Original Article

Translucency and color stability of advanced lithium disilicate ceramic material: An *in vitro* study

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Abstract

Context: The dental restoration can closely resemble the tooth structure around it when the color and translucency are the right combination. Color stability and translucency are critical factors influencing the optical blending of restorations with natural dentition, enhancing their overall esthetics.

Aim: This study aimed to compare the translucency and color stability of advanced lithium disilicate (ALD) ceramic material in comparison to conventional lithium disilicate ceramics.

Materials and Methods: Eighty specimens, measuring 12 mm × 14 mm, were fabricated from two types of ceramics: lithium disilicate glass-ceramic (LDS) and ALD. Two types were used for each material, High translucency (HT) and Medium translucency (MT). The samples were divided into 4 groups ($n = 20$) based on the material and the translucency. Each group was subsequently separated into two additional subgroups based on thickness, specifically 0.5 and 1.0 mm ($n = 10$). The translucency parameter (TP) was determined by employing a spectrophotometer to measure color on both white and black backgrounds. The experiment involved subjecting samples with a thickness of 1 mm to a total of 10,000 thermocycles, followed by immersing them in coffee for 12 days. Color change (ΔE) was calculated using CIELAB color coordinates at the initial state, as well as after the application of TC and immersion.

Results: A significant difference in TP existed between LDS (18.16 ± 2.149) and ALD (15.115 ± 0.877) for 0.5 mm thickness ($P < 0.05$). Color change for both materials was perceivable above ΔE 1.2. Only ALD MT showed ΔE 3.03 above the acceptability threshold.

Conclusion: The translucency of LDS was more than ALD at a thickness of 0.5 mm. In both materials, the color change was above the perceptibility threshold but within the clinical acceptable limits except for ALD MT which had a color change above the clinical acceptability threshold.

Keywords: Color change; computer-aided design and computer-aided manufacturing; dental ceramic; lithium disilicate

INTRODUCTION

Ceramic restorations have grown in popularity because of their superior esthetics and durability over other restorative materials.[1] A restoration's cosmetic appearance should be consistent with the surrounding dental tissues. This requires optical properties to be close to those of natural teeth.[2]

Because they have an impact on the aesthetic outcome of ceramic restorations, optical characteristics including color stability and translucency of restoration are significant factors.[3] The restoration can closely resemble the tooth structure around it when the color and translucency are the right combination.[4,5] The criterion known as translucency parameter (TP) is commonly employed in the evaluation of dental materials to determine their degree of translucency. The measurement is acquired through a spectrophotometer,

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which evaluates the difference in color of a substance against a background of white and black colours.[6] The choice of materials must take translucency into consideration because it is one of the main esthetic controls. There are variations in the composition, microstructure, crystalline content, and phases of all ceramic systems which have an impact on the optical properties of these systems. Greater opacity frequently happens when the amount of crystal content is raised to attain higher strength.[5,7]

The lithium disilicate (LDS) material, which possesses a glassy-crystalline structure, was first presented to the field of dentistry in 1998 by Ivoclar Vivadent. Since its introduction, it has gained significant popularity and is widely regarded as one of the most often used all-ceramic materials in the field. Later, the company produced IPS e.max® CAD for computer-aided design and computer-aided manufacturing (CAD-CAM).[8] This material is offered as partially crystallized blocks of lithium metasilicate, which are strong and rigid enough to mill easily using a CAD-CAM system. The microstructure of these blocks consists of platelet-shaped crystals with 0.1–1.5 grain sizes. The milled restorations are then put through a crystallization process. The ultimate tensile strength of the resulting crystalline material is measured to be 360 MPa, whereas its fracture toughness is determined to be 2.25 MPa. This material consists of a glassy matrix, in which 65%–70% of its composition is comprised fine-grain LDS crystals, specifically Li2Si2O5.[8,9]

Several studies have investigated the color stability and translucency of LDS restorations and reported excellent results. The material has proven to be resistant to discoloration. Moreover, the translucency of the material is suitable for cases that require thin esthetic restorations with high translucency as well as cases that require full coverage restorations to mask mild discoloration of the tooth.[10-15]

In the dental industry, a novel glass-ceramic material known as Cerec Tessera (manufactured by Dentsply Sirona, Germany) has been recently introduced. This advanced material is specifically designed for chairside CAD-CAM. This material can undergo firing in 4 min and 30 s. The material contains virgilite crystals (LiAlSi2O6) in addition to lithium disilicate (Li2Si2O5). According to manufacturer standards, this material's biaxial strength exceeds 700 MPa. This material is a new product with very few studies available regarding its color stability and translucency.[16] The current study aimed to compare a novel, advanced lithium disilicate ceramic to conventional lithium disilicate ceramics and examine its color stability and translucency. The null hypothesis stated that no difference exists between advanced lithium disilicate and lithium disilicate all-ceramic materials in terms of translucency and color stability.

MATERIALS AND METHODS

The translucency and color stability of two materials, namely lithium disilicate glass-ceramic (LDS) IPS e.max® CAD blocks (Ivoclar Vivadent, Liechtenstein, Germany), and advanced lithium disilicate (ALD) CAD blocks, namely the CEREC Tessera^{TE} (Dentsply Sirona) were investigated in the current study. Two levels of translucency, high translucency (HT) and medium translucency (MT), were selected from both materials, with shade A2. The samples were manufactured with two distinct thicknesses, specifically 0.5 and 1.0 mm. These samples were then evenly dispersed among eight separate groups, as depicted in Figure 1.

The sample size was selected accordingly at alpha 0.05 with effect size 0.55 and power of 0.83. The total sample size should be at least 80 (10 in each group).

Sample preparation

The blocks were sectioned into rectangular samples of 12 mm × 14 mm and two thicknesses (0.5 and 1.0 mm) using a diamond saw (Isomet 1000, Buehler, Midwest USA). Polishing was conducted using a polishing machine (Jean Wirtz, Germany) utilizing silicon carbide paper with grit

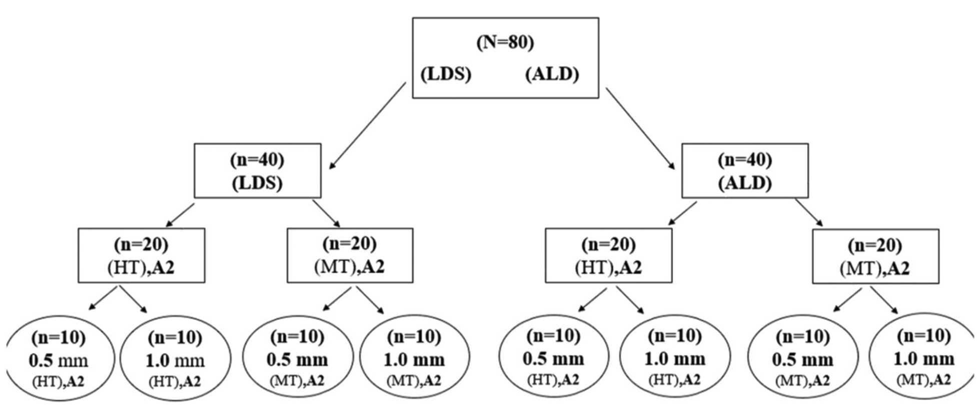

Figure 1: Sample distribution according to the materials, level of translucency and thickness

sizes of 600, 800, 1000, and 1200. The polishing process was performed under a continuous flow of water at a rotational speed of 300 revolutions per minute.

The specimens in a partly crystallized state (blue state) of LDS were initially subjected to crystallization in a porcelain furnace, as per the guidelines provided by the manufacturer. Then, for all samples (LDS and ALD), a small amount of glaze pastes and glaze liquid (Ivoclar Vivadent, Liechtenstein) (Dentsply sirona) were mixed thoroughly on a plastic slab, until it reached a creamy and stringy consistency. Subsequently, the mixture was administered onto the surface using a brush to get a consistent thickness. The application process commenced from the center and progressed toward the outside surface of the specimen, ensuring the attainment of a single layer of coating without any excessive accumulation. The specimens were positioned onto the firing tray and afterward inserted into the Programat CS furnace (Ivoclar Vivadent, Schaan, Liechtenstein). The firing protocol was implemented by utilizing fire cycles and parameter configurations as outlined in the manufacturer's specifications.

Translucency parameter measurements

Following the completion of the firing cycle, the specimens were let to cool at ambient temperature to obtain baseline data. In this stage, the baseline color of each specimen was measured by a spectrophotometer device (LabScan XE, Spectrophotometer, HunterLab, USA).

The CIE L^*, a^*, and b^* coordinates were acquired by employing a light source illumination (D65) that replicates typical daylight conditions. The spectrophotometer apparatus was subjected to calibration processes against white (L^* 88.81, a^* −4.98, and b^* 6.09) and black (L^* 7.61, a^* 0.45, and b^* 2.42) backgrounds.

The measurements were replicated thrice, and the average of the measurements was taken into account. The determination of T*P* values was achieved by employing the subsequent formula:

$$TP = ([Lb - Lw]2 + [ab - aw]2 + [bb - bw]2)\ ½$$ [17]

The variable L^* denotes the attribute of lightness or the black/white dimension of a color, a^* signifies the red-green axis, and b^* represents the yellow-blue axis. The color coordinates B and W are used to express color values in relation to the black and white background.

Colour change measurements

The specimens, which had a thickness of 1.0 mm, were subjected to artificial aging by the use of a thermocycle (TC) (Huber 1100, SD Mechatronik GmbH, Germany) for about 10,000 cycles. This duration of aging is equivalent to 1 year of clinical function.[18] Thermocycling was carried out over a temperature range of 5°C to 55°C, with a dwell duration of 30 s and a transfer time of 10 s. Following the completion of the heat cycling procedure, the samples were immersed in a coffee solution (Nestle Middle East Manufacturing LLC, Dubai). The solution was prepared by mixing a 15 g of coffee powder with 250 ml of hot water. The mixture was thereafter allowed to cool to a temperature suitable for consumption. The coffee solution underwent a filtration process to eliminate any remaining particulate matter. The specimens were submerged in a white plastic cup containing a coffee solution while being continuously stirred. The white plastic cup was thereafter placed in an incubator (General Incubator, JSR Research Inc, Gongju-City, Korea) and incubated at a temperature of 37ºC for a duration of 12 days. This duration was chosen to replicate the consumption of the beverage solution over a period of 12 months.[19] The coffee solution was altered on a daily basis. Before color measurements, the specimens underwent a cleaning process involving the use of distilled water and subsequent drying with blotting paper.

The L^*, a^*, and b^* coordinates were measured again subsequent to accelerated aging and immersion protocols. The measurements employed a D65 light source illuminant and a white background. The color disparities (ΔE) of each sample were computed in relation to the initial color measurement utilizing the CIElab color-difference equation ΔE. This was done to assess the extent of change over different time intervals, employing the following formula:

$$\Delta E = ([L1^* - L0^*]2 + [a1^* - a0^*]2 + [b1^* - b0^*]2)\ ½$$

The symbol ΔL^* represents the disparity in L, denoted as the difference between $L1^*$ and $L0^*$. This disparity signifies the luminosity of the item, ranging from light to dark. The symbol Δa^* represents the discrepancy between two values of a, denoted as $a1^*$ and $a0^*$. The sign Δb^* is used to denote the difference between two values of b, namely $b1^*$ and $b0^*$.

A smaller ΔE value indicates a reduced magnitude of color alteration. Conversely, a greater ΔE value indicates a more pronounced alteration in color. According to Paravina *et al*., detectable ΔE values were defined as those over 1.2, while clinically unsatisfactory levels were defined as those exceeding 2.7.[20]

Statistical analysis

The data that were gathered were inputted into the Statistical Package for the Social Sciences (SPSS version 26.0, IBM Corp, USA). The data normality was examined by the Shapiro–Wilk and the Kolmogorov–Smirnov tests. An independent *t*-test was conducted to compare the TP and color change ΔE values of the two materials. A significance level of <0.05 was employed.

RESULTS

Normality tests were satisfied, and the data were normally distributed ($P > 0.05$).

The TP ranged between 16.364 and 21.019 with a mean of 19.157 ± 1.454 in LDS HT 0.5 mm and ranged between 9.649 and 11.535 with a mean of 10.779 ± 0.534 in ALD MT 1 mm [Table 1].

There was a statistically significant difference in TP between LDS 0.5 mm thickness and ALD 0.5 mm ($P = 0.001$). LDS 0.5 mm HT had higher TP than ALD 0.5 mm HT (19.157 + 1.454 and 15.363 + 0.841, respectively). Similarly, LDS MT 0.5 mm had a higher TP than ALD MT 0.5 mm (18.16 + 2.149 and 15.115 + 0.877, respectively). No significant difference in TP existed between 1 mm thickness samples of the two materials whether MT or HT ($P > 0.05$).

There was a statistically significant difference ($P < 0.001$) between HT and MT samples for both materials only in 1 mm thickness groups. No significant difference existed in TP of 0.5 mm thickness within the same material between MT and HT ($P > 0.05$).

There was statistically significant difference ($P = 0.001$) between 0.5 mm and 1 mm thickness in all groups.

The mean, standard deviation, minimum, and maximum values of ΔE after coffee thermocycling are shown in Table 2. The mean ΔE ranged between 1.946 ± 0.536 in LDS MT and 3.030 ± 1.317 in ALD MT.

Independent sample *t*-test showed that LDS MT had significantly less color change than ALD MT (1.946 + 0.536 and 3.03 + 1.317, respectively) ($P < 0.05$). No significant difference existed between color change of LDS HT and ALD HT ($P > 0.05$).

The mean ΔE values for all groups were above the perceptibility threshold of 1.2. However, only ALD MT showed color change above the acceptability threshold of 2.7.

DISCUSSION

Lithium disilicate is often regarded as a very suitable option for single all-ceramic restorations owing to its exceptional esthetic properties and good mechanical properties. Advanced lithium disilicate is one of the recently introduced materials which is claimed by the manufacturer to have comparable and even superior mechanical properties to lithium disilicate. The current study investigated the optical properties of the newly produced lithium disilicate material by a comparative assessment of its TP and color stability in comparison to conventional lithium disilicate.

The ceramic samples in the current study were disks with two different thicknesses, used to mimic the usual clinical situations. For ceramic veneers and crowns, the material thickness is usually about 0.5 and 1 mm depending on the clinical needs and desires.

The needed translucency of all-ceramic materials differs according to the clinical situation. Some cases require high translucency to allow light to pass through and obtain better esthetic results while other clinical cases require masking the color of the substructure by making the restoration less translucent.[14]

Results in this study revealed significant differences in translucency between lithium disilicate and advanced lithium disilicate in 0.5 mm thickness groups, so the null hypothesis was rejected. The findings of this investigation are consistent with a previous study whereby they observed that conventional lithium disilicate exhibited higher TP values in comparison to the new variations of the material.[16] Nevertheless, the present investigation did not observe a significant disparity in TP between the two materials when evaluated at a thickness of 1 mm. This could indicate that LDS is preferable for thin restorations like veneers when more translucency is desired, but no difference is expected for crowns.

The variation in translucency among materials may be attributed to differences in their crystal structures. ALD contains virgilite in their matrix which could contribute to the reduced TP in comparison to LDS. In addition, it should

Table 1: Descriptive analysis of translucency parameter

Translucency	Thickness (mm)	Group	n	Mean±SD	Minimum	Maximum
HT	0.5	LDS	10	19.157±1.454	16.364	21.019
		ALD	10	15.363±0.841	14.548	21.722
	1	LDS	10	13.646±0.852	12.298	14.677
		ALD	10	13.229±0.872	9.709	12.643
MT	0.5	LDS	10	18.160±2.149	14.140	16.731
		ALD	10	15.115±0.877	14.056	16.837
	1	LDS	10	11.096±1.084	12.097	15.011
		ALD	10	10.779±0.534	9.649	11.535

SD: Standard deviation, HT: High translucency, MT: Medium translucency, ALD: Advanced lithium disilicate, LDS: Lithium disilicate glass-ceramic

Table 2: Descriptive analysis of ΔE

Translucency	Group	*n*	Mean±SD	Minimum	Maximum
HT	LDS	10	2.668±1.106	1.694	4.883
	ALD	10	2.631±0.984	1.288	2.829
MT	LDS	10	1.946±0.536	1.077	4.129
	ALD	10	3.030±1.317	1.545	5.040

SD: Standard deviation, HT: High translucency, MT: Medium translucency, ALD: Advanced lithium disilicate, LDS: Lithium disilicate glass-ceramic

be noted that the lithium disilicate crystals found in LDS are of a size >1 µm, which is larger when compared to the lithium disilicate crystals of ALD, measuring at 0.5 µm, as well as the virgilite crystals, which range from 0.2–0.3 µm.[9]

When comparing HT and MT for both LDS and ALD, no difference in TP was evident at 0.5 mm thickness while a significant difference existed at 1 mm thickness. This indicates that low thicknesses HT or MT will give comparable translucency, while at 1 mm thickness, HT provides higher translucency than MT.

In relation to the variable of thickness, the findings of the present investigation indicate a statistically significant disparity in T*P* values between the 0.5 mm and 1 mm thicknesses across all groups. 0.5 mm specimens had higher TP than 1 mm specimens whether HT or MT in both materials. This comes in conformity with previous studies. The relation between the material thickness and the TP values appears to be an inverse relationship, where any increase in the material thickness results in a clear decrease in the T*P* values and vice versa.[3,13]

To assess color stability in the present investigation, a combined procedure was employed which included subjecting the samples to thermocycling followed by beverage (coffee) immersion for 12 days to represent 1 year of clinical function.[7,19]

The ΔE mean values were higher in MT ALD than MT LDS. The ΔE values for all groups were above the perceptibility threshold of 1.2. However, only MT ALD showed color change (3.03) above the acceptability threshold of 2.7.[20] This contradicts the result of Demirel *et al*., who reported the ΔE values of ALD, LDS, and ZLS were <0.8 which is below the clinically perceptible threshold. This could be due to difference in study protocols. In our study, the number of TCs was 10,000 followed by coffee immersion to reflect more clinical situation, whereas in the previous study, they did only 5.000 cycles which might not be enough to cause significant changes in the ΔE values.[16]

On the other hand, the study of Subaşı *et al*., conformed to the current study as they have reported perceivable colour changes after coffee thermocycling of LDS and ZLS.[13]

There are some limitations of the current study that need to be considered. As this study was conducted *in vitro*, the results may have been influenced by the difficulty in accurately simulating the oral environment. Both surfaces of the specimens underwent coffee exposure. Hence, it is reasonable to consider that the alterations in color may have been magnified to a greater degree than what is perceptible in clinical settings, given that only one surface of the restoration is subjected to staining agents within a clinical context. It is imperative to recognize that within clinical environments, the resin cement and the underlying color can influence the final colour outcome of the dental restoration.[21] Furthermore, it should be noted that the samples included in the study were flat in nature, which stands in contrast to the anatomically contoured and curved clinical crown restorations.

CONCLUSION

Within the limitations of the present study, it has been concluded that:

- The translucency of advanced lithium disilicate is comparable to lithium disilicate. However, the translucency of lithium disilicate was higher at a thickness 0.5 mm
- The color change in both materials was above the perceptibility threshold. Color change of advanced lithium disilicate MT was above the clinical acceptability threshold.

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Conflicts of interest

There are no conflicts of interest.

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