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Color Masking of Two Types of Medium Translucency Lithium Disilicate Ceramic Restorations by Spectrophotometry

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ABSTRACT

Background and Objective: One of the problems in aesthetic treatment is the fabrication of monolithic ceramic restorations that have both the ability to cover discolored substrate and appropriate translucency so that it can have similar appearance to the remaining dental structure. The aim of this study was to determine the color coverage of two types of medium translucency lithium disilicate (LDS) ceramic restorations by spectrophotometry.

Methods: In this in-vitro study, 15 A2 colored LDS discs using heat-pressed technique were prepared in two methods: MT monolithic LDS discs (thickness of 1.5 mm) and core-veneer discs (0.9 mm MT veneer and 0.6 mm high opacity core). The discs were placed on 3 substrates: amalgam, composite and non-precious gold-colored alloy (NPG). Therefore, there were five groups (n=3); monolithic discs on amalgam (ML-A), monolithic discs on NPG (ML-NPG), monolithic discs on composite (ML-C), core-veneer discs on amalgam (H-A) and core-veneer discs on NPG (H-NPG). The color coordinates of samples were measured three times under the same lighting conditions on black and white backgrounds. CIEDE 2000 (ΔE00) and translucency parameter (TP) were calculated. One-way analysis of variance and Post-hoc Tuckey test at significance level of 0.05 were used for analysis.

Findings: The highest and the lowest value of ΔE00 was observed in H-NPG (6.80±0.73) and H-A (1.43±0.19) groups, respectively. There was a significant difference between the studied groups in terms of ΔE00 ($p<0.001$). The highest and the lowest amount of TP was observed in H-NPG (8.33±0.14) and ML-NPG (2.53±0.82) groups, respectively. There was a significant difference between the studied groups in terms of translucency parameters ($p<0.001$).

Conclusion: Monolithic LDS disc covers NPG substrate better and LDS core-veneer disc covers amalgam substrate better.

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Introduction

Dental ceramics are the most common material used for long-term aesthetic restorations due to their excellent biocompatibility, high strength and optical properties very similar to dental structure (1). Among different ceramic systems, lithium disilicate (LDS) glass ceramic (Li2O5Si2) has been the focus of many dentists. Advantages of this ceramic system include: high strength due to 70% increase in LDS crystals, the ability to be etched with HF, better aesthetic features with access to translucency and more diverse colors, an easier manufacturing method with lost wax process compared to layering method, and greater preservation of the tooth structure with monolithic restoration (2-6).

One of the challenging treatments is masking discolored substrate and metal core with ceramic material to create a natural-looking dental restoration (7). The results of studies by Czigola et al., Nossair et al. and Iravani et al. showed that thickness and translucency of ceramic cause significant changes in the final color of restoration (6, 8, 9). In the study of Bacchi et al., monolithic discs showed significantly higher ΔE00 and TP compared to core-veneer discs (7). In the study of Pires et al., ΔE of cemented high opacity (HO) hybrid LDS were lower than low translucency (LT) LDS monolithic (10). In the study of Basso et al., monolithic discs covered C4 substrate well, but they could not cover metal substrate (11).

Some important factors which determine the final color of ceramic crown are the type of ceramic, its translucency and color of supporting substrate (12-15). The more opaque the ceramic, the greater the coverage of discolored substrate (10). As it has been claimed, thickness of 0.6-0.8 mm HO LDS ceramic is able to mask the discoloration of underlying substrate completely, but esthetic appearance in monolithic ceramic restorations decreases (16).

In order to compare and match the color of teeth, visual and instrumental methods can be used (17, 18). In this study, due to high accuracy, reliability and repeatability in tooth color selection by spectrophotometry, we used Vita Easyshade V (Vita Zahnfabrik, Bad Sackingen, Germany) (19). ΔE can be used to measure color masking ability of ceramic systems when placed on different substrates (20). CIELAB is a standard parameter to measure color changes, but for more accurate color changes between measured and perceived, the use of CIDE2000 formula (ΔE00) is recommended. In CIED2000 formula, the perception threshold is 0.8 and acceptable threshold is 1.8 (21). Translucency parameter (TP) can be used to measure translucency of ceramic systems when placed on different substrates. TP represents the variation of translucency parameter of a material with same thickness on black and white backgrounds (9, 22). The first null hypothesis is that color changes (ΔE00) of different groups are different from each other and the second null hypothesis is that TP of different groups are different from each other.

Given that few studies have been conducted on color masking of medium translucency (MT) LDS ceramic, we decided to compare masking ability of MT monolithic and core-veneer LDS ceramic restorations on two substrates amalgam and NPG alloy in comparison to composite resin by spectrophotometry.

Methods

This in-vitro study was carried out after approval by the ethics committee of Guilan University of Medical Sciences with code IR.GUMS.REC.1401.122.

Preparation of ceramic discs: 15 A2 colored LDS ceramic discs (Ivoclar Vivadent, Schaan, Liechtenstein) were prepared in two methods by heat-pressed technique: 1. MT monolithic discs with thickness of 1.5 mm and diameter of 7 mm. 2. core-veneer discs (MT veneer with a thickness of 0.9 mm and HO ingot with a thickness of 0.6 mm). Samples that had defects in the structure or thickness were excluded from the study.

In order to simulate different clinical conditions with different substrates, we used amalgam, composite resin and NPG alloy. Both types of discs were randomly placed in groups. There were five groups (n=3) as followed: LDS monolithic discs on amalgam substrate (ML-A), LDS monolithic on NPG alloy (ML-NPG), LDS core-veneer on Amalgam (H-A), LDS core-veneer on NPG alloy (H-NPG) and monolithic LDS on composite (ML-C) (control group).

Preparation of substrates: Substrate samples were made in 4 mm thickness and 7 mm diameter circular mold. Amalgam (Sinaloux, Alborz, Iran) and composite (FGM, Joinville, Santa Catarina, Brazil) substrates were prepared by direct method and NPG (Verabond, AalbaDent, USA) substrate by lost wax method according to the manufacturer's instruction. To make amalgam substrate, amalgam was condensed into the molds, and to make DA2 color composite resin substrate, two layers of 2 mm were placed inside the molds. Each layer was cured for 20 seconds. A glass slab and a 500 mg weight were placed on the last layer of unset amalgam and composite was unpolymerized for 30 seconds in order to make their surface smooth and even. Then, the surface of composite samples was cured and after removing the glass slab, it was post-cured. Generally, the curing method in this study is as follows: using a light cure device (Bluedent LED smart, Bulgaria) with light intensity of 800 mw/cm ^{2} and probe diameter of 8 mm perpendicular to the sample for 20 seconds. At the beginning and during study, the output intensity of the light cure device was measured regularly using a radiometer (RD-7, Ecel Ind. E Com. Ltda, Ribeirao Preto/ Sao Paulo, Brazil). In order to make NPG alloy substrate, six molds were fixed on a glass slab with wax. The samples were waxed up and then casted according to manufacturer’s instruction using lost wax method (Ducatron casting machine, France). Finally, amalgam samples after 24 hours and composite and NPG samples immediately were polished using 600 and 1200 grit sandpaper under running water (11).

Bonding ceramic discs to substrates: The bond surface of all three substrates as well as discs were sandblasted with 50 micron aluminum oxide particles at a distance of one cm with a pressure of 1.5 bar for 30 seconds. All the samples were cleaned in an ultrasonic dental cleaning machine (Aj Teb,China) containing deionized water for 10 minutes (10). Then, the bonding surfaces of ceramic discs were conditioned according to the following method: first, they were etched by HF 10% (Cobalt, Iran) for 20 seconds and washed with water for 30 seconds. After drying, silane (Ultradent, South Jordan, Utah, USA) was applied to the inner surface of discs for one minute according to the manufacturer's instruction. Finally, A2 color self-adhesive cement (SuperCem, DentKist, inc, Eli-Dent group S.P.A. Korea) was used to cement discs to the substrates, and the core disc and veneer disc were light cured together.

Colorimetric procedure: Vita Easyshade V was used to record the color coordinates of the samples. The device was calibrated before each use. The tip of the device was placed in the center of the discs. Color parameters of each sample were measured three times in the same lighting condition on black and white backgrounds. The CIEDE 2000 (ΔE00) formula was used to calculate the color changes.

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

Where ΔL', ΔC' and ΔH' are the mathematical differences in lightness, chroma, and hue between two different measurement periods and is a function that accounts for the interaction between chroma and hue differences in the blue region and for dental color space is close to zero. SL, SC, and SH are the weighting functions that adjust the total color difference for variation in the location of the color difference pair L, a, b in coordinates. KC, KL, and KH are the parametric factors that are correction terms for experimental conditions. RT is a rotation function for the interaction between chroma and hue differences in the blue region. Monolithic LDS disc on composite substrate (ML-C) was considered as control group, so ΔE00 of all samples were calculated compared to the control group. TP represents the variation of translucency parameter of a material with the same thickness on black and white background.

$TP= [(L^*_b - L^*_w)^2 + (a^*_b - a^*_w)^2 + (b^*_b - b^*_w)^2]^{1/2}$

Where CIELab values represent L*: lightness; a*: red-green; b*: yellow-blue and B and W represent black and white backgrounds, respectively (6).

Mean and standard deviation were used to describe quantitative data. The results obtained from this study were analyzed by SPSS version 24 (IBM Corp, Armonk, NY, USA). Due to the normal distribution of the data, one-way ANOVA was used and for pairwise comparison, Tuckey's post-hoc test was used, and p<0.05 was considered significant.

Results

The highest value of ΔE00 was observed in H-NPG group (6.8±0.73) and the lowest was in H-A group (1.43±0.19). According to ANOVA results, there was a significant difference between the studied groups in terms of ΔE00 (p<0.001). According to Post-hoc Tuckey results, ΔE00 between LDS monolithic groups was significant; ΔE00 was significantly higher in ML-A group compared to ML-NPG group (p<0.001). Likewise, among LDS core-veneer discs, ΔE00 was significantly higher in H-NPG group compared to H-A group (p<0.001). In groups with amalgam substrate, ΔE00 was significantly higher in ML-A group compared to H-A group (p<0.001). Also, in groups with NPG substrate, ΔE00 was significantly higher in H-NPG group compared to ML-NPG group (p<0.001) (Table 1).

Table 1. Comparison of color parameters (ΔE00) in the studied groups

Color parameters	ML-C Mean±SD	ML-A Mean±SD	ML-NPG Mean±SD	H-A Mean±SD	H-NPG Mean±SD	p-value
L_w	91.93±3.42	87.73±3.92	89.46±3.91	92.05±2.27	83.31±5.56	-
L_B	86.33±6.05	85.18±3.5	87.66±4.09	89.17±3.79	91.25±2.39	-
C_W	21.27±2.74	17.11±1.49	20.41±1.73	23.66±0.88	28.07±1.36	-
C_B	22.84±3.37	18.65±3.1	22.18±1.74	24.7±1.54	25.66±0.78	-
H_W	89.73±1.81	93.17±2.53	88.6±1.75	88.65±0.3	86.18±0.55	-
H_B	88.11±1.93	91.16±3.61	87.43±1.16	88.07±0.54	87.7±0.27	-
ΔE00*	-	3.36±0.1^A	1.75±0.23^B	1.43±0.19^C	6.80±0.73^D	<0.001

***Different superscript uppercase letters within columns represent significant differences (p<0.05).**

According to ANOVA results, there was a significant difference between the studied groups in terms of translucency parameter (p<0.001). The highest amount of TP was observed in H-NPG group (8.33±0.14) and the lowest was reported in ML-NPG group (2.53±0.82). Based on the results Post-hoc Tuckey, TP was significantly different between monolithic LDS disc groups; TP was significantly higher in ML-A than ML-NPG group (p<0.001). Likewise, TP was significantly different between core-veneer LDS disc groups; TP was significantly higher in H-NPG group compared to H-A group. In groups with amalgam substrate, TP was significantly higher in ML-A group compared to H-A group (p=0.034). Also, in groups with NPG substrate, TP was significantly higher in H-NPG group compared to ML-NPG group (p<0.001) (Table 2).

Table 2. Comparison of translucency parameters (TP) in the studied groups

Translucency parameters	ML-A Mean±SD	ML-NPG Mean±SD	H-A Mean±SD	H-NPG Mean±SD	p-value
L_W	87.73±3.92	89.46±3.91	92.05±2.27	83.31±5.56	-
L_B	85.18±3.5	87.66±4.09	89.17±3.79	91.25±2.39	-
a_W	-0.88±0.69	0.54±0.69	0.55±0.13	1.86±0.34	-
a_B	-0.21±1.14	1.02±0.49	0.96±0.31	0.98±0.14	-
b_W	17.06±1.53	20.41±1.73	23.66±0.88	28.02±1.33	-
b_B	18.61±3.12	22.12±1.71	24.71±1.56	25.64±0.77	-
TP[*]	3.06±0.57[a]	2.53±0.82[b]	2.91±0.03[c]	8.33±0.14[d]	<0.001

[*]Different superscript lowercase letters within columns represent significant differences (p<0.05).

Discussion

The mean ΔE00 obtained in study groups was higher than 0.8, which means that color difference between monolithic/core-veneer LDS discs and the underlying substrate has been clinically noticeable. In ML-NPG and H-A groups, where ΔE00 was 1.75 and 1.43, respectively, the color difference is within the acceptable range (less than 1.8). However, in H-NPG and ML-A groups, where ΔE00 was equal to 6.8 and 3.36, respectively, the color difference was not clinically acceptable. The obtained results showed that monolithic LDS discs cover NPG alloy substrate better and core-veneer LDS discs cover amalgam substrate better. The findings obtained from TP measurement confirmed the results of ΔE00 calculation. In the current study, both null hypotheses were confirmed.

Bacchi et al. and Wang et al. investigated the relationship between ΔE00 and TP. The results showed that there is a direct relationship between ΔE00 and TP so that TP increased with the increase of ΔE00 (7, 23). In the study of Czigola et al. A1 color LDS full ceramic crowns with two translucencies (high and low translucency) were prepared. The results of their study showed that ΔE00 was not less than 0.8 in any of the HT samples, which means that the color difference in HT crowns were clinically noticeable. Among 24 LT LDS crowns, 13 samples had ΔE00 lower than 0.8, which means that LT LDS ceramic had succeeded in covering the underlying substrate (6).

Iravani et al. prepared monolithic LDS discs (A2 color, HT and LT) and hybrid LDS discs (medium opacity LDS core). ΔE was measured for all samples on A4 colored substrate. The results showed that LT LDS had better coverage than HT discs (8). It can be claimed that HT monolithic LDS discs were not able to cover underlying substrates, while LT and MT LDS discs were able to cover underlying substrates in some cases. This finding may be due to optical properties of the material, as LT and MT LDS blocks have more LDS crystals compared to HT. Crystals reduce the internal scattering of light when passing through material and increase the internal absorption of light (24).

In a study by Basso et al., HT and LT LDS discs in different thicknesses were prepared in monolithic and hybrid form (zirconia framework). They were placed on A2 (tooth color), C4, silver and copper substrate. The results of study showed that lower thickness of discs led to an increase in ΔE00 and TP in the samples. Translucency in the hybrid samples was lower and masking ability was higher than monolithic samples. In this study, hybrid LDS discs covered the silver (amalgam) substrate better, which is in an agreement with our study (11).

In the study of Pires et al., the results showed that for both substrates, ∆E was lower in HO hybrid samples than in LT monolithic samples (10). The copper-aluminum alloy substrate can be more golden or coppery depending on the percentage of copper /aluminum. In their study, percentage of copper to aluminum was not mentioned, and image of the investigated substrates was not provided. If the copper-aluminum alloy substrate in their study was more coppery, this color difference with the current study (NPG) justifies the different results obtained between these two studies. But if the copper-aluminum alloy substrate was more golden in their study, the contradictory results of their study with the current study could be due to the difference in the materials used. In the study of Pires et al., monolithic LDS discs with LT and hybrid LDS with HO were used, while LDS discs with MT were used in the present study.

GE et al. investigated the effect of different post & cores on the color of full ceramic crowns. They used ceramic crowns made of Empress 2 ingot No. 100 and ceramic veneer powder No. 140 on Ni-Cr alloy post & core, Ni-Cr alloy coated with opaque composite, gold alloy and glass fiber reinforced with resin (control group). Based on the results of this study, ceramic crowns on gold alloy showed the same color as control group. Ni-Cr post & core made the color of crowns darker but when covered with opaque composite, produced an acceptable color. The results of this study are in an agreement with the current study about NPG alloy substrate. ∆E values of hybrid discs were higher than monolithic discs (25).

Several factors can affect the results of a study, including differences in thickness, translucency (high, medium, low), color (A1, A2, ...), shape (crown or disc), fabrication method of LDS (CAD/CAM or Heat press), monolithic or hybrid, thickness and type of framework in hybrid group, color and material of underlying substrate, the color of cement, the way to measure and calculate the color parameters and the manufacturer of materials. It is suggested that future studies be designed by removing these limitations so that more reliable results can be obtained and a systematic review of these data can be created.

According to the limitations of study, it can be concluded that monolithic LDS disc covers NPG alloy substrate better and core-veneer LDS disc covers amalgam substrate better.

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