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The Effect of Thickness And Accelerated Aging on Opalescence of Different Ceramic Material

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ABSTRACT

Purpose: The objective of the study was to evaluate the effect of ceramic material type and thickness on opalescence before and after accelerated aging.

Materials and methods: 180 all-ceramic slices were divided into three groups (n=60) according to the ceramic material (InCoris TZI, Empress CAD HT, and Empress CAD LT). Each group was further subdivided into four subgroups (n = 15) according to their thickness (0.5 mm, 0.8 mm, 1 mm and 1.2 mm).). CIE Lab coordinates were measured for each slice against black and white backgrounds using intraoral spectrophotometer and OP was calculated. All specimens were subjected to ac-celerated aging using autoclave (134 ºC, 0.2 MPa for 5 h) and OP was calculated after accelerated aging. Repeated ANOVA combined with a tukey-post hoc test were used to analyze the data obtained (P≤ 0.05).

Results: The results showed that ceramic material type and thickness have significant effect on opalescence with OP values (from 4.4±1.2 to 7.1±1.7) for InCoris TZI, (from 4.1±0.28 to 5.7±0.36) for CAD HT, and (from 5.9±0.7 to 8.7±4.6) for CAD LT, while the effect of accelerated aging was not statistically significant.

Conclusion: The dental ceramic type affected the opalescence with Empress CAD HT showing the highest OP values. Increasing thickness caused an increase in the opalescence of leucite reinforced glass ceramic, while it decreased the opalescence of zirconia. Therefore, manufactures should develop all-ceramic materials that can simulate the opalescence of natural teeth especially in esthetic ceramic restorations with lower thickness.

1. INTRODUCTION

Natural tooth simulation with all-ceramic dental restorations is a challenge in esthetic dentistry. This requires restorative materials with optical properties replicating that of the natural teeth.[1, 2] Like other biological tissues, teeth reflect, absorb, diffuse and transmit light reaching its surface. Thus, light reflection, absorption and transmission of dental ceramic restorative materials are properties that must be controlled for favorable esthetics and shade matching. [3, 4] In this respect, matching the optical properties of all-ceramic restorations with those of natural teeth is highly important. Factors such as the translucency, opalescence, fluorescence, thickness, contour of restorations, surface properties and type of ceramic material affect the final color of all-ceramic.[4] Opalescence and fluorescence of restorative dental materials are highly important optical properties required for an ideal restoration.[5]

Opalescence is an optical property, in which the material scatters light with shorter wavelengths, giving an object orange/brown appearance in the transmitted color and a bluish appearance in the reflected color.[6] An object can emit brilliant colors of opalescence when the refractive index constant between two substances exceeds 1.1. The human enamel is opalescent, confers an orange- brown tint to the tooth color under transmitted light and a blue tint under reflected light.[6] The opalescence value ranges from 19.8–27.6 for the human enamel. Ideally, ceramic restorations should have opalescence similar to that of natural human enamel.[7]

There are many methods of evaluating light transmission and reflection that have been reported to explain what happens when light strikes an object. The main color systems and color difference (ΔE) concepts used in science are based on the Commission Internationale de l'Eclairage (CIE) principles. Regarding the CIELAB system, ΔE is the standard parameter for color match perception.[8, 9]However, the CIELAB color space only considers (L*: value coordinate; a*: red– green coordinate; b*: yellow–blue coordinate), regardless of other components and factors on color perception, such as: opalescence, translucency, fluorescence, and surface texture.[6]

However, from its definition, opalescence can be calculated as the differences in the yellow-blue color coordinate (CIE _b*) and the red-green color coordinate (CIE _a*) between the reflected and transmitted colors, and is known as opalescence parameter (OP).[6]

The final color of all ceramic restorations is significantly affected by their chemical composition, crystal size and their innate optical properties such as fluorescence, opalescence, and translucency.[3] Presence of a glassy phase intermixed with micro-particles in ceramics results in light scattering that allow simulation of natural teeth translucency and opalescence. This results in color-reactive esthetic restorations that look natural and esthetic in any light, and react to light in the same manner as the natural tooth.[3, 10, 11]

Optical properties such as opalescence are affected by ceramic material type and thickness. Change in restoration thickness will also be accompanied by change in color, translucency and opalescence. In ceramic restorations, different thicknesses may be used depending on the design of restoration and intra oral conditions.[12, 13]

Thus, assessing the relationship between ceramic opalescence and its thickness in different esthetic restorations is imperative to improve the clinical results. Despite the correlation between ceramic thickness and optical properties of ceramic materials have been previously studied, the combined effect of ceramic type, thickness, and aging on opalescence is still lacking. Thus, it is sought to investigate the effect of different dental ceramic types and their thicknesses on opalescence before and after accelerated aging.

The first null hypothesis was that difference in ceramic material type and thickness has no effect on opalescence and the second null hypothesis was set that aging has no effect on opalescence.

2. MATERIALS AND METHODS

A total of 180 all-ceramic slices were divided into three groups (n=60) according to the ceramic material (InCoris TZI, Empress CAD HT, and Empress CAD LT) with shade corresponding to A2. Each group was further subdivided into four subgroups (n = 15) according to their thickness (0.5 mm, 0.8 mm, 1 mm and 1.2 mm). The ceramic specimens were obtained by cutting InCoris TZI blocks, Empress CAD HT blocks, and Empress CAD LT blocks using IsoMet 30HC precision cutting blade (Buehler, Illinois, USA) mounted on MICRACUT precision cutter (METKON Precision Cutting Machines, Turkey). The machine was adjusted using its built-in micrometer to cut the InCoris TZI block under water coolant into slices of approximately 0.6 mm, 1 mm, 1.2 mm, and 1.5 mm thickness, 20% larger than the desired final size to compensate for sintering shrinkage caused during the sintering stage, while Empress CAD blocks were cut into slices of 0.5 mm, 0.8 mm, 1.0 mm, and 1 mm.

The thickness of each slice was checked with a digital caliper and minor corrections were done using Wetordry Sandpaper sheet of grit 400, 600, and 1200 in the presence of water to ensure flat surface and desired thicknesses. The slices were then ultrasonically cleaned for 10 min in distilled water then air dried with oil free compressed air.

Prior to sintering the InCoris TZI slices were fully submerged in a plastic vessel containing A2 InCoris TZI Sirona coloring liquid allowing the slice disc to absorb the coloring solution for 5 min then the discs were removed from the plastic vessel and left to dry for 2 hours on a glass slab.

The InCoris TZI slices were placed on sintering boat filled with the sintering beads, at least 1 cm apart from each other, then sintered in Sirona inFire HTC speed for 90 min and 1540˚C. After sintering, the thickness of each slice was checked with a digital caliper. The final thicknesses of the slices were 0.5 mm, 0.8 mm,1.0 mm, and 1.2 mm.

Polishing was carried out by low-speed hand piece and an electric motor with a rate of 7000-10000 rpm under constant water coolant using Dialite ZR Intra-Oral Adjustment finishing and polishing system (Brasseler USA) and polishing paste ZI-Polish (Bredent, GmbH & Co.KG.), while polishing of Empress CAD was carried out using Jota (Jota, swizerland) Intra-Oral Adjustment finishing and polishing kit. All 180 ceramic slices were subjected to artificial accelerated aging using autoclave at 134˚c, 0.2 MPa for 5 hours.

All the specimens were tested for degree of opalescence using portable intraoral digital spectrophotometer (Vita EasyShade). Vita easy shade in "tooth single" mode was used to determine the values of CIELab coordinates from specimen placed on white and black background. Three measurements were taken for each specimen before and after artificial aging on white and black backgrounds and the average of each parameter (L*, a*and b*) was recorded. The values were used to calculate the opalescence parameter (OP) according to the following formula:

$OP = [(a_b - a_w)^2 + (b_b - b_w)]^{½}$ Were b is for black and w for white.

Statistical analysis

Data were explored for normality by checking data distribution, histograms, calculating mean and median values and finally using Kolmogorov-Smirnov and Shapiro-Wilk tests. All data showed parametric (normal) distribution and were presented as mean and standard deviation values. The significance level was set at $P \leq 0.05$. Statistical analysis was performed with IBM SPSS Statistics Version 20 for Windows.

3. RESULTS

The results showed that material type, thickness, aging and the interaction between the three variables had a statistically significant effect on mean OP. Since the interaction between the three variables is statistically significant, so the variables are dependent upon each other and comparison will be done between different levels within each variable.

Table 1:

Repeated measures ANOVA results for the effect of different variables on mean (OP).

Tests of Between-Subjects Effects					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Material	318.388	2	159.194	86.125	.000
Thickness	78.039	3	26.013	14.073	.000
Material * thickness	225.126	6	37.521	20.299	.000

df: degrees of freedom = (n-1), Significant at $P \leq 0.05$

3.1 Effect of material:

With 0.5 mm before aging, InCoris TZI showed the statistically significant highest mean OP, Empress CAD LT showed statistically significant lower mean OP, while Empress CAD HT showed the statistically significant lowest mean OP. **After aging,** Empress CAD LT showed the statistically significant highest mean OP. There was no statistically significant difference between InCoris TZI and Empress CAD HT; both showed the statistically significant lowest mean OP values. **With 0.8 mm before aging as well as after aging,** there was no statistically significant difference between InCoris TZI and Empress CAD LT; both showed the statistically significant higher mean OP values, while Empress CAD HT showed the statistically significant lowest mean OP. **With 1.0 mm before as well as after aging,** Empress CAD LT showed the statistically significant highest mean OP. There was no statistically significant difference between InCoris TZI and Empress CAD HT; both showed the statistically significant lower mean OP values. **With 1.2 mm before aging**, Empress CAD LT showed the statistically significant highest mean OP. There was no statistically significant difference between InCoris TZI and Empress CAD HT; both showed the statistically significant lowest mean OP values. **After aging,** Empress CAD LT showed the statistically significant highest mean OP, Empress CAD HT showed the statistically significant lower mean OP, InCoris TZI showed the statistically significant lowest mean OP. (Table 2)

3.2 Effect of thickness:

With InCoris TZI before aging, there was no statistically significant difference between 0.5- and 0.8-mm thicknesses; both showed the statistically significant highest mean OP values. There was no statistically significant difference between 1.0 mm and 1.2 mm thicknesses; both showed the

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statistically significant lowest mean OP. **After aging,** 0.8 mm showed the statistically significant highest mean OP. There was no statistically significant difference between 0.5mm, 1.0 mm and 1.2 mm thicknesses; all showed statistically significant lower mean OP values. **With Empress CAD LT before aging,** 1.0 mm showed the statistically significant highest mean OP. There was no statistically significant difference between 0.8 as well as 1.2 mm thicknesses; both showed statistically significant lower mean OP values. 0.5 mm showed the statistically significant lowest mean OP. **After aging,** there was no statistically significant difference between 0.8, 1.0- and 1.2-mm thicknesses; all showed the statistically significant highest mean OP values. 0.5 mm thickness showed the statistically significant lowest mean OP. **With Empress CAD HT before aging,** there was no statistically significant difference between 0.5, 0.8, 1.0 mm as well as 1.2mm thicknesses. **After aging,** there was no statistically significant difference between 1.0- and 1.2-mm thicknesses; both showed the statistically significant highest mean OP values. There was no statistically significant difference between 0.5 mm and 1.0 mm thicknesses; both showed the statistically significant lowest mean OP values. (Table 2)

Table 2:

Effect of aging on OP of each material within each thickness.

	Thickness	Before aging		After aging		P value
		Mean	Std. Deviation	Mean	Std. Deviation	
Zirconia	.50	6.7320^{ab}	.76965	3.7740^{a}	.56061	<0.001
	.80	7.0964^{a}	1.66022	7.2090^{b}	1.53840	0.806
	1.00	5.1977^{bc}	1.75184	4.6505^{a}	1.14609	0.233
	1.20	4.4161^{c}	1.20306	4.0154^{a}	.73695	0.382
P value		<0.001		<0.001		
~~Cad~~ LT	.50	5.8501^{a}	.71922	5.0617^{a}	1.69053	0.086
	.80	6.3087^{ab}	.87413	7.1828^{b}	.67198	0.058
	1.00	8.6509^{c}	4.63225	7.5937^{b}	.53350	0.022
	1.20	7.7507^{bc}	.28518	7.6270^{b}	.44918	0.787
P value		<0.001		<0.001		
CAD HT	.50	4.1487	.27534	4.0566^{a}	.58946	0.841
	.80	4.7229	.47243	4.1464^{a}	.78079	0.209
	1.00	5.0144	.27909	5.0432^{b}	.67142	0.95
	1.20	5.7078	.35562	5.3503^{b}	.23689	0.435
P value		0.067		<0.001		

Significant at $P \leq 0.05$

3.3 Effect of aging:

With InCoris TZI 0.5, there was a statistically significant decrease in mean OP after aging. While with 0.8, 1.0 as well as 1.2 mm, there was no statistically significant change in mean OP after aging. **With Empress CAD LT** 0.5mm, 0.8, and 1.2-mm thicknesses, there was no statistically significant change in mean OP after aging. With 1.0 mm thickness, there was a statistically significant decrease in mean OP after aging. **With Empress CAD HT** 0.5, 0.8, 1.0- and 1.2-mm thickness, there was no statistically significant change in mean OP after aging. (Figure 1)

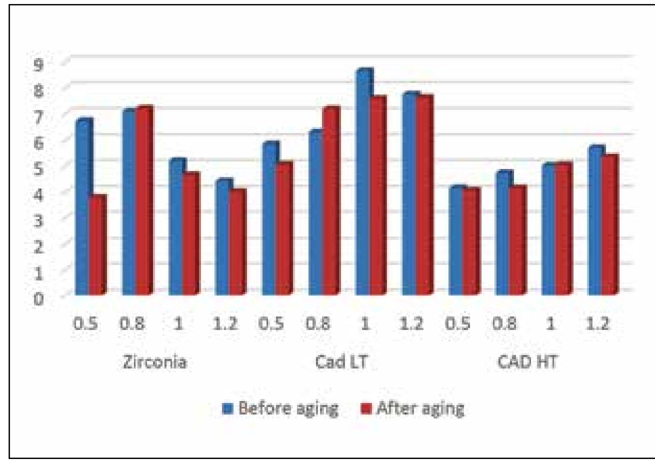

Figure (1) — Bar chart representing mean OP before and after aging of each material within each thickness

4. DISCUSSION

This study revealed a difference in the opalescence of different ceramic materials as well as different thicknesses within each type of ceramic. Therefore, the first null hypothesis that difference in material type and thickness has no effect on opalescence was rejected and the second null hypothesis that aging has no effect on opalescence was accepted.

The ceramic samples were machine cut with a low speed diamond saw under coolant, a commonly used cutting procedure in literature.[(14)] This cutting procedure showed surface quality close to that of CAD/CAM milling as evident by ***Wang et al*** in 2008[(15)] who stated that the roughness of saw machine grinding with diamond coating disc was lower (1.18µm) than that with CAD/CAM milled (1.91 µm). Thus, no further treatment before coloring step was made. Samples were disc shaped instead of being anatomical for perfect standardization of measuring steps. ***Beheur F et al*** [(16)] mentioned that discs may be the more accurate way to measure light translucency as important factors like size and surface quality can be standardized. Literature was rich with those studies in which translucency of all-ceramic materials was evaluated using flat specimens of standardized thickness.[(17, 18)]

Leucite reinforced glass ceramic was used in this study for its well-known excellent esthetics, natural optical properties and superior translucency.[(19, 20)] The Vita A2 shade, which is high in value and relatively low in saturation, was selected for specimens in this study; representing a frequently selected light shade.

The use of the Vita Easyshade spectrophotometer for obtaining the CIELab color coordinates is commonly used in the field of dental research[(21-24)] for obtaining the color difference (ΔE) Translucency parameter (TP), and opalescence parameter for the specimens.

The long-term stability of Y-TZP in the presence of water is limited by the continuing transformation from the tetragonal to monoclinic phase, which could raise low-temperature degradation (LTD).[(25)] LTD affects microstructure, surface topography which is expected to have its effect on color, translucency and opalescence as well as durability.

Autoclave aging proved to produce some degree of aging, therefore, it was a reliable method to propose an accelerated test for LTD.[(26)] It was suggested by ***Chevalier et al*** that 1h of autoclave at 134°C had theoretically the same effect as 3 to 4 years in vivo.[(27)] Ten years was considered a reasonable lifetime for dental applications, as well as the time it takes for 25% of monoclinic to develop according to Lughi et al [(25,28)] The ISO

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standards states that a maximum acceptable amount of monoclinic phase after accelerated aging procedures for 5hours at temperature of 134°C and pressure of 2 bar should be of 25 weight percent.[28] This was used here in this study for setting aging parameters. ***Lughi et al***[25] stated that the activation energy dictates lifetime prediction at room or body temperature according to the ISO standards. The activation energy is approximately the same for all yttria stabilized zirconia ceramics.

Regarding opalescence the present study showed variations in opalescence derived from the type of ceramic material. Translucent zirconia (Incoris TZI) showed the mean OP values ranging (from 4.4±1.2 to 7.1±1.7), IPS Empress CAD HT showed mean OP values (ranging from 4.1±0.28 to 5.7±0.36), and IPS Empress CAD LT (ranging from 5.9±0.7 to 8.7±4.6).

These results were in accordance with a study that used a spectrophotometer to study the opalescence of materials. The range of opalescence parameter values were 1.6–6.1, 2.0–7.1,1.3–5.0 and 1.6–4.2 for the core, veneer, A2- and A3-layered specimens, respectively in which the type of ceramic material significantly influenced opalescence. [6] It was reported [29] that the OP value, which can contribute to the vitality of dental restorative composites should be at least 9. ***Kim H-K and Kim S-H*** [11] stated that dental restorative materials showing OP values between 4 and 9 could be considered to have some opalescence which is only slightly discernible to the naked eyes. In the present study, all specimens recorded OP below 9 which according to previous studies[11, 29], is considered non-opalescent.

The results of the present showed that the material thickness had significant effect on opalescence parameter, for zirconia as thickness increase opalescence decreases with no significant difference between thicknesses of 0.5 mm and 0.8 mm and also between 1mm and 1.2mm while with leucite reinforced ceramic (IPS Empress CAD High Translucency and IPS Empress CAD Low Translucency) as the thickness increases the OP values increases.

A ceramic restoration comprises an opalescent material, ceramic, A2 shade and a masking agent. Decreasing the masking agent, will increase the share of the opalescent agent in scattering of blue light. Thus, higher opalescence is expected in objects with lower masking effect, given the optimal grading and volume of opalescent particles. Although the leucite ceramic was more translucent than the zirconia[30], it does not contain adequate amount of opalescent material.

In leucite glass ceramics, increase in thickness was accompanied by increase in opalescence. This could be attributed to the fact that greater thicknesses allow light to be transmitted through the media since incomplete masking occurs. This possibly explains the increase in opalescence. On the other hand, a 1-mm thick specimen of zirconia has complete masking. Thus, the process is reversed. In other words, in complete masking, light will not be transmitted through the media. Thus, as a result of increased thickness opalescence significantly decreases in zirconia specimens due to their severe masking effect.

The results were in accordance with ***Arimoto et al***, [31] who concluded that opalescence and translucency were significantly increased in resin composites when the thickness is more than 1mm, in which opalescence significantly increased and translucency significantly decreased.

Based on the study ***Valizadeh et al,*** [32] who evaluated the effect of ceramic material type (feldspathic, IPS e.max, zirconia and Enamic) and thickness (0.5 mm and 1.0 mm) on opalescence it was concluded that opalescence was affected by the dental ceramic thickness and type. Except for IPS e.max, ceramics evaluated in this study exhibited increase in opalescence as thickness of specimens increased. All opalescence values were lower than that of human enamel.

The results of the study showed that aging has no significant effect on opalescence for all tested materials and thicknesses except for 0.5 mm thickness of zirconia which can be attributed to the process of low temperature degradation starting at surface layers.[25] Since surface layers affected by low temperature degradation constitutes higher percentage of the total surface area in 0.5 mm specimens compared to other thicknesses, therefore their effects on opalescence can be more pronounced.

5. CONCLUSION

Within the limitations of this study, the dental ceramic type affected the opalescence with Empress CAD HT showing the highest OP values. ~~Increases~~ the thickness caused an increase in the opalescence of leucite reinforced glass ceramic, while it decreased the opalescence of zirconia.

CLINICAL SIGNIFICANCE

Different types and thicknesses of dental ceramics have different opalescence values which are also different than opalescence values of natural tooth enamel. Therefore, manufacturers should strive to develop all-ceramic materials with opalescence values that simulate that of natural teeth, especially in esthetic ceramic restoration with lower thickness.

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