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Influence of the background, substrate and thickness in light behaviour and colour of zirconia-reinforced lithium silicate (ZLS) glass-ceramic

Influência do fundo, substrato e espessura no comportamento da luz e cor das cerâmicas de dissilicato de lítio reforçadas com zircónia (ZLS)

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ABSTRACT

Objective: To evaluate the influence of background, substrates and thickness on the color and light behaviour of two ZLS glass ceramics. **Material and Methods:** Standardized disc-shape specimens (12 x 1.2 mm), color A1 HT, of Celtra Duo and Vita Suprinity (n=30), were tested over a white/black background, and divided in five groups (n=6) to be tested over five substrates (polished gold alloy, white zirconia and composite, dentine and enamel A1 colour). The L*, C*, h*, a*, b* and ΔE values, were recorded in two thicknesses (1.2 and 2.4 mm). Translucency parameter (TP), contrast ratio (CR) and opalescence parameter (OP) were calculated. Data was analysed with non-parametric tests: Mann Whitney between ceramic materials for thickness, Wilcoxon for thicknesses in substrates and ceramic material and Kruskal-Wallis with Bonferroni corrections tests ($p<0,01$) for substrates. **Results:** For 2.4 mm, the ΔE values were always higher independently of ceramic material or substrates. Vita Suprinity registered lower values than Celtra Duo. Zirconia substrate registered the lower values. For 1.2 mm, dentine registered the lower values. Gold alloy and composite substrates registered the lower ΔE values for 1.2 mm Celtra Duo and 2.4 mm Vita Suprinity specimens. CT and OP higher values and TP lower values were registered for 2.4 mm Vita Suprinity. It was impossible to calculate for Celtra Duo specimens. **Conclusions:** Background, substrate and thickness had significant influence in light behaviour and final color of ZLS glass ceramics. Substrates Gold alloy and dentine exhibited clinical acceptable ΔE values for 1.2 mm Celtra Duo specimens.

KEYWORDS

Color, Lithium Disilicate, Zirconia, Ceramic, Dental Materials.

RESUMO

Objetivo: Avaliar a influência do fundo, do substrato e da espessura no comportamento da luz e na cor de duas cerâmicas ZLS. **Material e métodos:** Discos de cerâmica (12 x 1.2 mm) de cor A1 HT, de Celtra Duo e Suprinity (n=30), foram testados sobre fundo branco/preto e cinco substratos (liga Ag-Au-Pt polida; zircónia branca; compósito, dentina e esmalte de cor A1). Os valores L*, C*, h*, a*, b* e ΔE foram registados em duas espessuras (1.2 mm e 2.4 mm). O parâmetro de translucidez (TP), o parâmetro de opalescência (OP) e o índice de contraste (CR) foram determinados. Foram realizados testes não paramétricos: Mann Whitney entre cerâmicas por espessura, Wilcoxon entre categoria de espessura por substrato e cerâmica; Kruskal-Wallis com correção de Bonferroni para substratos (p <0,01). **Resultados:** Para 2,4 mm, o ΔE foi sempre superior independentemente do material ou substrato. Os valores de Suprinity foram inferiores aos de Celtra Duo. O substrato zirconia obteve o ΔE mais baixo. Para 1,2 mm, a dentina obteve o ΔE mais baixo. A liga dourada e o compósito obtiveram ΔE mais baixo para Celtra Duo 1,2 mm e Suprinity 2,4 mm. Para Suprinity, CT e OP foram maiores para 2,4 mm e menores para TP. Não foi possível calcular para Celtra Duo. **Conclusão:** O fundo, substrato e espessura tiveram influência significativa no comportamento da luz e cor das restaurações de cerâmica ZLS. Apenas os substratos metal e dentina apresentaram valores clinicamente aceitáveis, para Celtra Duo na espessura de 1.2 mm.

Palavras-chave:

Cor, Dissilicato de Lítio, Zircónia, Cerâmica, Materiais Dentários.

INTRODUCTION

Metal ceramic restorations are still the gold standard [1,2]. The search for newer ceramic materials that behave like a real tooth and be more aesthetic solutions for all ceramic restorations is still on demand [3,48]. The Clinical selection of ceramic systems is based on the mechanical and optical properties of the materials [4-6].

Lithium disilicate ceramics has been used as standard reference for monolithic anterior and posterior restorations as well as for complete rehabilitation of dentitions [7]. Recently, a zirconia-reinforced lithium silicate ceramic has been introduced which aims to combine the benefits of both ceramics, thereby enabling single tooth restorations with high flexural strength and aesthetic properties [8,9]. The inclusion of zirconia particles in the lithium silicate glass matrix has been reported to reinforce the ceramic structure by providing crack interruption [9]. Additionally, smaller silicate crystals in the lithium silicate glassy matrix result in a high glass content, which may lead to better translucency than that of conventional lithium disilicate ceramics [10].

Zirconia-reinforced lithium silicate (ZLS) glass-ceramic is a synthetic feldsphatic ceramic [11]. It is indicated for inlays, onlays, full-contour anterior and posterior crowns and also for implant-supported prostheses [9,12]. Glass ceramics such as these have been developed to overcome deficiencies on crack propagation and degradation under fatigue and create higher-performance ceramic materials [13,14]. To manipulate these harder materials, many useful techniques have been developed, mainly Computer-aided design and Computer-assisted manufacturing (CAD-CAM) [15]. However, regardless the material mechanical properties, color reproduction is still a difficult challenge, both in clinical and laboratory environment [3,6-9,16-19, 48,49,50].

Limited information is available regarding the optical properties of this type of ceramic materials and how color is affected by underlying foundation or substrates and thickness variation. When these materials don't use a metal substructure or complete opaque zirconia for support, they can achieve light scattering and transmission that is similar to natural teeth [4-6].

In clinical situations, such as restoring discolored teeth or metal posts and cores that need to be covered with a material which has lower translucency and higher masking ability [20]. However, some substrates that replace lost tooth structure or serve as implant abutments, may affect the resulting shade matching of ceramic restorations, like metallic post and cores for its dark color [17-19]. The same behaviour happens for composite resin and zirconia for its white opaque color [20,21].

Therefore, clinicians should be familiar with the translucency of newly introduced monolithic CAD-CAM materials when they choose the most appropriate material for a specific clinical situation [20]. Understanding the color and light behavior of these materials is important for the esthetic success of restorations. Different backgrounds may affect the color integration of restorations with surrounding teeth and compromise the overall rehabilitation [48,49, 50].

Color, as described by Munsell, is a tridimensional phenomenon, composed by hue, croma and value that must be matched in restorations [14]. These color properties can be expressed numerically, for precise communication, since 1976, through the Commission International de l'Éclairage system (CIEL*a*b*) in terms of three coordinate values (L*, a* and b*), when a spectrophotometer is used. Color science and theory is determinant to calculate other important color properties that need to be matched by restorations, such as translucency (the gradient between opacity and transparency), opalescence (exhibiting a milky iridescence like that of an opal) and fluorescence (invisible radiation as a result of incident radiation of a shorter wavelength), like the observed in real teeth [3]. Vita EasyShade® Compact V (Vita Zahnfabrik, H. Rauter GmbH & Co., Bad Säckingen, Germany) is a portable spectrophotometer widely used for shade-matching research, and the reliability and accuracy of its shade measurement has been supported by several studies [22-26,48]. This equipment measures tooth or restoration color and color differences (ΔE), which allow to establish perceptibility and acceptability thresholds. According to ISO/TR 28642, the perceptibility limit is established for ΔE ≤ 1.2, related to the minimal ΔE detected by an observer, and the acceptability limit for ΔE ≤ 2.7, related to the ΔE tolerance for color correction [27].

The purpose of this study was to evaluate the color and light behavior of two different (ZLS) glass-ceramics. Four null hypotheses were evaluated. First, the two ceramic materials don't have influence in the restoration color. Second, the substrates don´t have influence in the restoration color. Third, the backgrounds don't have influence the restoration color. Finally, the material thickness doesn't have influence on the restoration color.

MATERIAL AND METHODS

Two different Zirconia-lithium silicate glass-ceramic materials were used (Vita Suprinity – Vita Zahnfabrik, H. Rauter GmbH & Co., Bad Säckingen, Germany and Celtra Duo – Degudent GmbH, Hanau, Wolfgang, Germany), both in VITA A1 HT color blocks, applied over two different totally opaque backgrounds (black and white) and five different substrates (white zirconia - Nobel Biocare AB, Stockholm, Sweden; yellow gold alloy - Yellow Special, Cendre & Methaux, Switzerland; composite A1 - Tetric EvoCeram, Ivoclar, Lichenstein; enamel and dentin - obtained from a A1 color central incisor).

Specimen preparation

Following Riquieri et al. [28] protocol, the Zirconia-lithium silicate glass-ceramic materials were machined in a conventional lathe (Nardini, Americana, São Paulo, Brazil) to obtain cylinders (~ 12 mm diameter) sliced into discs in a precision cutting machine (Isomet 1000, Buehler, Lake Bluff, IL, USA). A metallic device with a central cavity and the desired dimensions (12 mm; 1,2 mm) was used to allow the specimens to be better polished (Ecomet 250 GrindrPolisher, Buehler, Lake Bluff, IL, USA) to a mirror like surface in both sides, using silicon carbide papers of #400-, #600-, #1200- and #2500-grit (Buehler, Lake Bluff, IL, USA). Final thickness of 1.2 mm was controlled with a digital caliper (Dexter, USA) according to ISO 6872:2008 [29]. A total of 30 specimens of each material were prepared.

Background preparation

Square shape (5 x 5 cm, 2 mm thick), mirror like surface, black (it was impossible to determine color parameters with Vita Easyshade V spectrophotometer) and a white (L* = 72.6; a*= -1.3; b*= 9.1; C*=9.2 and h*=98.1) opaque acrylic material, obtained commercially (Acrilcorte, Lisbon, Portugal), used to measure Translucency Parameter and Contrast Ratio.

Substrates preparation

White zirconia (Nobel Biocare AB, Stockholm, Sweden), yellow gold alloy (Yellow Special, Cendre & Methaux, Switzerland) and Composite A1 (Tetric EvoCeram, Ivoclar, Lichenstein) substrates were size calibrated using a metallic sampler (Porcelain Sampler Ref. 7015, Smile Line, St-Imier, Switzerland) in disc shape (12 mm diameter X 2 mm thickness). Enamel and Dentin substrates were obtained from an upper central incisor tooth, color A1 (checked with Vita EasyShade® Compact V, Vita Zahnfabrik, H. Rauter GmbH & Co., Bad Säckingen, Germany). Tooth was mounted in a custom made white transparent acrylic block (Orthocryl®, Dentaurum, Inspringem, Germany), with buccal surface parallel to block wall, and polished in a polishing machine (Ecomet 250 Grinder Polisher, Buehler, Illinois, USA), with silicon carbide papers of #120-, #500- and #1000- grit (Buehler, Illinois, USA), to expose a flat enamel wall (~10 mm diameter). After obtaining color measurements over enamel, same procedure was applied to obtain a dentin surface. Substrates were stocked according to ISSO (ISO/TS 11405) [30].

Color determination

For color determination over the five substrates, both materials specimens were randomly distributed in five groups (n=6). Color was determined under standard illumination (D65 with 1500 lux), using a portable spectrophotometer Easyshade Compact V nº H50953 (Vita Zahnfabrik, H. Rauter GmbH & Co., Bad Säckingen, Germany).

To ensure a center position of the specimens over the backgrounds and substrates, as well as, to block external light and ensure a perfect perpendicular position of the tip of the spectrophotometer, specimens were positioned in a two sided custom-made black opaque acrylic older (Acrilcorte, Lisboa, Portugal). One side fit the specimens and the other side fitted the equipment tip. Specimens and substrates where coupled applying a glycerol drop and digital pressure to ensure the contact and continuity between surface materials.

To ensure the same center positioning of the custom-made holder over the tooth exposed enamel and dentine surface area, a support framework was made using a white hard dough (Plastilina, Jovi, China).

Five measurements were made, and the mean average was calculated for each measured parameter. Calibration of the instrument was made after each five measurements. Double thickness measurements (1.2 + 1.2 mm) were also made using an extra specimen of each material group (always the same), positioning it under the specimen with glycerol.

Color measurements over substrates were performed over the white background, using the "Verifying the shade of a ceramic restauration" mode of the equipment, and ΔE, L*, C* and h* values to A1 VITA color were registered.

Color measurements over backgrounds were performed using the "Averaged shade measurement" mode, and L, C, h, a, b, values and ΔE, L*, C* and h* to color correspondence were registered.

Optical properties determination

Specimens were randomly numbered (n=30) for optical properties determination.

Translucency Parameter (TP) was determined by calculating the difference between color measurements against the black (*B*) and white (*W*) backgrounds, according to the following formula:

$$TP = \sqrt{\left(L_B^* - L_W^*\right)^2 + \left(a_B^* - a_W^*\right)^2 + \left(b_B^* - b_W^*\right)^2} \quad (1)$$

L* values were also used to calculate Luminance (*Y*) using the following formula:

$$Y = \left(\frac{L^* + 16}{116}\right)^3 \times Y_n \quad (2)$$

The *Y* values calculated over the white background were used to determine the Contrast ratio (CR), according to the following formula:

$$CR = \frac{Yb}{Yw} \quad (3)$$

Opalescence parameter (OP) were calculated based on a* and b* values over black and white backgrounds, using the following formula:

$$OP = \sqrt{\left(a_B^* - a_W^*\right)^2 + \left(b_B^* - b_W^*\right)} \quad (4)$$

Statistical analyses

Statistical analyses were made using SPSS version 25 (IBM, Armonk, USA). Shapiro-Wilk test didn't confirm ΔE normality distribution. ΔE differences between materials for different thickness were tested with Mann Whitney U test. ΔE differences between substrates were tested with Kruskal-Wallis with Bonferroni correction. ΔE differences between substrates and thickness for the ceramic types were tested with Wilcoxon test.

RESULTS

Color differences (ΔE)

The ΔE values of the two different materials to color A1 VITA, on two different thicknesses, are presented in Table I. Vita Suprinity showed less ΔE values variance and statistically significant ($p<0.001$) lower ΔE values (6.60 ± 0.61, $\bar{x} \pm s$) compared to Celtra Duo in the 2.4 mm thickness (7.56 ± 1.16, $\bar{x} \pm s$). This thickness also revealed statistically significant ($p<0.001$) higher ΔE values compared to 1.2 mm in both materials. (Figure 1).

The ΔE values were always statistically significant ($p<0.001$) higher in 2.4 mm, independently of the substrate tested. Statistically

Table I - Descriptive statistics referring to ΔE, depending on the type of Ceramic and Thickness category

Ceramic	ΔE				*p*
	Thickness = 1.2 mm		Thickness = 2.4 mm		
	$\bar{x}$ (s)	median (IIQ)	$\bar{x}$ (s)	median (IIQ)	
Celtra Duo	3.90 (1.59)	3.46 (2.62)	7.56 (1.16)	7.59 (1.30)	**< 0.001**
Vita Suprinity	4.59 (0.74)	4.60 (0.86)	6.60 (0.61)	6.47 (0.92)	**< 0.001**
p	0.056		**< 0.001**		

x: mean; s: standard deviation; IIQ: interquartile range.

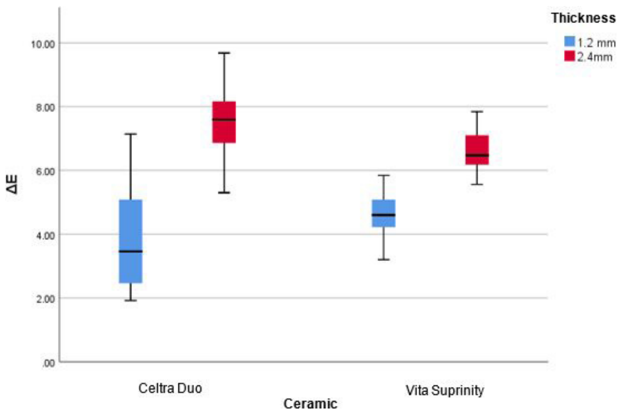

Figure 1 - ΔE Boxplot per Thickness category and type of Ceramic.

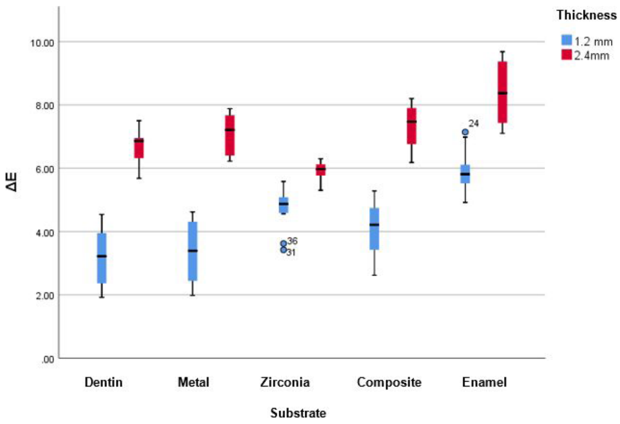

Figure 2 - ΔE Boxplot per Thickness category and Substrate type.

significant differences were also found in the multiple comparation between substrates, as shown in Table II (Figure 2).

Zirconia substrate showed less ΔE values variability, independently of the thickness tested (4.73 ± 0,63, $\bar{x}$ ± s for 1.2 mm and 5.92 ± 0.29, $\bar{x}$ ± s for 2.4 mm). Zirconia ranked lower on the increasing order of ΔE values registered for 2.4 mm (Zirconia (5.92 ± 0.29, $\bar{x}$ ± s), Dentine(6.70 ± 0.47, $\bar{x}$ ± s), Metal (7.08 ± 0.63, $\bar{x}$ ± s), Composite (7.32 ± 0.68, $\bar{x}$ ± s)and Enamel (8.39 ± 1.03, $\bar{x}$ ± s) than for 1.2 mm (Dentine (3.17 ± 0.93, $\bar{x}$ ± s), Metal (3.36 ± 1.02, $\bar{x}$ ± s)), Composite (4.07 ± 0.81, $\bar{x}$ ± s), Zirconia (4.73 ± 0.63, $\bar{x}$ ± s)and Enamel(5.90 ± 0.64, $\bar{x}$ ± s)).

Greater the thickness, higher the ΔE values in all Substrate/Ceramic subgroup tested, although no statistically differences (p>0.001) were found. Double increase of thickness does not correspond to a uniform increase of ΔE values and variation is more pronounced on Celtra Duo ceramic, as shown in Table III (Figure 3).

Table IV shows that ΔE statistically significant values (p<0.01) were found between ceramic material for some Substrate/Thickness subgroups. Celtra Duo registered lower ΔE values

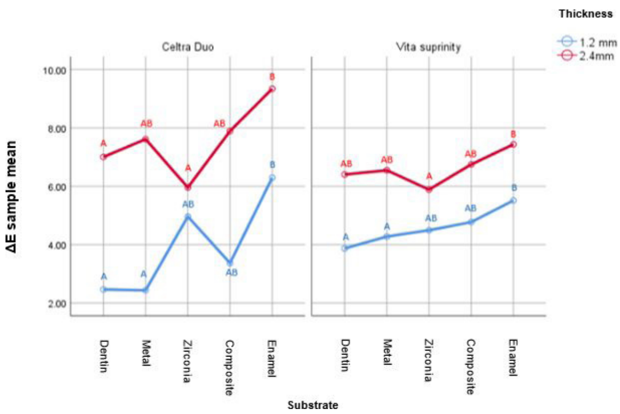

Figure 3 - Graphical representation of the ΔE sample mean by Substrate, type of Ceramic and Thickness category

for Metal (2.44± 0.39, $\bar{x}$ ± s) and Composite (3.37± 0.42, $\bar{x}$ ± s) substrates in 1.2 mm, and superior ΔE values for Metal (7.67± 0.44, $\bar{x}$ ± s), Composite (7.89± 0.27, $\bar{x}$ ± s) and Enamel (9.34± 0.29, $\bar{x}$ ± s) substrates in 2.4 mm thickness.

It may be possible an interaction between ceramic and thickness variables, duo to the fact that higher thickness of Vita Suprinity showed higher ΔE values in 2.4 mm, contrary to the lower ΔE values shown in 1.2 mm thickness,

Table II - Descriptive statistics for ΔE, depending on the Substrate and Ceramic Thickness

Substrate	ΔE				*p*
	Thickness= 1.2 mm		Thickness = 2.4 mm		
	x̄ (s)	median (IIQ)	x̄ (s)	median (IIQ)	
Dentine	3.17 (0.93)	3.22 (1.59) [A]	6.70 (0.47)	6.86 (0.63) [AB]	**0.002**
Metal	3.36 (1.02)	3.39 (1.87) [AB]	7.08 (0.63)	7.21 (1.27) [AC]	**0.002**
Zr	4.73 (0.63)	4.87 (0.49) [BC]	5.92 (0.29)	5.97 (0.35) [B]	**0.003**
Composite	4.07 (0.81)	4.21 (1.32) [AB]	7.32 (0.68)	7.47 (1.14) [AC]	**0.002**
Enamel	5.90 (0.64)	5.81 (0.59) [C]	8.39 (1.03)	8.37 (1.94) [C]	**0.002**
p	**< 0.001**		**< 0.001**		

Column with p-values refer to comparisons between Thickness categories, by Substratre.
Lines with p-values refer to comparisons between Substrates, by Thickness category. Substrates identified with the same letter do not present statistically significant differences between them, p>0.001, relative to E, in each category of Thickness.
x: mean; s: standard deviation; IIQ: interquartile range.

Table III - Descriptive statistics for ΔE, depending on the Substrate, the type of Ceramic and Thickness category

Ceramic	Substrate	ΔE				*p*
		Thickness = 1.2 mm		Thickness = 2.4 mm		
		x̄ (s)	median (IIQ)	x̄ (s)	median (IIQ)	
Celtra Duo	Dentine	2.46 (0.53)	2.36 (0.24) [A]	7.00 (0.25)	6.92 (0.16) [A]	0.028
	Metal	2.44 (0.39)	2.44 (0.72) [A]	7.61 (0.24)	7.67 (0.44) [AB]	0.027
	Zr	4.96 (0.34)	4.87 (0.26) [AB]	5.96 (0.37)	6.06 (0.42) [A]	0.046
	Composite	3.37 (0.42)	3.42 (0.10) [AB]	7.89 (0.27)	7.90 (0.54) [AB]	0.028
	Enamel	6.29 (0.62)	6.11 (1.20) [B]	9.34 (0.29)	9.37 (0.44) [B]	0.028
p			**< 0.001**		**< 0.001**	
Vita Suprinity	Dentine	3.87 (0.67)	3.89 (1.22) [A]	6.40 (0.46)	6.32 (0.58) [AB]	0.028
	Metal	4.28 (0.31)	4.31 (0.52) [A]	6.55 (0.36)	6.40 (0.54) [AB]	0.028
	Zr	4.49 (0.78)	4.82 (1.46) [AB]	5.89 (0.22)	5.90 (0.36) [A]	0.028
	Composite	4.77 (0.27)	4.74 (0.22) [AB]	6.75 (0.41)	6,76 (0.54) [AB]	0.027
	Enamel	5.51 (0.37)	5.60 (0.52) [B]	7.44 (0.26)	7.43 (0.30) [B]	0.027
p		**0.001**		**< 0.001**		

Column of p-values refer to comparations between Thickness categories, by Substrates.
Lines of p-values refer to comparisons between Substrates by Thickness category and by Ceramic type.
Substrates identified with equal leters do not present statistically significant differences between them, p>0.001, relative to E, in each combination of Thickness/Ceramics.
x: mean; s: standard deviation; IIQ: interquartile range.

Table IV **-** Descriptive statistics for ΔE, depending on the type of Ceramic, Thickness category

Thickness	Substrate	ΔE				*p*
		Celtra Duo		Vita Suprinity		
		x̄ (s)	median (IIQ)	x̄ (s)	median (IIQ)	
1.2 mm	Dentine	2.46 (0.53)	2.36 (0.24) [A]	3.87 (0.67)	3.89 (1,22) [A]	0.015
	Metal	2.44 (0.39)	2.44 (0.72) [A]	4.28 (0.31)	4.31 (0,52) [A]	**0.002**
	Zr	4.96 (0.34)	4.87 (0.26) [AB]	4.49 (0.78)	4.82 (1,46) [AB]	0.589
	Composite	3.37 (0.42)	3.42 (0.10) [AB]	4.77 (0.27)	4.74 (0,22) [AB]	**0.002**
	Enamel	6.29 (0.62)	6.11 (1.20) [B]	5.51 (0.37)	5.60 (0,52) [B]	0.065
p			**< 0.001**		**0.001**	
2.4 mm	Dentine	7.00 (0.25)	6.92 (0.16) [A]	6.40 (0.46)	6.32 (0.58) [AB]	0.041
	Metal	7.61 (0.24)	7.67 (0.44) [AB]	6.55 (0.36)	6.40 (0.54) [AB]	**0.002**
	Zr	5.96 (0.37)	6.06 (0.42) [A]	5.89 (0.22)	5.90 (0.36) [A]	0.394
	Composite	7.89 (0.27)	7.90 (0.54) [AB]	6.75 (0.41)	6.76 (0.54) [AB]	**0.002**
	Enamel	9.34 (0.29)	9.37 (0.44) [B]	7.44 (0.26)	7.43 (0.30) [B]	**0.002**
p		**< 0.001**		**< 0.001**		

Column of p-values refer to comparisons between types of Ceramics, by Substrate, in each Thickness category.
Lines of p-values refer to comparisons between Substrates, by Thickness category and by Ceramic Type.
Substrates identified with equal letters do not present statistically differences between them, p>0.001, relative to E, in each combination of Thickness/Ceramics.
x: mean; s: standard deviation; IIQ: interquartile range.

even though zirconia substrate has less evident difference (Figure 4).

Color index

The color, L*, C*, h*, a* and b* values registered over the black and white backgrounds, in both thicknesses, are presented in Table V.

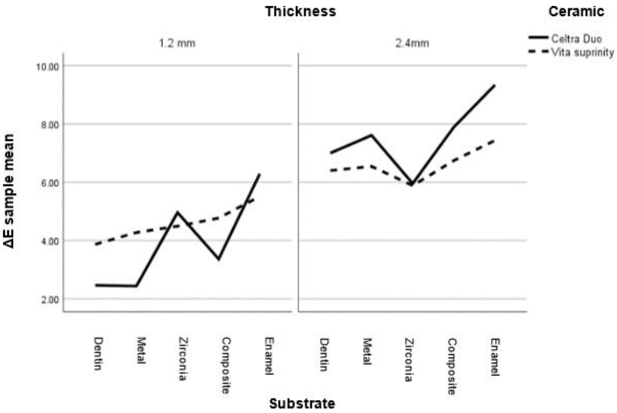

Figure 4 - Graphical representation of the ΔE sample mean per type of Ceramic, Thickness category and Substrate.

Vita Suprinity showed different colors, under the black or white background and also for both thicknesses. The color (B1 VITA) presented by the instrument for the Celtra Duo ceramic over the white background was consistent for both thicknesses, but it was impossible to determine colors under the black background.

The C* and b* values over the white background are higher for Vita Suprinity than for Celtra Duo, independently of thickness.

The L* values decreased with increased thickness for both ceramics, over the white background.

It was impossible to determine color parameters of Celtra Duo material over the black background. For that, the ceramic indexes were only calculated for Vita Suprinity and are presented in Table VI. The increase in thickness also increased the ceramic indexes values.

Table V - Descriptive statistics regarding the reading values given by the spectrophotometer, depending on the type of Ceramic, Thickness category and the background

Ceramic	Values	Color index			
		Thickness = 1.2 mm		Thickness = 2.4 mm	
		White	Black	White	Black
		x̄ (s)	x̄ (s)	x̄ (s)	x̄ (s)
Celtra Duo	L*	99.85 (0.26)	Error	87.09 (0.60)	Error
	a*	-2.79 (0.14)	Error	-1.88 (0.09)	Error
	b*	14.20 (0.39)	Error	12.76 (0.27)	Error
	C*	14.48 (0.36)	Error	12.91 (0.27)	Error
	h*	101.13 (0.80)	Error	98.39 (0.54)	Error
	color	B1	Error	B1	Error
Vita Suprinity	L*	92.75 (0.89)	60.12 (1.54)	79.75 (0.68)	72.2 (0.79)
	a*	0.32 (0.21)	-5.65 (0.20)	1.37 (0.10)	-3.6 (0.24)
	b*	28.93 (0.95)	5.79 (1.04)	23.78 (0.80)	14.5 (0.82)
	C*	28.93 (0.95)	8.15 (0.60)	23.83 (0.81)	15.0 (0.74)
	h*	89.33 (0.38)	134.74 (6.17)	86.82 (0.57)	103.9 (1.66)
	color	A3	D4	B3	C1

x: mean; s: standard deviation.

Table VI - Descriptive statistics related to Vita Suprinity ceramics, in relation to the optical properties indexes

Optical properties	Vita Suprinity	
	Thickness = 1.2 mm	Thickness = 2.4 mm
	x̄ (s)	x̄ (s)
TP	40.46 (1.99)	12.94 (1.03)
CT	0.34 (0.03)	0.78 (0.03)
OP	3.52 (0.33)	3.90 (0.28)

TP: translucency parameter, CT: contrast ratio and OP: opalescence parameter. x: mean; s: standard deviation.

DISCUSSION

Four null hypotheses were rejected, as significant differences for ceramic materials, substrates, backgrounds and material thickness were found and have influence on the restoration color.

The presented study evaluated the color properties of Zirconia-reinforced lithium silicate glass-ceramics and it simulated behavior for aesthetic single restoration over five different substrates, intended to simulate its use on the possible clinical situations over teeth (Enamel, Dentine and Composite) or implants (Zirconia or Gold colored abutments). Results showed that ΔE values were influenced by brand, thickness, substrate and background, confirming anterior studies on ceramic materials [31-34].

The increase in thickness showed higher ΔE values. In a different study, Vita Suprinity and other ceramic glass materials (IPS e.max CAD and Empress CAD) showed the contrary, revealing a less influence of the substrates on increased thicknesses between 1 and 2.5 mm, and clinical acceptable values (ΔE < 3) for the last over titanium and yellow zirconia substrates [35]. In the present study it was only registered the same clinical acceptable values for Celtra Duo ceramic on 1.2 mm thickness over dentin or yellow metal.

Celtra Duo showed lower ΔE values in 1.2 mm than Suprinity, but almost double values in doubled thickness (2.4 mm). Suprinity presented less variance to the increased thickness. These results suggest that Vita Suprinity light scattering is different from Celtra Duo, being the latest a more translucent material and more affected by the substrate color.

Zirconia substrate showed the lower ΔE values variance between substrates for both thicknesses. That may be related to the fact that as registered the higher L value, reflecting all the incident light because it is almost opaque on thicknesses higher than 0.6 mm [36].

Clinically the ceramic material choice is driven by the substrate color and thickness available for the restoration. Based on the results, if the available space is 1.2 mm than Celtra Duo would express lower ΔE values over the composite or gold color metal substrates, materials usually used in highly compromised tooth crown structure. If thickness increases to 2.4 mm, highly difficult to achieve over teeth but possible over implants, Vita Suprinity would be the choice to use over gold color metal, composite or enamel substrate. ΔE values, of both materials and thicknesses tested, over dentine substrate were high, extremely above the clinical acceptability threshold (ΔE ≤ 2.7) [27]. If considered that sound enamel would be the best substrate to achieve a perfect match color, using the same color material block, under the condition of the present study it is difficult to have clinical acceptable results in restorations made with materials and thicknesses tested.

Vita EasyShade® Compact V operates on L*, a*, b* for tooth mode and L*, C*, h* for restoration mode. Considering the L*, C*, h*, a*, b* values over the white background registered, the closest values registered were the a*, related to red content on green-red axis. The blue-yellow axis, expressed on b* were higher, revealing more yellow content. The L* was much higher but considering the white background it was expectable. However, considering that specimens compare to restorations, not to tooth, the C* values related to Croma and h* values related to Hue are way out of range to the target color. The results should drive attention to the color formulation of material blocks, to better understand if it is being addressed to achieve the restoration integration.

In the present study, material blocks were HT A1 VITA, but the Vita Easyshade equipment registered B1 VITA for Celtra Duo in both thicknesses and for Vita Suprinity it registered A3 VITA for 1.2 mm and B4 VITA for 2.4 mm thicknesses, over the white background. This color discrepancy may be attributed to color interaction with background, and the translucency difference between the two materials, showing more variability for Vita Suprinity. Available literature is not specific on background color parameters. In the present study, the white background registered: L* = 72.6; a*= -1.3 and b*= 9.1. The b* value shows a shift in the yellow side, in line with the different color registered towards the Vita B group for both materials.

It was impossible to calculate the color indexes TP, CR and OP, for Celtra Duo material, because it was impossible to register color determinants L*, C*, h* and/or a*, b* and ΔE* values over the black background with Vita Easyshade V spectrophotometer, showing an equipment limitation for these type of study on this type of ceramic materials. However, it can be stated that Celtra Duo is more prone to be influenced by the black background to a level that goes beyond the equipment capacity to register, thus indicating that Celtra Duo is a more translucent material than Vita Suprinity. This is in accordance with the registered ΔE values for different thickness, previously discussed.

Although the studied materials are presented, by fabricants, as equal and very similar to lithium di-silicate materials [37], they show difference light and color behavior between themselves and to lithium di-silicate. The differences must be related to its physical properties. The studied materials have slightly different zirconia content on its composition (according to manufacturer the Celtra Duo presents 10.1% ZrO2 and Vita Suprinity 8-12% ZrO2), susceptive of altering the physic/chemical properties and interaction with light, due to different scattering effect of light on crystalline and vitreous materials [28].

According to the fabricants Celtra Duo material as shown higher translucency values when compared to IPS e.max CAD, on 1 and 2 mm thicknesses polished specimens [38]. Fabricants related the result to the presence of small crystals (0.6-0.8 μm) on the glass matrix, smaller than the IPS e.max CAD particles (2.5 μm), revealing a higher proportion of glass matrix on Celtra Duo material [39]. On the zirconia reinforced lithium silicate ceramics, the zirconia grains diminish size after crystallization phase, making the material more translucent [28].

Vita Suprinity (A2 VITA) as also showed better translucency results (22.43 ± 0.69, $\bar{x}$ ± s) than IPS e.max CAD (20.41 ± 0.41, $\bar{x}$ ± s), 2 mm thicknesses specimens [40]. In another study with some CAD-CAM monolithic materials, Vita Suprinity (A2 VITA) showed lower translucency (14.26 ± 0.52, $\bar{x}$ ± s for 0.5 mm, and 23.30 ± 0.72, $\bar{x}$ ± s for 1 mm) than IPS e.max CAD, but the material blocks were LT, different from the previous study and the present, wish used HT blocks. The Vita Suprinity results are inside the range values obtained in the present study (40.46 ± 1.99, $\bar{x}$ ± s for 1.2 mm and 12.94 ± 1.0, $\bar{x}$ ± s for 2.4 mm). Translucency also decreased with thickness increase. However, the Vita Suprinity opalescence values, in that study, were the highest from all the materials tested (10.56 ± 0.61, $\bar{x}$ ± s for 1 mm) higher than the ones registered in the present study (3.52 ± 0.33, $\bar{x}$ ± s for 1.2 mm, and 3.9 ± 0.28, $\bar{x}$ ± s for 2.4 mm). Opalescence values almost don´t change with different thicknesses [41].

In a study that tested transmittance (360 – 540 nm), it was concluded that Celtra Duo had lower transmittance values than IPS e.max CAD and VITA Enamic, and transmittance decreased when thickness increased from 1 to 2 mm [42]. To better understand translucency properties between Celtra Duo and Vita Suprinity it is advisable to test both materials for transmittance (%T) in the visible spectrum. Translucency is a key factor to a correct material selection for a restoration [3,43].

The radio opacity of Celtra Duo and Vita Suprinity is higher than IPS e.max CAD material, due to their zirconia content. Radio opacity is an important property, allowing for radiographic control, especially important on dental implant rehabilitation control and recurrent caries and marginal adaptaion disorders [44].

In vitro tests over flat enamel and dentin surfaces are never easy, and the methodology used in the present study isn't perfect, but it was an improvement from other studies methodology. Choosing a tooth with the same color as the material block was the closest to real conditions. However, enamel/dentine translucency is always different from the shade guide colors [45]. There isn't always a perfect match between teeth and shade guides [46].

The use of portable spectrophotometers is more prone to introduce errors during color registration. The use of a positioner helps stabilize the equipment, especially over flat surfaces like the specimens tested [45,47]. In the present study, it was crucial to use a black opaque positioner that helped to center measurements over the specimens and substrates, but also to block light interference with the tip of the spectrophotometer. Another framework was also used to assure the same position of the first positioner over the same area of the enamel and dentine tooth surfaces.

Zirconia reinforced lithium silicate glass ceramics are still recent in the market, and few researches are available, showing very different conditions on tested materials, thicknesses, color and translucency of blocks and equipment, revealing some inconsistency in between study results. The presented study was the first to compare simultaneously these two materials on color and light behavior. It also presented a new methodology that should be considered for future studies. The conditions should be standardized, and cement materials should be added to test measurements.

Future research should focus on comparisons with different shades and the use of different batches of the same material. Also, of interest would be to study the influence of luting materials thickness and shades of different manufacturers on the final color and translucency of these materials.

CONCLUSIONS

Under the limitation of this in vitro test, we can conclude that the tested variables (ceramic material, thickness, substrate and background) have influence in the color of the zirconia reinforced lithium silicate ceramic restorations.

Celtra Duo ceramic in a 1.2 mm thickness over gold color metal and dentine substrates evidenced clinical acceptability results.

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Conflict of Interest

The authors have no proprietary, financial, or other personal interest of any nature or kind in any product, service, and/or company.

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Regulatory Statement

None.

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Legend:

CAD – CAM = Computer-aided design and manufacturing

h^* = Hue

C^* = Chroma

L^*= Luminance

ΔE = Difference between two colors

CIE = Commission Internationale de l'Eclairage

a^*= Red/green coordinate

b^*= Yellow/blue coordinate

T =Translucency

HT = Higher translucency

LT = Lower translucency

TP = Translucency parameter

B = Black

W = White

CR = Contrast ratio

OP = Opalescence parameter

Zr = Zirconia