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Comparison of translucency for different thicknesses of recent types of esthetic zirconia ceramics versus conventional ceramics … (in vitro study)

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ABSTRACT

Purpose: To compare the translucency of 6 different types of ceramic material using three different thicknesses.
Materials and methods: Square shaped specimens were cut from different types of ceramics with variable translucencies (e.max CAD HT, e.max CAD LT, ultra-translucency zirconia, top-translucency zirconia, super-translucency zirconia and high-translucency zirconia). Total samples of 144 specimens were divided into 6 main groups according to material; each group was divided into 3 subgroups according to thickness used (0.4, 0.6 and 1 mm). Using spectrophotometer each specimen was tested three times against white and black background and the average was taken to calculate translucency parameter (TP).
Results: Viewing the mean of translucency between studied groups, group EMHT (9.10 ± 1.45) scored the highest TP followed by group EMLT (8.36 ± 1.42) then group UTZ (6.66 ± 2.49), TTZ (6.25 ± 0.95), STZ (4.93 ± 0.96) and HTZ (4.83 ± 1.34) showed the lowest value. Each material showed a difference in mean value with different thicknesses. At 0.4 mm thickness one-way ANOVA revealed no significant difference between EMHT and UTZ (P = 0.942).
Conclusions: Glass ceramics showed higher TP values than crystalline based ceramics which means e.max is more translucent than zirconia. The thickness of the material has direct effect on its translucency. Ultra-translucency zirconia is the most recommended material to be used in conservative esthetic cases.

1. Introduction

In dentistry esthetics is a philosophy concerned specially with the appearance of dental arches. In prosthodontics, it is the art of replacing dental tissues by artificial materials that are well camouflaged to be seen as natural dental tissues. This could only be achieved by thorough knowledge of form, color, translucency and surface texture [1].

Translucency was overlooked by many practitioners despite it is the element that adds a life-like appearance to the restoration [2]. It is the characteristic of allowing the passage of light while scattering it in such a way that the complete image can't be clearly seen. Thus, translucency stands somewhere between complete opacity and transparency [3]. It can be adjusted by controlling the absorption, reflection, scattering and transmission of light through the material. Low reflectance and high scattering and transmission of light result in increasing translucency [4].

The increased demand of dental client for natural looking restorations has resulted in development of metal-free ceramic system. The non-metallic substructure veneered with porcelain provided a deeper translucency close to natural tooth [5], which was described as one of the primary element in controlling esthetics [6,7].

Rapid evolution of zirconia in dental practice was a rational conclusion for quest of material combining between the mechanical properties of PFM restorations, superior biocompatibility and esthetics of glass ceramics. Zirconia restorations are well-known for their excellent mechanical properties such as fracture toughness and flexural strength [8] which were achieved by increasing their crystalline content that may be reflected on preserving valuable tooth structure through conservative preparation.

Although zirconia ceramics has the ability to reflect the intended color, beginning with inner layer as seen in the dentin and enamel structure of natural teeth [7], unfortunately it has greater opacity because of increase light scattering due to the difference in refractive indices between crystals and matrix, porosity and the inhomogeneity of crystals [9].

Recently zirconia materials have evolved greatly and the worms have mutated in to butterflies. The addition of yettria into zirconia resulted in increased translucency starting from high translucency

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zirconia (HTZ) and ending with the super (STZ), ultra (UTZ) and top (TTZ) translucency zirconia. The later were claimed to have translucency that may surpass e.max material.

Translucency can be measured according to different equations using different instruments. Translucency parameter (TP) and contrast ratio (CR) are the most common parameters used. Translucency parameter represents the color difference between a material of uniform thickness over a black and a white background, and corresponds directly to a common visual assessment of translucency [10].

Spectrophotometers are generally used to measure surface colors. They are designated to measure the ratio of the light reflected from a sample to the light reflected from a white reference across the visible spectrum at intervals of 5, 10, or 20 nm. The results are expressed by spectral reflectance function [11]. While using spectrophotometers (SP) translucent specimens are subject to edge loss of the light, which occurs during reflectance measurements when light is scattered to the edges without being reflected, resulting in systematic errors in SP-based color coordinates [12].

The hypothesis of this study is that translucency of HTZ will match that of e.max, moreover the translucency of STZ, UTZ and TTZ will surpass that of e.max.

2. Materials and methods

2.1. Specimen grouping

Total sample size was 144 cubes divided into six main groups according to the material used (IPS e.max (HT), IPS e.max (LT), Ultra-translucency Zirconia (UTZ), Top-translucency Zirconia (TTZ), Super-translucency Zirconia (STZ), and High-translucency Zirconia (HTZ), Each group was further subdivided into three subgroups according to thickness used (0.4 mm, 0.6 mm and 1 mm).

2.2. Specimen preparation

2.2.1. Lithium disilicate ceramic specimens

Lithium disilicate blocks (IPS e.max CAD HT and LT, A2 shade, Ivoclar Vivadent) were mounted in accutome (Struers Ensuring Certainty), Using cutting Wheel with thickness of 0.4 mm, 1000 rpm rotation and speed of 0.075 mm/s, and under cooling system eight specimens (16 × 14) mm were cut from each thickness.

Specimens were cleaned with ultrasound in a water bath for 10 min then entered a ceramic furnace (Programat P700 furnace; IvoclarVivadent) for crystallization process according to manufacturer instructions.

2.2.2. Zirconia ceramic specimens

Using an AutoCad (AutoDesk,mac,2017), A square design of (10 × 10) mm with variable thickness according to the subgroups was drawn and imported as STL (Standard Triangulation Language) file to CAD/CAM software (inLab CAM Software, Dentsply, sirona) and design was done (Fig. 1). A block of each material was mounted in the milling machine (inLab MC X5, Dentsply, sirona) and 8 square shape specimens of each thickness were milled in dry mode with same dimensions using diamond-coated burs for zirconia (0.5,1 and 2.5 DC).

Specimens were cut from the block and finished in order to remove the remaining part of the sprue using rubber disk, then entered the furnace for sintering following the manufacturer instructions.

2.2.3. Frames fabrication

As the size of the spectrophotometer's lens is larger than the size of the specimens, plexi frame was prepared by laser cut containing depression in which the lens can properly fit on it preventing any light to escape from the side aspects. In the middle of this depression a square shape hole was cut (10 × 10) mm in order to standardize the surface area which the light will pass through.

Another two transparent frames were fabricated as holders for the specimens, one for lithium disilicate with (14 × 16) mm hole and the other for zirconia with (10 × 10) mm hole. White and black plexi squares were cut and used as background.

2.3. Specimen testing

The color of each specimen was measured using spectrophotometer according to the Commission Internationale de l'Eclairage (CIE) system, which evaluates the degree of perceptible color change based on three coordinates; L* (lightness, in which 100 represents white and 0 represents black), a* (red–green chromatic coordinate) and b* (blue–-yellow chromatic coordinate) [13,14].

For translucency measurements, The L*a*b* color notation of each specimen were measured consecutively against a black background and a white background [15]. The translucency parameter (TP) was obtained by calculating the color difference between the specimen over the white background and that over the black background as follows;

$$TP = [(Lw^* - Lb^*)^2 + (aw^* - ab^*)^2 + (bw^* - bb^*)^2]^{1/2}$$

Where subscript '*w*' refers to the color coordinates over the white background, and the '*b*' refers to those over the black [16].

2.4. Statistical analysis

Statistical analysis was conducted to compare the translucency for different thicknesses of recent types of esthetic Zirconia ceramics with conventional ceramics. Kolmogorov-Smirnov normality tests were considered to evaluate the normality of the data distributions. One-way ANOVA tests were conducted to analyze the differences in translucencies. Bonferroni post-hoc tests were applied as a post-hoc test to detect the significant different group/s.

3. Results

Ceramic type, thickness and translucency were correlated to each

Fig. 1. Software design for zirconia specimens before milling.

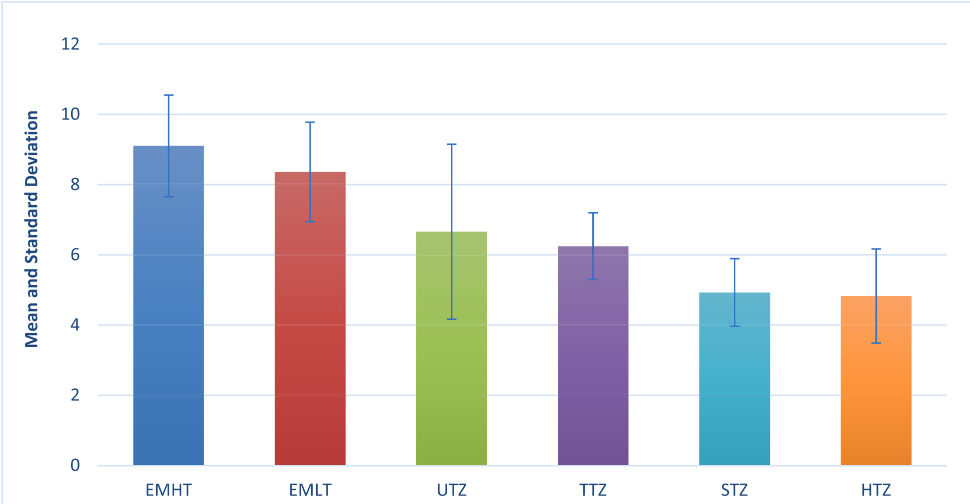

Fig. 2. Mean and standard deviation values of translucency parameter (TP) according to material type.

other as follow:

3.1. Testing the translucency regarding material type

Statistical analysis was calculated for all studied groups regardless their thicknesses. One-way ANOVA test revealed that there were significant differences between the groups P = 0.000. EMHT group (9.10) scored the highest TP mean value followed by EMLT group (8.36). Whereas the lowest was scored by HTZ group (4.83) preceded by STZ group (4.93). UTZ and TTZ groups scored (6.66) and (6.25) respectively as shown in Fig. 2.

Bonferroni post-hoc test was applied to detect the pairwise significant difference among groups. Significant differences among subgroups were found except between EMHT and EMLT, UTZ and TTZ and between STZ and HTZ, where *P*-value > 0.05.

3.2. Effect of different material types with same thickness on translucency

Fig. 3 presents the mean and standard deviation of the TP values which were calculated for groups with the same thicknesses. In 0.4 mm thickness the highest TP mean value was for EMLT (9.83) followed by EMHT, UTZ, TTZ, STZ with TP value of (8.42), (7.58), (6.55), (4.99) respectively and HTZ showed the lowest mean value (4.79).

In 0.6 mm thickness, TP value of EMHT was the highest (9.51) followed by EMLT (8.66), UTZ (8.45), STZ (5.65), TTZ (5.50) and the lowest was HTZ (5.41), While in 1 mm thickness an observed drop in TP value of UTZ (3.95) with raising in TTZ TP value (6.69), followed by EMLT (6.60), HTZ (4.28) and STZ (4.14), while EMHT showed the highest value (9.37).

According to One-way ANOVA test, P values were lower than 0.05 in all studied thicknesses, there were significant differences between studied materials in the three studied thicknesses.

Bonferroni post-hoc test revealed significant differences in the three studied thicknesses. The results showed that in 0.4 mm thickness there are significant differences between all groups except EMHT and UTZ (P = 0.942), and between UTZ and TTZ (P = 0.353), also between STZ and HTZ (P = 1.000).

In 0.6 mm thickness, P value for EMHT showed no significant differences when compared to EMLT and UTZ (P = 1.000), while EMLT showed significant differences with all other groups except UTZ. Also (P > 0.05) when comparing TTZ with both STZ and HTZ; also STZ and HTZ were compared, while all other groups showed significant difference with (P < 0.05).

In 1 mm thickness all groups present significant difference when comparing with each other except EMLT and TTZ, UTZ and both SYZ and HTZ, also STZ and HTZ, (P = 1.000).

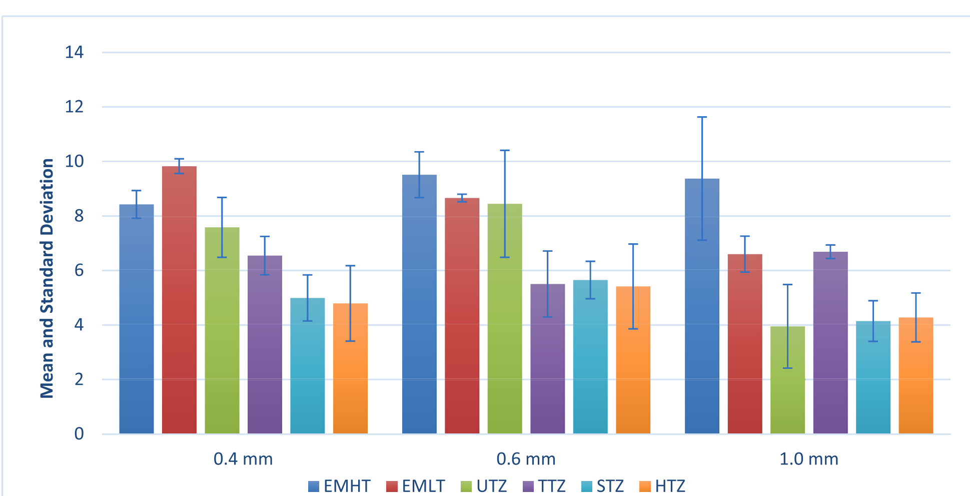

Fig. 3. Mean and standard deviation values of TP according to studied material and thickness.

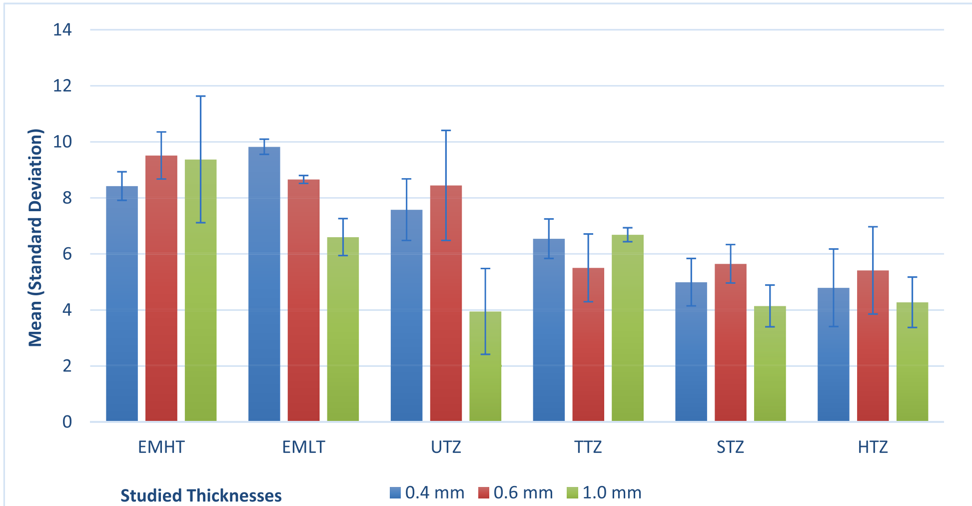

Fig. 4. Mean and standard deviation values of translucency parameter (TP) according to studied thickness and studied material variables.

3.3. Effect of different thicknesses of the same material on translucency

Statistical analysis was calculated for studied thicknesses of material according to their types (Fig. 4). Applying One-way ANOVA revealed no significant differences in both EMHT group (P = 0.271) and HTZ groups (P = 0.243). On the other hand, there were significant differences in the remaining groups; EMLT (P = 0.00), UTZ (P = 0.00), TTZ (P = 0.017), and STZ (P = 0.003).

Bonferroni post-hoc test revealed significant differences between all thicknesses (0.4, 0.6, and 1 mm) of EMLT group. In UTZ groups, the 1 mm thickness has significant differences comparing with 0.4 mm (P = 0.000) and with 0.6 mm (P = 0.000). There was significant difference between 0.6 mm with 1 mm thickness in both TTZ (P = 0.0 27) and STZ (P = 0,002) group. There were no significant differences in the compared remaining thicknesses of the last two studied groups.

4. Discussion

In the current study a lot of procedures were implemented to securely protect the target of the study as well as aid in its standardization. Square-shaped specimens were fabricated instead of crowns, to guarantee that the light is reflected at the same level and distance from the specimen surface to the lens of the spectrophotometer, and to eliminate any other factors which may affect translucency as surface curvature, cement shade or natural tooth discoloration [17].

Different thicknesses were studied to test the relationship between translucency and thickness as it was said that the relationship between contrast ratio and the thickness is linear [18]. Several thicknesses were cut from each material starting from 0.4 mm as it is indicated for zirconia veneers [19], 0.6 mm as minimum thickness of IPS e.max CAD [20] and 1 mm used in full crowns.

Direct transmission, total transmission, and spectral reflectance are the three methods for evaluating the translucency of dental ceramics [21], in this study the spectral reflectance was determined and TP method was used. The TP is defined as the difference between the colors reflected from a material with uniform thickness over a black and a white background, and provides a value corresponding directly to human visual perception of translucency [6].

The spectrophotometer is a scientific standardized colorimetric equipment used for measuring and matching colors which numerically specifies the perceived color of an object. Industrial spectrophotometer has been used in this study for translucency determination because spectrophotometers with small window size may cause edge-loss phenomenon which affects the accuracy of measurements [22].

In this in vitro study, results showed that e.max in its both translucencies scored higher mean of TP values than all types of zirconia. This was translated as higher translucency because the more difference in TP values found between white and black background, the more translucent was the material. These findings were opposite to earlier results stated by Telyani in 2017, who found that according to translucency, there was no significant difference between lithium disilicate glass ceramic and zirconia glass-free ceramics. This might be attributed to the use of crowns over resin dies which may affect other parameters, as well as comparing different thicknesses to each other [23].

In zirconia, altering the grains to a more uniform size and configuration and reducing the number and size of the porosity lead to several levels of translucencies [24]. Regarding the TP values, UTZ showed the highest one followed by TTZ then STZ and HTZ, while Bonferroni test showed no significant differences between UTZ and TTZ and between STZ and HTZ.

The 0.4 mm thickness of EMLT showed higher TP value than EMHT. The standard thickness of e.max is 0.6–1 mm, below 0.6 mm thickness the effect of firing temperature on e.max might be the cause of this conflicting findings.

Antonson and Anusavice (2001) investigated that translucency of dental ceramics is a function of ceramic thickness. They found a positive linear correlation between contrast ratio and thickness [25]. The present study demonstrated similar results as there were significant differences between the three studied thicknesses except EMHT which had no significant difference regarding to thickness. This could be attributed to the refractive index of the lithium disilicate glass crystals matching that of the glassy matrix. The absence of porosity prevents scattering of the light, thereby improving transmittance values. A linear well-organized crystalline structure was seen with the high transmittance glass ceramics.

The significantly lower transmittance values for the EMLT compared with EMHT may be attributed to the less regular arrangement of the crystals leading to increased scattering and reflectance [26]. This explains the higher TP values of EMHT in 0.6 and 1 mm in comparison with EMLT.

Comparing EMHT with UTZ in 0.4 mm thickness, the results showed no significant difference between them. As the manufacturer instructions recommended that the minimum thickness of e.max to be 0.6 mm so using UTZ in esthetic cases are preferable than e.max to be more conservative to tooth structure.

Looking for a more translucent zirconia by manipulating several factors may negatively affect other properties of the material as strength and transformation toughening mechanism. HTZ showed the lowest TP values among all groups in almost all thicknesses which means that it has the lowest translucency, but following manufacturer instructions it seems to be the most suitable material to be used for posterior restorations as it combines high strength and acceptable optical properties.

The result of the present study were in accordance with Harada et al. (2016) who found that UTZ was significantly more translucent than all other types of zirconia, and e.max CAD HT showed translucency more than all studied materials [27].

The suggested hypothesis for the present study was rejected. The translucency of HT zirconia didn't match that of e.max, moreover the translucency of ST, UT and TT didn't surpass that of e.max.

5. Conclusions

Within the limitations of the present in-vitro study, the following could be concluded:

1. Ultra-translucency zirconia is the material of choice in conservative esthetic cases, as it showed no significant difference when compared with EMHT at 0.4 mm thickness which is recommended for zirconia not for e.max.
2. Top-translucency zirconia could present an acceptable option for fabricating esthetic restoration.
3. Thickness of ceramic restoration is a primary factor affecting translucency.

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