Effect of Translucency and Thickness on Translucency Parameters of "Advanced Lithium Disilicate" Chairside CAD/CAM Ceramic

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Abstract

Chairside CAD/CAM technologies are being introduced in the dental market and many kinds of materials including ceramic have been developed for these technologies. Glass-ceramic has been promoted for restorations because of its favorable optical properties. Optical properties can be indicated in different ways, including translucency. Translucency is an important factor in esthetic outcomes. Material with higher translucency will allow light beams to pass through restoration and affect the final shade of restoration. Furthermore, lower translucency may mask discolored substrates, adversely affecting restoration aesthetic. The translucency parameter has been used to evaluate the translucency of ceramic restoration. However, advanced lithium disilicate is new to chairside CAD/CAM ceramic, and its studies of translucency parameters (TP_{00}) are less investigated. For this reason, the purpose of this in vitro study is to compare the translucency parameters of a newer chairside CAD/CAM ceramic with those of an extensively studied CAD/CAM glass-ceramic material. 2 types of CAD/CAM glass-ceramic blocks: IPS e.max CAD (ECAD), and CEREC tessera (Tessera) with 2 translucency (HT), and (MT) in shade A2 were sliced into 4 groups of thickness (1 mm, 1.5mm, 2mm, and 2.5 mm), containing 8 pieces per group. A dental spectrophotometer was used for determining translucency parameters (TP_{00}). The data were analyzed using multiple ANOVA and Tukey HSD post hoc tests ($\alpha = 0.05$). The result of the present study revealed that the type of glass ceramic, translucency, and thickness significantly influenced TP_{00}. TP_{00} values of all ceramic materials significantly decreased with increasing thickness. Regardless of material type, HT groups showed significantly higher TP_{00} than MT groups. ECAD showed significantly higher TP_{00} than Tessera, but at 2.5 mm-thickness, no significant difference was found between MT ECAD and MT Tessera. There was no difference in TP_{00} values between MT ECAD and HT Tessera at the same thickness. The TP_{00} values of MT Tessera, which has 0.5 mm less thickness than HT ECAD and HT ECAD show no significant difference. The study concluded that the type of ceramic materials, translucency, and thickness influenced TP_{00}. Tessera groups showed lower TP_{00} than ECAD groups, but MT groups did not show any difference at 2.5 mm-thickness. The TP_{00} values of MT ECAD were similar to those of HT Tessera. MT Tessera, which has 0.5mm thickness less than HT ECAD provided similar TP_{00} values as HT ECAD.

Keyword: *Chairside CAD/CAM, Glass-ceramic, Translucency Parameters*

1. Introduction

The computer aid design/computer aid manufacturing (CAD/CAM) system has been introduced in dentistry with many advantages (Lambert et al., 2017). compared to the conventional way of manual manufacture, CAD/CAM systems standardize the fabrication restoration process, saving time and reducing errors in fabrication (Lambert et al., 2017; Marchesi et al., 2021). Chairside CAD/CAM technology is a system for fabricating restoration chairside and immediate cementation (Marchesi et al.,2021). The increase in chairside CAD/CAM processes led to manufacturers developing their materials with the aim of reducing dental operating time and fabricating precise and esthetic restorations (Lambert et al., 2017; Marchesi et al., 2021; Vichi et al., 2014).

Glass-ceramic was the first to be developed for chairside CAD/CAM systems (Marchesi et al., 2021). The microstructure and composition of ceramics influence the reflection, diffusion, absorption, and transmission of light, which create favorable optical properties (Della Bona, Nogueira, & Pecho, 2014). The optical properties such as the translucency of restorative materials are a major factor in the esthetic outcome and must be considered (Della Bona et al., 2014). Translucency is described as a state between transparency and opacity (Kim et al., 2009). It is a property of material that occurs when light pass through it; the light is reflected, scattered, and transmitted through the material (Della Bona et al., 2014; Kim et al., 2009). A large amount of light transmission through the material indicates that the material more translucent (Awad et.al., 2015; Nogueira, & Della Bona, 2013). By allowing greater light transmission, the translucency of ceramic restoration can mimic the appearance of enamel, which shows the color of the tooth structure underlying the restoration (Della Bona et al., 2014). This affects the final shade of restorations. Not only does high translucency of ceramic influence the final shade of restoration, but also low translucency improves the esthetics. With low translucency, glass-ceramic materials may mask discolored tooth substructure adversely affects restoration a esthetic. The translucency of restoration materials may be determined by the translucency parameter (TP_{00}) (Dos Santos et al., 2021; Reid et al., 2023; Vichi et al., 2023). The methodology for measurement of the TP_{00} is the color difference between material over black and white backgrounds (Dos Santos et al., 2021; Reid et al., 2023; Vichi et al., 2023). Previously, studies (Czigola et al., 2019; Johnston, 2014; Pop-Ciutrila et al., 2021) showed TP_{00} values depended on the type, shade, thickness, or translucency of glass-ceramic.

Nonetheless, glass-ceramic restorations have achieved success in esthetics, and the demand for more esthetics and stronger ceramic restorations has increased. Consequently, in 2021, Dentsply Sirona ~~is~~ will introduce “CEREC Tessera”- a new advanced lithium disilicate ceramic for chairside CAD/CAM systems (Dentsply Sirona, 2022; Reid et al., 2023). The formula of CEREC Tessera is comprised of two crystals: lithium disilicate ($Li_2Si_2O_5$) and virgilite ($Li_{0.5}A1_{0.5}Si_{2.5}O_6$) which is a lithium aluminum silicate embedded in zirconia to enrich the glassy phase (Dentsply Sirona, 2022). The virgilite is a round and porous crystal that provides CEREC Tessera with additional strength (Dentsply Sirona, 2022). However, the information on virgilite crystal in published research was scarce. CEREC Tessera provides outstanding strength and esthetic restoration. Additionally, it can be fired quickly. The glaze firing takes four minutes and thirty seconds, which causes faster processing time (Dentsply Sirona, 2022; Reid et al., 2023).

The information in the published research on advanced lithium disilicate for evaluating the translucency parameter was less investigated. The purpose of this study was to investigate the translucency parameter of advanced lithium disilicate, by comparing it with extensively studied CAD/CAM ceramic material under conditions that modify 4 thickness and 2 translucencies of the ceramic. The null hypothesis was that no difference exists in the translucency parameters based on the type of glass-ceramic materials, thickness, or translucency.

2. Objective

To assess the translucency parameter of a newer chairside CAD/CAM glass-ceramic with variations in translucency and thickness, comparing it with extensively studied CAD/CAM ceramic material

3. Materials and Methods

Two types of glass-ceramic materials: lithium disilicate – (IPS e.max CAD) (Ivoclar Vivadent, Schaan, Liechtenstein); ECAD, advanced lithium disilicate – (CEREC Tessera) (Dentsply Sirona, Charlotte, NC, USA); Tessera were obtained in high translucency (HT) and medium translucency (MT), both in shade A2.

Figure 1 High and medium translucency E.max CAD blocks

Figure 2 High and medium translucency CEREC Tessera blocks

The sample size was calculated from the equation;

$$n = \frac{[(Z_{\alpha}^2 + Z_{\beta}^2)(\sigma_1^2 + \sigma_2^2)]}{\Delta^2}$$

The mean and standard deviation (SD) were obtained from a previous study (Jirajariyavej, Wanapirom, & Anunmana, 2018). Z_{α} = 95% confidence interval, Z_{β} = 95% power, and Δ = mean difference between 2 groups, indicating a required at least sample size of 4.

The specimens were prepared by slicing from 14 x 12 x 15 mm^3 CAD/CAM ceramic blocks using a low-speed precision saw (Isomet 1000 precision saw; Buehler) in four thicknesses: 1.0, 1.5, 2.0, and 2.5 mm, containing 8 pieces per group test. The evaluated surfaces of the ceramic specimens were smoothed and standardized using 600-grit abrasive paper under water cooling (Reid et al., 2023). The thickness control of the specimens was assessed at the center of each specimen with a digital caliper (Digital Micrometer IP-65, Mitutoyo). The crystallization and glazing process was performed in a vacuum furnace according to the manufacturer's instructions.

Figure 3 Specimens were sectioned from E.max CAD blocks in four thickness

Figure 4 Specimens were sectioned from CEREC Tessera blocks in four thickness

Table 1 Chemical composition of the materials in this study

Material	Manufacture	Definition	Chemical composition	Translucency in this study	Lot number
IPS. e.max CAD	Ivoclar Vivadent, Schann, Liechtenstein	Lithium disilicate	57-80% SiO_2; 11-19% Li2O; 0-13% K_2O; 0-11%P_2O_5;0-8% ZnO; 0-12% others + coloring oxides	HT MT	YB54GB Z03G45
Cerec Tessera	Densply Sirona, Charlotte, NC, USA	Advanced lithium disilicate	$Li_2Si_2O_5$: 90% Li_3PO_4: 5% $Li_{0.5}A1_{0.5}Si_{2.5}O_6$ (LAS, lithium alumino silicate-virgillite)	HT MT	16013116 16013448

A dental spectrophotometer (VITA Easyshade V; VITA Zahnfabrik) was used for color measurements. The specimens were measured against a white and black background. The spectrophotometer was calibrated using a calibration plate at the base of the charging station before all measurements. The aperture of the spectrophotometer was placed in contact with the surface of each specimen. The translucency parameter (TP_{00}) was determined by calculating the color difference of the same specimen between black (B) and white (W) backgrounds.

Figure 5 The spectrophotometer (Vita Easyshade) and its charging station

The following formula was used to calculate TP_{00} (Dos Santos et al., 2021; Reid et al., 2023; Vichi et al., 2023):

$$TP_{00} = \sqrt{\left(\frac{L'_B - L'_W}{K_L S_L}\right)^2 + \left(\frac{C'_B - C'_W}{K_C S_C}\right)^2 + \left(\frac{H'_B - H'_W}{K_H S_H}\right)^2 + R_T\left(\frac{C'_B - C'_W}{K_C S_C}\right)\left(\frac{H'_B - H'_W}{K_H S_H}\right)^2}$$

L, C, H are lightness, chroma, and hue. R_T is the rotation factor that accounts for the interaction between chroma and hue in the blue region. S_L, S_C, and S_H adjust the color difference for variation in the l a b system. K_L, K_C, and K_H are the terms for experiment conditions. (For this study, $K_L=K_C=K_H=1$)

The distributions of variables were evaluated using the Shapira-Wilk test. The test showed a normal distribution and the data were analyzed using multiple ANOVA to evaluate the effect of glass-ceramic type, translucency, and thickness on the translucency parameters. The mean TP_{00} values were compared with Tukey HSD multiple comparison tests. (all test $\alpha=0.05$) All statistical analysis was done with a statistical software program (IBM SPSS Statistics V25.0; IBM Corp).

4. Result and Discussion

4.1 Result

Table 2 Means and SD of TP_{00} values

Translucency	Type	1 mm	1.5 mm	2 mm	2.5 mm
High (HT)	Lithium disilicate (ECAD)	12.05 ± 0.69^{Aa}	9.65 ± 0.59^{Ab}	7.53 ± 0.56^{Ac}	5.74 ± 0.50^{Ad}
	Advanced lithium disilicate (Tessera)	10.67 ± 0.74^{Ba}	7.87 ± 0.58^{Bb}	5.28 ± 0.42^{Bc}	4.16 ± 0.52^{Bd}
Medium (MT)	Lithium disilicate (ECAD)	11.45 ± 0.59^{Ba}	8.82 ± 0.94^{Bb}	5.25 ± 0.52^{Bc}	3.17 ± 0.53^{BCd}
	Advanced lithium disilicate (Tessera)	9.27 ± 0.69^{Da}	6.73 ± 0.69^{Db}	3.96 ± 0.39^{Dc}	2.49 ± 0.48^{BCDd}

Upper letters refer to the difference in TP_{00} among glass ceramic types and lower letters refer to the difference of TP00 among the thickness of ceramic

Table 1 shows the mean±SD TP_{00} values. An increase in the thickness of the restoration from 1 to 2.5 mm decreases the TP values in every ceramic specimen. High - translucency (HT) ceramics have higher TP_{00} values than the medium translucency (MT) group. Tessera groups have lower TP_{00} values than ECAD groups.

Table 3 Three-way analysis of variance of combinations of type, thickness, and translucency of ceramic

Source	Sum of Squares	df	Mean square	F	Sig
Thickness	906.950	3	302.317	830.143	.000
Translucency	69.797	1	69.797	191.659	.000
Type	87.384	1	87.384	239.952	.000
Thickness * Translucency	7.858	3	2.619	7.193	.000
Thickness * Type	3.003	3	1.001	2.748	.046
Translucency * Type	.289	1	.289	.793	.375
Thickness * Translucency * Type	4.688	3	1.563	4.291	.007
Error	40.787	112	.364		
Total	7629.592	128			

The Three-way ANOVA of TP_{00} values indicated significant differences and interactions among all groups (P <.05); see table 2.

The Turkey HSD post hoc test determined that TP_{00} values had significant differences within the ceramic group, with ECAD having higher values than Tessera. When considering the type of ceramic, for high translucency groups, ECAD showed significantly higher TP_{00} values than Tessera at all thicknesses. For medium translucency groups, ECAD showed significantly higher TP_{00} values than Tessera at 1, 1.5, and 2 mm-thicknesses, but it was not significantly different at 2.5 mm-thickness. There were no significant differences between MT ECAD and HT Tessera at the same thickness. When the thickness of HT ECAD was less than MT Tessera by 0.5 mm, no significant difference was found.

4.2 Discussion

Translucency can be indicated in several ways (Dos Santos et al., 2021; Johnston, 2014; Reid et al., 2023; Skyllouriotis, Yamamoto, & Nathanson, 2017; Vichi et al., 2023). The translucency parameter (TP) and contrast ratio (CR) are commonly used to indicate translucency (Skyllouriotis et al., 2017; Vichi et al., 2023). TP is the color difference between specimens over a white background and a black background (Czigola et al., 2019; Johnston, 2014; Skyllouriotis et al., 2017; Vichi et al., 2023). CR is the ratio of the reflectance of a specimen placed over a black background to that over a white one of known reflectance, and it is defined as an estimate of opacity (Skyllouriotis et al., 2017). Some studies (Barizon et al., 2013; Nogueira, & Della Bona, 2013) compared TP and CR methods and described correlation. Nevertheless, from the previous comparative studies, there is no consensus on the method of choice to quantify the translucency of restorative materials. TP is considered the test that is often used in dental research to indicate translucency (Czigola et al., 2019; Johnston, 2014; Skyllouriotis et al., 2017; Vichi et al., 2023). TP is calculated based on the CIELAB color different formula (Dos Santos et al.,2021). Aiming to improve the correlation between color measurement and visual perception, the Commission Internationale de l'Eclairage (CIE) has introduced the CIEDE2000 system (Gomez-Polo et al., 2016a). Furthermore, the reports (Gomez-Polo et al., 2016a; Gomez-Polo et al., 2016b; Gomez-Polo et al., 2020) have shown that CIEDE2000 is more effective in showing color differences similar to visual perception than CIELAB. The CIEDE2000 system has been used to calculate the translucency parameter (TP_{00}) (Dos Santos et al., 2021; Reid et al., 2023; Vichi et al., 2023).

The results support the rejection of the null hypothesis, in that TP values are influenced by types of glass-ceramic, thickness, and translucency. This finding is consistent with the other studies (Czigola et al., 2019; Johnston, 2014; Pop-Ciutrila et al., 2021; Reid et al., 2023). The influence of thickness and types of glass-ceramic on translucency parameters of restorative materials has been previously evaluated (Johnston, 2014; Pop-Ciutrila et al., 2021). previous reports (Gunal, & Ulusoy, 2018; Johnston, 2014; Oh et al., 2018) have shown that thickness directly affects the transmission of light through ceramic. The greater the thickness of restoration materials, the lower the translucency (Barizon et al., 2013). Pop-Ciutrila et al. (2021) showed that translucency of dental ceramic materials was significantly affected by thickness and type. Additionally, Arif, Yilmaz, and Johnston (2019) concluded that the translucency of ceramic restoration materials increased with decreasing thickness, with the amount of change being material-dependent.

The results of the present study show that all of the test materials lost translucency as the specimen thickness increased. With lower thickness, the dental ceramics can mimic the optical characteristics of enamel which allows light transmission and show color of underlying tooth structures (Gunal, & Ulusoy, 2018), while higher thickness presents opacity property of the material that may mask the discolored tooth substructures (Dos Santos et al., 2021). For this reason, the thickness of the restoration and the color of the underlying tooth structure should be considered before tooth preparation because these factors affect aesthetic of the restoration. When considering types of ceramic, ECAD showed higher TP_{00} values than Tessera at the same thickness for high translucency groups and 1, 1.5, and 2 mm-thickness for medium translucency groups. The glassy phase of Tessera consists of zirconia, which lowers the viscosity of the glass. This allows the glass to penetrate the porous structure of the virgilite crystal and interlock with it, which increases the strength of CEREC Tessera (Dentsply Sirona, 2022). Several studies (Jirajariyavej, Wanapirom, & Anunmana, 2018; Reid, et al., 2023) showed zirconia had low translucency. This may cause Tessera groups to show lower TP_{00} values than ECAD. This study did not evaluate the microstructure of glass-ceramic, which may affect translucency parameters due to the limited ~~of~~ time. Future studies should assess the effect of the microstructure of glass-ceramic on its optical properties. There was one published study evaluating the translucency parameters of CEREC Tessera and IPS e.max CAD. Reid, et al. (2023) presented no significant difference in translucency parameters between CEREC Tessera and IPS e.max CAD. This previous study is contrary to the findings in the present study that reported ECAD showed higher TP_{00} values than Tessera at the same thickness for high translucency groups and 1, 1.5, and 2 mm-thickness for medium translucency groups, but it agrees with the result that reported MT ECAD showed similar TP_{00} values to MT Tessera at 2.5 mm thickness. However, the optical properties, including the translucency parameter, of CEREC Tessera have been less investigated. Further studies are necessary for a better understanding of the translucency parameters of CEREC Tessera. For medium translucency groups, TP_{00} values of ECAD showed no significant differences from Tessera at 2.5 mm thickness. This finding shows two types of glass-ceramic have the same TP_{00} values at 2.5mm thickness, which may be used to mask the discolored tooth substructures and be used for restorations that require a thickness greater than 2.5 mm such as crowns for dental implants. When comparing the TP values of HT Tessera and MT ECAD, there is no significant difference at the same thickness. This result indicates that the translucency of HT Tessera is similar to that of MT ECAD. Furthermore, MT Tessera, which has 0.5 mm less thickness than HT ECAD, shows similar translucency to HT ECAD. This report is useful for restoration material-selection. MT Tessera is suitable for minimal tooth preparation when the restorations require the same translucency for masking discolored underlying substructures. All findings in the present study indicate that the translucency parameters of these groups of materials are similar. In addition to the similar translucency among the group of test materials, there are other optical properties that must be considered in fabricating restoration (Reid et al., 2023).

As a limitation of the present study, the translucency parameters are chosen to evaluate the translucency of glass ceramic restoration materials. Furthermore, previous studies (Dos Santos et al., 2021; Skyllouriotis et al., 2017) showed the translucency parameter was one of the methodologies that can be used to assess the masking ability of dental materials. Future studies, that consider the masking ability of discolored surfaces and the translucency parameters of glass ceramic restoration materials should be performed to evaluate the correlation between masking ability and translucency parameters within materials.

5. Conclusion

The type of ceramic materials, translucency, and thickness influenced TP_{00}. Tessera groups showed lower TP_{00} than ECAD groups, but MT groups did not show any difference at 2.5 mm-thickness. The TP_{00} values of MT ECAD were similar to those of HT Tessera. MT Tessera, which has a 0.5mm thickness less than HT ECAD, provided similar TP_{00} values as HT ECAD.

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