Color Stability of Hybrid Ceramics Exposed to Beverages in Different Combinations

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Abstract

Background: The aim of this study is to evaluate the color stability of hybrid ceramics stored in different combinations of different beverages that would be consumed in a daily routine.

Methods: The specimens were prepared with resin nano-ceramic (Lava Ultimate, 3M Espe, USA) and hybrid ceramic (Vita Enamic, Vita Zahnfabrik, Germany). The specimens were aged in a thermocycler machine for 10,000 cycles. They were stored in different combinations of beverages (water, tea, coke, coffee, red wine, pomegranate juice, turnip juice) for 12+12 hours-time. The surface roughness measurements were made with a profilometer. The color measurements of the specimens were measured with the spectrophotometer. The color values (L-a-b) of the specimens, and mean surface roughness values (Ra) were recorded at the end of the 1st (D1), 7th (D7), 14th (D14) and 28th (D28) days.

Results: When the solution groups are examined; significantly more color changes were observed in the LG4, EG4, LG6 and EG6 groups than in the other groups ($p<0.01$). Except for the samples in the LG6 (D28) and EG6 groups (D28); more color changes were observed in the Lava samples than the Enamic samples in all groups and periods.

Conclusion: More color changes (except for the samples stored in coffee-wine) were observed in the Lava samples than in the Enamic samples in all groups and periods. The combination of coffee-tea and coffee-wine beverages may have accepted most coloring beverages for hybrid ceramics within the limitation of this study.

Introduction

The successful survival of a well-prepared restoration is possible if it can maintain its physical and mechanical properties as well as its esthetic properties. Today high strength hybrid ceramics prepared with only computer-aided manufacture are becoming very popular [1]. The main factors of this popularity are their superior biocompatibility, improved mechanical properties, and low plaque accumulation on their surfaces [2, 3].

At the same time, hybrid ceramics are considered successful in mimicking dentin with ease of milling and adjusting [4]. Lava Ultimate was launched in 2011 [5] and Vita Enamic was launched in 2013 [6]. Indicated for both inlay-onlay restorations and crown restorations.

The color stability of the restoration is the most sought-after esthetic property. In this respect, hybrid ceramics provides ease of work for dental clinicians and technicians. In studies on the color stability of ceramics, mostly tea, cola, and coffee were used as coloring agents [7, 8]. The classic CIELab color formula developed by the Commission of Internationale de l'Eclairage (CIE) includes lightness, hue, and chroma; reported as L*, a*, and b*. L* stands for Lightness and takes a value between 0 and 100 [9]. 0 represents black, 100 represents white. a* refers to saturation on the red-green axis, b* refers to saturation on the yellow-blue axis. Color differences are calculated with the help of these parameters as ΔE values with a formula. CIE introduced the CIEDE2000 color formulation in 2000 with the addition of two new parameters [10]. The CIEDE 2000 color system is widely used for the color measurement of ceramics [11].

While determining the color stability, one of the most important issues is the surface roughness of the studied material. Among the factors that will cause roughening of the surface of the restorative materials in the oral environment are nutrition type, salivary flow, temperature difference, and bacterial flora diversity of the environment. It has been proven that the method of measuring surface roughness with a profilometer gives successful results. The measurement of mean Ra value as 0.3 μm, is granted as the limit clinically acceptable in the literature [12].

The effect of different beverages consumed on the same day by an in vitro investigation on hybrid ceramics' that thermal aged is unclear. Thus, the difference of our study from other coloring studies is that many drinks were evaluated together, just like in our daily life. The first null hypothesis tested was that; “the storage with different combinations of water, coffee, tea, coke, red wine, pomegranate juice, and turnip juice would not cause a color change in both hybrid ceramics”; and the second null hypothesis tested was that; “the storage with different combinations of the beverages would not cause a color change in hybrid ceramics in overall storage time (1,7, 14, and 28 days)”.

Materials And Methods

The ceramics, polishing material and their properties used in the study were listed in Table 1. The study design was schematized in Fig. 1. For the preparation of samples in the study; 14mm. length, A2-HT colored-resin nano-ceramic blocks (Lava Ultimate, 3M Espe, Minnesota, USA) and HT/2M2 colored-hybrid ceramic (Vita Enamic, Vita Zahnfabrik, Germany) blocks were used. Specimens of 1 mm were obtained using a precision cutting device (Metkon Industrial Equipment, Istanbul, Turkey). Then all specimens were polished with a polishing set (Shofu Super Snap Rainbow Technique Kit, Shofu Dental Corporation, San Marcos, USA). The polishing procedure was performed in order of polishing with a super-snap disk at 15,000 rpm, polishing with dura white-stone at 30,000 rpm and polishing with composite fine-disk at 20,000 rpm, according to the manufacturer’s recommendations. All polishing procedures were performed on both sides of the samples with a low-speed handpiece (Kavo Ewl 4990; Kavo Dental Gmbh, Germany) by the same investigator. After the polishing was completed, all specimens were stored in distilled water for 24 hours.

Table 1
The materials and their properties used in the study

Material	Composition	Translucency/Shade	Lot Number	Manufacturer
Vita Enamic	Feldspathic ceramic (86%), acrylic polymer (14%)	HT/2M2	51040	Vita Zahnfabrik
Lava Ultimate	Resin nanoceramic (79%), polymer matrix (21%)	HT/A2	33140	3M ESPE
Shofu Super Snap Rainbow Technique Kit	Silicon carbide, aluminum carbide	-	0715012	Shofu Dental Corporation

The samples were aged in distilled water baths of 5°C and 55°C with a dwell time of 30 sec for 10000 cycles in a thermocycler machine (Thermocycler THE1100, SD Mechatronic GmbH, Feldkirchen-Westerham, Germany); equivalent to the use of restoration in the mouth for 1 year. The specimens were randomly divided into 8 groups (n = 8). They were stored in different combinations of beverages for 12 + 12 hours-time. The beverages used in this study were listed in Table 2. The groups tested with different beverage combinations were listed in Table 3. The samples were kept in lidded containers that prevent evaporation of the staining solutions throughout the study. The beverages were renewed every 12 hours. Specimens were kept in an incubator (Incubator EN 25 032 Core, Core Materials Manufacturing Industry & Trade Co., Istanbul, Turkey) at 37°C, continuously, except for solution changes, and the measurements. Before the color measurements, the samples were washed under running water for 10 seconds and then dried with a tissue.

Table 2
The beverages used in the study

Beverage	Preparation	Manufacturer
Water	–	Distilled water
Tea	One tea bag was put in 150 mL of boiled water for 5 minutes	Lipton Co., Rize, Turkey
Coke	–	Coca Cola Co., Istanbul, Turkey
Coffee	10 g of coffee powder was put into 500 ml of boiled distilled water. After 10 min of stirring, coffee solution was filtered through a filter paper	Nescafe Classic, Nestle, Bursa, Turkey
Red Wine	–	Mediterranean pearl, Deva Wine Co., Manisa, Turkey
Pomegranate juice	It is obtained from pomegranate fruit by squeezing method (250 ml of pomegranate juice was obtained from 1 kg of pomegranate)	–
Turnip juice	–	Dimes Food Co., Izmir, Turkey

Table 3
Groups tested with different beverage combinations

Groups	Beverages	Group Name	
	(12h – 12h)	Lava Ultimate (L)	Vita Enamic (E)
G1	water- water	LG1	EG1
G2	coffee- water	LG2	EG2
G3	coffee- coffee	LG3	EG3
G4	coffee- tea	LG4	EG4
G5	coffee- coke	LG5	EG5
G6	coffee- wine	LG6	EG6
G7	coffee- pomegranate juice	LG7	EG7
G8	coffee- turnip juice	LG8	EG8

L, a, b values were determined using a spectrophotometer (Vita Easy Shade Advance 4.0, Vita Zahnfabrik, Bad Säckingen, Germany). Color measurements were made on each surface under standard D65 lighting conditions and on a white background at the end of the 1st (D1), 7th (D7), 14th (D14), and 28th (D24) days. ΔE_{00} values were calculated using the following CIEDE 2000 color-difference formula.

$$\Delta E_{00} = \left(\left(\frac{\Delta L^*}{k_L S_L} \right)^2 + \left(\frac{\Delta C'}{k_C S_C} \right)^2 + \left(\frac{\Delta H'}{k_H S_H} \right)^2 + R_T \left(\frac{\Delta C' \Delta H'}{S_C S_H} \right) \right)^{1/2}$$

Also, surface roughness measurements of the samples were made with a profilometer (Taylor Hobson Surtronic 25, Leicester, UK) with a 0.25 mm cut-off value at the end of the 1st (D1), 7th (D7), 14th (D14), and 28th (D24) days. The constant measuring speed of 0.5 mm / sec was used to determine an average surface roughness profile (Ra) in µm.

Statistical analysis

The sample size calculation was performed using G*Power v. 3.1.9.3 software (Heinrich-Heine-Universität Düsseldorf, Germany). The sample size, at the level of $\alpha = 0.05$ and with an effect size of 0.6 and power of 0.8. Accordingly, a total of min 48 subjects should be studied, with n = 6 in each group.

Statistical analysis was performed using the IBM SPSS Statistics for Windows (Version 22.0, IBM Corp., Armonk, NY, USA) package program. Descriptive statistics are presented as mean ± standard deviation (SD) for continuous data. Normality distribution was assessed by the Shapiro–Wilk test. Mann Whitney U test was used for non-normally distributed data in continuous variable comparisons between two groups. Kruskal–Wallis test was used for non-normally distributed data in continuous variable comparisons between more than two groups. After Kruskal–Wallis test, Mann–Whitney U tests with the Bonferroni correction post hoc multiple comparison test were used to determine which group caused the difference respectively. Pearson Correlation test was performed to analyze the relationship between the amount of color change and the roughness change values. In the statistical evaluation, p-value < 0.05 was considered significant.

Results

Descriptive statistics of color differences (ΔE_{00}) values for each hybrid ceramic after 1-day (D1), 7-day (D7), 14-day (D14), 28-day (D28) of stored in each beverage combination were listed in Table 4. Also, graphs of the color differences on Lava groups (Fig. 2), and color differences on hybrid ceramics (Enamic groups) due to time (Fig. 3) are in the figure as below. Descriptive statistics of surface roughness (Ra) values for each hybrid ceramic after 1-day (D1), 7-day (D7), 14-day (D14), 28-day (D28) of stored in each beverage combination were listed in Table 5.

Table 4
Descriptive statistics of color differences (ΔE_{00}) values for each groups after 1 day (D1), 7 day (D7), 14 day (D14), 28 day (D28)

Time	Lava Groups	*p3*	Mean ± SD	Enamic Groups	*p3*	Mean ± SD	*p1*
D1	**LG1**	0.001*	0.76 ± 0.49$^{(A)}$	**EG1**	< 0.001*	0.88 ± 0.33$^{(A)}$	0.443
D7		< 0.001*	0.84 ± 0.19$^{(A)}$			0.9 ± 0.18$^{(A)}$	0.701
D14			0.87 ± 0.32$^{(A)}$			0.71 ± 0.44$^{(A)}$	0.277
D28			1.08 ± 0.4$^{(A)}$			0.67 ± 0.41$^{(A)}$	0.048*
p**2**			0.239			0.319	
D1	**LG2**	0.001*	3.66 ± 1.74$^{(a,B)}$	**EG2**	< 0.001*	0.97 ± 0.12$^{(a,A)}$	0.011*
D7		< 0.001*	7.11 ± 3.21$^{(ab,C)}$			2.69 ± 0.59$^{(b,B)}$	0.035*
D14			7,89 ± 3.71$^{(bc,BD)}$			1.98 ± 0.32$^{(b,BD)}$	0.002*
D28			8.95 ± 4.24$^{(c,B)}$			2.1 ± 0.24$^{(b,AB)}$	0.002*
p2			< 0.001**			0.002**	
D1	**LG3**	0.001*	3.5 ± 1.06$^{(a,B)}$	**EG3**	< 0.001*	1.51 ± 0.19$^{(a,BC)}$	0.002*
D7		< 0.001*	5.82 ± 1.75$^{(ab,BC)}$			2.63 ± 0.28$^{(ab,B)}$	0.009*
D14			6.63 ± 2.26$^{(bc,BD)}$			2.03 ± 0.23$^{(bc,BD)}$	0.002*
D28			7.74 ± 2.43$^{(c,B)}$			3.5 ± 0.42$^{(c,CE)}$	0.004*
p2			< 0.001**			< 0.001**	
D1	**LG4**	0.001*	2.83 ± 0.97$^{(a,AB)}$	**EG4**	< 0.001*	2.06 ± 0.49$^{(a,CD)}$	0.179
D7		< 0.001*	7.05 ± 1.58$^{(ab,C)}$			5.89 ± 0.57$^{(ab,C)}$	0.180
D14			9.2 ± 1.83$^{(bc,BD)}$			7.63 ± 0.77$^{(bc,C)}$	0.085

Time	Lava Groups	*p3*	Mean ± SD	Enamic Groups	*p3*	Mean ± SD	*p1*
D28			12.68 ± 1.33 *(c,C)*			11.93 ± 1.01 *(c,D)*	0.406
p2			<0.001**			< 0.001**	
D1	**LG5**	0.001*	1.98 ± 1 *(a,AB)*	**EG5**	< 0.001*	1.26 ± 0.23 *(a,AB)*	0.250
D7		< 0.001*	3.84 ± 1.55 *(ab,AB)*			2.12 ± 0.38 *(ab,AB)*	0.035*
D14			3.97 ± 1.63 *(bc,AD)*			1.77 ± 0.44 *(bc,AB)*	0.004*
D28			5.15 ± 2.14 *(c,AB)*			3.09 ± 0.38 *(c,BC)*	0.110
p2			< 0.001**			< 0.001**	
D1	**LG6**	0.001*	3.75 ± 1.09 *(a,B)*	**EG6**	< 0.001*	2.3 ± 0.38 *(a,D)*	0.006
D7		< 0.001*	8.93 ± 2.09 *(ab,C)*			7.69 ± 1.44 *(ab,C)*	0.225
D14			10.39 ± 2.3 *(bc,CB)*			9.69 ± 2.09 *(bc,C)*	0.482
D28			11.16 ± 3.2 *(c,C)*			12.76 ± 1.72 *(c,D)*	0.250
p2			< 0.001**			< 0.001**	
D1	**LG7**	0.001*	3.96 ± 1.16 *(a,B)*	**EG7**	< 0.001*	1.94 ± 0.3 *(a,CD)*	0.002*
D7		< 0.001*	7.5 ± 1.28 *(b,C)*			5.41 ± 1.39 *(bc,C)*	0.013*
D14			6.44 ± 1.44 *(c,BD)*			4.08 ± 0.94 *(ab,CD)*	0.013*
D28			7.66 ± 1.61 *(b,B)*			5.57 ± 0.73 *(c,CD)*	0.006*
p2			< 0.001**			< 0.001**	
D1	**LG8**	0.001*	3.44 ± 0.64 *(a,B)*	**EG8**	< 0.001*	1.14 ± 0.47 *(a,AB)*	0.002*

Time	Lava Groups	*p3*	Mean ± SD	Enamic Groups	*p3*	Mean ± SD	*p1*
D7		< 0.001*	5.18 ± 1.3$^{(b,BC)}$			2.35 ± 0.45$^{(bc,AB)}$	0.003*
D14			5.23 ± 1.6$^{(b,D)}$			1.61 ± 0.57$^{(ab,AB)}$	0.002*
D28			6.63 ± 1.89$^{(c,B)}$			2.48 ± 0.25$^{(c,ABE)}$	0.002*
p2			< 0.001**			< 0.001**	
There is a significant difference between the measurement values over time (*p1* < 0.001)							
There is a significant difference by beverage type over time (*p2* < 0.001) (*a,b,c)*							
There is a significant difference by hybrid ceramic type over time (*p3* < 0.001) *(A,B,C,D,E)*							
The two-way analysis of variance in repeated measures							
p1: Mann Whitney U test							
p2: Friedman F test							
p3: Kruskal Wallis variance test							
The mean difference (*p*) was set significant at the 0.05 level							
The same superscript indicates statistical indifference							

Table 5
Descriptive statistics of surface roughness (Ra) values (μm) for each groups after 1 day (D1), 7 day (D7), 14 day (D14), 28 day (D28)

Time	Lava Groups	*p3*	Mean ± SD	Enamic Groups	*p3*	Mean ± SD	*p1*
D1	**LG1**	0.988	0.16 ± 0.03	**EG1**	0.924	0.16 ± 0.02	0.740
D7		0.686	0.19 ± 0.04		0.009*	0.15 ± 0.03*(A)*	0.042*
D14		0.332	0.21 ± 0.04		0.003*	0.15 ± 0.01*(A)*	0.006*
D28		0.922	0.16 ± 0.06		0.016*	0.14 ± 0.01*(A)*	0.999
p2			0.058			0.198	
D1	**LG2**	0.988	0.15 ± 0.03*(a)*	**EG2**	0.924	0.17 ± 0.03*(ac)*	0.296
D7		0.686	0.16 ± 0.07*(a)*		0.009*	0.24 ± 0.07*(b,BC)*	0.109
D14		0.332	0.3 ± 0.15*(b)*		0.003*	0.29 ± 0.09*(b,BC)*	0.520
D28		0.922	0.16 ± 0.04*(a)*		0.016*	0.15 ± 0.03*(c,AC)*	0.895
p2			0.020**			0.001**	
D1	**LG3**	0.988	0.15 ± 0.06*(a)*	**EG3**	0.924	0.17 ± 0.03	0.189
D7		0.686	0.16 ± 0.04*(a)*		0.009*	0.18 ± 0.03*(AC)*	0.374
D14		0.332	0.28 ± 0.11*(b)*		0.003*	0.21 ± 0.05*(AC)*	0.246
D28		0.922	0.18 ± 0.07*(ab)*		0.016*	0.2 ± 0.05*(BC)*	0.520
p2			0.022**			0.077	
D1	**LG4**	0.988	0.16 ± 0.05*(a)*	**EG4**	0.924	0.16 ± 0.02*(a)*	0.896
D7		0.686	0.17 ± 0.04*(ab)*		0.009*	0.25 ± 0.1*(b,BC)*	0.039*
D14		0.332	0.35 ± 0.18*(b)*		0.003*	0.33 ± 0.08*(b,B)*	0.847

Time	Lava Groups	*p3*	Mean ± SD	Enamic Groups	*p3*	Mean ± SD	*p1*
D28		0.922	0.15 ± 0.05(a)		0.016*	0.21 ± 0.07(ab,BD)	0.080
p2			0.031**			0.013**	
D1	**LG5**	0.988	0.15 ± 0.04	**EG5**	0.924	0.18 ± 0.07	0.474
D7		0.686	0.19 ± 0.06		0.009*	0.17 ± 0.03(AC)	0.561
D14		0.332	0.31 ± 0.22		0.003*	0.26 ± 0.1(BC)	0.949
D28		0.922	0.17 ± 0.03		0.016*	0.21 ± 0.04(BD)	0.106
p2			0.133			0.088	
D1	**LG6**	0.988	0.15 ± 0.04	**EG6**	0.924	0.16 ± 0.02	0.358
D7		0.686	0.16 ± 0.05		0.009*	0.17 ± 0.06(AD)	0.948
D14		0.332	0.25 ± 0.11		0.003*	0.32 ± 0.24(BC)	0.898
D28		0.922	0.15 ± 0.02		0.016*	0.18 ± 0.05(ACD)	0.265
p2			0.056			0.066	
D1	**LG7**	0.988	0.15 ± 0.04	**EG7**	0.924	0.16 ± 0.03(a)	0,422
D7		0.686	0.19 ± 0.05		0.009*	0.21 ± 0.05(a,BCD)	0,897
D14		0.332	0.24 ± 0.09		0.003*	0.36 ± 0.13(b,B)	0,034*
D28		0.922	0.16 ± 0.05		0.016*	0.21 ± 0.03(a,BD)	0,077
p2			0.177			0.001**	
D1	**LG8**	0.988	0.15 ± 0.04(a)	**EG8**	0.924	0.17 ± 0.02(a)	0.304
D7		0.686	0.22 ± 0.12(a)		0.009*	0.2 ± 0.04(a,BCD)	0.949
D14		0.332	0.37 ± 0.18(b)		0.003*	0.36 ± 0.17(b,B)	0.948
D28		0.922	0.17 ± 0.04(a)		0.016*	0.2 ± 0.04(a,BC)	0.158

Time	Lava Groups	*p3*	Mean ± SD	Enamic Groups	*p3*	Mean ± SD	*p1*
p2			0.002**			0.021**	
There is a significant difference between the measurement values over time (*p1* < 0.001)							
There is not a significant difference by beverage type over time (*p2* = 493) *(a,b,c)*							
There is not a significant difference by hybrid ceramic type over time (*p3* = 154) *(A,B,C,D)*							
The two-way analysis of variance in repeated measures							
p1: Mann Whitney U test							
p2: Friedman F test							
p3: Kruskal Wallis variance test							
The mean difference (*p*) was set significant at the 0.05 level							
The same superscript indicates statistical indifference							

The highest color difference (12.68 ± 1.33) among the Lava groups was in the LG4 group, which was kept for 28 days. The highest color difference (12.76 ± 1.72) among the Enamic groups was in the EG6 group, which was kept for 28 days. When the solution groups are examined; significantly more color changes were observed in the LG4, EG4, LG6 and EG6 groups than in the other groups ($p < 0.01$). When the color changes between Lava and Enamic samples are compared; except for the samples in the LG6 and EG6 groups, which were kept for 28 days, more color changes were observed in the Lava samples than in the Enamic samples in all groups and periods. In the LG2, LG3, LG7, and LG8 groups, statistically significantly more color changes were observed than the EG2, EG3, EG7, and EG8 groups in each period ($p < 0.05$). In both materials, no significant color differences were observed in the LG1 and EG1 groups depending on time. Except for the EG2 group, the least color change was observed on the 1st day and the most color change was observed on the 28th day in all solution groups ($p < 0.001$).

The highest roughness value (Ra) among the Lava samples; was observed in the measurements made on the 14th day in the LG8 group (0.37 ± 0.18 µm). The highest roughness values (Ra) among Enamic samples were observed in the EG7 and EG8 groups as 0.36 ± 0.13 µm and 0.36 ± 0.17 µm, respectively, in the measurements made on the 14th day ($p < 0.05$). When each group is evaluated within itself; The highest in-group roughness values were measured on the 14th day in all groups except the EG1 group. This difference was statistically significant in LG2, LG3, LG4, LG8, EG2, EG4, EG7, EG8 groups ($p < 0.05$). When analyzed according to the same periods; there was no statistically significant difference in roughness values between Lava groups in any of the different time groups ($p > 0.05$). There was no statistically significant difference in the roughness values between the groups in the measurements made on the 1st day in the Enamic groups ($p > 0.05$). But the roughness values were statistically significantly different between the different Enamic groups in the measurements made on the 7th,14th, and 28th days ($p < 0.05$).

The correlation test results between the amount of color change and the roughness change values are given in Table 6. There is a positive correlation between color change and roughness values on the groups of LG6 7th day, LG8 1st and 7th day (Positive correlation: When the values increase in one of the variables, the other variable also increases, or if one of the variables decreases, the other variable also decreases). There is a negative correlation between color change and roughness values on the groups of LG5 7th day, EG4 1st day (Negative correlation: When values increase in one variable, decrease in the other variable).

Table 6
Correlations between color change and roughness values on different days between groups

Time	Lava Groups	r	p	Enamic Groups	r	p
D1	LG1	0.297	0.517	EG1	0.006	0.990
D7		0.049	0.917		-0.535	0.216
D14		0.638	0.123		-0.287	0.533
D28		0.752	0.051		-0.507	0.245
D1	LG2	-0.287	0.532	EG2	-0.020	0.967
D7		0.403	0.370		-0.029	0.950
D14		0.572	0.179		-0.352	0.438
D28		0.497	0.256		0.185	0.691
D1	LG3	-0.023	0.961	EG3	0.072	0.877
D7		0.294	0.523		0.353	0.438
D14		0.019	0.968		-0.350	0.442
D28		-0.329	0.471		0.194	0.677
D1	LG4	-0.212	0.648	EG4	-0.829*	0.021*
D7		-0.576	0.176		-0.479	0.276
D14		0.169	0.718		-0.487	0.267
D28		0.071	0.880		-0.269	0.560
D1	LG5	-0.322	0.481	EG5	-0.090	0.848
D7		-0.898**	0.006**		0.002	0.996
D14		0.082	0.861		-0.239	0.606
D28		-0.450	0.311		0.024	0.960
D1	LG6	-0.254	0.582	EG6	-0.196	0.673
D7		0.760*	0.048*		0.016	0.973
D14		-0.737	0.059		-0.408	0.364
D28		-0.609	0.147		-0.449	0.312
D1	LG7	0.674	0.097	EG7	-0.421	0.347
D7		-0.475	0.282		0.628	0.131

Time	Lava Groups	r	p	Enamic Groups	r	p
D14		0.008	0.986		-0.056	0.905
D28		-0.392	0.384		0.230	0.619
D1	**LG8**	0.800*	0.031*	**EG8**	-0.410	0.361
D7		0.803*	0.030*		0.618	0.139
D14		-0.334	0.464		0.519	0.233
D28		0.217	0.640		0.109	0.815
r : Pearson Correlation coefficient						
Interpretation of the correlation coefficient (r):						
r < 0.2; very weak correlation or no correlation						
r = 0.2-0.4; weak correlation						
r = 0.4-0.6; moderate correlation						
r= 0.6-0.8; high correlation						
r > 0.8; very high correlation						
** Correlation is significant at the p<0.01 level						
* Correlation is significant at the p<0.05 level						

Discussion

Some beverages have been reported to cause more staining in composite or ceramic restorations in the literature. The knowledge that coffee is the most coloring beverage has been proven in many color stability studies on resin and hybrid ceramic materials [13–15]. In our study, in which coffee was accepted as the main coloring beverage, it was determined that the most staining was observed after 28 days for Lava ($\Delta E = 12.68$) after storing in coffee-tea (LG4) and for Enamic ($\Delta E = 12.68$) after storing in coffee-wine (EG6) among all groups.

Except for the EG2 group, the least color change was observed on the 1st day and the most color change was observed on the 28th day in all solution groups ($p < 0.001$). The first null hypothesis tested in this study was partially rejected because; the storage with different combinations of water, coffee, tea, coke, red wine, pomegranate juice, and turnip juice had a significant effect on color change in both hybrid ceramics due to staining over time.

The hybrid resin matrix falls into the dental ceramics category because they contain more than 50% inorganic particles [16]. Ceramic is inert, but the organic structure is weak. Coffee may easily be diffused to the organic matrix of hybrid material dependent on the water absorption capacity. Also, the water absorption capacity of BIS-GMA was reported to be higher than those of UDMA, TEGDMA, and BIS-EMA [17, 18]. Lava contain BIS-GMA, as discint from Enamic. In the present study, in comparison of the color changes between Lava and Enamic samples (except for the samples in the LG6 and EG6 groups), more color changes were observed in the Lava samples than the Enamic samples in all groups and periods.

To better reflect the intraoral thermal exchange conditions, the samples were kept in the thermal cycle (10,000 cycles) in our study. Lava and Enamic samples were kept in coffee for 5000 thermal cycles in a study by Acar et al. [13]. In the study, the highest color change has been observed in nanocomposite resin (Filtek Supreme Ultra Universal) followed by nanoceramic resin (Lava Ultimate), hybrid ceramic (Vita Enamic) and lithium disilicate ceramic (IPS e.max CAD) respectively, similar to our study. The study differed from our study in that they were polished the specimens with silicon carbide abrasive papers only and coffee was used for staining every 8 hours-time replaced with fresh coffee. Also, they have brushed the specimens with toothpaste after thermal aging.

Sagsoz et al. [19]. investigated staining resistance of CAD/CAM blocks (including Lava Ultimate and Vita Enamic) surface polished with different polishing kits. The specimens were immersed in tea, Turkish coffee, fermented black carrot juice and distilled water for 1 day, 1 week, and 1 month. A month later unpolished Lava specimens were found dramatically higher ΔE values had than unpolished Enamic specimens. They claimed that this result could be attributed to the water absorption of monomers. Any thermal aging protocol was not applied in the study. Also, based on the study of Ertaş et al. [20], it was reported that the 1-month immersing period would be equivalent to 2.5 years of clinical aging in the study.

To the results of the present study, no significant color differences were observed in the LG1 and EG1 groups depending on the time in both hybrid ceramics. The second null hypothesis tested of the study was partially accepted because; the storage with different combinations of the beverages had a significant effect on color change in hybrid ceramics in overall storage time.

In our daily life, we consume various types of drinks in succession throughout the day that can cause discoloration on our teeth or restorations. However, a single type of colored beverage does not reflect the staining potential of human feeding behavior. In the literature, there are also studies conducted according to the pH of coloring beverages [21]. It is thought that low-pH beverages will increase staining due to abrasion of the surface [22].

Arocha et al. [23] investigated color stainability of Lava Ultimate, Paradigm and two indirect laboratory-processed composites after being immersed in coffee, red wine, black tea, distilled water during 4 weeks period. Staining solutions were renewed every two days but without any thermal aging protocol. Similar to our study's results, ΔE_{00} values of Lava Ultimate specimens immersed in red wine were higher than immersed in coffee, black tea and distilled water. Based on previous studies, they concluded that this result may facilitate staining by softening the resin matrix of alcohol. ΔE_{00} values (11.16) of Lava specimens in group LG6 (statistically not different from the specimens in LG4) after the 28th day were higher than the others in our study.

In our study, color measurements were made with the Easyshade device, which was reported most accurate color measurement device (92.6%) in the literature [24, 25]. CIEDE2000 color formula has been determined as being better to color differences which perceivable with the human eye than CIELab color formula [26]. A ΔE color difference between 1.5-3 is determined as observable alteration (noticeable) on the National Bureau of Standards (NBS) system of expressing color differences [9]. Color differences of more than 3.3 is acceptable easily detectable with laypeople but color differences as smaller than 3.3, is detectable only talented person is reported in a study [27].

It has been reported in the literature that surface roughness affects the color stability of ceramics. Ra > 0.2 μm is preferred for preventing biofilm retention to the restorations [28]. A 0.3 μm-Ra is a generally accepted standard for creating a smooth restoration surface [28]. Besides, existing a Ra > 0.3μm, it has been reported that patients have discomfort and feel by their tongue or lip contact on restoration surface [12]. Hybrid ceramics were reported more resistant than conventional ceramics in surface roughness due to extrinsic coloring agents [29]. In our study, the highest roughness value among the Lava samples; was observed in the measurements made on the 14th day in the LG8 group (0.37 ± 0.18 μm). The highest roughness values among Enamic samples were observed in the EG7 and EG8 groups as 0.36 ± 0.13 μm and 0.36 ± 0.17 μm, respectively, in the measurements made on the 14th day. Also, all recorded Ra values were under 0.4 μm in the present study.

The biggest limitation of our study is that it is an in-vitro study. Although temperature changes are imitated, a complete reflection is not possible due to the presence of many factors such as bacteria in the oral flora, the structure of saliva and hygiene habits. Therefore, more in-vivo studies should be conducted.

Conclusion

Due to the results of the present study - except for the samples stored in coffee-wine - more color changes were observed in the Lava samples than in the Enamic samples in all groups and periods. Also, the highest surface roughness values were detected in 14 days for all samples. The combination of coffee-tea and coffee-wine beverages may have accepted most coloring beverages for hybrid ceramics within the limitation of this study.

Abbreviations

°: Degree, **°C:** Centigrade degrees, **%:** Percent, **Bis-EMA:** Bisphenol A diglycidyl methacrylate ethoxylated, **Bis-GMA:** Bisphenol A diglycidyl methacrylate, **CAD:** Computer-aided design, **CAM:** Computer-aided manufacturing, **μm:** Micrometer, **mm:** Milimeter, **rpm:** Revolutions per minute, **sec:** Second, **TEGDMA:** Triethylene glycol dimethacrylate, **UDMA:** Urethane dimethacrylate.

Declarations

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Ethics approval and consent to participate

Not applicable

Consent for publication

Not applicable.

Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that "they have no competing interests".

Authors Contribution

K.Y. Study conception and design, acquisition of data, analysis, interpretation of data, drafting of the manuscript.

I.S. Study conception and design, acquisition of data, analysis, and interpretation of data, critical revision. Both authors read and approved the final manuscript.

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Figures

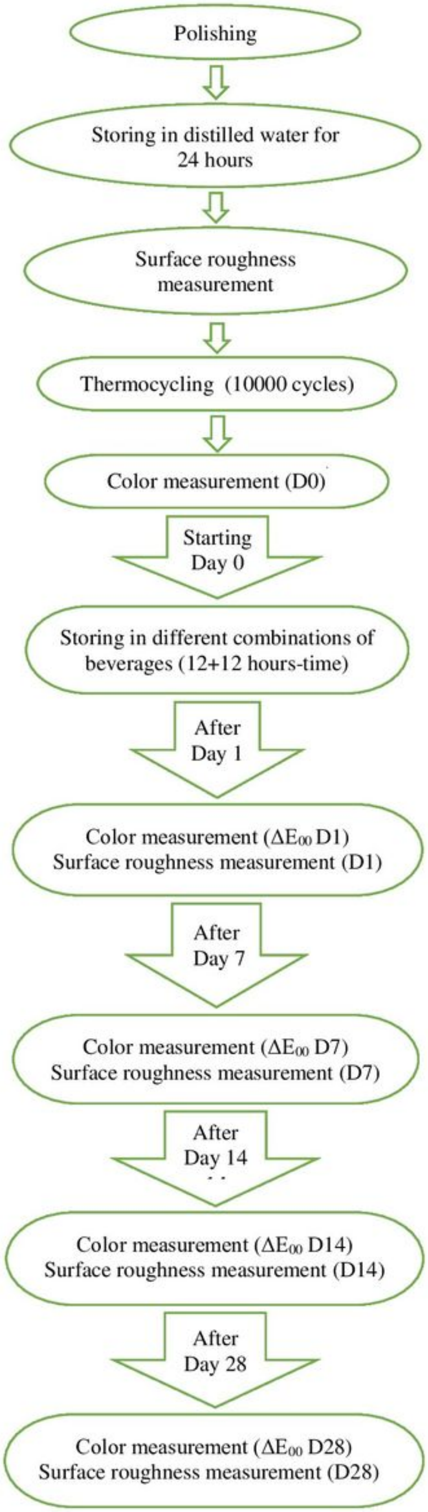

Figure 1

Diagram of the study design

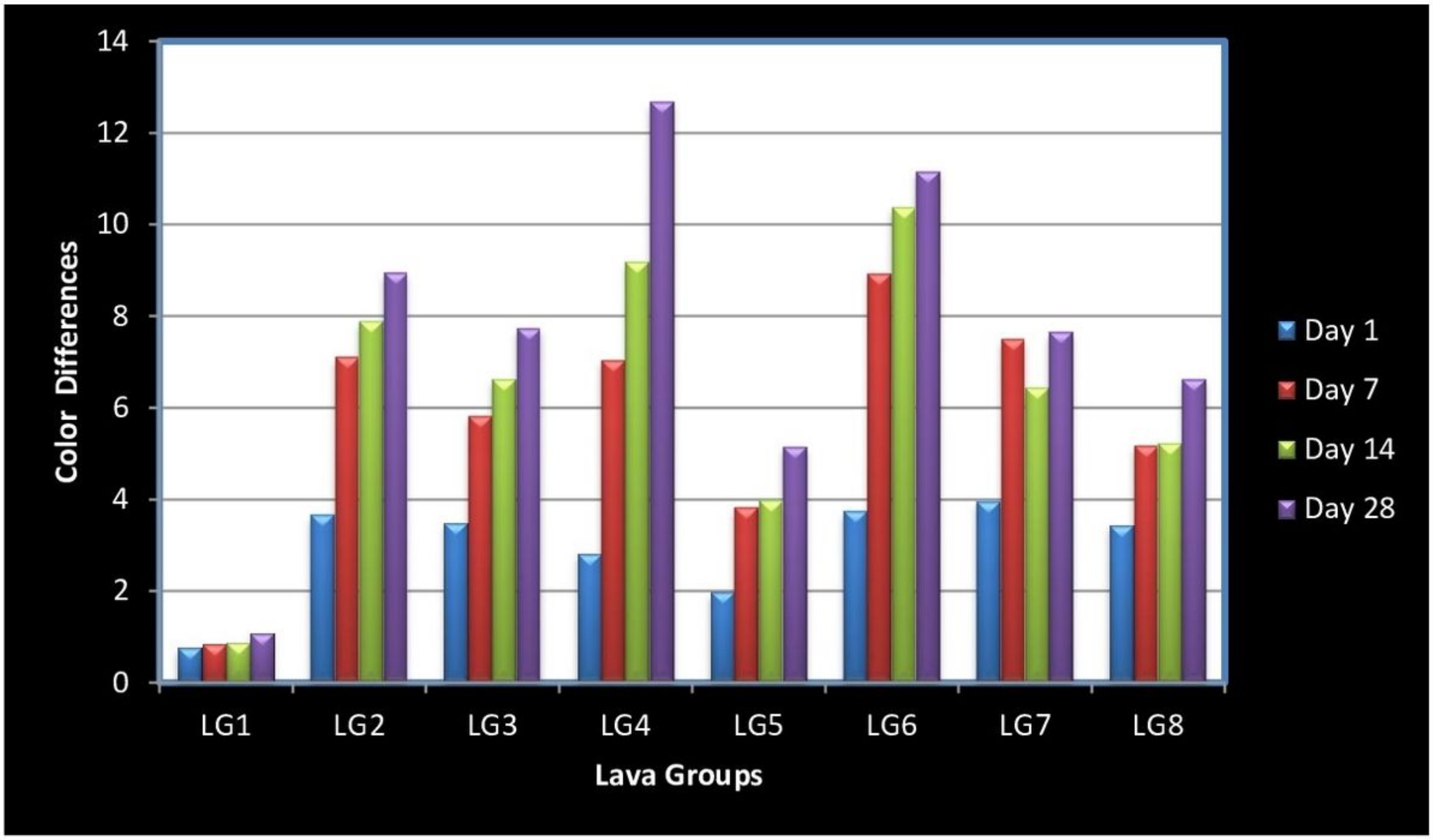

Figure 2

Graph of the color differences (ΔE_{00}) on Lava groups due to time

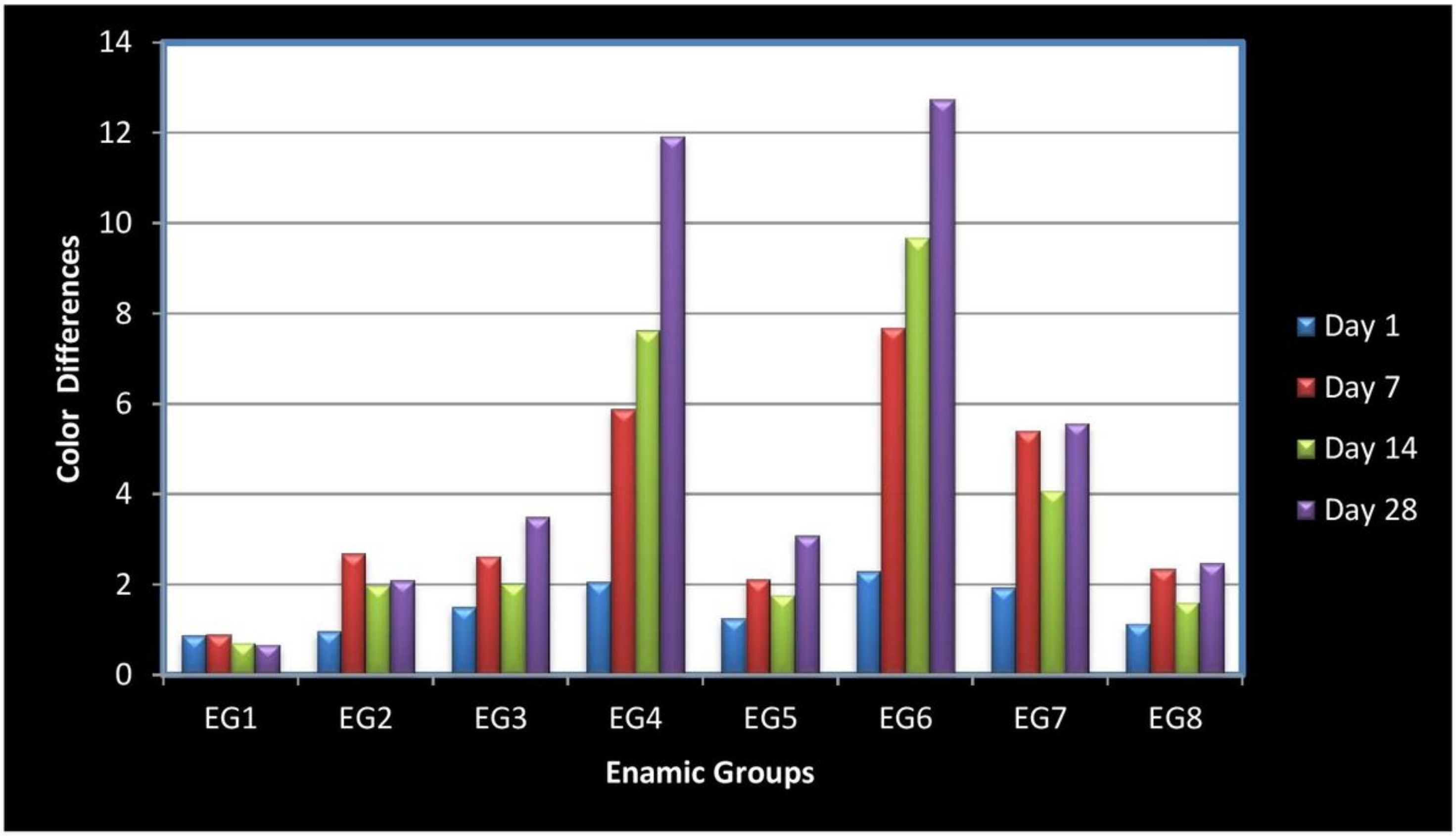

Figure 3

Graph of the color differences (ΔE_{00}) on Enamic groups due to time