Heliyon 10 (2024) e34172

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon

Research article

Impact of common social habits on optical properties of lithium disilicate glass ceramic crowns: An in vitro study

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ARTICLE INFO

Keywords:
CAD/CAM
Lithium disilicate glass ceramic
color
Habits
Spectroscopy
Staining

ABSTRACT

Statement of the problem: Patient stratifications considered the stability of color and treatment longevity are key success of restoration. Daily consumption of colored beverages, such as coffee, tea, and soft drinks, as well as the use of globally consumed materials, such as smokeless tobacco (ST), snuff, Khat, and Yerba mate, can change the color of restorative materials, such as lithium disilicate glass ceramics (LDGC). These changes can ultimately lead to treatment failure.
Purpose: This in vitro study aimed to evaluate color changes, translucency, and opalescence of full anatomical LDGC crowns exposed to commonly used and potentially colorant solutions.
Materials and methods: Ninety LDGC specimens/crowns were prepared and divided into nine groups according to immersion solution (control, Saudi Coffee, Cola, Khat, Yerba mate, Nescafe, ST Snuff, and Mixed Fruit Juice). The specimens were immersed in colorant solutions for 15 days with alternating twice daily at 37 °C. Color parameters were measured with a spectrophotometer and calculated using two backgrounds (black and white). Data were subjected to ANOVA followed by the Student t-test and Bonferroni test at a significant difference level ($\alpha = 0.05$).
Results: The greatest color change (ΔE^*) among groups after immersion was observed in Yerba mate (7.6 ± 1.6). The mean difference of before and after staining within Yerba mate group was 3.14 ± 1.6 ($p = 0.001$). Translucency mean values of groups after immersion into staining media were ranging between 7.6 ± 1.2 and 9.1 ± 2, showing a slight decrease compared with pre-staining values but was not significantly different. Immersion in Mixed Fruit Juice significantly reduced opalescence (7.4 ± 1.9) compared to (8.8 ± 1.7) before staining.
Conclusion: The findings confirm that appropriate user guidance helps to preserve both translucency and opalescence as well as prevent color changes. This can improve patient compliance and promote treatment longevity.

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https://doi.org/10.1016/j.heliyon.2024.e34172
Received 27 March 2024; Received in revised form 27 June 2024; Accepted 4 July 2024
Available online 5 July 2024

1. Introduction

Lithium disilicate glass ceramics (LDGC) have gained importance and clinical preference in the field of dentistry because of their mechanical and optical characteristics. LDGC, which has a refractive index close to that of natural tooth structure, offers the needed esthetic appeal because they can closely resemble the appearance of natural teeth [1]. As a result, LDGC crowns are widely used in prosthetic crown replacements and veneers [2]. Optical properties, including color and stainability of LDGC, should be studied to maintain proper application in restorative dentistry with the expected exposure of the material to variable media in the oral cavity. The color stainability of LDGC is influenced by many factors, such as hydrothermal aging, surface finishing, and polishing, and exposure to pigmenting materials, such as coffee, tea, etc. [3,4].

The frequent daily intake of dyed beverages, such as coffee, tea, and soft drinks, and the habitual consumption of variant materials, such as smokeless tobacco, smokeless snuff, Khat, Yerba mate, etc. have emphasized the need to explore the effect of staining substances on the color properties of LDGC. Previous studies assessed the effect of certain culture-specific habits, such as the oral use of khat, smokeless tobacco, smokeless snuff, and Yerba Mate, and the consumption of drinks, such as Cola, Nescafe, and Saudi Coffee daily [3–7].

Oral consumption of smokeless tobacco is practiced in Africa, North America, Southeast Asia, Europe, and the Middle East. This practice consists of inserting a portion of tobacco or tobacco product in the mandibular sulcus and chewing or sucking it for a sometime: a "chaw," which refers to a portion of tobacco with a size similar to a golf ball, is generally chewed, whereas a "quid" is usually smaller and held in the mouth rather than chewed [8,9]. Khat is practiced in countries like Ethiopia, Yemen, and Saudi Arabia by putting it at the buccal sulcus of the mandibula for many hours daily. Yerba Mate tea is widely consumed in South American countries. Gawon–Gzella et al. reported the increasing frequency of Yerba Mate consumption because of its marketed pro-health effects [10]; however, the brown color of this drink may influence the color of dental structures and materials. Furthermore, colored beverages such as cola, coffee and tea are the three most popular drinks commonly used worldwide.

Several methods have been utilized to quantify color. The CIE Lab color system, which was developed by the International Commission on Illumination (CIE) in 1976, has become a universally accepted colorimetric reference system for quantification and interpretation of clinical values of colors and differences in color changes. The CIE Lab color system, also known as Lab*, is a device-independent 3D color space that allows accurate measurement and comparison of all perceivable colors by using three color values, namely, L* for lightness, a* for red/green value, and b* for blue/yellow value. It is a global color system that simplifies color communication regardless of the device used [11].

This study aimed to evaluate optical properties, including mean color changes, translucency, and opalescence of full anatomical LDGC crowns after staining in different adverse materials such as Khat, smokeless tobacco, Yerba mate, smokeless snuff, and drinks, such as Cola, Nescafe, Saudi Coffee, and fruit juice, which are habitually consumed daily worldwide. The null hypothesis is that optical properties, including mean color changes, translucency, and opalescence of full anatomical LDGC, are not significantly different after staining in different materials.

Table 1
Materials and devices used in the study.

Material	Composition	Color	Application per day	Manufacturers
Highly esthetic Lithium Aluminum Disilicate	90 % Li2Si2O5, 5 % Li3PO4, 5 % Li0.5Al0.5Si2.5O6	MT A2 C14	–	Dentsply Sirona, Germany
Yerba Mate	Caffeic acid, caffeine, caffeoyl derivatives, caffeoylshikimic acid, chlorogenic acid, feruloylquinic acid, kaempferol, quercetin, quinic acid, rutin, and theobromine	Green	2	Industeria Argenteina
Cola	Sugar, caramel, caffeine, orthophosphoric acid, water	Black	2	Coca-Cola
Khat	Alkaloids, terpenoids, flavonoids, sterols, glycosides, tannins, amino acids, vitamins, minerals	Green	1	
Smokeless Tobacco	Largely manufactured by powdering the tobacco along with ash, flavors, oils, calcium oxide, and black pepper	Black	2	
Mixed Fruit Juice	Major aliphatic hydrocarbons of Vimto® were hydroxymethyl furfurole, tetradecane, hexadecane, dodecane, octadecane and 9-octadecenamide while aromatic hydrocarbons were vanillin, benzoic acid, diisooctyl phthalate, butanoic acid, piperonal, bis (2-ethylhexyl) phthalate, and germacrene	Red	1	Aujan Industries L.L.C., Vimto ®
Saudi Coffee Mix	Instant Saudi Coffee, Cardamom, Cloves, Nondaily Coffee Creamer, Saffron, used as Hot Coffee	Yellowish	2	Baja Food Industrial Co., Saudi Arabia
Nescafe Classic coffee	Sugar, glucose syrup, instant coffee (11 %), palm kernel oil, soluble fibre, skimmed MILK powder (0.7 %), MILK protein, salt, stabilizers, lactose (MILK), acidity regulator, emulsifiers, natural flavorings, MILK fat, color	Black	2	Nestle, Saudi Arabi
Smokeless tobacco (Snuff)	Water. With Swedish portion snus water and pouch material comprise more than half of the product mass; with chewing tobaccos water and sugars comprise around 60 % of the products.With these STPs, tobacco was a minor component (30–35 %) of the product mass	White	2	Snus, Sweden

2. Materials and methods

2.1. Study design and ethical approval

This in vitro study assessed the effect of nine daily globally consumed colorants on the optical properties of LDGC, namely, mean color changes (ΔE*), translucency (TP), and opalescence (OP). A total of 90 CAD/CAM LDGC anatomical crowns were fabricated. Table 1 presents the materials and devices used. This study was approved by the Ethics in Research Committee at Jazan University (Rec-44/07/496).

2.2. Sample size estimation and teeth preparations

Ninety sound molar teeth were collected from different clinics with sound clinical crowns and extracted due to periodontal causes. The extracted and used teeth had almost the same dimensions and a means of the occluso–cervical height (8.4 ± 0.35 mm), mesio-distal (11.37 ± 0.28 mm), and bucco-lingual dimension (10.86 ± 0.42 mm). The teeth were prepared to receive full-ceramic crowns as described previously [12,13]. G*Power (version 3.1.9.7, 2020, Heinrich Heine University Düsseldorf, Düsseldorf, Germany) was used to approximation the specimen sizes while assuming a nine-group assessment. The alpha was set at 0.05 with a power of 80 %, and an effect size of 0.40 was used to calculate the sample size. A total sample size of 90 samples was initiate to be enough [9].

2.3. Sample manufacturing and grouping

All prepared teeth were scanned using an intraoral scanner (CEREC Primescan; Dentsply Sirona). All crowns were fabricated with a CEREC Primemill system (CEREC SW, Version 5.2.9, Dentsply Sirona). The anatomical crowns were constructed with lithium disilicate with virgilite (Cerec Tessera™, Medium Translucency, C14; Dentsply Sirona). Cutting dimensions of the samples were determined, considering a 0.2%–0.3 % shrinkage during the crystallization of LDGC. The final dimensions of the full-anatomy LDGC crowns were 2 ± 0.2 mm thick on the occlusal surfaces (the area of color parameter measurements), as determined using a digital caliper (Guanglu, Gullin, China).

The crowns were consecutively polished with 600, 800, and 1000 grit silicon carbide (SiC) papers with water, as recommended by the manufacturers. Each polishing step was carried out for 60 s at 300 rpm by a single operator [14–16]. Following final adjustments, the crowns were cleaned, dried, and glazed using universal stain and glaze liquid (Dentsply Sirona). According to the manufacturer's instructions, the crowns were fired in a porcelain oven under vacuum to complete the crystallization (Fig. 1). The crowns were stored in sterile sealed packs until they could be further analyzed. For test purposes, crowns were divided randomly into nine groups according to the staining material type.

2.4. Color parameter measurements

All measurements have been performed by a single trained operator under standardized testing conditions. The shade MT A2 C14 was utilized as the standardized shade for all crowns. After polishing and crystallization, the crowns were cleaned in an ultrasonic bath of isopropyl alcohol for 5 min before to measurements. A spectrophotometer Vita® Easyshade (VITA Easyshade, VITA Zahnfabrik, Bad Säckingen, Germany) with a calibration plate was used to assess and record the CIELAB coordinates (L*, a*, and b*) of the CAD/CAM ceramic crowns at 555 nm to compare the anatomical crowns given that the human eye is penetrating to wavelengths extending among 380 and 780 nm and is the most sensitive to 555 nm. This wavelength was set based on the recommendation of the International Commission on Illumination (CIE 015:2018).

The spectrophotometer handpiece was held perpendicular to the crowns without incandescent light. The optical handpiece was

Fig. 1. Representative images of the anatomical Lithium Aluminium Disilicate crowns.

inserted into the calibration port of the spectrophotometer to calibrate the device for each crown, following the manufacturer's recommendations [14,15,17].

The values for the assessed anatomical LDGC crowns were measured at the center of each crown three times with the device, and the results were averaged. After bringing the anatomical crowns from the laboratory, cleaning them, and calibrating the spectrometric device, all anatomical crowns were filled with black and white modeling clay (MODELING CLAY, Class, Belgium). For each group, a black and white clay was filled separately. The first readings of the color parameters (baseline values) were recorded and documented as L1, a1, and b1. Meanwhile, L2, a2, and b2 were used for the color parameters after 15 days of immersion and staining with different materials, as shown in Fig. 2(a and b).

The recorded values were used to calculate optical parameters as follows; The mean color changes (ΔE*) are the difference between two colors in an L*a*b* color space. To determine the value, the difference in color measurements of the samples before and after 15 days of staining and immersion were evaluated by using the following formula [14,15,17].

$$\Delta E^* = [(L1^*\text{-}L2^*)^2 + (a1^*\text{-}a2^*)^2 + (b1^*\text{-}b2^*)^2]^{1/2}$$

where ΔL* = the differences between L1 (before) and L2 (after the immersion)
Δa* = the differences of a1 (before) and a2 (after the staining)
Δb* = the differences of b1 (before) and b2 (after the staining)

The translucency parameter (TP) was determined by calculating the color difference amongst the same specimens against black and white backgrounds, according to the subsequent equation [14–16]:

$$TP = [(L_B^* - L_W^*)^2 + (a_B^* - a_W^*)^2 + (b_B^* - b_W^*)^2]^{1/2}$$

The subscripts B and W refer to the color coordinates against black and white backings, respectively. TP values can range from 0 (for a totally opaque material) to 100 (for a totally transparent material). High TP values indicate the greater ability of light to pass through an object.

The opalescence parameter (OP) was determined from the values a* and b* coordinates that were documented using a spectrophotometer (VITA Easyshade, VITA Zahnfabrik, Bad Säckingen, from Germany) from the CAD/CAM ceramic crowns placed on black (B) and white (W) backgrounds according to the following equation [14–16]:

$$OP_{BW} = [(a_B^* - a_W^*)^2 + (b_B^* - b_W^*)^2]^{1/2}$$

The subscripts B and W refer to the color coordinates against black and white backgrounds, respectively.

2.5. Immersion of anatomical crowns in different staining materials

The immersion in khat was carried out, as reported earlier [18–20]. Khat was prepared and offered by the Substance Abuse and Toxicology Research Center Jazan University. The homogenate of khat leaves was prepared from fresh mincing of fresh leaves in 100 % distilled water (V/W). Khat was kept in a freezer at an ultralow temperature of −80 °C until use. Khat was then mixed with NaOH until its pH was comparable to that of saliva and oral cavity. All anatomical crowns were immersed in Khat for 15 days [18,20]. The same procedures were conducted daily to obtain fresh solutions.

All anatomical LDGD crowns were immersed and stained in black ST for 2 weeks [4,9]. The black ST was mixed with water to a thick consistency. The crowns were immersed for 10 min, with a constant weight bearing down to ensure that the crowns remained immersed for 10 min (the actual time used for ST) and simulate the force generated during the dipping of ST. The ST preparations were changed twice daily according to actual practice [21].

Smokeless snuff had with a covering bed and was ready to dissolve in saliva after being placed in the buccal sulcus. The crowns were immersed between the snuff and covered on top. The crowns were stained for 10 min, with a continuous weight bearing down to ensure that the crowns were persistently stained for 10 min (the actual time used for smokeless snuff) to simulate the force produced during the dipping of snuff. The snuffs were replaced twice daily according to actual practice [22].

Yerba mate tea staining solutions were prepared by adding 15 g to 250 ml of boiled distilled water. The mixture was then added to boiling water after 10 min, and the powder materials were changed every 12 h daily [23,24]. Nescafe Classic coffee staining solution

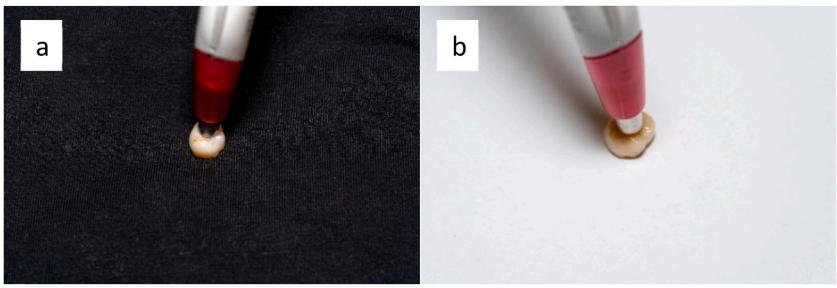

Fig. 2. During measurements of optical parameters on a. black and b. white backgrounds.

was prepared by adding 15 g to 250 ml of boiled distilled water. The test solution was changed daily and stirred once every 12 h to maintain homogeneity [5,17,25,26]. After the immersion period of 15 days, the anatomical crowns were removed from the testing solution.

Following the baseline color assessments, 10 anatomical crowns were stained in Saudi Coffee during the aging period. Instant hot Saudi Coffee comes in a nitrogen-flushed package for single use. Saudi Coffee was prepared from each packet (30 g) by mixing with 0.5 l of boiled water at 100 °C and boiling for 15 s. New coffee solutions were changed every 12 h [6,27]. Two cups of Mixed Fruit Juice (2 g) were steeped in 30 ml of cold water for 3 min. Anatomical LDGC crowns were immersed in the prepared solutions completely in a vertical position. Cola was ready to be used and changed every 12 h [3,26,28]. The same procedures were repeated with normal saline [25].

All staining media, materials, and solutions were shaken well and used. All crown-containing solutions were kept in an incubator at 37 °C. and the staining solution was refreshed every 12 h. Strict adherence to the preparation protocols was ensured. Each group was stained in a separate container and kept inside an incubator during the staining period. Following the aging process, all anatomical crowns were dipped 0 times in distilled water after being removed from the staining media. The anatomical crowns were dried with tissue paper and left in place until complete dryness.

2.6. Statistical analysis

Mean and standard Deviation (SD) of color change (ΔE^*), TP, and OP of full0-contour anatomical CAD/CAM crowns were recorded before and after immersion in nine different social habits, beverages, and aging. Microsoft Excel 13 software was used to input the data and analyze it using Statistical Package for Social Science (SPSS) version 24.0 (SPSS Inc., Chicago, IL, USA). One-way ANOVA, paired Students t-test, and Bonferroni test were applied to detect any significant difference among groups. $P < 0.05$ was set at the significant level. Then, ΔE^* values were linked and compared to reach a clinically acceptable threshold of 4.2 units, as mentioned in the previous study [6]. ANOVA and Student t-test were used to compare color changes among different groups and staining materials. Color changes were set in every single group to 50 %:50 % perceptibility and acceptability thresholds to assess if such changes are clinically acceptable.

3. Results

Maintenance of ceramics optical properties such as mean color change, translucency, and opalescence are significant for patient satisfaction and essential to avoid esthetic failure of dental treatment over time.

3.1. Color changes on white and black background (ΔE^*)

Mean and standard deviation (SD) of color changes of crowns on white and black backgrounds were calculated in each group before and after staining (Table 2). One-way ANOVA showed a statistically significant difference among the groups ($p = 0.001$). The post-hoc Tukey HSD test was applied to identify which groups were significantly different from each other. The Yerba Mate group displayed a statistically significantly higher mean color change (7.6 ± 1.6) than the other groups (p-values of comparisons between the Yerba Mate group and others were less than 0.01). The mean color changes before immersion into staining media were comparable with each other across the groups and were not significantly different ($p = 0.44$). The comparisons of mean color changes on white and black backgrounds within groups before and after staining were evaluated using paired t-tests (Table 3). The mean color changes of the Yerba Mate group significantly increased after staining ($p = 0.001$).

3.2. Translucency parameter

Table 4 shows the mean translucency and SD of various social habit groups before and after immersion into staining media. Translucency was not statistically significantly different among the groups after immersion into different media ($p = 0.44$). Pre-

Table 2
Mean and standard deviation (SD) of color changes on the white and black backgrounds of various social habit groups.

Group	Color Changes (before staining)			Color Changes (after staining)		
	Mean	SD	p-value	Mean	SD	p-value
Control	3.3	1.2	0.44	3.8	0.9	0.001
Saudi Coffee	4.5	1.6		5.1	0.9	
Cola	4.4	1.3		3.2	1.1	
Khat	4.3	1.4		4.3	1.8	
Yerba Mate	4.5	1.9		7.6	1.6	
Nescafe	4.7	1.2		3.8	1.7	
ST	3.9	0.8		4.4	1.8	
Snuff	4.5	1.4		4.3	1.2	
Mixed Fruit Juice	3.9	0.9		3.1	2	

- ANOVA statistical analysis was performed to compare means between groups at $p < 0.05$ for the staining variable.

Table 3
Color changes on white and black background within each social habit group before and after staining test.

Group	Color Changes			
	Difference Mean	SD	t	p-value
Control	0.52	1.2	1.3	0.23
Saudi Coffee	0.64	1.3	1.5	0.16
Cola	−1.2	1.4	−2.5	0.03
Khat	−0.07	2.0	−0.1	0.9
Yerba Mate	3.14	1.6	6.1	0.001
Nescafe	−0.94	1.7	−1.7	0.12
ST	0.39	1.5	0.8	0.45
Snuff	−0.12	1.4	0.3	0.78
Mixed Fruit Juice	−0.90	1.9	1.5	0.17

- Paired *t*-test statistical analysis was performed to compare means of pre- and post-staining tests within each group at $p < 0.05$.

Table 4
Mean and standard deviation (SD) of translucency of various social habits groups.

Group	Translucency (before staining)			Translucency (after staining)		
	Mean	SD	p-value	Mean	SD	p-value
Control	7.9	1.2	0.2	7.6	1.2	0.44
Saudi Coffee	8.4	1.0		8.3	0.9	
Cola	8.7	1.4		8.5	1.3	
Khat	9.2	1.9		9.1	2.0	
Yerba Mate	8.4	1.7		8.2	1.1	
Nescafe	9.8	1.9		8.9	1.7	
ST	9.1	2.6		7.7	1.8	
Snuff	8.4	1.3		8	1.5	
Mixed Fruit Juice	9.5	1.2		8.8	2.6	

- ANOVA statistical analysis was performed to compare means between groups at $p < 0.05$ for each variable.

staining translucency mean values were statistically similar across groups ($p = 0.2$). The mean values of translucency within groups were compared before and after testing social habits (Table 5). Translucency slightly decreased after immersion into staining media and was not statistically significantly different before and after staining within groups.

3.3. Opalescence parameter

The mean opalescence and SD values of the groups are revealed in Table 6. Differences in mean opalescence were statistically insignificant ($p = 0.74$) between the stained groups and between the pre-test groups ($p = 0.32$). Opalescence means that the values of the specimens before and after exposure to staining media were statistically similar within each group, except for the Mixed Fruit Juice group, where the parameter was significantly reduced after immersion ($p = 0.04$) (Table 7).

4. Discussion

In a sociological research done by Krut et al., the level of patient satisfaction with dental care was determined based on survey results [29]. Treatment received, cost of paid services, and clarity of received information about the dental problem were among the factors discussed. Understanding the effects of the patients' daily social habits on the materials selected to rehabilitate different dental

Table 5
Translucency within each social habit group before and after staining test.

Group	Translucency			
	Difference Mean	SD	t	p-value
Control	−0.26	1.4	−0.6	0.56
Saudi Coffee	0.01	1.0	−0.02	0.98
Cola	−0.2	1.0	−0.63	0.54
Khat	−0.11	2.1	−0.2	0.87
Yerba Mate	−0.14	1.5	−0.3	0.77
Nescafe	−0.90	1.8	−1.6	0.15
ST	−1.35	2.8	−1.5	1.7
Snuff	−0.40	1.5	−0.8	0.43
Mixed Fruit Juice	−0.60	2.4	−0.8	0.45

- Paired *t*-test statistical analysis was performed to compare means of pre- and post-staining tests within each group at $p < 0.05$.

Table 6
Mean and standard deviation (SD) of opalescence of various social habits groups.

Group	Opalescence (before staining)			Opalescence (after staining)		
	Mean	SD	p-value	Mean	SD	p-value
Control	7.2	1.4	0.31	7.1	1.1	0.74
Saudi Coffee	7.2	0.9		7.6	1.1	
Cola	7.7	1.4		8.1	1.4	
Khat	8.2	2.1		7.7	1.9	
Yerba Mate	8.3	2.3		7.9	1.4	
Nescafe	8.5	2.3		8.1	1.6	
ST	7.6	1.7		7.1	1.5	
Snuff	8.6	2		7.5	1.1	
Mixed Fruit Juice	8.8	1.7		7.4	1.9	

- ANOVA was performed to compare means between groups at $p < 0.05$ for each variable.

Table 7
Opalescence within each social habit group before and after the staining test.

Group	Opalescence			
	Difference Mean	SD	t	p-value
Control	−0.10	1.3	−0.2	0.82
Saudi Coffee	0.48	0.9	1.6	0.13
Cola	0.38	1.4	0.8	0.42
Khat	−0.55	2.4	−0.7	0.49
Yerba Mate	−0.32	2.5	−0.4	0.7
Nescafe	−0.51	2.6	−0.6	0.56
ST	−0.55	1.5	−1.1	0.29
Snuff	−1.20	2.7	−1.4	0.2
Mixed Fruit Juice	−1.39	1.9	−2.3	0.04

- Paired *t*-test statistical analysis was performed to compare means of pre- and post-staining tests within each group at $p < 0.05$.

anomalies is determinantal to facilitate the selection of a material and educating the patient before starting the treatment to prevent future perceived failures by the patient because of lack of clarity by the dentist. Daily habits are hard to break and involve patients in decision making by clarifying the effects to avoid future problems related to staining and failure of the expensive dental treatment.

This study aimed to assess the optical properties of LDGC crowns after immersion in diverse materials and conducted a social habit in different parts of the world. Specific solutions of substances used socially worldwide are used to predict treatment outcomes. Most studies investigated the stainability of different beverages (tea, coffee, and red wine) on dentition or composite materials. From the author's knowledge, no known studies were found investigating the staining potential of Yerba Mate, Mixed Fruit Juice etc., on lithium disilicate ceramics. The three optical properties tested were mean color change (ΔE^*), translucency (TP), and opalescence (OP).

There was an overall color change of the crowns after immersion for 15 days in the different materials. The Yerba Mate group had the highest mean color change of 7.6 ± 1.6. Studies have not evaluated the effect of Yerba Mate on crowns or teeth. Yerba Mate is a bitter drink prepared by pouring hot water on coarse Yerba Mate leaves. A special metal straw with a colander at the end was used to sip the drink. The colander at the end filtered the coarse leaves. The beverage has a powdery grainy texture that may abrade the surface of the ceramic and create a surface that is liable to stain with the dark brown chromogen of the drink. A beverage that resembles Yerba Mate in its composition is black tea and coffee. Sarembe et al. reported that black tea and red wine produced the highest staining effect on dental enamel treated with chlorhexidine [30].

Translucency was not statistically significantly different before and after staining, but a slight overall decrease was found after immersion. Translucency is defined as an optical property of a material that occurs when a light beam passing through is partly scattered, reflected, or transmitted. The greater the quantity of light that passes through the material, the higher the translucency [31]. In the present study, the full anatomic crowns had a 2 ± 0.2 mm thickness, which might be too thick for the translucency to be affected by the colorants. Future studies should assess the stainability of different solutions on thinner restorations to simulate veneers. Finally, opalescence values did not change within groups, except for Mixed Fruit Juice (A sugary concentrate of fruit juice composed mainly of grape, black currant and raspberry with coloring foods composed of concentrates of carrot and hibiscus), where this parameter significantly decreased after immersion ($p = 0.04$).

The effect of Khat on polished or glazed CAD/CAM ceramic shows acceptable mean color changes [20]. Similar values were recorded for similar materials after staining it in green tea and coffee [5]. Also, immersion of different types of CAD/CAM ceramic materials in smokeless tobacco recorded the average color change as 2.7 and 4.8 [4]. Different type of LDGC recorded a mean color change less than 2 after staining with Arabic-Coffee [6], and marginally similar value recorded for the same materials after immersion in Cola for 2 weeks [3].

The opalescent property of a material becomes bluish once reflected and orange once transmitted [32]. This phenomenon may be elucidated by the fact that red-colored beverages have a chemical structure that confers them with high staining ability. Tannins are

astringent, polyphenolic biomolecules that bind to proteins, amino acids, and organic compounds. Red wine, berries, and chocolate are examples of food that contain tannins; the presence of this compound indicates a decrease in bluish reflection after its exposure to the red chromogen of fruit juice [33]. The acidity of beverages might also erode the surface of the ceramic, causing roughness, which aids in the retention of chromogens on the crown.

The three mechanisms that contribute to the formation of extrinsic stains were suggested by Eriksenand Nordbö as follows: (a) chromogenic bacteria in dental plaque produce colored components; (b) colored substances retain on the surface as they pass through the oral cavity; and (c) chemical transformation of pellicle components form color products [34,35]. In the current study, the second mechanism may explain the staining.

We can infer that additional research is needed to examine the effects on samples following clinical adjustments or polishing of the surfaces to stimulate actual clinical scenarios. Moreover, extended thermocycling/aging could also be included to replicate clinical scenarios where adjustments are required to examine its effect on LDGC stainability. Absence of oral environment condition and clinical situation with different temperatures which represent the oral cavity can be considered as a limitation of this study. Further studies are needed to investigate the effect of chromogenic materials on lithium disilicate ceramics in an environment that simulates the microflora of the oral cavity and plaque.

5. Conclusion

The following conclusions are drawn.

1. The changes in the overall mean color were clinically unacceptable for Yerba Mate group and significantly increased after immersion
2. The translucency of CAD-CAM materials was slightly influenced by different drinking habits but did not lead to unacceptable discrepancies after immersion.
3. The colorants significantly influenced opalescence, particularly for the Mixed Fruit Juice group, which caused a reduction in its values after staining.

Funding

This research was funded by The Deanship of Graduate Studies and Scientific Research, Jazan University, Saudi Arabia (Project Number: GSSRD-24).

Availability of data and materials

Data associated with the study has not been deposited into a publicly available repository. Data are available from the corresponding author on reasonable request.

CRediT authorship contribution statement

Arwa Daghrery: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Resources, Project administration, Funding acquisition, Formal analysis, Conceptualization. **Waad Khayat:** Writing – review & editing, Formal analysis, Data curation. **Nassreen Albar:** Writing – original draft, Investigation, Formal analysis, Conceptualization. **Maysaa Khojah:** Writing – original draft, Visualization, Conceptualization. **Eman Jabarti:** Resources, Project administration, Methodology, Investigation, Formal analysis, Conceptualization. **Heba Mitwalli:** Methodology, Investigation, Formal analysis, Data curation. **Mohammed Al Moaleem:** Writing – original draft, Methodology, Investigation, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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