veneer restorative materials been used in this study. Hybrid ceramics can be a good choice for dental veneer restoration with a clinically acceptable color change. Composite resins have the highest color change among other tested esthetic restorative materials, their color change in these staining agents was visually perceptible as well as clinically unacceptable. Practitioners should take into consideration the staining susceptibility of the resin composites.

References

1. de Oliveira ALBM, Botta AC, Campos JÁDB, et al. Effects of immersion media and repolishing on color stability and superficial morphology of nanofilled composite resin. Microsc Microanal 2014;20(4): 1234–1239. DOI: 10.1017/S1431927614001299.
2. Fontes ST, Fernández MR, de Moura CM, et al. Color stability of a nanofill composite: Effect of different immersion media. J Appl Oral Sci 2009;17(5):388–391. DOI: 10.1590/s1678-77572009000500007.
3. Arocha MA, Basilio J, Llopis J, et al. Colour stainability of indirect CAD-CAM processed composites vs conventionally laboratory processed composites after immersion in staining solutions. J Dent 2014;42(7):831–838. DOI: 10.1016/j.jdent.2014.04.002.
4. Gawriołek M, Sikorska E, Ferreira LF V, et al. Color and luminescence stability of selected dental materials in vitro. J Prosthodont 2012; 21(2):112–122. DOI: 10.1111/j.1532-849X.2011.00808.x.
5. Davidson SL. Principles of Color Technology, 2nd ed., by Fred W Billmeyer, Jr, and Max Saltzman. Wiley-Interscience, New York, 1981, 240 pp. Color Res Appl 1982;7(3):275–276.
6. Motro PFK, Kursoglu P, Kazazoglu E. Effects of different surface treatments on stainability of ceramics. J Prosthet Dent 2012;108(4): 231–237. DOI: 10.1016/S0022-3913(12)60168-1.
7. O'Brien WJ, Groh CL, Boenke KM. A new, small-color-difference equation for dental shades. J Dent Res 1990;69(11):1762–1764. DOI: 10.1177/00220345900690111001.
8. Goldstein GR, Schmitt GW. Repeatability of a specially designed intraoral colorimeter. J Prosthet Dent 1993;69(6):616–619. DOI: 10.1016/0022-3913(93)90292-v.
9. Palla ES, Kontonasaki E, Kantiranis N, et al. Color stability of lithium disilicate ceramics after aging and immersion in common beverages. J Prosthet Dent 2018;119(4):632–642. DOI: 10.1016/j.prosdent.2017.04.031.
10. Johnston WM, Kao EC. Assessment of appearance match by visual observation and clinical colorimetry. J Dent Res 1989;68(5):819–822. DOI: 10.1177/00220345890680051301.
11. Paravina RD, Swift EJ. Color in dentistry: Match me, match me not. J Esthet Restor Dent 2009;21(2):133–139. DOI: 10.1111/j.1708-8240.2009.00246.x.
12. Cengiz S, Yüzbaşioğlu E, Cengiz MI, et al. Color stability and surface roughness of a laboratory-processed composite resin as a function of mouthrinse. J Esthet Restor Dent 2015;27(5):314–321. DOI: 10.1111/jerd.12167.
13. Dietschi D, Campanile G, Holz J, et al. Comparison of the color stability of ten new-generation composites: An in vitro study. Dent Mater 1994;10(6):353–362. DOI: 10.1016/0109-5641(94)90059-0.
14. Acar O, Yilmaz B, Altintas SH, et al. Color stainability of CAD/CAM and nanocomposite resin materials. J Prosthet Dent 2016;115(1):71–75. DOI: 10.1016/j.prosdent.2015.06.014.
15. Ertas E, Guler AU, Yucel AC, et al. Color stability of resin composites after immersion in different drinks. Dent Mater J 2006;25(2):371–376. PMID: 16916243.
16. Joiner A. Tooth colour: A review of the literature. J Dent 2004;32 (Suppl 1):3–12. DOI: 10.1016/j.jdent.2003.10.013.
17. Samra APB, Pereira SK, Delgado LC, et al. Color stability evaluation of aesthetic restorative materials. Braz Oral Res 2008;22(3):205–210. DOI: 10.1590/s1806-83242008000300003.
18. Ghahramanloo A, Madani AS, Sohrabi K, et al. An evaluation of color stability of reinforced composite resin compared with dental porcelain in commonly consumed beverages. J Calif Dent Assoc 2008; 36(9):673–680. PMID: 18856169.
19. Saygili G, Şahmali S, Demirel F. Colour stability of porcelain repair materials with accelerated ageing. J Oral Rehabil 2006;33(5):387–392. DOI: 10.1111/j.1365-2842.2005.01409.x.
20. Macentee M, Lakowski R. Instrumental colour measurement of vital and extracted human teeth. J Oral Rehabil 1981;8(3):203–208. DOI: 10.1111/j.1365-2842.1981.tb00494.x.
21. Ertan AA, Sahin E. Colour stability of low fusing porcelains: An in vitro study. J Oral Rehabil 2005;32(5):358–361. DOI: 10.1111/j.1365-2842.2004.01415.x.
22. Ayaz EA, Bagis B, Turgut S. Effect of antiasthmatic medication on the surface roughness and color stability of dental restorative materials. Med Princ Pract 2014;23(1):24–28. DOI: 10.1159/000354297.
23. Ghinea R, Pérez MM, Herrera LJ, et al. Color difference thresholds in dental ceramics. J Dent 2010;38(Suppl 2):e57–e64. DOI: 10.1016/j.jdent.2010.07.008.
24. Belli R, Geinzer E, Muschweck A, et al. Mechanical fatigue degradation of ceramics versus resin composites for dental restorations. Dent Mater 2014;30(4):424–432. DOI: 10.1016/j.dental.2014.01.003.
25. Vasudeva G. Monomer systems for dental composites and their future: A review. J Calif Dent Assoc 2009;37(6):389–398. PMID: 19831015.
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(2):118–124. DOI: 10.1016/j.prosdent.2005.05.004.
27. Poggio C, Ceci M, Beltrami R, et al. Color stability of esthetic restorative materials: A spectrophotometric analysis. Acta Biomater Odontol Scand 2016;2(1):95–101. DOI: 10.1080/23337931.2016.1217416.
28. Türkün LS, Türkün M. Effect of bleaching and repolishing procedures on coffee and tea stain removal from three anterior composite veneering materials. J Esthet Restor Dent 2004;16(5):290–301. DOI: 10.1111/j.1708-8240.2004.tb00056.x.