The Effect of Ceramic Thickness and Number of Firings on the Color of Two All-Ceramic Systems Measured by Spectrophotometer

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ABSTRACT

Background: This in vitro study was carried out to evaluate the effects of various veneering dentin ceramic thicknesses and repeated firings on the color of lithium disilicate glass-ceramic (IPS e.max Press) and zirconium-oxide (IPS ZirCAD) all-ceramic systems, measured by clinical spectrophotometers (Easyshade Advance 4.0) .
Materials and methods: The 72specimens cube-shaped have the dimension of about 11 mm in width, 14 mm in length, 1mm in thickness, these cores divided into 3 groups according to the type of material each group have (24)core specimens. Each group had been divided into three sub-groups (each having 8 specimens) according to veneering with dentin ceramic thicknesses: as 0.5, 1, or 2 mm (n=8). IPS e.max press and ZirCAD cores group had been veneered with IPS e.max Ceram dentin ceramic shade A2 according to manufacturer's instructions and the metal group had been veneered with IPS classic dentine ceramic with shade A2 according to manufacturer's instructions. Repeat firings (3, 5 and 7 times) had been applied on all the specimens. Color differences among ceramic specimens had been measured using a clinical spectrophotometer (VITA Easyshade); the color data had been expressed according the Vita Classic shade guide.
Results: The shade of all specimens had been compared inside the subgroups and with the main groups. The percentage of color agreement among the subgroups showed the color of all ceramic systems had been affecting by firing interval, the ceramic thickness and brand of ceramic. The number firings intervals applied on the all ceramic system has a significant effect on the final color, the increase of firing number change the color to a darker and reddish color. The 5th firing interval is the point at which the major color changes happened (darker shade), and in next interval (7th firing) less color changes happened. The thickness of veneering ceramic affected the color significantly. The 0.5 mm specimens in all groups showed the highest percentage of agreement (less color changes) after firing intervals, then the 1mm came and the least percentage of agreement (highest color changes) was the 2 mm specimens. The Brand of veneering ceramic and the type of core record a significance difference in color changes when exposed to firing heat.
Conclusion: With limit of this study, the final color of the all ceramic system definitely affected by the number of firing cycle exposed to, and the veneering ceramic thickness have a clear effect on the final shade of the all ceramic tested.
Keywords: Color, shade measurement, Dental porcelain, Dental Zirconia, e.max all ceramic system, CAD/CAM. (J Bagh Coll Dentistry 2016; 28(2):7-13).

INTRODUCTION

All-ceramic restorations are developed rapidly and used widely nowadays; there is a lack of information on the way that the color is affected by manipulation and fabrication procedures. Most all ceramic systems require the application of two layers of ceramic material, such as a core (strong ceramic) and a veneering porcelain (weak ceramic) [(1)] with different shade, opacity, and thickness, to provide a natural appearance [(2, 3)]. All ceramic restorations without a metal core allow more light transfer within the restoration, this happened by improving the color and translucency of the restoration; however, a perfect esthetic tooth-colored restoration cannot be ensured [(4)]. The amount of light that is transmitted, absorbed, and reflected depends on, the size of the particles compared to the incident light wavelength and the quantity of crystals within the core matrix, their chemical nature [(5)].

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The translucency of the Core was also considered as a primary factor in controlling esthetics and a critical consideration in the selection of the materials [(6)]. Many factors affect the ability of a ceramic system to produce good match with corresponding shade guides, such as condensation techniques, firing temperatures and dentin ceramic layer thickness. The effects of dentin thickness on the color of metal-ceramics were studied, and the researchers reported that a clinically acceptable shade match was influenced by this parameter [(7)]. A study examining color changes of surface colorants after firing have demonstrated pigment breakdown at firing temperatures [(8)].

Hue, Chroma and Value color parameters of metal-ceramic specimens, which were fired 1.68°C and 21°C above the manufacturer's instructions firing temperature, indicated substantial differences in color [(9)].Instrumental measurements can quantify color shade and allow communication to be more uniform and precise. Development of advanced computerized colorimeters and spectrophotometers has increased their use in dental applications. Spectrophotometers measure the absorption or transmittance or reflectance factors of an object for one wavelength at a time.

MATERIAL AND METHODS

Sample preparation:

Group A(Zirconia based all ceramic system):

Twopresented Y-TZP block (IPS e.maxZirCad, IvoclarVivadent, Schaan, Liechtenstein)were divided to specimens (dimensions: 1.4-1.5 mm in height, 15.5mm in width,19mm in length). Then the specimens were sintered in furnace (InFireHTC speed sintering furnace, Sirona) According to the cycle recommended by manufacturer. After sintering, approximately 25% shrinkage was occurred in zirconia specimens. After sintering, the dimensions of specimens was about (11.7 mm in width, 14.3 mm in length, 1 in height), Then(24) zirconia core specimens were divided randomly to three subgroups according to the veneering ceramic thickness added, each subgroup contains (8) specimens. These subgroups are:

Group A1: Zirconia core of 1 mm and veneering ceramic thickness 0.5 mm.

Group A2: Zirconia core of 1 mm and veneering ceramic thickness 1 mm.

Group A3: Zirconia core of 1 mm and veneering ceramic thickness 2 mm.

All specimens were cleaned with water for (10) minutes in a digital ultrasonic cleaner (model cd-4820\china), and air dried. A Liner was applied to all specimens by using a brush to create an even layer [7].Then Zirliner was fired in calibrated porcelain furnace (P3000, Ivoclarvivodent, Schaan, Liechtenstein) according to the manufacturer's recommendations. Then the ceramic (IPS e.max Ceram dentine A2) was added incrementally onto the customize- made stainless steel mold (on one of the surfaces of the Zirconia) by using brush, the excess liquid sucked off with paper tissue, the veneering procedure was continued until the mold completely filled. Because of the volumetric shrinkage during firing of porcelain, the rings of the custom made mold designed larger in size to compensate the shrinkage and achieve the exact thickness needed. Eight samples of each thickness (0.5mm, 1mm and 2 mm) of veneering ceramic prepared. Firing of ceramic\dentin was performed in a calibrated porcelain furnace (p 3000, Ivoclar Vivadent, Schaan, Liechtenstein) according to the manufacturer's recommendations. The same firing cycle repeated 3 times before the first shade test and 2 firing cycles added after each testing procedure (5 and 7 firings).

Group B (e.maxPress all ceramic system):

Twenty four Specimens prepared by cut the thermoforming sheet (Forplast, Roko), have dimensions of about (1mm thickness, 10 mm width,10 mm length) for the single specimen. All specimens attached to wax minor sprus, using blue wax wire, each four minor sprus attached to a major connector (Major spru). Investing was carried out with IPS Press VEST Speed (speed investment).Burn-out (wax elimination) technique used, the investment ring was removed from the burnout oven to the pressing furnace (P 3000\ Ivoclar vivadent) without cooling it. Then the pressing procedure achieved with e.mac press ingots

After cooling to room temperature the ring was broken by using plaster knife and cutting disc with care. All the specimens were cleaned from the investment remnants and the reacting layer was removed by immersing them in IPS e.max Press Invex Liquid for (10-30 min) and washed with water the sandblasted. The same procedure used of applying veneering ceramic in the zirconia group used in the e.max group and for the same thicknesses achieved.

Then (24) e.max core specimens were divided randomly to three subgroups according to the veneering ceramic thickness added, each subgroup contains (8) specimens. These subgroups are:

Group B1: e.max press core of 1 mm and veneering ceramic thickness 0.5mm.

Group B2:e.max press core of 1 mm and veneering ceramic thickness 1 mm.

Group B3: e.max press core and veneering ceramic thickness 2 mm.

Group C (porcelain fused to metal system) control group:

Twenty four specimens prepared by cut the thermoforming sheet (For-plast, Roko), in dimensions of about (1mm thickness , 10 mm width, 10 mm length) for the single specimen. The same steps used of spruing in the e.max press group. Then the usual steps of preparing and casting metal cores done (Investing, wax elimination ,casting , recovery of casting, finishing , oxide treatment , sandblasting , First opaque application and firing and Second opaque firing) **.** To obtain the desired dimensions of veneering ceramic, the same custom made mold is used in the same method of specimens of zirconia and e.max. Then (24) core specimens were divided randomly to three subgroups according to the veneering ceramic thickness added, each

subgroup contains (8) specimens. These subgroups are:
Group C1 (control group): metal core of 1 mm and veneering ceramic thickness 0.5mm.
Group C2 (control group): metal core of 1 mm and veneering ceramic thickness 1mm.
Group C3 (control group): metal core of 1 mm and veneering ceramic thickness 2 mm.

Color test

All the specimens were measured 3 times after the firing interval (3 firings, 5 firings and 7 firings). Each type of specimens was fired at a certain temperature as the manufacturer instructions.

Shade test by Easyshade Advance 4.0

The specimens were placed over a surface of fifty white A4 papers, to ensure a complete white background especially for the transparent specimens (e.max cores). The Easyshade Advance 4.0 device was turned on, calibrated and the option average reading was selected. Four to five captures were taken and the result of the average shade was recorded for each specimen like (A 3.5, B 3, A2, etc.).

RESULTS

Shade test Easyshade Advance 4.0 results:

Group A1 (Zirconia core with 0.5mm veneering ceramic thickness):

The results of this group (table 1) showed a relatively high percentage of agreement when comparing the samples inside the group after each firing interval, which means less color changes happened after firing.

Table 1: Shade results of group A1 (Zirconia core with ceramic thickness 0.5 mm)

Zirconia 0.5 mm	3rd firings	5th firings	7th firings
1	B3	B3	B3
2	B3	B3	B3
3	B3	B3	B3
4	A3	A3	A3
5	B3	B3	B3
6	B3	B3	B3
7	B3	B3	A3
8	B3	B3	B3

1. Percentage of agreement between the 3rd and 5th firing is 100 %.
2. Percentage of agreement between the 3rd and 7th firing is 87.5 %.
3. Percentage of agreement between the 5th and 7th firing is 87.5 %.

Group A2 (Zirconia core with 1mm veneering ceramic thickness):

The results of this group (table 2) showed a relatively low percentage of agreement when comparing the samples inside the group after each firing interval, which means much color changes, happened especially after the 7th firing. These results showed a different color changes behavior from the less veneering ceramic thickness 0.5mm (Group A1).

Table 2: Shade results of group A2 (Zirconia core with ceramic thickness 1 mm)

Zirconia 1 mm	3rd firings	5th firings	7th firings
1	B3	A3.5	A3.5
2	B3	B3	A3.5
3	B3	B3	A3.5
4	B3	A3.5	A3.5
5	B3	B3	A3.5
6	B3	B3	A3.5
7	B3	B3	A3.5
8	B3	B3	A3.5

1. Percentage of agreement between the 3rd and 5th firing is 75 %.
2. Percentage of agreement between the 3rd and 7th firing is 0 %.
3. Percentage of agreement between the 5th and 7th firing is 25 %.

Group A3 (Zirconia core with 2mm veneering ceramic thickness):

The results of this group (table 3) showed a relatively low percentage of agreement when comparing the samples inside the group after each firing interval, which means much color changes, happened especially after the 5th firing. These results showed a different color changes behavior from the less veneering ceramic thickness 0.5mm and 1 mm (Group A1 and Group A2).

Table 3: Shade results of group A3 (Zirconia core with ceramic thickness 2 mm)

Zirconia 2 mm	3rd firings	5th firings	7th firings
1	B3	A3.5	A3.5
2	B3	A3.5	A3.5
3	B3	A3.5	A3.5
4	B3	A3.5	A3.5
5	B3	A3.5	A3.5
6	A3.5	A3.5	A3.5
7	B3	B3	A3.5
8	B3	A3.5	A3.5

1. Percentage of agreement between the 3rd and 5th firing is 25 %.
2. Percentage of agreement between the 3rd and 7th firing is 12.5 %.
3. Percentage of agreement between the 5th and 7th firing is 87.5 %.

Group B1 (e.max core with 0.5mm veneering ceramic thickness):

The results of this group (table 4) showed a relatively high percentage of agreement when comparing the samples inside the subgroup after each firing interval and in comparing with other subgroup , which means less color changes happened after firing .the results also showed that there is a different color changes behavior between the Zirconia core specimens and the e.max core specimens that have the same veneering ceramic thickness and brand during the same firing cycles , that make the core material a real effecting factor on color of all ceramic system .

Table 4: Shade results of group B1 (e.max core with veneering ceramic thickness 0.5 mm)

emax 0.5 mm	3rd firings	5th firings	7th firings
1	B3	B3	B3
2	B3	B3	B3
3	A3	B3	A3
4	A3	A3	A3
5	B3	B3	A3
6	B3	B3	B3
7	B3	B3	B3
8	B3	B3	A3

1. Percentage of agreement between the 3rd and 5th firing is 87.5 %.
2. Percentage of agreement between the 3rd and 7th firing is 75 %.
3. Percentage of agreement between the 5th and 7th firing is 62.5 %.

Group B2 (e.max core with 1mm veneering ceramic thickness):

The results of this group (table 5) showed a relatively low percentage of agreement when comparing the samples after the 3rd and the 5th firing cycle inside the subgroup, which means much color changes, happened especially after the 5th firing that agree with**(11)** . These results showed a different color changes behavior from the less veneering ceramic thickness 0.5mm with e.max core (Group B1).

Table 5: Shade results of group B2 (e.max core with ceramic thickness 1 mm)

Emax 1 mm	3rd firings	5th firings	7th firings
1	B3	A3.5	A3.5
2	B3	A3.5	A3.5
3	B3	A3.5	A3.5
4	B3	A3.5	A3.5
5	B3	A3.5	A3.5
6	A3.5	A3.5	A3.5
7	B3	A3.5	A3.5
8	B3	A3.5	A3.5

1. Percentage of agreement between the 3rd and 5th firing is 12.5 %.
2. Percentage of agreement between the 3rd and 7th firing is 12.5 %.
3. Percentage of agreement between the 5th and 7th firing is 100 %.

Group B3 (emax core with 2mm veneering ceramic thickness):

The results of this group (table 6) showed a zero percentage of agreement when comparing the samples inside the group after the 3rd and the 5th firing interval, the percentage of agreement was also zero when comparing the samples after the 3rd and the 7th firing cycle, which means much color changes, happened especially after the 5th firing and there is no changes happened in color when increasing the firing till 7 times (100% of agreement between the samples after the 5th and the 7th firing cycles). These results showed a different color changes behavior from the less veneering ceramic thickness 0.5mm and 1 mm (Group B1 and Group B2) and even from Zirconia group with same veneering ceramic thicknesses.

Table 6: Shade results of group B2 (e.max core with ceramic thickness 2 mm)

Emax 2 mm	3rd firings	5th firings	7th firings
1	B3	A3.5	A3.5
2	B3	A3.5	A3.5
3	B3	A3.5	A3.5
4	B3	A3.5	A3.5
5	B3	A3.5	A3.5
6	B3	A3.5	A3.5
7	B3	A3.5	A3.5
8	B3	A3.5	A3.5

1. Percentage of agreement between the 3rd and 5th firing is 0 %.
2. Percentage of agreement between the 3rd and 7th firing is 0 %.
3. Percentage of agreement between the 5th and 7th firing is 100 %.

Group C1 control group (metal core with 0.5mm veneering ceramic thickness):

The results of this group (table 7) showed 100 percentage of agreement when comparing the samples inside the group after each firing interval, which means no color changes happened after firing. The comparison between the group C1 and groups A1, B1 showed that porcelain fused to metal system is not sensitive to firing.

Table 7: Shade results of group A1 (Zirconia core with ceramic thickness 0.5 mm)

Metal 0.5 mm	3rd firings	5th firings	7th firings
1	B3	B3	B3
2	B3	B3	B3
3	B3	B3	B3
4	B3	B3	B3
5	B3	B3	B3
6	B3	B3	B3
7	B3	B3	B3
8	B3	B3	B3

1. Percentage of agreement between the 3rd and 5th firing is 100 %.
2. Percentage of agreement between the 3rd and 7th firing is 100 %.
3. Percentage of agreement between the 5th and 7th firing is 100 %.

Group C2 control group (metal core with 1mm veneering ceramic thickness):

The results of this group (table 8) showed a relatively high percentage of agreement when comparing the samples inside the group after each firing interval, which means no color changes, happened after firing.

Table 8: Shade results of group C2 (metal core with ceramic thickness 1 mm)

Metal 1 mm	3rd firings	5th firings	7th firings
1	B3	B3	B3
2	B3	B3	B3
3	B3	B3	B3
4	B3	B3	B3
5	B3	B3	B3
6	B3	B3	B3
7	B3	B3	B3
8	B3	B3	B3

1. Percentage of agreement between the 3rd and 5th firing is 100 %.
2. Percentage of agreement between the 3rd and 7th firing is 100 %.
3. Percentage of agreement between the 5th and 7th firing is 100 %.

Group C3 control group (metal core with 2mm veneering ceramic thickness):

The results of this group (table 9) showed a zero percentage of agreement when comparing the samples inside the group after 3rd and 5th firing interval and after 3rd and 7th firing interval, which means the most dramatically changes in color happened after the 5th firing. These results showed a different color changes behavior from the less veneering ceramic thickness 0.5mm and 1 mm (Group C1 and Group C2) and from the other groups (Zirconia and e.max).

Table 9: Shade results of group C2 (metal core with ceramic thickness 2 mm)

Metal 2 mm	3rd firings	5th firings	7th firings
1	A3.5	A4	A4
2	A3.5	A4	A4
3	A3.5	A4	A4
4	A3.5	A4	A4
5	A3.5	A4	A4
6	A3.5	A4	A4
7	A3.5	A4	A4
8	A3.5	A4	A4

1. Percentage of agreement between the 3rd and 5th firing is 0 %.
2. Percentage of agreement between the 3rd and 7th firing is 0 %.
3. Percentage of agreement between the 5th and 7th firing is 100 %.

DISCUSSION

The effect of veneering ceramic brand on shade and reflection

Two types of veneering ceramic (IPS classic dentine ceramics and IPS e.max Ceram dentine) used in this study, the results showed that the metal group veneered with IPS classic have a different behavior of color changes from the e.max and Zirconia groups veneered with IPS e.max Ceram which they are undergo a relatively similar behavior of changes . that is mean color shade and even the reflection value affected by the veneering ceramic brand , IPS e.max Ceram is glass ceramic filled with fluorapatite crystals which does not contain feldspar or leucite that make it more translucent and the IPS classic (metal ceramic) is a feldspar-based ceramic which is more opaque . These differences in optical properties affect the results of this study that is agreed with Heffernan [5], Uludag [10] and Antonson [11].

The effect of firings number on the shade and the refection

Repeating firing have a different effect on each type ceramic system, the effect of firing depend on the chemical components of the ceramic system and the way that these components react with heat, many compound are decomposed and a new compounds formed after firing. The ceramic system consist of core, veneering layer and sometime an intermediate layer which have bonding or coloring function , the interaction between these layers different from one system to another, this interaction may give different byproducts when exposed to heat.

All these factors could give the ceramic system a unique optical property (that is depend on the chemical composition)dissimilar to the others, so this phenomenon is one of the explanations of the dissimilar reflection and color changes behavior of each type of ceramic system showed in this study results after multiple firing intervals.

According to this study results, there is a direct proportion among three variables:

1. The increase in thickness
2. The color which change toward darker and more reddish color
3. The increase of firing intervals.

This relation between these factors may happened because of the increase in the ceramic amount, more amount means more material and metal oxides, needs more heat to react and more time to reach the final shape and properties, this explain the relatively unique reflection behavior of the 2mm thickness. This results agreed with several studies have suggested that metal oxides are not color stable after they are subjected to firing temperatures, and color changes of surface colorants after firing have demonstrated pigment breakdown at firing temperatures [12].

It is noticeable when the shade measured of the thickness 2mm of each group, the percentage of agreement between the 3rd and the 5th firings in all group is almost 0% or less than 25%.

For the other two ceramics thickness (0.5 and 1 mm) the percentage of agreement between the 3rd and the 5th thickness almost higher, that is mean the color faced less changes.

The metal group recorded 100% of agreement between the 3rd and the 5thfirings for both thicknesses 0.5mm and 1 mm that make them extremely different from the 2mm thickness.

This study showed that the effect of multiple firing changed the color toward darker and more reddish shades, and that is agreeing with [10, 12]. It is clear that the 5th firing is the point at which the specimens undergo most of their changes, and in the next firing interval (7th) there are no huge changes the shade. The explanation may be because most of the decomposition, metal oxides losses, particles fusion and new bonding and by products happened in the early firing cycles and the material couldn't change more, that is an agreement with Uludag **[10]** and disagreed with Barghi **[13]** and Seghi **[14]**.

The effect of veneering ceramic thickness on shade and reflection

The thicknesses of the core and the veneering ceramic are represent the amount of tooth structure reduction during preparation. According to the results of this study, the increase in the thickness of veneering ceramic in the control group (Metal core) showed darker or more reddish and brownish color, that is happened with the 2mm thickness of veneering ceramic, the shade was (A3.5) according to the Easyshade readings in the 3rd firing (first interval), and for the 0.5 and 1mm veneering ceramic thickness when measured in the same criteria and number of firings(3rd firing) the shade was (B3) which lighter and yellower . In the last firing interval (the 7th firing) the 2 mm thickness showed an extreme shade change to became (A4), statically that mean a high significance difference from the 0.5 mm and 1 mm thicknesses in the metal group. That is agreeing with Dozic [2] and Hammad [15].

These criteria mentioned and explained by Hammad *et al.*[15] and Uludag *et al.*[10], they have been reported that" an increase in the dentin thickness can cause significant differences in the color of metal ceramics ,This has been attributed to diffuse reflection properties of the opaque ceramic, which have less effect on color as the dentin ceramic thickness increases.

In the two other groups (e.max core and zirconia core), the effect of the increase of veneering ceramic thickness became much less than in the metal group and that is clear from the shade measurement of three different thickness (0.5 , 1 and 2 mm) in the 3rd firing .

So, the effect of increase in ceramic thickness on color depend on the brand of the ceramic and contents , the least effect in the IPS e.max Ceram may be because of its' translucent nature , and the presence of the nanoscale fluorapatite crystals that are responsible for the material’s opalescence and thereby decisively contribute to its aesthetic properties. The material’s opacity (level of transparency) is mainly determined by the larger fluorapatite crystals (Scientific Documentation of IPS e.max Ceram). These results are agreed with Sithiamnuai *et al.* [16] who reached to a conclusion" When the thickness of the veneering ceramic was increased in both the brands (Vita VM9 and IPS e-max Ceram), color changes were observed as an increase shade elements".

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