STUDIA UBB CHEMIA, LIX, 4, 2014 (p. 87-94)
(RECOMMENDED CITATION)

TRANSLUCENCY VARIATION OF LITHIUM DISILICATE CERAMICS WITH CLINICALLY RELEVANT THICKNESSES

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ABSTRACT. The aim of this study was to investigate the relationship between translucency and thickness of IPS e.max lithium disilicate ceramics (Ivoclar Vivadent). 100 ceramic disks were pressed out in four opacities (high opacity (HO), medium opacity (MO), low translucency (LT) and high translucency (HT) and in five clinically relevant thicknesses (0.3mm, 0.6mm, 0.9mm, 1.2mm, 1.5mm +/-0.1mm) (n=5). The CIE L*a*b* colour parameters against black and white backgrounds were recorded with a dental spectrophotometer (VITA Easyshade®, VITA Bad Säckingen, Germany), in D65 light source (JUST LED Color Viewing Light, JUST Normlicht, Weilheim/Teck, Germany) in a dark room. The translucency parameter (TP) was calculated for each sample. The data were statistically processed with a 2-way ANOVA test, followed by the Tuckey Honestly Significant Difference (HSD). Results showed that TP values recorded for ceramic materials with higher opacity (HO, MO) were lower than those for materials with lower opacity (higher translucency) (LT, HT), with a high statistical significance ($P<.01$). There was an exponential regression curve between thickness and the TP values, with a very good correlation (R^2=0,981-0,998). In conclusion, translucency of dental ceramics was significantly influenced by thickness and type of material, with an exponential relationship between TP and thickness.

Keywords: *Lithium disilicate, translucency, ceramic thickness*

INTRODUCTION

Full ceramic restorations have been preferred to traditional metal ceramic due to their excellent esthetic properties and clinically acceptable mechanical properties. Ceramic materials were extensively investigated and constantly improved in order to provide tooth comparable optical properties [1-4]. Enamel

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and dentin, two functionally and optically different materials, are layered together and interact in a unique way to fulfill their functions [5, 6]. The additional difficulties faced when reconstructing teeth in the anterior area are small dimensions, convex surfaces of teeth, surface texture [7].

Translucency has been found to be one of the main factors influencing the esthetic result of ceramic restorations [8]. Translucency is also closely linked to light transmission through ceramics and to polymerization efficiency of underlying luting agents [9-12].

In order to assess translucency, several methods are used:

Absolute translucency determinations need a dual beam, integrating sphere radiometer or spectrophotometer which is able to record all the intensity of light transmitted through a sample in comparison to the intensity of light from a split beam. A quantitative measurement of absolute translucency was created by calculating the total transmission (T%) of light through the sample, by using a spectroradiometer, according to the formula

$$T\% = (L^*_{sample} / L^*_{source}) \times 100,$$

where L^*_{sample} stands for luminance recorded with the sample in place, and L^*_{source} stands for luminance reading with no sample in place [13].

Quantitative relative translucency, *contrast ratio* (CR), is registered with any system capable of registering standard radiation intensity and determination according to the formula

$$CR = L_B/L_W,$$

where L_B is the luminance flux (reflectance) with the specimen on a black background and L_W is the luminance flux (reflectance) with the specimen on a white background [13].

The *translucency parameter* (TP) appeared as an extension of the contrast ratio parameter and was introduced in 1995 in order to investigate the translucency of maxillofacial elastomers [13]. The TP formula is based on the color difference of the L*, a*, b* parameters for the samples on black and white backgrounds. The formula is:

$$TP = ((L^*_B - L^*_W)^2 + (a^*_B - a^*_W)^2 + (b^*_B - b^*_W)^2)^{1/2}.$$

The TP parameter was considered one of the most important visual evaluators [14] and has been one of the most widely used methods to compare relative translucency of dental materials.

In clinical situations when ceramic restorations are recommended, factors such as the available space as well as color and dimensions of the prosthetic appliance should be considered. Therefore, the relationship between translucency and thickness of ceramic restorative materials needs to be thoroughly investigated in order to achieve improved esthetic results.

Lithium disilicate glass ceramics are materials largely used nowadays, due to their mechanical and optical properties that enable the enlargement of the indications in comparison with other ceramic materials. The IPS e.max of the Ivoclar Vivadent Company is a concept designed to adapt to any indication for all-ceramic restorations. One of the processing categories is the IPS e.max Press, pressable ingots of lithium disilicate glass ceramics [15].

The translucency of dental ceramics has been identified within a certain range [16], mostly at material thicknesses recommended by the manufacturers. These values do not totally overlap those of natural enamel and dentin, and therein lays the difficulty to perfectly match the translucency of natural teeth [17-20]. The translucency parameter and CIE L*, a*, b* color parameters of ceramics have previously been investigated [16, 21-23] with either spectroradiometers, spectrophotometers, or dental spectrophotometers. However, the easiest to use and in reach devices for clinicians and dental technicians are dental spectrophotomers [24].

The aim of this study was to investigate the relationship between translucency and ceramic thickness for the IPS e.max Press lithium disilicate ceramics. The null hypothesis was that the translucency of ceramics was not influenced by the type of opacity of the ceramics or its thickness.

RESULTS AND DISCUSSIONS

The mean TP values for the IPS e-max Press ceramics used in this study ranged 5.67 to 12.78 (Table 1). The TP mean values decreased in the following order HT, LT, MO, HO, with the exception of the 0.3mm thickness where the order was LT, HT, MO, HO. The TP mean values ranged less for the more translucent materials (8.74 to 12.47 for HT and 8.34 to 12.78 for LT) and more for the more opaque ones (7.86 to12.01 for MO and 5.67 to 11.49 for HO). Also, the TP decreased with the increase in ceramic thickness for all opacities.

Table 1. TP mean value and standard deviation (SD) for the lithium disilicate glass ceramics

Ceramic opacity	0.3mm	0.6mm	0.9mm	1.2mm	1.5mm
HO	11.49	9.75	8.31	7.02	5.67
SD	*0.60*	*0.18*	*0.21*	*0.41*	*0.29*
MO	12.01	11.35	9.64	8.98	7.86
SD	*0.25*	*0.15*	*0.19*	*0.32*	*0.26*
LT	12.78	11.65	10.48	9.14	8.34
SD	*0.19*	*0.20*	*0.25*	*0.53*	*0.31*
HT	12.47	11.68	10.67	9.81	8.74
SD	*0.39*	*0.29*	*0.53*	*0.63*	*0.39*

The results of the 2-way ANOVA showed that both main factors (material and thickness) and their interaction were statistically significant (P<.01) (Table 2). The increase of the TP of the more translucent ceramics due to a decrease in thickness was greater than that of the more opaque ceramics.

Table 2. Results of 2-way ANOVA of TP values of lithium disilicate glass ceramics

Source	Sum of Squares	*df*	Mean Square	F
MATERIAL	75.98	3	25.33	17.20
THICKNESS	68.00	4	17.00	11.55
MATERIAL * THICKNESS	94.79	12	7.90	5.37
Error	117.78	80	1.47	
Total	10142.80	100		

The regression analysis of the TP by thickness revealed that the correlation between thickness and the TP value was exponential, according to the resulting equation. The calculations of the regression equations are illustrated in table 3. Very good correlation coefficients with very high statistical significance were found for all four materials tested (R^2=0,981-0,998).

Table 3. Regression analysis results of TP (y) by thickness (x) of lithium disilicate glass ceramics

Code	Regression equation	R^2	*P*
HO	$y = 13.822e^{-0.58x}$	0.996	<0.001
MO	$y = 13.63e^{-0.361x}$	0.981	<0.001
LT	$y = 14.38e^{-0.365x}$	0.995	<0.001
HT	$y = 13.816e^{-0.295x}$	0.9912	<0.001

R^2=correlation coefficient

The null hypothesis, that translucency was not influenced by the type and thickness of ceramics was rejected.

The results of our study are in agreement with literature [21, 25, 26] that translucency of ceramic materials decreases with the increase in thickness. Heffernan et al. [17, 18] stated that the difference in translucency of ceramic materials is mainly influenced by the varied crystalline structure and specimen thickness. The microstructure of lithium disilicate ceramics is represented by needle like crystals (3 to 6 µm in length), embedded in a glass matrix [15] that resemble the natural structure of enamel, thus facilitating the reproduction of a natural warm aspect of restorations.

The four types of ceramic opacities indicated TP values in agreement with the manufacturer indications. The high opacity ceramics had the smallest TP values and the more translucent materials had higher TP values. Increased opacity of the ceramic material (HO and MO) also meant greater decrease of the TP values with the increase in thickness of the sample. From a clinical point of view, this transfers into better masking capacity of the substrate when in a thinner layer, e.g. a 0.6mm substructure. Higher translucency of LT and HT ceramics translate into a smaller variation of TP in the range between the 0.3mm and 1.5mm samples. Clinically this will allow for a thinner layer of ceramics, hence a more economical tooth preparation in the cases where no masking of the tooth background is needed.

The thickness of the ceramic samples in our study was based on various clinical needs and indications. Veneers can be as thin as 0.3mm, ceramic copings up to 0.7mm [1, 23], and fully anatomical restorations have an average 1.5mm thickness on the labial surface [25] and 2mm thickness [27] in the incisal area [26].

The TP values for 1mm thick human enamel are 18.7 and 16.4 for dentin [28]. Several other studies have investigated the TP factor in dental ceramics [16, 21-23, 29, 30] using different types of materials and different recording devices. Optical parameters of ceramic materials can accurately be registered either by using a spectroradiometer or a spectrophotometer. Some studies compare the two methods and draw the conclusion that their findings correlate [16]. Other studies compared an oral spectrophotometer (Vita Easy Shade, Vita) with a reference spectrophotometer and concluded that the use of the oral spectrophotometer in research will mean different values than those recorded with a reference spectrophotometer, but still highly correlated [31].

Our study used the Vita Easy Shade dental spectrophotometer for the recording of the color parameters. The use of a different measuring device might be responsible for the differences in TP values, in comparison to the ones reported by Wang [21] who used a reference spectrophotometer. Also, the decrease in the window size when recording color parameters resulted in lower CIE L*a*b* measured values [32]. In addition, small-window tooth color recordings may result in edge loss of light due to tooth translucency [33].

The regression analysis used in the present study showed that the more translucent a ceramic material was, a greater change in TP would be expected as a result of thickness variation. This was in agreement with the results of Wang [21] and Antonson [34].

When creating esthetic reconstructions ceramic materials need to reproduce the structure, color, surface texture and translucency of natural teeth, in adequate material thickness and appropriate shade matches [23, 35]. The color of the underlying background and the luting agent also play a role in achieving the desired masking effect of an esthetic reconstruction [36].

Based on the results of the present study and in relation to clinical considerations, the contribution of the discromic substrate to the final perceived color of a restoration should also be considered, along with the input of luting agents available.

CONCLUSIONS

Within the limitations of the present study, the following conclusions were drawn:

1. Translucency of dental ceramics was significantly influenced by both thickness and type of material.
2. There was an exponential relationship between TP and thickness of IPS e.max lithium disilicate ceramics. The more translucent the ceramic material was the higher the TP values were.

EXPERIMENTAL SECTION

Materials

The dental ceramic system evaluated in the present study is IPS e-max Press (Ivoclar Vivadent), in the four basic opacities: high opacity (HO), medium opacity (MO), low translucency (LT) and high translucency (HT). During the fabrication of the specimens, the recommended manufacturers' processing instructions were respected. 100 ceramic disks (10 mm diameter) were pressed out of calibrated wax by the lost wax technique. The disks were divided into four groups of opacity (HO, MO, LT, HT), each having five subgroups of thicknesses (0.3, 0.6, 0.9, 1.2, 1.5mm). The thickness of the ceramic disks was checked with a digital micrometer (0.3, 0.6, 0.9, 1.2, 1.5mm ± 0.1mm). In order to obtain a glossy surface of the ceramics, the surface to be analyzed of the disks was smoothened out and polished by using wet silica paper under finger pressure, in the sequence 400, 600, 800-grit.

Determination of translucency parameter

The CIE L*a*b* colour parameters were recorded using a dental spectrophotometer (VITA Easyshade®, VITA Bad Säckingen, Germany). The colour parameters lightness (L*) and cromacity (a* and b*) were measured on a black and a white background for all specimens. Saturated sucrose solution was interposed (refractive index n=1,5) between each ceramic disk and the background. The colour measurements were performed in a dark room, with a light source simulating natural daylight (D65) in a special viewing booth (JUST LED Color Viewing Light, JUST Normlicht, Weilheim/Teck, Germany).

The translucency parameter (TP) was obtained by calculating the colour difference between the specimen against the black background and against the white background with the following equation [13]:

$$TP = ((L^*_B-L^*_W)^2 + (a^*_B-a^*_W)^2 + (b^*_B-b^*_W)^2)^{1/2},$$

where L^* refers to the value, a^* to redness to greenness cromatic parameter, and b^* to yellowness to blueness cromatic parameter. The subscripts B refers to the colour coordinates on the black background and W to those on the white background.

Three measurements were made for each specimen on each background, and the average value was recorded. High TP values indicate high translucency and low opacity and low TP values indicate low translucency and high opacity.

Statistical analysis

The effects of the material and thickness on the TP values of the lithium disilicate ceramics were analyzed with a 2-way analysis of variance (ANOVA), followed by the Tuckey Honestly Significant Difference (HSD) test by using statistical software (SPSS 17.0; SAS, Chicago, Ill). The relationship between the thickness and TP values of each ceramic group was evaluated with a regression analysis.

ACKNOWLEDGEMENTS

This study was supported by PN-II-PT-PCCA-2011-3-2-1275.

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