Impact of background on color, transmittance, and fluorescence of leucite based ceramics

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This study evaluated the impact of tooth shade on differences in color (ΔE), lightness (ΔL), chromaticity coordinates a*b* (Δa and Δb), transmittance and the degree of fluorescence of CAD/CAM leucite based ceramic (LBC). Ten disks were fabricated of LBC; Empress CAD, A2, thickness of 1.5 mm and eight disks of resin-nano-ceramic (RNC; Lava Ultimate) in different colors to simulate variations in substrate shade. The associations of LBC disks with different color substrates were analyzed with a spectrophotometer; ΔE, ΔL*, Δa*, Δb*, and transmittance were measured and calculated. Fluorescence was evaluated with a fluorescence system (Fluorescence System, Biopdi). All substrate shades influenced the optical properties of LBC, with regard to color, luminosity, coordinate a* and b*, transmittance, and fluorescence (p<0.001). Substrate colors with high saturation (A3.5 and C2) presented highest impact, whereas colors with lowest saturations (BL, B1) showed less impact. Substrate color influenced the optical properties of ceramic restorations.

Keywords: Optical properties, Transmittance, Fluorescence, CAD/CAM materials, Background shade

INTRODUCTION

All-ceramic restorations are able to reproduce the natural characteristics of dental tissues, giving excellent esthetic results. Also, their excellent optical properties1-3 allow transmission and reflectance of light, enabling a close-to-nature reproduction of translucency and color of natural teeth.4-6 Ceramics are also selected for restorations due to their excellent biocompatibility3 and satisfactory mechanical properties4,5. In order to reproduce the correct natural appearance of dental restorations, it is necessary to understand some important optical phenomena like reflectance, transmittance, absorption and fluorescence7-12. Transmittance is particularly important for dental restorations and is also referred to as the amount of light transmitted through the material after disregarding the reflected and absorbed light13. The high transmittance of dental ceramics compared to metal alloys makes the control of the final appearance of restorations more difficult, as the color of dark backgrounds (e.g., metal posts) may be transmitted resulting in quantitative measurements that are not limited by photography methods21,22. Alternative methods use fluorimeters or spectrofluorimeters, resulting in quantitative measurements that are not limited by photography methods23.

Fluorescence is the optical property responsible for the perception of the “tooth vitality”10. This phenomenon takes place when light with short wavelength (invisible to the human eye) is absorbed by a material and afterwards reflected with a larger wavelength within the visible region. Fluorescence is therefore a consequence of the interaction of light with the atoms present at the surface of the material13. Dentin is three times more fluorescent than enamel and is responsible for most of the fluorescence behavior seen in teeth (Fig. 1)16. When natural teeth are exposed to ultraviolet (UV) light, they emit bluish-white fluorescence, while they appear yellowish-white under daylight17. Esthetic restorative materials should have enough fluorescence in order to give a natural appearance for the restoration in different light conditions18-21. Exhibiting satisfactory fluorescence, they are also able to illuminate the gingival areas where the interfaces between tooth and restoration are located, therefore decreasing the typical grayish area of the metal-ceramic fixed dental prostheses18-21. There are different methods that may be used to measure fluorescence. Some of them use photographs of the material under UV light, resulting in qualitative results, which are quite subjective and dependent on many factors such as type of camera, type of flash or light and also the observer21,22. Alternative methods use fluorimeters or spectrofluorimeters, resulting in quantitative measurements that are not limited by photography methods23.

The CIELAB system is frequently used to observe color differences. This system is composed by luminosity (L*), a* and b* coordinates. Coordinate L* correspond to the lightness of the material and to differences between the brightness or darkness. The coordinate a* corresponds to differences in red-green axis. Coordinate b* corresponds to differences in yellow-blue axis. Therefore, the identification of specific materials’ color changes with the spectrophotometer is possible.

Some studies showed that the tooth substrate shade...
has great impact on the final esthetic result of all ceramic restorations and could be one of the most important factors affecting their appearance. Ceramic veneers are usually fabricated as thin layers, especially when preservation of dental structures is desired by clinicians. Thin ceramic restorations have high transmittance and therefore the substrate shade has significant influence on the final optical result of all ceramic materials. The optical behavior of ceramic materials in specific clinical conditions has not yet been fully addressed by the current literature. For example, little has been published on the effect of the substrate value (lightness) on the final color of the restoration. In fact, lightness is considered one of the most important optical properties, since the human eye is more sensitive to this property than to hue or chroma. In addition, the effect of the material fluorescence on the optical properties of the final restoration has not yet been determined for a number of clinical conditions. Therefore, the aim of the present study was to evaluate the impact of the tooth substrate shade on the color differences, transmittance, and fluorescence of CAD/CAM leucite based ceramics (LBC). The first null hypothesis tested was that there are no differences in color (ΔE), luminosity (ΔL*) and coordinates a* (Δa*) and b* (Δb*) when the same LBC specimen is coupled to different substrate shades. The second null hypothesis was that transmittance of the pair LBC/substrate is not influenced by the substrate shade. The third null hypothesis was that the changes in substrate shade were not able to modify the degree of fluorescence of the CAD/CAM leucite based ceramics.

**Specimens fabrication**

Figure 2 illustrates all detailed steps of the research. The specifications of all materials as colors, compositions, lot numbers, and manufactures are listed in Table 1. Ten LBC disks were manufactured (thickness: 1.5±0.05 mm; diameter: 14 mm) to simulate a ceramic restoration (TC1 color A2). All disks were cut out of CAD/CAM leucite based blocks with high-translucency (Empress CAD, Ivoclar Vivadent, Schaan, Liechtenstein) with the Secotom-50 (Struers, Ballerup, Denmark) under constant water cooling and were mechanically polished (Abramin, Struers, Willich, Germany) on both sides by using a series of diamond grinding sheets (up to SiC P4000). Definitive thickness was determined with a digital micrometer (Mitutoyo IP65, Mitutoyo, Kawasaki, Japan).

To simulate different substrate values, eight disks (thickness: 2.0±0.05 mm; diameter: 12.0 mm; shades: A1, A2, A3, A3.5, B1, BL, C2, and D2) were fabricated using a RNC (Lava Ultimate, 3M ESPE, Seefeld, Germany). These specimens were also obtained from CAD/CAM blocks (Secotom-50, Struers) under constant water-cooling and underwent the same polishing procedures used for the ceramic disks.

All produced specimens were ultrasonically cleaned in distilled water for 5 min (Sonorex RK102H, Bandelin electronic, Berlin, Germany) and swiped with cotton on both sides to remove residues.

**Color difference for different substrates**

The color difference was determined comparing the parameters of each one of the eight combinations LBC/RNC with the average of L*, a* and b* values obtained from standard specimens. Each standard specimen consisted of three LBC disks (shade A2) that were stacked together to improve the thickness and obtain opacity. The L*, a* and b* parameters of each standard specimen was measured three times in reflectance mode over a white background (L*=111.71; a*=-.2.69, b*=9.46) in the center of its surface. These values of 10 standard specimens were averaged (L*=43.94, a*=-3.66 and b*=25.80) and used for posterior ΔE calculation.

Afterwards, the L*, a* and b* parameters for the different combinations LBC/RNC were obtained placing the LBC disk over the RNC disks with different shades (A1, A2, A3, A3.5, B1, BL, C2, and D2) using glycerin gel (Liquid Strip, Ivoclar Vivadent) to simulate the impact of different substrate shades (Fig. 1). Each experimental combination was measured 3 times in reflectance mode over the same white background and the averages L* a* b* were automatically calculated (UV Win LabTM, 2.8, Perkin Elmer, Waltham, MA, USA).

The color difference (ΔE) was determined according to the following formula:

\[ \Delta E = \sqrt{(L_s-L_c)^2+(a_s-a_c)^2+(b_s-b_c)^2} \]

Where the subscript “s” indicates the average value obtained from measurements of the standard specimens and the subscript “c” indicates the values measured in a specific LBC/RNC combination. Besides ΔE, lightness
Table 1  Material, manufacturer, lot, color and composition of all tested materials

| Material      | Lot Number | Color | Composition                                                                 | Manufacturer                      |
|---------------|------------|-------|-----------------------------------------------------------------------------|-----------------------------------|
| IPS Empress CAD | U22608     | HT A2/I 12 | leucite glass-ceramic of SiO$_2$-Al$_2$O$_3$-K$_2$O                          | Ivoclar Vivadent, Schaan, Liechtenstein |
| Lava Ultimate | N554166    | A1-LT | resin nano-ceramic-80 wt% nanoceramic particles bound in the resin matrix    | 3M ESPE, Seefeld, Germany         |
| Lava Ultimate | N495931    | A2-LT | resin nano-ceramic-80 wt% nanoceramic particles bound in the resin matrix    | 3M ESPE                           |
| Lava Ultimate | N634262    | A3-LT | resin nano-ceramic-80 wt% nanoceramic particles bound in the resin matrix    | 3M ESPE                           |
| Lava Ultimate | N547560    | A3.5-LT | resin nano-ceramic-80 wt% nanoceramic particles bound in the resin matrix    | 3M ESPE                           |
| Lava Ultimate | N552655    | B1-LT | resin nano-ceramic-80 wt% nanoceramic particles bound in the resin matrix    | 3M ESPE                           |
| Lava Ultimate | N552448    | BL-LT | resin nano-ceramic-80 wt% nanoceramic particles bound in the resin matrix    | 3M ESPE                           |
| Lava Ultimate | N552454    | C2-LT | resin nano-ceramic-80 wt% nanoceramic particles bound in the resin matrix    | 3M ESPE                           |
| Lava Ultimate | N554161    | D2-LT | resin nano-ceramic-80 wt% nanoceramic particles bound in the resin matrix    | 3M ESPE                           |
differences (ΔL) and chromaticity differences of coordinates a* (Δa*) and b* (Δb*) were also analyzed.

All reflectance measurements were performed with a spectrophotometer (Lambda 35 Perkin Elmer, Perkin Elmer) containing an integrating sphere with the measuring geometry D/8°, diffuse light at 10°, wavelength of visible light varying from 400 to 700 nm (1 nm intervals), opening width of 2 mm and scan speed of 460 nm/min.

Transmittance (T) for different substrates
The total transmittance was measured for each one of the LBC/RNC combinations used for ΔE. The bilayers were placed in the same equipment using the conditions described for reflectance measurements, however transmittance mode was used, and luminance values were obtained. Total transmittance (T) was calculated according to:

\[ T(\%) = \left( \frac{L_{\text{specimen}}}{L_{\text{source}}} \right) \times 100. \]

Where, L is the luminance of the specimens and of the source, respectively. L_{source} was obtained by making one measurement of L without any specimen placed in the optical path, which resulted in an L value of 30,000, corresponded to 100% of transmittance and served as the baseline for calculation.

Measurement of fluorescence
The degree of fluorescence was measured using an equipment to determine fluorescence for solids (Fluorescence System, Biopdi, Sao Paulo, Brazil) with a wavelength range of 405±15 nm. After calibration, the LBC/RNC combinations of disks were placed on the base of the equipment and an UV-light ray was emitted directly onto the specimen surface. Any fluorescence was captured by the apparatus and registered as fluorescence intensity versus wavelength intensity. First of all, pictures of samples were done inside the machine, using a LED and a green filter, allowing only emission of UV-light. Images were analyzed with software (Fluorescence System, Biopdi) and the fluorescence degree was determined and calculated using a fluorescence standard (a CAD-CAM block of RNC shade A2) that was considered as 100% fluorescence due its high degree of fluorescence. Afterwards, the fluorescence of each LBC/RNC combination was determined in terms of percentage in relation to that of the standard.

Statistical analysis
The differences in color (ΔE), lightness (ΔL), chromaticity (Δa* and Δb*) as well as the results of transmittance and fluorescence were statistically analyzed by calculating one-way ANOVA by a factor (substrate color) with a significance level of p<0.001 and multiple comparisons by Tukey’s honest significance test (p<0.05). Data were analyzed with SPSS version 22.0 (IBM, Armonk, NY, USA) and analysis results with p-values smaller than 0.05 were interpreted as statistically significant.

RESULTS

Color, luminosity, and chromaticity coordinate differences
The average of ΔE, ΔL*, Δa* and Δb* of each LBC disk was compared to allow the calculation of the fluctuation index (ΔS=2.06). This value confirmed that the used disks were homogeneous in relation to color. Means and standard deviations of parameters L*, a* and b* for the combination LBC/RNC with different shades and for the standard average of LBC disks (shade A2) are shown in Table 2.

1. Color difference (ΔE)
Table 3 shows the mean values of differences in color (ΔE), luminosity (ΔL*) and chromaticity (Δa* and Δb*) between the standard average (three LBC disks stacked together, shade A2) and each of LBC/RNC combinations with different shades. The highest ΔE values (p<0.001) were obtained when LBC disks (shade A2) were associated to background shades with the same hue (A2=10.33; A3=9.18 and A3.5=12.18). There were no statistical differences among the color difference measured for substrates A1, BL, and C2 (ΔE=4.08; 4.69 and 5.17, respectively), but they were statistically different from the standard average. Background hues B and D (B1=2.25; D2=2.15) resulted in similar ΔE values, which were significantly lower compared to those obtained for all other tested specimens. These values were also lower than the limit for human color difference perception in natural lighting conditions (ΔE=3.3)²³.

2. Lightness difference (ΔL)
Substrates A1 and BL (ΔL=−2.79 and −4.47, respectively) showed significantly lower ΔL values (p<0.001) compared to those obtained for the other substrates, which showed similar ΔL values.

3. Coordinates a* and b* difference (Δa* and Δb*)
Regarding variations of coordinates a*, except for substrate color BL, all substrate shades associated to LBC disks became more reddish compared to the standard, i.e., there was an increase in parameter a*, since the standard average showed a* values of 3.66 and, after association with the different substrates, all a* values increased, except for association with substrate BL (a*=3.61, Table 2). With respect to parameter b*, except for BL, all specimens also became more yellower, since the obtained b* values were higher than that obtained for the standard (b*=25.80) (Table 2).

As to Δa*, there were no statistical differences between substrate colors A1 and D2 (Δa*=−1.25 and −1.29, respectively) (p=0.99). All other shades showed statistically different Δa* values compared to A1 and D2. Substrate colors A2, A3, A3.5, and C2 (Δa*=-4.03; −3.68; −5.01, and −2.44, respectively) showed the lowest absolute values of Δa*, and these mean values were statistically different from each other. Specimens containing substrates B1 and BL (Δa*=-0.72 and 0.13, respectively) obtained the highest absolute Δa* values.
Table 2  Mean and standard deviation of the parameters $L^*$, $a^*$ and $b^*$ for the standard average (3 LS2 disks stacked together, shade A2) and of the combinations LBC/RNC with different shades (A1, A2, A3, A3.5, B1, BL, C2 and D2)

| Combination | $L^*$         | $a^*$         | $b^*$         |
|-------------|---------------|---------------|---------------|
| Standard average | 43.94±1.4 | 3.66±0.24 | 25.80±1.1 |
| LBC/A1      | 46.74±2.53 | 4.92±0.21 | 27.82±0.91 |
| LBC/A2      | 43.95±1.65 | 7.70±0.18 | 34.01±1.33 |
| LBC/A3      | 42.59±1.10 | 7.34±0.26 | 34.01±1.33 |
| LBC/A3.5    | 40.96±1.12 | 8.68±0.26 | 36.40±1.34 |
| LBC/B1      | 44.93±1.86 | 4.38±0.18 | 26.66±0.61 |
| LBC/BL      | 46.55±1.42 | 3.61±0.16 | 24.14±0.84 |
| LBC/C2      | 41.53±1.94 | 6.10±0.17 | 29.15±0.89 |
| LBC/D2      | 44.14±1.57 | 4.96±0.09 | 26.97±0.68 |

Table 3  Descriptive statistics with mean and standard deviation (SD) of color difference ($\Delta E$), luminosity difference ($\Delta L^*$) and chromaticity difference of coordinates $a$ ($\Delta a^*$) and $b$ ($\Delta b^*$) between the standard average (3 LS2 disks stacked together, shade A2) and the LBC/RNC combinations with different shades

| Combination of LBC with the following substrate shade: | $\Delta E$ | SD | $\Delta L^*$ | SD | $\Delta a^*$ | SD | $\Delta b^*$ | SD |
|-------------------------------------------------|--------|----|-------------|----|-------------|----|-------------|----|
| A1                                              | 4.08$^c$ | ±1.90 | -2.79$^b$ | ±2.53 | -1.25$^c$ | ±0.21 | -2.01$^b$ | ±0.91 |
| A2                                              | 10.33$^b$ | ±1.21 | -0.002$^a$ | ±1.65 | -4.03$^f$ | ±0.18 | -9.38$^c$ | ±1.21 |
| A3                                              | 9.18$^b$ | ±1.17 | 1.35$^f$ | ±1.1 | -3.68$^f$ | ±0.26 | -8.20$^c$ | ±1.33 |
| A3.5                                            | 12.18$^a$ | ±1.00 | 2.98$^b$ | ±1.12 | -5.01$^f$ | ±0.26 | -10.6$^c$ | ±1.34 |
| B1                                              | 2.25$^d$ | ±0.85 | -0.98$^e$ | ±1.86 | -0.72$^b$ | ±0.18 | -0.86$^b$ | ±0.61 |
| BL                                              | 4.69$^f$ | ±1.42 | -4.47$^b$ | ±1.42 | 0.13$^a$ | ±0.16 | 1.17$^a$ | ±0.84 |
| C2                                              | 5.17$^e$ | ±0.67 | 2.47$^a$ | ±1.94 | -2.44$^d$ | ±0.17 | -3.35$^b$ | ±0.89 |
| D2                                              | 2.15$^d$ | ±1.09 | -0.19$^a$ | ±1.57 | -1.29$^c$ | ±0.09 | -1.16$^b$ | ±0.68 |

The letters $^a$-$^c$ represents statistical differences of $\Delta E$, $\Delta L^*$, $\Delta a^*$ and $\Delta b^*$ between the groups.

It is important to note that in terms of variation in the final shade of the specimen in comparison to the standard, the negative or positive value of $\Delta a$ is not relevant. What really matters is how far from zero the $\Delta a$ value is, and this issue will be further explained in the discussion section.

With respect to $\Delta b^*$, no statistically significant differences were detected among the values obtained for A2, A3, A3.5 ($\Delta b^*$=−9.38; −8.20 and −10.6) (p=0.17). Also, the $\Delta b^*$ mean values obtained for substrates A1, B1, C2, and D2 ($\Delta b^*$=−2.01; −0.86; −3.35 and −1.16) were statistically similar and significantly higher than the mean values obtained for the previously mentioned groups (p<0.001). Substrate shade BL showed significantly higher $\Delta b^*$ (1.17) compared to all other groups. Again, the negative or positive value of $\Delta b$ is not relevant, but the how far from zero the value is.

Results of variance analysis as well as $p$ values are listed in Table 4.

Transmittance ($T$)
The percentage of $T$ varied significantly among the tested substrates ($p<0.001$) (Table 5). The highest values of $T$ were observed for substrates with low saturation, like BL and A1 (14.4 and 14.9%, respectively), which had similar transmittance values ($p>0.05$). The $T$ values of shades A2 (13.0%), B2 (13.0%), and B1 (13.5%) were statistically similar and significantly higher than those obtained for shades C2 (11.5%) and A3 (12.1%). The lowest transmittance mean value was obtained for shade A3.5 (11.1%) (Table 5).

Fluorescence
There were statistical differences among the
fluctuation values obtained for the different tested shades (p<0.001). All combinations of LBC (A2) disks with the different substrate shades resulted in significantly lower fluorescence compared to the RNC standard, which was considered as having 100% fluorescence (Table 6).

When LBC disks were associated to the same substrate shade (A2), the degree of fluorescence was 21.4%. The lowest fluorescence was obtained by shade A3.5 (22.4%), followed by C2, A2, and A3 in an increasing order (21.4, 22.4, and 21.4%). The highest fluorescence mean values were obtained for shade BL (46.7%) and B1 (42.8%), which were statistically different.

**DISCUSSION**

Results of color (ΔE), luminosity (ΔL*) and coordinates a* (Δa*) and b* (Δb*) differences showed important statistical significant differences among some of the associations LBC/RNC. Regarding the color difference (ΔE), the leucite based ceramic tested was affected by the substrate shade, what is in agreement with previous studies reported in literature. Almost all ΔE values were greater than 3.3, which represent the value of clinically perceptible color change. When the saturation of the substrate increased, higher ΔE values were observed for the corresponding LBC/RNC combination, indicating that tooth substrates with dark shades results in highest color differences, clinically detectable. Minor color changes (ΔE) were seen, when the LBC disk was placed over substrates with less color saturation, such as BL and B1, indicating that lighter substrate colors are easier for clinicians to deal with controlling the final shade of the restoration. In addition, previous studies also reported higher ΔE values when leucite based ceramics were placed over darker substrates.

No studies analyzing the effect of substrate color on parameters ΔL*, Δa*, and Δb* of the combination leucite based ceramic/substrate were found in the current literature. In the present manuscript, each factor (ΔL*, Δa*, and Δb*) was analyzed separately, due to the necessity to identify the influence of the background on them.

Important statistical differences were found for ΔL*, mainly on BL (ΔL*=−4.47). This indicates the alteration on luminosity against different substrate shades.

The values obtained for the parameters Δa* and Δb* suggest that substrate with highest color saturation like A3 and A3.5, significantly affects the final color of a leucite based ceramic restoration. The Δa* and Δb* values obtained for these substrates indicated they
result in a restoration with high amounts of yellow and red shades. Therefore, the first hypotheses, that there are no color ($\Delta E_b$), luminosity ($\Delta L^*$) and coordinates $a^*$ ($\Delta a^*$) and $b^*$ ($\Delta b^*$) differences between the ceramics when different substrate colors are simulated was rejected.

Differences in coordinates $a^*$ and $b^*$ are presented by the results by subtracting the coordinate $a^*$ value of the standard average from $a^*$ value of the combination LBC/RNC. Therefore, it is important to analyze its resulting positive/negative value; for example $\Delta a^*$ = 1.25 in A1 shade demonstrates less difference than $\Delta a^*$ = 5.03 in A2 shade. The coordinate $a^*$ corresponds to red-green axis and the coordinate $b^*$ to yellow-blue. The $\Delta a^*$ value below zero represents the specific specimen more colored in green (−values) than the standard average. If the value is above zero, the sample showed more red (+values). For the $b^*$ coordinate, $\Delta b^*$ below zero means the sample is more blue colored (−values) than the standard average and above zero means the sample is more yellow (+values).

Regarding transmittance, the results showed different values depending on the substrate shade and, as expected, decreased transmittance values were observed for darker substrates. There are different methods to evaluate the transmittance of a specimen, namely contrast ratio and translucency parameter\(^{30}\). However, these parameters do not allow a precise measurement of specimens displaying less than 50% of total transmittance\(^{35}\). In the present study, the measured of total transmittance indicated that all experimental groups had less than 50% of transmittance due to fact that the final specimen was relatively thick, as it had one layer of leucite based ceramic and another of RNC, resulting in total thickness of 3.5 mm. As shown in Table 5, there were statistically significant differences among almost all tested substrates, allowing for rejection of the second null hypothesis. The influence of the substrate shade on transmittance of restorations can be related to the fact that dark colors tend to result in more block of the light, decreasing the transmittance through the material. Moreover, lightness shades result in less influence due to allow the passage of the light through the restoration.

To evaluate the fluorescence degree of dental materials, different methods can be used and most of them have already been described in literature, such as the use of photographs\(^{21}\) and measurement performed with fluorimeter or spectrofluorimeter\(^{18}\). In the present study an innovative method was used to measure fluorescence, which allows for quantitative determination of the fluorescence degree in relation to a standard specimen. A RNC CAD/CAM block was used as standard as it is a substrate than can be easily reproduced by other researchers. Natural tooth could have been used as the standard, but it represents a much more variable substrate that cannot be reproduced easily\(^{16,17}\). Fluorescence results indicated that all associations of LBC with the different substrates were less fluorescent than the RNC standard. Hence, it is clear the placing a LBC layer over a RNC substrate results in lower fluorescence degree due to the decreased fluorescence. From the clinical standpoint, it is important to understand these results indicate that leucite based ceramic restorations might reduce the final fluorescence of the restored tooth compared to the surrounding teeth, although one should keep in mind that dental tissues are much less fluorescent than RNC and therefore these differences may not be so evident. Substrates with highly saturated shades (A3.5 and C2) were the ones with lower fluorescence mean values, while those with less saturated shades (B1 and BL) resulted in approximately double the fluorescence of the first two. Therefore, since the fluorescence was affected by the substrate shade, the third null hypothesis of this work was rejected.

No studies were found regarding the influence of substrate shade on transmittance and fluorescence of leucite based ceramics, making difficult to compare the results of the current investigation with those from the literature. All studied color parameters were significantly affected by the substrate color of leucite based ceramic. This outcome is probably related to the fact that CAD/CAM leucite based ceramic materials have relatively high total transmittance. However, it is important to note that there are commercial blocks with different degrees of transmittance available on the dental market (e.g. as low-translucency, LT, medium opacity, MO, and high translucency, HT) and therefore, the results observed in the present study may vary according the translucency of the block used.

Based on the present results, the authors would like to highlight the importance of taking into consideration the substrate shade when producing leucite based ceramic restorations. Backgrounds with dark colors such as A3 or A3.5 are very unfavorable for thin leucite based ceramic restorations (less than 2.0 mm in thickness). In such situations, specific procedures are necessary to overcome the problem of color matching of the final restoration\(^{19}\). To solve this problem, some authors recommend deeper axial preparation during preparation. Although this type of procedure is not ideal in terms of tissue preservation it allows both the clinician and the technician to mask the dark background with either the restoration itself or the luting material\(^{10}\).

Another important finding of the current investigation was that substrate shades with lower color saturation have less influence on the appearance of the final restoration in comparison to highly saturated substrates. Therefore, when less saturated substrates are present, it is possible to apply thinner ceramic restorations without jeopardizing the final clinical result in terms of color. It is also important to note that other factors affect the final color of leucite based ceramic restorations, like the optical properties of the resin cement and therefore, the use of try-in pastes for very thin restoration is mandatory in order to predict the final color after cementation.

Among the limitations of the current investigation, it is possible to cite that only one type of leucite based ceramic was evaluated, and therefore the validity of the
results presented here is limited to the evaluated brand. For future works, the influence of other factors such as resin cement shade and ceramic thickness should be considered.

CONCLUSION

It was possible to observe the importance of the substrate color on all evaluated parameters: shade, transmittance, and fluorescence. This highlights the importance to know the type of substrate against leucite based ceramic restorations and to improve the color of them to the most similar to natural teeth in order to achieve optimal esthetic results.

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CONFLICT OF INTEREST

All authors disclose any financial and personal relationships with other people or organizations that could inappropriately influence this work.

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