The influence of color parameters on the translucency of a ceramic material

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The aim of the present study was to determine the influence of the difference in color parameters on translucency of a ceramic material used for the fabrication of metal-ceramic restorations. Transparent porcelain was used with different concentrations of shaded porcelain to obtain disks with gradual changes in translucency. CIEL*a*b* parameters were recorded with a spectrophotometer and translucency parameter (TP) was calculated. ΔL* values were highly correlated with TP values. No significant correlation was found between TP and Δa*. Translucency was influenced by the changes in lightness and yellow–blue coordinate and disks that were more chromatic showed lower translucency values.

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1. Introduction

The advances in material sciences and technologies in the last decades made possible the use of highly esthetic all-ceramic crowns as a routine treatment in almost every dental office worldwide. The need of treatment using ceramic restorations addresses frequently to different types of coronal loss or discromia. Therefore, the ceramic materials used for the fabrication of restorations have not only to replace the missing tooth structures, but also to mask the discromic tooth substrate. Ceramic materials can accurately reproduce the natural appearance of tooth structures, if the appropriate shade and characteristics of teeth are precisely transmitted to the dental technician through a color map of the restored tooth. Besides dental shade, translucency is the key element in reproducing the vivid look of a natural tooth. Translucency is the property of a material that can be described as partial opacity or a state between complete opacity and complete transparency[1]. Translucency is best quantified by value (lightness) differences [2]. Highly translucent teeth appear darker, since they allow passing a larger amount of light. Teeth that are more opaque appear brighter, because light is reflected from their surface. The translucency of natural teeth tends to decrease from the incisal area towards the central area[3].

The ceramic powders differ in respect to their shade and translucency. In order to gain a natural aspect of the tooth, dental technician uses stratified ceramic masses in various shades and translucencies; basically, opaque, dentin, enamel and translucent ceramic powders are needed to build-up the restorations with a natural look. The relation between the color parameters and the translucency is not fully understood when it comes to the stratification methods used in feldspathic ceramic- dental technology.

The aim of the present study was to determine the influence of color parameters and the difference in color parameters on the translucency of a feldspathic ceramic material. The null hypotheses were: 1. The differences in color parameters did not influence the translucency; 2. The amount of shaded porcelain did not influence translucency values.

2. Materials and methods

2.1 Preparation of specimens

Transparent feldspathic layering porcelain (Noritake EX3 Tx0, Noritake Kizai Co., Japan) was blended with different concentrations of shaded porcelain (A3 body) to obtain 11 groups of disks (10mm diameter/0.8mm thickness, 3 disks/group) with gradual changes in translucency (Table 1). The firing cycles were performed in a sintering furnace (VITA Vacuumat 40T, VITA Zahnfabrik, Germany) according to the manufacturers' baking schedule. Finishing of both sides of the ceramic disks was done with carbide burs (fine grit) and sandpaper (320, 600, 1200 grit). After fabrication, the specimens were cleaned with distilled water in an ultrasonic bath (5 min, 25°C) and dried. All disks underwent a self-glazing firing cycle.

Table 1. The amount of shaded porcelain blended with the transparent porcelain for obtaining the eleven groups of disks.

Group	Tx0 (mg)	A3B (mg)	A3B (%)
1.	**800**	**0**	**0%**
2.	**784**	**16**	**2%**
3.	**768**	**32**	**4%**
4.	**752**	**48**	**6%**
5.	**736**	**64**	**8%**
6.	**720**	**80**	**10%**
7.	**704**	**96**	**12%**
8.	**688**	**112**	**14%**
9.	**672**	**128**	**16%**
10.	**656**	**144**	**18%**
11.	**640**	**160**	**20%**

2.2 Color measurements

Ceramic disks were measured with a dental spectrophotometer (VITA Easyshade, VITA Zahnfabrik, Germany) and CIE L*a*b* and chroma (C*) parameters were recorded over black and white ceramic tiles. An optical liquid (83.6% sucrose solution, refractive index~1.5) was interposed between the disks and the tiles, and the measurement tip of the dental spectrophotometer was held in tight contact with the surface of the disk. Three measurements were recorded for each disk. One experienced dentist performed all the measurements.

Translucency parameter (TP) was calculated according to the equation:

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

L_W^*, a_W^*, b_W^* are the color parameters recorded over white background and L_B^* , a_B^*, b_B^* are the color parameters recorded over black background. Differences in color parameters were calculated by subtracting the values over black background from values over the white background (ΔL*, Δa*, Δb*, ΔC*).

Descriptive statistics and Pearson correlation coefficients were computed between translucency values and ΔL*, Δa*, Δb*, ΔC*, as well as between translucency values (TP) and the concentration of shaded porcelain (Sp). Multiple linear regression analysis between TP as a dependent variable and ΔL*, Δa*, Δb*, ΔC* and Sp as independent variables was also performed.

3. Results

Descriptive statistics for TP, ΔL*, Δa*, Δb*, ΔC* is presented in Table 2.

Table 2. Ranges, means and standard deviations (SD) of TP, ΔL, Δa*, Δb*, ΔC**

	Range	Minimum	Maximum	Mean	SD
TP	12,39	53,88	66,27	59,36	3,34
ΔL*	12,70	53,50	66,20	59,18	3,43
Δa*	0,80	-0,60	0,20	-0,06	0,12
Δb*	4,30	2,30	6,60	4,47	1,23
ΔC*	6,20	-0,60	5,60	2,71	1,70

Pearson's correlation coefficients between TP and the differences in color parameters, Chroma (C*) and the amount of shaded porcelain (Sp) are listed in Table 3.

Considering that Pearson correlation coefficient takes values between +1 and -1, the closer the coefficient is to +1 or -1, the stronger the association. In this sense, ΔL* values were highly correlated with TP values. Moreover, a negative high correlation between TP and Δb*, and TP and ΔC*, and TP and Sp was also observed. No significant correlation was found between TP and Δa*.

Based on a linear multiple regression analysis in which TP was set as the dependent variable and the differences in color parameters and the amount of shaded porcelain (Sp) were set as the independent variables, the following predictors were obtained (Table 3).

Table 3. Pearson's correlation coefficients and predictors on the TP values based on multiple regression analysis ([a]Significant at the significance level of 0.01; [b]No significant correlation).

	***r*-value**	**β**	***t***	**R^2**
ΔL*	1[a]	1	576,195	1
Δa*	0,060[b]	0,060	0,593	0,004
Δb*	-0,843[a]	-0,843	-15,431	0,711
ΔC*	-0,864[a]	-0,864	-16,867	0,864
Sp	-0,871	-0,871	-5,594	0,885

The coefficient of determination (R^2) describes the amount of the total variance explained by a predictive model, in this case the regression equation, and varies between 0 (no correlation) and 1 (perfect correlation).The variation of translucency parameter could be best explained by the variation of ΔL*, since a coefficient of determination of 1 was obtained. Similarly, the change in translucency of the tested ceramic material could be explained by the variation of Δb*, ΔC* and the amount of shaded porcelain (Sp), although lower values for R^2 were obtained.

Regression equation for TP and Sp was computed as follows:

$$TP=-0.156*Sp+61.075,$$

meaning that if raising the amount of shaded porcelain (Sp) by 1%, TP value will drop by 15,6%. Correspondingly, the following equations were calculated for TP and ΔL*, TP and ΔC*, TP and Δb*:

$$TP=0,974*\Delta L^{*}+1,724;$$

$$TP=-1,698*\Delta C^{*}+63,977;$$

$$TP=-2,278*\Delta b^{*}+69,556.$$

Scatter plots of the differences in color parameters and TP values are presented in Fig. 1a,b,c,d. As shown in Fig. 1c, Δa* values did not follow a linear trend as for ΔL*, Δb*, and ΔC*, therefore supporting the hypothesis that there is no correlation between the variation of translucency parameter and the change on the a* axis for the tested material.

4. Discussion

The CIE L*a*b* color space has become largely used in dental research to report color parameters in studies on color selection. It is a rectangular coordinate system, where CIE L* coordinate (lightness or, value) is represented on a vertical axis, with values ranging from 0 (black) to 100 (white). Lightness is an achromatic property of color, which is one of the most important attributes. The CIE a* and the CIE b* coordinates represented on two horizontal axes, express the amount of redness-greenness or yellowness-blueness of a color. The CIE also defined cylindrical polar coordinates as correlates of lightness (L*), chroma (C*) and hue angle (h*)[4]. The CIE L*a*b* color coordinates are required for the calculation of the translucency parameter.

Dental ceramics are divided in three main classes: predominantly glassy materials, particle-filled glasses, and polycrystalline ceramics. Predominantly glassy materials are best mimicking the optical properties of enamel and dentine. Glasses in dental ceramics are obtained from minerals called feldspar and are based on silica (silicon oxide) and alumina (aluminum oxide). Therefore, these types of materials are also known as aluminosilicate glasses or feldspathic ceramics [5]. Several types of ceramic powders are required to be mixed, layered, and sintered in order to fully restore the anatomical shape of a tooth. According to the properties and the purpose of the ceramic masses, there are different types of shades, opacities/translucencies (opaque, dentine, enamel) and effects (opal, translucent, stains).

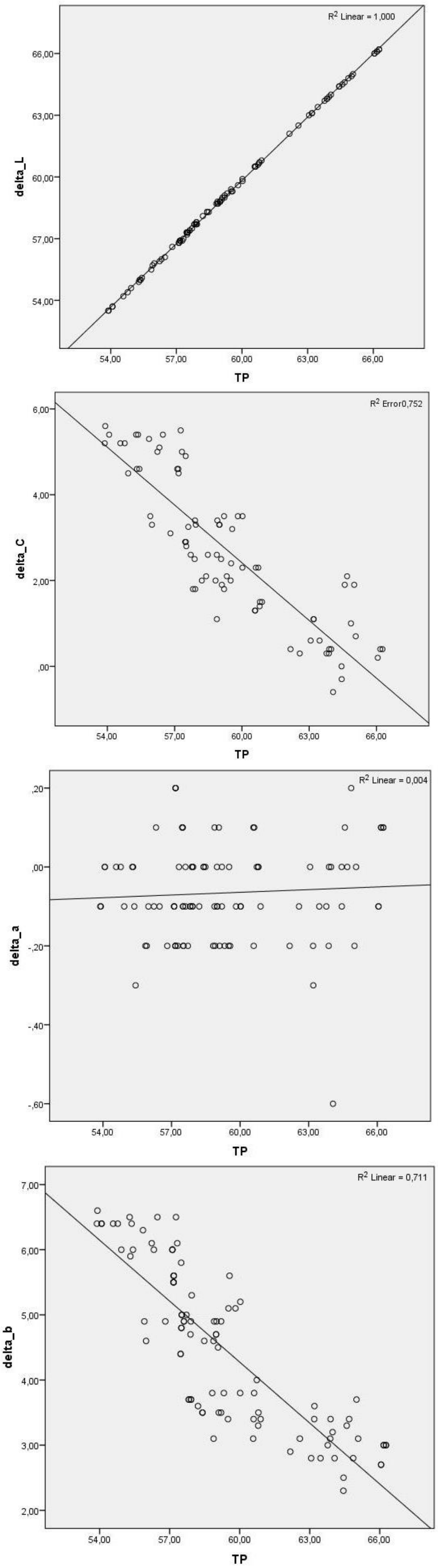

Fig. 1a,b,c,d. Scatter plots for TP and ΔL, ΔC*, Δa* and Δb*.*

Increased translucency correlated with improved esthetics is the primary advantage in using an all-ceramic restoration. However, translucency of a restoration varies greatly according to the type of ceramic material used. Oxide-based ceramics are more opaque, but have a high fracture resistance, while silica-based ceramics are more translucent and less resistant to flexural forces [6].

Several methods for translucency measurements are available: direct transmittance measurement, contrast ratio and translucency parameter determinations [7]. TP measurements were first reported by Johnston et al. [8] in 1995 who did direct measurements of translucency for maxillofacial elastomers. Since then, TP was used in numerous studies for reporting translucency values of different restorative materials [9-12]. In our study, we have used a dental spectrophotometer for recording the color parameters of the ceramic disks. One of the limitations could derive from this aspect, since most of the studies report that measurements were performed with professional spectrophotometers. However, Lim et al. [13] demonstrated that spectroradiometric and spectrophotometric measurements were different but highly correlated.

The first null hypothesis was partly rejected since significant correlations between TP values and the differences in color parameters were found, except for Δa^*. The difference in lightness between the black and white background was very high (ΔL^*=12,70 units), as compared to the difference in red-green coordinate (Δa^*=0,80 units). This could explain the strong correlation between TP and ΔL^*, and the lack of significant correlation between TP and Δa^*.

Moreover, correlation between TP values and the difference in chroma was also found to be significant which means that disks that were more chromatic were less translucent. Similar results were presented by Yu et al.[14] who assessed the influence of color parameters and the difference in color parameters by the background on the translucency of resin composites. They concluded that translucency was mainly influenced by the variation of L* and b* parameters.

The amount of shaded porcelain that was incorporated in the ceramic disks was highly correlated with TP values. By this, the second null hypothesis is rejected.

Multiple regression analysis was performed to determine which parameters could better explain the variation of translucency parameter. As it can be noted, the a* parameter could not explain the change in translucency for the tested ceramic material. The best predictive model was found for ΔL^*, followed by Sp, ΔC^*, and Δb^*. However, it should be taken into consideration that only one type of shaded porcelain was used (A3B), and therefore the predictive models fit only for this combination.

Conclusions: within the limitations of the study, it can be concluded that:

1. translucency was influenced by the changes in lightness and yellow–blue coordinate
2. disks that were more chromatic showed lower translucency values
3. by increasing the amount of shaded porcelain, translucency values dropped

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