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EFFECT OF STAINING SOLUTIONS ON COLOR AND TRANSLUCENCY CHANGE OF DIFFERENT MONOLITHIC CAD-CAM CERAMIC MATERIALS

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ABSTRACT

Purpose: To assess the effect of staining solutions on color and translucency change of different monolithic CAD-CAM ceramic materials.

Materials and methods: Sixty-six rectangular-shaped specimens were milled from different CAD-CAM ceramic materials with a precision saw and divided into 3 groups (n = 22): **ZLS group**, zirconia-reinforced lithium silicate; **ZR group**, 4 mol% yttria-stabilized tetragonal zirconia polycrystal (4Y-TZP); and **LD group**, lithium disilicate glass-ceramic. Each one was subdivided into 2 subgroups (n = 11) according to the assigned staining solution used (coffee and distilled water). Rotating silicon carbide paper was sequentially used for wet polishing of all specimens. The specimens' color and translucency parameter (***TP***) were evaluated using a reflective spectrophotometer at baseline and after staining procedures. Changes in color (ΔE) and translucency parameter (ΔTP) were calculated. One-way ANOVA followed by Tukey's post hoc test was used if ANOVA showed a significant *p*-value ($p < 0.05$).

Results: Staining solutions had a significant impact on the color change (ΔE) and the translucency parameter change (ΔTP) of all tested specimens. Coffee had the most significant effect on ΔE where the LD group recorded the largest ΔE (13.07 ±1.49) and the ZLS group showed the smallest ΔE (5.21 ±1.37). Also, coffee had the most significant effect on ΔTP where the ZR group recorded the largest ΔTP (3.3 ±0.07) and LD group recorded the smallest ΔTP (-0.5 ±0.2).

Conclusions: Color and translucency parameters of tested CAD-CAM ceramic materials were significantly influenced by staining solutions. The ZLS group showed significantly least color change than the ZR and LD groups. The ZLS group showed significantly highest translucency parameter initially (baseline) and after staining procedures than the ZR and LD groups while the LD group revealed significantly least translucency change than the ZR and ZLS groups.

KEYWORDS: Color change, Translucency parameter change, Monolithic CAD-CAM ceramic materials, Staining solutions.

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INTRODUCTION

The advance in computer-aided design-computer-aided manufacturing (CAD-CAM) technology allows the use of ceramic blocks in the fabrication of in-office monolithic ceramic restorations[1]. These restorations have gained its popularity because of their enhanced esthetics, acceptable mechanical properties, and excellent biocompatibility. in addition, chipping of veneering porcelain as the most frequent problem, especially in patients with parafunctional habits has been eliminated[2-7].

Different monolithic ceramic materials including zirconia-reinforced lithium silicate (ZLS)[8], lithium disilicate, 4 mol% yttria-stabilized tetragonal zirconia polycrystals (4Y-TZP) have been introduced with acceptable mechanical properties without influencing the esthetic outcome of the final restoration[9]. Lithium disilicate ceramics have become very popular due to the unique densely arranged interlocking needle-like metasilicate crystals incorporated in a glass matrix that is provided in a partially crystallized state to speed up the milling process followed by crystallization firing in a furnace at 850 °C under vacuum to reach ultimate strength (fracture toughness 2.25 MPa·m$^{1/2}$, flexural strength 360-500 MPa) [10,11] and esthetic potential. Additionally, ZLS ceramics containing 10% by weight zirconia dispersed in a silica-based glassy matrix have been introduced to strengthen the ceramic structure by interrupting of crack propagation[12]. This innovative composition combines the properties of zirconia and glass ceramics resulting in improved mechanical properties[13,14] and enhanced translucency[15]. High translucency monolithic (4Y-TZP) has been introduced as an evolution of zirconia-based ceramic restorations in which tetragonal and cubic phases are stabilized at room temperature reducing light scattering and thus improving translucency[16,17]. However, improvement of translucency resulted in reduction of fracture toughness to 2.5-3.5 MPa·m$^{1/2}$ and flexural strength to 700-800 MPa[18,19].

To achieve a successful dental restoration with a good prognosis, the material used must not only fulfill biological and mechanical demands, but also satisfy the increased patient demand for enhanced esthetics. Regarding optical properties, several studies showed that ZLS ceramics have a higher translucency than LD glass-ceramics[3, 20]. To the author's knowledge, no data are available in the literature about the color and translucency parameter change of 4Y-TZP ceramics following storage in staining solutions [21].

This in vitro study aimed to assess changes in the color and translucency parameters of monolithic CAD-CAM ceramic materials after staining procedures. The tested null hypothesis was that no differences would be found at baseline and after staining procedures.

MATERIALS AND METHODS

Table 1 shows the evaluated materials' composition as well as their manufacturers in the current study. The sample size was calculated depending on Eldwakhly et al study[22]. According to this study, a sample size of 9 specimens in each group had an 80% power with a significance level (α =.05) and an effect size (F=1.72) to test the null hypothesis that no differences in color and translucency parameters of the tested CAD-CAM ceramic materials would be found at baseline and after staining procedures; this was increased to 11 specimens in each group to achieve more consistent results. In 80% (the power) of those experiments, p was <0.05.

A total of sixty-six rectangular-shaped specimens (14 × 11 × 1 mm) were cut from CAD-CAM ceramic blocks by using a precision saw (Isomet 4000; Buehler, Lake Bluff, USA) under constant water irrigation and divided into 3 groups (n = 22): **ZLS group**, zirconia-reinforced lithium silicate; **ZR group**, 4 mol% yttria-stabilized tetragonal zirconia polycrystal (4Y-TZP); and **LD group**, lithium disilicate glass ceramic (Table 2). Each one was subdivided into 2 subgroups (n = 11) depending on the staining solution used. The color and translucency parameters of the tested CAD-CAM materials were evaluated at baseline and after staining procedures.

Specimens of ZLS group (n=22), were cut from Celtra Duo blocks (LT, A2, C14) and crystallized in a calibrated porcelain furnace (Vacumat 40T; Vita Zahnfabrik, Bad Sackingen, Germany) at 820 °C for 25 minutes. Specimens of ZR group (n=22) were cut 20% oversized from a partially sintered 4Y-TZP blocks (14 Z / STML, A2) to compensate for the post sintering shrinkage and sintered in a special sintering furnace (inFire HTC Speed; Dentsply Sirona, York, PA) at 1560°C for 90 minutes. Specimens of LD group (n=22) were cut from IPS e-max CAD blocks (LT, A2, C14) and were exposed to crystallization cycle 10 minutes at 850°C in the same calibrated porcelain furnace used for crystallization of ZLS specimens. The performance of crystallization and sintering procedures was done following the manufacturers' instructions. Checking and verification of the overall thickness of all specimens were done to a precision of 0.1 mm using digital calipers (Dial Caliper D; Aura-Dental, Aura an der Saale, Germany). The specimens were sequentially wet polished by using rotating silicon carbide paper (240-, 400-, 600-grit papers; Buehler, Lake Bluff, IL, USA) at 300 rpm then cleaned for 10 seconds by using a steam cleaner (EGV 18; Eurocem Srl, Milanese, Italy) and stored for 24 hours at 37 °C in distilled water.

TABLE (1): CAD-CAM materials' composition and their manufacturers used in the study

Product Name	Material	Composition	Manufacturer
Celtra Duo	Zirconia-reinforced lithium silicate ceramic (**ZLS**)	58% SiO2, Al2O3, K2O, Li2O, P2O510% ZrO2, CeO2, pigments	Dentsply Sirona
KATANA Zirconia STML	4 mol% Yttria-stabilized tetragonal zirconia polycrystal (**4Y-TZP**)	>99% ZrO_2+HfO_2+Y_2O_3, >4% yttrium oxide (Y_2O_3), ≤5% hafnium oxide (HfO_2), ≤1% other oxides	Kuraray Noritake
IPS e-max CAD	Lithium disilicate glass-ceramic (**LD**)	57-80% SiO2, 11-19% Li2O, 0-13% K2O, 0-11% P2O5, 0-8% ZrO2, 0-8% ZnO, 0-5% Al2O3, 0-5% MgO	Ivoclar vivadent AG

TABLE (2): Specimens grouping

Variables	Staining solutions		Total
	Coffee	Distilled water	
ZLS group Zirconia-reinforced lithium silicate	11	11	22
ZR group 4 mol% Yttria-stabilized tetragonal zirconia polycrystal (4Y-TZP)	11	11	22
LD group Lithium disilicate glass ceramic	11	11	22

The color assessment of the specimens was performed using a reflective spectrophotometer (RM200QC; X-Rite GmbH, Neu-Isenburg, Germany) with orifice size of 4 mm where the specimens were centralized in the measuring port against a white background (Commission Internationale de l'éclairage (CIE) $L^* = 88.81$, $a^* = -4.98$, $b^* = 6.09$) in accordance to the CIE $L^*a^*b^*$ color space relative to the CIE standard illuminant D65, where L^* points to the lightness degree (0–100), a^* to the color coordinate on the red/green axis and b^* to the color coordinate on the yellow/blue axis[23]. Calibration of the device before each record was done and the average of three recorded measurements for each specimen was calculated.

By using the same spectrophotometer, the translucency parameter (***TP***) values were obtained through calculation the color change of the specimens measured against black (CIE $L^* = 7.61$, $a^* = 0.45$, $b^* = 2.42$) and white (CIE $L^* = 88.81$, $a^* = -4.98$, $b^* = 6.09$) backgrounds relative to the CIE standard illuminant D65.: $TP = [(L^*_b - L^*_w)^2 + (a^*_b - a^*_w)^2 + (b^*_b - b^*_w)^2]^{½}$; where: TP – translucency parameter; L^* – degree of lightness; a^* – color coordinate on the red/green axis; b^* – color coordinate on the yellow/blue axis; the subscripts $_b$ and $_w$ point to the color coordinates against black and white backgrounds respectively[24].

Subsequently, random division of the specimens of each tested CAD-CAM material group into 2 subgroups (n = 11) depending on the staining solutions (coffee and distilled water). The coffee solution was prepared by pouring 20 grams of coffee (Nescafé® Classic, Nestlé S.A., Vevey, Switzerland) into 1 liter of boiled distilled water with stirring every 5 minutes for 10 seconds until cooling to room temperature, followed by filtering through a paper filter. The other used staining solution was distilled water (Health Aqua, Alexandria, Egypt).

By using a pH meter (AD11, Adwa Instruments, Szeged, Hungary), the measured pH for coffee solution was 5 and for distilled water was 6.9. Five mL of each staining solution in closed vials was used for immersion of the specimens individually that were stored in an incubator (2431/V, C.B.M. S.r.l. Medical Equipment, Torre Picenardi, Italy) at 37 °C for 4 weeks. To avoid yeast or bacterial contamination, the solutions were freshened daily; in addition, the staining solutions were stirred twice a day to reduce the particles' precipitation. After finalizing immersion time, each specimen was rinsed with distilled water and then wiped with gauze before reexamination of color and translucency parameters as prescribed for the baseline records.

Calculation of the color change (ΔE) of each sample was done using the subsequent equation: $\Delta E = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{½}$ where: ΔE – change in color; $\Delta L^* = L^*$after staining – L^*baseline; $\Delta a^* = a^*$ after staining – a^* baseline; $\Delta b^* = b^*$after staining – b^*baseline. The ΔE values above 1.2 were regarded perceptible, while values above 3.3 were classified according to the 50:50% threshold[25] as clinically unacceptable. Calculation of the differences in the ***TP*** values was done using the subsequent equation:

$\Delta TP = TP_{\text{after staining}} - TP_{\text{baseline}}$; where: ΔTP – translucency parameter change and the ΔTP values above 2 were regarded as perceivable[26].

For each tested CAD-CAM ceramic material, data were presented as mean and standard deviation (SD) values for ΔE and ΔTP. Data were explored for normality using the Kolmogorov–Smirnov test and the Shapiro–Wilk test.

Regarding ΔE, 2-way ANOVA was used for evaluating the effect of material type and staining solution. One-way ANOVA followed by Tukey's post hoc test was used when ANOVA showed a significant p-value. The comparison between ***TP*** baseline and after staining was done using Paired t-test while multiple comparisons between different materials was done using One-way ANOVA test followed by Tukey`s post hoc test.

Regarding **ΔTP**, 3-way ANOVA was used to evaluate each variable effect (baseline vs after staining, material type and staining solution). The significance level was set at $p < 0.05$. Statistical analysis was performed by using a statistical software program (IBM SPSS Statistics, v20; IBM Corp).

RESULTS

The means and standard deviations of color change (**ΔE**) results for tested CAD-CAM material groups as a function of staining from baseline are presented in table 3.

As demonstrated in table 3, Regardless of staining solutions totally, the LD group had a statistically significant ($p < 0.05$) highest color change mean value (**ΔE =** 8.55 ±1.835), followed by the ZR group (**ΔE** = 8.15 ±0.98) while the ZLS group had the lowest statistically significant ($p <$ 0.05) color change mean value (**ΔE**=4.03 ± 1.045) as proved by 2-way ANOVA (F=67.97, *p*=<.0001). Tukey's post-hoc test revealed statistically non-significant difference between LD and ZR groups.

Irrespective of tested CAD-CAM material groups totally, the coffee immersed subgroup had a statistically significant ($p < 0.05$) higher color change mean (**ΔE** = 10.01 ±1.26) than distilled water immersed subgroup mean value (**ΔE**=3.81 ±1.32) as shown by 2-way ANOVA (F=18.3, *p*= <0.0001).

Regarding the effect of staining solution on color change (**ΔE**) of tested CAD-CAM material groups, by using One way ANOVA, showed a significant difference ($p < 0.05$) in both coffee and water immersion subgroups. Tukey`s post hoc test for mutable comparison showed a significant difference in tested CAD-CAM material groups after coffee immersion, whereas the highest mean value in the LD group, followed by the ZR group and the least mean value in ZLS group. Also, the ZLS and ZR groups revealed a significant difference after water immersion, whereas the highest mean value was recorded in the ZR group, and the least mean value was found in ZLS group as shown in table 3.

TABLE (3): Color change (**ΔE**) values (Mean ±SD) for all groups as function of staining solutions from baseline

Variables	**Staining solutions**				**Total**		***p* value**
	Coffee		**Distilled water**				
	M	SD	M	SD	M	SD	
ZLS group (Celtra Duo)	5.21 [a]	1.37	2.85 [a]	0.72	4.03 [a]	1.045	<0.0001*
ZR group (Katana Zirconia STML)	11.75 [b]	0.92	4.55 [b]	1.04	8.15 [b]	0.98	<0.0001*
LD group (IPS e-max CAD)	13.07 [c]	1.49	4.03 [ab]	2.18	8.55 b	1.835	<0.0001*
Total	10.01	1.26	3.81	1.32			
***p* value**	< 0.0001*		0.03*		<0.0001*		

M: mean; SD: standard deviation; *Significant difference as p <0.05; same superscript letters in the same column refer to insignificant difference as p > 0.05; different superscript letters in the same column refer to significant difference as p < 0.05.

Translucency parameter *(TP)*

The means and standard deviations of translucency parameter (***TP***) results for tested CAD-CAM material groups as a function of staining from baseline are presented in table 4 and translucency parameter change (**Δ*TP***) results for tested CAD-CAM material groups are presented in table 5.

As demonstrated in table 4, regarding the coffee immersed subgroup, the comparison between baseline ***TP*** mean value and after immersion ***TP*** mean value was done using Paired t-test revealed a significant decrease in ***TP*** mean value of ZLS and ZR groups ($p < 0.05$), while the insignificant decrease in ***TP*** mean value of the LD group ($p > 0.05$). On the contrary, regarding distilled water immersed subgroup, there was an insignificant decrease in ***TP*** mean value for tested CAD-CAM material groups ($p > 0.05$).

Comparison between different CAD-CAM material groups was done using One-way ANOVA test revealed a significant difference between baseline ***TP*** mean value and after immersion ***TP*** mean value. Tukey`s post hoc test for multiple comparison revealed that the baseline ***TP*** mean value of the ZLS group was significantly the highest ($p < 0.05$), while an insignificant difference was found between the ZR and LD groups ($p > 0.05$) with both coffee and distilled water immersed subgroups. Also, a comparison between after immersion ***TP*** mean value revealed a significant difference between tested CAD-CAM material groups ($p < 0.05$) after coffee immersion whereas the ***TP*** mean value of the ZLS group was significantly the highest ($p < 0.05$) followed by the LD group, and the ZR group revealed the least ***TP*** mean value, while after distilled water immersion revealed that ***TP*** mean value of the ZLS group was significantly the highest ($p < 0.05$), while an insignificant difference was found between the ZR and LD groups ($p > 0.05$).

Moreover, a comparison between translucency parameter change (**Δ*TP***) was also performed and revealed significant difference ($p < 0.05$) between tested CAD-CAM material groups after both coffee and water immersion, whereas the LD group showed least statistically significant **Δ*TP*** value and the ZR group showed statistically significant highest **Δ*TP*** value (table 5).

TABLE (4): Translucency parameter (***TP***) values (Mean ±SD) for all groups at baseline and after staining

Variables	**Coffee**					**Distilled water**				
	Baseline *TP*		**After *TP***		***p* value**	**Baseline *TP***		**After *TP***		***p* value**
	M	**SD**	**M**	**SD**		**M**	**SD**	**M**	**SD**	
ZLS group (Celtra Duo)	13.3 [a]	0.5	12.1 [a]	0.8	0.004*	14.3 [a]	0.6	13.6 [a]	2.2	0.32
ZR group (Katana Zirconia STML)	10. 6 [b]	1.03	7.3 [b]	1.1	0.001*	11.3 [b]	2.2	9.95 [b]	2.02	0.14
LD group (IPS e-max CAD)	10 .6 [b]	0.2	10.1 [c]	1.5	0.28	10.7 [b]	0.2	10.4 [b]	2	0.62
***p* value**	<0.0001*		<0.0001*			<0.0001*		0.004*		

M: mean; SD: standard deviation; *Significant difference as p <0.05; Same superscript letters in the same column refer to insignificant difference as p > 0.05; Different superscript letters in the same column refer to significant difference as p < 0.05.

TABLE (5): Mean & standard deviation of Translucency parameter change (**Δ*TP***) values for all tested groups as a function of staining solutions:

Variables	Coffee		Distilled water		Total		*p* value
	MD	SD	MD	SD	M	SD	
ZLS group (Celtra Duo)	-1.2 [a]	0.3	-0.7 [a]	0.32	-0.95 [a]	0.31	0.001*
ZR group (Katana Zirconia STML)	-3.3 [b]	0.07	-1.35 [b]	0.17	-2.32 [b]	0.12	< 0.001*
LD group (IPS e-max CAD)	-0.5 [c]	0.2	-0. 3 [c]	0.08	-0.5 [c]	0.14	< 0.001*
***p* value**	< 0.0001*		<0.001*		<0.0001*		

SD: standard deviation; MD: mean difference; *Significant difference as p <0.05; Same superscript letters in the same column refer to insignificant difference as p > 0.05; Different superscript letters in the same column refer to significant difference as p < 0.05.

DISCUSSION

Depending on the results of this study, the color and translucency parameters of tested monolithic CAD-CAM material groups were significantly influenced by immersion in staining solutions, so the null hypothesis was rejected.

The rapid development of ceramic materials together with fabrication technology makes innovative use of tooth-colored dental materials exceedingly popular in esthetic dentistry with capability of restoring natural appearance, biocompatibility, chemical inertness and being friendly with opposing dentition(27).

An accurate understanding of physical, mechanical as well as optical properties is crucial to the success of esthetic restorative materials. This will create not only naturally appearing restorations but predict the longevity of esthetic outcome of these restorations in oral environment variations such as thermal fluctuations, humidity, nutrition type and smoking habits(28).

In the present study, zirconia-reinforced lithium silicate (ZLS), 4 mol% yttria-stabilized tetragonal zirconia polycrystals (4Y-TZP) in addition to lithium disilicate (LD) were chosen to evaluate the alterations in the color and translucency after consumption of common beverages (coffee and distilled water). The immersion time was 4 weeks which equivalent to 2.5 years of clinical aging(29).

This study followed the manufacturer's recommendations regarding sample thickness, surface polishing protocols, and firing steps. Polishing of tested ceramic materials was performed as an alternative to glazing as suggested by many studies(30,31,32) after the performance of any clinical occlusal adjustments by dentists which could increase surface roughness affecting color and translucency of CAD-CAM ceramic restorations(33), thus accurate polishing procedures were claimed to create smooth ceramic surfaces similar to glazed surfaces(31,32). Several studies(34-36) stated that the use of diamond tips and abrasive rubber might also enhance clinically accepted smoothness.

The present study was performed in agreement with earlier studies that utilized spectrophotometry and the CIE *L*a*b** coordinate system, which is a commonly used method for analysis of color and translucency parameters for dental purposes because of its repeatability, sensitivity, and objectivity[37,38]. The authors in previous studies[25,39,40] have reported that **ΔE** values ranging from 1 to 3 are visible perceptible to the naked eye while **ΔE** values above 3.3 are considered clinically unacceptable.

In the current study, the most significant color change (**ΔE**) after staining procedure was observed for the LD group followed by the ZR group without a significant difference between them. This may be attributed to the higher susceptibility of lithium disilicate glass ceramic to water-assisted slow crack growth (stress-corrosion) leading to the dissolution of Si-O-Si glass network in a wet environment through the role of H_3O+ and OH- ions and the H_2O molecules by fragmentation the silica molecules (Si-O-Si) and selective leaching of alkaline ions[41,42]; in combination with the elements' loss such as Na, K, Si, Al, and Zr from the ceramic restoration[42]. These mechanisms appear to result in surface degradation for LD group[43], whereas for the ZR group, it may be attributed to low temperature degradation (LTD) which in presence of water result in *t-m* phase transformation accompanied with micro-cracks formation in subsurface and particle displacement allowing staining solution to penetrate deeper in the material[44,45]. On the other side, the ZLS group showed the least color change (**ΔE**) after immersion in different staining solutions due to its fine rod-like small crystalline particles with homogenous structure[46].

The obtained results were in agreement with Alp et al[47] and Eldwakhly et al[22]. However, in disagreement with those of Pîrvulescu et al[48]. Regarding immersion solutions, the most significant color change (**ΔE**) occurred after immersion in coffee than distilled water. This was in accordance with a study by Kanat- Ertürk[21], who stated that staining beverages such as coffee and tea had an adverse impact on the color of the ceramic restorations. The staining and discoloration caused by coffee could be attributed to 22 types of acids including acetic acid, citric acid, malic acid and other molecular weight acids[49]. Moreover, both adsorption and absorption quality of ceramics together with penetration and absorption of yellow colorants and stains into the ceramic materials[50].

All **ΔE** records of the present study were above 3.3 which is clinically unaccepted, this may be explained by the limitations of this in-vitro study in which staining procedures application affected both surfaces of the tested specimens which is not the real clinical situation where the CAD-CAM material is bonded to a tooth surface and is exposed to staining solutions and light on only one side. The lack of cleaning or brushing of the samples during this study which is crucial factor affecting the staining susceptibility of the tested CAD-CAM materials, whereas rinsing with distilled water and wiping with gauze was done before color measurement. Also, the intermittent nature of real staining in the oral cavity is due to saliva and other fluids will dilute staining media so the staining effect by prolonged immersion may not resemble clinical realities[50].

The lower values recorded in the comparative studies could be attributed to the slightly different fabrication and polishing procedures of the specimens performed in all studies. In addition, the different drying procedures (light or hard wiping of the surfaces) may contribute to these differences. Therefore, more standardized studies with consistent conditions are needed to obtain a valuable comparison.

A potential translucency change (***ΔTP***) of monolithic CAD-CAM materials after immersion in different common beverages also was intended to be evaluated. The translucency parameter ***(TP)*** is strongly dependent on the microstructure, chemical composition, properties of polycrystalline ceramics such as the crystalline content, particle size, homogeneity, refractive index and porosity of ceramic materials determining its optical properties[51] and amount of light passage through the material giving the restoration a real life appearance[52]. The difference in the color of a uniform thickness of the material of when evaluated against white and black backgrounds[53] detects the translucency parameter ***(TP)***. The glass will be described as transparent when the crystals' size is less than the visible light wavelength (400 to 700 nm); and opaque when scattering and diffuse reflection of light occurs[54-57].

In the present study, the baseline ***TP*** value of the ZLS group was higher than that of the LD and ZR groups, which is in accordance with that of Awad et al [15] and Sen and Us [9] studies. This transparency difference was attributed to the fact that the lithium disilicate crystals in the lithium disilicate were 4 to 8 times larger than those in the zirconium-reinforced lithium silicate[9,15]. As a result of this, higher ***TP*** values due to the high glass content resulting from smaller crystals dispersed in the zirconia-reinforced lithium silicate glassy matrix of the ceramic[15]. It was supposed that differences in baseline ***TP*** values are due to the grain size, crystal content, and microstructural differences in the materials.

In the present study, the recorded ***TP*** values were statistically significant higher at baseline than after staining for tested CAD-CAM material groups. After coffee immersion, there was a significant decrease in ***TP*** values of the ZLS and ZR groups and an insignificant decrease in the LD group. On the other hand, after distilled water immersion, there was an insignificant decrease in ***TP*** values for tested CAD-CAM material groups.

The findings of the present study were disagreed with that of Hayran and Sarıkaya[58]. The possible explanation to this difference in ***TP*** values after staining may be due to post-staining surface cleaning procedures before color measurement. Moreover, it is believed that this reduced translucency might be due to the increased wettability resulting from the roughness of the ceramics caused by the acidic effects of cola, coffee, and black tea[58].

To the authors' knowledge, there is no data about the ***TP*** of 4 mol% yttria-stabilized tetragonal zirconia polycrystals (4Y-TZP) after immersion in different staining solutions.

Regarding translucency parameter change (**Δ*TP***), all tested CAD-CAM material groups showed negative **Δ*TP*** values after immersion in coffee and distilled water indicating increased opacity. The greatest **Δ*TP*** value was recorded for the ZR group (-2.32 ±0.12) which may be attributed to possible LTD occurring at the surface of the material as it contacts with moisture in addition to inhomogeneity of the crystal structure, as mentioned for **Δ*E***, followed by ZLS group (-0.95 ±0.31), and then LD group which recorded the smallest **Δ*TP*** value (-0.5 ±0.14) that may be attributed to the single type of crystal structure[59]. These findings could be also related to the surface finish of ceramic restorations after any clinical occlusal adjustments where polishing was made instead of glazing. spacing between words. Although polishing has been previously investigated and even proved to be an efficient alternative to surface glazing to produce a smooth surface for dental ceramics, it's still a matter of controversy and a subject for research to differentiate between polishing and glazing of dental ceramics and their effect on color stability and final strength[60].

Limitations of the study:

1. The absence of cleaning or brushing of the specimens before color measurement procedures.
2. Staining procedures affected both surfaces of the tested monolithic CAD-CAM materials which is not the real clinical situation where

only one side is exposed to staining solutions and light where the other side is bonded to a tooth surface.

3. The surface finish of tested monolithic CAD-CAM materials was polishing instead of glazing.

CONCLUSIONS

Within the limitation of this study, the following can be drawn:

1. Color and translucency parameters of tested monolithic CAD-CAM ceramic materials were significantly influenced by staining procedure.
2. ZLS group showed significantly least color change after staining procedure than ZR and LD groups.
3. ZLS group showed significantly highest translucency parameter initially (baseline) and after staining procedure than ZR and LD groups.
4. LD group revealed significantly least translucency change after staining procedure than ZR and ZLS groups.

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