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EFFECT OF SURFACE FINISHING PROTOCOLS ON COLOR AND TRANSLUCENCY OF ZIRCONIA REINFORCED LITHIUM SILICATE GLASS-CERAMIC AFTER THERMO-MECHANICAL AGING AND DIFFERENT STAINING SOLUTIONS

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ABSTRACT

Objectives: To investigate the color stability and translucency of zirconia-reinforced lithium silicate glass-ceramic prepared with different surface finishing procedures after thermo-mechanical aging and immersion in different beverages.

Materials and Methods: Sixty samples (1.5 mm thickness) were fabricated from heat-pressed and milled zirconia-reinforced lithium silicate glass-ceramic (ZLS). Forty rectangular plates of celtra duo (CD) (Dentsply sirona) were obtained by sectioning CAD/CAM blocks with diamond saw (IsoMet 4000) under water cooling. Ingots of celtra press (CP) (Dentsply sirona) were lab processed following the manufacturer's instructions, to obtain 20 disk-shaped samples. All samples were finished and divided into three groups (n=20), according to the finishing methods recommended by the manufacturer to obtain additional strength; (CD) polished and fired, (CD) glazed and fired, and (CP) glazed and power fired. The specimens were subjected to aging using chewing simulator integrated with thermocycling protocol. Then, each group was divided into 4 equal subgroups (n = 5) according to exposure to immersion medium (coffee, tea, Coca-Cola and distilled water). Color and translucency parameter (*TP*) were measured according to CIELAB color space using spectrophotometer at baseline and after subjecting the specimens to aging and different staining solutions. Changes in color *(ΔE)* and *TP (ΔTP)* were calculated. The data was analyzed using the analysis of variance (ANOVA) and Tukey's post hoc test ($p < 0.05$). The correlation between *ΔE* and *ΔTP* was studied using Pearson's correlation coefficient.

Results: Aging and staining significantly affected the baseline color and decreased *TP* of all specimens. Generally, regarding the tested groups, CD polished showed the highest *ΔE* and *ΔTP* and no significant difference between CP glazed and CD glazed groups ($p <0.05$). Regarding the staining solutions, coffee had the most significant effect on *ΔE* ($p<0.05$), followed by tea, then Coca-Cola, while water had the least effect. For each staining solution subgroup, polished CD had the highest *ΔE*. No significant differences in *ΔTP* were found between different types of staining solutions. For all the tested ZLS groups and staining solutions after aging, increased *ΔE* was correlated with decreased in translucency.

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Conclusions: Thermo-mechanical aging and staining beverages had a significant effect on color stability and decreased translucency of all surface finished zirconia-reinforced lithium silicate ceramics. Polished celtra duo showed the highest changes in color and translucency parameter compared to the glazed celtra duo and celtra press ZLS ceramics. Coffee had the most significant effect on the color change of all surface finished zirconia-reinforced lithium silicate ceramics.

KEYWORDS: Zirconia-reinforced lithium silicate, Celtra Duo, Celtra Press, glazing, polishing, translucency parameter, color change, aging.

INTRODUCTION

The widely spread esthetics in dental practice has resulted in increased demands for all ceramic restorations. Glass ceramics being kind of such restorations are tooth-colored and metal-free, they exhibit light transmission and scattering properties similar to natural teeth. (1) There are varieties of monolithic glass ceramic materials on the market that have been processed either in laboratories or using computer-aided design/computer-aided manufacturing (CAD / CAM) technology, to increase the range of restoration indications in fixed prosthodontics.(2)

In the lab, heat pressing technique was performed. Glass ceramic ingots are heated and allowed to flow under pressure into a restoration mold which formed by lost wax technique. (3) The obtained restoration by pressing has a low shrinkage, less porosity, and greater strength.(4) In the CAD-CAM system, the ceramic blocks are homogenous and defect-free with improved fracture resistance.(5) The milled restoration is rapid and does not undergo multiple firings.(6)

Since the introduction of lithium disilicate glass ceramics (IPS emax, Ivoclar, Vivadent), they are considered the most popular esthetic restorative materials to be fabricated using either a hot-pressing technique in the laboratory, or the technology of CAD-CAM.(7) The excellent esthetic appearance and high mechanical properties of lithium disilicate glass ceramics had encouraged the continuous development of glass ceramics to improve their properties by refining their crystal structure, which led to the introduction of zirconia reinforced lithium silicate glass-ceramics (ZLS).(8)

ZLS consists of crystalline phase made of lithium silicate crystals and a glassy matrix reinforced with 10% by weight zirconium oxide fillers which act as nucleating agent to interrupt crack propagation. (9) The enhanced translucency, together with proper flexural strength values, makes the material suitable for minimally invasive restorations.(9, 10) The manufacturers claim that the content of zirconia dioxide embedded in ZLS glass ceramics is ten times higher than in other glass ceramics.(11) Celtra Duo (Dentsply, Sirona) is a ZLS CAD/CAM block material made specifically for chairside application with CEREC. Celtra Duo is mainly composed of 58% silica, lithium-metasilicate, disilicate, and phosphate crystals, and 10% zirconia crystals. (11)

The manufacturer provides celtra duo in a fully crystallized state which allow the restoration to be milled and polished without firing before cementation. In order to obtain additional strength, another surface finishing protocol is provided, where the milled restoration can be glazed and fired or polished and fired. (12) Celtra Press (Dentsply, Sirona) is another ZLS in the form of pellet, which can be pressed in dental laboratory for the production of indirect ceramic restorations. (13) The restoration fabricated from Celtra Press ceramic can be directly cemented after pressing and glazing. Though, the manufacturer recommended finishing the restoration by special power firing step which increases ceramic strength to about 500 MPa. (14) With regard to the optical properties, ZLS materials have been improved in translucency, fluorescence and opalescence which provide a natural appearance and the desired esthetics. [10] For both the celtra duo and the celtra press, different shades and degrees of translucency are available to match each clinical case.

However, not only the mechanical and esthetic properties of the ceramic restorations are important for their success and longevity. It is also, important to maintain their color and translucency against oral aging conditions and staining beverages. [15] Aging factors like temperature, nutritional habits, chewing and humidity can cause changes in restoration color and translucency. [16] Furthermore, certain ceramic restorative materials have been proven to change color and translucency when exposed to staining solutions that mimic daily beverage consumption. [17]

Surface finishing, either by polishing or glazing of ceramic restorations, affect their surface texture which plays an important role in color and translucency stability.[18,19] However, data are limited on the influence of the finishing protocols for ZLS materials, whether glazing or polishing combined with firing, on color stability and translucency after aging and immersion in staining beverages.

Therefore, the purpose of this study was to evaluate the effect of artificial aging and different staining solutions on the translucency and color stability of monolithic zirconia reinforced-lithium silicate ceramic material with different finishing procedures. The tested null hypothesis was that the color and translucency of the tested ZLS restorative materials with different surface finishing procedures would not be significantly affected by aging and immersion in different staining solutions.

MATERIALS AND METHODS

High strength glass-ceramic, zirconia-reinforced lithium silicate (ZLS) was used in this study in two forms are listed in table 1. They were Celtra Duo in the form of CAD/CAM blocks for CEREC and inLab machines and Celtra Press ingots which is available to labs for pressing by lost wax technique.

TABLE (1) The ZLS materials tested in this study:

Matrial	Code	Form	Translucency/ shade	Manufacurer
Celtra Duo	CD	CAD blocks	MT/A2	Dentsply Sirona Hanau- Germany
Celtra Press	CP	Ingots	MT/A2	Dentsply Sirona Hanau- Germany

Specimen preparation:

A total of sixty specimens obtained from ZLS material by pressing and milling. The specimens were divided into three groups of 20 discs each (n=20), according to the finishing methods recommended by the manufacturer to obtain additional strength:

Group (1): Celtra duo (CD) polished and fired.

Group (2): Celtra duo (CD) glazed and fired.

Group (3): Celtra press (CP) glazed and power fired.

For celtra duo (CD), CAD/CAM blocks (18×14×12mm) were sectioned to obtain 40 rectangular plates (1.5×14×12mm) using a water-cooled low-speed diamond saw (IsoMet 4000; Buehler, Lake Bluff, USA). A digital caliper was used to confirm the 1.5 mm thickness of all 40 specimens. In order to be cleaned and free of grease, all disc samples were submerged for 10 minutes in an ultrasonic cleaner with distilled water. A single surface of each sample was then finished. Celtra Duo was provided with two finishing pathways after milling to obtain additional strength for the restoration, where the material can be polished and fired, or glazed and fired.

a) Polishing steps of Celtra duo:

Twenty-disc specimens were polished according to the manufacturer's instructions. A coarse rubber wheel was used to remove any irregularities and create a more uniform surface using a lab motor at a speed between 8,000 – 12,000 rpm's with light to medium pressure. The procedure was followed by a medium and then a fine wheel. Then, a fine diamond paste using a soft-medium Robinson brush was done to obtain a shiny surface for each disc specimen.

b) Glazing steps of Celtra duo:

For the other 20 specimens, a considerable amount of Celtra glaze was placed on a mixing palette and diluted with glaze liquid (Dentsply Sirona) to obtain a thinner consistency. A sufficient amount of glaze was applied to the entire single surface of each disc using a clean brush.

Firing of the (CD) samples:

All 40 polished and glazed samples were fired using a porcelain furnace (Programat EP 3000, Ivoclar Vivadent). The Pre-drying and drying steps of the firing program were necessary for glazed samples and skipped for the polished samples. The starting temperature was 500°C (table 2). The disc samples were placed on a firing pad, then on the firing table of the furnace.

Ceramic ingots of celtra press (CP) were lab processed following the manufacturer's instructions, to obtain 20 rectangular shaped samples. A specially designed bisected Teflon mold was machine milled, with a square mold cavity of 14 mm width and 2 cm length, to accommodate a molten wax pattern. The Teflon mold was assembled inside a metal cylinder and secured by a screw key. Cylindrical wax patterns (14×14×20 mm) were constructed using the Teflon mold, sprued and embedded in the ring containing mixed powder/liquid ratio of investment material (Celtra Press, Dentsply sirona) according to the manufacturers 'recommendation. Then, the investment ring was pre-heated at 700◦C for 30 min and transferred to a furnace (Programat EP 3000 Ivoclar vivadent) for pressing. After cooling down to room temperature, the obtained ceramic cylinders were divested and cleaned by air-particle abrasion. They were sectioned to obtain 20 rectangular plates (1.5×14×12mm) mm) using a water-cooled low-speed diamond saw (IsoMet 4000; Buehler, Lake Bluff, USA). The 1.5 mm thickness of each obtained disk was confirmed by a digital caliper. All disks were smoothed, polished, and cleaned in an ultrasonic cleaner with distilled water. A single surface of each sample was then glazed.

Glazing and firing steps of Celtra press (CP):

The obtained 20 disc samples were glazed. A sufficient amount of celtra glaze (Universal stain, Dentsply, Hanau, Germany) was applied to the entire single surface of each disc using a clean brush. The glaze firing cycle is preferred to be conducted with "PowerFire" as recommended by the manufacturer (table 3). PowerFire increases flexural strength of the Celtra Press restoration to its maximum > 500 MPa as claimed by the manufacturer.

Baseline Color and translucency parameter (TP) Assessment

The specimens' color was measured using a reflective spectrophotometer (X-Rite, model

TABLE (2) Firing chart of Celtra Duo Firing Recommendations for the Programat EP 3000

	Standby Temp.	Closing Time	Heating rate	Firing Temp.	Holding time	Vacuum	Long-term cooling	Cooling Temp.
	°C	min	°C/min	°C	min		°C	°C
Glazed	500	3:30	60	820	1:0	Off	750	50
Polished	500	1:00	60	820	1:0	Off	750	50

TABLE (3) PowerFire and Glaze chart of Celtra press Firing Recommendations for the Programat EP 3000

Drying	Closing	Pre-heating	Start Temp.	Heating rate	Final Temp.	Vacuum	Hold time	Cooling
min	min	min	°C	°C/min	°C		min	min
2:00	2:00	2:00	400	55	1^{st}:760 2^{nd}:750	Off	2:00	5:00

RM200QC, Neu-Isenburg, Germany). [20] The aperture size was adjusted to 4 mm and the specimens were placed in the center of the measuring port. A white background (CIE L*= 88.81, a*= -4.98, b*= 6.09) was selected. The spectrophotometer was calibrated before each sample measurement. Three measurements for each specimen were taken and the average was calculated. Measurements were made according to the CIE L*a*b* color space relative to the Commission Internationale de l'Eclairage (CIE) standard illuminant D65 [21], where L* refers to the degree of lightness (0–100), a* to the color coordinate on the red/green axis and b* to the color coordinate on the yellow/blue axis.

For measuring the translucency, the specimens' color was measured using the same spectrophotometer against white (CIE L* = 88.81, a* = −4.98, b* = 6.09) and black (CIE L* = 7.61, a* = 0.45, b* = 2.42) backgrounds relative to the CIE standard illuminant D65.

The translucency parameter *(TP)* values were obtained by calculating the difference in the color of the specimens against black and white backgrounds using the following formula: 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, and (b*) color coordinate on the yellow/blue axis. The subscripts (b) and (w) were color coordinates against black and white backgrounds respectively. [22]

Thermo-mechanical aging:

After the initial color and translucency (baseline) measurements, All 60 specimens were subjected to the thermo-mechanical aging test. The aging test was repeated 37,500 times to clinically simulate the 3 months chewing condition, accompanying thermo cycling. [23]

The thermo-mechanical aging test was done using Robota chewing simulator integrated with thermocycling. The thermocycling protocol was performed at 5°C/55°C with Dwell time: 60 seconds. The simulator device was operated on servo-motor (AD-TECH, Germany) thermodynamically and simulates vertical and horizontal movements simultaneously. The device has four chambers. Each chamber consists of an upper Jackob's chuck as tooth antagonist holder that can be tightened with a screw and a lower plastic sample holder in which the specimen can be fixed. A weight of 5 kg was exerted, which is comparable to 49 N of chewing force.

Staining Protocols

After thermo-mechanical aging, the 20 specimens of each tested group were randomly divided into 4 equal subgroups (n = 5) according to exposure to immersion medium; coffee, tea, Coca-Cola solutions and distilled water.

To prepare coffee solution, 20 gm of coffee (Nescafe Classic, Nestle Egypt) was poured into 1000 ml of boiled distilled water. Tea solution was prepared by pouring 20 gm of tea (Lipton, Egypt) into 1000 ml of boiled distilled water. Each solution was stirred every 5 min for 10 s until cooling down to room temperature, and then filtered through a filter paper.

Coca-Cola solution (Coca-Cola Company, Cairo, Egypt) and distilled water (Health Aqua, Alexandria, Egypt) were also used as the 3rd and 4th immersion medium at room temperature.

Specimens were submerged individually into closed vials containing 5 ml of each immersion medium and stored in an incubator (CBM.Torre Picenardi(CR), Model 431/V, Italy) at 37ºC for 7 days. The solutions were freshened daily to avoid any contamination from yeast or bacteria. The solutions were stirred twice a day to reduce the precipitation of particles in the staining solutions. By the end of the immersion period, specimens were washed with distilled water and wiped with gauze. Color was then re-assessed.

Color (*ΔE*) and translucency(*ΔTP*) changes Assessment:

The color and translucency measurements were performed after aging and immersion in different beverages. The Specimens' color was measured using the same procedure as described in the baseline measurements. Color change (*ΔE*) of each specimen was calculated using the following formula:

ΔE = [(ΔL)2 + (Δa*)2 + (Δb*)2]½* Where: L* = lightness (0-100), a* = (change the color of the axis red/green) and b* = (color variation axis yellow/blue).

*ΔL** = L*after staining – L*baseline,

*Δa** = a*after staining – a*baseline,

*Δb** = b*after staining – b*baseline.

The ΔE values greater than 2.6 were considered perceptible [24], whereas values greater than 5.5 were considered clinically unacceptable color match based on spectrometry measurement. [25]

Differences in the translucency parameter values (*ΔTP*) were calculated using the following formula: *ΔTP = TP (after staining) – TP (baseline)*

Statistical analysis:

The results were investigated using Graph Pad Instat (Graph Pad, Inc.) software for windows. P value < 0.05 was considered statistically significant with the satisfactory power level set at 80% and a 95% confidence level. Continuous variables were expressed as the mean and standard deviation. The data was explored for normality using the Kolmogorov–Smirnov test and the Shapiro–Wilk test, and showed a parametric (normal) distribution. The two-way analysis of variance (ANOVA) was performed to evaluate the effect of each variable (Surface finishing group and staining solution). The one-way ANOVA followed by Tukey's post hoc test was used if ANOVA showed a significant p-value. The correlation between *ΔE* and *ΔTP* was investigated using Pearson's correlation coefficient.

RESULTS

Color change (*ΔE*)

The means and Standard deviations for color change (*ΔE*) results for all surface finished groups as function of staining solutions from baseline and after thermo-mechanical aging are presented in table 4 and graphically drawn in figure 1 and 2.

As demonstrated in table 4 and figure 1, irrespective to staining solutions, it was found that polished CD group in general recorded the highest mean significant *ΔE* value of (5.88±1.31), while glazed CD recorded the lowest statistically significant (p <0.05) mean *ΔE* value (4±1.17) as proven by two way ANOVA (F=17.9, P=<.0001). Pair-wise Tukey's post-hoc test showed non-significant difference between glazed CP and glazed CD groups.

TABLE (4) Color change (ΔE) results (Mean±SD) for all surface finished groups as function of staining solutions from baseline

Variables	*Staining solutions*				*Total*
	Coffee	*Tea*	*Coca-Cola*	*D Water*	
CD Glazed +fired	5.86^{B}a±1.63	3.92^{B}b±1.08	3.48^{B}b±0.45	2.75^{A}b±1.52	4^{B}±1.17
CD Polished +fired	7.18^{A}a±1.08	6.65^{A}ab±2.53	5.44^{A}bc±0.71	4.27^{A}c±0.94	5.88^{A}±1.31
CP Glazed +Power fired	5.42^{B}a±0.58	$4.8\ ^{B}$ab ±1.37	4.58^{AB}ab±1.59	3.74^{A}b±0.89	4.63^{B}±1.11
Total	6.15a±1.1	5.12b±1.66	4.5b±0.91	3.58c±1.11	

Different subscripts indicate significant differences within the same surface finished group subjected to different staining solutions. Different superscripts indicate significant differences between different surface finished groups subjected to the same staining solution.

Concerning to the influence of different staining solutions on *ΔE* in the tested materials with different finishing protocols in general, it was found that coffee had the most significant effect (p<0.05), followed by tea, then Coca-Cola, while water had the least effect on *ΔE* (p<0.05) as revealed by two way ANOVA (F=16.2, P= <0.0001). Pair-wise Tukey's post-hoc test demonstrated non-significant (p>0.05) difference between tea and Coca-Cola immersed subgroups.

As regard to the effect of each staining solution on *ΔE* of the tested ZLS groups (figure 2). By one way analysis of variance (ANOVA), it was found that all groups showed significant *ΔE* with coffee where the highest mean value in polished CD, followed by glazed CD, then glazed CP group. Also, all tested groups showed significant ΔE mean values with tea and Coca-Cola but non-significant *ΔE* mean value with distilled water. In the last three staining solutions, the highest *ΔE* mean value was observed in polished CD, followed by glazed CP, then glazed CD.

Translucency parameter change (ΔTP) values

The means and SDs for translucency parameter change (*ΔTP*) results for all surface finished groups as function of staining solutions from baseline and after thermo-mechanical aging are presented in table 5.

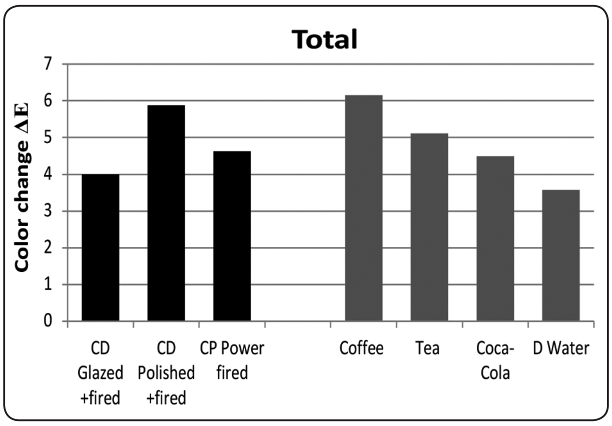

Fig. (1) Histogram of the mean values of color change for surface finish groups totally and total effects of staining solutions from baseline

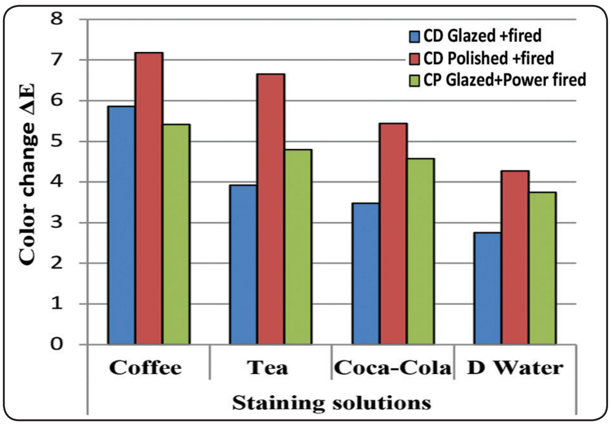

Fig. (2) Histogram of the mean values of color change for all surface finish groups as function of staining solutions from baseline

TABLE (5) Translucency parameter change (ΔTP) results (Mean±SD) for all surface finish groups as function of staining solutions

Variables	*Staining solutions*				*Total*
	Coffee	*Tea*	*Coca-Cola*	*D Water*	
CD Glazed + fired	$-2.67^{A}_{a}\pm1.48$	$-0.66^{C}_{b}\pm0.98$	$-2.94^{A}_{a}\pm2.50$	$-0.80^{B}_{b}\pm0.9$	$-1.77^{B}\pm1.47$
CD Polished + fired	$-1.8^{A}_{a}\pm2.27$	$-3.6^{A}_{a}\pm0.9$	$-3.72^{A}_{a}\pm1.6$	$-4.3^{A}_{a}\pm1.69$	$-3.36^{A}\pm1.6$
CP Glazed +Power fired	$-2.2^{A}_{a}\pm1.78$	$-2^{B}_{a}\pm1.2$	$-1.43^{A}_{a}\pm2.1$	$-0.7^{B}_{a}\pm2.03$	$-1.58^{B}\pm1.8$
Total	$-2.2_{a}\pm1.8$	$-2.1_{a}\pm1.03$	$-2.7_{a}\pm2.09$	$-1.9_{a}\pm1.54$	

Different subscripts indicate significant differences within the same surface finished group subjected to different staining solutions. Different superscripts indicate significant differences between different surface finished groups subjected to the same staining solution.

In general, the translucency parameter demonstrated significantly decreased mean values after aging and staining. Regardless to staining solutions, it was found that polished CD group in overall recorded the highest statistically significant *ΔTP* mean value ($p < 0.05$), while glazed CP group recorded the lowest statistically significant *ΔTP* mean value ($p<0.05$) as proven by two way ANOVA test ($F=10.14$, $P=0.0001$). Pair-wise Tukey's post-hoc showed non-significant difference between glazed CD and glazed CP groups.

Concerning to the influence of different staining solutions in general, it was found that Coca-Cola recorded highest *ΔTP* mean value followed by coffee then tea, while distilled water recorded the lowest *ΔTP* mean value ($p>0.05$) as demonstrated by two way ANOVA ($F=0.8$, $P= 0.48>0.05$). There were no significant differences in *ΔTP* between the different types of staining solutions.

As regard to the effect of each staining solution on *ΔTP* of the tested ZLS groups. It was found that all groups showed non-significant difference in *ΔTP* mean values with either coffee or Coca-Cola. Whereas, a significant difference was observed in *ΔTP* mean values with either tea or water by one way ANOVA.

In the correlation test, there was a moderate inverse correlation between *ΔTP* and *ΔE* ($r = -0.3917$), representing that with increased *ΔE*; a decreased translucency was observed for all surface finished ZLS materials subjecting to aging and all the immersion solutions in the study (Figure 3).

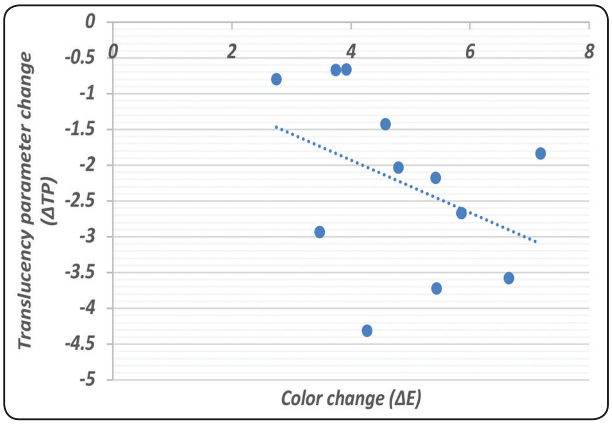

Fig. (3) Linear chart showing the correlation between color change (ΔE) and translucency parameter change (ΔTP)

DISCUSSION

Based on the results of this study, the color and translucency of the tested ZLS restorative materials with different surface finishing procedures would be significantly affected by aging and staining solutions. So, the null hypothesis was rejected.

Advances in all ceramic materials have led to the continuous development of many dental ceramic restorations with improved mechanical and optical properties for their success and longevity. Color stability and translucency are considered as significant clinical optical parameters in the evaluation of all ceramic restorations. [15] The ZLS material consists of homogeneous, fine, rod-like crystalline structure with an average crystal size of about 0.5 mm. Alp et al [37] explained that this smaller crystal particle and homogeneous structure of ZLS compared with lithium disilicate glass ceramic (LDS) had resulted in smaller color change of polished ZLS than polished LDS which have an average crystal size of approximately 1.5 mm.

Certain beverages and oral conditions such as temperature, humidity, and chewing can discolor dental restorations and affect their esthetics.[26,27,28] Moreover, previous studies reported that surface finishing procedures and surface roughness of dental ceramics affected their color stability and translucency. [18, 19]

The in vitro effects of commonly consumed drinks (coffee, tea, Coca-Cola, and water) plus artificial aging on the color and translucency of monolithic zirconia reinforced-lithium silicate ceramic (Celtra) material with different finishing procedures were investigated. In many previous studies evaluating color stability, coffee was the most commonly used staining solution followed by tea and cola. [16,20,29,30] Artificial accelerated aging was done using masticatory simulator which includes thermocycling and mechanical loading. This is in vitro method was used in several studies to simulates the oral environment. [31]

This study followed the manufacturer's recommendations regarding sample thickness, different surface finishing protocols, and firing steps. The selected thickness of all specimens was 1.5 mm which is the minimum thickness of crown restoration using celtra materials. Glazing or polishing is recommended for zirconia-reinforced lithium silicate monolithic restorations to improve esthetics. Firing was performed after finishing and glazing or polishing of celtra ceramic materials to gain additional strength. So, in this study the effect of the firing step on color changes could be considered insignificant as it was applied to all group specimens. [30]

In the current study, the results indicated that the highest mean significant ΔE value occurred in the polished CD group. There was no significant difference between the two glazed groups. The higher color stability of either CD or CP glazed ceramics may be explained by the smoother surfaces obtained from glazing more than mechanical polishing, which result in less stain retention after storage in drinks. [30] The result was in accordance with Yılmaz et al [19] who reported that glazed ceramics presented statistically higher color stability with regard to polished ceramics by using polishing points and polishing paste.

This also explained that immersion in coffee or tea caused highest mean values of color changes in the polished CD group than the other two glazed groups. The values of ΔE for polished CD group were above the 5.5 threshold of being clinically unacceptable, whereas, the values of ΔE of the two glazed groups were perceptible and clinically acceptable. According to Kanat-Ertürk, [30] staining beverages such as tea and coffee had an adverse result on the color stability of the ceramic restorations.

Although surface roughness was not the subject of this study, all groups showed color changes which could be attributed also to the using of chewing simulator integrated with thermocycling as it produced rougher and wavier ceramic surface resulting from wear. [32]

It was also observed, after aging and immersion in Coca-Cola, all groups demonstrated color changes. The composition of Celtra ceramic material contains 5% phosphorous pentoxide and cola drinks are containing the same compound that produces phosphorous acids. This may explained the enhanced the affinity of cola to the celtra material.[20]

The mean *ΔE* values of all groups were perceptible and clinically acceptable, which may be due to the low amount of yellow colorant in composition of cola. [33]

Translucency denotes the passing of light through the material that can give the restoration a lifelike esthetic appearance. [34] In the present study, the recorded TP values after aging and staining were significantly lower than those at baseline in all the tested groups. Alterations in translucency in general could be attributed to changes in surface texture of the material [35] which result from accelerated aging. [36]

In the current study, the greatest *ΔTP* was recorded in the polished CD group and showed a statistically significant difference with the two glazed CD and CP groups. This may be due to the more changes occurred on the surface properties of polished CD in terms of roughness after thermo-mechanical aging compared to the other glazed groups.

Alp et al [37] found that Coffee thermocycling decreased the translucency of ZLS but no significant differences were observed between the translucency of glazed and polished surfaces. This finding was in accordance with the result of this study.

There were no significant differences between different staining solutions. However, Coca-Cola recorded the greatest decrease in translucency, which may be due to the hygroscopic property in phosphorous pentoxide found in the composition of celtra. This compound has a great affinity for cola liquid resulting in changes of the material body texture. [20]

The correlation test indicated a negative relationship between *ΔTP* and *ΔE*. After immersing all the tested groups in staining solutions and aging, the increased in color change corresponded to a decreased translucency. This correlation may explain the color change of ceramic restoration that occurred due to the absorption of stains, water sorption, or a change in surface topography was followed by a change in the light scattering properties of the materials. [20]

The limitations of this in vitro study are that only one thickness was investigated and the samples were stained on both surfaces and not bonded to the tooth structure to mimic the clinical condition. Further studies are needed to consider these limitations.

CONCLUSIONS

Within the limitations of this in vitro study, the following conclusions were drawn:

1. Thermo-mechanical aging and staining beverages had a significant effect on the color of all surface finished zirconia-reinforced lithium silicate ceramics.
2. Aging and staining solutions had a significant decrease in the translucency of zirconia-reinforced lithium silicate ceramics.
3. Polished celtra duo showed the highest changes in color and translucency parameter compared to the glazed celtra duo and celtra press ZLS ceramics.
4. Coffee had the most significant effect on the color change of all surface finished zirconia-reinforced lithium silicate ceramics.

REFERENCES

1. J. R. Kelly and P. Benetti. Ceramic materials in dentistry: historical evolution and current practice. Aust Denl J 2011; 56 (1): 84–96.
2. Spitznagel FA, Boldt J, Gierthmuehlen PC. CAD/CAM ceramic restorative materials for natural teeth. J Dent Res 2108; 97(10):1082-91.
3. Giordano R, McLaren E. Ceramics overview: classification by microstructure and processing method. Compendium 2010; 31(9):682-97.
4. Fasbinder, D.J. Clinical performance of chairside CAD/CAM restorations. J Am Dent Assoc 2006, 137, 22S–31S.
5. Wendler M, Belli R, Petschelt A, et al. Chairside CAD/CAM materials. Part 2: Flexural strength testing. Dent Mater 2017; 33(1):99–109.
6. Ng J, Ruse D, Wyatt C. A comparison of the marginal fit of crowns fabricated with digital and conventional methods. J Prosthet Dent 2014; 112: 555–60.

7. Silva L, Lima E, Miranda R, Favero S, Lohbauer U, Cesar P. Dental ceramics: A review of new materials and processing methods. Braz Oral Res 2017; 31:133-45.

8. Fasbinder DJ. A review of chairside CAD/CAM restorative materials. J Cosmetic Dent 2018; 34(3): 64-74.

9. Elsaka S, Elnaghy A. Mechanical properties of zirconia reinforced lithium silicate glass-ceramic. Dent Mater 2016; 32(7): 908–14.

10. Sen N, Us YO. Mechanical and optical properties of monolithic CAD-CAM restorative materials. J Prosthet Dent. 2018; 119(4):593–9.

11. Celtra Duo® Celtra block for cerec and inlab. DeguDent GmbH, Hanau, Wolfgang, Alemanha: Dentsply Indústria e Comércio Ltda; 2014.

12. Riquieri H, Monteiro J, Viegas D et al. Impact of crystallization firing process on the microstructure and flexural strength of zirconia-reinforced lithium silicate glass-ceramics. Dent Mater 2018; 34(10):1483-91.

13. Wolfart S, Eschbach S, Scherrer S, Kern M. Clinical outcome of three-unit lithium-disilicate glass-ceramic fixed dental prostheses: up to 8 years results. Dent Mater 2009; 25:e63–71.

14. Stawarczyk B, Dinse L, Eichberger M et al. Flexural strength, fracture toughness, three-body wear, and Martens parameters of pressable lithium-X-silicate ceramics. Dent Mater 2020; 36: 420–30.

15. Stawarczyk B, Sener B, Trottmann A, et al: Discoloration of manually fabricated resins and industrially fabricated CAD/CAM blocks versus glass-ceramic: effect of storage media, duration, and subsequent polishing. Dent Mater J 2012; 31:377-83.

16. Palla ES, Kontonasaki E, Kantiranis N, Papadopoulou L, Zorba T, Paraskevopoulos KM, et al. Color stability of lithium disilicate ceramics after aging and immersion in common beverages. J Prosthet Dent 2018; 119: 632-42.

17. Buyukkaplan SU, Özarslan MM, Barutcigil Ç, Arslan M, Barutcigil K, Yoldan EE. Effects of staining liquids and finishing methods on translucency of a hybrid ceramic material having two different translucency levels. J Adv Prosthodont. 2017; 9(5):387–93.

18. Motro P, Kursoglu P, Kazazoglu E. Effects of different surface treatments on stainability of ceramics. J Prosthet Dent 2012; 108: 231-7.

19. Yilmaz C, Korkmaz T, Demirk¨opr¨ul¨u H, et al. Color stability of glazed and polished dental porcelains. J Prosthodont 2008; 17: 20-4.

20. Eldwakhly E, Ahmed DRM, Soliman M, Abbas MM, Badrawy W. Color and translucency stability of novel restorative PRESS/CAM materials. Dent Med Probl 2019; 56(4): 349–56.

21. Johnston WM: Color measurement in dentistry. J Dent 2009; 37Suppl 1: e2-6.

22. Johnston WM, Ma T, Kienle BH. Translucency parameter of colorants for maxillofacial prostheses. Int J Prosthodont 1995; 8(1):79–86.

23. Nawafleh N, Hatamleh M, Elshiyab S and Mack F, Lithium Disilicate Restorations Fatigue Testing Parameters: A Systematic Review. J Prosthodont 2016; 25: 116–26.

24. Bergmann C and Stumpf A. Dental ceramics: Microstructure, properties and degradation. Springer-Verlag Berlin Heidelberg. 2013: p 64.

25. Douglas R, Steinhauer T, and Wee A: Intraoral determination of the tolerance of dentists for perceptibility and acceptability of shade mismatch. J Prosthet Dent 2007; 97: 200-8.

26. Erdemir U, Yildiz E, Eren MM, Ozel S. Surface hardness evaluation of different composite resin materials: Influence of sports and energy drinks immersion after a short-term period. J Appl Oral Sci 2013; 21(2):124–31.

27. Heydecke G, Zhang F, Razzoog ME. In vitro color stability of double-layer veneers after accelerated aging. J Prosthet Dent 2001; 85: 551-7.

28. De-Souza F, Casemiro L, Garcia L, Cruvinel D. Color stability of dental ceramics submitted to artificial accelerated aging after repeated firings. J Prosthet Dent 2009; 101: 13-8.

29. Al Ben Ali A, Kang K, Finkelman MD, Zandparsa R, Hirayama H. The effect of variations in translucency and background on color differences in CAD/CAM lithium disilicate glass ceramics. J Prosthodont 2014; 23:213–20.

30. Kanat-Ertürk B. Color Stability of CAD/CAM Ceramics Prepared with Different Surface Finishing Procedures. J Prosthodont 2020; 29(2):166-72.

31. Güngör MB, Nemli SK, Bal BT, Tamam E, Yılmaz H, Aydın C. Fracture resistance of monolithic and veneered all-ceramic four-unit posterior fixed dental prostheses after artificial aging. J Oral Sci 2019; 61(2): 246-54.

32. Habib SR, Alotaibi A, Al Hazza N, Allam Y, AlGhazi M. Two-body wear behavior of human enamel versus monolithic zirconia, lithium disilicate, ceramometal and composite resin. J Adv Prosthodont. 2019 Feb; 11(1): 23-31.

33. Bagheri R, Burrow MF, Tyas M. Influence of food-simulating solutions and surface finish on susceptibility to staining of aesthetic restorative materials. J Dent 2005; 33: 389-98.

34. Heffernan MJ, Aquilino SA, Diaz-Arnold AM, Haselton DR, Stanford CM,Vargas MA. Relative translucency of six all-ceramic systems. Part II: Core and veneer materials. J Prosthet Dent. 2002; 88(1):10–5.

35. Ferracane JL, Palin WM. Effects of particulate filler systems on the properties and performance of dental polymer composites. In:Vallittu P, ed. Non-Metallic Biomaterials for Tooth Repair and Replacement.Cambridge, UK: Woodhead Publishing 2013: 294–335.

36. Kurt M, Turhan Bal B. Effects of accelerated artificial aging on the translucency and color stability of monolithic ceramics with different surface treatments. J Prosthet Dent 2019; 121(4):712.e1-.e8.

37. Alp G, Subasi MG, Johnston WM, Yilmaz B. Effect of surface treatments and coffee thermocycling on the color and translucency of CAD-CAM monolithic glass-ceramic. J Prosthet Dent 2018; 120: 263-8.