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The effect of repeated firing of Zirconia based porcelain on the color coordinates in vita system

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ABSTRACT: There is some controversy about the effect of repeated firing of zirconia based porcelain on the color coordinates in vita system. Color matching between restoration and natural teeth is a common clinical problem. Despite careful shade selection, color of the restoration may be affected by fabrication procedures such as number of firing. The purpose of this study was to evaluate the effect of repeated firings on the color changes of dental ceramic. In this experimental in vitro study, 24 disc-shaped specimens (10 mm in diameter with 0.6 mm core thickness and 0.5 mm dentin veneering thickness) from vita ceramic system were made. Vita porcelain mixed with deionized water, applied to the core and fired at 1100°C. To guarantee the proper thickness, the specimens measured with micrometer and corrected with diamond rotary cutting instruments. Then the specimens were divided into 3 groups based on the number of firings. After repeated firing the color readings were determined with a spectrophotometer before and after firings, and L^*, a^*, and b^* coordinates and total color variation (ΔE) were analyzed. ΔE was calculated using the formula $\Delta E= [(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2]^{1/2}$. According to the data, ΔL index changes were 2.6±0.13, 5.4±2.2 3±2.3 for third, fifth and seventh firing frequency, respectively ($P<0.05$). Δa index changes in firing frequency of third, fifth and seventh were 0.3±0.02, 0.44±0.1 and 0.46±0.35, respectively ($P<0.05$). Δb index changes in third, fifth and seventh firing frequency was ranked 0.9±0.12, 1.8±0.5 and 1.1±0.8, respectively ($P<0.05$). It seems firings times affected the color of vita ceramic system where more firing times increased discoloration of zirconia based porcelain in vita system.

Keyword: Repeated firing, Color coordinates, Vita dental ceramic system, zirconia base

INTRODUCTION

During the past decade ceramic restorations have become increasingly common in spite of some of their disadvantages such as brittleness, catastrophic failure and wearing of opposing teeth. They are popular because of their superior esthetic properties, biocompatibility, and longevity (Qualtrough and Piddock, 1997; Van Dijken, 1999; Peutzfeldt, 2001). They are perceived to be one of the most conservative means of restoring unaesthetic anterior teeth. During the past decades veneers were temporarily used by actors during filming; at that time adhesive systems did not exist, and therefore long-term retention was not possible (Calamia, 1989).

Core veneered all-ceramic restorations are possible substitutes for the strong but less esthetic metal core sub-structures. Combining the strength of ceramic cores and superior esthetics of a weaker veneer ceramic can result in a reliable and more biocompatible restoration (Lawn *et al.* 2001). The introduction of zirconium dioxide or zirconia opened the door for designing fixed all-ceramic partial dentures without any limitation regarding the size of the fixed partial denture (Tinschert *et al.* 2001). Its unique qualities, strength, transformation toughening, white color, chemical and structural stability made zirconia the core material of choice (Guazzato et al. 2004). Various veneering ceramics are specially developed for zirconia corematerial. Sometimes a special liner is used to modify the color of the core. Omitting this liner did not weaken zirconia-veneer bond strength but it influenced the type of failure for one tested commercial system to an increased chance of interfacial failure (Aboushelib *et al.* 2005). Besides veneer ceramics used for standard layering technique, new ceramic veneers were developed to enable a new manufacturing method where the molten veneer is pressed against the zirconia core. These materials were aimed to create veneered zirconia restorations with good clinical performance. Ceramic restorations are fabricated with porcelain layers of different shade, opacity and thickness to seem natural appearance.

So several factors can affect the final success of ceramic restorations and the cosmetic result depends on the obtained process and the techniques as well as experience of the porcelain technicians (Dozic´ *et al.* 2003). The final color of the veneer depends on 3 chief factors and their interaction with each. These factors are the color of the tooth/substructure, the thickness and type of ceramic material used, and the resin cement selected. Combining the 3 is the means by which an optimal esthetic outcome can be realized (Zappala *et al*. 1994; Bichacho, 1995; Calamia and Calamia, 2007; Li *et al.* 2009).

Some properties of ceramic materials such as color stability, biocompatibility and durable aesthetics made them the best choice for conservative restorations. However, there are many limitations for ceramic restorations; i.e. brittleness, more laboratory-handling procedures and their hardness that may subject opposite teeth to abrasion (Nikzad *et al.* 2010). The demand for tooth-colored restorations has grown considerably recently. This phenomenon has been both a bane and a boon to the dental profession (Isgro *et al.* 2005).

To achieve improved contour, color, and esthetics, multiple firing procedures are necessary for the fabrication of all-ceramic restorations, especially when using the standard layering technique to match the esthetics of the natural dentition (Rayyan *et al.* 2014). The main aim might be the thermal incompatibility among ceramic core and veneering porcelains, which can introduce residual thermal stresses resulting in fracture or cracking of the restoration. In other words, dental ceramics display a nonlinear thermal dimensional manner, and as a result of a modification in phases after heat treatment, their structure modifies (Zeighami *et al.* 2013). Therefore the aim of the study was to investigate effect of repeated firing of zirconia based porcelain on the color coordinates in vita system.

MATERIAL AND METHODS

Twenty-four disc-shaped specimens (10 mm in diameter with 0.6 mm core thickness and 0.5 mm dentin veneering thickness) were made from zirconia based porcelain using vita ceramic system. Vita porcelain mixed with deionized water, applied to the core and fired at 1100oC for 6 hours. For fabrication of the specimens, the manufacturers' recommendations were followed. To guarantee the proper thickness, the specimens measured with micrometer and corrected with diamond rotary cutting instruments. The CAD/CAM system with thickness of 0.6 mm and diameter of 10 mm was used to fabricate zirconia core. On the upper side of the core, porcelain was made with .5 mm dentin veneering thickness. Then the specimens were divided into 3 groups based on the number of firings (n=8) (Uludag *et al.* 2007).

A. Firing process

In groups 1, the specimens were fried 3 times. In the group 2, the specimens were fried 5 times. In the group 3, the specimens were fried for 7 times. Then changes in color were measured using colorimetric method using spectrophotometer (Uludag *et al.* 2007).

B. Changes in color coordinates

The CIELAB measurements make it possible to evaluate the quantity of perceptible color changes in each specimen. The CIELAB color space is a uniform 3-dimensional color order system. Equal changes in any of the 3 coordinates can be perceived as visually similar. Total color differences were calculated with the following equation (Knispel *et al.* 1991):

$$\Delta E= [(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2]^{1/2}$$

The L* coordinate is a measure of the lightness-darkness of the specimen. The greater the L*, the lighter the specimen. The a* coordinate is a measure of the chroma along the red-green axis. A positive a* relates to the amount of redness, and a negative a* relates to the greenness of a specimen. The b* coordinate is a measure of the chroma along the yellow-blue axis that is, a positive b* relates to the amount of yellowness; a negative b* relates to the amount of blueness of the specimen. ΔL^*, Δa^*, and Δb^* represent the differences in CIE color-space parameters of the 2 colors (Knispel *et al.* 1991).

C. Statistical analysis

The results of testing were analyzed with statistical software (SPSS PC, Vers.20.0; SPSS, Chicago). Repeated-measures analysis of variance (ANOVA) was used to analyze the data (number of firings, ceramic brand, and ceramic thickness) for significant differences. The Tukey honestly significant difference (HSD) test. $P<0.05$ was considered as significant differences between treatments.

RESULTS AND DISCUSSION

The effect of repeated firing of zirconia based porcelain on the color coordinates in vita system is presented in tables and figures 1-3. As seen, repeated firing times (1, 3, 5 and 7) significantly diminished L index of color coordinates in zirconia based porcelain vita system ($P<0.05$).

According to the obtained results, a significant effect was observed on ?a index of color coordinates using different number of firing. As seen, "a" index significantly increased by increased firing times ($P<0.05$) where the highest ?a was detected after 7th firings in zirconia based porcelain vita system.

In this study, a significant difference was detected on "b" index of color coordinates in zirconia based porcelain vita system. The "b" index was 13.5±1 after once firing but increased up to 15.7±1.47 after 7 times of firing in zirconia based porcelain vita system ($P<0.05$).

Table 1: Effect of different firing on "L" index of color coordinates in zirconia based porcelain vita system.

Firing times	L index	ΔL	*P*
1	65.7±0.3	-	-
3	64±1.6	2.6±0.13	*P<0.05*
5	62.9±1.7	5.4±2.2	*P<0.05*
7	62.9±1.6	3±2.4	*P<0.05*

Table 2: Effect of different firing on "a" index of color coordinates in zirconia based porcelain vita system.

Firing times	a index	Δa	*P*
1	0.63±0.3	-	-
3	0.85±0.5	0.3±0.02	*P<0.05*
5	0.97±0.25	0.44±0.1	*P<0.05*
7	1.1±0.41	0.46±0.35	*P<0.05*

Table 3: Effect of different firing on "b" index of color coordinates in zirconia based porcelain vita system.

Firing times	b index	Δb	*P*
1	13.5±1	-	-
3	14.3±0.7	0.9±0.12	*P<0.05*
5	15.3±1.12	1.8±0.5	*P<0.05*
7	15.7±1.47	1.1±0.8	*P<0.05*

As seen from the figure 1, "?L" index fraction of color coordinates suddenly declined after 3rd firing process and the same procedure continued in the groups which firing process continued until 7th firing process (P<0.05). Interestingly "Δa" index fraction of color coordinates in zirconia based porcelain vita system significantly increased from 1 to 3 firing time (p<0.05). Furthermore, the same fraction obtained in the other groups (5 and 7 times of firings).

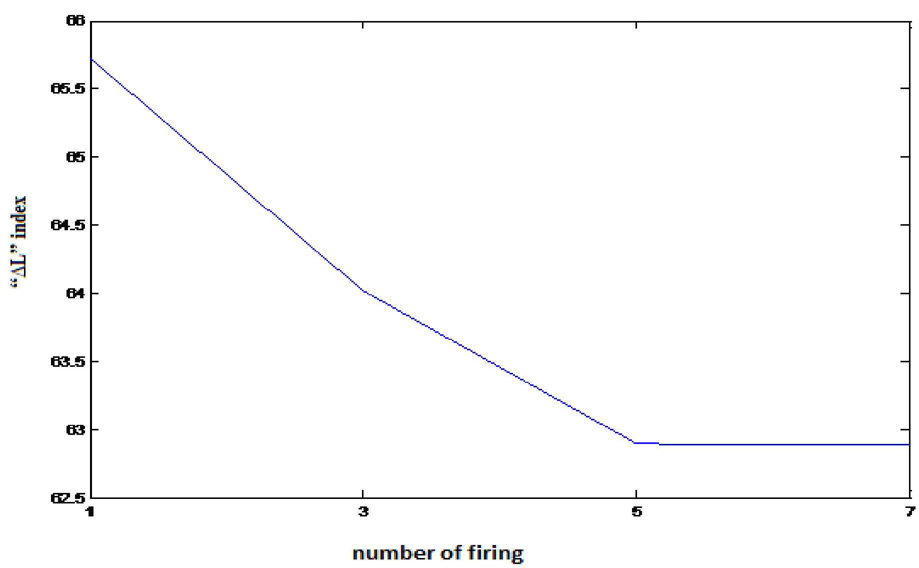

Fig. 1. Effect of different firing on "ΔL" index fraction of color coordinates in zirconia based porcelain vita system.

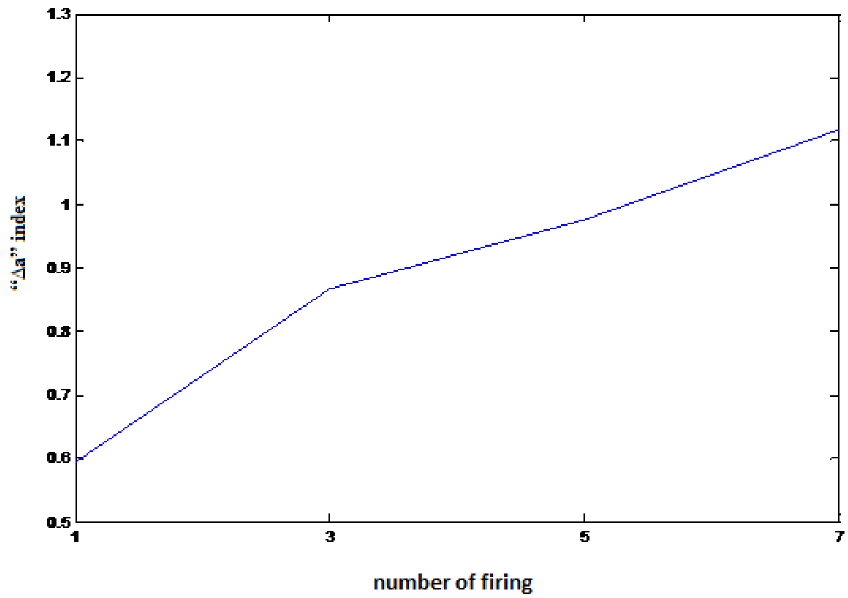

Fig. 2. Effect of different firing on "Δa" index fraction of color coordinates in zirconia based porcelain vita system.

A slight increase detected in on "Δb" index fraction of color coordinates after 3 times firing. After the 5 times of firing, "Δb" index increased to more than 15 and the highest promote was detected after 7 times of firing in zirconia based porcelain vita system. This in vitro study measured the color changes of ceramic specimens prepared at different fired numbers of times.

The results of this study support the hypothesis that there is correlation between color differences and firing times. The L*a*b* values of ceramic systems were affected by the different fired numbers of times. The color of a tooth is determined by a combination of intrinsic and extrinsic colorimetric effects.

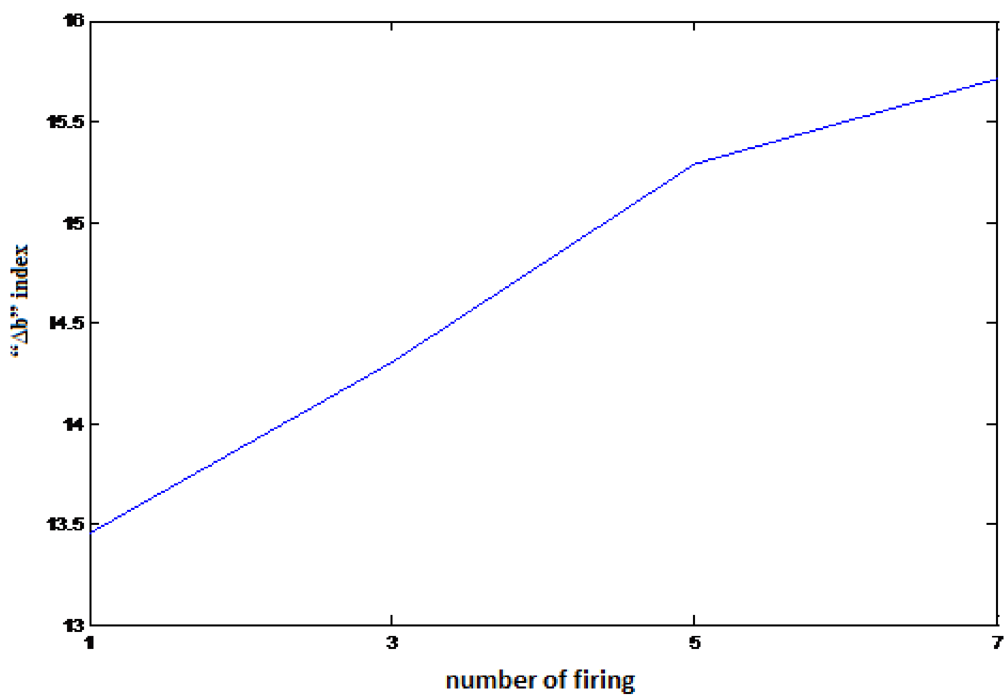

Fig. 3. Effect of different firing on "?b" index fraction of color coordinates in zirconia based porcelain vita system.

The intrinsic properties color is associated with the reflection and absorption of light; with the extrinsic properties related to coloring materials interacting with enamel, such as coffee, tea, tobacco (Chu *et al.* 2004). Factors such as enamel thickness, shape, surface texture, dominant color of dentin, double layer effect and light source may further complicate the visual perception of the various nuances of the whole tooth (Joiner, 2004).

The final color of the veneer depends on three chief elements and their interaction with one another. These elements are: the color of the tooth/substructure, the type of ceramic material used and the resin cement selected. Combining the three is the means by which an optimal esthetic outcome can be realized (Zappala *et al.* 1994; Calamia and Calamia, 2007; Li *et al.* 2009). Enamel behaves like a translucent object, allowing the passage of light, which permit visualization of the dentin while also providing the scattering of light at a wavelength of blue through its hydroxyapatite crystals (Joiner, 2004). There is no ceramic dental product that can simultaneously display characteristics of opacity and translucency in a single material. Therefore, manufacturers have offered ceramics for infrastructure building, opaque ceramic coverage for the construction of the dentin and translucent glazes to be used in layering techniques (Bichacho, 1995).

In our study, the "L" index diminished while the "b" and "a" indexes increased in response to more firing times. Ceramists or manufacturers contend that porcelain manipulative variables cause shade variability. Numerous features effect the ability of a ceramic system to produce an satisfactory match with corresponding shade guides, like condensation techniques, firing temperatures (O'Brien *et al.* 1991) and dentin thickness (Barghi and Lorenzana, 1982; Jacobs *et al.* 1987; Douglas and Przybylska, 1999) have been explored. The influence of dentin thickness on the color of metal-ceramics was deliberate, and the authors reported that a clinically acceptable shade match was influenced by this parameter (Jacobs *et al.* 1987). Reports examining color changes of surface colorants after firing have demonstrated pigment breakdown at firing temperatures (Crispin *et al.* 1991; Mulla and Weiner, 1991; Lund and Piotrowski, 1992). Hue and value color parameters of metal-ceramic specimens, which were fired 1.68°C and 218°C above the manufacturer's recommended firing temperature, indicated substantial differences (Jorgenson and Goodkind, 1979). In visual reports of multiple firing of porcelain, color changes were not reported (Barghi and Goldberg, 1977; Barghi, 1982). Although studies (Barghi, 1982) have demonstrated the minimal effect of repeated firings on the color of body ceramic, O'Brien *et al.* (1991) Reported perceivable differences (?E=1) between the color of ceramic specimens that were fired 3 and 6 times. The ΔE value afterward repeated firings was undetectable for the In-Ceram specimens (ΔE>1), except for the 0.5-mm-thick specimens fired 7 times, and just at perceivable levels for the IPS Empress specimens. Contrariwise, statistically analyzed L*a*b* color factors exhibited significant differences with repeated firings. An increase in the number of firings resulted in an appreciable decrease in L* values, which created darker specimens for both all-ceramic systems. It was reported a* and b* color values increased after repeated firings, leading in specimens of ceramics that were redder and more yellow. Furthermore, color changes occurred, especially after 5 firings, and less color change was detected with subsequent firings. Color change after repeated firings may also be attributed to the color stability of metal oxides during firing. Several studies (Crispin *et al.* 1991; Mulla and Weiner, 1991; Lund and Piotrowski, 1992) have recommended certain metal oxides are not color stable after being subjected to firing temperatures.

Crispin *et al.* (1991) and Lund and Piotrowski (1992) reported that yellow and orange hue stains were the least color stable at the manufacturers' suggested firing temperatures. Mulla and Weiner (1991) also indicated that blue was the most unstable stain, whereas orange demonstrated the highest color stability at higher firing temperatures. Although significant differences were detected in L*a*b* parameters, the magnitude of mean color differences triggered by several dentin thicknesses and repeated firings for both all-ceramic systems were at an acceptable perception level. Clinical success and color stability of ceramic restorations depend on laboratory and clinical variables. Finally, further studies on the interaction of the ceramic materials with luting agents and other substrates are needed.

CONCLUSION

It seems firings times affected the color of vita ceramic system where more firing times increased discoloration of zirconia based porcelain in vita system.

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