MEDICAL SCIENCE MONITOR

DATABASE ANALYSIS

e-ISSN 1643-3750
© Med Sci Monit, 2023; 29: e939341
DOI: 10.12659/MSM.939341

Received: 2022.12.26
Accepted: 2023.01.11
Available online: 2023.01.17
Published: 2023.02.07

Comparison of the Degree of Staining of Computer-Aided Design-Computer-Aided Manufacture (CAD-CAM) Ceramic Veneers by Green Tea, Coffee, and Coca-Cola Using a Digital Spectrophotometer

Authors' Contribution:
Study Design A
Data Collection B
Statistical Analysis C
Data Interpretation D
Manuscript Preparation E
Literature Search F
Funds Collection G

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Financial support: None declared
Conflict of interest: None declared

Background: The majority of dental professionals currently recognize lithium disilicate E-max ceramic veneers as a the most widely used, conservative, and effective cosmetic materials in dentistry. This study aimed to compare the degree of surface changes – roughness (Ra), depth (Rz), and mean color changes (ΔE_{00}) – of computer-aided design-computer-aided manufactured (CAD/CAM) ceramic veneers materials of varying thicknesses caused by staining by green tea, coffee, and Coca-Cola using digital spectrophotometer.

Material/Methods: This study was conducted at King Khalid University, College of Dentistry. Lithium disilicate glass ceramic (LDGC) material was used to create 60 rectangular slices using the CAD/CAM system. The material thickness and the type of beverage were measured. The specimens were immersed in beverages according to the manufacturer's instructions. Specimen description and tomography were completed with a 3D noncontact surface metrology using interferometry. The "VITA Easy-Shade" spectrophotometer was used to measure ΔE_{00}. It was recorded after 2 weeks for different material thicknesses after immersing samples in green tea, coffee, and Coca-Cola staining materials.

Results: Significant changes in ceramic thickness were found in Ra and Rz of 0.07 and 1.00 mm after 14 days of staining. Coca-Cola showed a significant difference in Ra and Rz with 1.00 mm thickness measurement compared to the 0.07 mm group with ≤ of 0.05, which was considered statistically significant. Highest ΔE_{00} were recorded among samples stained by Coca-Cola, followed by coffee, for both thicknesses.

Conclusions: Those findings support previous studies using spectrophotometric analysis of staining of CAD-CAM ceramic veneers that Coca-Cola followed by coffee resulted in the greatest color ΔE_{00} change.

Keywords: Coffee • Color Perception • Dental Materials • vita veneering ceramic D

Full-text PDF: https://www.medscimonit.com/abstract/index/idArt/939341

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Background

Aesthetic dental care has become one of the most common procedures in clinical settings, which can be attributed to high aesthetic perceptions of dental care among people, which ultimately leads to optimal health and enhanced aesthetics, with most patients now having serious concerns about color and shape of their teeth [1].

Computer-aided design (CAD) and computer-aided manufacturing (CAM) have become increasingly widespread in dentistry throughout the previous 35 years. This technology is used in dental clinics and laboratories and is practical for use with partial veneers such as labial veneers, inlays, onlays, and full veneers such as crowns, fixed partial prostheses, implant abutments, and even full-mouth rehabilitation [2].

Ceramic veneers are currently recognized by most dental professionals as a conservative, successful, and predictable cosmetic procedure. One of the most widely used materials for making porcelain veneers is the lithium disilicate E-max system [3,4]. Lithium disilicate glass ceramic (LDGC) prosthetic materials dominate the field of dentistry because of their capacity to successfully replicate natural teeth with a high rate of long-term survival as compared to other ceramics [5]. LDGC is usually marketed as IPS e.max CAD and consists of a crystalline phase (70%) and a glassy matrix. After crystallization, the color of a substance is determined by the dispersion of coloring ions in its matrix [4,6,7].

The surface texture of the restoration as surface roughness (Ra) and surface depth (Rz) has a substantial impact on aesthetics and durability of this ceramic material [8,9]. A rough surface has a negative impact on color and light reflection. The rougher the surface, the lower the optical reflection [10]. Polished surfaces and the spread of subcritical cracks are strongly associated with Ra and Rz [11,12]. The roughness caused by restoration adjustment can exacerbate surface flaws and damage the porcelain [13,14]. Thus, glazing and polishing of ceramic materials reduces surface roughness (Ra) and increases its luster, ultimately decreasing plaque accumulation [9].

Visual color difference thresholds are useful as a tool for quality assurance and a reference for choosing aesthetic materials [15,16]. As a result, the examination of color changes with color-measuring devices, such as spectrophotometers, is now widespread. These devices can record and express hues numerically. The chromaticity of an object is measured using the Commission Internationale de l'Éclairage L*a*b* (CIELab) system. L* measures the color's luminance or lightness, a* evaluates its red-green content, and b* evaluates its yellow-blue content [17]. Thus, the mean color change (ΔE*) values can be determined using L*a*b* [18,19]. Elamin et al described the use of digital spectrophotometry units in analysis the shade guided among different groups of patients [20].

Thus, developing a ceramic veneer with an appropriate aesthetic hue is important, but it is equally important to keep these veneers' colors consistent in oral conditions. Numerous studies have assessed how surface texture affects color stability of ceramic materials [1,9,15,21]. Diet and popular drinks like tea, coffee, and Coca-Cola have a clear impact on the color stability of a porcelain material. According to reports, tea can significantly impact color stability [17,22]. Several studies indicated that coffee also has a significant impact on color change of restorative materials [23,24]. Additionally, coffee and Coca-Cola were reported to be the primary causes of porcelain material deterioration [25-33]. However, we found that very few studies have analyzed the alteration in color stability and surface manipulation of these ceramic materials of varying thicknesses by using all 3 beverages.

The combined effects of staining on the change in surface characteristics and mean color change due to different beverages have not been studied. Therefore, this study aimed to compare the degree of changes such as surface roughness (Ra), surface depth (Rz), and mean color changes (ΔE_{00}) of computer-aided design-computer-aided manufactured (CAD/CAM) ceramic veneers materials of varying thicknesses by green tea, coffee, and Coca-Cola using the VITA Easy-Shade V digital spectrophotometer. Our null hypothesis was that there would be no significant differences in the mean values of Ra, Rz, and ΔE_{00} of LDGC CAD/CAM ceramic restorative material with different thickness and stained with green tea, coffee, and Coca-Cola.

Material and Methods

Study Design and Sample Size Calculation

This study was conducted in the King Khalid University, College of Dentistry, in the end of 2022. Study objectives were to determine the effects of staining with tea, coffee, and Coca-Cola on different thicknesses of lithium disilicate glass ceramic CAD/CAM Veneer on surface topography as roughness (Ra) or depth (Rz) and mean color changes (ΔE_{00}) after aging and staining for 14 days. Power analysis calculation was performed to determine the sample size required to obtain a statistically significant outcome. The result showed that 30 samples per group (10 samples for each subgroup) were required at a 95% confidence level, a power of 80%, and a standard deviation of 0.4 [34,35].

Specimen Fabrication and Grouping

Lithium disilicate glass ceramic (LDGC) (IPS e.max CAD) CAD/CAM ceramic block material (VITA Zahnfabrik, H. Rauter Bad

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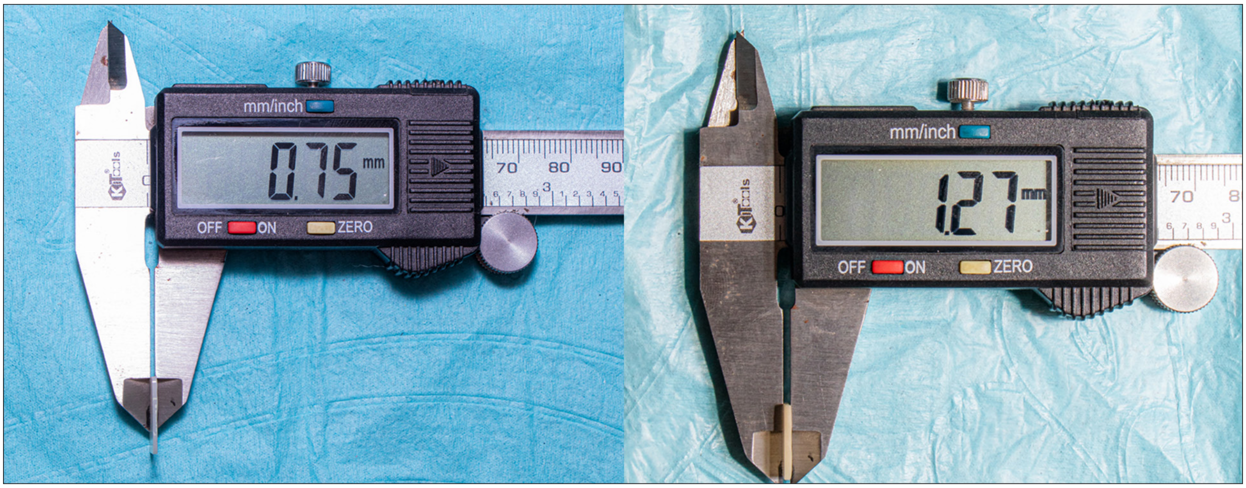

Figure 1. Measuring of thickness (0.07 and 1.00 mm) ceramic laminate veneer by using a digital micrometer.

Säckingen, Germany) was used to create 60 specimens using the CAD/CAM system (Amann Girrbach, GmbH, Durrenweg 40 75177 Pforzheim, Germany). The specimens were in the form of rectangular ceramic disks had sizes of 12 mm in diameter and 0.07 and 0.10 mm in thickness. Using a digital caliper, the specimens' thicknesses were determined (**Figure 1**). Prior to the final heat treatment in the furnace for complete crystallization, a glaze layer (IPS e.max Ceram Glaze paste, Ivoclar Vivadent, Schaan AG, Liechtenstein) was applied to all specimens on the experimental side (side of staining) for the LDGC group. The 2 thickness groups were divided into 3 subgroups according to the immersion beverages – green tea, coffee, and Coca-Cola – with 10 samples each.

Surface Topography Measurements

Specimen description and tomography were completed with 3D noncontact surface metrology using interferometry (Bruker Contour GTK, Bruker Nano Surfaces Division, Tucson, AZ, USA) in the materials laboratory of King Saud University. Through an upright scan interferometer with a 5 Michelson amplification lens, a field of interpretation of 1.5 mm, a Gaussian regression filter, a scan speed of 1, and a thresholding of 4, specimens were computed or measured. We used a microscope equipped with the Vision 64 (Bruker) software suite, which manages tool placements, which assess the statistics and generate graphical results. Assessments were reserved across the specimens at 3 time points – before immersion and staining (baseline), then after green tea, coffee, and Coca-Cola immersions, and 14-days aging (after) – and the differences were recorded as the Ra and Rz changes. Each specimen was scanned 3 times (at the center and both corners) and then averaged to calculate the surface roughness (Ra) and surface depth (Rz) values in µm, calculated in accordance with ISO 11562 recommendations for standardization [34-36].

Figure 2. Reading of color parameters from VITA Easy-Shade spectrophotometer.

Color Parameter Measurement

By placing the ceramic specimen on a gray background, the color of CAD/CAM ceramic samples was assessed as measured before or at baseline [17,37,38]. The digital spectrophotometer VITA Easy-Shade V (VITA Easy-Shade, V, Bad Säckingen, Germany) was used to measure color. Colors' three-dimensional (3D) dimensions are numerically represented by CIELab values [37]. Spectrophotometers measure the color parameters such as L*, a*, and b* values, where L is the axis of lightness, a is the value representing the axes of chromaticity (green-red), and b is the value representing the axes of color (blue-yellow). The light reflected from the item is used to determine these 3 coordinates. The average change in color is ΔE*. These measures had previously been applied to research evaluating ceramic CAD/CAM material colors. For each specimen and in the center, readings of L*, a*, and b* were done twice, and the mean values were recorded. On the basis of baseline measurements, the specimens were evaluated for color change. **Figure 2** shows a screenshot from the digital spectrophotometer used by VITA Easy-Shade. These measurements were used

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as a baseline before (L1, a1.b1) the specimens were immersed in green tea, coffee, and Coca-Cola and stained [17,37,38].

An aging process was accomplished for all specimens during this staining and immersion time. After immersion, all CAD/CAM ceramic specimens were dipped in distilled water following removal from the different staining materials; the specimens were then checked several times to ensure that the staining material was completely removed. Then, specimens were dried with white tissue paper and left to air dry. All color parameters change measurements for L, a, and b were calculated and registered again by the same operator at time intervals of 14 days, with the same settings, and with a gray background and recorded as (L2, a2, b2). The average color changes (ΔE_{00}) values were recorded after 2 weeks for the different material thickness and surface staining using the following equation: ΔE_{00} = ((L1* - L2*)^2 + (a1* - a2*)^2 + (b1* - b2*)^2 "×½. ΔE_{00} values for staining types of beverages and the tested CAD/CAM materials were calculated as described earlier in the literature [17,37,38].

Specimens' Immersion in Beverage Materials and Aging

The samples were submerged in different staining materials of Green Tea, Coffee, and Coca-Cola for Fortnight (Food Industrial Co., Riyadh, Saudi Arabia). The solutions utilized in this investigation were marketed for single use and were offered in a nitrogen-flushed box. According to the manufacturer's recommendations, for green tea, and coffee, the staining of the different solutions made from each packet (30 g) was combined with 0.5 L of hot water (100°C) and allowed to continue boiling for 15 s (0.6 gm for each 1 mL), while for Coca-Cola, the samples with different thickness were totally immersed in containers. For all samples, 2 packets of 30 g each were used every day, and the Coca-Cola, green tea, and coffee were replaced every 12 h [9,15,24,30].

Statistical Analysis

The IBM SPSS 20.0 program for descriptive statistics was used to calculate the mean and standard deviation (SD) of Ra and Rz as well as mean color change (ΔE_{00}) values of the LDGC material with different thickness in white backgrounds before and after staining and aging. The values were presented by tables as the means and SD of Ra, Rz, and ΔE_{00}. For repetitive measurements, one-way analysis of variance (ANOVA), followed by *t* tests, and/or Bonferroni test were performed to compare the cases exposed as different thickness (0.07 and 1.00 mm) of the tested materials and different immersion beverages (coffee, green tea, and Coca-Cola). *P* values ≤0.05 were considered statistically significant.

Results

Descriptive Results

During the coffee, green tea, and Coca-Cola staining and aging process for surface topography and color measurements parameters, no specimens were missing or lost. Before and after beverage staining, the mean and SD of surface characteristics (Ra and Rz) and mean color changes (ΔE_{00}) values of the studied CAD/CAM ceramic material with different thickness are shown in **Table 1**. Significant changes in ceramic thickness were measured in surface roughness (Ra) of 0.07 mm and 1.00 mm after 14 days immersion in different beverages (*P* value<0.01). Similarly, in surface depth (Rz), a significant difference was measured in material thickness of 0.07 mm and 1.00 mm (*P* value <0.01). Overall, the average mean color change was considered significantly different in both thickness of LDGC CAD/CAM material in the different immersion beverages, as shown in **Table 1**. **Table 2** shows the ANOVA results between and within the groups. **Figure 3** shows that the highest ΔE_{00} were recorded among samples stained by Coca-Cola, followed by coffee beverages for both thicknesses, with ΔE_{00} values are represented in the figure. As shown in **Table 2** a significant difference was recorded and registered among and within the groups before and after immersion in different beverage solutions for LDGC samples ceramic in different thicknesses according to ANOVA with *P* values 0.001.

Comparing Groups Using Bonferroni Test

According to the Bonferroni test, for all specimens with different thicknesses tested, the LDGC CAD/CAM material immersed in Coca-Cola has shown Ra and Rz as a significant difference in 1.00 mm thickness measurement compared to the 0.07mm group with maximum surface alteration were immersed in coffee and Coca-Cola as compared to green tea (*P* value <0.05), as shown in **Table 3**. Also, the Bonferroni test revealed that the specimens with maximum ΔE_{00} were LDGC samples immersed in green tea and coffee as compared to Coca-Cola samples (*P* value<0.05), and only for 0.07 mm thickness samples. According to the *t* test (**Table 4**), no significant difference was found in surface roughness (Ra) and surface depth (Rz) for material thickness and the different staining materials. The ΔE_{00} for the tested ceramic material with 0.07 mm and 1.00 mm and different staining materials showed a slightly significant difference in overall parameters (*P* value <0.05). **Table 5** presents the interaction of Ra, Rz, and ΔE_{00} changes of different CAD/CAM ceramic material thicknesses and immersion materials. For Ra, a significant difference was noted in the tested parameters (*P*<0.001, 0.011). Similarly, a significant in Rz was found among the ceramic thicknesses and immersion materials (*P*<0.018, 0.010), while for mean color change (ΔE_{00}), significant differences in all interactions were recorded (*P*<0.001) for all variables.

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Table 1. Mean and standard deviation of surface roughness (Ra) surface depth (Rz), mean color change (ΔE_{00}) of different ceramic thickness groups, before, after, and the overall changes in relation to types of immersion materials.

Ceramic thickness	Immersion materials	Mean (SD) before	Mean (SD) after	Mean (SD) changes
Ra				
0.07 mm	Tea	0.16 (0.033)	0.19 (0.033)	0.03 (0.063)
	Coffee	0.22 (0.071)	0.25 (0.081)	0.03 (0.076)
	Coca-Cola	0.31 (0.033)	0.36 (0.070)	0.05 (0.054)
	P-value	0.001*	0.001*	0.001*
1.00 mm	Tea	0.17 (0.040)	0.18 (0.041)	0.01 (0.041)
	Coffee	0.36 (0.064)	0.39 (0.74)	0.03 (0.069)
	Coca-Cola	0.37 (0.042)	0.44 (0.66)	0.07 (0.054)
	P-value	0.138	0.088	0.062
Rz				
0.07 mm	Tea	0.17 (0.054)	0.19 (0.045)	0.02 (0.051)
	Coffee	0.25 (0.036)	0.29 (0.042)	0.04 (0.059)
	Coca-Cola	0.31 (0.053)	0.39 (0.071)	0.08 (0.062)
	P-value	0.001*	0.001*	0.001*
1.00 mm	Tea	0.14 (0.044)	0.18 (0.051)	0.04 (0.080)
	Coffee	0.27 (0.621)	0.29 (0.028)	0.02 (0.064)
	Coca-Cola	0.31 (0.032)	0.40 (0.083)	0.09 (0.088)
	P-value	0.001*	0.030*	0.050*
ΔE_{00}				
0.07 mm	Tea	1.16 (0.082)	1.36 (0.083)	1.20 (0.824)
	Coffee	1.80 (0.286)	2.60 (0.372)	2.80 (0.329)
	Coca-Cola	2.81 (0.199)	3.01 (0.370)	3.20 (0.234)
	P-value	0.001*	0.001*	0.001*
1.00 mm	Tea	1.10 (0.038)	1.38 (0.018)	1.28 (0.895)
	Coffee	2.49 (0.162)	3.11 (0.232)	2.62 (0.923)
	Coca-Cola	3.14 (0.123)	3.62 (0.173)	3.18 (0.996)
	P-value	0.001*	0.000*	0.042*

Discussion

Many patients now prefer tooth-colored ceramic restorations. These patients' needs have been partially satisfied by the significant advancements in the cosmetic and physical characteristics of all ceramic restorations. However, the most difficult aspect of cosmetic restorations is attaining color consistency, not only with natural tooth structure, but also in the oral environment [39]. LDGC ceramics are now widely used in dentistry, and we selected this ceramic as our study material due to its superior efficacy, cytocompatibility, and aesthetics [40]. To meet the increasing demands, these restorations need to be both color-stable and biocompatible in the oral environment [30]. However, these materials are vulnerable to a variety of oral conditions that can result in stains and minor color changes affecting surface topography [41]. Thus, the present study assessed the effect of 2 different thicknesses of lithium disilicate glass ceramic veneer on surface characteristics or topography as surface roughness (Ra) and surface depth (Rz) and mean color changes (ΔE_{00}) after aging and immersion in different beverages.

The optical qualities of restorations can be modified in the oral environment [13,21]. Numerous studies have shown the significance of acidic solutions, altering the optical characteristics and surface roughness of different CAD/CAM restorative dental materials [15,17,25,34,42-46]. Green tea, coffee and Coca-Cola are the most regularly consumed acidic drinks in daily life. Green tea and coffee have a pH of 5.8 and consist

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Table 2. ANOVA test for calculating significant differences among the group and within groups.

	Sum of squares	Mean difference	Mean square	Frequency	Significant difference
Between groups	.070	2	.035		
Within groups	.112	57	.002	17.777	.001*
Total	.182	59			
Between groups	.085	2	.042		
Within groups	.133	57	.002	18.156	.001*
Total	.218	59			
Between groups	.867	2	.434		
Within groups	1.169	57	.021	21.143	.001*
Total	2.036	59			

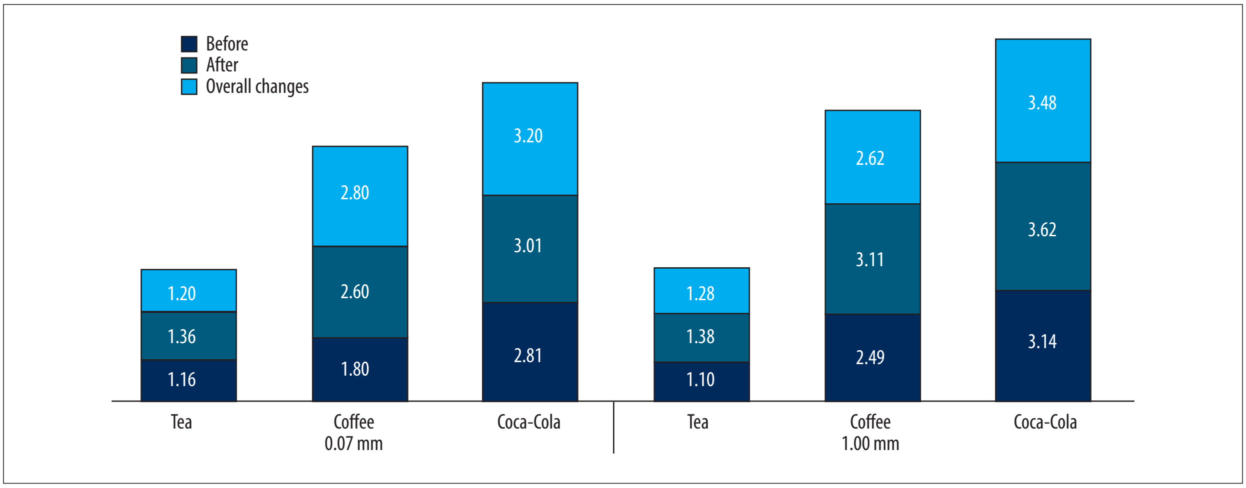

Figure 3. Means of color changes in relation to material thickness and stained beverage.

of caffeine, tannates, citrates and chlorogenic acid, whereas Coca-Cola has a pH of 2.5 and is made up of phosphates, carbonated water, and caramel [47,48]. Staining of ceramics caused by these low-pH acidified beverages may compromise the cosmetic outcome [49-51], thereby reducing durability of the material, resulting in roughness, abrasion, and subsequent staining of teeth, ultimately causing patient dissatisfaction [52]. Therefore, we analyzed the effect of all 3 beverages on ceramic material of varying thicknesses in our study.

In addition, maintaining prothesis color is crucial in the oral environment. Numerous studies have evaluated the relationship between color stability and surface topography of various dental restorations. Research has revealed that porcelain discoloration is connected to diet, immersion time, and the type of surface treatment [9,16,24,26,28,30,35]. Gupta et al [53] evaluated the ceramic materials' color stability after exposure to commonly consumed beverages: tea, coffee, and Coca-Cola. This differed from our study, as they measured only color changes after 1 day, 15 days, and 30 days for all the solutions. In our study, we analyzed color changes along with surface topography measurements after immersing for 14 days. In the present study, the baseline stain was carried out for 2 weeks to enhance stain absorption since ceramic materials quickly absorb fluids in the first 2 weeks. Additionally, 2 weeks of coffee staining were utilized, which, according to coffee producers, indicated 14 months' worth of coffee consumption [36].

Surface roughness (Ra) was investigated in this study because it is a crucial aesthetic feature of ceramic restorations. Smooth surfaces are less likely to discolor and become colonized by bacteria, making them less vulnerable to periodontal and recurrent caries [36,54]. We utilized a digital caliper to evaluate the thickness of each sample, thereby excluding any variables

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Table 3. Bonferroni test to measure mean surface and color changes.

Ceramic thickness	Immersion materials	Tea	Coffee	Coca-Cola
Ra change				
0.07 mm Ra	Tea	-----	0.258	0.000*
	Coffee	0.258	-----	0.000*
	Coca-Cola	0.000*	0.000*	-----
1.00 mm Ra	Tea	-----	0.125	0.065
	Coffee	0.125	-----	0.000*
	Coca-Cola	0.065	0.000*	-----
Rz change				
0.07 mm Rz	Tea	-----	1.000	0.000*
	Coffee	1.000	-----	0.000*
	Coca-Cola	0.000*	0.000*	-----
1.00 mm Rz	Tea	-----	1.000	0.000*
	Coffee	1.000	-----	0.000*
	Coca-Cola	0.000*	0.000*	-----
ΔE_{00} change				
0.07 mm ΔE_{00}	Tea	-----	0.000*	0.000*
	Coffee	0.000*	-----	0.290
	Coca-Cola	0.000*	0.290	-----
1.00 mm ΔE_{00}	Tea	-----	0.224	0.320
	Coffee	0.224	-----	0.126
	Coca-Cola	0.320	0.126	-----

that could affect the final results of color change and surface roughness. We observed significant changes in ceramic thickness measured in surface roughness (Ra) and surface depth (Rz) of 0.07-mm and 1.00-mm samples after 14 days of immersion in different beverages. Similar findings were reported by Al-Angari et al in 2021, who discovered a rise in Ra following the simulation of 1 year of coffee consumption [36]. Aldosari et al in 2021 [9] also found similar findings after 14 days of Arabic Qahwa immersion and stated that Ra values for zirconia, hybrid, and feldspathic CAD/CAM ceramics increased.

It has been shown that the ceramic thickness and the color change of ceramic restorations are related. Uludag et al [55] evaluated the impact of porcelain thickness on the color stability of porcelain restorations and discovered that as ceramic thickness increased, there was a perceived reduction in color change values (ΔE^*). However, when varied thicknesses of all porcelain materials were employed, no significant difference in color change was seen [24]. Also, Abdelkader et al in 2020 found no discernible changes in color change while employing differing thicknesses of all materials (1.00 mm and 0.6 mm) [30]. However, this was contrary to our findings, as significant changes in ceramic thickness were measured in surface roughness (Ra) and surface depth (Rz) of 0.07 mm and 1.00 mm after 14 days of immersion in different beverages. We also found that overall, average mean color change was significantly different in both thicknesses of LDGC CAD/CAM material immersed in different beverages.

Mean color change was greatest with Coca-Cola. Also, the CAD/CAM material immersed in Coca-Cola and coffee was significantly different in Ra and Rz of 1.00 mm thickness compared to the 0.07 mm group. This finding was similar to the study done by Kara et al in 2022, where a similar finding was reported in mean color change values of sample groups having greater thickness [39]. This could be explained by the diverse settings utilized in each study. This finding could be attributed to the acidity of the Coca-Cola solution, dissolving silica and alkaline ions from the glaze layer, causing the surface to corrode, as evidenced by the increased roughness. Additionally, it is consistent with earlier research that found that CAD-CAM lithium disilicate and feldspathic ceramic surfaces became significantly rougher due to the low pH of acidic liquids and high temperatures, such as with coffee [14,42,49,56].

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Table 4. *t* test for all the different ceramic thicknesses in relation to immersion material.

Ceramic thickness	Immersion materials	Parameter	P-value
0.7 mm	Tea	Ra changes	0.212
	Coffee		
	Coca-Cola		
1.0 mm	Tea		0.182
	Coffee		
	Coca-Cola		
0.7 mm	Tea	Rz changes	0.076
	Coffee		
	Cock-Cola		
1.0 mm	Tea		0.055
	Coffee		
	Coca-Cola		
0.7 mm	Tea	ΔE_{00} changes	0.006*
	Coffee		
	Coca-Cola		
1.0 mm	Tea		0.032*
	Coffee		
	Coca-Cola		

Table 5. ANOVA interaction of tested parameters in relation to material thickness and immersion materials.

Ra changes					
Source	**Type III sum of squares**	**Df**	**Mean square**	**F**	**Sig.**
Intercept	0.120	1	0.120	62.313	**0.000***
Immersion materials	0.21	2	0.010	5.315	**0.011***
Ceramic thickness	0.000	0	–	——	——
Immersion materials × ceramic thickness	0.000	0	–	–	–
Error	0.052	27	0.002	–	–
Rz changes					
Immersion materials	18.060	2	9.030	1.350	0.269
Ceramic thickness	40.439	1	40.439	6.046	**0.018***
Immersion materials × ceramic thickness	67.538	2	33.769	5.049	**0.010***
Error	321.066	48	6.689		
ΔE_{00} changes					
Immersion materials	.001	2	0.001	9.962	**0.001***
Ceramic thickness	.001	1	0.001	18.826	**0.001***
Immersion materials × ceramic thickness	.001	2	0.001	10.850	**0.001***
Error	.003	48	5.386E-5		

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However, other studies evaluated the color porcelain materials stability concerning the surface texture, concluding that accurate polishing procedures could create smooth ceramic surfaces similar to glazed surfaces [51,53]. Glazing has been found to produce smoother surfaces than glass ceramic polishing [48]. Manufacturers also advocate glazing or polishing to improve the aesthetics of lithium disilicate [24]. This emphasizes significance of reglazing any ceramic material after making any alterations. In our study, we performed similar heat treatment in the furnace and a glaze layer was applied over ceramic specimens. The current study's findings also concur with those of previous studies [24,26], and those by Sagsoz et al, Saba et al, Acar et al, and Palla et al, which came to the same conclusion and advised the reglazing step of samples after immersions in widely consumed beverages like tea and coffee [27,28,51,58].

Since color perception is a psychophysical phenomenon that varies both between individuals and within an individual at different times, the color measurements in the current study were conducted using a spectrophotometer. We used a spectrophotometer in our study to measure color change because it has been proved to be more precise than most other shade-taking methods. Instrumental measurement has the advantage of numerically expressing colors, thereby eliminating the subjective errors associated with color assessment [20,60]. Thus, in order to express the degree of color and relative color changes of all the specimens, we used the "VITA Easy-Shade" spectrophotometer to measure color. Colors' three-dimensional (3D) dimensions are numerically represented by CIELab values [37,61]. It is difficult to determine the average color change ΔE^* value that is noticeable or clinically acceptable. The detectable and clinically acceptable thresholds, however, were found to be ΔE^* 2.8 and 4.2 units, respectively, in in vivo research [24,31,37]. In our study, we noticed significant differences among tested parameters. Overall, the average mean color change was significantly different in both thicknesses of LDGC CAD/CAM material in the different beverages. The highest ΔE_{00} was recorded among samples stained by Coca-Cola, followed by coffee for both thicknesses. Also, maximum ΔE_{00} values were found in LDGC samples immersed in green tea and coffee as compared to Coca-Cola and only for 0.07 mm thickness samples. This finding was also in accordance with studies by Alghazali et al in 2012 and Abdalkadeer et al in 2020, wherein they also found similar significant differences with Coco-Cola as compared to other beverages [30,37]. Adawi et al in 2021 also demonstrated similar results. On immersion in hot Arabic Qahwa and cold coffee, ΔE_{00} values for tested materials in glazed or polished specimens varied significantly [16]. For ΔE_{00} values recorded after 2 weeks, our results were comparable to those of previous studies conducted with glazed specimens immersed in hot coffee by AlMawash et al, Colombo et al, Özyılmaz et al, and Aydin et al [23,26,61,62]. However, our results differed from those of Yerliyurt and Sarikaya, Eldwakhly et al, Seyidaliyeva et al, and Aboushahba et al [10,63-65], as they did not observe maximum discoloration with Coca-Cola and coffee.

Despite the effective methods used, the current study was unable to replicate the identical in vivo conditions, since there is no uniform technique for simulating the physiological condition of the soft and hard tissues of the mouth. Furthermore, the generalizability of the study's findings may be constrained by differences in nutrition, immersion time, and oral hygiene practices among individuals. Additional in vivo experiments are required to assess the vulnerability of different brands of ceramic materials to discoloration, analyzing various physical, mechanical, and optical properties of various CAD/CAM materials like translucencies, compressive or flexural strength, and compare it with various polishing materials or oral hygiene aids. Furthermore, the incorporation of specific color parameters and scanning electron microscopic studies are needed. Also, a major limitation was that these 3 beverages had various pH values, which was not evaluated.

Conclusions

We found significant changes in surface roughness (Ra) and surface depth (Rz) in 0.07 mm and 1.00 mm groups after 14 days of immersion in different beverages. For all specimens with different thicknesses tested, the CAD/CAM material immersed in Coca-Cola showed significant differences in Ra and Rz in the 1.00 mm thickness group compared to the 0.07 mm group. The ΔE_{00} was significantly different in both thicknesses of LDGC CAD/CAM material in the different beverages. Overall, the findings from this study support previous studies using spectrophotometric analysis of staining of CAD-CAM ceramic veneers, showing the highest ΔE_{00} in samples stained by Coca-Cola, followed by coffee, for both thicknesses.

Declaration of Figures' Authenticity

All figures submitted have been created by the authors, who confirm that the images are original with no duplication and have not been previously published in whole or in part.

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