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Translucency of New Lithium Disilicate Ceramics After Ageing and Immersion in Coffee Solution

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Abstract

Aim To evaluate translucency parameters of different lithium disilicate glass-ceramic materials after thermocycling and coffee staining.
Material and method Three different rectangular-shaped specimens were prepared using three distinct 1.2 mm thick lithium disilicate glass ceramics (IPS e.max CAD, LD_C; Cerec Tessera, LD_A; Initial LiSi Block, LD_F) by using a precision cutting device. All specimens were standardised by polishing with abrasive silicone paper. Thereafter, the specimens were subjected to thermal cycling (5000 cycle, 5-55 C, 30 sn dwell time) and then immersed in coffee solution for 30 days. The colour coordinates of each sample before and after ageing were recorded, and the relative translucency parameter (RTP) was calculated using the CIEDE 2000 formula. The results were then subjected to statistical analysis by one-way ANOVA and a post hoc Tukey test.
Results There was a significant difference between the groups in terms of RTP both before and after staining ($p<0.001$).The LD_A group had the highest RTP value. Before staining, LD_C showed the lowest RTP value, while there was no significant difference between LD_C and LD_F after staining ($p=0.781$) These findings may guide the selection of materials for esthetically demanding restorations.
Conclusion LD_A had the highest RTP value regardless of staining, but only LD_F had an RTP change below the clinically acceptable threshold after coffee staining ($\Delta RTP=2.10$).

Keywords Coffee staining, Dentistry, Lithium disilicate, Thermocycling, Translucency

Introduction

Glass-ceramics have become a desirable material in dentistry due to a number of advantageous properties, including biocompatibility, chemical inertness, high mechanical properties, superior esthetics, optical properties and machinability (1). The initial formulations of glass ceramics principally comprised feldspathic reinforcements (2). Subsequently lithium silicate-based glass-ceramics became increasingly popular, and as time went by, numerous lithium silicate-based glass-ceramics were introduced to the market by various manufacturers (3).

Lithium disilicate glass ceramics have become a material of choice for many dental practitioners, frequently preferred for dental prosthetic rehabilitation (3-5). They have a wide range of clinical indications due to their excellent biocompatibility, advanced esthetics and mechanical properties that outperform most of their competitors among glass ceramics (3, 4, 6).

Lithium metasilicate glass-ceramic blocks are made and delivered to dentists in a partially crystallised state. The material is a glassy matrix of lithium metasilicate crystals, suitable for machining. Lithium metasilicate glass-ceramics are heated to become lithium disilicate. This makes them more rigid and hard, but not suitable to be worked by a machine (7).

Lithium aluminosilicates (LAS) are a type of glass ceramic with low expansion and aesthetic qualities. The potential use of LAS glass-ceramics as materials for dental restorations is limited due to their relatively low mechanical properties. Research has been conducted to enhance the mechanical properties of LAS glass while maintaining its favourable characteristics.(8)

Lithium disilicate, initially IPS Empress 2, became IPS e.max, a dominant material in CAD/CAM dentistry (9). The material displays a purple hue during its intermediate state, which is attributed to the stains used for identification. This material needs a specific time and temperature in its metasilicate state to reach a fully crystallised state (10). Many new lithium disilicate glass ceramics are on the market (3). These include new lithium disilicate CAD/CAM blocks (Tessera, Dentsply Sirona) introduced in 2021. The new material is aluminium silicate crystals, Virgilite, in a glassy zirconia matrix. The ceramic's exceptional fast-firing feature is its defining advantage. Tessera is a composite of lithium disilicate and virgilite crystals, embedded in zirconia glass. Virgilite enhances lithium disilicate's mechanical strength (11).

The crystallisation heat treatment is key in making glass-ceramic dental prostheses comprising lithium disilicate. Crystallisation reduces brittleness and relieves stresses caused by machining. This improves the material's strength and fracture toughness while adjusting the optical and aesthetic aspects (12). Simplifying the clinical steps allows manufacturers to produce fully crystallised, millable and cementable blocks (13). The new blocks save costs and time. Fully crystallised lithium disilicate

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glass ceramic does not require firing and can be delivered after polishing (14).

While there are numerous studies investigating the mechanical, wear-resistance, and optical properties of fully crystallised lithium disilicate glass-ceramics, there is a paucity of literature examining their translucency properties. Therefore, the present study aimed to evaluate and compare fully crystallized lithium disilicate with nano-lithium disilicate and a commonly used lithium disilicate glass-ceramic material in terms of translucency after thermocycling and stain susceptibility. Although many studies explore the optical properties of lithium disilicate ceramics, their performance after prolonged coffee exposure remains underexplored.

The null hypothesis was that the material type would not affect the translucency parameter after thermocycling and staining.

Material and Methods

Three different A2-shaded lithium disilicate ceramic blocks were tested, namely advanced lithium disilicate (LD_A; CEREC Tessera, Dentsply Sirona), lithium disilicate (LD_C; IPS e.max CAD, Ivoclar Vivadent), and fully crystallized lithium disilicate (LD_F; Initial LiSi Block, GC Corp) (n=10). The A2 shade was selected due to its common use in clinical practice. Specimens with a thickness of 1.3 mm were prepared using a diamond disc under constant water-cooling on a precision cutting device (Microcut 201; Metkon Instruments Inc.). Subsequently, each specimen was polished on 600-, 800-, and 1,000-grit abrasive silicone papers, respectively, in order to obtain a standard thickness. The thickness of the specimens was verified with the use of a digital caliper (Absolute Digimatic; Mitutoyo).

The glazing process of the LDS specimens was performed using a powder-liquid glaze (e.max Ceram Glaze Powder/Glaze and Paint Liquid; Ivoclar Vivadent), whereas for the LD_A specimens, a spray glaze was applied in a uniform coating (Universal Spray Glaze; Dentsply Sirona). The glaze was applied to a single surface of the specimens, resulting in a final thickness of 1.2 mm, in accordance with the International Organization for Standardization (ISO) standard 6872:2015. To ensure reliability, the thickness of the specimens was subsequently measured with a digital caliper. To calculate the relative translucency values of the specimens, colour coordinates (L^*, a^* and b^*) were recorded on black ($L^*=16.73$, $a^*=-2.53$, $b^*=2.13$) and white backgrounds ($L^*=71.1$, $a^*=-3.86$, $b^*=-2.7$) using a spectrophotometer (VITA Easyshade V; VITA Zahnfabrik). The observations were conducted at 2-degree angles with the D65 illumination curve. Each measurement was repeated on three times and the mean values were calculated. The spectrophotometer was calibrated every 3 measurements.

The samples were subjected to thermocycling (Thermocycler; SD Mechatronic, Feldkirchen-Westerham, Germany) in accordance with the methodology described in previous studies; 5,000 cycles, 5-55 °C, 60 s holding time. Subsequently, the specimens were immersed in a coffee solution for a period of 30 days. The coffee solution was prepared by combining 3 g of coffee with 300 g of boiled distilled water. The coffee solution was renewed every 12 hours. Prior to repeating the measurements for relative translucency parameter (RTP), each specimen was brushed with toothpaste (Sensodyne, GlaxoSmithKline) for 30 seconds and cleaned in an ultrasonic cleaner. Once the specimens had reached a state of complete dryness, the colour coordinate measurements were repeated in accordance with the aforementioned methodology.

RTP calculated according to the CIEDE2000 equation:

$$\boldsymbol{RTP_{CIEDE2000}} = \left[\left(\frac{L_B - L_W}{K_L S_L}\right)^2 + \left(\frac{C_B - C_W}{K_C S_C}\right)^2 + \left(\frac{H_B - H_W}{K_H S_H}\right)^2 + R_T\left(\frac{C_B - C_W}{K_C S_C}\right)\left(\frac{H_B - H_W}{K_H S_H}\right)\right]^{0.5}$$

B: black background,

W: white back

L: Lightness

C: Chroma

H: Hue

All K values in the equation are set as 1. RTP values was assessed according to the thresholds of clinical perceptibility (RTP: 0.62 units) and acceptability (RTP: 2.62 units) thresholds.

Statistical analysis of the data was performed using a software programme (IBM SPSS statistics, v25; IBM Corp). The data obtained were assessed for normal distribution and homogeneity using the Shapiro-Wilk test and Levene's test. Normally distributed and homogeneous data were then statistically analysed by one-way ANOVA test and multiple comparisons were performed by post-hoc Tukey test ($\alpha = 0.05$).

Results

Statistical analysis test revealed that different lithium disilicate glass-seramic material did affect RTP values ($p < 0.001$) before staining. There were significant differences between 3 groups. Table 3 summarizes the descriptive statistics of RTP values. LD_A had the highest ΔRTP values after thermocycling, followed by LD_F (21.82). LD_C had the lowest ΔRTP (20.22), showed significant differences compared to LD_F and LD_A. These findings indicate that LD_A exhibits superior translucency, potentially due to its smaller crystal size and unique composition.

Significant differences between the groups were also observed in the post-staining measurements ($p< 0.001$). LD_A had the highest RTP value ($p< 0.001$), while no significant difference was observed between LD_C and LD_F ($p=0.781$).

Table 1: Composition and Manufacturer of Materials

MATERIAL	CHEMICAL COMPOSITION	MANUFACTURER
LD_C	57–80 % SiO_2, 11%–19% Li_2O, 0%– 13% K_2O, 0%–11% P_2O_5, 0%–8% ZrO_2, 0%–8% ZnO Coloring oxides: 0%–8%	Ivoclar Vivadent, Schaan
LD_A	$Li_2Si_2O_5$: 90% Li_3PO_4: 5% $Li_{0.5}Al_{0.5}Si_{2.5}O_6$ (virgilite): 5%	Dentsply Sirona, Charlotte
LD_F	81% SiO_2, 8.1% P_2O_5, 5.9% K_2O, 3.8% Al_2O_3, 0.5% TiO_2, 0.6% CeO_2	GC Corp

Table 2: Crystallization and Glaze Firing Parameters

		Stand By Temperature	Pre-Drying Time:	Closing Time	Pre-Heating Time	Heating Rate	Firing Temperature	Holding Time	Vacuum On/Off
LD_A	Crystallization	NR	NR	NR	NR	NR	NR	NR	NR
	Glaze Firing	400°C	2 min	2 min	2 min	55°C/min	760°C	2 min	-
LD_C	Crystallization	403°C	-	6 min	-	60°C/min	770°C/850°C	10 min	770/850°C
	Glaze Firing	403°C	-	6 min	-	60°C/min	725°C (Holding)	1 min	450/724°C

Table 3: Mean ± Standard deviation and 95% Confidence Interval (CI) RTP values of materials

	BEFORE STAINING		AFTER STAINING	
STUDY GROUPS	Mean ± Standard Deviation	95% CI Lower-Upper Bound	Mean ± Standard Deviation	95% CI Lower-Upper Bound
LD_C	20.22± 0.93	19.43 - 20.99	23.73± 0.74	23.20-24.26
LD_A	23.07± 0.76	22.43 – 23.70	26.34± 0.51	25.97-26.71
LD-F	21.82± 0.67	21.25-22.38	23.92± 0.58	23.50-24.33

Discussion

Translucency, defined as the amount of light transmitted or diffused from the substrate, is a substantial optical property for dental ceramics (15). This results in a more natural appearance and also allows for the assessment of the extent to which background colour of an object affects the final hue or colour of the prosthesis. The translucency of dental materials under various conditions is therefore considered an important parameter.

Pigments can be applied to dental ceramics to acquire a high translucency look but this can be lost after several months of exposure to different substances such as toothpaste or tea and coffee (15). Coffee, which is the choice of staining solution in this study, is known to have an impact on the translucency of dental materials (16-18). In a study investigating the changes in translucency of materials stained with tea, cola, ginger, and coffee, it was found that the solution causing the greatest change in translucency was coffee (19). Another study using coffee, cola and tea as staining solutions also concluded that exposure to coffee had a greater impact on translucency (20). The higher colour variation caused by coffee compared to tea and cola has been explained by staining due to a yellow pigment with different polarities (21).

The translucency of dental ceramics is affected by various factors, including the number of firing cycles, hydrothermal aging, thickness, chemical composition, and the size and morphology of the crystals. Especially dimension, shape and the percentage of crystal fraction have a substantial impact (22). While there are studies in literature which show that translucency increases as the firing cycle number increases in research carried out with glass ceramics (23, 24), there are also researchers who have concluded that translucency decreases as the firing number increases (25). In different studies, the decrease in translucency after repeated firings was attributed to changes in crystal size and/or orientation (25-27).

Number of crystals in the ceramic composition is a major factor that affects the translucency of ceramics. It has been stated that as the number of crystals in a glass matrix increases, the translucency of the ceramic decreases (28, 29). Moreover, higher translucency is found in lithium silicate-based glass ceramics with smaller crystals and when similar refractive indices exist between glass and crystalline phases. Lithium silicate-based glass ceramics are available in a variety of colour translucencies and shades. The colour shades are adjusted during the manufacturing stage by integrating pigment oxides into the glass matrix, while the translucency is controlled by nanoscaling of the crystals. (30)

Considering the three different lithium-disilicate used in this study, Lisi (0.3µm) had the smallest crystals, followed by Tessera (0.5µm and virgilite crystals of 0.2-0.3 µm) and E-max (1-1.5µm). (3) When examining the relationship between crystal size and translucency, as claimed in the previous paragraph, E-max, which is stated to have the lowest translucency in this study, has the largest crystal sizes. However, Lisi, which has the smallest crystal sizes has lower translucency than Tessera, which contradicts the previous paragraph.

In this presented study, the null hypothesis of the study was rejected since different lithium disilicate materials were found to have different RTP values. An examination of previous studies in the literature reveals that comparisons of E-max and Tessera in terms of translucency have produced differing results. While no statistically significant difference was found in one of the studies (28), it was concluded that there was a statistically difference in the two others, and both of them stated that E-max was more translucent than Tessera. One of the studies in question, the researchers claimed that the higher translucency of E-max is due to the increase in translucency as the crystal size of the materials grows (20, 31). These findings do not support the data obtained in the current study.

In another study focusing on the difference between E-max and Lisi, it was stated that there was a statistically significant difference between these two materials in terms of light transmittance at 1.50 mm thickness, It has been suggested by researchers that the possible reason for this difference is that LiSi had dense crystals approximately 1 to 1.5 µm in size, whereas E-max has long, rod-like crystals about 3 to 4 µm in size. Additionally, LiSi surfaces exhibit more porosity and a rougher surface compared to the E-max group. (32) Findings of the present study do not support the results of the study referenced above. Differences among findings could be attributed to variations in methodology.

This current study has several limitations. One of these limitations was being an in-vitro study which means that the study was conducted in an environment different from real life conditions. Another limitation is that the study was carried out using discs of the same shape instead of dental crown forms, and all the discs had the same thickness, meaning that variations in thickness were not evaluated. The use of only one measuring device in the study can also be considered as a limitation. As an in vitro study, the findings may not fully represent clinical conditions, such as the effects of mixed beverages or long-term oral environment exposure. Future studies could explore these materials under more complex oral conditions, including varying pH levels and abrasive forces.

Conclusion

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

1. Different lithium disilicate glass ceramics show different RTP values.
2. LD_A exhibited the highest RTP value regardless of coffee staining.
3. LD_F had an RTP change below the clinically acceptable threshold after coffee staining (ΔRTP=2.10).

Declarations

Author Contributions: *Conception/Design of Study- A.A.D.T., M.D.; Data Acquisition- A.A.D.T., M.D.; Data Analysis/Interpretation- A.A.D.T., M.D., E.K.; Drafting Manuscript- A.A.D.T., E.K.; Critical Revision of Manuscript- A.A.D.T.; Final Approval and Accountability- A.A.D.T., M.D.; Material and Technical Support- M.D.; Supervision- A.A.D.T.*

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