



Effect of Thickness on Fluorescence of Some Clinical Dental Ceramics

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| Article Info | ABSTRACT |
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| <p>Article type: Original Article</p> <hr/> <p>Article History: Received: 2 Feb 2021 Accepted: 27 Nov 2021 Published: 25 Nov 2021</p> <hr/> <p>* Corresponding author: Department of Operative Dentistry, School of Dentistry, Tehran University of Medical Sciences, Tehran, Iran</p> <p>Email: drdaryadar1368@gmail.com</p> | <p>Objectives: This study aimed to develop a new method for measurement of fluorescence and compare the fluorescence of some clinical dental ceramics in different thicknesses.</p> <p>Materials and Methods: Forty-eight samples of feldspathic (Vita VM9, A2), IPS e.max (Ivoclar HT, A2), zirconia (Korox Zircostar, A2) and Enamic (Vita A2) ceramics were used in this study in 0.5 and 1 mm thicknesses. The fluorescence of the samples was measured by using a developed technique. The results were analyzed by two-way ANOVA and Duncan post-hoc test. $P < 0.05$ was considered significant.</p> <p>Results: Enamic, feldspathic and e.max ceramics had significantly different fluorescence in descending order ($P = 0.000$). Fluorescence of ceramics increased with an increase in their thickness from 0.5 to 1 mm ($P = 0.007$).</p> <p>Conclusion: The results confirmed the applicability of the presented method for measurement of fluorescence of dental ceramics. While, the thickness of restoration determines the concentration of the fluorescent agent, some additional technical information is required for justification of the observed trend in the studied ceramics.</p> <p>Keywords: Fluorescence; Ceramics; Zirconium Oxide; VITA Enamic</p> |
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INTRODUCTION

Reconstruction of smile is among the most challenging and esthetically satisfying treatments. Dental ceramics are extensively used in a variety of dental restorations due to their optimal durability, esthetic properties, and biocompatibility [1]. Tooth discoloration leads to numerous esthetic problems. Several attempts have been made to improve the appearance of discolored teeth. For most people, achieving an esthetic smile is a more important factor than restoring the normal

alignment of their teeth [2].

There is a growing interest in fluorescence properties of teeth, and new esthetic fluorescent restorative materials are continuously produced by the manufacturers. Optical properties of natural teeth have attracted the attention of dental professionals towards fluorescence [3].

An ideal esthetic restorative material should have fluorescence properties similar to those of natural teeth [4]. Color, fluorescence, translucency, and opalescence are optical

properties that influence the appearance of teeth [5,6].

Translucency refers to the property of a material to pass light through, not necessarily in a regular manner. This definition justifies why an object cannot be seen clearly through translucent materials [5,7,8]. Fluorescence of the teeth is due to the energy absorption in short wavelengths and its reemission at a longer wavelength. In other words, the teeth act as a blue-colored light source due to their intrinsic fluorescence. Because of the natural, inherently yellow color appearance of the teeth, and their inherent fluorescence property, ultraviolet light makes the teeth whiter and brighter [3,4,9]. Opalescence of the teeth is a selective light scattering phenomenon in a translucent medium that scatters the blue parts of light [5,10].

The esthetic value of dental ceramic restorations is influenced by numerous factors, including color, translucency, fluorescence, surface texture, and shape. Thickness has a prominent effect on the overall color and translucency of ceramic restorations. Changes in thickness of porcelain layer affect both color and translucency [11,12].

Kim et al. [13] reported that by an increase in thickness of zirconia ceramics, their lightness decreased. Moreover, a reddish, bluish tint developed, and translucency increased.

There are two general methods for measuring fluorescence. The first method is based on measuring the maximum emission in excited versus non-excited state. The second method is based on the color difference between the two aforementioned states. However, there is no reported comprehensive method for fluorescence measurement covering all aspects of fluorescence [3]. Due to the diversity of methods used for the analysis and measurement of fluorescence and complexity of the optical and industrial instruments, it is difficult to compare the results reported in the literature. The aim of the current study was to determine the fluorescence of IPS e.max, Enamic, feldspathic and zirconia ceramics in different thicknesses. Moreover, a method was developed and studied for fluorescence

measurement.

MATERIALS AND METHODS

The commonly used dental ceramics including Vita VM9 feldspathic ceramic (A2; Vita Zahnfabrik, Bad Säckingen, Germany), IPS e.max (Ivoclar HT, A2; Ivoclar Vivadent, Schaan, Lichtensitein), zirconia (ZircoStar, A2; Kerox Dental Ltd., Diósd, Hungary) and Vita Enamic (A2; Vita Zahnfabrik, Bad Säckingen, Germany) ceramics were used in this study.

From each ceramic, 12 discs, each 10 mm in diameter, were fabricated in two different thicknesses of 1 mm (n=6) and 0.5 mm (n=6), and glazed according to the manufacturers' instructions. The final thickness was controlled using a digital caliper (Mitutoyo Corp., Tokyo, Japan).

Fluorescence measurement:

A novel method was developed for measurement and evaluation of the fluorescence property of the samples. The logic behind the setup, light source characteristics, tuning of the required parameters, and evaluation of fluorescence are described in the following two sections.

Maximum excitation estimation:

In order to accurately compare the fluorescence of the samples, a pilot study was conducted to determine the maximum efficiency of excitation. A photoluminescence spectrometer (LS55; Perkin Elmer, USA) was used. As fluorescence of dental materials mostly peaks around 430 nm [4, 9, 14], the sensor was adjusted at this wavelength and a pre-scan test ran. The spectrometer excited the samples with a predefined wavelength range (200-800 nm) and measured the emission at 430 nm wavelength. One sample of each ceramic was tested as described. The results are shown in Figure 1.

It is clear that the zirconia ceramic is not excited in the studied wavelength range. Another interesting property of all the curves in Figure 1 is that they reached maximum excitation at wavelengths about 350-360 nm. This allowed us to compare the ceramic fluorescence with a LED excitation light source which emits at the same wavelength.

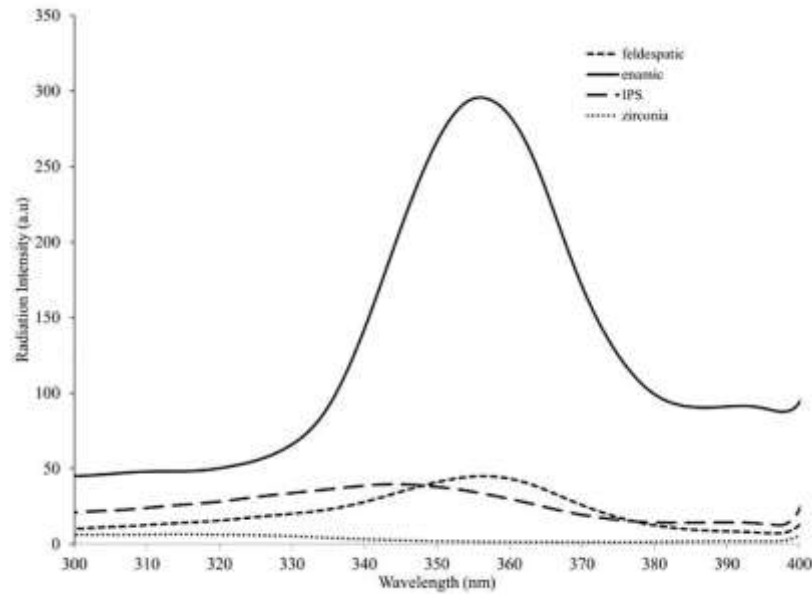


Fig. 1. Radiation intensity of the IPS e.max, Enamic, feldspathic, and zirconia ceramics

For the zirconia ceramic, a pilot study of fluorescence measurement confirmed lack of excitation observed in Figure 1. Thus, this ceramic was omitted from the study.

Fluorescence measurement:

A novel approach for the fluorescence measurement was designed in this study. A visible spectroradiometer (CS-2000; Konica Minolta, Japan) was used for this purpose.

The samples were illuminated in two modes. At first, the samples were lit by a collimated incandescent light source and the device was calibrated using its white tile. The reflectance of the samples was then measured. Afterwards, a custom-made UV LED source was applied for excitation of the samples. The UV-LED projector was made using 6 industrial 1 W, 360 nm UV LEDs obtained from the market.

The mixture of incandescent and UV light shined over the white tile, and the system was calibrated once again. Then, the reflectance of the excited samples was measured using the spectroradiometer. In order to take full advantage of the sample surface, the optical aperture of the spectroradiometer was adjusted at 1°.

This would allow measuring a circle about 2.9 mm in diameter over the sample. The measurement set up is shown in Figure 2. As shown in Figure 2a, the reflectance measurement was done according to the instrument manual. The set-up in Figure 2b differs only in the light source with Figure 2a which includes UV as the light source.

For Figure 2b, it can be written that:

$$R_w = \frac{I_w}{I_w^0} \quad \text{Equation (1)}$$

$$R_{s,stimulated} = \frac{I_{s,stimulated}}{I_s^0} \quad \text{Equation (2)}$$

Dividing equation 1 by equation 2 and considering $I_w^0 = I_s^0 = I^0$ would give :

$$\frac{R_{s,stimulated}}{R_w} = \frac{I_{s,stimulated}}{I^0} \quad \text{Equation (3)}$$

Where I_w , I_w^0 , R_w , $R_{s,stimulated}$, I_s^0 represent the intensity of the reflected light from the white tile, the intensity of the emitted light from the white tile, reflectance of the white tile, reflectance of the UV stimulated sample, and the intensity of the emitted light from the sample, respectively.

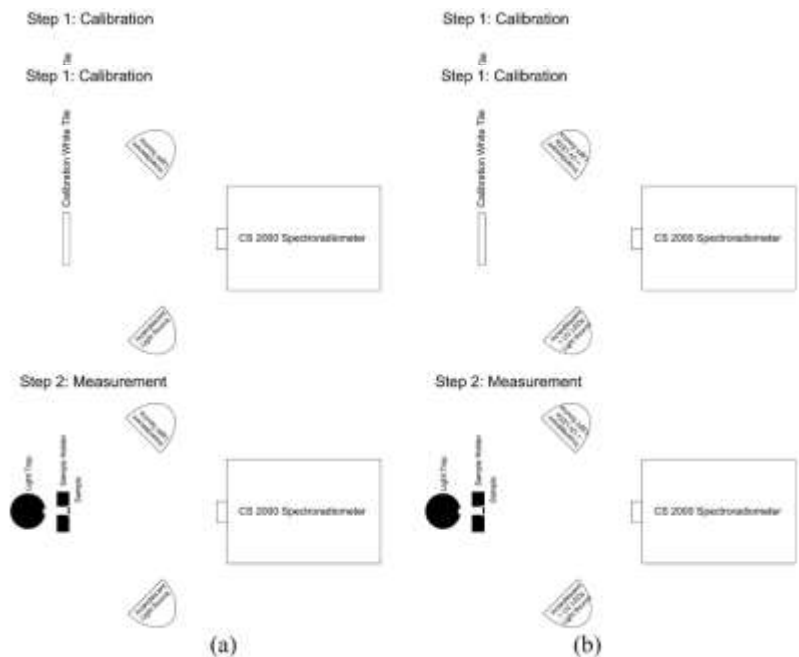


Fig. 2. Two setups

As shown in equation (3), the reflectance of UV-stimulated sample could be measured by calibrating CS-2000 spectroradiometer with the UV+ incandescent light source and then measuring the fluorescence of the sample.

With the same rationale, the reflectance of a non-stimulated sample could be measured via the equation (1). The fluorescence index was calculated from the difference between the excited and non-excited reflectance values at the maximum emission wavelength.

Figure 3 illustrates the Enamic (1 mm) base and excited reflectance values. As shown, the curve shows the typical behavior of a fluorescent dye/pigment reflectance graph [15]. This approves the designed procedure for measuring the fluorescence. As described in the Introduction section, the difference between the peaks of fluorescence emission and the baseline unexcited reflectance is recorded as the index of fluorescence.

Statistical analysis:

Two-way ANOVA was applied to compare the measured fluorescence between the ceramic types (factor 1) and different thicknesses (factor 2). Moreover, the Duncan post-hoc test was applied to find the cause of significant difference reported by ANOVA. $P < 0.05$ was considered statistically significant.

RESULTS

As the interaction between the ceramic thickness and ceramic type was insignificant ($P=0.94$), the factors were analyzed independently. A significant difference was noted between the fluorescence of ceramics ($P < 0.001$). The results of the post-hoc test are shown in **Error! Reference source not found.**

Table 1. Post hoc analysis of the ceramic type factor (n=12)

| Ceramic type | Subset | | |
|--------------------|--------|--------|--------|
| | 1 | 2 | 3 |
| E.max | 14.967 | --- | --- |
| Feldspathic | --- | 41.492 | --- |
| Enamic | --- | --- | 95.808 |

It should be noted that the sample size was 6 for each ceramic type in each thickness. Thus, there were 12 samples of each ceramic type in all thicknesses. All ceramics were significantly different from each other in terms of fluorescence. Enamic showed maximum fluorescence (95.8 ± 1.2) while e.max exhibited minimum fluorescence (14.96 ± 0.5) among the studied ceramics. Meanwhile, feldspathic ceramic showed a fluorescence index of 41.492.

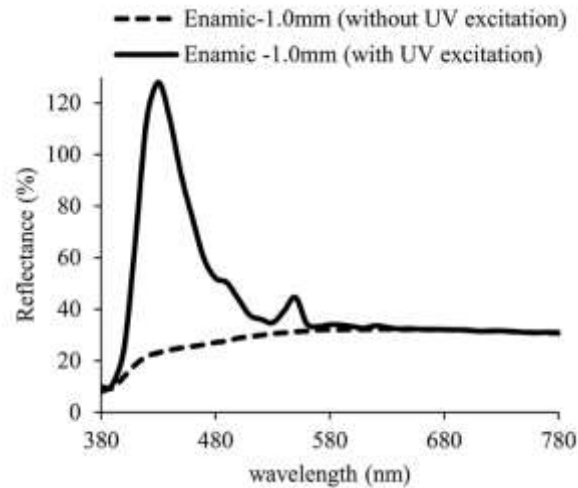


Fig. 1. Reflectance curves of a 1-mm Enamic sample in the excited and non-excited states

The results of two-way ANOVA showed a significant difference ($P=0.007$) between the studied thicknesses. At 0.5 mm thickness, the fluorescence index was 48.12 ± 1.290 while in 1 mm thickness, the fluorescence index was 53.39 ± 1.290 . This means that the fluorescence significantly increased with an increase in thickness from 0.5 to 1 mm. Figure 4 shows the mean fluorescence and the confidence interval values. A steady trend of increase in fluorescence existed with an increase in thickness. Moreover, the mean and the

confidence interval of the fluorescence of different ceramics are shown in Figure 5. The same trend of fluorescence in Figures 4 and 5 confirmed absence of interaction between thickness and ceramic type.

DISCUSSION

According to the results, fluorescence significantly increased as the thickness increased from 0.5 to 1 mm. This could be probably caused by the increase in the fluorescent media with the increase in thickness.

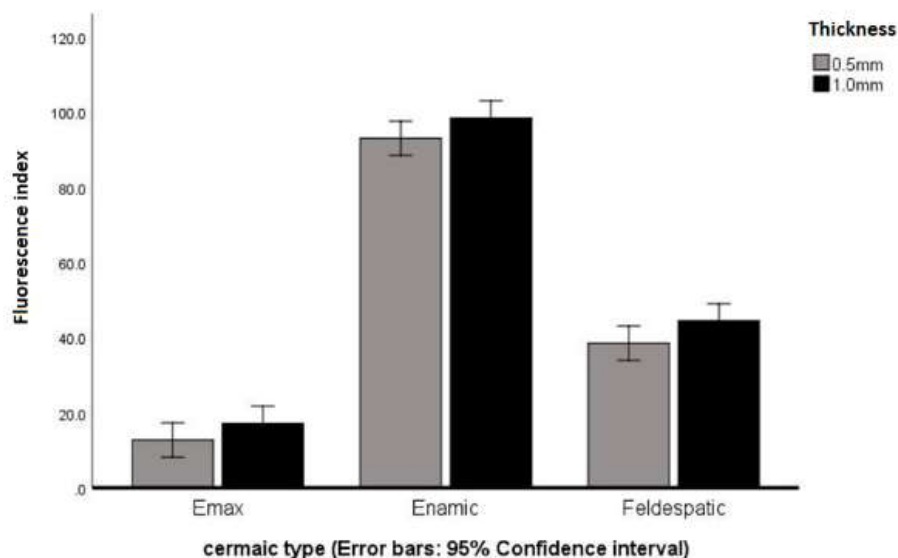


Fig. 2. Fluorescence of IPS e.max, Enamic and feldspathic ceramics in different thicknesses

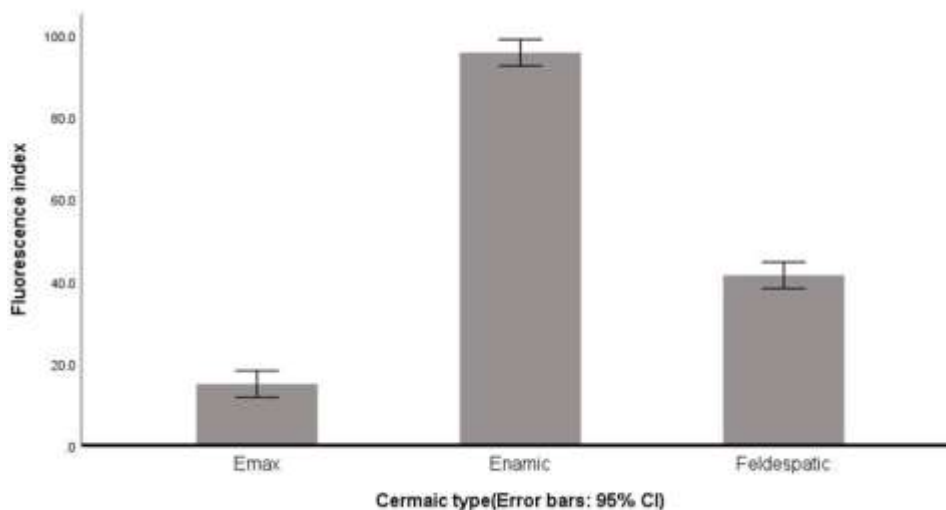


Fig. 3. Fluorescence of IPS e.max, Enamic and feldspathic ceramics

In other words, thickness is somehow representative of the concentration in solutions. It is common to see an increase in the fluorescence of fluorescent solutions up to the quenching concentration [15]. To the authors' knowledge, although thicker ceramics can be translated to a more aggressive treatment, there are no studies on the correlation of fluorescence and thickness of ceramic restorations, and only a few studies about the correlation of fluorescence and thickness of composite resins are available [16, 17]. Our results, except in one case, were in contrast to those of Tabatabaei et al [17]. They argued that fluorescence decreases with the thickness due to the concentration of the fluorescent colorant in the restoration, which is close to the quenching concentration. It appears that this was not the case in our study. Unlike Tabatabaei et al, [17] Tavares et al. [16] reported insignificant difference in fluorescence of different thicknesses of the studied composite resins. Such a controversy in the results can be due to the excitation wavelength of composites as was discussed in the fluorescence measurement section of the current study. In other words, when the fluorescent colorant is insensitive to the excitation wavelength, the increase of thickness might not have any influence on the

fluorescence property of the restoration.

It is worth mentioning that the accuracy of the proposed rationalization needs technical information which is not often disclosed by the manufacturers. It was observed that fluorescence significantly decreased from Enamic to feldspathic and then to e.max. Although there is no study to compare our results with in this respect, it should be noted that the highest fluorescence does not necessarily mean the best. In other words, too much fluorescence can result in unwanted unnatural bluish tint in the teeth. Regardless of mechanical and physical properties of the studied ceramics, the best ceramic for use would be the one with a fluorescence close to that of natural teeth. According to Kim et al, [18] zirconia has no fluorescence property and our result complied with their statement. Thus, application of the modified liquid and liner layer over the restoration surface can effectively improve the fluorescence property of zirconia restorations. Fluorescence measurement of dental materials is mostly done via two methods in the literature. The first is to use RGB cameras for recording of fluorescence images. A naive interpretation of fluorescence has been reported based on the gray scale level of the restored teeth. The gray scale image was considered as the intensity of fluorescence.

Considering the bluish cast of fluorescence, it is easy to see that the gray or the blue channel intensity of dental images cannot be regarded as fluorescence. Moreover, it has been reported in the literature that CCD cameras do not reveal linear responses. This implies that the intensity of images could not be linearly correlated with the fluorescence intensity [19, 20]. The other method is the classic method of using spectrofluorometers. These instruments excite the specimens and measure the radiance of emissions in the direction perpendicular to the excitation direction. These devices are mostly equipped with two monochromators to make monochromatic light and enable the detection of the reflection of the desired wavelength. The use of two monochromators makes these devices too expensive [3]. The presented method in the current study has the advantage of controlling the intensity and the excitation wavelength. The radiometer can measure the radiance of dental materials from every direction. It is also possible to measure the fluorescence of every part of the tooth even in vivo.

CONCLUSION

A new method for the measurement of fluorescence of the teeth was introduced. Flexibility and feasibility of the present method can be an aid for measurement of curved and natural dental surfaces. Four commonly used ceramic restorations were studied regarding their fluorescence. The results showed that Enamic, feldspathic, and e.max ceramics had a significant difference in fluorescence in a descending order. Moreover, thickness had a significant effect on fluorescence presumably due to the increase in the length of the fluorescent medium.

CONFLICT OF INTEREST STATEMENT

None declared.

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